Water Markets of the United States and the World: A Strategic Analysis for the Milwaukee Water Council Milwaukee, Wisconsin

Prepared at the University of Wisconsin-Milwaukee

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Executive Summary

Introduction

This report has been constructed to help the Milwaukee Water Council and its members, as well as the U.S. water technology industry, gain a better understanding of state, national, and international water markets and the business opportunities available. It is intended to give a sense of immediate and near-term needs of municipalities, states, and nations to better address the many water problems that increasingly challenge the globe. While the report does not cover all states or all nations, it does reveal the needs of a mix of states and a mix of nations, especially those that currently have the largest markets for water-related capital and operating expenditures.

The U.S. is a prime target because it is both very familiar, and it has the world's largest market for water-related goods and services. To further aid understanding, not only are states collectively analyzed through EPA assessments, but also a dozen individual states are examined in detail. The 12 states were chosen to be sure to cover the two largest water challenges, the Chesapeake Bay region and all of California, dry states and wet states, small states and large states, all with varying political settings.

The states analyzed included: California, Colorado, Florida, Iowa, Maryland, Minnesota, New York, Pennsylvania, Texas, Washington, Wisconsin, and Wyoming

The states also represent the range of water challenges existent in the U.S. These vary from the rapidly growing need to provide additional potable water to enlarging populations who want to reside in water-poor states to agricultural needs, mining needs, electric utility needs, and so forth. The range is incredibly varied.

The international sample consists of the largest markets and representatives of six continents. The nations include two others in North America, one in South America, five countries in Africa, 27 countries in Europe that are part of the EU plus Switzerland, Russia, and three smaller nations, three countries in Asia, and all of Australia. Some of these countries have individual reports while others have just a snapshot.

The countries included in the analyses largely appear in Table 1 because they are among the largest water markets in the world. By far the largest is the U.S. market at $107 billion in 2010 and growing quite rapidly. The second-largest, Japan ($59 B), is not included because it is an extremely slowly growing market that appears to rely heavily on its own products for solutions. The third-largest market, China, estimated at $47 B in 2010, could very quickly replace Japan in the #2 slot, as it places greater and greater emphasis on addressing the very dramatic water needs of China. Here is a country with 21% of the world's population and 7% of the world's water, a high percentage of which is contaminated.

The list continues with countries from across the world, each with its own story to tell.

Table 1 Largest Markets Total 2010 ($)		
	Markets by Size	
Countries	**Dollars ($b)**	**Included**
United States	107	YES
Japan	59	NO
China	47	YES
Germany	29	YES
France	23	YES
Italy	16	YES
Australia	15	YES
Brazil	15	YES
United Kingdom	13	YES
Spain	11	YES
Korea	10	YES
Saudi Arabia	8.5	YES
Mexico	7.3	YES
Poland	6.6	YES - Partial
South Africa	6.1	YES
India	5.9	YES
Netherlands	5.5	YES
Canada	5	YES
Others Included		
Russia	4.5	YES
Switzerland	4.4	YES
Algeria	4.0	YES
Egypt	3.5	YES
Morocco	1.6	YES
Tunisia	0.8	YES

Source: Global Water Intelligence 2010

Some common, market opportunities exist across geographic boundaries to one degree or another. The states and nations need solutions to problems of:

- Insufficient water quantity and/or quality
- Available water resources not being where demand for water is located
- Wastewater treatment expansions and upgrades
- Energy costs playing an increasingly important role in water decisions
- Water policies not keeping up with the changing water needs
- Resistance to change, be it in policies or practices
- Insufficient monetary resources allocated to addressing water needs

Elements of each of these are included in the analyses. Most of what is covered is the basics – water resources, water treatment and distribution, wastewater collection, wastewater treatment, and water-use efficiency. These are the major areas of need and investment.

Water Problems by Geographic Area: U.S. States

Team members created a large matrix of an assessment of the presence and scale of some 77 identified water problems. These were broken into 12 different categories and researched for 12 states. It was the assessment that then allowed the team to focus on those problems in each state that were identified as being the most challenging in terms of scale and impact. It is these that appear in the chapters that follow. The list below reveals the most commonly shared, pressing, water problems.

Water Problems Shared by Several States:

- Aging water and wastewater infrastructure
- Insufficiently sophisticated wastewater treatment
- Unsustainably high levels of water usage and aquifer depletion
- High irrigation demand and outdated water rights
- Agricultural & urban-use contamination of surface and ground water
- Necessity for greater use of reclaimed water
- Drought and climate change impacts
- Contaminated river and lake sediment
- Storm water runoff, contamination, flooding, and combined sewer overflows
- Inadequate groundwater controls and monitoring of aquifers
- Confined Animal Feeding Operation (CAFO) water pollution
- Hydraulic fracturing, coal-bed methane, and other energy extractions that contaminate water
- Invasive species

The listing shows that there are common problems across states. "Hydro-fracking" in search of natural gas is an issue for 31 states. Water contamination and aging infrastructures are common across most states. Drought affects some three-fourths of the states. CAFOs are a growing challenge as is unsustainable levels of water consumption. But there are also problems that are somewhat unique to states, at least in terms of severity, as well.

Some states have few, severe water problems. Minnesota, home to 12,229 inland lakes and a portion of Lake Superior, has been well watered and well governed. The combination has led to relatively few, severe water problems. Its major cities do not even have combined-sewer overflow problems that plague many cities across the U.S. Thus, it is very different from California that has population centers far from water sources, storm-water challenges, salt-water intrusion into groundwater, high levels of agricultural irrigation, and a long list of severe water challenges.

The states that have the largest populations and the most difficult water challenges are California, Florida, Texas, and Maryland. But all states do have challenges; the scale and composition are just different. Markets exist in each. Minnesota, for example, has needs for very clean water for specific industries, but storm water is much less of a problem than it is in neighboring Wisconsin or Washington state.

This is a thumbnail sketch that is meant to give a sense of the commonality of water problems. Countries such as the U.S. may have much more extensive water treatment and distribution and wastewater collection and treatment systems than almost all other nations. But the U.S. also has problems of:

- Aging infrastructure
- Populations moving to where new infrastructure is needed
- Inadequate infrastructure for the current operations
- More and more specialized water uses and needs
- Unsustainable levels of water consumption
- Inadequate financial resources directed at the problems.

The U.S. basically needs water resources, infrastructure, treatment, wastewater collection and treatment in the same fashion as all other nations. Some of the details are different. And some of the solutions will certainly be different. But many of the basics are shared across state and national boundaries.

Water Problems by Geographic Area: Countries

Countries do share water problems. In some places particular problems are more acute than they are elsewhere. The list that follows shows an assessment of the acute presence of a series of problems across a sampling of the countries that are discussed in some detail in the chapters in this report.

The common major problems include:

- Water resources – an insufficient supply, especially where it is needed
- Inadequate water and wastewater treatment systems
- Surface and ground water contamination
- Storm water flooding & contamination
- Financial resources to pay for water and wastewater treatment systems
- Regulatory enforcement

There are many variations on these themes, depending largely on whether the countries are fully developed or developing, what climates they have, what natural water resources they have, with whom they share boundaries and watersheds, and the like. There are common and uncommon problems. There are problems caused by human actions and other by nature. Our analysis of 36 countries in this report reveals the range and the common themes among nations.

Key Factors Affecting the Future

There are a number of factors that are driving the market for water and water solutions. Not all are present everywhere, but most are universal. These factors include the following:

- Increasing population

- Increasing incomes for more citizens
- Increase in health standards or desired health standards
- Increased recognition of the importance of sufficient, clean water
- Increased population locating in places with too little water
- Increased recognition of growing water shortages and the need to reuse both water and various elements that it often contains, for example, phosphorous
- Increased need for a range of technical answers, from simple sand filtration to sophisticated water desalination, from primary wastewater treatment to tertiary treatment that allows multiple water reuses
- Increased need for policy solutions to better manage water

Water Market Opportunities

The world's market for water-related equipment and operations is projected to be $483 B in 2010, growing to well over $600B by 2016. By contrast the world's IT market today is $650B; the Cell Phone market is $600B; Pharmaceuticals are $450B; and Telecom Equipment is $300B.

Globally, an estimated $89B will be spent on capital equipment for water collection, treatment, and distribution in 2010. Concurrently, some $82B will be spent on wastewater collection and treatment. These figures constitute about 35% of the total capital and operations expenses in water for 2010.

Select market opportunities in the U.S.

Listed below is a summary of the larger markets identified in the twelve states that were examined in detail. These markets were determined after the analysis, as we attempted to identify the most important market areas in each given state. A similar exercise was undertaken for each country or region as well. Each chapter begins with a matrix of the most important identified markets. The summary here is intended to give a sense of the commonality of several problems and markets. Those markets that were not as common are identified by state but not included below.

Key Markets	States	Niche Markets	States
Water & Wastewater Infrastructure, Monitoring, Upgrades, Replacement	CA, FL, IA, MD NY, PA, WA	Real-time Monitoring of Pipes, Pipe Repair Technology, Leak Detection	CA, NY
Agriculture: Irrigation, Contamination	CA, PA, TX,WY	Highly efficient irrigation; low-water crops, chemical controls	CA, FL, IA, TX, WI
Agriculture: Concentrated Animal Feed Operations (CAFOs)	CA, FL, IA, MD TX, WI	Bio-digesters, Control Policies	CA, FL, IA, MD, TX, WI

Key Markets	States	Niche Markets	States
Groundwater Contamination, Monitoring & Mitigation	CA, FL, MN, PA, WA, WY	Real-time Networked Monitoring & Barriers to methane entering wells	CA, CO, FL, MN, TX
On-site Natural Gas Exploration – Hydro-Fracking, Natural Gas Production	CO, NY, PA, TX, WY	Lower-impact technology for exploration & production of gas & oil	CO, NY, PA,TX, WY
Water Conservation/Efficiency	CA, FL, IA, MN TX, WA	Smart metering; low-use technology	CA, FL, IA,MN
Storm water Management; CSOs	FL, MD, NY, WA	Gray-water systems	NY, TX, WA
Advanced Wastewater Treatment	FL, MD, WA, WY	Nutrient Recovery Technologies	MD, TX, WI
Industrial energy Efficiency	NY, PA, TX	Bio-fuel Water Efficiency	IA, MN

Key advice: Watch California and the Chesapeake Bay region for insights into what sorts of problems are priorities and what sorts of solutions will be entertained. Also note the list below contains some common solutions for problems found in multiple states:

- Energy-efficient pumps, valves, filters, membranes, treatment systems, etc.
- Water-efficient products and processes for agriculture, domestic use, and industry
- Real-time, sensing equipment for groundwater & treated water
- Desalination processes that are energy efficient
- More effective and efficient tertiary, wastewater-treatment processes
- Efficient wastewater-treatment processes for capturing phosphorous and other valuable ingredients, such as energy, in wastewater
- More water-efficient agricultural practices
- Super-efficient Concentrated Animal Feeding Operation (CAFO) waste-collection and utilization systems
- Much more effective products and processes for conserving and reclaiming water used in energy seeking, solutions such as on-site treatment, zero-liquid discharge (ZLD) process, and alternative extraction methods
- New solutions for fixing/replacing aging infrastructure that is in the ground or in the treatment plant
- Storm water containment, control, and decontamination procedures and technologies
- Point-of-use/point-of-entry water treatment systems

More ideas appear in the state chapters and especially in the EPA summary. More ideas are being generated daily. A list at the end of this summary illustrates this with a sampling of new ideas that surfaced in the last two years. Some will undoubtedly be transformed into extremely viable solutions.

Each chapter on a nation contains a brief assessment of some specific niche markets beyond the basic needs for more and better water and wastewater treatment systems or better water sources or more efficient domestic and agricultural ways of operating. To give you an idea of some of what is found in the chapters, here are some niche market ideas that were drawn from analyses of China and Brazil.

China	**Brazil**
Niche Markets	**Niche Markets**
Residential-scale WT	WWT new & upgrades
Upgrades to WWTP	On-site treatment; rural treatment
W &WW regulation application	Urban flood control
Industrial water efficiency	Desalination; water system leak repair
New WT & WWT technologies	New WT & WWT technologies

W = Water; WT = Water Treatment; WW = Wastewater; WWT = Wastewater Treatment
WWTP = Wastewater Treatment Plant

Sample of Recent Innovations

Here is some of the latest thinking on how to address common water problems across the globe. How these ideas will be implemented from one country to the next will vary. But there are places in which many of these ideas should succeed.

Sample of Innovations in Use or Development: Mind Stretchers

- Human and animal urine capture and reuse as fertilizer
- Lower-cost and lower-energy-consumptive desalination processes
- Phosphorous and other elements' capture and reuse
- Building-scale or use-scale water and wastewater treatment systems
- Water efficiency in agriculture, using crops that require less water and more- efficient irrigation
- Efficient water products and processes across all uses
- Water resources: capture, protect, and use more natural sources
- Microbial fuel cells that run on sewage
- Specialized anaerobic digestion

Policy Solutions

Many water problems will not be solved without changes in public policy. This is true, whether it is the U.S. or any nation. Policies drive the adoption of new technologies. And policies help reduce the extent and incidence of water problems. For example, reducing the presence of phosphorous in surface and ground waters can largely be accomplished through a mix of policies that reduce the amount of phosphorous runoff from agricultural fields and urban lawns. Another example is containing storm water, something that can be attempted with an expensive collection system or something that can be avoided or reduced through a series of public policies that regulate land uses, increase the permeability of developed parcels, require the containment of all storm water that falls on each developed parcel of land, and so forth.

Listed below are other examples of policies that help address major water issues. These are applicable in the U.S. and most other countries. They are listed here because our examination of water problems across the globe often suggested the utter necessity of policy changes to address and often best address the problems noted.

Policy Examples

- Required upgrading of water infrastructure: policies that require fewer water collection and distribution leaks or fewer storm water leaks into sanitary sewers
- More extensive and higher levels of treatment of wastewater
- Limits on and monitoring of groundwater usage
- More extensive groundwater quality monitoring
- Intrastate agreements and greater limits on aquifer depletion
- Policy on pricing water to ensure thoughtful water consumption
- More stringent septic tank regulations on monitoring and discharges, especially near surface waters and known aquifers
- More stringent regulation and standards for energy exploration, extraction, and refining
- Promotion of natural plants to promote the cleaning of surface waters

The list can be and is extended in some of the chapters in this report. It is very clear that technology is important but that policies are what will really drive the efforts to clean water and wastewater and help to ensure that future populations will have access to the water they need to survive and thrive.

Next Steps

The chapters in the report have revealed a good deal about the issues and markets surrounding access to water, treatment and distribution of water, efficient and inefficient use of water, collection and treatment of waste water, real-time monitoring of ground and surface water for both quantity and quality, special markets - such as confined animal feeding operations (CAFOs) or specific industries like electric power generation and oil and gas exploration and production, water reuse, and a host of other challenges. The insights are on the written page, but few will spend the time to explore its many pages without some additional assistance. So, an important task is deconstructing what is contained in this report and parsing it out to companies, firms and researchers who may have an interest in particular parts.

Step One

- Make the connections and educate the companies, firms and researchers that are known to have related interests.

Step Two

- Make this information more accessible by developing a large-scale matrix that breaks out by location the water conditions (quality and quantity) extant, the current issues that have risen to be of greatest concern, the potential solutions identified to address the specific issues, and the industry's most likely to be working on or providing the solutions along with an assessment of the current market strength in each geographic area.

- Construct more specific assessments of product and process markets in each of the geographies covered in the report. What would assist the WC effort is to go a bit further in the specific assessment of the market growth rate for each geographic area among the markets that have been identified as most important to address.
- Utilize the many insights that EPA provides on both its appraisal of water problems in the U.S. and its assessment of technologies that have promise through a more direct route to pertinent topics to speed distribution of this useful information.

Step Three

- Make connections between market knowledge and regional firms and researchers who are not yet aware that some of this information is of great value and interest to them.

Step Four

- Gather the market knowledge from the region as it tries to meet the growing domestic and foreign water-policy and water-technology needs.

Step Five

- On a larger focus, to truly contribute to solutions, the region must help to answer the larger question of what it will take for the U.S. to be more competitive globally in water solutions. This effort is aimed at learning what it is the WC can do to help its members become truly competitive and to show the solutions to others in the U.S.

Step Six

- Concurrent with several others because it can help further develop markets for water solutions, develop and implement the testing and wide application of the "blue footprint" concept.

Chapter 1

Introduction

Water markets across the globe are enlarging. New opportunities are sprouting. The challenge is learning of the opportunities and then figuring out how one best responds. This report aims to assist Water Council members in learning of business opportunities. The opportunities are not detail specific, but they are noted in a variety of settings. Whether one is looking for water opportunities in energy exploration and extraction or municipal water-pipe repair/replacement, the markets are substantial and growing.

As one searches for outlets for new technology, product, or process, it is important to be aware of a number of factors and trends that play important roles in the market for water products and services. This chapter notes several of the points that the authors think are important. Most are taken from work done by Global Water Intelligence, a firm that tracks developments worldwide in the water sector.[1] The points are made in what is meant to be a quickly accessible fashion. If more detail is needed, the chapters that follow help to fill several of the gaps, as will reference to original documents noted in bibliographies.

Challenges

Water has been a challenging sector in which to make money. The challenge comes because of five main factors:

- High fixed costs and modest returns, often below economic cost
- Water is worthless; the value is in treating and transporting
- Politics - public regulation and "right-to-water" mentality
- Connection fees are often the significant barrier to widespread water provision in developing countries. Connection fees, not water tariffs, should be subsidized to address this problem.
- Equipment-supply firms have limited returns on investments because of the high proportion of sales to municipal utilities that seek low-cost alternatives and long-proven approaches

These factors have usually created slow-growth paths for the firms supplying water markets. That may be changing, as worldwide demand for water is increasing while natural supply basically remains the same.

Global Trends

Global trends have been changing. Among the most notable trends are the following:

- Higher water tariffs - 10% increases on average recently
- "Unbundling" of water utilities from governments, moving toward regulated monopolies and some privatization
- Expanding Chinese stimulus program for wastewater treatment

[1] Global Water Market 2011: Meeting the world's water and wastewater needs until 2016. Global Water Intelligence. Oxford, UK. 2010.

- Increasing Mexican investment in wastewater projects
- Conflicting projections on desalination: some say relatively flat growth through 2014 while others point to substantial increases because of decreasing costs
- Burgeoning interest in water reuse to help solve water access problems
- Greatest percentage growth is in the East Asia/Pacific and Middle East/North Africa water markets, but the largest market remains the US, which is growing rapidly

Positive Developments
Equipment is beginning to change with the advancement of new technologies and with the welcoming of new technology from certain governments.

- China is now specifying micro/ultra-filtration processes for wastewater treatment.
- Many countries are placing more emphasis on sophisticated control/feed systems to reduce chemical use in water and wastewater treatment
- Sludge management and disposal processes and technologies are becoming more important due to regulatory trends
- Zero Liquid Discharge processes for oil/gas extraction market (current market is still relatively small) is growing because of the desire to sidestep wastewater treatment regulations

Other technologies and innovative processes are more welcomed, as efficiency, especially energy efficiency, is becoming a more important consideration. Whole new markets are finally opening, although often not a quickly as many would hope.

Market Size, Growth Rates, and Components
Nevertheless, the world's water market is estimated to be $483 billion in 2010.[2] This includes capital expenditures and operating expenditures. Capital expenditures on water infrastructure are estimated to be $89 billion in 2010, rising to $131 billion by 2016 (a compound annual growth rate [CAGR] of 6.4%). Total capital expenditures on wastewater infrastructure are estimated at $82 billion in 2010, rising to $115 billion by 2016 (a CAGR of 5.6%).[3]

The largest markets are led by the United States, which is both large and growing rapidly. As the reports on the dozen states will reveal, there are many different opportunities in the US, especially if governments make the commitments to address what are often large and growing problems. Some of those problems have been brought to harsher light in 2010, as severe weather has greatly taxed existing approaches and infrastructure. The US is not alone.

Japan is large but hardly growing. China's market, by contrast, is quite large and expected to grow between 6% and 9.9% annually. This means China could grow from an estimated $48 billion in 2010 to as much as $83 billion by 2016, if it grows at 9.9% annually. Spain may grow from $11 billion in 2010 to $25 billion in 2016. That is substantial growth as well. Opportunities abound.

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[2] Lola Adesanya, et al., *Global Water Market 2011*. Oxford, UK. 2010. p. iv.
[3] Ibid., p. iv.

Table 1 Largest Water Markets Total 2010 ($)		
Countries	**Dollars ($B)**	**Annual Growth Rate***
United States	107	4
Japan	59	1
China	48	3
Germany	29	1
France	23	2
Italy	16	4
Australia	15	1
Brazil	15	4
United Kingdom	13	2
Spain	11	5
Korea	10	2
Saudi Arabia	8.5	3
Mexico	7.3	3
Poland	6.6	2
South Africa	6.1	3
India	5.9	4
Netherlands	5.5	2
Canada	5.0	2
* Key to Rates		
1 = <2%		
2 = 2-5.9%		
3 = 6-9.9%		
4 = 10-14.9%		
5 = 15%+		

Source GWI 2010

In terms of rates of growth for the larger water markets, the smaller markets are generally the fastest growing relatively (Table 2). There are a few exceptions: the United States, Italy and Brazil. All warrant close attention by those in the water industry.

Table 2 Fastest Growing Water Markets 2010-2016	
Countries	**Dollars ($B)**
15%+ CAGR	
Spain	11.0
Hungary	1.8
Argentina	1.3
Romania	0.9
10-14.9% CAGR	
United States	107.0
Italy	16.0
Brazil	15.0
India	5.9
UAE	4.4
Iran	3.8
Indonesia	2.5
Malaysia	1.7
Morocco	1.6

Source: GWI 2010

Global water markets are basically divided into water and wastewater. For ease of understanding their budgets are divided into capacity and operations expenditures. Capacity expenditures cover the repair or expansion of the facilities. Operations cover the expenses related to the cleaning and distribution or collection of water or wastewater. Most of the Milwaukee region's water firms are involved in capacity building, so that will be the main focus on the discussions in this report.

Table 3 reveals the scale of capacity expenditures ($175 billion in 2010). Overall, they constitute 44% of the total water-industry expenditures in 2010. Some 92% of these expenditures are for water or wastewater utility and industry capacity building. This includes procurement of water resources, water network rehab, expansion of water distribution systems, expansion of wastewater collection networks, wastewater treatment plants, wastewater network rehab, and related activities.

Table 3 Global Water Capacity Expenditures 2010		
Markets	**Dollars ($B)**	**% of total**
Equipment	44	25
Site Work	35	20
Pipes	35	20
Pumps & valves	22	13
Pipe Rehab services	27	16
Professional/other	12	7
Total	175	101*

*Rounding error   Source: GWI 2010

To be a bit more precise, some $89.2 billion will be spent in 2010 on municipal water capacity expenditures. The various components of the total include:

Water network rehabilitation	$31.0 B
Water resources, excluding desal	19.0
Water treatment plants	16.8
New Water Networks	11.4
Seawater & brackish water desal	10.8
Total	$89.2 B

One interesting point is that desalination (desal) is only a $10.8 billion industry at this point. It is growing rapidly, as costs decline. But it is about 12% of the total water capacity expenditures and 2% of total water-related expenditures globally. Water reuse, another rapidly growing sector, is currently about a $4 billion-a-year industry. To date traditional approaches are far more important across the globe.

A growing water market that is not included in these numbers is that of residential water treatment. A firm called Verify Markets just released a study that indicates that this market will grow rapidly, especially in Asia and Latin America. In 2009 the largest markets were Japan ($2.2B), the US ($1.65B), China ($1.13B), South Korea ($716M), and India ($588M). In Latin America, Brazil is the market leader. The markets in China and India are expected to at least double within seven years. To appeal to these markets, several manufacturers are launching gravity-based water purifiers.

Municipal wastewater capacity expenditures total modestly less than water ($82.8 billion) in 2010. The basic components of these expenditures are:

Wastewater treatment plants	$30.8 B
Wastewater network rehabilitation	25.5
New wastewater networks	17.1
Other wastewater	9.4
Total	$82.8 B

The forces that are driving the expenditures are population growth, income growth, new regulations, and growing water scarcity.

Another way to look at markets is to focus exclusively on industry and examine which industries have the largest markets for water and wastewater treatment equipment. In 2010, the industrial water and wastewater equipment market is estimated to be $14.1 billion. Table 4 shows the scale of the markets by particular industry and the expected annual growth rate in size of the market between 2010 and 2016. Food & Beverage is the largest and growing almost 5% per year. They have shown new interest in water-reuse applications. Pharmaceuticals are growing even faster, around 6%. They have an increasing interest in ultra-purification applications. Oil & Gas are growing 24% per year and have interest in purification of produced and process water and in the potential reuse of process water.

Table 4 Industrial Water and Wastewater Equipment Market 2010-2016

Markets	Dollars ($B)	CAGR (%)
Food & Beverage	3.3	4.8
Pharmaceuticals	1.8	5.9
Power Generation	1.5	7.4
Pulp and Paper	0.8	7.0
Oil and Gas	0.7	24.3
Mining	0.6	4.4
Chemicals	0.6	10.0
Microelectronics	0.6	9.0
Refining	0.4	6.2
Metals, textiles, & automotive	0.5	13.0
All others	3.2	7.5
Total	**14.1**	**7.5**

Source: GWI 2010

Listed below are various points on why specific markets have been assigned the growth rates that they have. The notes are abbreviated but still give insights into forces shaping markets.

- **Food and Beverage- $3.3B (CAGR 2010-2016: 4.8%)**
  - Increasing pressure for corporate sustainability will increase efficiency
  - High biological load, opportunities if regulations (food safety or effluent) increase in India and China
  - Increasing reuse of non-contact water, UF, MF & RO

- **Pharmaceutical- $1.8B (CAGR 2010-2016: 5.9%);** interest in ultra-purification applications

- **Power generation- $1.5B+ (CAGR 2010-2016: 7.4%)**
  - Complex environmental regulations for effluent and water scarcity are pushing the industry toward closed systems. Categories of use include:

- Boiler feed water
    - Requires ultrapure water
    - Traditionally use ion exchange (IX)
- Cooling water
    - 1,000 MW plant requires 1,500 m^3/minute
    - In places of water scarcity this may be a closed-system w/ treatment
- Ash transport
- Flue-gas desulpherisation (FGD)
- Zero liquid discharge systems (no effluent to regulate) are one of the fastest growing

– Potential for massive growth, especially China, India, and nuclear
– $500m market for mobile water services that allow power plants to function when water treatment operations go offline for maintenance

- **Oil and gas- $700M (CAGR 2010-2016: 24.3%)**
    - Processing needs vary greatly by application, but major ones are
        - RO and IX for process water
        - Removing hydrocarbons
        - Removing high levels of salinity
    - *Will be the fastest growing industrial water sector over the next few years*
        - Rising oil prices ensure demand
        - Drilling in areas of water scarcity
        - Increasing environmental restrictions make treatment cost effective

- **Chemical- $615M (CAGR 2010-2016: 10%)**
    - Growing markets in Middle East (esp. oil producing) and BRIC states, as well as China, mostly for in-house reuse but will need to treat effluent if regulations increase
    - In US, Europe, Japan demand is for water reuse and water efficiency

- **Microelectronics- $550M (CAGR 2010-2016: 9%)**
    - Ultrapure water (UPW)

- **Mining- $480M. (CAGR 2010-2016: 4.4%)**
    - Used in dust suppression, drilling lubrication, ore slurries
    - Need treatment processes that remove toxic compounds: arsenic, mercury, cyanide. Chile and Australia are looking to expand mining, both have water scarcity issues

- **Refining industry- $395M (CAGR 2010-2016: 6.2%)**
    - Removal of ammonia, phenol, cyanide
    - Will grow slowly until there is pressure for more refineries (est. 2014)

- **Metals production- $120M (CAGR 2010-2016: 14.5%)**
    - Hit hard by economic crisis, current overcapacity

- **Automotive- $120M (CAGR 2010-2016: 17.6%)**
  - Down from $240M in 2007, much of growth will be recovering
  - Not highly water intensive, but need for reuse and high quality

Given the many components of the market, players have options. The players need to be strategic as they proceed. Global Water Intelligence has identified several trends that they think should influence firm behavior. Among the top strategic considerations are the following:

- Low cost operators and contractors will win out in SE Asia, India, and Africa.
- Infrastructure funding is taking water assets off public balance sheets.
- Sludge management and value from waste (nutrient extraction, innovative uses, etc.) are growing markets. The largest markets are Western Europe, East Asia/Pacific, and North America. Smaller but still significant markets are: Middle East/North Africa and Eastern Europe. EU regulation is European market driver.
- Oil and gas production: water treatment and technology companies will enter into joint ventures with oil and gas field service companies as regulatory climate will increasingly favor near zero liquid discharge approaches.
- Market diversification will drive growth. The most successful companies will be those that find a market niche.

Market Summaries

The chapters that follow reveal in some detail water challenges, water-product demand, changing regulations, growing markets, and technologies used and needed for 12 states, the US as a whole, and 36 countries, some 25 of which in greater detail.

Chapter 2 - Water Markets in 12 US States

Introduction

In order to learn more of the opportunities in water in the US, we decided it would be wise to examine a set of individual states as well as explore what EPA is currently doing and where its initiatives are heading. This chapter contains the detail reports on each of 12 states.

The states were chosen for a variety of reasons. California was chosen because it has a full range of pressing water issues and because it has the largest population, the most current approaches, the importance of agriculture, and enormous pressures to change practices and adopt new technologies. It also has water laws that represent the Western States' tradition versus how water law is approached east of the Mississippi River.

Several east-coast states were chosen because of their larger population size, their location, their water problems, the age of their water infrastructure, and their current approaches. These states are Maryland, New York, and Pennsylvania. Several Midwestern states were chosen to learn of their regional problems, the mix of rural and urban, and the markets that Milwaukee-based firms have been serving for years. These states are Iowa, Minnesota, and Wisconsin.

Two southern states were included because they, along with California, usually appear on the lists of the most water-challenged states in the nation. Florida has limited water resources and rapidly growing population pressure. Texas is also rapidly growing, and it has pressure from agricultural, energy exploration, energy refinement, electrical power plant operation, and several other factors that place many competing demands on the water resources of the state.

Of the three other states, two are Rocky Mountain states – Colorado and Wyoming ─ and one is a west coast state that contains high desert, a large urban area, and a rainforest, the state of Washington. Each has some unique water challenges while sharing multiple water challenges with other states.

The states are organized alphabetically. The chapters are somewhat similar in nature in terms of format. All aim to describe the water challenges, current approaches, and what is seen as coming problems and approaches. Public officials and environmental-group leaders in all states were contacted in attempts to learn what they see as likely changes in approaches that might affect the market opportunities in each state in the near term.

2.1 California

Key Markets	Niche Markets
Water conservation	Smart/sub-metering technologies; low water-use technologies; gray-water systems;
Infrastructure	Real-time monitoring technologies for pipe conditions; targeted pipe repair technologies
Agriculture	Technology facilitating better farm-gate irrigation data; technology allowing for higher yield, less water-consumptive crops (Central Valley); real-time sensor networks for nutrient and chemical sampling; synthetic nutrient balancing of natural fertilizers to control excess phosphorus;
Groundwater contamination	Real-time, networked groundwater quality monitoring

Summary of Key Issues

California, more than any state, embodies within its borders the host of water challenges confronting the country at large. At 36.9 million (2009 estimate), California's population rivals and surpasses that of many large countries. Some estimates place the state's population in 2030 as high as 71 million, while more conservative estimates place it somewhere above 50 million. Although much of the state's population is concentrated in coastal regions, the interior Central Valley is the single most profitable produce-growing region in the country. California itself is responsible for 13% of the nation's GDP and thus any water constraints or challenges faced by the state are bound to have national implications. Already facing serious challenges regarding riparian rights from river flow originating as far away as Colorado, rapidly depleting aquifer levels – greatly strained following the state's most recent multi-year drought -, and a host of environmental and industrial pressures, the state will increasingly look to diversify its approach to addressing water concerns. Some of the primary issues facing the state include:

- Sustainable supply/facing growth constraints
- Aging infrastructure: collection/distribution; reservoirs
- Agriculture: high irrigation demand; pesticide/herbicide contamination; CAFO pollution
- Groundwater: contaminants entering groundwater; degraded quality at tap; saltwater intrusion
- Aquifer depletion: groundwater controls/limits (or lack of) and monitoring
- Desalination issues and costs
- Invasive species
- Climate impacts: drought; seismic events

Population Indicators

	2009 (est.)	2015	2035
Urban Population	36,128,589	-	-
Rural Population	833,075	-	-
Total	**36,961,664**	**40,123,232**	**+50,000,000***

* Figures vary widely, but most projections place the state's population above 50,000,000 by 2035
2015 projection http://www.bcnys.org/whatsnew/2005/0420censuspoptable.htm

<u>Economic Indicators</u>

Total GSP: $1,622,116 (in millions)
US Rank: 1
World Rank: 9
GSP per capita: $42,325 USD (*US average - $39,138*)

Water Use
Average per capita daily use (*domestic*): 124g (US avg. = 90g)
* USGS, 2005

Withdrawals *(in thousand acre-feet per year)*

	Fresh	**Saline**	**Total**
CA Withdrawals	36,800	14,400	51,300

Background

- Groundwater accounts for about 30% of CA's overall dedicated water supply in average precipitation years, increasing to about 40% statewide in dry years
- At least 43% of Californians are at least partially dependent on groundwater supplies for drinking water annually
- During years in which rainfall is scarce and surface water deliveries are unavailable, groundwater can provide up to 100% of irrigation water for certain areas
- For some communities where surface water is not accessible or economically feasible, groundwater makes up 100% of a community's public water
- Under average conditions the Department of Water Resources (DWR) predicts that supply will meet demand up through 2030. However, in dry years projected demand is expected to exceed supply for almost all areas (with the exception of agriculture)
- California's population is currently growing at a rate of approximately 2M per year and could potentially reach 71M by 2030
- The megacity spanning from Santa Barbara to the Mexican border and centered around the city of Los Angeles is expected to grow to 41M by 2020 from its current 28M
- CA public water systems rely on more than 17,000 groundwater wells and surface water supplies to meet consumer water supply need
- In 2005, California ranked number 1 for percent of bottled water share (23.9%) and third for per capita consumption (51.2 g) behind Arizona and Louisiana.

Projected 20-year Need (Drinking Water Infrastructure)

A survey of water infrastructure needs by the US EPA identified the following needs in California: transmission/distribution = $22,988.5M; Source = $2,515.3M; Treatment = $7,549.7M; Storage = $5,735.6M; Other = $257.3M; Total = $39,046.3M (2007)

Projected 20-year Need for Community Water Systems (CWS)
Serving 10,000 Residents or Fewer

CWS's Serving 10,000 or Fewer People	
Transmission/Distribution	$3,383.5M
Source	$521.7M
Treatment	$839.4M
Storage	$791.7M
Other	$74.6M
Total 20-year need of CWS's serving 20 people or fewer	$5,610.9M
Total 20-year need of all CWS	$38,944.9M
% of CWS need related to systems serving 10,000 or fewer persons	14.4%

Source: EPA Drinking Water Infrastructure Needs Survey and Assessment 2007

Key Issue: Sustainable Supply/Facing Growth Constraints

Key Dimensions

- CA has no statewide groundwater use permitting system. Landowners are entitled to a "reasonable use" of groundwater on property overlying the groundwater basin
- Surface water, however, is not an entitlement and surface-water rights are appropriated through a state-administered permitting system
- Water scarcity is beginning to limit growth in the energy sector which has traditionally relied on it because of its efficiency for use in cooling, as well as reduced capital costs (thermoelectric power generation accounted for 41% of US water withdrawals in 2005)
    - The 2003 Integrated Energy Policy Report included the adoption of a policy that discourages fresh water use for power plant cooling
- Current supplies of usable groundwater estimated at some 250MAF (six times the size of the state's surface water reservoirs)
- In an average year, between 25 and 40 percent of the state's water supply comes from groundwater (and as high as two-thirds in dry years)
- California users extract an average of 14.5B gallons of groundwater per day (more than any other state and twice as much as Texas, the second-ranked state)
- 16M Californians depend on groundwater for drinking water supplies
- CA also has more agricultural irrigation wells than any other state (more than 71,000)
- Approximately 750,000 acres of agricultural land in the Lower Sacramento River Valley are irrigated using groundwater

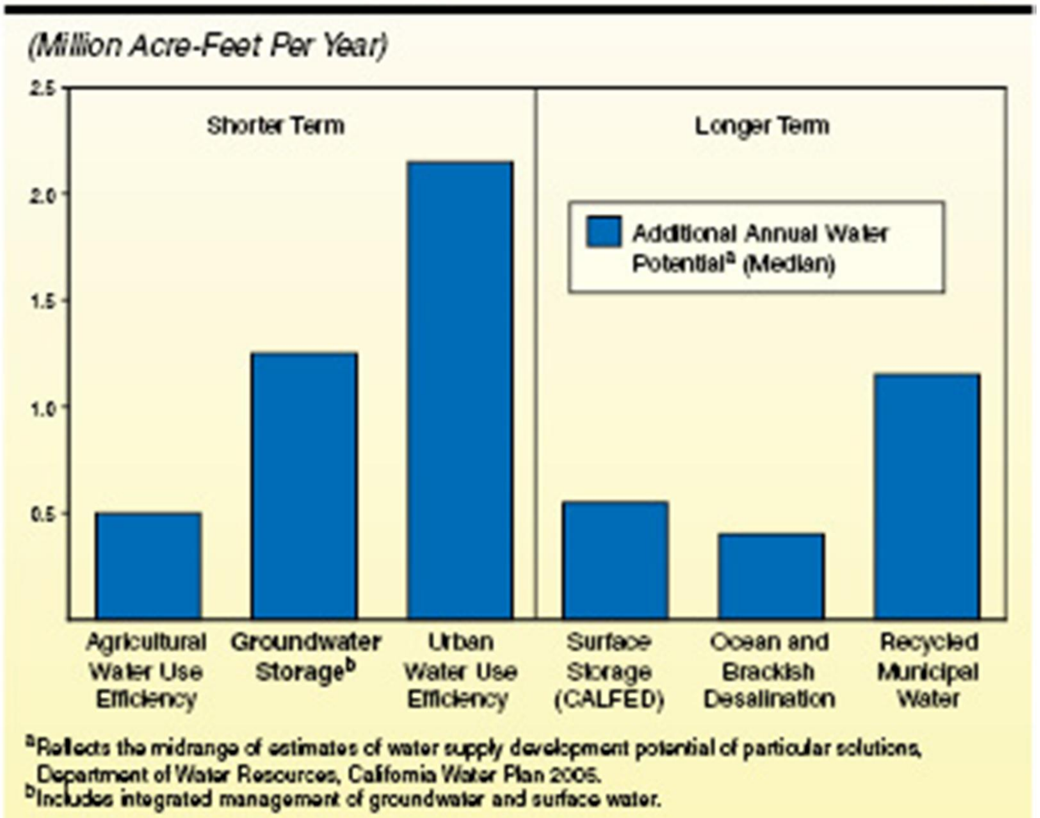
Action Needed

- In its 2009 update to the California Water Plan, the DWR identified a lack of data as one of a number of problems with regards to estimating groundwater supply
- Lack of comprehensive data and the need to piece together disparate pieces of information from various sources is also anticipated to aggravate the cost of future water assessments and initiatives

- Although more than 140 local groundwater management plans have been submitted to the DWR as part of AB 3030, these plans have generally not been used in statewide water planning due to the lack of such plans for some communities (they were voluntary) and the lack of a requirement that the plans be used to implement or improve groundwater balances in affected basins. Furthermore, data submitted reflect a single point in time and the reports lacked a uniform format that would have allowed for comparisons between groundwater basins
- The DWR has analyzed a number of short- and long-term options for strengthening water supply reliability throughout the state:
  - **Short-term**: 1) agricultural water use efficiency; 2) groundwater storage; 3) urban water use efficiency
  - **Long-term**: 1) surface storage; 2) ocean and brackish desalination; 3) recycled municipal water

Figure 3

Groundwater: A Key Option for Additional Water Supply



Impending Water Policy Changes/Conditions to Address Issue

SBX7 6—2009 Water and Groundwater Legislation Package

- Requires monitoring and public reporting of groundwater elevations in all groundwater basins in CA
- Local agencies are responsible for monitoring elevations and reporting results to DWR

- The DWR is responsible for periodically reporting on groundwater status throughout the state (including elevations) and issuing a public report
- To incentivize compliance, counties with local agencies not conducting the required monitoring would be barred from receiving state water grants and loans
- As part of the legislative package, an $11.1B bond measure was passed by the Legislature (including $1B specifically allocated for groundwater supply and quality), with further potential for funding groundwater management in various other provisions of the bond measure

Technology Needed
- Technologies allowing for more accurate estimates of groundwater levels
- Water reuse systems that help to reduce agricultural water use pressures on groundwater supplies, particularly in the event of drought
- More efficient groundwater recharge methods
- Technologies helping to reduce amounts of lost water

Availability of Technology
Leak Control Technologies
- Continuous acoustic monitoring
- Advanced metering infrastructure communication
- District Metered Areas (DMAs) for audit and leak control
- Pressure monitoring
- GIS analysis

Other water reuse/recycling technologies include:
- Wastewater biofiltration systems
- Membrane bioreactor technology for water reuse
- Low-pressure membranes
- Advanced water filtration for reclaimed water systems

Key Issue: Water Infrastructure - Aging infrastructure Collection/Distribution

Key Dimensions
- Estimated $17.5B in drinking water infrastructure needs over next 20 years (2005)
- Estimated 222 million gallons of drinking water lost each day to leaking pipes (2005)
- Estimated $14.4B in wastewater infrastructure needs (2005)
- Initial 2009 State Water Project (SWP) allocations to water agencies and irrigation districts was only 15% of the total requested amount
- In fiscal year 2008, the state received a mere 0.53% ($115M) of the $21.8B necessary to meet the state's water and sewer system needs
- California's most recent Intended Use Plan under the Drinking Water State Revolving Fund program lists 4,087 projects at a total cost of $8.9B

Action Needed
- The National Utility Contractors Association has estimated that for every $1B spent on water infrastructure, nearly 27,000 jobs are created

- Fully addressing the outstanding $21.8B in state water needs would spur an estimated 582,024 employment opportunities
- In January 2006, there was a 841,490 gallon sewage spill at Manhattan Beach and Hermosa Beach lasting over 15 hours and threatening underlying groundwater and resulting in hazardous bacteria levels along almost nine miles of shoreline for four days and the closing of popular beaches for an additional 23 days

Impending Water Policy Changes/Conditions to Address Issue

- Because of extreme fiscal constraints in the state most water investments are likely to be postponed for some time

Technology Needed

- Technologies facilitating the cost-effective repair of aging/compromised water infrastructure
- Technologies providing real-time data on the quality of water infrastructure enabling targeted repairs

Availability of Technology

There are a number of available technologies that aid in the detection of water leaks. These include:

- Continuous acoustic monitoring
- Advanced metering infrastructure communication
- District Metered Areas (DMAs) for audit and leak control
- Pressure monitoring
- GIS analysis

Available Technology

Pipe rehabilitation, replacement & repair*	Self-healing smart materials; structural spray-on linings; sewer odor and corrosion control insert; etc.
Pipe testing, inspection & assessment technologies*	Sonar; ultrasonic; isotope hydrology; digital, modular and robotic technologies; remote monitoring and wireless technologies; FELL (Focused Electrode Leak Locator); sewer scanner and evaluation technology (SSET); smart sewer assessment systems (KARO, PIRAT, TriScan); etc.

*See report "Water and Wastewater Infrastructure Technology Overview" for fuller listing

Key Issue: Aging Infrastructure - Reservoirs

Key Dimensions

- Precipitation, accounting for some 35% of CA's annual 200M acre-feet, is captured and stored in reservoirs and groundwater basins
- Lake Oroville (the SWP system's main reservoir) was only at 28% of capacity in April 2009 - this is consistent with the state of other CA reservoirs

- 69 of California's 1,247 dams are in need of rehabilitation in order to meet state dam safety standards
- 59% of state high-hazard dams have no emergency action plan (EAP)
- California has 687 high-hazard dams (those whose failure would cause a loss of life and significant property damage)

Action Needed

- More/better funding of water infrastructure projects
- Conservation to reduce demand place on existing infrastructure

Impending Water Policy Changes/Conditions to Address Issue

Safe, Clean and Reliable Drinking Water Supply Act (AB2775)

This is an $11B ($22B with interest) water bond measure set to be included on the November ballot. This bill has become somewhat controversial and current Gov. Schwarzenegger, along with other legislative leaders, is attempting to remove it from the 2010 ballot (postponing it till 2012). This represents an about-face from the governor's previous stance, with Schwarzenegger having previously asserted that the bond is vital to ensuring California can provide sufficient water to state residents. He had even proposed spending $1.8B of the bond in next year's budget. Because of its importance, Schwarzenegger feels it would be best not to jeopardize the bill by including it on this year's ballot. The bill includes a provision that would allow corporations to own and operate taxpayer-built reservoirs and other water storage projects, a provision that the legislature has attempted to remove from the bond. Water conservation projects and efforts to revive the Sacramento-San Joaquin River Delta would not be affected by a postponement, although some projects in the delta and elsewhere would be affected.

Agriculture

Because such a large amount the country's produce is grown in California, agricultural water use in state is a pressing national concern.

Key Issue: High Irrigation Demand

Key Dimensions

- Agriculture is key to CA's economy: some 88,000 farms and ranches in the state generated $36.6B in gross income in 2007 (California Department of Food and Agriculture) and $100B in related economic activity
- 2005 irrigated acreage estimated to be 8.7M acres, with an additional 540,000 acres of multi-crops, for a total of 9.2M acres of irrigated crop area
- Amount of actual irrigated cropland can range from year to year: in 2000 there were an estimated 9.6M acres of irrigated cropland with some 34.2MAF of applied water as irrigation
- There are signs that water-use efficiency has improved in recent decades: agricultural production per unit of applied water (tons/acre-foot) increased by 38% for 32 of California's crops from 1980-2000; inflation-adjusted gross crop revenue per unit of applied water (dollars/acre-foot) increased by 11% from 1980-2000
- Guidance for improving agricultural water use efficiency: Agricultural Water Suppliers Efficient Water Management Practices Act of 1990 and federal Central Valley Project Improvement Act of 1992

- Beginning in July 2009, the Agricultural Water Management Council (AWMC) brought together 79 agricultural water suppliers and four environmental organizations in order to improve water use efficiency through the implementation of efficient water management practices
    - Council recognizes and tracks water supplier water management planning and implementation of cost-effective efficient water management practices via a review and endorsement procedure
    - Signatories voluntarily commit to implement locally cost-effective management practices
    - Signatories represent more than 4.6M acres of retail irrigated acreage; 5.86M acres of agricultural land
- Agricultural Water Management Planning Act (SBx7 7 – 2009): agricultural water suppliers supplying water to 10,000 or more irrigated acres are required to develop and adopt a water management plan with specified components and must implement cost-effective efficient water management practices. Suppliers providing water to less than 25,000 irrigated acres are not required to implement the requirement of the bill unless funding has been provided to the supplier)

Action Needed

- The Irrigation Research and Training Center at the California Polytechnic State University, San Luis Obispo estimates that an additional 3.8M acres could be converted to precision irrigation (such as drip or micro-spray irrigation)
- 2000 estimates for CALFED Programmatic Record of Decision (ROD) estimated that efficiency improvements could result in water savings between 120,000 and 563,000 acre-feet per year (AFY) by 2030 at a cost of between $35 and $900 per acre-foot (CALFED, 2000a).
    - Total cost for this level of water use efficiency up through 2030 is estimated at $0.3B to $2.7B, including $220M for lining the All-American Canal and Coachella Branch Canal (see CALFED Water Use Efficiency Program Plan for details on cost estimates and assumptions)

Current Approach

- Regulated Deficit Irrigation (RDI):
- Efficient irrigation technologies
- Improved irrigation scheduling
- Anaerobic treatment lagoons for partial biological waste digestion (can be unlined if built prior to late 1990's)
- Liquid manure soil injection - controls odors, usable with no-till agriculture
- Biogas capture for energy generation

Technology Needed

- Technology facilitating better farm-gate irrigation data (and data in general)

Availability of Technology

Improved irrigation systems, such as drip irrigation, will be important to reduce the amount of water necessary for agricultural uses. Drip irrigation systems lose less water to evaporation than traditional systems such as sprinkler irrigation (http://ga.water.usgs.gov/edu/irdrip.html).

Available technologies to address high irrigation use include:

- Micro- and drip irrigation
- Water saving irrigation technologies:
  - Automated diversions
  - Gated pipe application
  - Surge valves

Micro-irrigation systems currently are being produced, which involve low-cost drip technology and state-of-the-art technology (http://www.iwmi.cgiar.org/publications/Water_Policy_Briefs/PDF/WPB23.pdf). Examples of these available technologies include:

- Low-cost
  - Pepsee easy drip technology
  - Bucket and drum kits
  - Micro sprinklers
  - Micro tube drip systems
- State-of-the-art
  - Conventional drip systems
  - Sprinkler systems

Crop yields are generally higher when drip irrigation systems are used. Additionally, users of low-cost systems, such as Pepsee systems, can begin to see returns after as little as one year. However, low-cost systems are usually more appropriate for very small landowners.

Key Issue: Pesticide/Herbicide Contamination

Key Dimensions

- Over 50 pesticides have been found in California groundwater, approximately half of which can be attributed to leaks and spills, the other half most likely being the result of normal field application
- Methyl Iodide, a known human carcinogen and neurotoxin that has also been linked to late-term miscarriages is poised to be approved for application to California's strawberry fields (85% of US strawberry crop); new regulations would set safe levels at 120 times the level recommended by an independent panel

Action Needed

- Improved leakage and spill detection/prevention
- Pesticide alternatives allowing for lighter field application
- Technologies enabling more effective removal/mitigation of pesticides in groundwater
- Policies targeted pesticide control and overview in the state

Technology Needed

- Field-embedded real-time sensor networks for nutrient and chemical sampling
  - Higher spatial resolution
  - Timely data acquisition

- Sensor network control of variable rate fertilizer application equipment
- Real-time nutrient mixing and balancing
- Synthetic nutrient balancing of natural fertilizers to control excess phosphorus

Key Issue: Confined animal feeding operation pollution

Key Dimensions

- CA is estimated to have between 1,000 and 1,200 confined animal feeding operations (CAFOs), which are referred to in CA legislation as "confined animal facilities" (CAFs)
- CAFs fall under the jurisdiction of the State Water Resources Control Board and nine semiautonomous Regional Water Quality Control Boards (Regional Water Boards)
- Most commercial CAFs are located in the Central Valley Region (including about 80% of dairies)
- In CA, CAFs are prohibited from discharging into a water of the United States, and few such discharges occurs largely thanks a strong state enforcement program

Action Needed

- Regulations to cover a majority of small CAFOs, currently regulated only under special determinations
- Watershed-level authorities for NPDES permitting

Technology Needed

Technology needs include (EPA Summary Draft)

- Monitoring and control systems for treatment lagoons to enhance BNR processes
- Retrofit liner technology for existing lagoons
- Cost-effective high-efficiency manure treatment systems
- Nutrient recovery - especially phosphorus
- Zero liquid discharge processes for environmentally sensitive watersheds and dry fertilizer production
- Phosphorus/nitrogen balancing - for optimum fertilization efficiency without excess phosphorus
- Nutrient testing and automated blending systems to achieve appropriate nutrient concentrations for a variety of agricultural needs
- Systems for aquaculture
- Manure solids application technology for no-till agriculture
- Heavy metals and arsenic reduction technology
- Alternatives to "preventive" antibiotics use in animals
- Integrated energy/fertilizer production
- Sophisticated field-level and watershed-level modeling tools (the GIS-based Hydrologic Unit Water Quality Tool (HUWQ) and Soil and Water Assessment Tool (SWAT) are examples)

Availability of Technology

Currently available technology includes (EPA Summary Draft):

- Anaerobic treatment lagoons for partial biological waste digestion (can be unlined if built

prior to late 1990's)
- Liquid manure soil injection - controls odors, usable with no-till agriculture
- Biogas capture for energy generation

Key Issue: Erosion/Sedimentation

Key Dimensions
- A 2006 report by the USGS (Historical Shoreline Change and Associated Coastal Land Loss Along Sandy Shorelines of the California Coast), which studied more than 450 miles of sandy shoreline, concluded that net shoreline change in the short-time (25-40 years) indicates that 66 percent of California's beaches are eroding. Central California, spanning from Fort Reyes to Santa Barbara, showed the highest percentage of erosion. Long-term coastal shoreline change, however, showed significant expansion, likely due to large-scale coastal engineering and beach nourishment projects in Southern California, as well as a high influx of sediments from coastal rivers in Northern California.
- Two of the largest five US metropolitan areas border the sea in California, which the shoreline being essential to recreation, commerce, security and navigation
- In January and February of 2010, a combination of swells, high tides and strong winds removed as much as 30 to 40 feet of beachfront in the Los Angeles area.
- Erosion is a challenge to some estimated $3 trillion in real estate investments along the Atlantic and Gulf coasts in the US (as well as some 155M people)
- Forest fires have also posed a challenge to preventing erosion in the state

Action Needed
- Improved building codes and land management practices to limit development near streams and sensitive areas

Available Technology
- Stream fencing
- Biodegradable erosion control mats

Key Issue: Groundwater - Contaminants Entering Groundwater

Key Dimensions
- 305(b) Report (State Water Resources Control Board), a biannual report detailing conditions of CA's groundwater resources, found that:
  - More than one third of the areal extent of groundwater in the state is too contaminated to be safely used for all of the purposes designated by the state as appropriate and desirable
  - Sources identified as contributing to groundwater contamination include: septic systems, landfills, leaking underground storage tanks, and agricultural operations
- Findings by the National Resources Defense Council concluded that:
  - In addition to one third of areal extent groundwater being contaminated beyond being able to support all designated uses, at least 40 percent of areal extent groundwater is either impaired by pollution or threatened with impairment

- Threats to groundwater basins in CA include: salinity, organic compounds, pesticides, nutrients, and metals, among others
- Large numbers of drinking water wells do not meet drinking water standards, which requires various levels of treatment prior to delivery to users
- Groundwater contaminants have been found to exceed state and federal standards in many regions of the state
- A variety of human activities affecting groundwater quality have also been identified, including: storage tanks, agriculture, land disposal, septage, and industrial point sources

- San Fernando Valley: currently the site of a 2 mile wide, 7-10 mile long toxic chemical plume that has forced officials to close dozens of water wells and may eventually force them to stop drawing local water altogether unless a $850 million cleanup effort is undertaken
  - Between 50 and 55 wells are shut at any given time in the North Hollywood and Rinaldi-Toluca mine fields
  - Annual amount of money DWP spends on imported water now at $174 million (up from just $7.3 million in 2007)
  - Without investment city may be forced to stop withdrawing water from Valley wells within 5 to 10 years
  - DWP currently drafting plans for $850 million treatment complex to remove carcinogenic cleaning solvents, including Chromium 6 (used for aerospace and related industries in ‘40s and ‘50s
  - DWP water sources: 13% from aquifer; 37% from California Aqueduct; 1% from recycled water; 49% purchased from the Metropolitan Water District
  - Concerns about flows from the Colorado River have increased
  - A report from the Los Angeles County grand jury has raised concerns about contamination from the aerospace industry and noted that the DWP had close 54 of its 115 wells in the Valley as of late 2009
  - Of the remaining 61 wells, 44 had recorded various contaminants above MCLs established by the California Department of Public Health
  - LADWP has predicted that without a cleanup effort water from the San Fernando Basin Aquifer will be unavailable within 5 years
  - The San Fernando Basin Aquifer holds approximately 3.2MAF (enough to supply LA for five years)

Action Needed

- Increased conservation
- Cost-effective techniques for the treatment of contaminated groundwater supplies

Technology Trends and Needs (EPA Summary Draft)

- Real-time, networked groundwater quality monitoring
  - Fiber optic
  - Web-enabled
- Potable water and irrigation water production

Key Issue: Degraded Water Quality at Tap

Key Dimensions

- Public water systems are estimated to serve approximately 36.6M (97%) of the state's 37.7M inhabitants
- In March 2008, the town of Alamosa (pop. 8,500) experienced an extensive salmonella outbreak that sickened at least 389 individuals (16 hospitalized)

Action Needed

- Improved water monitoring
- Stricter controls and legislation addressing water quality

Current Approach

- Ultraviolet (UV) disinfection treatment – for compliance with Stage 2 Disinfection Byproducts Rule and Long Term 2 Enhanced Surface Water Treatment Rule
- Arsenic removal technologies, such as adsorptive (disposable) media to allow small water systems to comply with the reduced arsenic MCL
- Biological treatment: fixed bed, fluidized bed and membrane bioreactors (currently for treatment of perchlorate; under demonstration for nitrate and other contaminants)
- Desalination (using funds allocated under Proposition 50)

Technology Needed

Needs (Water and Wastewater Infrastructure Technology Overview)

- Communications and control systems integrated to measurement and modeling systems that enable necessary and timely decisions and adjustments of flow rates, flow paths pressure, disinfectant, corrosion control, and inspection and maintenance activities
- Storage tank design or operation modifications to reduce residence time
- Point of entry or point of use treatment
- Water quality, corrosion, and structural integrity monitoring that is more intensive, extensive, rapid, accurate, and economical.
- Pressure management for new systems - pressure management is one of the most Effective new approaches to leakage control. It may provide the added advantage of Reducing main breaks

Areas for high-priority research (Water and Wastewater Infrastructure Technology Overview)

- Evaluate chemical methods to control H_2S in sewer pipes
- Improvements in oil and grease control
- Water distribution mains must consider water quality and hydraulic considerations as much as pipe integrity
- Research methods to clean and line piping with tuberculation (small mounds of corrosion products on the inside of iron pipe), with minimal access points
- Methods to coat or recoat ferrous mains without blocking services
- Private lateral rehabilitation
- Magnesium hydroxide crown spray systems

Availability of Technology

Water Treatment

Advanced options for DBP (disinfection by-product) control

- Magnetic Ion Exchange (MIEX®) - proprietary polymer bead resin with magnetic core
- Actiflo®CARB - proprietary ballasted clarification with powdered activated carbon adsorption
- Nanofiltration
- Granular activated carbon (GAC),
- Ozone/Biofiltration - biologically reactive GAC
- Automated mains flushing systems - received categorical approval from EPA in 2010

Emerging Technologies

- Energy efficient in-tank mixing systems that maintain a uniform water "age" in the tank and prevent thermal stratification
- Chlorine dosing systems that operate in tanks or reservoirs to maintain an effective level of disinfectant in the distribution system
- UV systems that achieve uniform dosing, even in turbid water
- Pre-treatment filters that minimize organic matter and resulting DBP formation
- Granular activated carbon (GAC) adsorbents (effective on a broad range of contaminants, including radon)
- Point of entry and point of use filtration, especially for sensitive applications such as hospitals
- Dual distribution systems that utilize separate pipes for fire hydrants and potable supply; in this arrangement, the potable supply pipes can be much smaller (typically 2" vs. 6" or larger), greatly reducing water residence time in the network. An additional benefit of dual distribution is that the water used for fire suppression may not have to be treated to potable standards.
- Real-time monitoring and instantaneous wireless notification of disinfectant residual, DBP, and biological contaminant levels at various points in the distribution network
- Alternative disinfecting agents (for example, chloramines, hydrogen peroxide, chlorine dioxide, ozone, copper and silver compounds), that may produce fewer DBPs and/or maintain effective residuals for an extended period of time

For water systems that rely primarily on groundwater monitoring to satisfy the requirements of the rule, the greatest need is for enhanced, cost-effective monitoring and control systems.

- Trend toward real-time monitoring
- Multiple site/strata monitoring
- Web-enabled networked systems linked by RF or cellular technology
- Automated systems that do not rely on operator interpretation to determine results
- Units that monitor multiple contaminant classes: biological, chemical, and radiological

Key Issue: Aquifer Depletion
Unlike its progressive stances in areas such as renewable energy and recycling, water policy and regulations have lagged behind. There are, however, mounting pressures for greater regulation of water resources in the state.

Key Dimensions

- State aquifers have become increasingly crucial as a result of reduced Sierra snowpack and its accompanying runoff
- Many argue that stricter regulations are critical to protecting CA's $36B agricultural economy
- 50ft drop in surface of aquifer in Kaweah sub-basin of the San Joaquin basin since 2006
- In the Central Valley (Kern, Kings and Tulare Counties), overdraft of 800,000AF per year has led to declines of over 200ft in some areas
- Given that the Central Valley is home to one sixth of all US irrigated land, lack of sustainability in the region is sure to have a large impact on the US economy
- According to a NASA report using data collected by the Grace program, California's Sacramento and San Joaquin drainage basins have together lost more than 30 cubic kilometers (about 7,926B gallons) of water since late 2003. Most of that loss occurred in the agricultural Central Valley, which is irrigated via a combination of groundwater and surface water
- Grace data reveals that the rate at which water is being pumped for irrigation is not sustainable under current trends
- Droughts are estimated to cost the US economy some $6 to $8 billion annually

Action Needed
The following are recommendations from the Legislative Analyst's Office:

- Phase in a more comprehensive groundwater monitoring system to allow the state to focus funding and technical assistance efforts in the areas of greatest need
- Establish Active Management Areas (a defined geographic area where specific rules are established to govern the withdrawal and use of groundwater), in circumstances where groundwater overdraft potential or the extent of pollution problems are the highest
- Bring science and law together to modernize groundwater law to accurately reflect the physical interconnection of surface water and groundwater
- Consider phasing in statewide groundwater permitting over a multiyear period, based on data from expanded monitoring requirements, while maintaining local control over implementation of permitting to the extent possible

Impending Water Policy Changes/Conditions to Address Issue

- State legislation decreasing allocations of surface waters to the San Joaquin Basin is expected to place further strains on the region's groundwater

Availability of Technology
Groundwater monitoring technologies which would address unsustainable supply and aquifer depletion include:

- Real-time monitoring
- Multiple site/strata monitoring

- Web-enabled networked systems linked by RF or cellular technology
- Automated systems that do not rely on operator interpretation to determine results
- Leak control technologies:
  - Continuous acoustic monitoring
  - District Metered Areas (DMAs) for audit and leak control
  - Pressure monitoring
  - GIS analysis

Key Issue: Groundwater Controls, Limits (or lack of) and Monitoring

Key Dimensions

- CA lacks a comprehensive groundwater monitoring program and available information is frequently considered questionable
- Agencies monitoring state groundwater (state and federal) fail to properly coordinate data and activities
- GAMA (Groundwater Ambient Monitoring and Assessment) Program – state comprehensive groundwater quality and monitoring program
- Data collected for GAMA is made available via GeoTracker GAMA, a publicly-accessible internet database
- Although over 95% of state residents get drinking water from public or municipal sources, some 1.6M state residents get their drinking water from over 600,000 private domestic wells
- 305(b) Report – although considered a comprehensive assessment of the state of CA's groundwater, this biannual report has been criticized as incomplete and unreliable and the value of the groundwater data therein contained has been called into question. Problems identified include data-collection inaccuracies and lack of substantiation for basic assumptions
- The State Water Resources Control Board has even stated that it does not itself consider groundwater data included in the Report (for which it is responsible) to be reliable

Action Needed

- The National Resources Defense Council has made the following recommendations regarding groundwater monitoring in CA:
  - The state agencies responsible for protecting and managing California's groundwater resources (particularly the State Water Resources Control Board, the Department of Health Services, and the Department of Water Resources) should improve the scope and quality of their information by instituting a more systematic and ongoing monitoring program and by standardizing the formatting of the data gathered;
  - A single agency should be responsible for compiling all of the information and for making that information readily accessible to the general public;
  - The significant inadequacies and errors contained in the 305(b) Report should be remedied through a complete reformation of this critical statewide groundwater assessment;
  - The agency or agencies responsible for protecting California's groundwater resources and the health of California's residents should develop a better understanding of the

actual contaminants that are affecting the groundwater and the sources from which they come;
- The Legislature should ensure that adequate funding is provided to support these programs;
- The Legislature should ensure adequate implementation and enforcement of prevention programs to prevent further contamination of groundwater resources;
- The agency or agencies responsible for remediation of contamination within groundwater basins should ensure timely remediation of already contaminated sites;
- The Legislature should institute "polluter pays" provisions for groundwater contamination to compensate the individuals or agencies conducting remedial activities. However, it should clearly provide that remediation is not to be contingent upon identification of the responsible parties and that collection of compensation is not to be a prerequisite to remedial action.

Current Approach

- Farmington Groundwater Recharge and Seasonal Habitat Program (launched 2003) – 1— year, $33.5M project to begin restoration of the Eastern San Joaquin Groundwater Basin
  - Direct recharge facilities developed through the program currently contribute more than 11,000 acre-feet per year towards the program's original recharge goal of 35,000 acre-feet annually
- Orange County Water District (OCWD) and Orange County (OCSD) joint recharge project – recharge aquifer (provided over 75% of water to 2 million people) with highly purified, tertiary-treated wastewater. Following completion of the third phase, up to 115M gallons per day will be pumped to infiltration basins. First phase will add 75,000 acre-feet of water per year to the aquifer (enough for 200,000 families). The Groundwater Replenishment System is scheduled achieve full capacity by 2020.

Availability of Technology

Available groundwater monitoring technologies include:

- Real-time monitoring
- Multiple site/strata monitoring
- Web-enabled networked systems linked by RF or cellular technology
- Automated systems that do not rely on operator interpretation to determine results
- Units that monitor multiple contaminant classes: biological, chemical, and radioactive

Key Issue: Salt Water Intrusion

Key Dimensions

- Over 15.5 million tons of salt are brought into or mobilized in Central Valley waters each year (Economic and Social Cost Study, UC Davis) – expected to grow by 1 million tons per year by 2030
  - Annual cost of not acting on salt accumulation estimated to be $544 million per year by 2030 due to lost agricultural production, as well as $579 million in damage to pipes, pumps, water heaters and other equipment
- Climate change is considered responsible for further intrusion of saltwater, including in the Sacramento-San Joaquin Valley

- Salinas Valley
- Because of a history of saltwater intrusion in the Central and West Coast Basins of California dating back to the early 1900s, in the 1950's the city of Los Angeles began efforts to create a barrier by injecting potable water into a system of wells to effectively create a pressure barrier against seawater intrusion. The project proved successful and led to the creation of the West Coast Basin Barrier Project, the Dominguez Gap Barrier Project, and the Alamitos Gap Barrier Project. Both potable and recycled municipal wastewater (treated via microfiltration, reverse osmosis, and advanced oxidation in some cases) are injected into the CWCB (Central and West Coast Basins) to depths of up to 700ft. For 2007/2008, the cost of injection water was approximately $14M, with maintenance costs approaching $4M to $5M.
- Because of aging infrastructure, rising water and maintenance costs, as well as concerns about the availability of long-term potable water, efforts are currently underway to optimize barrier performance, minimize costs, and to ensure that barriers continue to be effective. Reduced pumping itself would significantly help to reduce barrier efforts and associated costs by allowing groundwater levels to rise. Some attempts are being made to replace groundwater pumped from wells along the coast (used solely for industrial purposes) with recycled water.

Action Needed

- More cost-effective alternatives to injection barrier system in the face of rising costs and aging infrastructure
- To address salt accumulation in the Central Valley:
  - Water efficiency, which helps to reduce imported water and accompanying salts
  - Use of lower salt products and processes
  - Increased use of treatment and softeners that do not discharge salt
  - Education about salinity

Current Approach

- Salinas Valley Water Project – project aimed at reducing seawater intrusion in the Salinas Valley by reducing groundwater pumping used for farming
  - $33M project – includes changes to Lake Nacimiento Dam spillway to control water releases from two South County reservoirs, improving dam safety and flood control
  - River water will ultimately be combined with recycled water for irrigation of some 12,000 acres of farmland
  - Property owners will pay approx. $66 per acre-foot of water
  - The constructed diversion facility for withdrawal of river water will operate 8 months per year with withdrawals of up to 10,000AF per year
  - Funding for the project including a $5.5M state grant, bonds to be paid back through $1M per year in property assessments, and $750,000 in annual revenue from the sale of electricity generated by the hydroelectric plant at Lake Nacimiento, among other sources
- To address salt accumulation in the Central Valley:
  - On-farm water reuse and salt precipitation
  - Reverse osmosis concentration and truck disposal to existing ocean outfalls
  - Brine reinjection into oil extraction areas
  - Water management and water source replacement

- Current source control for salts going into domestic sewers

Key Issue: Desalination Issues & Costs

Key Dimensions
Interest in and use of desalination in CA is on the rise. However, not everyone in the state is unanimously behind the use of desalination to meet CA's water needs.

- The Surfrider Foundation recently filed a lawsuit against the San Diego Regional Water Quality Control Board aimed at challenging a permit allowing for the withdrawal of 300M gallons of seawater a day at a desalination facility. It is feared that these withdrawals will destroy millions of fish eggs and other forms of marine life each year.
- The Pacific Institute asserts that California could be better served through conservation programs, saving fully one-third of water use through conservation program, 85% of which could be saved at lower costs than procuring new sources such as desalination.
- Precautions, such as softening water without the use of salt, are critical to the health of state farmland.

Action Needed

- Desalination is also a growing issue on agricultural lands where steps need to be taken to desalinate water used for irrigation and for domestic use to keep it from entering agricultural land. Laws requiring alternative methods need to be reinstated or enacted throughout the state.

Similar steps to address increased salinity in the state's surface waters must also be taken.

Key Issue: Energy Consumed by Water Treatment

Key Dimensions

- According to the California Energy Commission (CEC), water-related energy use consumes approximately 20 percent of the California's electricity
- The CEC estimates that fully 75 percent of electricity use related to water in California is associated with the end use of water (primarily water heating)
- Due to dropping aquifer levels, more water being pumped long distances, more desalination in place, increased use of reverse osmosis, and more tertiary water treatment, energy plays an increasingly important role in CA water

Key Issue: Climate Impacts - Climate Change Threaten Water Availability/Quality

Key Dimensions

- Climate change impacts on water availability in CA include changes to snowpack, sea level, and river flows
- Changes are expected to exacerbate flood risks and affect water supply reliability
- Sierra snowpack, responsible for 65% of CA's water supply, is expected to experience a 25-40% decrease by 2050. Snowpack has already increased by about 10 percent during the last century, which translates to decrease of some 1.5MAF of snowpack storage
- Increased weather variability is expected to result in longer and more severe droughts, as well as increases in sea level, all of which is expected to threaten the sustainability of the

Sacramento-San Joaquin Delta, which supplies water to 25 million people, as well as millions of acres of prime farmland

- Climate change is also expected to reduce the reliability of California's hydroelectricity operations
- Agriculture is expected to experience increased demand for irrigation, largely resulting from drought
- Flooding is a likely outcome of higher winter river flows
- Sea level rise will threaten many Delta levies
- Warmer river temperatures are expected to affect cold-water species such as salmon http://wwwdwr.water.ca.gov/climatechange/docs/ClimateChangeWhitePaper.pdf

Action Needed

- Sustainable funding for statewide and integrated regional water management
- Fully develop potential of Integrated Regional Water Management (IRWM):
- Aggressive increases in water use efficiency
    - The California Department of Public Health is currently developing strategies to achieve a 20 percent per capita water use reduction statewide by 2020
    - As of 2010, all Urban Water Management Plans must include provisions to fund and implement all economic, feasible, and legal urban best management practices established by the California Urban Water Conservation Council (CUWCC)
    - All local governments must adopt State Model Water Efficient Landscape Ordinance (MWELO) or equivalent
- Integrated Flood Management
- Expansion of water storage and conjunctive management of surface and groundwater resources
    - Local agencies should implement AB 3030 Groundwater Management Plans are part of IRWM, including management plans to: effectively use aquifers as water banks; protect and improve water quality; prevent seawater intrusion of coastal aquifers caused by rises in sea level; monitor withdrawals and levels; identify and pursue opportunities for interregional conjunctive management; provide for sustainable groundwater use
- Fix Delta Water Supply, Quality and Ecosystem Conditions
    - Source of water for 25 million Californians
- Preserve, update and increase monitoring, data analysis and management
    - Large gaps in state hydrologic observational network (rain and snow gages, etc.)
    - Better and more consistent monitoring of critical variables (temperature, precipitation, evapotranspiration, wind, snow level, vegetative cover, soil moisture and stream flow)
    - Higher elevations and wilderness areas are in particular need of expanded monitoring
    - Improved observations of atmospheric conditions
    - Accurate measurement of water use to facilitate better planning and management
- Plan for and adapt to sea level rise
- Identification and funding of focused climate change impacts and adaptation research analysis

Current Approach

- The Department of Water Resources (DWR) has sought to address these issues through mitigation and adaptation measures:
  - DWR has announced plans to use low carbon fuel sources for State Water Project energy supplies instead of coal fired power plants

Impending Water Policy Changes/Conditions to Address Issue

- "As directed by the recently signed water legislation (Senate Bill X71), state agencies must implement strategies to achieve a statewide 20 percent reduction in per capita water use by 2020, expand surface and groundwater storage, implement efforts to fix Delta water supply, quality, and ecosystem conditions, support agricultural water use efficiency, improve state-wide water quality, and improve Delta ecosystem conditions and stabilize water supplies as developed in the Bay Delta Conservation Plan. (BH-2, W-3, 6, and 7; A-1; TEI-3).

Key Issue: Drought

Key Dimensions

- Owing to a combination of consecutive dry years, drought conditions in the Colorado River Basin, and low snowpack levels due to climate change in the Sierra Mountains, many California communities have faced mandatory restrictions and/or higher water bills

Action Needed

- Increased water banking
- More water conservation measures, both during periods of drought and otherwise to ensure water banks are not exhausted in the event of a drought
- Procurement of alternative water sources, likely to include increased desalination for coastal areas

Key Issue: Seismic Events Threat

Key Dimensions

- According to the California Earthquake Authority (CEA), California has a 99.7 percent chance of experiencing a 6.7 magnitude earthquake or larger during the next 30 years
  - 67% chance of a 6.7 magnitude or larger earthquake striking Los Angles
  - 63% chance of a 6.7 magnitude or larger earthquake striking the San Francisco Bay area
- The chances of experiencing a 7.5 magnitude earthquake or larger over the next 30 years is 46 percent
- Larger quakes are more likely to occur in the southern portion of the state than the north
- The USGS believes the Southern San Andreas Fault, near Los Angeles, is overdue for a large seismic event

Action Needed

- A panel convened by the USGS to address potential infrastructure issues resulting from an expected large seismic event centering around the Southern San Andreas Fault came to the following conclusions:

- “Fault movement will likely cause major damage of the infrastructure crossing it, including the main aqueducts bringing water to Southern California from Northern California and the Colorado River. Repairs may be hampered due to damaged roads and large scale-fires.”
- “The most severe damage will be closest to the fault, but even in the Los Angeles area there will be damage to pipelines and other infrastructure due to intense shaking. In addition, the Met / LADWP outages from aqueduct damage will impact the local water supply.”
- “In the first few days after the quake, there may be no water available due to infrastructure breaks and loss of power. After that, repairs will bring supplies online slowly. Each agency will be busy with their own systems, and repairs may take weeks to 6 months or more. New water pipelines may be in very short supply, as they are not in stock and will need to be manufactured.”
- “A "Potable Water Plan" should be devised to describe to the public how to use water during the first few days of the emergency, when treatment plants may be offline. Avoid "Boil Water Orders" because gas lines in homes may be ruptured and people with gas stoves may cause unintended explosions. Instead, a "Purified" or "Bottled" water order should be made to emphasize drinking treated water instead of boiling it.”

- Groundwater basins were identified as the key to making up water shortages in the event of a large earthquake and recommendations included:
  - Fully utilization of basins as underground reservoirs
  - Maintenance of water wells to ensure ability to pump excess capacity
  - Interconnections with adjacent municipalities for ensure water distribution redundancy
  - Utilization of available aquifer storage space
  - Establishment of emergency pumping ordinances to allow additional pumping in affected areas

Key Issue: Atmospheric Deposition of Contaminants

Key Dimensions

- Mercury deposition has been found to be an issue in California lakes and cannot always be explained by leaching from rocks and soil; it has been suggesting that some of the deposition occurring originates from across the Pacific Ocean in China (China relies heavily on coal-fired power plants which are a major source of mercury pollution)
- In June 2010, the results of a landmark study conducted by the San Francisco Estuary Institute were released. The study sampled sport fish for methyl mercury, PCBs, DDT and other contaminants from nearly 300 popular fishing lakes in California
  - 21 percent of lakes had at least one fish species with mercury concentrations above 0.44 parts per million (unsafe for ingestion by young children and women of child-bearing age)

Key Issue: Invasive Species

Key Dimensions

- At least 212 introduced species in San Francisco Bay alone

- On average, a new invasive species is introduced to CA every 60 days, for a total of 6 new establish invasive species per year
- Economic losses from invasive species in CA are calculated at $3B per year
- Problems associated with invasive species are expected to worsen as population growth continues and along with increased imports from increasingly diverse places grow
- Agriculture has been heavily affected by invasive species such as cottony cushion scale; mealybugs, whiteflies; aphids, the glassy-winged sharpshooter, and Diaprepes root weevil; a more recent addition is the light brown apple moth, which has been attacking plants of agricultural, urban and natural importance
- Invasive weeds are responsible for significant degradation of CA's natural areas. Invasive weeds include yellow star thistle, saltcedar, and arundo
- Freshwater supplies are threatened by invasive species such as zebra and quagga mussels
- Urban invasive species include Formosan termites, yellow jacket wasps, Africanized honey bees, Diaprepes root weevil, as well as insects that kill eucalyptus, which is an important source of urban shade
- Aquatic environments (marine and freshwater) faced threats from exotic water weeds, both floating and submerged, invasive crustaceans, worms, and mollusks

Action Needed

- Risk assessment
- Early detection and invasive pathway analysis
- Rapid development of control or eradication measures
- Improved integrated Pest Management

Key Issue: Reuse and Recycling of Water - Public Opinion Against

Key Dimensions

- In 1918 the State Board of Public Health introduced regulations governing the use of sewage for irrigation purposes (considered first planned reuse in US); in 1978, public health laws were developed to regulate the use of recycled water
- Irrigation is the most common use for reused water in CA - At least 20 food crops are currently irrigated using reused water in CA, as well as 11 non-food crops
- Landscape irrigation is the second most common use of reused water
- Water reuse is also used in office and commercial buildings for toilet and urinal flushing
- Groundwater recharge is also a common use of reused water in California
- Purple Book (State of California, 2001) – state health laws relating to recycled water

Impending Water Policy Changes/Conditions to Address Issue

- In 2009, Senator Alan Lowenthal (D, Long Beach) authored SB 1258, which requires the state Department of Housing and Community Development to update the state's Plumbing Code to include new indoor and outdoor uses for gray water (currently in process)

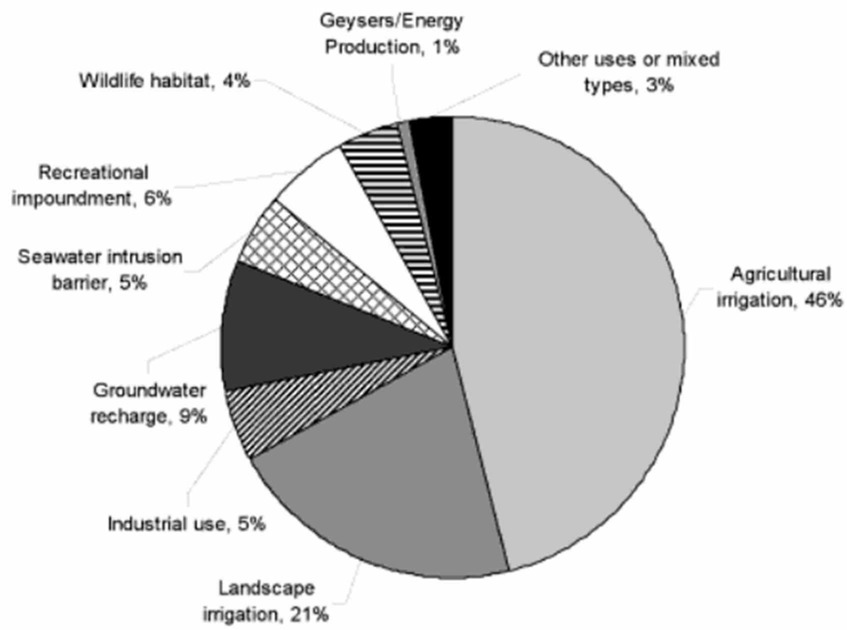


Figure 4.2 Reuses of water in California, with information from: Asano *et al.*, 2007.

Availability of Technology
Some water reuse/recycling technologies include:

- Wastewater biofiltration systems
- Membrane bioreactor technology for water reuse
- Low-pressure membranes
- Advanced water filtration for reclaimed water systems

Key Issue: Stormwater - Urban Runoff Contamination

Key Dimensions

- Model Urban Runoff Program - "How-to" guide for addressing polluted urban runoff in small municipalities (less than 100,000 people)
- A University of California study has identified urban runoff as the main source of pesticide in California's rivers: some portions of the American and San Joaquin Rivers contains pesticide levels high enough to kill some invertebrates
  - Nearly all residential runoff samples were found to contain pyrethroid levels that were toxic to the test organism *(Hyalella azteca)*
  - Pyrethroids are commonly found in household insecticides (e.g., Raid)
  - Use of pyrethroids has increased three-fold during the last ten years, likely in part due to a ban on organophosphate insecticides

Current Approach

- 15 management measures identified to address urban nonpoint sources of pollution affecting state waters:
- Santa Monica Urban Runoff Recycling Facility (S.M.U.R.R.F.) – state-of-the-art facility for treatment of dry weather runoff water (from excess irrigation, spills, construction

sites, pool draining, car washing, washout from paved areas, as well as some initial wet weather runoff)

- An average of 500,000 gallons per day or urban runoff from Santa Monica and Los Angeles is treated by conventional and advanced treatment systems at SMURRF:
- Runoff diverted by city's two main storm drains to SMURRF and treated to remove contaminants such as trash, sediment, oil, grease, and pathogens
- Treatment process include: removal of trash and debris via coarse and fine screening; dissolved air flotation (DAF) to remove oil and grease; de-gritting systems to remove sand and grit; micro-filtration to remove turbidity; ultra-violet (UV) radiation to kill pathogens
- Treated water is safe for all landscape irrigation and dual-plumbed systems as prescribed by the California Department of Health Services
- Treated water meets all Title 22 requirements

Technology Needed

- Street berms
- Flow regulators
- Pollutant-trapping sumps
- Control systems for solids and floatables
- Built-in adaptability
- Real-time data collection systems
- Integration with complementary (e.g., weather prediction, Doppler radar, rainfall measurement) information systems

Availability of Technology

Available stormwater mitigation technologies include:

- Bio-retention ponds and bioswales
- Green roofs
- Rain barrels and rain gardens

Technology to address combined sewer overflows includes:

- Sewer flow monitors
- Bed pipe barriers to reduce the concentration of suspended solids around mining sites
- Settling ponds

Key Issue: Monitoring and Water Conservation - Inadequate Metering of Use

Key Dimensions

- The smart water technology industry is expected to be valued at 16.3B by 2020
- About half of California's water utilities have some smart meters in their service areas
- Use of smart meters is considered vital to compliance with recently passed CA law stipulating that cities cut water use by 20% over next ten years
- It is estimated that smart meters can cut water consumption by 5%-15%
- Sacramento and Fresno have begun to install water meters
- San Diego is considering requiring meters for individual units in multi-family buildings

- Traditional manual meter reads can cost from 50 cents to $1.50 per read; smart water meters can significantly reduce this cost or even do away with it altogether
- Buildings with existing meters are expected to need to replace them every 15 to 20 years, which will offer an opportunity to convert to smart water meters

Key Issue: Water Conservation

Key Dimensions

- The Pacific Institute has estimated that, under its High Efficiency scenario, water use could decline by as much as 20% below 2000 levels up through 2030 while still meeting total demand, representing a total decline of some 8.5MAF
- The DWR's Current Trends (CT) scenario for water use in the state (2005) shows applied water use in excess of 40MAF by 2030
- The Pacific Institute's analysis concludes that all three potential scenarios for the water use in 2030 (Less Resource Intensive, More Resource Intensive, and Current Trades) include only modest improvements to water efficiency
- Although DWR's projections show a total increase in applied water use, agricultural water demand is expected to decline by 2030, even for the More Resource Intensive scenario
- Urban water demand is expected to increase by 1.5MAF, even under the DWR's Less Resource Intensive scenario. The More Resource Intensive scenario shows an increase of 5.8MAF

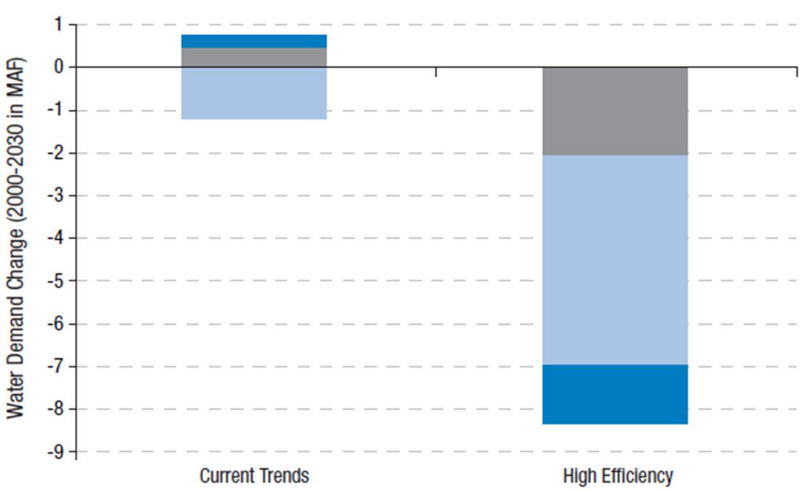


Figure ES-5
Urban and Agricultural Water Demand Change (2000-2030) by Geographic Region in the Current Trends and High Efficiency Scenarios

North
Central
South

Action Needed

Necessary actions towards improved water efficiency as identified by the Pacific Institute are:

- Pricing policies eliminating subsidization of inefficient water use.
  - Ensuring urban and agricultural water rates reflect true cost of water, including non-market costs

  - Phasing out of water subsidies on the Central Valley Project (particularly for low-value, water-intensive crops)
  - New rate structures encouraging efficient water use
- Promotion of water-efficient technologies and practices (urban and agricultural sectors):
  - New water-efficiency standards for residential and commercial appliances (toilets, washing machines, dishwashers, showers, faucets, etc.)
  - Comprehensive rebates for the purchase of water-efficient appliances
  - Further development and deployment of efficient irrigation technologies and new crop types
- Greater legislative, regulatory, and administrative support:
  - Programs allowing for the transfer and marketing of water saved through efficiency improvements
  - Creation of statewide system of water data monitoring and exchange
  - Collection and publication of comprehensive water-use data for all users
  - Design and implementation of comprehensive local groundwater monitoring and management programs statewide
- Educational programs
- Better combined land and water planning
  - Require demonstration of secure, permanent water supply before approval of new urban and suburban developments
  - Require demonstration of water-efficient housing designs before approval of developments
  - Protect high-quality agricultural land, as well as related watersheds, from urbanization

Key Issue: Water Pricing

Key Dimensions

- Water pricing still lags in California, and some conservation efforts have failed due to a lack of enforceability. In 2007, for instance, residents in San Diego County were asked to voluntarily cut water use by 20 gallons per day. Instead, residents actually used more water.
- Los Angeles households currently pay $2.80 for the first 885 gallons of water use per day. An additional 885 gallons costs only $3.40, or 20% higher than the first 885 gallons. The average household uses approximately 350 gallons per day.
- The Pacific Institute, in its High Efficiency scenario for water use in California by 2030, calls for a 41% increase over 2000 water prices

Action Needed

- More aggressive increasingly block rate structures to more accurately reflect the cost of water

Current Approach

- The California Public Utilities Commission recently directed the Fontana Water Company to implement a two-tiered water conservation rate structure for customers (effective July 1, 2010)
  - Customers using less water will see lower bills

- First 16 units (1 unit = 100 cubic feet/748 gallons) of water used each month will be billed at Tier 1 rate; water usage above 16 units will be billed at Tier 2 rate, which is 15% higher per-unit than Tier 1

2.2 Colorado

Key Markets	Niche Markets
Water Conservation	Smart/sub-metering technologies; low water-use technologies; gray-water systems; technologies enabling acquisition of new supplies (such as cloud-seeding or moisture accumulation technologies)
Hydro-fracking/Natural Gas Production	Lower-impact technologies for accessing and retrieving gas/oil deposits; technologies for treatment of brackish water from hydro-fracking activities; less water consumptive processes for natural gas extraction
Infrastructure	Technologies reduce up-front and maintenance costs for infrastructure; real-time monitoring technologies; targeted pipe repair technologies
Groundwater Contamination	Hydraulic barrier technologies (to prevent flow of methane into water wells);

Population Indicators

	2009 (est.)	2015	2035
Urban Population	4,338,362	-	-
Rural Population	686,386	-	-
Total	**5,024,748**	**5,049,493**	**7,798,107**

http://www.bcnys.org/whatsnew/2005/0420censuspoptable.htm

Economic Indicators

Total GSP: $216,537 (in millions)
US Rank: 19
World Rank: 49
GSP per capita: $41,344 USD (*US average - $39,138*)
http://en.wikipedia.org/wiki/Comparison_between_US_states_and_countries_by_GDP_(PPP)

Water Use
Average per capita daily use (*domestic*): 121g (US avg. = 90g)
* USGS, 2005

Withdrawals *(in thousand acre-feet per year)*

	Fresh	Saline	Total
CO Withdrawals	15,300	16.8	15,300

Background
As a headwaters state, all water in the state of Colorado, both surface and ground, is generated by precipitation in the form of rain or snow. Colorado generates roughly **95 million acre-feet (MAF)** of water annually from precipitation, the vast majority of which is absorbed into the state's forests and rangelands. According to projections by the Colorado Water Conservation

Board, by **2030** Colorado will need to secure an additional **630,000 acre-feet** of water in order to meet future population growth. Eighty percent of that demand is expected to be met by current and planned water projects. Strategies that have been identified to help Colorado address the remaining 20% gap include conservation and more efficient use of water, alternative agricultural transfers to permanent dry up, and increased water storage capacity.

A short breakdown of allocations of Colorado's water includes:

- **16 MAF** flows to states creeks and rivers
- **6 MAF** used to meet needs of CO's 5 million residents (80% diverted directly out of rivers; 20% pulled from groundwater/aquifers)
- Roughly 86% of water used (from total 6MAF) is for agricultural purposes; less than 7% used to meet municipal demands; 2% for industrial needs; 2% for recharging groundwater and aquifers; 3% for environmental and recreational needs

Although the numbers would seem to point to agricultural water conservation measures as a means of securing more water for municipal and industrial uses (M&I), such measures are limited by legal, physical, and economic factors.

Because CO is a headwaters state, two-thirds of the water generated annually on average is legally obligated to downstream users:

- **8.8 MAF** to states west of the Continental Divide (Utah, Nevada, California, New Mexico, Arizona) as well as Mexico
- **1.4 MAF** to states on the Atlantic side of the Continental Divide (Nebraska, Kansas, and Wyoming)

Although there are eight major basins within the state of Colorado, the three basins expected to experience the largest growth in population in actual numbers are the **Colorado River Basin** (244,600), **South Platte Basin** (1,926,000) and **Arkansas Basin** (457,900).

Drought cycles are common in CO, and water supply can fluctuate drastically depending on annual precipitation. For instance, during the drought of 2002, CO generated only 4 MAF of surface water, which forced the state to implement drastic conservation measures and raised concerns about CO's ability to ensure water to downstream states. State reservoirs and storage systems are still recovering from the 6 MAF of water drawn to meet demand at the time. Despite these constraints, CO's population is projected to grow by an additional 2.8 million persons by 2030. Although approximately 90% of Colorado's residents live along the Front Range (Eastern Colorado), about 80% of the state's water comes from Western Slope rivers and streams. This disconnect will likely exacerbate the need for inter-basin transfers within the state.

Projected 20-year Need (Drinking Water Infrastructure)

A survey of water infrastructure needs by the US EPA identified the following needs in Colorado: transmission/distribution = $3,156.7M; Source = $371.7M; Treatment = $2,150.2M; Storage = $696.7M; Other = $24.8M; Total = $6,400.1M (2007)

Projected 20-year Need for Community Water Systems (CWS)
Serving 10,000 Residents or Fewer

CWS's Serving 10,000 or Fewer People	
Transmission/Distribution	$958.1M
Source	$177.3M
Treatment	$562.4M
Storage	$247.7M
Other	$12.5M
Total 20-year need of CWS's serving 20 people or fewer	$1,958.0M
Total 20-year need of all CWS	$6,398.8M
% of CWS need related to systems serving 10,000 or fewer persons	30.6%

Source: EPA Drinking Water Infrastructure Needs Survey and Assessment 2007
http://www.americanwhitewater.org/content/Article_view_articleid_29797_display_full_
http://www.agwaterconservation.colostate.edu/Ag_water_conservation_paper_draftSept11.pdf
http://cwcb.state.co.us/NR/rdonlyres/28EC5194-260F-4B83-A3FD-413FFE12CBCD/0/Section5_Gap_11707.pdf

Summary of Key Issues:

- Sustainable Supply/Growth Constraints
- Aquifer Depletion
- Aging Infrastructure: Collection/Distribution
- Contaminants Entering Groundwater
- Hydro-fracking/Natural Gas Production
- Climate Change and Water Availability
- Invasive Species
- Overuse: Demand/Renewable Supply

Key Issue: Water Demand - Sustainable Supply/Growth Constraints

Key Dimensions
Colorado River Basin:

- Supplies 2 countries, 7 states, 30M users (Colorado River)
- Irrigates over 3M acres of farmland across the country
- Climate change projected to reduce runoff by 10-30% in the region
- 10% reduction means approx. 58% of scheduled deliveries will be missed by 2050
- 20% reduction means approx. 88% of scheduled deliveries will be missed by 2050
- Due largely to population growth in the region, the river's flow is almost entirely prescribed (i.e., already allocated to specific users)
- Coloradans use approx. 208g/day for domestic uses (national average approx. 179)
- Per capita off-stream use (water removed from surface streams) is 3,690g/day (exceeded only by Idaho, Montana, Nebraska and Wyoming)

- Recent research suggests that municipal water demand could grow by as much as 250,000 acre-feet in the next two decades (about a million users)
- In total, roughly 30 million people depend on Colorado River water

South Platte Basin:
- Nearly two-thirds (**409,700 acre-feet**) of increased M&I water demand in Colorado will be in the South Platte Basin area (combined South Platte Basin Roundtable and Metro Roundtable areas)

Arkansas River Basin:
- Expected to face a **gap of 32,800 acre-feet** between supply and demand by **2030** (but could potentially increase three-fold depending on implementation of current water supply initiatives)
- Of total **2 MAF** used annually, about **1.7 MAF** are diverted for agricultural uses (consistent with statewide figure of 85%)
- An **additional 173,000 acre-feet** are expected to be needed to support growth in the region through 2040

Action Needed
- More water reuse
- More conservation
- Transfers between users
- Increased water banking
- Ensuring state water supply planning adequately addresses conservation needs
- Increased restrictions on growth where water supplies cannot be adequately met

Current Approach
- In June 2009, **rain catchment** was legalized in the state of Colorado. The change in law is expected to affect some **250,000 individuals** with private wells. Any rainwater collection had previously been illegal, but a 2007 study determined that 97% of rainwater falling in the Denver region never came anywhere close to streams and that most water was being absorbed by plants or evaporating.
- **Smart metering** (Water Smart Meter, etc.)
- **Cloud seeding** – according to the American Meteorological Society and the World Meteorological Organization, winter cloud seeding has been demonstrated to produce between **5-20% more snow** in target watersheds. In a headwater state such as Colorado, increased snow has direct implications for snow pack and stream flow. The American Society of Civil Engineers is currently developing guidelines for cloud seeding (Standard Practice for the Design and Operation of Precipitation Enhancement Projects).
- The **Colorado Water Conservation Act of 1991** requires that all water providers with annual demands of 2,000 acre-feet or more have an approved Water Conservation Plan (a bill passed in 2004 required that existing plans be updated). Approved plans are also necessary to obtain loans from the Colorado Water Conservation Board (CWCB) or the Colorado Water Resources and Power Development Authority.

Steps to be included in the Water Conservation Plan include:
- Characterize water use and forecast demand
- Profile proposed facilities
- Identify conservation goals
- Identify conservation measures and programs
- Evaluate and select conservation measures and programs
- Integrate resources and modify forecasts
- Develop implementation plan
- Monitor, evaluate and revise conservation activities and the conservation plan

Impending Water Policy Changes/Conditions to Address Issue
- HB-1358 – Water Smart Homes (http://www.ourcolorado.org/media-center/factsheets/hb-1358-water-smart-homes.html)
  - Not passed, but signals potential future legislation
  - Would have incentivized low water-use fixtures, appliances and landscaping
  - Predicted that the construction of 100,000 Water Smart homes by 2050 would result in savings of 2B gallons/yr (approx. 6,132 acre-feet).
- Proposed measures include the creation of a pipeline from Wyoming to meet Colorado's growing water needs. The future of this proposal is, however, likely to be affected by the outcome of the 2010 gubernatorial race (Scott McInnis supports this solution).

Technology/Policies Needed
- Technologies catering to growth pressure/water gaps: illustrative of this gap is the halted construction of an airport in Archuleta County due to insufficient water pressure
- Low water-use appliances
- Sub-metering initiatives, such as Aurora's WaterSmart program that provides residents with real-time information on water use and cost
- Innovative rate structures to combat excessive consumption by individual and corporate consumers
- More aggressive promotion of xeriscaping and incorporation of xeriscaping requirements into municipal by-laws
- Gray-water systems

Availability of Technology
Many of the technologies needed to address Colorado's growing water constraints are currently available, such as the WaterSmart Meter program which already rolled out in the city of Aurora and is expected to be deployed throughout other state municipalities. Many of the approaches being considered and currently used in Colorado originate from legislative measures and innovative increasing block-rate structure pricing schemes that encourage lower water use while simultaneously generating needed revenue from more consumptive users.

More novel approaches, such as the state's cloud seeding program, have gained momentum in recent years following the apparent success of studies begun in the 1960s and are likely to serve an increasingly important role as the state fights to keep apace of population growth and the effects of climate change.

http://www.nytimes.com/2009/06/29/us/29rain.html?_r=4&ref=todayspaper
http://www.allbusiness.com/environment-natural-resources/ecology-environmental/10307152-1.html
http://americancityandcounty.com/mag/government_cooling_colorados_water/
http://cwcb.state.co.us/WatershedProtectionFloodMitigation/WeatherModification/CloudSeeding/

Key Issue: Aquifer Depletion

Key Dimensions:

- 2009 report by the Colorado Division of Water Resources indicates levels dropping as much as **30 ft/yr near** heavily mined areas (such as Castle Rock)
- Drops range from **10 to 450 ft/yr**
- Although underground water reserves are vast, they are largely non-renewable in CO
- Currently **60-40 ratio** of renewable to nonrenewable water use (South Metro Water Supply Authority)
- If current growth trends continue, 500,000 people could be dependent on Denver Basin groundwater in the next five years
- One of the most consumptive uses of water in the state is for corn via central-pivot irrigation uses primarily water pumped from the High Plains (Ogallala) aquifer, which is already experiencing rapid draw-downs and services about 30% of all irrigation used in the US.
- It is estimated that **77%** of state agriculture will be unfeasible if new water supplies are not secured by 2050 (Statewide Water Supply Initiative)

Action Needed

- Diversion of surface water from other sources (e.g., mountain rivers)
- Reuse and diversion of water typically destined for agricultural uses in eastern CO
- Goal of **85% renewable water by 2030** (South Metro Water Supply Authority)
- Protection of in-stream flows and environmental restoration of systems affected by dams and diversions (among other issues)
- Reallocation of water from agricultural to municipal uses
- Conjunctive uses (using aquifers for water during dry periods and as storage basins during wet periods)
- Aggressive incorporation of gray-water systems into legislation (grey water can currently only be used for below-ground uses, such as leach fields)
- "Strengthening and expanding any existing local and regional groundwater conservation efforts may be one of the most effective ways to minimize groundwater depletion and the destruction of significant remaining blocks of wildlife habitat." (Environmental Defense Report)

Current Approach

- In line with a shift to more renewable sources of water, in June 2009 the collection of rain water became legal in the state (expected to affect some **250,000** residents with private wells)

- Water conservation via low water-use appliances
- Sub-metering initiatives, such as Aurora's WaterSmart program that provides residents with real-time information on water use and cost
- Increasing block-rate structures to discourage excess consumption

Impending Water Policy Changes/Conditions to Address Issue

- "**SB 10-025:** The water efficiency grant program is currently scheduled to be repealed on July 1, 2012. This bill postpones the repeal until July 1, 2020 and authorizes up to $550,000 of annual appropriations from tier2 of the severance tax trust fund operational account beginning July 1, 2010."
- "**SB 10-78:** This bill concerns the use of reusable effluent that has been discharged back to a water body from a domestic wastewater facility after being put to beneficial use. The bill defines the term "decreed consumptive use water", defines "reusable effluent" to include decreed consumptive use water, and authorizes an appropriator to use, reuse, and make a succession of uses of the return flows of reusable effluent."
- "**HB 10-1051:** This bill requires water providers' water efficiency plans to include specific elements and requires annual reporting to the Colorado Water Conservation Board of the total amount of water provided to major sectors of water customers."

Technology/Policies Needed

- Increased use of greywater systems to promote conservation and reduce dependency on non-renewable sources. This will involve changes to Colorado's greywater legislation, which effectively treats greywater and blackwater as one in the same.

Availability of Technology

- While greywater technologies are currently available, legal barriers currently obstruct their implementation and will continue to do so until such policies are revised (greywater is generally not distinguished from blackwater in state legislation)
- Groundwater monitoring technologies which would address unsustainable supply and aquifer depletion include:
  - Real-time monitoring
  - Multiple site/strata monitoring
  - Web-enabled networked systems linked by RF or cellular technology
  - Automated systems that do not rely on operator interpretation to determine results
  - Leak control technologies:
    - Continuous acoustic monitoring
    - District Metered Areas (DMAs) for audit and leak control
    - Pressure monitoring
    - GIS analysis

http://blogs.nationalgeographic.com/blogs/news/chiefeditor/2010/06/passing-the-point-of-peak-water.html
http://www.westernresourceadvocates.org/media/pdf/Colorado%20Water%20Rate%20Structures.pdf
http://www.ethanolproducer.com/article.jsp?article_id=3570

Key Issue: Water Infrastructure - Aging Infrastructure Collection/Distribution

Key Dimensions:

- Estimated **$2.6B** in wastewater projects needed
- **395 wastewater projects** in need of state or federal assistance (including **$444M in new projects**)
- Highest-priority projects total **$202M**
- **$45.32B** needed in expenditures over next **20 yrs** for drinking water alone (American Society of Civil Engineers)
- **$5.32B** investment need in drinking water infrastructure over next **20 yrs.**
- Ranked 34th in the quantity of hazardous waste produced and 33rd in the total number of hazardous waste producers
- **$2.13B** in wastewater infrastructure needs.
- 2008 budget spent $66 million less on non-transportation infrastructure projects than state agencies believed they needed
  http://www.denverpost.com/news/ci_11954468

Action Needed

- 395 wastewater projects in need of state or federal assistance (including $444M in new projects)
- $45.32B needed in expenditures over next 20 yrs for drinking water alone (American Society of Civil Engineers)
- $5.32B investment need in drinking water infrastructure over next 20 yrs.

Current Approach

- "**HB 06-1337** created the fund, administered by the Water Quality Control Division, to credit fines and penalties for violations of the Colorado Water Quality Control Act to the fund to be used for the following purposes:
  - Improving water quality in the community or water body impacted by the violation
  - Design, construction or upgrades of domestic wastewater treatment plants
  - Grants for stormwater projects
  - Non-federal match for Nonpoint Source Grants"
- **CWCB Water Project Loan Program:** provides low-interest loans to agricultural, municipal and commercial borrowers to develop raw water resource projects in CO (est. 1971). Pertains to construction or rehabilitation of existing raw water storage and delivery facilities (reservoirs, pipelines, diversion structures, groundwater wells, water rights purchases, flood control projects)

Impending Water Policy Changes/Conditions to Address Issue

- "**HB 10-1006:** This bill concerns increased funding (up to 5%) for the Division of Water Resources/ State Engineers Office from the tier 1 operational account of the Severance Tax Trust Fund."

Technology/Policies Needed

- Given the crippling cost of infrastructure upgrades required by the state, technologies able to reduce both up-front and maintenance costs while complying with state and federal regulations should prove highly attractive.
- Like projects throughout the US, CO would stand to greatly benefit from the creation of an American Investment Bank modeled off of institutions such as the European Infrastructure Bank

Availability of Technology/Legislative Solutions

- A new EPA water infrastructure policy released in May 2010 instructs states to adopt smart-growth principles in allocating the $3.3B in water infrastructure funding distributed by the federal government each year. States should prioritize upgrades to drinking water and wastewater infrastructure in cities over projects intended to serve new developments on the suburban fringe.
  http://www.waterinfo.org/node/4442
- There are number of available technologies that aid in the detection of water leaks. These include:
  - Continuous acoustic monitoring
  - Advanced metering infrastructure communication
  - District Metered Areas (DMAs) for audit and leak control
  - Pressure monitoring
  - GIS analysis

Key Issue: Aging Infrastructure - Reservoirs

Key Dimensions

- Average age of infrastructure (Colorado Springs):
  - Reservoirs: 83yrs
  - Treatment plants and collection mains: 30 some yrs
  - Hydrants and water distribution mains: 20 some yrs
- 9 of CO's 1,935 dams in need of rehabilitation to meet state safety standards
- 2% of high-hazard dams lacking emergency action plan (EAP)
- 169 dams operating at restricted capacity until repairs can be made
  - 30 shovel-ready dam projects ($11M)
  - 8 classified as "high-hazard" (human lives at risk in case of failure)

Action Needed

- Significant upgrades to state water infrastructure
- Increased funding mechanisms to ensure future water infrastructure needs can be met
- Conservation measures and technologies may help to delay the need for expensive infrastructure upgrades and increased capacity while funds remain largely unavailable for such projects

Current Approach

- In 1971 the Colorado Water Conservation Board established the CWCB Construction Fund to finance projects aimed at increasing consumption of CO's undeveloped river

entitlements and repairing or rehabilitating the state's existing water storage and delivery facilities. These loans cannot be used for domestic water treatment and distribution systems.
- In 2005 the Colorado General Assembly enacted the Colorado Water for the 21st Century Act, which established a process to address the state's growing water demand.
- In 2006 the Water Supply Reserve Account was created to act as a funding mechanism for water projects in the state

Impending Water Policy Changes/Conditions to Address Issue
- Upcoming gubernatorial race may set tone for additional reservoir capacity in the state of Colorado, with two of the candidates conceding additional storage is a priority, while a third has been aggressively promoting a new pipeline from Wyoming. What this would mean for the state of existing reservoirs is unclear.
- In 2003 voters rejected a referendum that would have allowed for the issuance of $2B worth of bonds to fund water projects in the state

Technology/Policies Needed
- New funding mechanisms for large infrastructure projects, such as the proposed national infrastructure bank modeled on the European Infrastructure Bank.
- Given the crippling cost of infrastructure upgrades required by the state, technologies able to reduce both up-front and maintenance costs while complying with state and federal regulations should prove highly attractive.

Availability of Technology
- A new EPA water infrastructure policy released in May 2010 instructs states to adopt smart-growth principles in allocating the $3.3B in water infrastructure funding distributed by the federal government each year. States should prioritize upgrades to drinking water and wastewater infrastructure in cities over projects intended to serve new developments on the suburban fringe

Key Issue: Groundwater - Contaminants Entering Groundwater

Key Dimensions
- Uranium and methane are common sources of groundwater contamination in Colorado and have been determined to be related to drilling and mining operations in many cases
- Despite claims by drilling companies that the number of contaminated wells is insignificant, exhaustive examination of methane problem on Colorado's Western Slope offers strong scientific evidence (Garfield County) that gas drilling has degraded water in dozens of water wells
- 2-butoxyethanol (2-BE) has been identified as a common contaminant private wells and it is suspected that its presence is related to fracking activities in the state (identity of chemicals used in fracking operations are currently protected as trade secrets)
- Methane in groundwater has also been linked to drilling activities in the state
- 19 of CO's 63 counties rely solely on groundwater for drinking water and domestic uses
- 539 public water supply systems serving over 429,000 people (1990)

- Private wells/public water supply systems served approx. 24% of state's population (780,000)
- Manure pollution has also become a growing concern in Colorado:
    - CO currently has no permitting process for feedlot operators
    - Although the state does have regulations to prevent water pollution at feedlots, it has no real enforcement capacity and feedlots remain effectively unregulated
    - CO voters recently adopted an initiative on large-scale hog operations, but those regulations have yet to be implemented
    - Most of the state's large hog operations are located in the eastern portion of the state, directly above the Ogallala aquifer

Action Needed
- Stricter monitoring of mining/fracking activities in the state
- State and federal policies designed to limit the adverse effects on such activities on the state's water supplies

Current Approach
- The EPA recently launched a $1.9M probe into the health and safety implications of fracking
- Produced water and fracking fluids can be treated with some of the same technology used in desalination processes.
    - Reverse osmosis (RO) membrane filtration
    - Electrodeionization (EDI)

Impending Water Policy Changes/Conditions to Address Issue
- In late May 2010 a CO lawmaker withdrew an amendment to the water-infrastructure bill (H..R. 5320) that would have required drillers to disclose chemicals used during hydraulic fracturing to state regulators or the EPA under the Safe Drinking Water Act.
- The 2010 gubernatorial race could prove pivotal for the future of regulations pertaining to water and fracking/drilling activities, with candidate Maes questioning regulations designed to protect the state's natural resources, particularly water, from drilling activities

Technology/Policies Needed
- "Hydraulic barrier" – Petroglyph, whose coal-bed methane operations have been suspended in Colorado's southern plains until methane intrusion into home wells can be addressed, has proposed the creation of a hydraulic barrier to prevent the flow of methane into water wells.
- Fracking will likely need to be addressed via a combination of policies and technologies, as the likelihood of ending the practice altogether in the state is low and corporate pushback has been very strong. One approach is the use of less harmful methods for accessing gas deposits in the state.

Availability of Technology
- Available groundwater monitoring technologies include:
    - Real-time monitoring

- Multiple site/strata monitoring
- Web-enabled networked systems linked by RF or cellular technology
- Automated systems that do not rely on operator interpretation to determine results
- Units that monitor multiple contaminant classes: biological, chemical, and radioactive

- **Cavitation hydrovibration**: this a process using a device known as a cavitation hydrovibrator that fractures rock using a pressurized water pulse action on rock stratum to increase the degree of fracturing. The device is considered "green technology" and relies solely on water without the need for the toxic "chemical cocktail" employed in standard hydrofracturing. However, such techniques do not yet address the need to limit gas leakage to private wells in the state.
  http://www.propublica.org/feature/colorado-study-links-methane-in-water-drilling-422http://coloradoindependent.com/36601/epa-chemicals-in-water-might-be-result-of-fracking
  http://www.flyrodreel.com/blogs/tedwilliams/2010/june/southwest-republicans-companies

Key Issue: Energy Production/Consumption - Hydrofracking/Natural Gas Production

Key Dimensions

- According to John Sanders, Water Program Director and Freshwater Ecologist for the Colorado branch of The Nature Conservancy, the following areas related to consumptive water uses for energy production are of primary concern: for extraction, power plants, and, primarily, oil shale.
- "Coal-bed methane gas operators pump about 650 million barrels of water from coal aquifers each year. About 80 percent of that water is not put to any specific beneficial use, and in some cases turns temporary drainages into year-long flows." Discharge fluid includes abnormally high levels of:
  - Sodicity
  - Sodium
  - Barium
  - Biocarbonates
  - EC
  - Iron

Action Needed

- Stricter regulations governing hydrofracking and coal-bed methane operations in the state

Current Approach

- In 2009, the Colorado Supreme Court ruled that coal bed methane producers would be required to abide by the same water rules and regulations as other state water users (coal bed methane producers had previously been allowed to pump larger amounts of tributary groundwater without a water right or approval from the State Engineer and water courts.

Impending Water Policy Changes/Conditions to Address Issue

- The EPA is currently holding public meetings regarding a likely study on the effects of fracking on drinking water (a previous 2004 EPA study finding no evidence of threats to drinking water is considered flawed)
  - Natural gas industry groups have urged the EPA to limit the scope of the study, while environmental groups want the study to also examine eventual effects of fracking on air quality

  http://www.google.com/hostednews/ap/article/ALeqM5gLXf0nHAGhLFCfEEqwX1fPMFpo3wD9GUI9800

Technology Needed

- Process capable of cleaning brackish product water resulting from fracking
- Less water consumptive processes for the extraction of natural gases
- Real-time, networked groundwater quality monitoring
  - Fiber optic
  - Web-enabled
- Portable on-site treatment - Veolia and GE Water have recently developed units for the oil and gas industry
- Less energy-intensive processes and methods
- Treatment units that run on the natural gas produced by the wells
- Treatment technologies that derive process energy from the wastewater itself
- Zero liquid discharge (ZLD) processes - to avoid the need for NPDES permits for liquid concentrate disposal
- Filtration media and technologies to enable processing of water in temporary, constructed reservoirs
- Frack water recycling and reuse
- Filtration and recovery of hydrocarbons
- Potable water and irrigation water production
- Alternative gas extraction methods, including nitrogen injection
- Compost "socks" and other methods of berm construction to contain runoff at well pads

Availability of Technology

- Researchers at the West Virginia Water Research Institute at the National Research Center for Coal and Energy at WVU are currently developing an on-site system for the treatment of fracking water for safe discharge into streams. Frack water, which comes back to the surface containing salts, minerals and solid particle, can be harmful to streams if not treatment. Treatment is, however, prohibitively expensive. The goal of the project is to treat frack water to a point where it can be reused for fracking purposes, therefore reducing water consumption levels for fracking.
  http://statejournal.com/story.cfm?func=viewstory&storyid=81291
  http://www.ens-newswire.com/ens/apr2009/2009-04-20-093.html

- Additional alternatives to conventional hydraulic fracturing should be explored. One example of fracturing which does not use conventional chemicals is CO_2 – sand fracturing. Standard practice generally involves the injection of a water-based solution with nitrogen, sand, and other chemicals to create fractures (U.S. Department of Energy, 1997). CO_2 – sand fracturing does not use water or oil-based fluids and instead relies on liquid carbon dioxide. Alternatives that do not use harmful chemicals would avoid the possible contamination of groundwater.

- Technologies that treat the discharged water from coal-bed methane extraction are also needed. One example of existing technology is the Higgins Loop continuous ion exchange technology. This process, used by EMIT (an Exterran Company) "utilizes a continuous countercurrent ion exchange (CCIX) method for removing sodium and other cations from the CBM produced water" (http://www.emitwater.com/higgins_loop.html). Total treatment costs using this process range from $0.25 to $2.00 per barrel (ALL Consulting, 2006).

There are several available technologies for hydraulic fracturing and for the production of coal-bed methane:

- Treatment of hydraulic fracturing fluid and coal-bed methane discharge with reverse osmosis (RO) membrane filtration and electrodeionization (EDI)
- Portable on-site treatment of discharge
    - Units for the oil and gas industry have been developed by Veolia and GE Water
    - On-site treatment units which are power by natural gas from the wells
    - Hydraulic fracturing water recycling and reuse
    - Alternative gas extraction methods, such as nitrogen injection
    - Berms and fibrous construction fences to contain runoff

Key Issue: Climate Impacts - Climate Change and Water Availability
In accordance with the CWCB's report, Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation, climate change will have a significant effect on the state's use and distribution of water.

Key Dimensions

- Hydrological cycle has changed (less snow pack in mountains, temperature increases, stream peak flows now earlier in year)
- Colorado River drainage basin expected to become warmer and more arid
- Temperatures expected to increase by 2-4ºC by 2050
- Stream flows in the Colorado River Basin are expected to decrease from 5% - 20%
- Precipitation is expected to remain relatively stable, but increased temperatures will impact snow and water supplies
- Changes in seasonality related to temperature changes are also expected to complicate pre-existing appropriation systems and interstate compact regimes

Action Needed

- Increased in-state storage capacity has been suggested as a means of ensuring state water supply
- Plans for water diversions have also been put forward, such as Aaron Million's plan to build a water pipeline from Wyoming to help meet growing Front Range water demands

- "Water conservation and relatively small pre-planned delivery shortages tied to declining reservoir levels can play a big part in reducing our risk." – Ken Nowak, Center for Advanced Decision Support for Water and Environmental Systems

Current Approach
- Approaches to addressing likely climate change impacts in the state of Colorado include plans for additional storage capacity. Such plans, however, are dependent on the procurement of funds in an already underfunded infrastructure environment.
- Conservation measures

Impending Water Policy Changes/Conditions to Address Issue
- The state of Colorado has developed the **Colorado Climate Agenda**

Technology Needed
- Technologies aimed at conservation and water reuse will likely prove an important factor in planning for climate impacts and population growth
- Those technologies assisting in the acquisition of new supplies or more efficient use of existing supplies

Availability of Technology
- Colorado has experience some success with its cloud seeding program http://www.rockymountainnews.com/news/2008/oct/07/report-warming-to-cut-colorado-water-supply/

Key Issue: Ecological Damage - Invasive Species

Key Dimensions
- Tamarisk ("salt cedar") is Colorado's primary invasive species concern
  - Highly-consumptive tree-like species
  - Can consume up to 200 gallons of water per day
  - Large Tamarisks can transpire as much as 300 gallons of water per day (USDA)

  http://www.fs.fed.us/t-d/pubs/pdfpubs/pdf09222829/pdf09222829dpi72.pdf

Action Needed
- Removal of species along riverbanks and watersheds
- Containment/elimination of Tamarisk
- The USDA recommends pulling of tamarisk, a process that requires less pesticide application and which can avoid problems associated with re-sprouting; however, pulling tamarisk and treating the sprouts the following year with herbicides cost 13 percent more than cutting tamarisk and treating the sprouts http://www.fs.fed.us/t-d/pubs/pdfpubs/pdf09222829/pdf09222829dpi72.pdf

Current Approach
- Removal of tamarisk along 120 miles of the San Miguel River has recently been completed
- Tamarisk Beetle: introduced as biological control agent during 1990s

- Manual removal of tamarisk using a small dozer after which the trees are subsequently burned. The USDA has sought more cost effective and less disruptive means (particularly concerning the effects of removal on soil); tamarisks cannot simply be cut as they quickly re-sprout, a process that also tends to result in the growth of a more robust root structure

Figure 1—The Star Hill JAWZ attachment was used to pull tamarisk plants from the ground.

Star Hill JAWZ attachment used to pull tamarisk from the ground
(source: http://www.fs.fed.us/t-d/pubs/pdfpubs/pdf09222829/pdf09222829dpi72.pdf)

Impending Water Policy Changes/Conditions to Address Issue

- Although there are no changes to legislation on the horizon regarding this particular invasive species, recent research suggests that the Tamarisk may in fact be no more consumptive that native Colorado species.

Technology Needed

- In light of recent claims that the Tamarisk is not, in fact, as consumptive as first believed, technologies able to more accurately assess the consumptive use of plants in river watersheds would help to ensure that the state does not dedicate limited funds to removal of species no more consumptive than native varieties

Availability of Technology

- The Tamarisk Beetle and removal are the primary means of controlling tamarisk in the state and its watersheds
- Star Hill JAWZ attachment: although cutting reduced the need for herbicide to treat tamarisk sprouts, cutting and herbicide treatment remains 13.4% less costly when comparing total costs

Costs of Pulling vs. Cutting

	Cutting	Pulling
Cutting or pulling time	76.25 h	91 h
Horsepower	Bobcat S160-56 hp	Bobcat T300-81 hp
Maintenance	15.25 h	18 h
Fuel used	92 gal	148 gal
Labor cost	$1,410.93	$1,680.78

Cost of cutting vs. cost of pulling tamarisk at Cimarron National Grassland. Labor was valued at $15.42/hour. Pulling took longer due to greater number of trees on pulling plot than cutting lot. Each plot was 25 acres.
(source: http://www.fs.fed.us/t-d/pubs/pdfpubs/pdf09222829/pdf09222829dpi72.pdf)

Potential Development Areas - Agriculture
Regional variation of watering requirements for different crop types
(http://www.ext.colostate.edu/pubs/crops/04718.html)

- Potential market for programs/devices enabling farmers to better predict crop requirements and optimal efficiency outcomes

- "Net crop water requirement is estimated using models that are based on weather variables. Estimate seasonal crop water requirement by using these models and averaging weather conditions over many years. This will create an average weather year. Tables 1 and 2 are a summary of net water requirements of different crops and effective precipitation for different locations in eastern Colorado and western Colorado, respectively. To figure the net irrigation requirement, subtract the effective rain (Average Effective Precipitation from Tables 1 and 2) from the net crop water requirement. The gross irrigation water requirement is the net irrigation requirement divided by the irrigation system efficiency (fraction of one). For example, corn for grain in Burlington requires 26 inches of water. Effective precipitation is 11.28 inches for the season; therefore the net irrigation requirement is 14.72 inches. The gross irrigation requirement for a center pivot with 80 percent irrigation efficiency is 18.4 inches. For a furrow irrigation system with 55 percent irrigation efficiency, the gross irrigation requirement is 26.7 inches.

- In Colorado's semi-arid climate, irrigation is important to increasing evapotranspiration (ET) and grain yields, supplementing rainfall in periods when ET is greater than precipitation. However, not all of the water applied by irrigation is used for ET. Inefficiencies in applications by the system result in losses. As yield is maximized, more losses occur since the soil is closer to field capacity and more prone to losses, such as deep percolation, which cause the deviation from the straight line (Figure 2). By applying less than needed for maximum yield, water can be saved. As seen in Figure 2, a reduction in water applied from point A to point B can save water with little or no yield reduction."

Table 1. Estimated seasonal water requirement (consumptive use) in eastern Colorado (inches/season).													
	Burlington	**Byers**	**Cheyenne Wells**	**Colo Spgs**	**Holly**	**Greeley**	**Lamar**	**Longmont**	**Rocky Ford**	**Springfield**	**Sterling**	**Trinidad**	**Wray**
Alfalfa	35.64	32.13	36.14	30.04	39.34	30.91	30.91	30.91	37.75	37.44	35.24	33.29	35.24
Grass hay/ pasture	31.06	27.45	31.74	26.04	34.66	26.63	34.16	26.17	32.92	32.61	28.01	28.10	30.92
Dry beans	19.22					18.42		15.83		18.75			18.75
Corn, grain	26.00		25.81	20.49	29.40		26.81	21.66	27.73	26.67		21.31	25.42
Corn, silage	22.82		22.11	18.22	26.12	21.74	19.74	24.28		20.29	19.15		
Corn, sweet						22.75			20.37				
Melons					15.85		15.80		15.13				
Potatoes						28.14							
Small vegetables					18.71	17.70	18.85		22.23				
Sorghum grain	21.51	20.46		15.99	25.20	19.48	22.64			22.65			16.09
Soybeans													10.41
Spring grains		12.49					11.82	11.36	14.15	10.44	14.29		15.17
Sugarbeets	29.98		30.43		34.83	29.31	34.27	25.48	32.70	32.28	29.99		29.99
Wheat, winter	18.99	16.42	18.55	14.06	19.65	16.38	19.30	18.46		18.64	12.53	16.14	
Av. Precip.	16.35	18.57	16.26	15.73	5.33	12.20	5.33	12.74	12.53	15.36	14.92	12.80	18.51
Av. Eff. Precip.	11.28	10.39	11.68	10.59	10.72	7.32	11.00	6.99	8.89	10.93	6.68	8.28	12.56

Table 2. Estimated seasonal water requirement (consumptive use) in western Colorado* (inches/season).

	Cannon City	**Cortez**	**Durango**	**Gunnison**	**Fruita**	**Meeker**	**Monte Vista**	**Norwood**	**Salida**	**Walden**
Alfalfa	39.69	29.36	27.49	17.99	36.22	23.55	23.58	23.58	24.83	12.89
Grass hay/ pasture	33.49	24.74	23.17	17.12	31.44	21.43	19.85	20.40	20.90	13.61
Dry beans					19.93					
Corn, grain					25.12					
Corn, silage	22.21	17.98	16.06		22.67	17.34				
Orchards w/o cover crop	27.12									
Orchards w/ cover crop					25.71					
Potatoes							16.49			
Small vegetables					18.06		6.79			
Spring grains (barley, wheat)		13.51	14.79	16.73		19.61	15.46	12.66	11.38	18.04
Sugar beets					31.58					
Wheat, winter	18.70	20.13	18.83		18.95					
Av. Precipitation	12.99	12.90	18.59	11.00	8.30	17.06	7.25	15.73	11.37	9.56
Av. Eff. Precipitation	9.28	5.09	8.34	3.80	3.98	6.19	3.93	6.05	5.66	3.02

*Colorado Irrigation Guide, 1988 Net irrigation requirement is the difference between crop consumptive use and effective precipitation.

2.3 Florida

Key Markets	Niche Markets
Brackish Water Desalination	Well Monitoring
Water Efficiency Devices	Tertiary WWT Efficiency
Storm water Harvesting	Efficient Citrus Watering Devices
Groundwater Contaminant Removal	Water Efficiency Policies
Basic Water & Wastewater Infrastructure	Residential water filters and wastewater treatment capacity for reuse

Drivers
Population:
2008 18 million
2020 23 million
2030 28 million
2008-2030 = 36% Increase

Economic Indicators: 2008

Real GDP	$603,462 million
GDP per Capita	$32,925 (33rd in nation)
Change 2005-2008	-1.6%

Background
Rapid population growth, both current and projected, has increased the demand on Florida's aquifers for water. Florida is one of the rainiest states, receiving an average of fifty-three inches of rain per year and the majority falls from June through September. However, over seventy percent (70%) of the state's annual rainfall is lost to evaporation. Approximately 90% of Florida's drinking water is supplied from groundwater, with the remaining 10% supplied by surface water. However, a "hydrologic divide" splits the state into two in a wavy, east-west line above Orlando. While 56% of the state's rain falls to the north of this line, 78% of the permanent population resides to the south (Barnett, 2007).

Compounding Florida's water arithmetic is a dramatically growing population. Projections show Florida surpassing New York to become the 3rd most populated state by 2020. The current population hovers at 18 million persons and is expected to increase to 23 million by 2020, a 17% increase. It is expected to jump to 28 million by 2030 (Census, 2008). In addition, over 70 million tourists visit the state each year, further adding to the water demand. Floridians use an average of 174 gallons of water per person, per day, bringing the state's total water use to 6.8 billion gallons per day (freshwater) in 2005. Total demand for water is expected to increase to 8.7 billion gallons per day by 2025, a twenty-eight percent jump.

The Florida Senate encouraged local governments in 2005 to establish "urban service boundaries" denoting areas "appropriate for compact contiguous urban development." An urban service boundary does not necessarily seek to limit growth but steer it in a direction that is feasible for infrastructure and municipal services to support. The legislation which passed is remarked as the most significant change to Florida's growth management laws since 1985 and is referenced throughout this report. An update to the Florida growth management legislation was signed by the governor in 2009. Unfortunately, the bill was ordered taken off the books by a circuit judge in August 2010 when it was declared unconstitutional and in conflict with previous statutes (Peltier, 2010). With this setback for the senate, there seems no end in sight for Florida's thirsty population. Florida's wealth runs on population growth, spurring new development and construction. At the peak of the housing boom in 2005, Florida accounted for thirteen percent of new home starts nationally and seeks ways to continue to allow this level of growth to occur, which drives interest in water. Florida may be called the "Sunshine State" but it has built its image, and economy, on its water. Florida tourism brings in nearly $60 billion a year, but Florida is rapidly depleting its leading industry.

Water Management Districts (WMDs)
Florida is broken into five water management districts, created by the 1972 Florida Water Resources Act, which brought all waters of the state under regulatory control. Each management district is governed by nine members (13 for southwest district), appointed by the governor and confirmed by the state senate to serve a four-year term. Each district administers flood control programs and manages ground and surface water resources, with the overall charge of balancing the needs of current and future populations and natural systems. Although each district issues consumptive water use permits to public utilities and suppliers, each utility sets its own rate structures.

- Northwest (NWFWMD): 11,300 mi^2, 16 counties, 1.3 million people, covers the panhandle
- Suwannee River (SRWMD): 7,600 mi^2, 15 counties, 310,000 people, covers area between panhandle and peninsula
- St. Johns River (SJRWMD): 12,300 mi^2, 18 counties, 3.9 million people, covers northeast Florida
- Southwest (SWFWMD): 10,000 mi^2, 16 counties, 4.7 million people, covers west-central Florida
- South Florida (SFWMD): 17,000 mi^2, 16 counties, 7.5 million people, covers area from Lake Okeechobee to Florida Keys

Summary of Key Issues

- Sustainable Supply/Growth constraints
- Groundwater Contamination
- Aquifer depletion
- Salt water intrusion
- Desalination
- Reuse/Conservation
- Water Infrastructure

Key Issue: Sustainable Supply/Growth Constraints

Key Dimensions
Future projections of water demand for the state show the Power Generation, Commercial/ Industrial/Institutional and Recreational Irrigation use sectors correspond to steady increases in

total demand but will remain under 1 billion gallons per day. On the other hand, the use trends and projections for the state show a clear, increasing movement relative to the population increase for the largest use sectors of Public Supply and Agricultural Irrigation.

- Population expected to increase to 28 million by 2030, from 18 million currently
  - Brings FL up to 3rd largest state
- 2005 Total state water withdrawals = 18.3 billion gallons/day (bgd)
- 2005 Freshwater (ground + surface) use = 6.8 bgd, 37% of total withdrawal
  - 40% agriculture, 37% public supply, 8% power generation (Marella, 2009)
  - Up to ½ public water supply devoted to landscape irrigation
- 2025 demand for fresh water = 8.7 bgd, a 30% increase from 2000
  - 43% public supply anticipated, 33% agriculture, 5% power generation
  - South Florida, Southwest Florida and St. Johns River Water Management district are the largest current and projected users

Table 1. Florida freshwater use and demand projections (mgd) by water management district.

DISTRICT	2000 USE	2025 DEMAND	CHANGE mgd	CHANGE %
Northwest Florida (NWFWMD)	311.88	443.34	131.46	42.15%
South Florida (SFWMD)	4,000.02	4,242.58	242.56	6.06%
St. Johns River (SJRWMD)	1,482.03	1,785.95	303.92	20.51%
Suwannee River (SRWMD)	323.34	n/a	n/a	n/a
Southwest Florida (SWFWMD)	1,332.72	1,510.22	177.50	13.32%

*Suwannee River Water Management District did not complete water supply planning in 2004

Parts of Florida in four of five water management districts are estimated to have insufficient groundwater supplies before the 2025 planning horizon, noted by the number of designated "water use caution areas" throughout the state. A water use caution area is designated by a water management district, "where water resources are or will become critical in the next 20 years." Districts then impose "special requirements for existing water users and permit applicants to prevent or remedy impacts to water and related natural resources or the public interest (FAC, 2010).

- Although the Suwannee River Water Management District did not complete water supply planning, projections show an insufficient supply for the Upper Santa Fe River Basin for 2030 (SRWMD, 2009).
- St. Johns River Water Management District will require a 200 mgd reduction in demand (or alternative source) to meet the 300 mgd total increase, 2000-2025, without unacceptable impacts to natural resources (SJRWMD, 2006). The entire district is designated a water use caution area.
- Nearly ninety percent of southern Florida is designated a water use caution area

In 2006, three water managers formed the Central Florida Coordination Area (CFCA), covering lands where the boundaries of the 3 WMDs meet in the Orlando metropolitan area. It was agreed that the growth in public water supply in central Florida from traditional groundwater supplies is not sustainable (CFCA, 2006). Reports predict a groundwater deficit in the Central Florida Coordination Area, based on projected increase in demand 1995-2025, which will need to be met with alternative water sources (SJRWMD, 2006):

- 2025 projected withdrawal (demand) of Floridan Aquifer = 787.72 mgd
- Sustainable yield of Floridan Aquifer = 594-709 mgd
- Anticipated Floridan Aquifer deficit = 79-194 mgd

Current approach

The Water Resources Act of 2005, via Florida Administrative Code Section 373, requires "future growth and development planning reflect the limitations of available ground water and other water supplies" (NWFWMD, 2005). And, starting in 1997, each water management district was required to implement water supply assessment and supply plans on a 5-year cycle. These measures have at least brought out the information that much of Florida does not have the water resources to sustain itself. Yet, it has caused water utilities to search for alternative water supplies which are costly and years off before implementation. The current approach to the looming fresh water shortage is rooted in conservation:

- Minimal conservation efforts at the household level
- Some wastewater re-injection and reuse
- Utilities searching for alternative supplies
- "Creative" solutions suggested such as a water pipeline, 500 miles of interconnected pipes to diversify public water supply sources for the central Florida area. This idea was proposed in 2009 (Patterson, 2009) and its current status is unknown.

As of 2007 (the most recent data available), the Florida Department of Environmental Protection recorded 80 different existing or planned Aquifer Storage and Recovery (ASR) wells throughout the state. ASR wells store treated water to be drawn in the future for beneficial use, through the same well. ASR water consists of treated drinking water, raw to partially-treated ground or surface water and reclaimed water and, is used for public consumption, surface water augmentation, wetlands enhancement, irrigation, or as a saltwater-intrusion barrier. These wells are located almost exclusively in the coastal areas of Tampa, Fort Meyers, Miami, Fort Lauderdale and Palm Bay to Daytona Beach.

Action Needed

The largest contributor to Florida's water supply problem will be controlling the population's demand for water, via aggressive conservation, reuse and pricing methods.

- Conservation or consumption-based water pricing structures
- Large-scale enforcement of water use restrictions
- More reuse state-wide
- Establishment of alternative water supplies & funding
- Monitoring on private well use
- Upgrades to high-efficiency plumbing fixtures

Impending Policy Changes to Address Issue
Water management districts in the Central Florida Coordination Area are not issuing groundwater withdrawal permits to public supply utilities for any water over the 2013 demand projections. The message is clear, public water utilities must be prepared to meet public demand with alternative water sources, as well as aggressive water reuse and conservation.

As water management districts are in the process of preparing their 2010 plan updates and evaluating alternative supply options, aggressive conservation measures will no doubt be put on the books:

- Jacksonville area utilities estimate that, through a broad spectrum of conservation measures, they could meet 41% of their increased water needs (Patterson, 2010)

Technology Needed

- Alternative Water Supplies
  - Desalination and brackish treatment
- Water efficiency devices created and extensively used
- Storm water harvesting on a large scale

Availability of Technology

- Technology is available for desalination of brackish well or seawater, but the technology can be made much more efficient.
- Technology is available for water-use efficiency but neither regulations nor pricing is in place in Florida to promote greater water-use efficiency.
- Appropriate means of stormwater harvesting in these settings are available, but what is needed are better ways and the adoption of such ways.
- Policies are in place that helps reduce water demand, starting with limits on landscaping use of water but these can be improved.

Key Issue: Groundwater Contamination

Key Dimensions
Flow exchanges between the Floridan aquifer and Upper Surficial aquifer mean the water is relatively "new" or "young." The thin, surficial aquifer, although not pumped extensively for drinking water, eventually recharges the Floridan Aquifer. This is a problem, due to the fact that significant ground – surface water interchange means groundwater is vulnerable to contaminants from activities at the land surface. Hot-spots of contamination exist across the state due to pre-regulated industrial activity, as well as naturally-occurring contaminants in the ground. While public water systems are required to test and treat for these contaminants, many private wells are at risk. Florida has over 3 million supposedly potable, private wells in the state which remain unregulated through the Federal Safe Drinking Water Act (GWPC).

Arsenic

- Aquifer Storage & Recovery (ASR) wells testing for high levels of arsenic near Tampa (Barnett, 2005)

- 2007 study on ASR wells concluded that oxic water reacts with pyrite in Suwannee Limestone of the Floridan aquifer system during an ASR cycle, releasing arsenic (CH2M HILL, 2007).
- Arsenic is rarely detected in monitoring wells located 350 feet from the ASR well during recharge. Yet during recovery, "a consistent pattern of arsenic concentration" was detected in several ASR wells.
- Mixing between recharge water and native Floridan aquifer system water stimulates microbial growth, presumably due to organic content in recharge water.
- These findings will provide a "significant challenge" for systems that store water in this part of the Floridan aquifer system.

- High arsenic concentrations in soils and groundwater are a result of natural occurrences, fertilizer, herbicide and agricultural use
  - Private wells in Tampa Bay area: Hernando County, Hillsborough County, Pinellas County have been testing positive for arsenic, in addition to wells in Miami area and others scattered across state
- Floridan aquifer system also contains nitrate, VOC's and radon, especially near Tampa

Ethylene Di-Bromide (EDB)

- Found in private wells from agricultural use (FDEP, 2008)
  - To 2009, over 2,500 wells in over 38 counties identified as contaminated

Nitrate-Nitrogen

- Agricultural use: central, southern Florida groundwater contaminated from citrus crops
- Wastewater reuse for irrigation has shown to contribute small amounts of nitrate to groundwater, relative to the amount of fertilizer contribution
- Northern Florida springs experiencing an abundance of nitrate-N in the Upper Floridan Aquifer over the past 50 years (Katz, 2004)
- On-site sewage disposal systems: Private wells near septic tanks can become contaminated in rainy season (June-October). On-site sewage treatment and disposal systems treat approximately ¼ of the state's wastewater (FDOH).

Current Approach

Effective January 1, 2005, the state adopted the primary and secondary drinking water standards as the state groundwater standards. This means all reuse water and land application projects must meet the same treatment levels. State agencies currently administer a variety of programs to locate and remediate contaminated areas.

- Florida Wellhead Protection Program: A 500-foot (circular) radius is established around all wells which serve community public water systems.
- The Delineated Areas Program maps areas of known contamination, as well as ensures more stringent standards for new well construction and monitored testing of known contaminants. For wells found to be contaminated, they are remediated or connected to a public water supply. Homeowners are provided with bottled water systems until a proper solution is made, such as public supply connection or in-home filtration.
- Florida Source Water Assessment and Protection Program: The Florida Department of Environmental Protection is initiating this program as part of the federal Safe Drinking Water Act.

Action Needed

- Private potable well monitoring for contaminants
- Testing for arsenic and other contaminants
- Removal of contaminants from private wells; most commonly done via residential in-home point-of-use filtration

Enforcement of TMDL's has been at issue for the past decade in Florida. Environmental group, Florida Clean Water Network, filed a lawsuit against the US EPA in 2002 for failing to uphold its duties related to the Clean Water Act. The EPA had repeatedly allowed Florida to use the state Impaired Waters Rule to set standards, rather than the approved water quality standards of a Total Maximum Daily Load (TMDL). As a result, enforcement of state water quality was lacking and has prompted the EPA to step in and review the state's polluted waters 303(d) listings since 1998. The EPA is set to release a final set of TMDLs in November 2010.

Impending Policy Changes to Address Issue

Several pieces of legislation were either recently passed or are pending in Florida:

- State statue requires local governments adjacent to impaired waterways to adopt a rule limiting the use of nitrogen. This has resulted in several local bans of residential fertilizer application during the summer months or use of fertilizer with reduced levels (less than 5%) of phosphorus.
- Florida SB 550-2010, the Statewide Septic Tank Evaluation Program addresses groundwater contamination due to on-site sewage disposal. This bill requires a septic tank inspection every 5 yrs, effective January 1, 2011.
- The Florida DEP, with the five WMDs, are currently developing a statewide Stormwater Treatment Rule, expected to be completed no sooner than July 2011. The rule will require performance standards and design for treatment best management practices. It is anticipated new development projects will require an "85% reduction of the post-development average annual loading of nutrients" (FDEP, 2010).
- The US EPA is currently reviewing numeric nutrient criteria standards (TMDL) for waters of the state, expected to be complete November 14, 2010. For more info: http://www.epa.gov/waterscience/standards/rules/florida/

Technology Needed

- Treatment for contaminants
    - VOC's, radon, EDB, nitrates, especially point-of-use filtration
    - Ways to reduce usage of these contaminants
    - Water filters for private use, especially cost effective
- Removal of dissolved oxygen in recharge water to eliminate arsenic mobilization
- Devices for on-site removal of stormwater pollutants
- Nitrate-Nitrogen removal techniques and technology
- Groundwater monitoring devices

Availability of Technology

Nitrate is currently removed from drinking water using three methods: distillation, reverse osmosis and ion exchange. Many residential applications use these methods however, common carbon adsorption filters, mechanical filters of various types and standard water softeners do not remove nitrate-nitrogen.

VOC's can be removed with polymer membranes using pervaporation techniques. Various types of activated carbon filters are also used.

Several common methods exist for removal of arsenic in water: coagulation filtration, lime softening, activated alumina, reverse osmosis, electrodialysis reversal and nanofiltration. Emerging technologies include hybrids of the previous methods with direct filtration, with emphasis on the addition of iron as a removal method.

Key Issue: Aquifer Depletion - Floridan Aquifer

Approximately 90% of Florida's public water supply comes from groundwater, the remaining ten percent from surface waters. Nearly 60% of this groundwater was supplied by the Floridan aquifer system in 2005 (Marella, 2009). The highly productive, 100,000 square mile system of carbonate rocks (limestone and dolomite) underlies the entire state of Florida, as well as parts of South Carolina, Georgia and Alabama. It is over 3,000 feet thick in south Florida and thins to less than 600 feet to the north. The Floridan aquifer underlies the intermediate aquifer system in southwest Florida. The highest is the surficial aquifer system, over much of central and southern Florida, the sand and gravel aquifer in the far northeast and Biscayne aquifer along the southeast coast. Much of the water in the Floridan aquifer south of Lake Okeechobee is saltwater (Miller, 1990).

Key Dimensions

Excessive groundwater pumping has caused a myriad of problems for Florida, including coastal salt-water intrusion, brackish groundwater, and lowered flows of lakes, streams and rivers. Moreover, draining the aquifer results in a destabilization of the limestone beneath the land surface, causing massive sinkholes and depressions. Sinkholes are a natural product of the karst topography of Florida, but they are also a symptom of larger aquifer depletion. Although Florida receives an average 53 inches of precipitation yearly, 70% is lost to evaporation, and Florida's rapid growth and urbanization has resulted in less surface area available for aquifer recharge.

- Florida is the largest consumer of groundwater east of the Mississippi River; 6^{th} in nation in groundwater withdrawals in 2005 (Marella, 2009)
- Periods of low rainfall occur naturally, and the rain patterns, weather cycles and high population make Florida vulnerable to drought (FDEP, 2007).
  - Average precipitation levels, minus levels of evapotranspiration were estimated as "available precipitation" by the USGS in 2004: south Florida = 5-10 in/yr, central Florida = 10-15 in/yr, north Florida = 15-20 in/yr and, northwest Florida = 20-25 in/yr
- The majority of recharge to the Floridan Aquifer System "occurs in the areas where it is unconfined or semi-confined, at approximately 10-25 inches per year, whereas in the areas of confinement, the recharge is less than 1 inch per year" (USGS)
- Extreme pumping for agricultural use, like that seen in January 2010 to stave off frozen citrus and other crops, results in private drinking water wells dried up or significantly lowered and sinkhole formation.

- Wetlands have been negatively impacted from drawdown of the surficial aquifer in three water management districts (CFCA, 2010).

Current Approach
Water management districts are authorized to acquire land for the preservation and conservation of water resources. For the protection of groundwater, districts purchase land in "prime recharge areas" (NWFWMD, 2005). These recharge areas are protected from future development, provide habitat for local and/or endangered wildlife and vegetation and public recreation opportunities and flood protection.

In addition, treated wastewater is used as aquifer recharge across Florida. In 2005, the state returned one-third of its total volume of reclaimed wastewater in order to recharge the aquifer system (Marella, 2009). This recharge totaled 220 mgd, a meager 5% of total state ground water withdrawals.

In order to address sinkholes and dried-up wells related to aquifer draw-downs from agricultural pumping in 2002, the Southwest Florida WMD changed its rules for new well casing depths. The District required well casing depths to be at a minimum of 105 and 147 feet below land, depending on location in Hillsborough County. As a result of the 2010 freeze, the District is again analyzing its procedures and policies, including the creation of a new water use caution area, with the aim to have changes in place by the 2011 winter.

Action Needed
- Conservation in many water uses
- Alternative water supplies
- Increased reuse, recharge of aquifers
- Less water-intensive practices for crop-freeze protection

Impending Policy Changes to Address Issue
The USGS is currently undertaking the Floridan Aquifer Groundwater Availability Study of the complete Floridan Aquifer System, expected to be finished in 2013. This study updates the nationwide Regional Aquifer System Analysis program (1978-1995) and will focus on the sustainable yield and freshwater availability of the Floridan Aquifer System. It is sure to be an eye-opener to the water management districts when the study is published.

Water management districts are directed under federal and state law to establish MFLs, Minimum Flows and Levels for aquifers and surface water bodies; the levels ensure that wildlife and ecosystems are not harmed by overdrawing the resource. In addition, everglades restoration areas aim to return historic flows to wetlands. Both of these measures help to recharge the underlying aquifers. The South Florida Water Management District established new policies in 2010 for the Kissimmee River and Chain of Lakes restoration and Biscayne Bay Coastal Wetlands Restoration Project. In addition, the Comprehensive Everglades Restoration Plan is an on-going 30-year effort between state and federal agencies to revive the nation's everglades.

Technology Needed
- Improved methods of private well drilling

- Pump sensors for low-pressure and automatic shut-off in private wells
- Extensive well monitoring for water quantity used and water quality
- Systematic pricing of well water
- Efficient, effective tertiary treatment for water to be pumped into aquifers
- New, more efficient agriculture watering techniques for citrus and other major crops
- Water efficiency measures and devices
- Methods to accurately measure aquifer levels

Availability of Technology
Currently, the Floridan Aquifer System is being artificially recharged with deep-well injection of wastewater. Geographic information system (GIS) technology is being used more widespread as a tool to measure aquifer levels and chart locations of pumps, contamination and recharge areas.

Key Issue: Salt water intrusion

Key Dimensions
Salt water intrusion in coastal well fields is an ongoing problem in Florida, but worsening with the skyrocketing population's demands. The intrusion is worst along the southeast Atlantic coast, due to the different aquifers in this area. Although a relatively slow-moving phenomenon in the Floridan Aquifer, the Biscayne Aquifer may have suffered the most.

- Broward County in southeast Florida is among the worst salinated areas – salt is as far as 3 miles inland in parts
- Intrusion occurs as much as 100 feet per year in places under Biscayne Aquifer
  - Monitors show a chloride increase in the Biscayne Aquifer as early as 1900
- The South Florida Water Management District places strict limits on withdrawals from the shallow Biscayne Aquifer to halt the amount of coastal salt water intrusion, due to the area's skyrocketing population growth and pumping demands.
- The East Tampa Bay Most Impacted Area marks 708 mi^2 along the gulf coast where saltwater intrusion is greatest (SWFWMD, 2006)
  - Since 1990, there were no permitted increases in groundwater withdrawals in that area
  - Analysis of wells indicate it is necessary to reduce annual average groundwater withdrawals from 650 mgd to less than 400 mgd (62%); and closer to 200 mgd to slow or halt intrusion in the Tampa Bay area
- Intrusion is exacerbated by insufficient groundwater recharge during drought or from urbanization.
- Mangrove forests have encroached inland, up-river over the years and replaced cypress trees. Although not an invasive species, mangroves grow in saltwater marshes—their presence marks the salt water invasion inland.

There are several methods of saltwater intrusion, which makes determining where the saltwater is coming from and a solution to the problem that much harder to determine.

- Pumping:
  - Salt water slowly pushes back fresh, inland groundwater (horizontal intrusion);
  - Fresh water moves down toward wellhead, allows saltwater to rush in, and essentially take its place (vertical intrusion)

- Canal-Based: drainage canals built without salinity control structures (dams, locks) where water flows unimpeded, until surrounding groundwater levels are lowered to that of the canal. Tidal saltwater then moves inland through canals and seeps into the lowered groundwater.
- Remnant Saltwater (connate): when oceans receded thousands of years ago, not all of the water was flushed out. This is the least common and least studied of the three types of intrusion.

Salt water intrusion has several ramifications:

- Salination means supply wells have to be relocated inland and/or drilled deeper to hit the brackish Floridan Aquifer or alternative sources developed to supply the public demand
- As saltwater replaces freshwater, more treatment of pumped groundwater is needed, including more treatment as communities tap the brackish Floridan Aquifer in southern parts of the state

Current Approach

- Public supply utilities move well fields inland or abandon them altogether
- Buy (cheap) water from other municipalities
- Some looking at wastewater reinjection to push saltwater back

Action Needed

- Reduce/Eliminate pumping of groundwater, especially near coasts
- Diversify public water supply sources
- Save more aquifer recharge lands from development
- Push water efficiency for all uses
- Large-scale wastewater reinjection into aquifers
- Control structures on drainage canals to limit saltwater intrusion

Impending Policy Changes to Address Issue

Saltwater has been slowly pushing back freshwater in Florida for the last century in some areas. The state and water management districts are always looking at methods to slow, halt or reverse this process. The WMDs have mostly responded by establishing pumping limits to reduce further harm and continue to work on their water supply plans for 2010-2030.

Technology Needed

Devices are currently available for all of these needs but all can be improved upon

- More efficient treatment of brackish groundwater
- More types of ways to determine where/how saltwater intrusion occurs
- Water efficiency devices
- New control devices on canals to limit saltwater inflow

Availability of Technology

California-based Saltwater Separation, LLC, owns patents for a Saltwater Intrusion Prevention System. The system inhibits the movement of a saltwater plume into freshwater, by injecting air and low-quality freshwater into the water body that creates freshwater circulation cells. These cells push the saltwater back.

Other systems to detect saltwater intrusion include remote sensing with GIS applications, as well as computer modeling simulations.

Key Issue: Desalination

Key Dimensions
Florida is home to over 140 desalination plants (compared to some 38 in Texas and 33 in California), which produce around 515 million gallons per day, roughly 40% of the freshwater produced nationally (FDEP, 2010). Only three of Florida's plants currently use saline ocean water: Tampa Bay and two in the Florida Keys. The remaining plants use a variation of desalination techniques on brackish groundwater, a source of water that requires less energy than seawater for desalination. As more and more communities are limited by the amount of permitted fresh water withdrawals, desalination appears to be the golden ticket for many utilities. This begs two questions: what to do with the briny discharge water and how to conserve energy from the process?

- Power generation was the largest user of saline surface water in 2005 (Marella, 2009). For this reason, many feasibility studies are performed for siting desalination plants adjacent to power plants, in order to take advantage of the power plant's cooling water.
- Desalination consumes 5 kwH of energy per m^3 (264 gal) of fresh H_2O produced. This represents 40-50 percent of a facility's operating cost.
- Desalinated seawater averages a cost of $5 per 1,000 gallons at a 10 mgd facility and brackish desalination averages $3 per 1,000 gallons at a 10 mgd facility (FDEP, 2010); versus Milwaukee's cost of $1.79 per 1,000 gallons.

A brief look at some of the major players in Florida desalination:

- Collier County (20 mgd) and Hollywood (18 mgd) use reverse osmosis
- Boca Raton (40 mgd) uses nanofiltration – largest in the Western Hemisphere
- Sarasota County (20 mgd) uses electro dialysis reversal – largest in the world
- Tampa Bay desalination plant – largest in North America
    - Design capacity of 25 mgd, built w/ future expansion possible to 35 mgd
    - Reports of production between 16-20 mgd freshwater
    - Draws 44 mgd of seawater from the adjacent Apollo Beach power plant (Hillsborough Bay)
    - Used to supplement other freshwater supplies and not always in production depending on season and surface water levels
    - Discharge solution (70:1 concentrated) is diluted with cooling water from the power plant then returned to Tampa Bay
    - Reverse Osmosis with 1,000 hp maximum energy recovery
    - On average, may consume *roughly* over 120,000 Megawatts per hour per year (MWhr/yr) of energy
    - Average daily energy use may be *roughly* equivalent to 73,000 barrels of oil (42 gal/barrel)

Current Approach
As water management districts are limiting the amount of freshwater pumping allowed, cities and water utilities are increasingly considering the desalination of seawater and/or briny groundwater as alternative public supplies. In the South Florida Water Management District alone, eight brackish water desalination plants are under construction, expected to be complete by 2012 (FDEP, 2010).

Action Needed
Any technology which makes the desalination processes more energy efficient and cost efficient, including upgrades or innovations for the processes used:

- Reverse Osmosis (RO), nanofiltration, electro dialysis reversal
- Energy recovery units

Also, Florida is in need of funding for alternative water supply development. Since the enactment of SB 440 in 2005, state funding has been steadily reduced, leaving public supply utilities and water management districts scrambling for capita to afford alternative supply projects.

Impending Policy Changes to Address Issue
The state and water management districts have had policies in place to encourage the use of desalination for several years. The 2005 growth management legislation ordered municipalities to link water supply plans with water sources. As growth in the state's population continues, cities will have to consider desalination more seriously as an alternative water source.

Technology Needed

- Effective pre-treatment process which is unaffected by the type of source water used
- Energy Recovery Systems (ERS)
- More efficient pumps/membranes
- Reuse options for brine discharge or better disposal methods
- Much more efficient means of desalination, especially less energy consumptive or utilizing renewable energy to power desalination facilities

Availability of Technology
Development work is being done on the technologies noted above. Desalination is becoming more efficient through enhanced filters and pumps but none of the methods are "breakthrough" in terms of dramatic efficiency gains. Hybrid processes, combining membrane technology like RO with thermal technology like distillation, will be the future of desalination research and technology, as noted by the National Research Council in 2008. Future technology may even include off-shore vessels for desalination. More research & development is needed to truly answer the challenge.

Key Issue: Reuse/Conservation

Key Dimensions
On paper, Florida is a model of water conservation and reuse. The state was awarded the EPA's first Water Efficiency Leader Award in 2006, and water reuse by all state agencies was made an

official state objective in 2005. In 2008, the state reused 667 mgd of treated wastewater. However, given the state's dire need for water as the population swells, water conservation on the personal level is moving backwards. Per-person water use dropped nationally between 1995 and 2000, but increased 5 gallons per person per day in Florida, to 174 gallons per capita over the same timeframe (Barnett, 2005).

- 25-75% of domestic water use is for outdoor purposes, depending on the season
- 25-30% all potable water use in the Tampa Bay region is used for lawn and landscape irrigation (Tampa Bay Water, 2005)
  - 70% of all single-family homeowners have automatic in-ground irrigation systems
- Many homeowners associations do not allow alternatives to lush green grass lawns
- 667 mgd of reclaimed water was used in Florida in 2008, representing only 42% of the total domestic treated wastewater volume (FDEP, 2010). A majority of this water was used toward irrigation. This brings the per-capita average 2008 re-use flow to 35.4 gal per day, per person.
- Data indicate the use of reclaimed water may only offset 25% of potable water use.
- All reclaimed water piping is required to be purple in color and the cost of laying new pipe for reuse is high in established communities.
- Reclaimed water can contain salt content that harms plants but it shouldn't be a problem with the right type of plants.

Table 2. Water reuse capacity vs. flow by water management district (FDEP, 2008)

DISTRICT	FRESHWATER USE 2005	TOTAL WWT FLOW 2008	REUSE CAPACITY 2008	REUSED FLOW 2008
Northwest Florida (NWFWMD)	668.88	95.1	143.8	55.99
South Florida (SFWMD)	3,466.34	847.2	490.8	236.09
St. Johns River (SJRWMD)	1,300.52	309.4	390.4	168.61
Suwannee River (SRWMD)	327.77	10.9	16.1	9.71
Southwest Florida (SWFWMD)	1,109.62	325	494.8	196.43
TOTAL (mgd)	6,873.13	1,587.6	1,535.9	666.83

Current approach

Many water management districts allow outdoor lawn watering two days a week during restricted hours, or only one day per week during drought. In times of stress to the water supply, such as during the 2006-2009 drought, water utility staff in the Tampa Bay area issued several fines and even carted some homeowners off to jail enforcing the watering restrictions.

Each district, utility or community offers a range of programs and handouts aimed at improving personal conservation. One of those is the Florida Water Star program, a voluntary, third-party certification for increased water efficiency in residential homes, specific to Florida's water needs. The program addresses landscape, irrigation and indoor features on the residential, commercial or community level. At this stage, the program is only recommended and some communities offer financial incentives for certification. The program began in the St. Johns River district and has spread to the South Florida and Southwest Florida Water Management Districts.

Further, the state has implemented several pilot projects for agricultural irrigation reuse, most notably Water Conserv, operating over two decades. Florida statute prohibits irrigating "salad crops" (those that are not peeled, skinned or thermally processed before consumption) with direct contact irrigation methods of reused water. Results of Water Conserv have shown minimal negative impact on crops watered with direct methods and this statute to be unnecessary. This represents a potential for future policy change.

Action Needed

- Extreme measures such as that in Las Vegas to exchange landscaping in favor of "Florida Friendly" plants
- Strict enforcement of outdoor water use restrictions
- High water efficiency standards for golf courses
- Improved capacity and ability for wastewater flow capture at treatment plants
- Require less water-consumptive crops and methods of farming
- More micro-irrigation used for landscapes
- Expand use of state mobile irrigation labs and incentives to farmers; irrigation labs evaluate and refine irrigation practices for increased water efficiency

As noted previously (Patterson, 2010), Jacksonville area utilities estimate that, via a broad range of conservation methods, 41% of the area's future water needs could be met. However, the article goes on to claim that this range of proposed conservation is likely not to happen. The level of conservation required to offset future needs appears unlikely for Florida residents to comprehend, much less take on. For example, during a three-year period of drought, a sprinkling ban was put in place for the Tampa Bay area after reservoir levels dropped dangerously low. When the watering ban was lifted, although emergency restrictions still remained in place, many residents clamored to turn on their sprinklers, claiming the impending cost of replacing dead landscaping represented an economic hardship (Zinc, 2009).

Impending Policy Changes to Address Issue

On July 2, 2009, Senate Bill 2080, The Water Rights Bill, was signed into law. The aim of this bill is to allow homeowners to replace their St. Augustine turf lawns with "Florida Friendly" landscaping, thus overriding any municipality, homeowner association or restrictive covenant. The bill also includes new procedures for the approval of water use permits by water management districts. While the new landscape provisions could save water for irrigation use and reduce fertilizer use and runoff, the next goal will be to encourage homeowners to implement the nine principles of Florida Friendly landscapes, as they are not currently mandatory.

The state also has a goal in place to achieve 65% reuse of total domestic treated wastewater by 2020. Considering Florida reused 42% of its wastewater in 2008, this will require a 55% increase in reuse over the next ten years.

Technology Needed

- Soil moisture sensors for lawn irrigation
- Rain switches for automatic irrigation systems
- Irrigation system control devices, programmable with: day of week, season, time of day; ability to incorporate multiple start times or time of day; automatic shut-off with rainfall and; operational flexibility to accommodate any seasonal variations in rainfall, irrigation or water shortage restrictions
- BMP's for agricultural and landscape irrigation
- Monitoring devices for home water consumption
- Highly refined wastewater treatment that removes chemicals, pesticides, pharmaceutical residue, salt, etc.

Availability of Technology

Several companies currently manufacture smart meters and advanced irrigation sensors. However, the technology needs to be required to both reduce the costs and stimulate the creation of new generations of more efficient and effective devices.

Key Issue: Water Infrastructure

Key Dimensions

Florida's infrastructure supports not only its current population, but the projected 17% increase in people over the next ten years. Florida is in need of reliable infrastructure to carry its treated potable water and reclaimed wastewater to the permanent population, in addition to its yearly tourist influx. Also needed are leak detection and prevention measures in its infrastructure: estimates are that leaking pipes lose a total 364 million gallons of water per day (Barnett, 2005).

The EPA released its Clean Watersheds Needs Survey of 2008, documenting projects now or in the next twenty years with unfunded capital costs to meet the goals of the Clean Water Act. Most of Florida's $31.9 billion in needs ('08 dollars) are located in southern, coastal counties and those with large current and projected population centers.

- **Florida represents 10.7% of the nation's total needs**
- 2008 state wastewater and stormwater needs total $31.9 billion, up 21% from needs documented in 2004. The increase is due to improved reporting, aging infrastructure, stricter standards and population growth.
  - 54% Wastewater Treatment ($17 B) including plant upgrades to meet secondary and advanced treatment standards, pipe repair and replacement; 32% Decentralized wastewater treatment ($10.2 B) (septic systems); 8% Stormwater management ($2.5 B) including treatment systems and conveyance infrastructure; and 7% Nonpoint Source Control Needs ($2 B) including water resource restoration and cropland best management practices

Florida is also in need of $12.8 billion in capital investments for potable water, according to the EPA's Drinking Water Infrastructure Needs Survey and Assessment of 2007. This survey also looks at capital improvement projects for the next twenty years, in order for water systems to continue providing safe potable water to the public. The total amounts are estimates of the projects eligible for Drinking Water State Revolving Fund monies.

- State drinking water needs total $12.8 billion, four percent of the national need
  - 56% Transmission/distribution ($7.2 B), 28% Treatment ($3.5 B), 8% Storage ($975 M), 7% Source ($887 M), 1% Other
- The need is seen largely due to population growth demands, deteriorated infrastructure and/or to achieve compliance with the Safe Drinking Water Act.

Current Approach

Senate Bill 360-2005, Infrastructure Planning and Funding, appropriated $1.5 billion for transportation, water and school infrastructure programs, doling out $75 million for water infrastructure. Annual funding from the state is matched by each water management district, but has steadily declined over the years and was not funded at all in the 2009-2010 fiscal year.

Action Needed

First, water must be made a greater priority in Florida. Clearly, the state is growing and existing practices are not enough to sustain the current needs and future demands of its citizens.

Impending Policy Changes to Address Issue

Florida allotted $212.4 million of the 2009 American Recovery and Reinvestment Act to both the Clean Water and Drinking Water State Revolving Loan Funds.

Technology Needed

Florida is in need of not only new infrastructure, but repairs to its existing infrastructure, in order to handle its population demands. Technology is available but it can be improved upon and should be if the scale of need is truly addressed. Wastewater treatment plant upgrades and technology, along with affordable measures for leak detection in potable water transmission systems should be focused on. New technology for water treatment at both centralized and decentralized locations should also be considered.

- Leak prevention
  - Pipe liners
  - Better seals
- Leak detection
- Less-intrusive methods of laying pipe in established communities
- Wastewater treatment capacity upgrades
- High quality distribution systems that are resistant to saltwater corrosion
- Advanced fresh/waste water treatment technology

Availability of Technology

Engineers at the University of California-Irvine are working with robots to detect and repair leaks, from inside of the pipe, with carbon fiber. Other leak detection methods include:

- Acoustic monitoring
- Pressure monitoring
- GIS methods

Advanced wastewater treatment methods include various levels of biological treatment, as well as nanofiltration, membrane filtration and media filters.

Priority Steps to Be Taken
In order to tackle the needs of a growing population, pending EPA requirements, and continued drought periods, Florida must first expand its state budget for water and wastewater infrastructure. Establishing funds and policies to collect the money will be needed right away to tackle the state's dire waterworks. A second means to raising needed capital is pricing water in such a way that people treat it as the finite resource it is. Each utility must carefully analyze its pricing structures and perhaps even revise its methods. Pricing should also be uniform across utilities and water management districts, where it is often not, to eliminate water wars or potential possessive attitudes over water. Black & Veatch's 2009 Water and Wastewater Rate Survey consistently ranked Jacksonville and Miami (the only two Florida cities surveyed) in the top 20 of 50 of the lowest water rates for residential and commercial use. Miami was 46 of 50 for the largest commercial sector. Further, Miami ranked the absolute cheapest in water rates for the residential use average of 3,750 gallons, at $5.07 ($1.32 per 1,000 gal).

Conservation-based rate structures can also be the first step to achieving higher levels of personal conservation. Since restricting population growth and migration may be extreme, Florida needs to get a handle on its water conservation. Aggressive conservation efforts must be put in place, followed and enforced. A 2003 report on the state's reuse strategies set a goal that "65 percent of all domestic wastewater will be reclaimed and reused for beneficial purposes," as well as a "75 percent reuse fraction for newer reuse facilities." Florida is getting there, in small steps. In the future, one hundred percent of outdoor irrigation needs must be met with reclaimed water.

Yet, conservation is of no benefit if the technology and infrastructure are not in place. Third, there must be drastic upgrades to wastewater treatment facilities and high efficiency plumbing fixture upgrades across the board. Treatment plants must be upgraded with the capacity to reuse the maximum flow possible. Older buildings must be updated with high efficiency fixtures; rebates and swap-out programs have proven successful across the nation in order to achieve this step and should be explored in Florida. The standards for wastewater collection, treatment and reuse options must be improved across the board. The standards for drinking water quality must also be raised, and then met, via procurement, treatment and distribution. Improvements to desalination technology will continually be in demand. Upgraded filters, pumps and membranes, which reduce cost, are needed. Alternatives to desalination, especially reverse osmosis, are also an option and there is certainly a market for cost-effective water treatment.

Florida is currently restoring the nation's Everglades system, Upper St Johns River Basin and other surface water bodies to their historic flow and reestablishing minimum flow levels. All this work is difficult in times of drought when the public water supply is not diverse enough. Continued aquifer recharge, combined with aquifer storage, will ensure the waters of the state are not irrevocably damaged for generations to come.

With absurdly low water prices, coupled with the "Sunshine State" moniker, many have claimed Florida's residents simply do not value their precious resource. As the public supply utilities and water management districts work to provide clean, safe drinking water to the state's 18 million people and growing, plus 70 million tourists, the automatic lawn irrigation systems click on and off effortlessly—even in the rain. Still, in times of severe drought, residents have water when they turn on the tap. Where is the incentive for people to conserve and reuse like the state's second motto, "Use it Again, Florida!"? If Floridians expect water to continue to flow from their faucets, it must change its habits before it dries up.

<u>Florida References</u>

Barnett, C. (2005, August 1). Unfiltered. Retrieved from: http://www.floridatrend.com.

Barnett, C. (2007). *Mirage: Florida and the vanishing water of the eastern US* Ann Arbor: University of Michigan Press.

Black and Veatch. (2010). 2009/2010 50 Largest cities. *Water/Wastewater Rate Survey.* Retrieved from: http://www.bv.com/Downloads/Resources/Brochures/rsrc_EMS_Top50RateSurvey.pdf

Central Florida Coordination Area. (2006, September 18). *Recommended Action Plan for the Central Florida Coordination Area.* Retrieved from http://www.cfcawater.com

CH2M HILL. (2007, August). *Final Technical Report: Arsenic mobilization in two Suwannee Limestone aquifer storage and recovery systems.* Submitted to Southwest Florida Water Management District.

Florida Department of Environmental Protection. (2007, April 17). Florida Drought Action Plan. Retrieved from: http://www.dep.state.fl.us/drought/news/2007/files/florida_drought_action_plan.pdf

Florida Department of Environmental Protection. (2008, March 5). *"Draft" Stormwater Quality Applicant's Handbook*.

Florida Department of Environmental Protection. (2008, June 26). *Groundwater Delineation Program.* Retrieved from: http://www.dep.state.fl.us/water/groundwater/delineate.htm

Florida Department of Environmental Protection. (2010, March). Sustaining Our Water Resources. *Annual Report on Regional Water Supply Planning.*

Florida Department of Environmental Protection. (2010, April). Desalination in Florida: Technology, Implementation and Environmental Issues. Retrieved from:

Florida Department of Environmental Protection. (2010, May). 2008 Florida Reuse Inventory. *Water Resource Inventory.* Retrieved from: http://www.dep.state.fl.us/water/reuse/docs/inventory/2008_reuse-report.pdf

Florida Department of Environmental Protection. (2010, May 12). State Agency Use of Reclaimed Water in 2009. Retrieved from: http://www.dep.state.fl.us/water/reuse/docs/2009-all-agency-summary-report.pdf

Florida Department of Environmental Protection and University of Florida. (2009, January). Florida-friendly landscape guidance models for ordinances, covenants and restrictions. *A Florida Friendly Landscape Publication.*

Groundwater Protection Council. *State Fact Sheet.* Retrieved from: http://www.gwpc.org/e-library/documents/state_fact_sheets/florida.pdf

Katz, B. G. (2004). Sources of nitrate contamination and age of water in large karstic springs in Florida. *Environmental Geology, 46, (689-706).*

Marella, R.L. (2004). Water withdrawals, use, discharge, and trends in Florida, 2000. *US Geological Survey Scientific Investigations Report 2004-5151, 136 p.*

Marella, R. L. (2009). Water Withdrawals, Use, and Trends in Florida, 2005. *US Geological Survey Scientific Investigations Report 2009-5125*.

Miller, J. A. (1990). HA-730G: Floridan aquifer system. *Groundwater Atlas of the United States: Alabama, Florida Georgia, South Carolina.* United States Geological Society. Retrieved from: http://pubs.usgs.gov/ha/ha730/ch_g/index.html

Northwest Florida Water Management District. (2005). District Water Supply Management Plan.

Patterson, S. (2009, February 19). Water grid plan carries big price, big controversy. *Florida Times-Union.* Retrieved from http://www.jacksonville.com.

Patterson, S. (2010, August 23). State water advice: Waste not want less. *Florida Times-Union.* Retrieved from http://www.jacksonville.com

Reilly, T.E., Dennehy, K.F., Alley, W.M., and Cunningham, W.L. (2008). Ground-Water Availability in the United States. *US Geological Survey Circular 1323.* Retrieved from: http://pubs.usgs.gov/circ/1323/

St. Johns River Water Management District. (2006). Technical Publication SJ2006-2: *District Water Supply Plan 2005.* Palatka, Florida.

Suwannee River Water Management District. (2009, October 8). *District Water Supply Plan 2010 Planning Area/Upper Santa Fe Work Group Meeting* [PDF document]. Retrieved from: http://www.srwmd.state.fl.us/documents/Water%20Resources/Water%20Supply%20Planning/Presentations/BradfordCountyWorkshop100809.PDF

US Census Bureau

Water Reuse Work Group. (2003, June). Water reuse for Florida: strategies for effective use of reclaimed water. Retrieved from: http://www.dep.state.fl.us/water/reuse/docs/valued_resource_FinalReport.pdf

Zinc, J. (2009, May 28). Tampa lifts sprinkling ban. *The St. Petersburg Times.* Retrieved from: http://www.tampabay.com/news/environment/water/article1005348.ece

2.4 Iowa

Key Markets	Niche Markets
Wastewater treatment plant upgrades	Animal waste treatment
Water treatment infrastructure	Water pollution remediation
Water quality monitoring	Agricultural chemical application control
Water efficiency	Biofuel water use efficiency
Network rehabilitation	Closed-loop cooling systems

Population Indicators

	2009 (est.)	2015	2035
Urban Population	1,706,727	-	-
Rural Population	1,301,129	-	-
Total	**3,007,856**	**3,026,380**	**3,407,575**

2015 projection
http://www.bcnys.org/whatsnew/2005/0420censuspoptable.htm
2035 projection
http://data.iowadatacenter.org/datatables/State/st2010populationprojections20002040.pdf

Economic Indicators

Total GSP: $113,552 (in millions)
US Rank: 30
World Rank: 65
GSP per capita: $36,751 USD (*US average - $39,138*)

Introduction

Agriculture poses the greatest threat to the quality and quantity of water in Iowa. In the first hundred years of settlement, 95% of Iowa's wetlands were drained, 70% percent of forests were cleared, and more than 99% of prairies were plowed. (Human Impacts) This dramatically increased erosion, flooding, and non-point source pollution from field runoff. Modern agriculture, which relies heavily on nutrient and chemical application to support crop yields, contributes to high levels of sedimentation, nutrient loading, and agricultural chemicals entering Iowa water bodies. Concentrated animal feeding operations (CAFOs) generate massive quantities of sewage, creating disposal and spillage issues. Increasing biofuel production requires more intensive groundwater use as well as pushing marginal land into production. A complete list of the most severe water problems faced by the State of Iowa:

- Agricultural Impacts
    - Sedimentation
    - Nutrient loading
    - Chemical contamination
- Groundwater availability
- Combined Animal Feeding Operations
- Impacts of Biofuel production

Water in Iowa

According to the Code of Iowa:

- All waters are considered public wealth and subject to the control by the state
- Public waters are to be put to (maximum) beneficial use in the interests of Iowans
- Waters are to be managed as sustainable resources, thereby protecting beneficial uses into the future

The Iowa Code gives the State and the Iowa Department of Natural Resources (IDNR) a strong legislative base for regulating water. Over the past decade, the state and the IDNR have been moving toward stronger water quality and quantity controls for both surface and groundwater. On April 10, 2010 Governor Chet Culver signed the Iowa Surface Water Protection Act. Among other things, the bill created a Water Resources Coordinating Council that will coordinate the effort to improve water quality. The bill also authorizes the DNR to create watershed-based assessment programs, a move away from the current county-based system. A 2009 water policy review by the IDNR is perhaps the best indicator of the direction legislation is heading. The review recommended defining "sustainable" in the Iowa Code, a small step but one that would give the IDNR a more powerful framework for regulating local water issues. Under the proposed definition, regulations will consider the effects of proposed water uses on everything from ecosystems, predicted availability, efficiency of use, and a hierarchy of uses.

Water Usage

Public water supplies (PWS) (defined as serving an average of 25 or more people) provide 90.9% of Iowans (2.65m) with drinking water. There are 1,987 PWSs in the state. Over 94% of PWS serve populations of fewer than 3,300 people. Approximately 300,000 people are served by private wells.

Source	**Population Served**
Groundwater	55.4%
Surface water	35.3%
Influenced groundwater	9.3%

However, 92.4% of PWS are groundwater-based (the remaining 8% serve 45% of the population). Of the 90.9% of Iowans receiving drinking water from a public water system, over 95% received drinking water meeting all health-based drinking water standards in 2008. In the same year, 193 PWSs had a total of 386 violations, the leading by number of violations contaminants were:

Health Violations Public Drinking Water Systems 2008	
Total coliform bacteria	215
Nitrate	39
Fecal coliform for E. coli	26
Disinfection byproducts*	24
Nitrite**	16
Copper	15
Lead	15

Total	386

*Disinfection byproducts include trihalomethanes and haloacetic acids. **Nitrate violations are down from 148 in 1999 and disinfection byproducts are down from 70 in 2005.
(Drinking Water Compliance Report)

Cost and energy used for water treatment.

- Drinking water
  - $2.67/1,000 gal
  - 2.77 kWh/1000 gal
- Wastewater
  - $2.10/1000 gal,
  - 1.6 KWh/1000 gal

(Sauer:2002)

Iowa water withdrawals (all figures 2005)

- Population- 2,970,000
- Per Capita Usage- 1,134 gal/day

Withdrawals- Mg/day	Total
Groundwater	683
Surface Water	2,680
Total use	3,370

Total Use by Sector	Mg/d
Public Supply	398.0
Domestic	34.6
Irrigation	33.3
Livestock	116.0
Aqua-culture	16.4
Industrial	190.0
Mining	47.4
Thermoelectric power	2,530.0

(Water Use Per Capita)

Key Issue: Agriculture Related Problems

Key Dimensions
With over 22 million acres of the state in row crop production (85%), run-off from fields poses a range of threats to water quality in Iowa. Levels of nitrogen and phosphorus in Iowa's waters are generally two to 10 times the levels considered appropriate for Midwest streams (USGS). Ninety-two percent of nitrogen and 80 percent of phosphorus enters Iowa waters through nonpoint sources. (NRDC) Consequences of elevated levels include increased nuisance algae levels, blooms of potentially toxic algae, formation of cancer-causing compounds, and low

dissolved oxygen levels. These figures highlight the extent of the problems caused by agriculture:

Sedimentation

- Silt is the number one pollutant in Iowa. Damage from erosion exceeds $54m annually and is a major pollutant in 85 of the 159 impaired waters in Iowa
- 84% of Iowa streams reported major sediment impacts
- A 1994 survey of Lake Red Rock indicated that almost half of the lake volume had been filled with sediment.
- Rising prices for agricultural products (and therefore the value of agricultural land) means marginal land is being pushed into production that otherwise would be available for conservation programs. Of the 2 million acres enrolled in the Conservation Reserve Programs in 2007, 1.2 million were due to expire from 2007-2010. Only 66.9% have been extended or re-enrolled.

Agricultural Chemicals

- 13.6% of private drinking water wells had atrazine concentrations above EPA MCLs (maximum contaminant levels).
- A USGS survey found atrazine levels above EPA levels in all 343 samples of four eastern Iowa watersheds.
- 234,000 people in Iowa were exposed to atrazine in their drinking water above state or federal health-based limits from 1998-2003. (NRDC Atrazine)
- 95% of the population utilizing surface water for drinking had source water contaminated with herbicides. Of the two primary methods for weed control, tillage and herbicides, the trend is shifting toward less tillage and more herbicides and will likely continue as fuel costs rise. (NRDC)

Nutrient Loading

- 18.3% of drinking water wells have nitrate levels above federal health standards
- Manure and commercial fertilizer account for 33% of N and 99% of P inputs
- USGS estimates 70% of N and P delivered to Gulf Coast “Dead Zone” from agricultural sources, IDNR estimates Iowa may be responsible for 25% of nitrate-N.
- Nitrogen and Phosphorus contamination is responsible for the impairment of 32 lakes and 33 river sections in the state.

(Statewide Rural Well Survey)
(IDNR Nonpoint Source Management Program)
(NRDC Atrazine)

Current Approach

Efforts to control agricultural pollution are hindered by a lack of direct evidence of the effects of agricultural inputs on water quality. It is well understood in Iowa that nitrogen, phosphorus, tillage, and chemicals will continue to be used in agricultural production. (Iowa Farm Bureau) Further, farmers and regulators continue to uphold the view that unless it can be proven that fewer inputs are needed, an abundance of nutrients and chemicals is the best guarantee of a good harvest. In light of this, the IDNR is focusing monitoring on a few select watersheds with the goal of a clearer understanding of how inputs affect water quality. (IDNR Interview) Without an accurate analysis of where non-point pollution is coming from, the current approach relies on voluntary best management practices (BMPs).

- **Iowa ambient surface and ground water monitoring program**. Since 2000 Iowa has provided approximately $14 million in funding, allowing for "tremendous strides" in improving water monitoring capabilities. (ambient monitoring gaps)
  - 156 wells with quarterly samples for groundwater monitoring. There is one well for every 360 sq. mi., with a goal of an additional 300 wells.
  - 130 gauges to measure surface water stream flow.
  - Aquifer data collection, including seismic characterization, pump tests, and groundwater quality and age dating. (INDR Water Management Strategy)

- **2007 Watershed Water Quality Taskforce** was established to recommend voluntary approaches and estimate costs to improve local water quality.

- **2004 Iowa Phosphorus Index-** Formulaic algorithm based on erosion, runoff, and subsurface drainage to estimate Phosphorus loading risk to specific watersheds. Used to guide voluntary management decisions.

- **Lake Restoration Program**. Created during the 2005-2006 legislative session (annual funding of $8.6m), it is modeled after the Federal Clean Lakes Program and administered by the DNR. The DNR identified a list of 35 high-priority lakes and estimated $197 million would be needed for restoration (EPA-backed figure). Major restoration efforts have been completed at seven lakes, and work is in progress at 26 lakes. (IDNR Lake Restoration 2009 Report and 2010 Plan)

- Other programs include:
  - EPA Clean Lakes Program helped fund 50 water quality projects across the state, reducing the average rate of soil erosion from 7.5 to 5.4 tons/acre/year, resulting in a reduction of soil loss by 54.5m tons per year.
  - The Wetlands Reserve Program offers landowners the ability to sell wetlands easements and provides cost-sharing for wetlands construction
  - The Conservation Reserve Program is a voluntary program that pays farmers annually to retire highly erodible land for 10 years.
  - The Prairie Pothole Joint Venture raises money ($2m annually) for wetlands acquisition and easements. Since 1987, 27,000 acres of wetlands have been acquired at a cost of $25m.
  - Iowa has 100 county-based Soil and Water Conservation Districts. Iowa is in the process of moving toward a watershed-based regulation. (IDNR interview)

For a more comprehensive list see http://www.ia.nrcs.usda.gov/programs/guide.html

Policy

Regulating agriculture is extremely difficult as it is contributes 27% of the economic output of the state and is represented by significant vested interests. The cornerstone of Iowa's water quality legislation is an Anti-Degradation policy- Rule 567-61.3(1)b. Each water body is given a designated class based on maximum beneficial use, and each class corresponds to specific water quality standards. This policy was strengthened by the Iowa legislature in 2006 to require the IDNR to conduct Use Attainability Analysis (UAA) for all Iowa water bodies. This includes monitoring impaired waters and establishing TMDLs for all water bodies downstream of a continuously discharging wastewater facility. The legislation also upgraded the designation of all perennial rivers and streams to Class A1 unless the UAA shows it is not necessary. This will require more stringent nitrogen and disinfection requirements at 357 wastewater treatment plants, at a cost of **$790-$956m**. However, this only deals with point-source pollution.

- SF 467 Ag & Natural Resources Budget 2010 highlights-
  - $1.5m for Conservation Reserve Enhancement Program
  - $2.55m for watershed protection
  - $7m for soil and water conservation practices
  - $2.955m for water quality monitoring
  - $18m for Reserve

What needs to be Done

- Recognizing that voluntary programs do not create full participation needed for results. (NRDC)
- Reclaim wetlands and conservation easements. Conservation Reserve Enhancement Program (CREP) shows wetlands remove 40-90% of nitrate and 90+% of herbicides.
- The major hurdle concerning regulations is tracing contaminants to their source. This is partly due to a lack of monitoring resources, as well as a county-based regulatory structure. Iowa needs to be able to increase monitoring, especially real-time capabilities, to accurately regulate non-point sources of contamination. Only when major incidents occur, such as large-scale fish kills following a CAFO spill, can the source be identified and action taken.
- Focus on Phosphorus - A study of conservation algorithms (using surveys and imagery to apply BMPs) showed that targeting nitrogen reductions alone leads to an increase in total phosphorus loadings in 8 of 13 watersheds. Following the algorithm prescriptions for P-N reductions would carry a net cost of $322m per year, and achieve a total reduction in P of 36% and N of 31%. The study considered 7 BMPs. (Iowa Conservation Practices, Gaps)
- The official position of the Iowa Farm Bureau is that such high levels of N & P in the water are a necessary consequence of producing economically viable crop yields. The factors determining N loss are complicated and specific to climate and location. Therefore, local BMPs are favored over regulatory changes. An “optimal mix” of conservation practices may achieve a 40% reduction in phosphorus and a 31% reduction in nitrogen, at a cost of $613m per year. (Iowa Farm Bureau)
- Recognize economic incentives: the City of Storm Lake has pursued an aggressive water quality and economic development program on Storm Lake. They estimate (based on a joint EPA and IDNR study) that the improvements will bring in an additional $10.7m in new income and 690 new jobs from the increased use of the lake. (Otto:2005)

Technology

The major technology needed is remote, real time, water monitoring networks. Real time technology is readily available, but remote testing does not often include nutrients.

- WARMER project- 2.5 million euro real time water monitoring network. http://www.ysihydrodata.com/news_story16.htm
- Dissolved Gas Analyzer- "The Bay Instruments DGA is a customized membrane inlet mass spectrometer designed for high precision and rapid analysis of dissolved air gases in natural water samples."
  - Detects air gases in water including stable isotopically labeled gases.
  - Direct measurement of dissolved N_2, O_2, and Ar concentrations in environmental water samples. Does not require headspace equilibration.
  - Analysis time of <2 minutes per raw water sample, typical.
  - http://www.bayinstruments.com/
- Green Eyes- "Designs and implements integrated and fully automated nutrient monitoring systems that can measure various nutrients and ecosystem health indicators in bodies of water at high frequencies and post the findings automatically to the Web"
  - Testing reveals capability to see rapid changes associated with rainfall and tides.
  - Currently in discussion with New York DEC for a "Water to Web" system.
  - http://www.greeneyesobserving.com/news1.html
- YSI 9600 is a real time nitrate monitor. Tested in Louisiana in 2004.
  - www.ysi.com
  - http://www.ysi.com/media/pdfs/A531-Real-Time-Continuous-Nitrate-Monitoring-Provides-a-Window-on-Nutrient-Loading-in-Lake-Ponchartrain.pdf
- Systea nitrate monitor- http://www.systea.it/
- http://www.shimadzu.com/products/environ/5iqj1d00000097fz.html

Key Issue: Groundwater

Key Dimensions

Iowa has five main aquifers, two of which have adequate modeling data. The state is not facing an immediate shortage of groundwater; however, drawdown levels in major pumping areas have already reached 50-150'. There is also a concern that such drawdown levels may alter the flow of groundwater and cause poorer quality water to move into pumped areas. Water levels will drop as much as 200' in 20 years in the central areas of the state, if usage increases by only 25% (usage increased by about 50% from 1990-2007). A network of 51 monitoring wells was installed in to monitor water levels. Due to relatively thick confining beds, the rate of groundwater recharge rate is very small in some areas.

Agricultural drainage wells were created to drain waterlogged soil, beginning in the early 1900s. These wells are as deep as 400', supplied by networks of drain tiles (clay pipes). Research has shown that ADWs increase receiving aquifer contaminant concentrations, including pesticides, fertilizers, manure, bacteria, and sediment. CAFOs in north-central Iowa commonly site multi-million gallon earthen manure storage lagoons near ADWs. From 2004-2008 alone three spills have resulted in manure lagoons draining directly into groundwater though ADWs.

Groundwater quality in the state is generally good. The IDNR compared two studies of rural wells, originally completed in 1988-1989 (SWRL) and re-tested in 2006-2008 (SWRL2) to look at water quality. The findings from 2008:

- 43% of wells had total coliform bacteria detections, 11% had E. coli.
- 49% had detectable nitrate, 12% had concentrations above EPA MCL, down significantly from 1988-1989 levels.
- 94% had chloride detections; there is no natural source of chloride in Iowa.
- 48% had arsenic detections, 8% were at or above EPA MCL.

Current Approach

- The Iowa DNR and Iowa Geological and Water Survey (IGWS) are in the process of evaluating groundwater levels with the addition of state funding in 2007. A main goal of this funding is to develop predictive models of the Dakota and Jordan Aquifers. (Jordan Aquifer). Legislative appropriation is $500k annually, with water allocation permit fees generating an additional $500k.
- The IGWS is working to delineate a zone budgeting system to control future withdrawal in high use areas (most new wells will agglomerate around existing growth centers, further exacerbating local conditions).
- IDNR estimates that 200 feet of drawdown increases the cost of a 500 GPM well by $25k annually. (Jordan Aquifer)

Policy

The Iowa Administrative Code Ch 52.4(3) states that groundwater levels are not to decline more than 200' from the 1975 baseline in any high use area. Iowa also has water quality standards for specific classes of groundwater. (Cambrian Aquifer)

In 2009 the IDNR adopted new water withdrawal permitting fees (455B.265 and IAC 567--50.4(2).

- Fees only apply to users of 25,000+ gallons/day
- The IDNR estimates fees will generate $46,000/year, whereas fees based on withdrawal rates may have generated $1.2m. These permits are contingent on proving that withdrawal will not adversely impact local water quality (see 567—53.5(455B) for specific conditions).
- The fees will not significantly change the current price of water, but will provide leverage for restricting use if shortages occur.

What Needs to be Done

The IDNR is taking a pro-active approach to groundwater quantity and quality. Monitoring is improving, but needs be able to produce accurate models before tighter regulation will be enacted. The Iowa legislature needs to continue to fund monitoring and data gathering.

Technology Needed

Technology needed is similar to surface water monitoring.

- Multi-level groundwater monitors

- Single borehole monitors- http://www.slb.com/~/media/Files/water/case_studies/water_multilevel_monitoring.ashx

Key Issue: CAFOs

Key Dimensions
Iowa has over 2,100 large CAFOs producing 50 million tons of waste a year. The main components of CAFO manure that cause pollution are nutrients, ammonia, pathogens, feed additives (antibiotics, hormones), salts and heavy metals (zinc and copper). Pollutants enter water by lagoon spills, discharges, and seepage, poor siting (flood plains, sandy soils, proximity to aquifer recharge zones), and are vulnerable to heavy rains (feedlot runoff and lagoon overflows). Livestock play an essential role in traditional, diversified family farms as an additional source of income and fertilizer. However, the current trend going back 50 years is moving strongly toward fewer producers and vertically integrated operations, making integrating livestock production into agriculture difficult. Concentrated operations produce more manure than crop and pasture land can assimilate. In 1988 there were 41,000 hog producers, down to 18,000 in 1997. From 2004-2008 there were 51 manure spills into Iowa waters. (NRDC)

- 70% of Iowa farms had hogs in 1960, now down to 12%.
- 329 spills from livestock facilities occurred from 1992 to 2002, 108 of which were responsible for 2.6 million fish killed.
- Over 40% of private drinking water supplies are considered "unsafe" because high levels of coliform bacteria are present. (Human Impacts)
- Because the composition of manure varies, so does the rate of conversion into usable nitrogen. Farmers often over-apply to ensure an adequate supply. Manure is "cheap insurance", if it were converted into a more consistent product by CAFOs it could be applied more exactly.

Current Approach

- CAFOs are regulated by the IDNR. The main components of the regulation are manure storage and disposal, and establishing NPEDS permits.
- Iowa does not require a construction permit for operations with less than 200,000 pounds of swine. Annual inspections are required for operations with an earthen manure lagoon. (NRDC Iowa AG)
- A 1946 law prevents local control over siting of CAFOs. Improper siting, such as in areas prone to flooding or where there is a shallow water table, increases potential for contamination.
- Manure applicators must be certified, but even at recommended application levels contaminants can enter waterways through runoff (CAFO impact)

Policy

According to the Iowa Department of Natural Resources, the regulations concerning CAFOs are may be tweaked, but they are unlikely to be significantly modified. A few recent policy initiatives have been passed that deal with manure storage and disposal.

- HF 735- Stockpiling of Manure. Dry manure stockpiles in use for six months or more over a two year period must have a base and cover that are impermeable and will not allow manure to leach or wash into waterways. This does not apply to manure coming from a CAFO constructed prior to 2006.
- SF 432- Liquid and Dry Bedded Manure. This bill limits the application of liquid manure to snow covered ground from December 21st to April 1st, and frozen ground from February 1st to April 1st, except in emergency situations. The bill also applies NPDES rules and regulations to liquid manure application and dry manure stockpiles. This bill narrowly avoided a last-minute amendment exempting all CAFOs built before 2009 (almost all).

What needs to be Done

- Strengthen IDNR enforcement of the Clean Water Act by monitoring CAFOs and issuing NPDES permits. The Iowa Chapter of the Sierra Club filed a formal petition with the EPA in 2007 to strip the IDNR of its authority to issue operating permits to CAFOs for failing to require adequate pollution controls and act on program violations.
- Strengthen local control over siting and size of operations
- Strengthen regulation of antibiotics, especially those that are crucial for human health.
- Systematic, sustained monitoring of ecosystems around CAFOs, including effects of input spikes

Technology Needed

- Water monitoring around CAFO sites
- On-site water treatment may become standard for CAFOs, in which case decentralized, commercially-viable water treatment systems will be needed.

Key Issue: Energy Production

Key Dimensions

Iowa leads the nation in ethanol production, accounting for approximately ¼ of the nation's supply. There are over three dozen operating plants, with several under construction and expansion. (Energy Data) The US Energy Independence and Security act of 2007 mandates that ethanol production will increase from 34 billion liters in 2008 to 57 billion liters in 2015. The bulk of ethanol production increase from 2005-2008 occurred in the central corn belt where little irrigation is required. The danger is that increasing production further means growing feedstock in areas that require irrigation. This includes parts of Iowa (southern and central), and states that depend on the Ogallala aquifer such as Kansas, Nebraska, and Texas. Higher prices for grain will encourage farms to increase production on marginal land and decrease overall acreage in conservation programs. A new study published in the journal Environmental Science and Technology found that corn-based ethanol production doubled from 2005-2008, and related water use has more the tripled.

- In 2006, field inspectors found 128 violations at ethanol plants. One plant was cited for a fish kill caused by improper spreading of liquid wastes, and another for releasing contaminated wastewater in an attempt to dilute a manure spill at a neighboring cattle operation. (DM Register Biofuel)

- The ratio of gallons of water needed to produce a gallon of ethanol varies greatly depending on the amount of irrigation needed. In Iowa, where less than 1% of corn acreage is irrigated, processing is the main water requirement at 2-10 gallons of water per gallon of ethanol. For irrigated corn, that ratio can climb to 2,000 gallons of water per gallon of ethanol.
- The acreage of irrigated corn planted in Nebraska reached all-time highs in 2007 & 2008, with over 3.64 million acres planted. As a consequence, the Ogallala Aquifer is being drawn down at record rates; water tables have fallen up to 130' in some areas.
- There are three main waste streams from ethanol production. The first is salt, which builds up in cooling towers and boilers and must be discharged. The second comes from purifying water needed for various processes resulting in brine effluent. Finally, wastewater with high biochemical oxygen demand is a byproduct of microbe decomposition of the cellulosic feedstock. (Water and Biofuels congress).

Current Approach
Biofuel production in Iowa is regulated the same way as any industrial facility. Plants must get permits for groundwater withdrawal and adhere to state regulations for air pollution and wastewater effluent.

Policy
The Iowa Code rates water priorities; if water shortages occur, water for energy production may be restricted. As groundwater modeling improves, plants will have to site near available water or increase water conservation. If ethanol demand continues to increase, plants will come under increased scrutiny and there will be strong incentives for plants to adopt new conservation technologies.

What needs to be Done
- Water quantity monitoring to ensure sustainable use
- Monitoring of effluent from biofuel plants
- Evaluate impacts of increasing crop production on water quality
- Increase water efficiency in ethanol production

<u>Iowa References</u>

Center for Health Effects of Environmental Contamination, University of Iowa. (2009, August) Iowa Statewide Rural Well Water Survey Phase 2.
Governor Culver Signs Iowa Surface Water Protection Act. (2010, April 10). Environmental News Services

Hodne, Carol J. (2005, April) *Concentrating on Clean Water: The Challenge of Concentrated Animal Feeding Operations.* Iowa Policy Project.

Iowa Department of Natural Resources. (2000) *State Nonpoint Source Management Program.* Available http://www.iowadnr.gov/water/nonpoint/plan.html
Iowa Department of Natural Resources. (2007, October) Iowa Conservation Practices: Historical Investments, Water Quality, and Gaps. Power point.

Iowa Department of Natural Resources. (2008) *State of Iowa Public Drinking Water Program 2008 Annual Compliance Report.*
Iowa Department of Natural Resources. (2009) *Iowa Water Plan 2009. Policy Review: Water Allocation and Water Use.* Available at: http://www.iowadnr.gov/water/files/quantity_waterplanreview09.pdf
Iowa Department of Natural Resources. (2009, December 30) Lake Restoration 2009 Report and 2010 Plan.
Iowa Department of Natural Resources. Importance of Iowa's Aquatic Resources. Available at http://www.iowadnr.gov/education/plndwr.html
Iowa House File 2400: Surface Water Protection Act. Available at:
http://iowahouse.org/wp-content/uploads/2008/03/hf-2400- surface-water- protection-act.pdf
National Resources Defense Council. (2007) *Atrazine Contamination in Iowa.* Available at docs.nrdc.org/health/files/hea_07091201c.pdf
National Resources Defense Council. America's *Animal Factories, Chapter 8: Iowa.* Available http://www.nrdc.org/water/pollution/factor/stiow.asp
Nitrate and Phosphorus Levels in Eastern Iowa Streams are Among the Highest in the Nation. (2001, May 23) United States Geological Survey News Release.
Otto, Daniel. (2005) *Water Cleanup: What's the Economic Impact for Iowa Communities?* Iowa Ag Review:11(2)
Sauer, Pat and Anne Kimber. (2002) *Energy Consumption and Costs to Treat Water and Wastewater in Iowa.* Iowa Association of Municipal Utilities.

2.5 Maryland

Key Markets	Niche Markets
Wastewater treatment	Enhanced nutrient removal technology
Water monitoring/testing	Monitoring for emerging contaminants
CAFOs	Biodigesters
Storm Water Management	Phosphorous Removal Technologies & Policies
Water Infrastructure	Trading of Phosphorous Reductions

Population
2000: 5,296,486
2010: 5,779,380
2030: 6,684,260
2000-30: +26%

Background
The most important water issue in the state of Maryland is the health of the Chesapeake Bay Watershed. The largest asset to state wealth, the Bay's health directly affects the state's economy, surface waters and streams. Every water quality issue in the state can be directly linked to the health of the Bay. Further, the Chesapeake Bay Watershed Blue Ribbon Finance Panel reported in 2004 that the economic value of the entire Chesapeake watershed may exceed $1 trillion, annually.

Maryland Department of Planning projects a 26% population increase from 2000 to 2030 of nearly 1.4 million people (MDP, 2009). Maryland is the fifth-most-densely populated state in the nation. While much growth has historically occurred in the central part of the state, in the Baltimore and Washington D.C. regions, rapid growth is projected in other areas, particularly the Eastern Shore. The Delmarva Peninsula, as it is also known, has traditionally been home to the state's primary agriculture industry and resources (MDP, 2008). Over recent decades, much agricultural and forested land has been lost to development. Developing areas suffer from degraded water quality and other congestion-related issues

Summary of Key Issues
- Chesapeake Bay Watershed Health
- Infrastructure Needs
- CAFO Pollution
- Contaminated & Degraded Surface Waters; Stormwater Runoff
- Groundwater Supply and Contamination

Key Issue: Chesapeake Bay Watershed Health

Key Dimensions
Although the 64,000 square-mile Chesapeake Bay watershed extends across six states and the District of Columbia, the actual bay lies almost entirely within Maryland. The Bay watershed has experienced the largest population growth compared to all other coastal watersheds in the United States. Reports show that, if the current population trends continue through 2030, the

area of developed land in the watershed will increase by over sixty percent (Phillips, 2007). Approximately twelve percent of land in the watershed is currently classified as "developed." In Maryland alone, current growth and development trends will lead to a loss of 560,000 acres. Rapid population growth means rapid development, which leads to more surface runoff heading to the Bay.

- Bay watershed 1950 population = 8.1 million
- Bay watershed 2009 population = 17 million
- Expansion of suburban areas led to a 41 percent increase in impervious surface in the watershed in the 1990s alone, compared to an 8% population increase over that time. Impervious surface covers 18% of urban land in the watershed (Phillips, 2007).

The Chesapeake Bay received an overall score of "C" and met only 24% of its water quality goals in 2009; the bay had a mix of good and poor levels of water quality and biological health indicators (FLC, 2010). Despite this dismal achievement, overall health of the Bay in 2009 was the highest it had been since 2002, relying on studies of water quality and biotic indicators. One explanation for the improved health points to the decreased flow of the Susquehanna River in 2009, which positively affected the middle and lower portions of the Chesapeake Bay (EcoCheck, 2010).

- 89 of 92 segments of the Bay (97%) and its tidal waters are impaired (FLC, 2010)
- 52% of watershed streams rated poor or very poor in 2009
- Mean concentrations of total nitrogen and phosphorous in streams is highest in agricultural and urbanized basins
- Natural variations in stream flow will greatly influence seasonal and annual nitrogen loads to the Bay
- 2004 study finds highest sediment loads enter the Chesapeake Bay from the Potomac and Susquehanna River basins (Phillips, 2007).
- Many emerging contaminants have been detected in Bay wildlife, but their associated threat is still unknown.

Current approach

Since 1983, the Chesapeake Bay Program, under the Clean Water Act, was the federal effort responsible for cleaning up the Bay. It was a largely volunteer effort and resulted in minimal progress toward improved Bay health. The *Chesapeake 2000 Agreement* stated that the EPA would create a Bay-wide pollution Total Maximum Daily Load (TMDL) by the end of 2010, if voluntary actions to reach water quality goals were not successful.

In May 2009, President Obama declared the Chesapeake Bay Watershed a "National Treasure," stepping up Federal cleanup and enforcement efforts. The executive order established the Federal Leadership Committee, which will be responsible for overseeing future cleanup efforts and ensuring the Bay meets its future water quality goals.

In conjunction with the executive order, the US EPA began development of a Bay-wide Total Maximum Daily Load (TMDL), a sort of "pollution diet" for all watersheds that feed the Bay. The Bay TMDL seeks to ensure that commitments to achieve water quality standards are met by the year 2025 and will require states to develop and implement specific actions and strategies within two-year, measurable increments. An interim goal is set to achieve 60% of the water quality standards by 2017. The Bay TMDL will set limits for Nitrogen, Phosphorous and Sediment.

The cleanup strategy lists four overall goals that are essential to the health of the Chesapeake Bay: "restore clean water, recover habitat, sustain fish and wildlife and, conserve land and increase public access" (FLC, 2010). Twelve key outcomes to meeting those goals are outlined in the plan:

- Meet water quality standards for dissolved oxygen, clarity/underwater grasses and chlorophyll-a in the Bay and tidal tributaries by implementing 100 percent of pollution reduction actions for nitrogen, phosphorus and sediment no later than 2025, with 60 percent of segments attaining water quality standards by 2025;
- Improve the health of streams so that 70 percent of sampled streams throughout the Chesapeake watershed rate fair, good or excellent, as measured by the Index of Biotic Integrity, by 2025;
- Work with producers to apply new conservation practices on four million acres of agricultural working lands in high priority watersheds by 2025 to improve water quality in the Chesapeake Bay and its tributaries;
- Restore 30,000 acres of tidal and non-tidal wetlands and enhance the function of an additional 150,000 acres of degraded wetlands by 2025;
- Restore riparian forest buffers to 63 percent, or 181,440 miles, of the total riparian miles (stream bank and shoreline miles) in the Bay watershed by 2025;
- Restore historical fish migratory routes by opening an additional 1,000 stream miles by 2025, with restoration success indicated by the presence of River herring, American shad and/or American eel;
- Restore native oyster habitat and populations in 20 out of 35 to 40 candidate tributaries by 2025;
- Maintain sustainable blue crab interim rebuilding target of 200 million adults (1+ years old) in 2011 and develop a new population target for 2012 through 2025;
- Restore naturally reproducing brook trout populations in headwater streams by improving 58 sub-watersheds from "reduced" classification (10-50 percent of habitat loss) to "healthy" (less than 10 percent of habitat loss) by 2025;
- Restore a three-year average wintering black duck population in the Chesapeake Bay watershed of 100,000 birds by 2025;
- Protect an additional two million acres of lands throughout the watershed currently identified as high conservation priorities at the federal, state or local level by 2025, including 695,000 acres of forest land of highest value for maintaining water quality;
- Increase public access to the Bay and its tributaries by adding 300 new public access sites by 2025.

The EPA has also stepped up enforcement actions since 2009, sending a message to polluters it is serious about improving the Chesapeake Bay health (Blankenship, 2010).

Impending Policy Changes to Address Issue

On track to release its TMDL for the Chesapeake Bay Watershed by the end of 2010, the EPA released draft amounts in July and August 2010. Each state within the watershed also released draft Watershed Improvement Plans in September, in accordance with the EPA's mandate. These plans lay out the methods by which each state will achieve its respective TMDLs.

Total Chesapeake Bay Watershed TMDL Draft Allocations in million pounds/year (MDE, 2010)

	BAY	**MD DRAFT ALLOCATION**	**MD Reduction from 2009**
NITROGEN	203.14	39.09	21%
PHOSPHOROUS	12.52	2.72	18%
SEDIMENT	6,066 - 6,673	1,116 - 1,228	12%

In terms of Maryland's contribution to the EPA's TMDL program, Maryland's draft Watershed Improvement Plan announces that Maryland will achieve its goals for the Bay by 2020, five years ahead of schedule, as well as achieve 70% of its goals by 2017 (EPA mandates 60%). Maryland drains to 58 of the impaired Bay segments and is subject to 174 of 294, 59%, of the EPA's TMDLs. Primary strategies to accomplish the goals laid out in Maryland's Watershed Improvement Plan include (MDE, 2010):

- Develop new technology and approaches prior to 2017;
- Increase the scope of implementation of existing strategies; and
- Improve regulatory requirements to increase reductions achieved.

As part of the plan, Maryland will rely most heavily on phosphorous reduction measures, in order to achieve its sediment TMDL goals. This is due to the fact that phosphorous tends to bind to sediment particles; therefore, efforts to limit phosphorous, like decreasing erosion and runoff, can lead to reduced sediment loading to streams and rivers that feed the Chesapeake Bay (Blankenship, 2010).

The Maryland Legislature created the *Chesapeake and Atlantic Coastal Bays 2010 Trust Fund*, to provide financial assistance for the Bay restoration efforts outlined in the Chesapeake 2000 Agreement. Money is allocated to the Trust Fund through the annual state budget and government bonds, specifically for non-point source, pollution-control projects. In addition, the BayStat program was created to measure, evaluate and administer the Trust Fund and other government actions to clean up the Chesapeake Bay. In 2009, $9.6 million was allocated to the fund.

Action Needed

In order to achieve the goals set forth by the EPA, each state must dedicate the personnel and resources necessary to undertake such a task. Cleanup of the Chesapeake is a nationwide goal since Obama's declaration of the Bay as a National Treasure. Upon release of the draft TMDLs, New York, in particular, questioned its role and claimed the EPA's requirements for its share of pollution reduction were "unfair" (Roeder, 2010). A multi-state, inter-agency commitment will be crucial to the success of the Chesapeake Bay.

Maryland, as well as Pennsylvania in particular, is examining "nutrient trading" to achieve improved Chesapeake Bay health. The concept of nutrient trading is gaining acceptance as a tool to improve water quality, and the economic incentive of nutrient credits is attracting entrepreneurs to develop new technologies in the water quality field. Nutrient trading occurs when one pollution source, for example, a farm, meets a baseline of nutrient reduction goals and sells credits when it exceeds those goals, to another source within the same watershed, for example a wastewater treatment facility (PDEP, 2007). Sale of credits from new nutrient-reducing technologies will serve to demonstrate their commercial-scale application and create new, cost-effective options in the effort to improve water quality.

Continued best management practices for agriculture and stormwater management are a proven method of reducing polluted runoff into the Bay watershed. Further, improved land use for feedstock production could more than double the watershed's annual rate of progress toward water quality goals. If 766,000 acres of winter rye is planted in rotation, a 4 million pound reduction of nitrogen entering the Bay could be expected.

Technology Needed

Future recovery of the Chesapeake Bay and its watershed will require extremely advanced and refined treatment and detection technologies such as the following:

- Enhanced nutrient removal in wastewater treatment
- Enhanced monitoring and data collection methods
- Improved runoff reduction methods
- Biological nutrient removal
- Treatment for endocrine disrupters
- Detection and treatment methods for emerging contaminants

Availability of Technology

Several wastewater treatment plants in Maryland have already been upgraded with enhanced nutrient removal technology. However, this still remains a costly process.

Key Issue: Infrastructure Needs

Key Dimensions

Due to the EPA's pending TMDL allocations for the Chesapeake Bay, many wastewater treatment plants are in need of serious upgrades to meet the federal standards. Maryland estimates that upgrading its treatment facilities is the key to reducing its pollution into the Bay.

The Clean Watersheds Needs Survey is conducted every four years by the US EPA. The survey assesses the amount of unfunded capital costs across the nation. Maryland documented $13.9 billion in infrastructure needs in 2008, a 92% increase from 2004 (EPA, 2008). Counties with the highest needs are located in the Baltimore and Washington D.C. regions.

- $4,715 million in Wastewater treatment, Pipes, Combined Sewer Overflows
    - 60% wastewater treatment alone
- $3,755 million in Stormwater management
- $4,971 million in Decentralized wastewater treatment please discuss this further; it sounds very important for many – the decentralized part

The EPA also conducted the most recent Drinking Water Infrastructure Needs Survey in 2007. Maryland is in need of $5.4 billion in infrastructure needs (EPA, 2009).

- $3,497 million in Transmission/distribution
- $1,134 million in Treatment

After severe drought in 1999, the governor of Maryland directed the state to address water infrastructure needs. Statistics suggested average system unaccounted water (system leakage) is 15 to 20 percent. The report also revealed many systems are operating within 90% of design capacity to produce potable water; aged and inaccurate meters are misrepresenting data and rate structures should be evaluated to promote conservation practices (Linaweaver, 2000).

Current approach

Maryland has already started the process to retrofit several of its wastewater treatment facilities. The Bay Restoration Fund of 2004 (Senate Bill 320) captures a $2.50 monthly fee paid by wastewater treatment plant users, to upgrade 66 of the largest treatment plants in the state, representing 95% of the total flow to the Chesapeake Bay and its tributaries. Enhanced nutrient removal at the facilities is planned to reduce wastewater pollutant flow to 3.0 milligrams per liter (mg/l) total nitrogen and 0.3 mg/l total phosphorus. Property owners with on-site sewage disposal systems are also required to pay a $30.00 annual fee. Sixty percent of the income generated funds voluntary septic system upgrades and the remainder is used for planting cover crops.

The state also requires notification of any combined or sanitary sewer overflow events and maintains a list for public records. Records searched returned results of 1,692 overflow or bypass events for the year 2009.

Action Needed

Reports point to the fact that many water distribution facilities, as well as wastewater treatment facilities, are in need of adequately trained staff (MDE, 2008). Competent water managers are in demand to fulfill the state's and EPA's requirements for improved water quality. Staff training, recruitment or certification programs could be a useful addition at many facilities. Also, due to the unfunded capital costs of infrastructure needs, rate structure increases may be an option to complement state and federal funding for system upgrades and repairs.

Impending Policy Changes to Address Issue

Under the Federal American Recovery and Reinvestment Act, Maryland was awarded $121.6 million to fund Clean Water and Drinking Water State Revolving Loan Fund projects in June of 2009. Eighty-two different projects were either complete or under construction as of August 2010, from wastewater treatment plant improvements to drinking water system upgrades.

Technology Needed

- Enhanced nutrient removal (ENR)
- Biological nutrient removal (BNR)
- Automated water meters – for facility and private use
- Leak detection in distribution systems
- Cost-efficient methods of pipe lining or repair

Key Issue: Contaminated & Degraded Surface Waters

Key Dimensions

In 2002, the state reported sixty percent of rivers and streams as impaired and 38% of all watersheds as impaired in 2006. Not only do many of these surface waters drain to the Chesapeake Bay, two-thirds of the state population relies on surface water for public consumption. The Baltimore and Washington D.C. urban areas retrieve their drinking water from surface water sources. Studies indicate that biological impairment of streams can occur when as little as five percent of the watershed is covered by impervious surface (Phillips, 2007). The largest contribution to poor surface water quality in Maryland is the "continuing accumulation of nutrients in estuaries and lakes from agricultural runoff, urban runoff, natural nonpoint source runoff and point source discharges" (Garrison, 1998).

- 10% of Nitrogen and 31% of Phosphorous reaching the Chesapeake Bay is from stormwater systems (Blankenship, 2010).
- The most commonly listed TMDL's for surface waters of the state (since 1995) from highest to lowest are: iron, aluminum, sulfate, nitrate, ammonium, fecal coliform, phosphorous and nitrogen (MDE and others, 2008).
- Degradation products of pesticides in streams (and groundwater) are often found in larger concentrations than the parent compounds. Atrazine, metolachlor, simazine most commonly detected in surface waters (Phillips, 2007).
- The antibiotic Oxytetracycline (OTC) was found in sediments from two streams in the Eastern Shore of the Chesapeake watershed. Data indicate that presence of OTC could result in increased nutrient loading to the estuary (Phillips, 2007).
- A decline in the amount of state navigable waters has resulted from siltation – soil erosion from poor farming practices

Current approach

Maryland has taken several steps, many of which coincide with Chesapeake Bay restoration efforts, to reduce pollution to surface waters. A 2007 state senate bill prohibited the use, sale, manufacture and distribution of household detergent containing over 0.5% phosphorous by weight. It is estimated the ban will reduce 13,000 lbs of phosphorous per year currently associated with commercial dishwashers (Wilson, 2009).

Action Needed

Continued policy directives which lower the impact of stormwater runoff and surface water pollution are necessary not only in Maryland, but all Chesapeake Bay watershed regions. Any other site best management practices and technology improvements which can be implemented will benefit the state's waters and Chesapeake Bay.

Impending Policy Changes to Address Issue

Maryland Stormwater Management Act of 2007 required environmental site design (ESD) techniques be implemented to the maximum extent practical on new and redevelopment construction sites as of May 4, 2010. Previous legislation only encouraged ESD. These steps (akin to Low-Impact Development) aim to return a site to pre-development conditions, thereby reducing impervious surfaces and combing stormwater, erosion and sediment control strategies.

Technology Needed

- Contaminant removal
- Pesticide treatment and reduced use of pesticides

Availability of Technology

- Infiltration and inflow control for collection systems
  - Interceptor devices that eliminate re-suspension of pollutants
  - "First flush" filtration for storm drains
- Collection system pre-treatment (e.g. In-Pipe bacterial injection)

Key Issue: Groundwater Supply and Contamination

Key Dimensions

Maryland is one of the most geologically, hydrologically diverse states in the northeast. Five physiographic provinces yield significantly different quantities and qualities of water. For this reason, the actual amount of groundwater availability can only be measured at a site-specific level currently. State-wide ground water use exceeds 214 million gallons per day (mgd) (Clearwater and others, 2000) and provides drinking water for nearly one-third the state population (MDE, 2003). About 16% of the state receives its drinking water supply from private wells (MDE, 2008 b).

Although generally, Maryland has good quality groundwater, local contamination and quality vary depending on the aquifer being pumped. In areas where the aquifers are unconfined, they are more susceptible to contamination from land surface activities. The aquifers of the Coastal Plain, covering the entire Eastern and Western Shores of the Chesapeake Bay and comprising half the state, are primarily confined (MDE, 2008 b). Conversely, west of the Coastal Plain, the aquifers are mostly of fractured rock and limestone, without a confining unit and highly susceptible to contamination. The fractured rock aquifers also yield highly varied quantities of water, where wells on neighboring properties can pump significantly different amounts.

Further, precipitation varies across the state, from around 46 inches in the west where rain fall is highest July to August, to 38.5 inches in the east, raining mostly in July to August (Clearwater and others, 2000). These factors affect the rate of aquifer recharge in different areas of the state. Many surface waters originate as groundwater, and groundwater also provides freshwater to the Chesapeake Bay.

The Maryland Department of the Environment published a brief overview of the groundwater conditions in the state, listing several sources of contamination (MDE, 2003):

- Elevated levels of nitrates are common in agricultural areas, as well as those served by on-site wastewater treatment systems
- Localized contamination exists from leakage of petroleum products
- MTBE, a petroleum additive, present in public supply wells, though it is commonly at levels below taste and odor thresholds
- Fecal contamination common in western area (Great Valley) of Maryland
- High levels of radium in Coastal Plain – Magothy and Patapsco aquifers
- High levels of radon in Piedmont aquifers

- Arsenic at levels exceeding EPA limits in southern Maryland and central-Eastern Shore – Aquia and Piney Point aquifers
- Iron in water can be excessive in areas of Piedmont and Coastal Plan (75% of state)

Coastal aquifers along the Chesapeake Bay and Atlantic Ocean contain both fresh and salt water. Closer to the ocean and with greater depth, water turns more saline in character (Clearwater and others, 2000). The volume and rate of withdrawal from the aquifer will affect the intensity of salt-water intrusion. How large a problem is this? Is it caused by municipal use or ag use? What is the market created for water efficiency devices?

Current approach

Comprehensive groundwater protection strategy for state

- Maryland's wellhead protection program has been in place since 1991. The protection areas are delineated by the amount of time groundwater travels to the water supply, as determined by groundwater flow models. The land use in the protection zone is strictly regulated from any designations which could potentially contaminate the ground including gasoline service stations, dry cleaner establishments and junk yards, etc.
- In coastal aquifers, groundwater pumping is carefully managed to prevent further salt-water intrusion.
- County health departments have remediation programs in place for private wells

Action Needed

Due to the geology of Maryland, local water supply and quality issues may become potentially serious problems. The state will need to perform detailed water supply planning with careful monitoring and management of public water supply sources. Also, continued emphasis on preventing contamination, groundwater protection and citizen education are keys to sustaining the groundwater supply available for public consumption.

Impending Policy Changes to Address Issue

Little is being changed at this point; attention is focused on surface waters and Chesapeake Bay.

Technology Needed

- Treatment for contaminants in public supply
- Groundwater quality monitoring
- Groundwater modeling for supply availability and planning
- Private well monitoring and treatment; both point of entry and point of use
- Brackish groundwater desalination could be needed as salt water intrusion pushes further inland

Availability of Technology

The widespread application of Geographic Information Systems (GIS) is allowing water managers to develop models of groundwater sources. GIS has allowed for more accurate data collection and inventory systems to assist in the planning of water resources and identify areas with contamination and potential contamination.

Several methods currently exist to treat for arsenic contamination, and many are becoming more widely used and available: Iron oxide adsorption, Activated Alumina adsorption, Anion exchange and Reverse Osmosis are the most common.

Maryland References

Bay Restoration Fund Advisory Committee. (2009, January). Annual status report. Retrieved from: http://www.mde.state.md.us/assets/document/BRF-AnnualStatusReport01-2009.pdf

Blankenship, K. (2010). Recent EPA enforcement actions intended to send message to polluters. *Chesapeake Bay Journal.* Retrieved from: http://www.bayjournal.com/article.cfm?article=3912

Clearwater, D., Turgeon, P., Noble, C., & LaBranche, J. (2000, January). An overview of wetlands and water resources of Maryland. Retrieved from: http://websrvr.mde.md.gov/assets/document/wetlandswaterways/water_resources.pdf

Eco-Check. (2010). Chesapeake Bay Report Card 2009. *Eco-Check Newsletter 261.* Retrieved from: http://ian.umces.edu/pdfs/ecocheck_newsletter_261.pdf

EPA. (2008). Clean Watersheds Needs Survey 2008: Report to Congress. Retrieved from: http://water.epa.gov/scitech/datait/databases/cwns/upload/cwns2008rtc.pdf

EPA Office of Water. (2009, February). Drinking water infrastructure needs survey and assessment: fourth report to Congress. *EPA 816-R-09-001*. Retrieved from: http://water.epa.gov/infrastructure/drinkingwater/dwns/upload/2009_03_26_needssurvey_2007_report_needssurvey_2007.pdf

Federal Leadership Committee for the Chesapeake Bay. (2010, May 12). Strategy for protecting and restoring the Chesapeake Bay watershed. (EPA-903-R-10-003). Retrieved from: http://executiveorder.chesapeakebay.net/file.axd?file=2010%2f5%2f Chesapeake+EO+Strategy%20.pdf

Garrison, S. (1998). National Water Quality Inventory: 1998 report to Congress. State fact sheet. Retrieved from: http://www.epa.gov/owow/305b/98report/md.pdf

Grumet, R. S. (2000). Bay, plain, and piedmont: A landscape history of the Chesapeake heartland from 1.3 billion years ago to 2000. *The Chesapeake Bay Heritage Context Project*. Annapolis, MD: US Department of the Interior, National Park Service. Retrieved from: http://www.chesapeakebay.net/content/publications/cbp_19653.pdf

Linaweaver, F. P. (2000, October). Maryland technical advisory committee report on water supply infrastructure. Retrieved from: http://www.mde.maryland.gov/assets/document/water_cons/techadvcommitteereport.pdf

Maryland Department of the Environment. (2010, September 1). Maryland's phase I watershed implementation plan for the Chesapeake Bay total maximum daily load. Retrieved from: http://www.mde.state.md.us/assets/document/MD_WIP_Phase_I_090110.pdf

Maryland Department of the Environment. (2008, September). Report to Governor: capacity development for Maryland public drinking water systems. Retrieved from: http://www.mde.state.md.us/assets/document/WSP-CDsep2008.pdf

Maryland Department of the Environment. (2008, July). Water for Maryland's future: what we must do today. *Final Report of the Advisory Committee on the Management and Protection of the State's Water Resources.* Volume I and II.

MDE & MDNR. (2008). The 2008 integrated report of surface water quality in Maryland. Retrieved from: http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/Maryland%20303%20dlist/2008_Final_303d_list.asp

Maryland Department of the Environment. (2003). An overview of Maryland ground water conditions. Retrieved from:

Maryland Department of Planning. (2009, June). 2008 Maryland Statistical Handbook. Retrieved from: http://planning.maryland.gov/msdc/md_statistical_handbook08.pdf

Pennsylvania Department of Environmental Protection. (2007). Nutrient trading: Chesapeake Bay watershed. *Fact Sheet.* Retrieved from: http://www.dep.state.pa.us/river/Nutrient%20Trading_files/Trading%20Fact%20Sheet-%203900-FS-DEP4073.pdf

Phillips, S.W. ed. (2007). Synthesis of US Geological Survey science for the Chesapeake Bay ecosystem and implications for environmental management. *US Geological Survey Circular 1316.* 63 p. Retrieved from: http://pubs.usgs.gov/circ/circ1316/

Roeder, L. (2010, September 7). Chesapeake Bay draft plans reflect differing state challenges, viewpoints. *The Bureau of National Affairs*: *Daily Environment Report*. Retrieved from: http://ehscenter.bna.com/PIC2/ehs.nsf/id/BNAP-893EN9

Wilson, S. T. (2009, June 9). Personal communication re: Chapter 187 (Senate Bill 766) and Chapter 188 (House Bill 1311) of 2007 Environment Phosphorus- Dishwashing Detergent. Retrieved from: http://www.mde.maryland.gov/assets/document/commercial_dishwashing_report.pdf

2.6 Minnesota

Key Markets	Niche Markets
Water Conservation/Efficiency	Septic System Replacement
Groundwater Contamination/Monitoring	Real-time Groundwater Sensor Systems
Reducing Ag Nitrogen & Phosphate Loss	Water-efficient Electricity Generation
Bio-fuels Manufacturing	Efficient Bio-fuel Manufacturing Processes

Major Problems
Minnesota will face increased demand for useable and accessible groundwater, as population and water use increase. Minnesota's groundwater supply is not always located where it is needed. Surface waters in Minnesota are under threat from aging individual private septic tanks. Minnesota is actively trying to assist property owners to replace leaking septic tanks near waterways.

- Lack of monitoring
- Reducing phosphorus/nitrogen/silt levels in waterways
- Groundwater drawn down and unsustainable use
- Bio-fuels manufacturing – a water and energy intensive process
- Aging infrastructure: Leaky private septic tanks

Demographic Indicators

Population	2000	2009	2020
Urban Population	3,489,300	--	--
Rural Population	1,430,200	--	--
Total Population	**4,919,500**	**5,266,200**	**5,900,700**

Population Growth Rate	2000-2009
Total Population Growth Rate	7.0%

Source: United States Census Bureau
(http://www.census.gov/population/www/projections/projectionsagesex.html)

Economic Indicators

Economic Indicator (2007)	Nominal GDP
Total GDP	$252.5 billion
GDP per capita	$41,060
GDP growth rate	1.6%

Source: United States Bureau of Economic Analysis
(http://www.bea.gov/scb/pdf/2009/06%20June/0609_gdp_state.pdf)

Background
Minnesota has water. It is the land of 12,292 lakes. These lakes cover 6% of the surface area of the state, more than any other state. Unfortunately for the state, the water is not evenly distributed. The western portion of Minnesota is quite dry, except for flooding problems in the

spring. Another issue that is geographically concentrated is the location of "impaired water." Greater than 80% of the EPA-defined impaired water is located in the rural areas of the state. The issue here is that misused, these waters could negatively affect the food grown there. Because of the ample natural water supply, irrigation is little used. The main water user is power generation (60%); municipal use and irrigation each use about 13% of the total. Groundwater is extremely important in all uses: some 90% of irrigation water comes from the ground as does 75% of drinking water. With so much water, wastewater treatment standards are a bit lower than elsewhere and enforcement is more lax. Water problems are likely to grow in scale, as the population of Minnesota is projected to grow 26% by 2030, and water use, unless changed, will grow by an even greater percentage.

Key Issue: Lack of Monitoring

Groundwater

The Minnesota Pollution Control Agency (MPCA) began monitoring statewide ground water in 1978, using a system developed by the United States Geological Survey. The program was reevaluated in 1990 to include a statewide baseline network, a trends analysis report and regional monitoring cooperatives. The result was the Groundwater Monitoring and Assessment Program.

Minnesota's Groundwater Monitoring program ended in 2001. Since then the bulk of water monitoring has been done through Minnesota's volunteer water monitoring program. However, volunteers are limited, measuring only transparency, appearance, recreational suitability, precipitation, and stream stage. Minnesota has statewide gauges that measure water flow; however, measuring water quality is not widespread. Most water quality sensors are located near the Twin Cities and mainly detect Volatile Organic Chemicals (VOC) only. (Minnesota Pollution Control Agency)

In terms of groundwater, Minnesota has a pool of about 10,000 domestic wells of which only 70 samples are taken each year. The number of samples is expected to decrease to 25 a year in 2010. The samplings produce results on chloride, nitrate and VOCs. Minnesota plans to transition to a trend network of groundwater monitoring to target problem areas. However, the maximum number of wells expected to be monitored is 150. (Minnesota Pollution Control Agency)

Surface water

The MPCA works with the Minnesota Department of Natural Resources to monitor contaminants within fish. The MPCA monitors 80 stream sites throughout the state. MPCA is also working to develop an Index of Biological Integrity for rivers and streams. Bio-survey techniques are being created to evaluate water quality within each major river basin using fish and macro-invertebrate communities.

Current Water Monitoring Strategy

- Condition monitoring: Identify overall environmental status of water bodies and aquifers in terms of their ability to meet existing standards and regulation.
- Problem Investigation Monitoring: Looking at specific problems and developing ways to mitigate the problem source.

– Effectiveness Monitoring: Measures how well a current approach or policy comes to solving a problem or reaching a goal.

Action Needed
Require regulated parties to do effectiveness monitoring – This would have the MPCA process data from regulated parties (people who acquire a necessary permit) to ensure that standards are being met. Estimated cost in $210,000 a year.

Reinstitute condition monitoring in Minnesota – Requires an expansion of data collection abilities of the MPCA. Cost $212,500 a year to monitor a lake system and $125,000 for lab analysis.

Minnesota must reinstate efforts of condition monitoring to develop an understanding of the current conditions of groundwater. New technology may allow an economical way to collect and analyze a large amount of important data. In situ real-time monitoring with data transmission capabilities would allow a statewide network to quickly identify and report problems which could receive more scrutiny.

Possible Technology Solutions
Westbay System – Schlumberger
- In-situ fluid pressure measurement
- Fluid pumping
- In-situ chemical sensing (P, T, pH, Redox, Conductivity, Dissolved Oxygen and other parameters)

In place in Orange County California:
- 600 monitoring zones installed in 55 deep multilevel monitoring wells currently monitor water quality and water movement in the groundwater basin; 200 conventional standpipe monitoring wells contribute an additional 200 monitoring zones.

ENDETEC – a subsidiary of Veolia
- Endetec provides an on-site microbiology testing device to test for E.coli and total coliform bacteria. Especially relevant for monitoring streams affected by nearby CAFOs.

Key Issue: Reducing Phosphorus Levels in Waterways
While attention has been centered on lowering phosphorus levels in the past, results remain elusive. There was a coordinated plan between the Minnesota Pollution Control Agency and the US EPA. The goal was to reduce phosphorus levels in the Minnesota River by 40%. The goal was not obtained due to the proliferation of phosphorus coming from nonpoint sources.

As the primary nutrient pollutant affecting Minnesota, phosphorus will continue to be a major battle line. It is not known how much phosphorus flowing into State water is discharged from both point and nonpoint sources. New laws have focused on easy targets, the wastewater treatment plants – reducing phosphorus content by 50%. However, a coordinated action plan incorporating phosphorus on all sources is the only way to drastically reduce contamination. (Minnesota House of Representative Research Department)

Current Phosphorus Strategy
Current implementation is based upon a 1996 strategy developed by MPCA

- Develop education/outreach information on environmental impacts of phosphorus.
- Cosponsor basin-wide phosphorus forums.
- Use basin management as the main policy context for implementing the phosphorus strategy.
- Broadly implement Minnesota's point-source phosphorus controls.
- Broadly promote lake protection activities.
- Address phosphorus impacts on rivers.
- Modify water-quality standards if necessary.

State Laws
2003 – Section 122 creates a state goal of reducing phosphorus from non-ingested sources entering municipal wastewater treatment system by at least 50 percent by a timetable established by the MPCA.

Phosphorus Treatment and Removal Technologies
Chemical Treatment Process at the wastewater treatment stage – creates a balance between added chemicals and phosphorus. The remaining phosphorus creates a sludge that must be properly disposed. The cost of this process includes power, capital costs and chemical costs. The chemical process is the least expensive way to remove phosphorus at the wastewater treatment stage. Of course decreasing phosphorus entering the water system is the most cost-effective way to decrease phosphors from waste water treatment plants.

The Biological Phosphorus Removal Process uses an activated sludge filled with microorganisms. Some Minnesota wastewater treatment plants have seen an average removal rate of 47%.

Depending on the phosphorus removal process selected for a wastewater treatment plant, the cost per gallon per day (gpd) can range from $0.20 to $5.25. (USEPA Municipal Nutrient Removal Technologies Reference Document)

Key Issue: Groundwater Drawn Down and Unsustainable Use

Water Users

- Power Generation: 853 million gallons in 2006
- Irrigation: 116 billion gallons – 90% comes from groundwater – in 2006
- In 2010 some 19 ethanol plants with more closing this year; 4 to 5 gallons of water used to produce 1 gallon of ethanol
- 70% of Minnesotans get drinking water from underground
- Recent increases in water usage has outstripped the increase in population

(Minnesota Department of Natural Resources)

Minnesota does have large quantities of groundwater; however, the groundwater is not always located where the need is. This creates situations where there is overuse of the water supply in some areas. If the recharge rate (the rate at which the aquifer regenerates water supplies) is less that than the drawn- down rate (the rate at which water is taken from the aquifer), then there is an unsustainable situation. The Minnesota Department of Natural Resources Division of Waters prepared a report describing the issues and needs concerning the sustainability of Minnesota's groundwater – the most important are highlighted here:

Technical Needs

- Accelerate physical and chemical testing of aquifers.
- Further analyze connections between aquifers and lakes, wetlands, streams, or springs.
- Expand the use of estimation techniques such as modeling to evaluate proposed development scenarios and describe the consequences of each.

Monitoring Needs

- Restore measurement frequency and expand the ground-water level monitoring network to develop water level
- Data for aquifers in areas of increasing ground-water demand.
- Capture and analyze ground-water level data and pumpage from permittees.
- Construct new ground-water level monitoring wells in selected locations to enhance the capability to anticipate needed information and monitoring.
- Expand and coordinate precipitation, stream flow, ground-water quality, and lake level monitoring to fully
- Examine the impacts of actual or potential ground-water withdrawals.
- Analyze and report information by aquifer, including an evaluation of the impacts of withdrawals.
- Recognize, monitor, and describe the impacts of surface activities on ground-water quality.

Regulatory Needs

- Determine whether adequate authority exists for the DNR Commissioner to designate water resources
- Management areas within which withdrawals may be limited and allocated based on limited water availability.
- Adjust permitted pumping rates or withdrawal amounts within water resources management areas when needed to meet the goals determined in the water planning effort.

There is a clear need for better monitoring of Minnesota's groundwater. Without knowing the recharge and drawn down rates there cannot be a clear understanding of Minnesota's groundwater.

Conservation will be the key to using groundwater wisely. Proper monitoring and regulation can help ensure that Minnesota's abundant resource does not become overused.

Water-efficient appliances, as well as low-flow showers and toilets can pay off -- reducing household water consumption to 49.6 gallons a day from the typical 72.5 gallons per day, according to the American Water Works Association.
Fix leaks: A leaky faucet dripping at a rate of one drop per second will waste around 2,700 gallons per year.

Small rain gardens -- shallow depressions planted with water-tolerant native vegetation -- can help recharge ground water when placed in strategic locations to capture runoff from drain spouts, parking lots, and other impervious surfaces. They also filter pollutants.

Parking lots and driveways can be made more permeable by using pervious paving stones and gaps in the pavement planted with grass or other vegetation.

Well-structured soils conserve moisture, improve recharge, and help keep contaminants out of ground water and surface water. Manure, composts, and cover crops can improve soil structure.

A US Department of Agriculture study found that across a range of soil types, from clay loam to loamy sand, the soil's available water content increased 10 to 20 percent when land managers reduced tillage or added another crop such as oats to a corn-soybean rotation.

For more information contact: DeVore, Brian. *Gauging Groundwater.* Minnesota Department of Natural Resources: 2010.
<http://www.dnr.state.mn.us/volunteer/marapr08/gauging_groundwater.html>

Bio-fuels – A Water and Energy Intensive Process
In 2010 there were 19 bio-fuel production facilities within Minnesota with the potential for more to be shuttered. Those operating use a good deal of water. Ethanol plants often use four to five gallons of water for each gallon of ethanol. In 2006, just in the state of Minnesota, drivers pumped 236 million gallons of bio-fuels mixed with gasoline into their cars. That means somewhere between .944B and 1.18 B gallons of water were used in making those bio-fuels. The current price of ethanol is reducing demand, as petroleum is more appealing.

It is not just the production of ethanol that affects water. Corn production is an energy and water intensive process which directly affects water quality due to more fertilizer being used. (Minnesota Department of Natural Resources)

Moreover, bio-fuel crops can release enough nitrous oxide to negate any benefits of burning bio-fuels rather than gasoline. But using native plants such as switchgrass can nearly eliminate the needs for water and fertilizers, and switchgrass has been tested as releasing over 5 times more energy than what was used to produce it. (CNN)

Goals of Minnesota's Ethanol Program:
- To build a new market for the state's largest crop (corn).
- To develop corn processing/ethanol production facilities in Minnesota.
- To increase the number of New Generation Farmer Coops.
- To replace 10% of imported petroleum Minnesota’s uses for gasoline (over $100 million

in annual savings).
- To help the Twin City Area meet US EPA standards for carbon monoxide.

Oregon Environmental Council. *Minnesota's Biofuel Programs: Economic and Environmental Impact*. February, 2005. http://www.oeconline.org/our-work/economy/biofuelspdfs/Minnesota-biofuels

Technology Solutions
The USDA has invested $80 million and the Department of Energy poured $385 million into bio-fuel development programs in 2009 alone. Technologies which have benefited from the government's investment include:

- Concentrated acid hydrolysis – allows a wide array of cellulosic materials to be converted into sugar which then can be used as renewable fuel
- Consolidated Bio-Processing – Genetically modifying bacteria and microbes that hydrolyze and ferment sugars into ethanol
- Range Fuels – Feedstock converted to a synthesis gas which is then passed over a 'proprietary catalyst' to convert the gas to alcohol.

The Minnesota Project. Transportation Biofuels in the United States: An Update. August, 2009. http://www.mnproject.org/pdf/TMP_Transportation-Biofuels-Update_Aug09.pdf

The US Department of Energy has also announced a $44 million in efforts to bring algae-based fuels to market. The promise of algae comes form their efficient ability to convert carbon dioxide into biomass and does not require a large amount of land. However, algae-base fuels must reduce the amount of freshwater and fertilizer needed.

Science News. *Algae as Biofuel Still Rough Around the Edges*. January, 2010. http://www.sciencenews.org/view/generic/id/55665/title/Algae_as_biofuel_still_rough_around_the_edges

Aging Infrastructure: Leaky Private Septic Tanks

About 450,000 homes, 75,000 cabins and 10,000 businesses and resorts rely upon individual onsite sewage treatment systems (ISTS). The Minnesota Pollution Control Agency has estimated that about 64,000 on these onsite treatment systems are nonfunctioning resulting in:

- Sewage discharging to ground and surface water
- Sewage being released into nearby ditches, streams or lakes.

To bring nonfunctioning or underperforming onsite treatment systems up to proper working order, Minnesota has pass State Statue 115.55 which requires the property owner to fix improper onsite systems within 10 months of discovery and notification from the local government.

Failing to resolve this problem will result in increasing harmful affects to waterways within and out of Minnesota. Bacteria and disease-causing organisms levels would continue to increase.

Poor onsite treatment systems contribute an estimated 7% to 15% of the annual nutrient load to Minnesota water ways. There would be adverse affects on recreation, tourism and public heath – via drinking water. (Minnesota Pollution Control Agency)

Legislation

- Minnesota currently has statues dictating minimum technical standards for individual and mid- size Subsurface Sewage Treatment Systems (SSTS).
- A framework for local implementation of SSTS programs
- A statewide licensing and certification of SSTS professional – SSTS Advisory Committee

(Minnesota Pollution Control Agency)

Current Needs

- Replaced existing ISTS with new ISTS with centralized management to provide monitoring and operational maintenance.
- Decentralize wastewater systems that combine localized failed ISTs into multi-household, soil-based systems with centralized management.
- Connect failed un-sewered areas to WWTPs with available capacity.
- Connect un-sewered areas to WWTPs that need improvements to handle additional capacity
- Develop new wastewater facility collection systems

The estimated cost to fix all problem ISTS: $1.2 billion.

MPCA. *10-Year Plan to Upgrade and Maintain Minnesota's On-site (ISTS) Treatment Systems.* 2004.

Technology Needs

If an ISTS undergoes a failure that cannot be solved using traditional methods, replacement may be inevitable and expensive. There are many alternatives when looking for ISTS including:

- Rock Lateral System – box chamber and perforated piping allowing controlled seepage into soil
- Leaching chamber system – a cavern with an open floor to the soil that holds effluent for a while before it seeps into the ground allowing bacteria to break down waste
- Mound system – collects effluent and allows for soil absorption – ideal for lots with high water table, clay or bedrock near the surface

Of course a properly functioning ISTS is good but one that can remove nitrogen is better.

De-nitrification is a process where nitrogen is converted into nitrogen gas during a aerobic/anoxic process within the septic tank. The nitrogen gases are released into the surrounding air. Approximately 75% of the nitrogen is converted into nitrogen gas through this process. An ISTS that reduces nitrogen typically costs $3,000 - $4,000 more than a traditional ISTS and requires an added operational cost because of the need for electricity. (www.tappwater.org)

2.7 New York

Key Markets	Niche Markets
Municipal water treatment systems	Water quality monitoring
Water efficiency	Water pollution remediation
Stormwater management	Leak detection
Plant energy efficiency	Industrial wastewater treatment
Network rehabilitation	Hydrofracking water treatment

Population Indicators

	2009 (est.)	2015	2035
Urban Population	18,001,623	-	-
Rural Population	1,539,830	-	-
Total	**19,541,453**	**19,546,699**	**20,460,301**

2015 projection
http://www.bcnys.org/whatsnew/2005/0420censuspoptable.htm
2035 projection
http://pad.human.cornell.edu/counties/projections.cfm

Economic Indicators

Total GSP: $957,873 (in millions)
US Rank: 3
World Rank: 16
GSP per capita: $46,957 USD (*US average - $39,138*)

Background

New York is on a precipitous edge. Having made great strides toward improving water quality following the passage of the Clean Water Act, the state is in danger of sliding back. The primary concern is infrastructure, which is barely able to keep up with current regulations. The state estimates it will need approximately $84 billion over the next 20 years to continue to comply with water quality regulations. This funding will address two key water quality challenges: Combined Sewer Overflows (CSOs) and increasing Total Maximum Daily Load (TMDL) requirements. New York State has approximately 10% of the nation's CSOs; New York City alone discharges 27 billion gallons of raw sewage and polluted stormwater into New York Harbor each year. There were 724 waters on New York's 2008 303d list that may be candidates for TMDL standards. Meeting new standards will require costly treatment infrastructure upgrades. Significant water issues include:

- Infrastructure
- Energy use in water treatment
- Combined Sewer Overflows and urban runoff
- Atmospheric deposition of contaminants

New York water withdrawals (all figures 2005)

- Population- 19,300,000
- Per Capita Usage- 788 gal/day

Withdrawals- Mg/day	Total	Saline
Groundwater	867	0.42
Surface Water	14,300	4,890
Total use	15,200	4,890

Total Use by Sector (Saline)	Mg/d
Public Supply	2,530
Domestic	140
Irrigation	51
Livestock	30
Aqua-culture	63
Industrial	301
Mining	34
Thermoelectric power	12,020 (4,880)

Municipal Water Treatment Facilities
There are 9,938 public water systems in the State of New York. Over 90% of residents are served by a public water supply; the remaining 10% use privately owned residential wells.

Drinking Water Supply Systems		
Population Served	Number of Systems	Population Served
Less than 3,300	2,525	3.8 %
3,300 to 50,000	293	21.6
50,000 to 100,000	11	20.0
Greater than 100,000	20	55.6

In 2008 the State reported 4,027 violations, the majority of which were monitoring and reporting violations. Ninety-seven percent of systems had no Maximum Contaminant Level (MCL) violations and ninety-eight percent had no treatment technique violations. Only 62% of systems reported no monitoring and reporting violations. (2008 Public Water Supply Compliance Report)

Nearly 95% of the population of New York is served by a public water supply and/or municipal wastewater treatment plant. There are 702 wastewater treatment plants with a combined capacity of 3.7b gallons per day, and 2,900 drinking water supply systems that produce an estimated 3.1b gallons/day. (Statewide Assessment of Energy Use)

Municipal Wastewater Treatment Plants		
Design Capacity	Number of WWTPs	Percent of State Capacity
Less than 1 MGD	520	3.8
1 to 5 MGD	106	7.5
5 to 20 MGD	43	13.1
20 to 75 MGD	19	23.8
Greater than 75 MGD	14	51.8

The New York City (NYC) water system supplies drinking water to almost half the population of the State of New York. The water supply draws on two main reservoirs, the Catskill-Delaware and the Croton. The Catskill-Delaware is one of the largest unfiltered surface water supplies in the world, providing on average 90% of the City's supply. The reservoirs have a total storage capacity of approximately 580 billion gallons, fed by a watershed covering 1,972 square miles. Since 1991 NYC has invested more than $1.5 billion to ensure the long-term water quality of the NY watershed. This has allowed the EPA to grant NYC a ten year extension to the Filtration Avoidance Determination in 2007, based on the City's continued compliance with its Long Term Watershed Protection Program. Details of the plan and EPA's response can be found at: http://www.epa.gov/region2/water/nycshed/2007fad.htm

Water Quality

New York State has significant water quality issues, although a 1998 USGS report claimed that over 95% of surface water had "good water quality that fully supports aquatic life uses." (USGS NY) While this may be the case, the 2010 state List of Impaired Waters (303(d) List) reported the following impairments for 828 instances-

- 24% are Acid Rain Lakes/Waters, down from 40% in 2006. The majority of this contamination is caused by atmospheric deposition from sources outside the state.
- 29% are fish consumption advisories
  - 85% of these are from historical contamination (mercury, PCBs)
  - 15% from atmospheric deposition of mercury; however delisted water bodies may still be impaired by this problem
- 24% are the result of stormwater, urban runoff and/or CSO impacts.
  - 40% are in the New York City metropolitan area
- 7% are due to Shell-fishing Restrictions around Long Island that are also the result of urban/stormwater runoff of pathogens.
- 3% are the result of high nutrient concentrations in small lakes, especially phosphorus

www.epa.gov/region02/water/waterbodies/impaired_waters_factsheet.pdf

Groundwater Quality

Groundwater across the state is generally of high quality. The USGS published three reports on groundwater quality in the state. The results are summarized below. A total of 96 wells were sampled. The following contaminants were found above Federal or State MCLs. Those marked with an * were found above EPA recommended, but not legal, levels.

Radon-222*	48
Iron	34
Manganese*	35
Coliform bacteria	18
Sulfate	5
Chloride	4
Sodium	17
Arsenic	2
Aluminum	1
Total wells sampled	96

http://ny.water.usgs.gov/htmls/pub/data.html

A particular area of concern is the Long Island Aquifers, which are under increasing pressure from high withdrawal rates. There are two main aquifers on Long Island, the shallow Magothy aquifer and the deeper Lloyd Aquifer. Historically, and in rural areas in the east, withdraws and discharges occurred in the shallow aquifer. As the Island continues to urbanize, municipal water systems draw from the deep aquifer (at a greater rate than natural recharge) and discharge into the ocean. Saltwater intrusion is becoming a significant problem and deeper wells are being drilled inland to replace contaminated supplies. A system of storm drains has been constructed to allow groundwater recharge, at the cost of carrying urban run-off into the water system. Continued development will result in higher rates of drawdown, increased urban contamination of recharge waters, and increased saltwater intrusion.

- Regulate development with high pollution potential in areas of high groundwater recharge
- Limit use of residential contaminants
- Water conservation
- Limit development

Key Issue: Infrastructure Needs

Key Dimensions
The combination of an aging infrastructure and the need for upgrades to meet stringent regulations make infrastructure the most pressing water issue in New York. According to the Department of Environmental Conservation (DEC), the conservative cost of repairing, replacing and updating New York's water infrastructure is $84 billion over the next 20 years. With limited federal and state assistance, the burden of maintaining infrastructure will fall on municipalities.

Drinking Water
Over the past 12 years the state received $967.5m ($36.2m in 2008) for the Drinking Water State Revolving Fund, which was leveraged to provide $2.38b in financing. Despite this investment, over 95% of projects submitted for funding remained unfunded. Driving forces in drinking water infrastructure needs include:

- Replacing aging equipment, including systems over 100 years old
- Meeting current and future drinking water contaminant levels

- Increased water security measures

System Type	Estimated Need
Non-NYC community systems serving >3,300	$8.2 billion
Non-NYC community systems serving <3,300	$2.0 billion
NYC	$28.0 billion
Infrastructure for dams	$0.5 billion
Total estimate	**$38.7 billion**
Private wells - serving 1.5m (not inc. in total)	$1.8 billion

One example of a major infrastructure issue is a leak in the Roundout-West Branch section of the Delaware Aqueduct. The 44.2 mile section, 13.5' in diameter, and pressurized to 517 psi, is leaking between 20 and 30 million gallons per day. It carries an average of 50% of NYC's annual water supply. The leak is also raising groundwater levels around the tunnel, leading to cross-contamination between wells and septic systems. (Stein, 2009) The reliable capacity of the system is declining, from 900 mgd to 840 mgd, at some point the aqueduct is likely to be shut down for repairs. The DEP is evaluating the following alternatives for repair- (climate change and NY)

- Building a redundant tunnel 45 miles long
- Optimization of existing system, including conservation measures in NYC and reclaimed wastewater.
- Pump water for treatment from New York Harbor or Hudson River. This option may face public resistance due to the perception of poor water quality. Pumping out freshwater may also increase saltwater intrusion.
- Increase groundwater withdrawals in Queens County. Potential for 10-80 mgd reliably, with up to 100 mgd for short-term demands. High capital costs due to high level of treatment necessary, but the source is considered sustainable.

Wastewater

Less than 40% of Wastewater Treatment Plants (WWTPs) have capital improvement plans. (Wastewater Infrastructure Needs) Driving forces include:

- Compliance with Clean Water Act. As TMDLs are established on the 824 waters currently on the state 303(d) list, greater restrictions on effluent levels will require significant treatment upgrades. Upgrades for advanced nitrogen removal technology at four plants in the Long Island Sound totaled $700m.
- Aging Infrastructure. In general, the 610 municipal WWTPs in the state are meeting baseline requirements, but 30% of sewers and 23% of WWTP equipment is more than 30 years old.
- There are 22,000 miles of sewers in the state, 30% of which are more than 60 years old.
- Five watersheds (of 17 total) have excessive nitrogen and phosphorus. Municipalities in these watersheds will have to retrofit their existing infrastructure to remove nutrients from water prior to release.
- New TMDLs- The Chesapeake Bay Tributary Strategy identifies the following cost estimates for New York State:
  - $240 million for agriculture

- $200 million for wastewater treatment facilities
  - $25 million for urban stormwater
  - $146 million for Onondaga Lake TMDL
- Enhanced Water Quality Standards-
  - $58 million to meet residual chlorine standard
  - $30.5 million for marine ammonia standard
- Pharmaceuticals and Personal Care Products Levels
  - Not accounted for in this study, but future regulations will drive wastewater treatment requirements in the future

Wastewater Infrastructure Category	**Details**	**Estimated Need (2008-2028)**	**Percent**
Protecting Water Resources	Returning wastewater to prevent source water depletion	$1.0 billion	3
Protecting Water Quality	MS4 retrofits to install nutrient removal systems ($1.0b) Chesapeake Bay Tributary Strategy*	$1.7 billion	5
Restoring Water Quality	Sewer systems for small municipalities	$0.7 billion	2
Maintaining Facilities	Annual WWTP budget deficit of $100m	$2.1 billion	6
Nonpoint Source Pollution Control		$3.0 billion	8
CSO Correction		$7.5 billion	21
Collection and Conveyance Systems		$6.6 billion	18
Municipal Wastewater Treatment Facility Upgrades	For secondary and advanced treatment	$13.6 billion	37
Total Municipal Estimate		**$36.2 billion**	**100**
Privately Owned Facilities	Residential complexes	$0.7 billion	
Septic Systems	1.5m units to replace	$8.4 billion	
Total Private Estimate		**$9.1 billion**	
Total	Public and Private systems	**$45.3 billion**	

Current Approach - Water Treatment

- New York City recently became the largest city in the world to adopt wireless water meters. Made by Aclara, the city will install 826,000 at a cost of $250 million. The meters save the cost of having each meter read individually, and report four times a day rather than four times a year.
- Increasing efficiency and accuracy of billing.

- Attempt to increase water main replacement from 60 to 80 miles a year, dependent on funding.
- NYC is investing in infrastructure required to continue compliance with the Filtration Avoidance requirements
- There are no significant plans for dealing with funding; issues are taken up on a case-by-case basis.

Wastewater Treatment

The state is addressing infrastructure needs on a case-by-case basis. The main areas of focus include the New York Watershed, Lake Ontario Basin and the Hudson River. There are no policy plans for addressing the problem as a whole. The City of New York includes a section on water quality in the PlaNYC 2030, which includes the following goals. Examples include:

- Budgeting $1.7 billion over 10 years for facility upgrades, dredging efforts, and floatables control projects, pumping improvements, and aeration projects. These projects are projected to increase CSO capture by 5 billion gallons.
- Incorporating stormwater management principles into Department of Transportation, Department of Design and Construction, and Department of Parks and Recreation projects.
- Expanding wet weather capacity at treatment plants
- Increase use of High Level Storm Sewers and holding tanks to reduce CSOs
  - Flushing Creek CSO retention tank- 43 million gallon capacity at a cost of $300 million
  - Paerdegat Basin- 50 million gallon storage facility at a cost of $318 million
- Green roof tax abatement
- Required greening of parking lots
- Implementing tree planting project
- Increase wetlands and wetland protection
- Significant wastewater infrastructure projects required to meet Clean Water Act requirements are underway, including:
  - Croton Water Filtration Plant
    - Expected to enter service in 2012
    - Will treat 1.2 million cubic meters per day
    - Cost currently at $2 billion, originally projected at $1.3 billion
    - Will use Dissolved Air Flotation, anthracite and sand filtration, centrifuge dewatering, and UV and chlorine disinfection
  - Newtown Creek Plant Expansion and Upgrade
    - Largest plant in NYC, treating 310 mgd (18% of city's wastewater)
    - Expanded capacity by 50% and expand secondary treatment to all inflow, though without upgrading nitrogen removal.
    - Part of $2.2 billion of upgrades over 13 years to achieve compliance with Clean Water Act
  - Ward's Island Water Pollution Control Plant
    - Plant opened in 1937
    - Second largest NYC plant, treating 270 mgd

    - Fitted with Stable High Ammonia Removal over Nitrate (SHARON) technology to increase nitrogen removal. End product is nitrite, which is converted to nitrogen gas leaving no biomass.
- Upgrading four treatment plants that discharge into Jamaica Bay at a cost of $100 million
- Staten Island Bluebelt System
    - Network of 50 completed BMPs that control urban stormwater flow.
    - City invested $60 million so far, with $330 for future Bluebelt programs.

What Needs to be Done
The keys to NY's infrastructure needs will be water and wastewater treatment technology and non-infrastructure solutions.

- Increase exploration of non-infrastructure options to reduce demand on treatment systems, starting with low-cost options first
- Reduce energy use and increase energy capture at treatment plants
- Incorporate innovative technology to reduce cost

Technology

- Water metering and leak analysis
- High-efficiency infrastructure components
- Water contaminant/security monitors
- See Energy Production Section below

Key Issue: Energy Usage

Key Dimensions
It is estimated that the water treatment sector in New York consumes 3 billion kilowatt-hours per year, enough energy to power roughly 500,000 households. Municipal wastewater treatment systems in the state use approximately 25% more electricity, on a per unit basis, than their national counterparts. Energy costs typically constitute 25-40% of wastewater treatment costs and 80% of drinking water processing and distribution costs. The combination of aging infrastructure and rising energy costs will create a strong economic impetus for facilities to increase energy management.

Although the greatest opportunities for energy efficiency improvements on a per unit basis are at small WWTPs, the greater capacity of the larger plants (which use 40% of energy used by the wastewater sector) offers significant opportunities. Recent trends will continue to increase energy usage in water treatment:

- Swimmable Hudson Initiative: requires WWTPs that discharge into the Hudson (40 total) to disinfect all effluent. Given the stringent residual chlorine requirements, many plants will use UV which will increase energy use by 10.5m kWh/y.
- Approximately 86 facilities (the majority less than 1 MGD) will be required to increase capacity due to regulations that require average annual influent to be below 95% of operating capacity

- Nutrient reduction initiatives requiring advanced treatment and compliance with nitrogen removal requirements in the Long Island Sound alone will result in an increase of 250m kWh/y. Other initiatives include:
  - New York City Watershed Protection Program
  - Great Lakes Initiative
  - Long Island Sound Initiative
  - Chesapeake Bay Initiative

Current Approach
The New York State Energy and Research Development Authority (NYSERDA) is studying was to reduce energy use and capture energy from WWTPs.

- FlexTech Program
  - Provides cost-shared funding for facility evaluations aimed at developing energy projects. Since 1998 the project has provided $2.2m in funding for more than 100 treatment facilities.
- Enhanced Commercial Industrial Performance Program
  - Provides financial incentives for the implementation of energy projects. Includes installing pre-qualified equipment and performance based incentives.
  - $4.5m to 28 municipalities.
- Anaerobic Digester Gas (ADG)-to-Electricity Program
  - Incentives for implementation of ADG-to-electricity projects at wastewater treatment facilities and farms. Up to $1m per facility.
- Research, Development and Demonstration Program
  - Cost-sharing funding program to develop, demonstrate, and test energy efficient technologies. Forty projects funded with $20.1m available

Action Needed

- According to a survey conducted by NYSERDA, energy consumption could be reduced by 10-20% at most facilities, with up to 50% reductions possible.
- Replacing aging motors with more efficient models could reduce consumption by 40m kWh per year
- Currently, 145 WWTPs use anaerobic digesters, representing 75% of the state's wastewater treatment capacity. Anaerobic digesters produce biogas that can be used to generate electricity or power operations at WWTPs.
- The electrical production potential of the existing 145 AD facilities is 25 MW, up to 31 MW if all facilities in the state installed AD.
- Approximately 45,000 MW per year of electricity is currently generated by NYS WWTPs, not including several WWTPs that use biogas to directly drive pumps and blowers.
- This is considered a very significant area of growth with the potential to offset the massive infrastructure costs anticipated by the state.

Technology

- Rentricity- uses a turbine and generator technology which uses a micro-turbine, generator, sensors, processors, and communications equipment to autonomously capture energy during water transmission. Especially effective when used with gravity driven systems. http://www.rentricity.com/

- Turning sewage into ethanol using solids from wastewater treatment. A company called Qteros has developed a bacterium that naturally eats plant materials and ferments cellulose into ethanol. Able to produce 120 to 135 gallons of ethanol per ton of waste mix, compared to 100 gallons per ton of conventional ethanol feedstock such as corn. http://www.qteros.com/
- Emefcy- Microbial Fuel Cell technology. "The fuel cell operates by catalytically separating component electrons and protons from the reactant fuel at the anode, and forcing the electrons to travel through a circuit, hence converting them to electrical power." http://www.emefcy.com/

Key Issue: CSOs and Urban Runoff Contamination

Key Dimensions

There are 1098 known outfall points in 60 municipalities; NYC alone has more than 450. Currently, 27 billion gallons of raw sewage and polluted stormwater discharge into New York Harbor each year. CSOs are a major source of water quality impairment for the 8% of river miles impaired by point sources, two percent of total lake acres impaired by point sources, and 61 percent of estuary square miles impaired by point sources. Urban Runoff accounts for 225 impaired water bodies (25%) on the state's 303(d) list.

- Deicing salts applied to roads during winter average 500,000 tons per year.
- Cities in the Capital Region, surrounding Albany, dump more than one billion gallons of untreated sewage into the Hudson every year. Overflows happen more than 230 times per year, the equivalent of constant overflow 80 days of the year.
- Syracuse has about half the levels of overflow and estimates $500 million to fix. (Aging sewer pipes)
- Buffalo's CSO abatement program is estimated to cost $528m.
- Concentrations of lead, mercury, and zinc in stream-bottom sediments are positively related to the percentage of urbanized land within the area.
- The Sawmill River at Younkers, the densest urban area in the study, had concentrations of metals among the highest in the nation.
- PCB levels exceeded the NYSDEC criteria for human health at all sites at which they were detected and were among the highest nationwide.

PCBs are found in almost every waterway in the state, though not always at significant levels. In the lower Hudson River, fish consumption advisories have severely affected what was once a thriving commercial fishing business (Lower Hudson). The major source of PCBs in the Hudson came from two General Electric plants, releasing 1.1 million pounds of PCBs into the Hudson from the 1940s to the early 1970s. In 1984, two hundred miles of the Hudson River was declared a superfund site. Roughly 17 million gallons of oil and other chemicals leaked into the Newtown Creek statuary (between Queens and Brooklyn) over 140 years of use by petroleum companies.

According to the NYDEC, major runoff contaminants include:

- Sediment

- 70% of sediment loads in urban watersheds caused by stream-bank erosion. Urban runoff is also a significant source
- Consequences: low light availability for aquatic plants, increased water temperatures, smothering of benthic organisms such as mussels and clams, and transporting pollutants.

- Nutrients
  - Sources include fertilizer, atmospheric deposition, animal waste, and stream bank erosion. In urban areas, residential lawns are a significant contributor to nutrient loading.
  - Impacts include hypoxia in the Long Island Sound, as well as high phosphorus levels in the Finger Lakes, Lake Champlain, and the New York City Reservoir system.
- Bacteria
  - Bacteria levels in stormwater runoff routinely exceed public health standards for water contact recreation.
  - Leading contaminant in many New York waters, leading to shellfish bed and beach closures.
  - A 2007 Riverkeepers water quality study found that 21 percent of samples collected north of NYC had counts of sewage indicating bacteria that exceeded federal single sample guideline for primary recreation contact. (http://www.riverkeeper.org/water-quality/hudson/)
- Trace Metals
  - Include cadmium, copper, lead and zinc, mercury
  - Major source is automotive, as wells as paints, road salts, and galvanized pipes.
  - Can be toxic to aquatic life in low concentrations, accumulate in sediments, and bioaccumulation in aquatic species
  - A 1995 study of the Hudson River Basin found the heavy metals in stream-bottom sediment corresponded strongly to urbanized areas. (Hudson
- Chlorides
  - Salts applied to road surfaces wash into waterways during snow melt and rain events.
  - One 1990 study of four Adirondack streams found severe impacts to macroinvertebrate species attributed to chlorides.
  - High salt concentrations can alter natural mixing cycles of lakes
- Thermal Impacts
  - Data suggest that increasing development can increase stream temperatures by five and twelve degrees Fahrenheit. The increase is relative to the amount of impervious cover in the drainage area.

Current Approach

- PlaNYC 2030- Sustainable Stormwater Management Plan
- Multi-Sector General Permit for Stormwater Discharges Associated with Industrial Activities-- Requires certain industries to develop stormwater pollution prevention plans and perform monitoring for the NYSDEC
- Stormwater Phase II—municipalities with CSOs are required to develop long-term control plans to abate discharges.
- Some counties, such as Westchester, are banning fertilizers containing phosphorus.

- Dredging of the Hudson began in 2009 to remove 15,000 pounds of PCBs, with a second phase to remove 135,000 pounds to begin after completion.
- Two reports by the Environmental Advocates of NY, citing primary documents and interviews with NYDEC employees, claim that the DEC is operating an "illegal water pollution program." The issue is that 90% of SPDES permits are not receiving the review mandated by the Clean Water Act. The DEC has seen extensive staff cuts, losing between 700-800 employees between 1995 and 2006, and claims it does not have to staff to adequately review permits. Rather than the required five years, 80% of SPDES permits have not been reviewed in 10 years.

What Needs to be Done
- Increase urban Best Management Practice to capture runoff at the source.
- Increase stormwater capture and treatment capabilities.
- Increase monitoring to track sources of pollution.
- Increase enforcement of NPEDS

Technology
- Curb inlet filters- http://www.hydroscreen.com/index.html, effective but costly on a large scale
- Site filtration systems- http://www.lithocrete.com/oceansafe/
- WARMER project- 2.5 million euro real time water monitoring network. http://www.ysihydrodata.com/news_story16.htm

Key Issue: Atmospheric Deposition

Key Dimensions
New York, and the Adirondacks in particular, have been a poster child for acid rain since the 1980s. The national average pH for lakes in 2002 was 4.4-6.0, while in New York State the average was 4.28-4.84. Acid deposition also results in elevated inputs of nitrogen in the form of nitric acid and nitrate. At deposition levels above 8 kg per hectare per year (kg/ha/yr) of nitrogen or nitrate, forested watersheds approach nitrogen saturation levels and nitrate levels in surface water increases. Nitrate inputs in New York State ranged from 13 to 27 kg/ha/yr in 2002.

Surface waters, particularly in the Adirondacks and Catskills, have been deteriorating, showing lowered pH, decreased acid-neutralizing capacity (buffer), and elevated toxic aluminum concentrations. A study in the late 1980s found that 48% of Adirondack lakes had no buffering capability or were "extremely sensitive to further acidification." The study also found a significant relationship between lake pH and the number of fish species present.

Analysis of lake sediment in the Northeast shows that mercury deposition has increased 2-5 times over the last 60 years. The main source of emissions is the combustion of mercury-containing fuels, such as coal-fired power plants which contribute ~30% of US anthropogenic emissions. In New York, 70 water bodies have fish consumption advisories because of high mercury levels.

Current Approach
New York State Atmospheric Deposition Monitoring Network was designed in 1985 to track air quality and acid deposition.

Liming- adding lime to lakes decreased acidity and has proved to be a cost effective (though short term as it is quickly flushed) solution to high-priority waters. However, the large number of water bodies negates the feasibility of this solution.

Policy
There are two main policies in New York, however, given the source of most pollutants it will require national policies to significantly reduce pollutants.

- Acid Deposition Reduction Program- http://www.dec.ny.gov/chemical/29847.html
- Zero Emission Vehicle Sales Mandate- http://www.dec.ny.gov/regs/4247.html

What Needs to be Done
Progress is being made, according to a study of 48 Adirondack lakes from 1992-2000.

- Improved acid-neutralizing capacity in 29 lakes
- Reduced inorganic aluminum in 28 lakes
- Increased pH in 18 lakes, decreased pH in 2 lakes.
- The rate of change suggests that it will be decades before many lakes reach the target acid-neutralizing value.

Technology

- The main contributing factors are air emissions, primarily coal power plant and vehicle emissions. Technologies for reducing air pollution will be the greatest asset.
- Increased monitoring, such as remote pH sensors, may help New York build a case against polluting states.

Key Issue: Natural Gas Drilling

Key Dimensions
Drilling for natural gas, particularly by a process known as 'hydrofracking,' is arguably the greatest single threat to water quality in New York. Several million gallons of water per well are combined with friction reducers, biocides, surfactants, and scale inhibitors and injected under high pressure to fracture the bedrock and allow the gas to come to the surface. The Marcellus Shale, a rock formation rich in natural gas deposits, runs under the southwest part of New York. There are already 13,000 active oil and gas wells in the state, about half using hydraulic fracturing. While the potential rewards are huge, potentially generating $488 million, so are the risks. The greatest is the watershed that supplies New York City with unfiltered drinking water, if contaminated the cost to filter water is estimated at $10b for construction and $100m annually for operation. They include:

- Gas migrating into structures with the potential for explosion. One house a Ohio blew up in 2007 after gas migrated from a well
- Groundwater contamination
  - Over 260 chemicals are used in fracking, many are toxic and remain in the ground, posing long term contamination concerns.

- In Pennsylvania, 13 wells were contaminated by natural gas, one blew up. (Dark Side of Natural Gas boom)

- The NYDEC tested 12 vertical wells drilled in the Marcellus in 2008 and 2009 and found that 10 had a radioactive derivative of uranium at levels hundreds of times the federal limit. (Drilling disposal)
- Wastewater also contains high levels of total dissolved solids (TDS), which are difficult to remove when taken to municipal wastewater treatment plants as is common in the Northeast. TDS levels in Pennsylvania skyrocketed after drilling wastewater was discharged by municipal treatment plants. (Drilling Wastewater)

Current Approach

Drilling is currently regulated by the Department of Environmental Conservation's Division of Mineral Resources. The state Oil, Gas, and Solution Mining Law requires drillers to "apply sound environmental principles" and returning affected areas to a condition that allows productive use of the land. (http://www.dec.ny.gov/energy/1536.html) Permits are required, requiring:

- Screening of the proposed well location for environmental sensitivities.
- A casing and cementing program for each well to prevent the flow of contaminants between underground formations.
- Setbacks from municipal water wells, surface water bodies, and streams.
- Proper containment and disposal for all wastes and drilling fluids.

Policy

Drilling policy is currently being debated, though at this point it seems the pressure to allow drilling will prevail. A bill to impose a one-year moratorium on fracking did not make it out of committee in either house during the 2010 legislative session. However, the NYSDEC announced in April that it will exclude the New York City and Syracuse watersheds from the current environmental review. Any drilling in the watershed will require a separate, costly, and lengthy permitting process that is in effect a de facto ban. (DEC drilling regulation) Drilling policy is currently being debated, the DEC has submitted a plan to the EPA, received comments, and is evaluating public comments. The final draft is expected to be released in the fall of 2010, and the Commissioner of the DEC said he expects drilling to begin by the summer of 2011. At the federal level, the EPA is currently reviewing a 2004 study of hydraulic fracturing that declared it was essentially harmless.

What needs to be Done

Protecting the unfiltered drinking water source is the primary concern, which for now appears to be intact. Despite claims that hydrofracking is relatively benign, there is a strong body of evidence to suggest it is not. The DEC needs to regulate this industry to prevent illegal dumping, ensure proper citing of wells, and to keep chemicals out of water supplies.

Technology

- On-site water treatment will be a key technology in this sector. If regulations in New York allow drilling, disposing of the wastewater will be one of the easiest regulations to target. A company called Range Resources, operating primarily in the Northeast, developed a technology to clean 80% of wastewater. This allows it to be left in the wells, while the remaining 20% is mixed with fresh water to open new wells. (Drilling Wastewater Disposal)

- NOMAD portable industrial water treatment. Returns 85% of feed water was distilled freshwater. http://www.fountainquail.com/

New York References

Field, Bradley. (2010, February 23). *NYS DEC's Regulation of Marcellus Shale Development.* Presented at The New York Water Environment Association. http://blog.sprlaw.com/2010/04/nysdec-excludes-watershed-areas-from-current-environmental-review-of-Marcellus-shale-drilling/

Licata, Angela. New York City Department of Environmental Protection. *Climate Change and New York City's Water Supply.*

Mouawad, Jad and Clifford Krauss. (2009, December 8). *Dark Side of a Natural Gas Boom.* The New York Times.

New England Interstate Water Pollution Control Commission. (2006, May). *The Cost of Clean and Safe Water- Sustaining Our Infrastructure.*

New York State Department of Environmental Conservation. (2008, March). *Wastewater Infrastructure Needs of New York State.*

New York State Department of Health. (2008, November) *Drinking Water Infrastructure Needs of New York State.*

New York State Department of Health. 2008 Public Water Supply Annual Compliance Report. http://www.nyhealth.gov/environmental/water/drinking/violations/2006/2006_compliance_report.htm

New York State Energy Research and Development Authority. (2005) *Mercury Deposition Monitoring Network: Adirondacks and Catskills.*

New York State Energy Research and Development Authority. (2005) *Acid Rain- Learning from the Past and Looking to the Future: A Primer.*

New York State Energy Research and Development Authority. (2008, November) *Statewide Assessment of Energy Use by the Municipal Water and Wastewater Sector.*

Sapien, Joaquin and Sabrina Shankman. (2009, December 29). *Drilling Wastewater Disposal Options in N.Y. Report Have Problems of Their Own.* Propublica.

Shiah, Vicki. (2010, April 28). *DEC Excludes Watershed Areas from Current Environmental Review of Marcellus Shale Drilling*.

Stern, Ira A. (2009, September) *New York City's Delaware Aqueduct: Wawarsing Leak Investigation.* New York Water Environmental Association.

USGS Circular 1165. (1995). *Water Quality in the Hudson River Basin: New York and Adjacent States, 1992-1995.*

2.8 Pennsylvania

Key Markets	Niche Markets
Drinking water and wastewater infrastructure	On-site treatment of hydraulic fracturing fluids and coal-bed methane discharge
Agricultural fertilizer technology and management	Technology to improve combined sewer systems and reduce combined sewer overflows
Wastewater treatment plant nutrient control technology	Technology to improve water use or recycle water in the generation of energy
Groundwater quality monitoring	

Demographic Indicators

Population	2000	2009	2020
Urban Population	9,464,000	--	--
Rural Population	2,817,000	--	--
Total Population	**12,281,000**	**12,605,000**	**12,787,000**

Population Growth Rate	2000-2009
Total Population Growth Rate	2.6%

Source: United States Census Bureau (http://www.census.gov/population/www/projections/projectionsagesex.html)

Economic Indicators

Economic Indicator (2007)	Real GDP
Total GDP	$533.2 billion
GDP per capita	$35,337
GDP growth rate	1.8%

Source: United States Bureau of Economic Analysis (http://www.bea.gov/scb/pdf/2009/06%20June/0609_gdp_state.pdf)

Background and Summary of Key Issues

Pennsylvania is home to over 12.6 million people. Individuals, industries, and agricultural producers rely heavily on groundwater. The state is also a major producer and exporter of energy, and its coal-fired power plants consume large amounts of water. The most severe water problems and most important issues for Pennsylvania are:

- Aging infrastructure and degraded tap water quality
- Manure fertilizer contamination and confined animal feeding operation pollution
- Groundwater and surface water contamination
- Groundwater controls and groundwater monitoring
- Groundwater recharge area protection
- Hydraulic fracturing and coal bed methane
- Water consumed by energy production
- Drought, ecological damage, and invasive species

- Combined sewer overflows and mining runoff
- Need to set higher drinking water standards and monitor well water

Key Issue: Aging Infrastructure and Degraded Tap Water Quality

Key Dimensions
The Pennsylvania Department of Environmental Protection's Sustainable Infrastructure Task Report (2008) outlined the state's capital needs (water infrastructure upgrades or replacements) and operating costs:

- Capital needs:
  - Drinking water: $11.5 billion
  - Wastewater: $25.0 billion
    - Total: $36.5 billion
- Operating needs over the next 20 years:
  - Drinking water: $38.9 billion
  - Wastewater: $74.7 billion
    - Total: $113.6 billion
- Total needs: $150.1 billion

The largest financial contributions to these replacements and upgrades are reported to be from user rates. Over the next 20 years, this contribution is expected to be $69.8 billion, a shortfall of $80.3 billion when taking into account capital and operating needs.

The Philadelphia Water Department recorded lead levels in drinking water which were above EPA standards. In addition to high lead levels (National Resources Defense Council, 2003):

- Chlorinated by-products such as total trihalomethanes (TTHMs) and haloacetic acids (HAAs) averaged at 80% of national standards and occasionally exceeded those standards.
- Lead levels were not in violation of EPA standards but exceeded health goals.
- Chemical spills and runoff occasionally contaminate Philadelphia city tap water.

Action Needed
The State Water Plan has a number of recommendations about how to address Pennsylvania's aging infrastructure (Pennsylvania Department of Environmental Protection, 2009):

- Use available funds to address the most pressing needs, including those which pose threats to public safety and health.
- Incorporate practices and technology into new developments which will promote cost-efficient and water-efficient practices.
- When addressing infrastructure for water supply and water quantity, consider non-structural alternatives and integrated water planning.

Current Approach
On July 23, 2010, Governor Edward Rendell announced that $129 million will be invested in 41 drinking and wastewater projects (http://www.wateronline.com/article.mvc/Pennsylvania-Governor-Rendell-Announces-0002). Some of these projects will involve infrastructure, such as new water distribution lines, storage tanks, a pumping station, and upgrades to treatment plants.

Pennsylvania has begun to address the need for green infrastructure solutions to water problems. For example, the report *Creating a Sustainable Solution for Pennsylvania* mentions the need to implement green solutions to stormwater runoff, such as planting more trees in urban areas, constructing riparian buffers, and utilizing more "rain barrels and cisterns, rain gardens, and green roofs" (Pennsylvania Department of Environmental Protection, 2008, p. 43).

Impending Water Policy Changes/ Conditions to Address Issue
The Pennsylvania State Water Plan suggests the need to authorize the creation of local management districts through new legislation or policy (Pennsylvania Department of Environmental Protection, 2009). These districts would be given the ability to collect fees and other sources of revenue, such as grants, for the planning, construction, and maintenance of stormwater infrastructure. However, there are no specific policies currently being discussed that address funding for infrastructure maintenance and replacement.

Technology/Policies Needed
If Pennsylvania is able to generate enough revenue to begin fixing and replacing water infrastructure, it will need to determine which pipes, plants, and other structures have the highest needs and priority. Leaking pipes and other types of infrastructure can significantly contribute to water loss, so the identification of these leaks may play a role in prioritizing needs.

Availability of Technology
There are number of available technologies that aid in the detection of water leaks. These include:

- Continuous acoustic monitoring
- Advanced metering infrastructure communication
- District Metered Areas (DMAs) for audit and leak control
- Pressure monitoring
- GIS analysis

Key Issue: Manure Fertilizer Contamination and Confined Animal Feeding Operation Pollution

Key Dimensions
Manure fertilizer is currently the second largest polluter of streams and rivers in Pennsylvania (http://www.nrdc.org/water/pollution/factor/stpen.asp). It has also affected shellfish in Chesapeake Bay and fish throughout state water bodies. Despite this, most state companies are not required to adhere to the manure pollution control program.

The improper use of manure spreading equipment has also contributed to runoff which increases the phosphorus and nitrogen levels in streams. When improper practices are used in the winter, the problem is exacerbated as melting snow contributes to runoff.

According to the USDA Forest Service, approximately 33% of riparian buffers in Pennsylvania are degraded (http://www.stormwaterpa.org/43). Riparian buffers are areas of trees and bushes along water bodies that filter both urban and agricultural stormwater runoff. Degradation of these buffers can exacerbate the amount of pollution which enter waterways.

Action Needed

Farming education programs need to be increased. These should address best management practices, such as the least-harmful techniques for manure spreading, the utilization of riparian buffers, and locating confined animal feeding operations away from water bodies. Pennsylvania might also consider requiring adherence to the manure pollution control program, since this is not currently necessary.

Current Approach

The Pennsylvania Stormwater Best Management Practices Manual instructs individual landowners and farmers how to plan, design, and implement riparian buffer restoration projects (http://www.stormwaterpa.org/43).

Pennsylvania was the first state to require Nutrient Management Plans for farms (http://www.dep.state.pa.us/dep/deputate/watermgt/Wqp/Forms/CAFO_Stratg.htm). It is intended to reduce manure pollution. Farms which have more than 2,000 pounds of animal weight per acre of land are required to adhere to this plan. Approximately 1,600 confined animal feeding operations are included.

The Nutrient Management Plan requires that application rates and locations of fertilization be determined, best management practices be implemented, and alternate areas for manure storage be identified. A nutrient management specialist is required to design the plan, and it must be re-evaluated every three years.

Impending Water Policy Changes/ Conditions to Address Issue

In June, 2005, the Pennsylvania Environmental Quality Board adopted amendments which brought state regulations for CAFOs in line with federal regulations (http://www.pabulletin.com/secure/data/vol35/35-43/1945.html). CAFOs will need to continue to obtain a permit under the NPDES program. In addition to NPDES requirements, other requirements are:

- Manure management
  - CAFOs have special permits which are more stringent than permits for smaller operations.
- Conservation practices
  - CAFOs and other agricultural operations are required to formulate and implement plans to limit runoff and to control erosion and sediment.
- Nutrient management
  - 840 large CAFOs are required to implement stormwater runoff controls, test soils for phosphorus and nitrogen, and determine crop needs for fertilizer in an effort to reduce nutrient loads.

Technology/Policies Needed

Technology needs include:

- Monitoring and control systems for treatment lagoons to enhance the removal of biological nutrients

- Retrofit liner technology for existing lagoons
- Cost-effective high-efficiency manure treatment systems
- Zero liquid discharge processes for environmentally sensitive watersheds and dry fertilizer production
- Phosphorus/nitrogen balancing - for optimum fertilization efficiency without excess phosphorus
- Nutrient testing and automated blending systems to achieve appropriate nutrient concentrations for a variety of agricultural needs
- Heavy metals and arsenic reduction technology
- Alternatives to "preventive" antibiotics use in animals

Availability of Technology
There are currently a few available technologies to address CAFO-related water issues. Anaerobic treatment lagoons are an option for the digestion of animal waste. New lagoons must be lined but those build prior to the late 1990s are allowed to be unlined. Liquid manure soil injection is also available to control odor when used with non-tilled agricultural practices. Finally, biogas capture can be used to convert manure gasses to energy.

Key Issue: Groundwater and Surface Water Contamination

Key Dimensions
Groundwater Contamination
Groundwater contamination is the result of high-volume hydraulic fracturing for shale gas in different areas of the state. The Marcellus Shale lies 5,000 to 8,000 feet beneath approximately 2/3 of Pennsylvania, containing trillions of cubic feet of natural gas (Pennsylvania Department of Environmental Protection, 2010 revision).

In 2009, residents of Dimrock sued Cabot Oil and Gas over water contamination and health problems that were alleged to be a result of hydraulic fracturing (Lustgarten, 2009). Tests of one resident's drinking water revealed high concentrations of aluminum, iron, and methane.

Surface Water Contamination
According to the Pennsylvania State Water Plan Principles, the state has over 2,700 miles of streams, out of 86,000 total miles, which are contaminated by excessive amounts of nutrients such as phosphorus and nitrogen (Pennsylvania Department of Environmental Protection, 2009). Nutrient pollution is also the primary problem in Chesapeake Bay, as these nutrients contribute to algae blooms and growth of other aquatic plants. This can reduce the oxygen in streams and cause the deaths of fish and other aquatic species.

Sedimentation has affected over 8,700 miles of streams (Pennsylvania Department of Environmental Protection, 2009). When sedimentation and metal contamination are added to phosphorus and nitrate contamination, the miles of impaired streams rise to 16,200 or 19% of the total. Sediment can exacerbate pollution by spreading excessive nutrients and heavy metals to other areas of the impaired water body. Examples of heavy metals present in high concentration in surface water are zinc, arsenic, selenium, lead, cadmium, copper, and mercury. Stormwater runoff can also introduce high levels of hydrocarbons into surface water.

Action Needed

Groundwater Contamination

Identification of contamination sources and prevention are the best techniques. Monitoring needs to be done in areas where sources of contamination are likely to be located. Such areas include industrial areas, mines, and hydraulic fracturing sites.

Surface Water Contamination

To address high nutrient levels in the Chesapeake Bay and other waterways, the state should provide additional funding to improve sewage treatment facilities (Pennsylvania Department of Environmental Protection, 2009). These improvements would likely allow plants to treat higher levels of nutrients. Sources of funding would come from loans, grants, or tax incentives.

Current Approach

The Pennsylvania DEP stated that well operators are required to use best management practices to control erosion, runoff, and contamination. However, it admitted that there is the possibility of occasional "disruption of water quality or flow in water wells" (Pennsylvania Department of Environmental Protection, 2010 revision, p. 2).

It has been proposed that municipal wastewater treatment plants remove nitrogen from sewage (Alliance for the Chesapeake Bay, n.d.). There are currently plans for a pilot program where 16 major plants would test the feasibility of removing nitrogen from effluent.

Impending Water Policy Changes/ Conditions to Address Issue

On December 8, 2009, Pennsylvania's Mercury Free Thermostat Act went into effect (PR Newswire, 2009). This law prohibits the selling and installation of new mercury thermostats, as well as improper disposal. Current, defective mercury thermostats which cannot be serviced, are also required to be recycled. Thermostats containing mercury can be turned in to dealers who previously sold them at no cost.

This law is intended to reduce mercury pollution in surface and groundwater. Before the law took effect, Thermostat Recycling Corporation had already recycled 37,000 mercury thermometers, removing 356 pounds of mercury from the environment.

Technology/Policies Needed

Pennsylvania needs to implement its 16 pilot programs for removal of nitrogen from effluent at wastewater treatment plants. This program should be expanded if results are positive. Strict regulations addressing hydraulic fracturing and coal-bed methane extraction are also needed. Pennsylvania needs to require fracturing and CBM companies to monitor and clean the water on site before it is discharged onto the ground or re-injected. New technologies will likely need to be created to address on-site treatment of water. Strict fines will be needed for failure to adhere to implemented rules.

Appendix E of the Pennsylvania Stormwater Best Management Practices Manual illustrates several products manufactured by ACF Environmental which remove sediment and hydrocarbons from water (Pennsylvania Department of Environmental Protection, 2005 draft).

Technologies listed in this draft include:

- Sediment control
  - Silt fences and triangular silt dikes to control runoff
  - Curb gutter filters
  - Aquabarriers and turbidity curtains
  - Polyacrylamide and gypsum which prevent the suspension of clay and silt in the water
- Temporary erosion control
  - Erosion control blankets
  - Turf reinforcement mats for streams, channels, pipe outlets, and roadsides
  - Articulating Concrete Block Systems
  - Cellular confinement systems
- Runoff control
  - Wire mesh porous pavement
  - Plastic porous paving systems
- Water retention
  - Modular Plastic Stormwater Storage Systems (MPSS)

ACF Environmental also manufactures the Nutrient Separating Baffle Box which is situated in-line with current pipes and filters hydrocarbons and other pollutants from stormwater (http://www.acfenvironmental.com). Water Quality Inserts are another example of a product made by the company. These filters are placed inside curbside grates and filter hydrocarbons which would otherwise pollute nearby water bodies.

Availability of Technology

Surface Water Contamination

Current water treatment technologies include chemical treatment of nutrients and aerobic and anaerobic biological treatment. Examples of treatment technologies available include ultraviolet disinfection, filtration, adsorption, and chlorination. Other technological solutions for nutrient control in wastewater treatment include:

- Alternatives to phosphorus addition for lead control in plumbing pipes
- Biological methods to mitigate legacy contaminants and heavy metals
- New microfiltration, ultrafiltration, nanofiltration and membrane filtration methods to remove trace amounts of PPCPs and EDCs from drinking water and wastewater
- Mercury mitigation
  - Stannous chloride reagent for in-situ air stripping
  - Slow release sequestrants - encapsulated nano-particles
  - Sodium thiosulfate to control methylation

Key Issue: Groundwater Controls and Groundwater Monitoring

Key Dimensions
There is a high need for groundwater controls and groundwater monitoring because community water systems provide approximately two million people with groundwater (Ground Water Protection Council, n.d.). There are also an additional one million private wells and springs in the state.

- It is estimated that at least 50% of the state's population uses groundwater for some or all uses.
- Approximately 9.7 billion gallons of surface and groundwater are withdrawn daily throughout the state (Swistock et al., n.d.).
  - In Southeastern Pennsylvania alone, daily major ground water withdrawals (those exceeding 100,000 gallons per day) have increased by more than 13 million gallons since 1975 (Delaware River Basin Commission, 1999).

Pennsylvania is one of the few states in the country that has no private well regulations (Swistock, Clemens, & Sharpe, 2009). Construction, testing, and treatment of private wells are also the sole responsibility of the homeowner.

With regard to water withdrawals, local and state regulation does not always match (Pennsylvania Department of Environmental Protection, 2008). Municipalities were granted the power to enact ordinances which they deem necessary to the health, safety, and general welfare of their citizens. Therefore, local water plans can vary widely, as can regulations for wells.

Action Needed
Because Pennsylvania relies so heavily on groundwater, it is important that more than 50 basins be selected for monitoring. Furthermore, Fixed Station Network (FSN) monitoring for long-term data has only been monitoring half of its 100 priority basins despite being operational for 15 years.

Many illnesses from water pollution do not have symptoms, so residents may not know that they are being exposed to pollutants if they do not voluntarily have their water tested. Therefore, regulations requiring the periodic testing of private well water might be necessary, considering the extent of groundwater use in the state.

The State Water Plan (Pennsylvania Department of Environmental Protection, 2009) recommends that legislation be enacted to establish standards for the construction of private wells. Local water plans should also be consistent with the State Water Plan to ensure uniformity of rules and regulations.

Current Approach
In 1985, the 50 most important groundwater basins out of the 478 in the state were chosen for monitoring (Ground Water Protection Council, n.d.).

- From 1985 to 1997, 10,000 samples from 1,089 wells were reviewed:
  - 10% to 25% of samples exceeded drinking water standards for:
    - pH (acidity and basicity)

        - Total dissolved solids (TDS)
        - Nitrates
        - Iron
        - Manganese
        - Turbidity

    - 2% to 3% of samples exceeded standards for:
        - Cadmium
        - Lead

Impending Water Policy Changes/ Conditions to Address Issue
The Source Water Assessment Protection Program (SWAPP) is being developed in addition to the Ground Water Protection Program. These programs are being developed to protect groundwater sources. However, more implementation efforts are needed at the local level of government.

Technology/Policies Needed
Technologies which are needed to address groundwater monitoring issues are:

- Real-time, networked groundwater quality monitoring
    - Fiber optic
    - Web-enabled
- In-situ monitoring systems
    - Sensors for long-term monitoring
    - Sensors for monitoring performance of wastewater treatment systems
    - Leak detection for technology for municipal landfills

Availability of Technology
Defiant Technologies of Albuquerque, NM, was recently awarded a $70,000 grant by the United States EPA and the Small Business Innovation Research (SBIR) program (Groundwater monitoring, 2010). They plan to develop a handheld chemical sensor that can detect groundwater contaminants. It is expected to be fit in small bore holes. Schlumberger Water Services also offers groundwater data loggers, modeling and simulation software, and the Westbay multilevel groundwater monitoring system (http://www.swstechnology.com/).

Key Issue: Groundwater Recharge Area Protection

Key Dimensions
Due to the heavy reliance on groundwater in the state, there exists the threat of reduction in the water table level.

- In the past, periods of low rainfall have reduced the yield of public well water by 30% to 40% in some areas of Southeastern Pennsylvania (Delaware River Basin Commission, 1999).

Action Needed
Section 2.20.4 of the Delaware River Basin Water Code states that withdrawals should be limited to the highest amount possible "that can be sustained without rendering supplies unreliable,

causing long-term progressive lowering of ground water levels" (Delaware River Basin Commission, 199, p.4).

- There needs to be mention of the estimated or actual amount of daily or annual withdrawal that this would amount to.

Current Approach

The Southeastern Pennsylvania Ground Water Protected Area was adopted by the Delaware River Basin Commission in 1980 (http://www.state.nj.us/drbc/pagwpa.htm). Groundwater withdrawal regulations were adopted for 76 watersheds in the protected area, using a two-tiered system:

- Tier 1: This is a warning that sub-basins may be stressed, and new applicants for withdrawals in this situation must implement programs such as "conjunctive use of ground water and surface water, expanded water conservation programs, programs to control ground water infiltration, and artificial recharge and spray irrigation."
- Tier 2: This is the maximum withdrawal limit.

Impending Water Policy Changes/ Conditions to Address Issue

The Delaware River Basin Water Code takes a step in the right direction by stating that withdrawals should not be unsustainable and cause extensive lowering of aquifer levels. However, policies implementing specific limits withdrawn are necessary because the state is so reliant on groundwater. Water conservation policies are necessary to limit water use during times of low rainfall when levels of public well water are severely reduced.

Technology/Policies Needed

Groundwater monitoring technology will be necessary if withdrawals are limited to a specific amount per day or per month. This type of technology can be used to measure aquifer levels and public well water levels. Water metering will also be necessary if limits are placed on water usage through conservation policies.

Availability of Technology

There is a high need for groundwater cost-effective monitoring systems and existing technologies include:

- Real-time monitoring devices
- Multiple site/strata monitoring
- Web-enabled networked systems linked by RF or cellular technology
- Automated systems that do not rely on operator interpretation to determine results

Key Issue: Hydraulic Fracturing and Coal Bed Methane

Key Dimensions

Since 1859, approximately 350,000 oil and gas wells have been drilled in the state (Pennsylvania Department of Environmental Protection, 2010 revision).

- In 2005, 3.6 million barrels (151.2 million gallons) of crude oil and 168 billion cubic feet of natural gas were produced.
- High amounts of water are needed to drill a well in the Marcellus Shale. This water is then considered wastewater which must be properly treated and disposed.

Many wells in the state were abandoned without being properly capped before current regulations existed. Pennsylvania's Growing Greener program provides funds to properly seal these wells, but many unplugged wells are considered hazardous (Pennsylvania Department of Environmental Protection, 2009 revision).

A listing of hazardous components used in hydraulic fracturing solutions was obtained from material safety data sheets by the State of Pennsylvania. Chemicals used by the vendors BJS, Fractech, Universal, Halliburton, and Superior are listed (http://www.dep.state.pa.us/dep/deputate/minres/oilgas/FractListing.pdf):

- The concentration in parts per million of the following chemicals used exceeded the EPA risk based concentration for residential tap water:
  - Propargyl alcohol
  - Methanol
  - Ethylene glycol

Coal bed methane extraction is also is an issue in Pennsylvania. The state has over 44,000 natural gas wells (Hopey, 2007). Current state law only requires that wells be spaced 1,200 feet apart and 300 feet away from a home. In 2005, 1.8 billion cubic feet of methane were extracted from wells and it is estimated that the state still has 2.7 trillion cubic feet in coal beds. Wells produce an average of 50,000 cubic feet of methane per day and have an operation period of up to 40 years.

Action Needed

Strict enforcement of existing laws needs to continue. Additionally, best management practices should be mandatory for well drillers. The Pennsylvania DEP provides education on best management practices, as well as compliance assistance to prevent environmental degradation resulting from hydraulic fracturing.

Well-water monitoring also needs to continue, as well as inspection of drilling sites to ensure that proper practices are being used and to ensure that hydraulic fracturing fluids are not leaking into the groundwater. Finally, the passage of the Federal "FRAC" act would require companies to disclose all of the chemicals in their fracturing fluids. This would allow officials to determine the health risks that these mixtures pose to drinking water.

Current Approach

Pennsylvania has several laws which regulate drilling for oil and gas (Pennsylvania Department of Environmental Protection, 2010 revision):

- Oil and Gas Act
- Coal and Gas Resource Coordination Act
- Oil and Gas Conservation Law

Environmental protection laws include:

- The Clean Streams Law
- The Dam Safety and Encroachments Act
- The Solid Waste Management Act
- The Water Resources Planning Act

Impending Water Policy Changes/ Conditions to Address Issue
"*FRAC Act: Fracturing Responsibility and Awareness of Chemicals*"
On June 9, 2009, this bill was introduced in the House and the Senate with the purpose of repealing the exemption for hydraulic fracturing in the Safe Water Act. This would force companies to reveal chemicals used in fracturing. Chemicals regarded as trade secrets would no longer be exempt.

Toxic Chemicals Safety Act of 2010
On January 21, 2010, the EPA announced that it would begin to reject Confidential Business Information (CBI) claims on the identity of chemicals which are known to pose health risks and are included in the Toxic Substances Control Act (TSCA) Chemical Inventory (United States Environmental Protection Agency, 2010). The TSCA was originally passed in 1976 and requires companies to notify the EPA if any chemicals used were found to pose risks to health or the environment. However, before the EPA's January announcement, companies could withhold chemical information if the chemical in question were determined to be a trade secret.

A discussion draft for the Toxic Chemicals Safety Act of 2010 was released on April 15, 2010. The act, if passed, would amend the TSCA (http://energycommerce.house.gov/Press_111/20100415/TCSA.Summary.04.15.2010.pdf). The Toxic Chemicals Safety Act would require industries "to submit to the EPA the data it needs and improves EPA's authority to compel testing by the chemical industry" (p. 1). The act would also ensure that information provided to the EPA is properly disclosed to the public.

Technology/Policies Needed
Pennsylvania does not currently have many solid regulations in place. It needs to implement rules which will force companies to disclose the chemicals in their fracturing fluids. Companies also need to be forced to treat discharged coal bed methane water on-site or transport it to a treatment facility instead of discharging the water onto the ground near the site.

A stricter well drilling permit process may also be needed. Pennsylvania needs to ensure that a new well will not have a negative impact on the surrounding environment and companies need to show that they have plans in place which will use best management practices before receiving a permit. Policies enforcing water quality monitoring of these wells are also needed.

Technology needed to address water problems related to hydraulic fracturing and coal bed methane extraction include:

- Monitoring for well water quality, including CO_2 and saline contamination
- On-site water treatment systems
- Enhanced coal bed methane recovery and CO_2 sequestration
- Water recycling and reuse

Availability of Technology
Technology used for desalination can also be used for treating discharged water from coal bed methane, as well as for treating hydraulic fracturing fluids. Examples of this type of technology

are reverse osmosis (RO) membrane filtration and electrodeionization (EDI). Other available technologies include:

- Portable on-site treatment - Veolia and GE Water have recently developed units for the oil and gas industry
- Treatment units that run on the natural gas produced by the wells
- Treatment technologies that derive process energy from the discharged wastewater itself
- Zero liquid discharge (ZLD) processes - to avoid the need for NPDES permits for liquid concentrate disposal
- Alternative gas extraction methods, including nitrogen injection
- Berms and other barriers to contain runoff at well pads
- Tools to locate and assess potential CO_2 sequestration sites
- Monitoring systems to detect CO_2 leakage into the atmosphere from underground storage sites

Key Issue: Water Consumed by Energy Production

Key Dimensions

According to Pennsylvania's State Water Plan Principles, the state exports $5.0 billion in electricity annually, over a power grid that covers portions of 13 states (Pennsylvania Department of Environmental Protection, 2009).

- The plan stated that based on growth and energy demand patterns, the state will need 15 new power plants by 2020.
- In the Susquehanna River Basin alone, a total of 11 major power plants (eight fossil-fueled and three nuclear) withdraw over 4.2 billion gallons of water daily and consume 168 million gallons daily.
- Marcellus Shale wells require 1 to 3 million gallons of water over 30 days for hydraulic fracturing. There have been 1,239 wells drilled in the Marcellus Shale from 2008 to 2010 (http://extension.psu.edu/naturalgas/news/2010/05/accelerating-activity). Of these wells alone, total annual water use would vary between 14.8 billion gallons to 44.6 billion gallons.
  - It is estimated that 50% of this amount is consumed and 50% is treated as wastewater and discharged or taken to an off-site location.

Action Needed

The possibility of 15 new power plants by 2020 means that the state will need to plan and implement methods of recycling water that is used in the production of energy (Pennsylvania Department of Environmental Protection, 2009). Water reuse has high potential because actual water consumption per day is far less than total withdrawal of water per day. Additional, off-site wastewater treatment plants may need to be constructed to meet these needs. Finally, developing alternative processes or more water-efficient biofuel production technologies may be important.

Current Approach

The first ethanol production plants are expected to go online in 2010 or 2011. While ethanol additives can result in cleaner emissions, biofuel production requires high amounts of water.

Impending Water Policy Changes/ Conditions to Address Issue

The Energy Independence Strategy (Pennsylvania Department of Environmental Protection, 2009) favors the development of alternative energy sources and technologies, including biofuels. $665.9 million has been earmarked to promote these alternative sources (http://www.dgs.state.pa.us/portal/server.pt/community/energy_independence/10473/about_eis/553042).

Technology/Policies Needed

There are a number of policies which have been implemented by the EPA to address issues such as hydraulic fracturing and coal-bed methane extraction. However, there appear to be fewer pending policies or legislation addressing the water-energy nexus. Pennsylvania enacted a statute that created the Great Lakes-St. Lawrence River Basin Water Resources Compact (http://www.ncsl.org/?tabid=18025). The compact addresses the need to encourage use of technology and other practices that would conserve water and outlines the importance of considering the relation between water use and energy.

Availability of Technology

Less water-intensive sources of energy need to be explored. Because Pennsylvania is heavily dependent on coal energy, more efficient water cooling technology may be needed.

Key Issue: Drought, Ecological Damage, and Invasive Species

Key Dimensions

Pennsylvania experienced several major droughts which led to the implementation of the 2002 Water Resources Planning Act (Swistock et al., n.d.). This required the state Department of Environmental Protection to determine in an updated State Water Plan how much water the state has, how much is currently used, and how much will be used in the future:

- 86,000 miles of streams and rivers
- 161,455 acres of lakes
- Enough groundwater to submerge the entire state under eight feet of water

Short-term droughts (characterized as lasting one to three months) occur approximately once every three years in the western half of the state and once every two years in the eastern half of the state (Union of Concerned Scientists, 2008). Rising temperatures in the summer will eventually increase the frequency of short-term droughts, assuming that rainfall will not increase to offset the increase in temperature.

According to the Governor's Invasive Species Council of Pennsylvania, there are several invasive species in state waters, including (http://www.invasivespeciescouncil.com/Profiles_Aquatics.aspx):

- Asian Carp
- Quagga and Zebra Mussels
- Wild Taro
- Alligator weed
- Water Chestnut
- Hydrilla

The Invasive Species Council states that "aquatic invasive species are responsible for significant annual losses" to the economy.

Action Needed

Pennsylvania produces 1% of total global emissions (Union of Concerned Scientists, 2008). Electricity accounts for 40% of the carbon dioxide emissions for Pennsylvania, and it also exports a large amount of the electricity it generates. Therefore, because carbon dioxide emissions can contribute to climate change and higher temperatures which can affect drought, efforts need to be made to begin using alternative energy sources.

Current Approach

Pennsylvania has three levels of drought declarations (Swistock et al., n.d.):

- Drought watch
  - Citizens are asked to volunteer decreasing water use by 5%.
  - Monitoring is increased from monthly to weekly.
- Drought warning
  - Citizens are asked to volunteer decreasing water use by 10 to 15%.
- Drought emergency
  - Non-essential water-use restrictions are imposed through Pennsylvania Emergency Management Agency (PEMA) regulations.
  - Monitoring is increased from weekly to daily.

Impending Water Policy Changes/ Conditions to Address Issue

Wyoming does not currently have impending policies or standards to address drought. However, federal regulations such as the National Invasive Species Act of 1996 (NISA) and the Final Vessel General Permit (VGP) of 2008 are attempts to address invasive species. Policies that are needed to address invasive species are:

- Remove moratorium on application of VGP to smaller vessels
- Implement ballast water reporting laws
- Integrate ballast water regulations with NPDES

Technology/Policies Needed

Technologies which are needed to meet new policy changes are:

- Chemical control of ballast water
- Biocide application to waters
- Barriers
  - Sound waves
  - Electrical impulses
  - Visual deterrents
  - Physical barrier

Availability of Technology

Some available or emerging technologies in this area include:

- UV disinfection of ballast water
- Ballast water control for recreation vessels

- Effluent monitoring for ballast control chemical concentrations
- Innovative barrier techniques

Key Issue: Combined Sewer Overflows and Mining Runoff

Key Dimensions
Combined sewer overflows (CSOs) are the greatest concern in urban areas such as Pittsburgh and Philadelphia. In Philadelphia, approximately 16 billion gallons are discharged annually from 164 point sources. As of 2002, the Pittsburgh area also discharged 16 billion gallons annually from CSOs (3 Rivers Wet Weather, 2002).

Abandoned mines and mining runoff introduce heavy metals into surface and groundwater and over 4,800 miles of streams are contaminated by these substances (Pennsylvania Department of Environmental Protection, 2009). Contaminants include zinc, arsenic, selenium, lead, and cadmium.

Mining companies are required to leave a 100 foot barrier of coal around the perimeter of the mine to support the surface and prevent runoff (Fialka, 2003). However, according to Paul Hummel, Pennsylvania's mine safety director, coal operators will often illegally mine portions of this buffer as well, creating only a 20 to 30 feet barrier.

Approximately 34% of the abandoned mines in the country are located in Pennsylvania (Fialka, 2003):

- Number of abandoned mines:
  - Pennsylvania: 1,700
  - United States: 6,000

Abandoned mines have contributed acid runoff, as well as heavy metal pollution (Pennsylvania Department of Environmental Protection, 2009). A 1996 study by the Pennsylvania Department of Environmental Protection (as cited Earle & Callaghan, 1998) found that 2,425 miles of stream in Pennsylvania failed to meet EPA water quality standards as a result of mining in 1995. This is 20% of the 11,997 miles of streams degraded from mining in the United States in 1970.

A USGS study examined the contaminants in discharged water from anthracite coal mines and found the following pollutants (http://pubs.usgs.gov/fs/FS-038-96/#HDR05): aluminum, calcium, cobalt, iron, lithium, magnesium, manganese, nickel, strontium, zinc, and sulfate.

Action Needed
Infrastructure upgrades are needed to reduce CSOs. Projects similar to the Milwaukee Metropolitan Sewerage District's deep tunnel could add capacity for occasions of high rainfall. Municipalities need to consider spending much more for upgrades than has been allotted.

If former mine owners or operators can be located, the Pennsylvania Department of Environmental Protection should coordinate remediation efforts with these individuals or companies. However, many mines have been abandoned for so long that the DEP might need to take control of cleanup efforts, itself. Buffers might keep mining runoff from seeping into area water bodies.

Current Approach
The Philadelphia Water Department (PWD) has implemented a combined sewer overflow program (Philadelphia Water Department, 2007). This program includes low-cost measures to reduce overflows. It will also involve improvements to the combined sewer system and a watershed approach to reducing sources of pollution. Capital improvement expenditures since 1997, combined with future estimates, total $100 million (http://www.phillyriverinfo.org/CSOLTCPU/CSOLTCP/pdf/LTCP%20Backgrounder%201105.pdf).

Pittsburgh also has a CSO Long Term Control Program which involves the mapping of 8 million feet of pipe and the installation of 200 flow monitors (http://www.mbakercorp.com/index.php?option=com_content&task=view&id=2183&Itemid=281).

In 1977, Congress passed the Surface Mining Control and Reclamation Act. The law is intended to assess fees to coal companies based on the amount mined (Fialka, 2003). The program has collected over $7 billion in fees which are placed in a federal trust used to reduce health and safety hazards of abandoned mines. However, there are still $1.5 billion in unspent funds and an estimated 80% of the abandoned mines have not been remediated.

The program allocates funds based on the amount of production, which has caused problems. Eastern states previously produced 75% of the country's coal, but almost all production has shifted to western states. Additionally, 93% of the problems caused by mining in the United States (contaminated water, underground fires, holes) are in the eastern states. These problems in the eastern half of the country would cost $6.6 billion to fix.

The Federal Surface Mining Control and Reclamation Act of 1977 requires the maintenance of existing vegetation or creation of new vegetation on formerly mined land (http://www.dep.state.pa.us/dep/deputate/minres/districts/cmdp/chap12.html). The vegetation prevents erosion and absorbs water, which would otherwise enter groundwater sources and create runoff.

Impending Water Policy Changes/ Conditions to Address Issue
New policies should place limits on the annual amount of discharged water from CSOs. Since the completion of the Deep Tunnel in Milwaukee, annual discharge has averaged 1.3 billion gallons per year (1994 to 2009 data). This is in comparison to 16 billion gallons discharged annually by Pittsburgh. Therefore, it would not be unreasonable to place a policy limiting discharge to 2 billion gallons per year in Pennsylvania metropolitan areas by 2020. Fines might be levied against cities that exceed this amount. This would force municipalities to spend more money to upgrade their combined sewer systems.

The Surface Mining Control and Reclamation Act has been helpful when coal mining companies still exist. However, many mines are decades old and a number of companies have since gone out of business. As a result, these companies cannot be assessed fees.

To ensure that this situation does not happen in the future with existing mining companies, policies should be created that force companies to put a certain amount of money into a reserve fund based on the amount of coal mined. This reserve fund could be used if the company goes out of business and environmental problems are found. Policies mandating better protection from mining runoff are also needed. Construction barriers could at least halt surface runoff.

Technology/Policies Needed

Water level monitoring for sewers will be needed. If upgrades are not performed to separate combined sewers into two components, solutions such as deep tunnels may be necessary. Construction runoff barriers and sediment traps may be necessary technologies in addressing mining runoff.

Availability of Technology

Available technology includes:

- Sewer flow monitors
- Bed pipe barriers to reduce the concentration of suspended solids around mining sites
- Settling ponds

Pennsylvania References

3 Rivers Wet Weather (2002). *The regionalization report: An initial study on options for regionalizing the management of sewage collection within the ALCOSAN service area*. Retrieved from http://www.3riverswetweather.org/f_resources/regionalization_report.pdf

Alliance for the Chesapeake Bay (n.d.). *Know your nitrogen: A guide to reducing nitrogen pollution at home*. Retrieved from http://www.dep.state.pa.us/dep/deputate/watermgt/General/know_your_nitrogen.pdf

Delaware River Basin Commission (1999). *Ground water protected area regulations: Southeastern Pennsylvania*. Retrieved from http://www.state.nj.us/drbc/regs/gwpa.pdf

Fialka, J. J. (2003, June 4). Perilous pits. *Wall Street Journal*. Retrieved from http://www.usmra.com/hummel.htm

Ground Water Protection Council (n.d.). *Pennsylvania ground water conditions*. Retrieved from http://www.gwpc.org/e-library/documents/state_fact_sheets/pennsylvania.pdf

Groundwater monitoring technology development gets EPA grant (2010, April 6). *Water World*. Retrieved from http://www.waterworld.com/index/display/article-display.articles.waterworld.drinking-water.water-resources.2010.04.Groundwater-monitoring-technology-development-gets-EPA-grant.QP129867.dcmp=rss.page=1.html

Hopey, D. (2007, April 29). Why gas bonanza is no boon to landowners. *Pittsburgh Post-Gazette*. Retrieved from http://www.post-gazette.com/pg/07119/781909-85.stm

Lustgarten, A. (2009, November 29). Pa. residents sue gas driller for contamination, health concerns. *ProPublica*. Retrieved from http://www.propublica.org/feature/pa-residents-sue-gas-driller-for-contamination-health-concerns-1120

National Resources Defense Council (2003). *What's on tap? Grading drinking water in U.S. cities*. Retrieved from http://www.nrdc.org/water/drinking/uscities/pdf/philadelphia.pdf

Pennsylvania Department of Environmental Protection (1996). *Section 303(d), List of waters, Bureau of Water Quality Management*. Retrieved from http://www.dep.state.pa.us/dep/deputate/minres/districts/cmdp/chap04.html

Pennsylvania Department of Environmental Protection (2005 draft). *Pennsylvania stormwater best management practices manual. Appendix E – Manufactured products*. Retrieved from http://www.dep.state.pa.us/dep/subject/advcoun/stormwater/Manual_DraftJan05/Appendix-E-jan-rev.pdf

Pennsylvania Department of Environmental Protection (2008). *Creating a sustainable solution for Pennsylvania: Governor's sustainable infrastructure task report*. Retrieved from http://www.portal.state.pa.us/portal/server.pt/community/sustainable_water_infrastructure_task_force/10565

Pennsylvania Department of Environmental Protection (2009). *Pennsylvania state water plan principles*. Retrieved from http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-76835/3010-BK-DEP4222.pdf

Pennsylvania Department of Environmental Protection (2009 revision). *Oil and gas well drilling and production in Pennsylvania fact sheet*. Retrieved from http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-74407/5500-FS-DEP2018.pdf

Pennsylvania Department of Environmental Protection (2010 revision). *Marcellus Shale fact sheet*. Retrieved from http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-77964/0100-FS-DEP4217.pdf

Philadelphia Water Department (2007). *The combined sewer overflows: A long term control plan and our rivers*. Retrieved from http://www.phillyriverinfo.org/CSOLTCPU/CSOLTCP_Update/pdf/OOW%20LTCP%20Billstuffer.pdf

PR Newswire (2009, December 16). Pennsylvania DEP highlights benefits of mercury-free thermostat law [News Release]. Retrieved from http://www.prnewswire.com/news-releases/pennsylvania-dep-highlights-benefits-of-mercury-free-thermostat-law-79422407.html

Swistock, B. R., Clemens, S., & Sharpe, W. E. (2009). Drinking water quality in rural Pennsylvania and the effect of management practices [Electronic version]. *Penn State University and The Center for Rural Pennsylvania*. Retrieved from http://www.rural.palegislature.us/drinking_water_quality.pdf

Swistock, B., Oliver, J., Clark, J., Rizzo, D., Boser, S., Wulfhorst, P., McCarty, T. (n.d.). Water conservation for communities [Electronic version]. *Penn State Agricultural Research and Cooperative Extension*. Retrieved from http://extension.psu.edu/water/resources/educational-materials/water-conservation/why-conserve-water/communitywaterconservation.pdf

Union of Concerned Scientists (2008). *Climate change in Pennsylvania: Impacts and solutions for the Keystone State*. Retrieved from http://www.climatechoices.org/assets/documents/climatechoices/climate-change-in-pennsylvania_impacts-and-solutions.pdf

2.9 Texas

Key Markets	Niche Markets
Water resource development	Salt water intrusion
Water conservation/efficiency	Smart meters; water efficient equipment
Concentrated animal feeding operations	Biodigesters; containment facilities
Ground water monitoring & mitigation	Phosphorous capture & reuse
Energy exploration & generation	Mercury capture; oil & gas exploration

Demographic Indicators

Population	2000	2009	2020
Urban Population	17,204,000	--	--
Rural Population	3,647,800	--	--
Total Population	**20,851,800**	**24,782,300**	**28,634,900**

Population Growth Rate	2000-2009
Total Population Growth Rate	18.8%

Source: United States Census Bureau
(http://www.census.gov/population/www/projections/projectionsagesex.html)

Economic Indicators

Economic Indicator (2007)	Nominal GDP
Total GDP	$1,148 billion
GDP per capita	$38,055
GDP growth rate	4.4%

Source: United States Bureau of Economic Analysis
(http://www.bea.gov/scb/pdf/2009/06%20June/0609_gdp_state.pdf)

Texas has compounding water problems. A booming population, large amounts of agricultural and livestock, increasing water intensive energy needs have converged to place a large strain on Texas' current capacity to provide safe drinking water. Furthermore, droughts have plagued Texas and will likely reappear throughout the 21st century. Everything is bigger in Texas, and, unfortunately that applies to problems too.

Summary of Key Issues

- Developing sustainable systems of water supply and efficient use of a resource that will feel pressure from increased demand
- Monitoring groundwater
- Mitigating the effects of Concentrated Animal Feeding Operation (CAFOs) on both groundwater and surface water
- Eliminating contaminates from water ways – specifically phosphorus and mercury
- Increased energy production and subsequent consumption of water

Key Issue: Developing sustainable systems of water supply to efficiently use a resource that will feel pressure from increased demand

Municipal water demand is expected to double in about 50 years. That is in addition to the tremendous increases expected from agriculture and energy industries. Texas will be increasingly challenged to live with the water that is available to it.

Groundwater provides 60% of the state's total water supply. Saltwater intrusion, contamination from oil and gas fields, increased demand, drought, non-compliance with existing EPA standards, and so forth all threaten groundwater supplies. The Texas Water Board predicts that groundwater supplies will decline for these many reasons by 32% by 2060 from 8.5 million acre-feet to 5.8 million acre-feet. Some portions of the State will lose 50% of their groundwater resources. Texas is said to be one of the four states with the most challenging water problems.

Although the threat towards groundwater has been clear, there has been little action to bring about a desirable water future for Texas. At present people can pump as much groundwater as they can, as long as it does not unreasonably affect another person's ability to use groundwater. This system favors the individual with the ability to afford a deeper well with a bigger pump. Water rights will have to be addressed in order to implement some semblance of groundwater management (The Threat of Aquifer Depletion in Texas, 2001).

Groundwater management was traditionally decentralized in Texas. In 2005 the Texas State Legislature finally required joint planning among groundwater conservation districts within groundwater management areas.

Water conservation can be a particularly effective policy to implement within urban areas. But there has been little movement in this direction. Instead, Texas has looked toward new sources of water, such as using desalination to create useable water from brackish groundwater. However, the process is energy intensive and creates a highly concentrated flow of wastewater. It appears that before Texas is able to make substantial improvements in their water future, changes in laws and centralization of policy must come first.

Key Issue: Monitoring Groundwater

Not only is groundwater being used at unsustainable rates, it has been and continues to be contaminated by a variety of chemicals. The most common contaminants included gasoline, pesticides, nitrates, salinity, and radioactive elements. The Texas Water Development Board currently collects information on 25 chemicals that may be contained within groundwater – far short of the EPA list of nearly 100 regulated contaminants. The TWDB also only monitors about 175 samples per year.

Moving forward Texas will need to vastly expand its capability to monitor groundwater—more samples at more locations looking for more contaminants. There is a need for more sophisticated sensors that can monitor water in situ. Otherwise water samples must be taken and transported to a lab for analysis. In situ monitoring with real time data being collected would give excellent information to determine the policies need to ensure that water is used and protected wisely. (State of the Groundwater Report 2008).

Legislation
1989 – Created the Texas Groundwater Protection Committee. Texas Water Code, 24.401 – 26.407.
1999 – EPA approval of Texas' Source Water Assessment and Protection Program.
(Texas Commission on Environmental Quality)

Current Policy
Texas Groundwater Protection Goal: "the existing quality of groundwater not be degraded. This goal of non-degradation does not mean zero-contaminant discharge [. . .] It is the policy of this state that: (1) discharges of pollutants, disposal of wastes, or other activities subject to regulation by state agencies be conducted in a manner that will maintain present uses and not impair potential uses of groundwater or pose a public health hazard; and (2) the quality of groundwater be restored if feasible."

There is room for far more monitoring and regulation in Texas. The projections of both quantity and quality demand it, yet the politics are such that major issues cannot yet be addressed.

Key Issue: Mitigating the effects of Concentrated Animal Feeding Operation (CAFOs) on both groundwater and surface water
Concentrated Animal Feeding Operations house hundreds or even thousands of animals within in a relatively small area. Waste generated from such facilities easily flow into water ways. Some 400 million gallons of manure flow from just one county (Erath) annually.

Phosphorus is a major element of waste from CAFOs and leads to large algae plumes that absorb oxygen in water and reduce or eliminate oxygen for other organisms. Currently, there is little over-site of CAFOs in Texas besides a permitting process and regulations from operating a CAFO within a certain distance (500 ft.) from a well.

Techniques such as channeling waste water through plant beds that can absorb phosphorus may work on small scales. However, developing on-site, wastewater-treatment systems that both collect and treat the waste may be the only way to deal with the quantity of waste that is produced. (Muir, Jim. AgriLife Research Texas A&M System and Texas Water Development Board)

Technology Needs

- Monitoring and control systems for treatment lagoons to enhance the removal of biological nutrients
- Retrofit liner technology for existing lagoons
- Cost-effective high-efficiency manure treatment systems
- Zero liquid discharge processes for environmentally sensitive watersheds and dry fertilizer production
- Phosphorus/nitrogen balancing - for optimum fertilization efficiency without excess phosphorus

- Nutrient testing and automated blending systems to achieve appropriate nutrient concentrations for a variety of agricultural needs
- Heavy metals and arsenic reduction technology
- Alternatives to "preventive" antibiotics use in animals

Key Issue: Eliminating contaminates from waterways – specifically phosphorus and mercury
Many water issues are interconnected. For example, the increase of livestock and CAFOs has lead to more surface water with higher concentrations of phosphorus due to the increase in contaminated runoff carrying manure. Texas produces about 280 billion pounds of animal manure, more than any other state (www.txpeer.org). Without proper care of the waste, runoff can quickly contaminate nearby rivers and streams. In the case of phosphorus caused by CAFOs the simplest and most cost-effective way of reducing contamination is through prevention.

Mercury is another element that threatens Texas waterways. Mercury can undergo a conversion in water to methyl mercury which is retained in fish and is the only form of mercury that can accumulate in aquatic food chains. Fish consumption is the primary source methyl mercury exposure in humans (Texas Commission on Environmental Quality). Methyl mercury is a neurotoxin that attacks the central nervous system in humans and can affect sensory, vision, auditory and coordination. The main source of mercury contamination in Texas is power plants. In fact, 10% of the nation's mercury emissions come from Texas plants. Aiding this odd achievement is the fact that five of the nation's top-ten mercury emitters are located in Texas.

Key Issue: Increased energy production and the role of water
Texas has made an effort to unlock new sources of water. "To me, it is not a matter of whether saltwater will one day be used as an abundant source for public use, but when and where" Governor Perry – 2004 (Texas Water Development Board). By 2004 there were more than 100 desalination plants in Texas, all of them treating brackish groundwater or surface water (www.edwardsaquifer.net). The largest plant is the Kay Bailey Hutchison Desalination Plant in El Paso that produces 27.5 million gallons of drinking water per day – costing $1.65 per thousand gallons. The average cost of water in the US is about $1.50 per thousand gallons – giving desalination in Texas a $0.15 premium. The cost of desalinated water is subject to the price of energy more than traditional sources of water. Desalination is an energy-intensive process due to the pumping necessary to push water through membranes. As the price of energy rises, so will the price of water produced through desalination.

Of course, traditional form of energy production such as coal power plants produce pollution that affects waterways and are water intensive processes in and of themselves. This creates the need to study the benefits of desalination, considering the wider affects of linking water production to increased energy needs.

Summary
In a state known for aversion to regulation, Texas is struggling to balance its growing demand for water with politically acceptable rules for water consumption and production. There are large markets for all sorts of water solutions, both technological and policy. Energy price increases will push policies forward, as it becomes increasingly clear that pollution prevention policies and

enforcement are less expensive than any alternatives. There are also ample opportunities in agriculture, oil and gas drilling and recovery, and industrial and domestic water conservation to give many firms market opportunities.

2.10 Washington

Key Markets	Niche Markets
Stormwater & wastewater infrastructure (pipes & treatment plants)	Greywater reuse
Stormwater mitigation technology	Freshwater barriers to protect against saltwater intrusion
Tertiary wastewater treatment technology	Combined sewer overflow mitigation
Water metering	
Groundwater/aquifer monitoring technology	

Demographic Indicators

Population	2000	2009	2020
Urban Population	4,831,000	--	--
Rural Population	1,063,000	--	--
Total Population	**5,894,000**	**6,664,000**	**7,432,000**

Population Growth Rate	2000-2009
Total Population Growth Rate	13.1%

Source: United States Census Bureau
(http://www.census.gov/population/www/projections/projectionsagesex.html)

Economic Indicators

Economic Indicator (2007)	Nominal GDP
Total GDP	$310.3 billion
GDP per capita	$40,218
GDP growth rate	4.4%

Source: United States Bureau of Economic Analysis
(http://www.bea.gov/scb/pdf/2009/06%20June/0609_gdp_state.pdf)

Background and Summary of Key Issues

The State of Washington is currently experiencing a number of water-related problems. The most severe problems share several themes, including unsustainable water use, drought, stormwater runoff, aging infrastructure, and inadequate water monitoring. A complete list of the most severe problems which the state is facing includes:

- Unsustainable supply and aquifer depletion
- High irrigation demand and outdated water rights
- Necessity for greater use of reclaimed water
- Drought and climate change
- Aging water infrastructure
- Contaminated river and lake sediment
- Stormwater runoff contamination, flooding, and combined sewer overflows
- Inadequate groundwater controls and monitoring of aquifers

Key Issue: Unsustainable Supply and Aquifer Depletion

Key Dimensions

Water shortage is already a problem and is likely to increase in severity in the future. Officials estimate that the state currently consumes 5.2 billion gallons of water per day (Washington Rivers Conservancy, n.d.). Assuming no changes in water usage per person, the overall consumption will increase as an additional 2 million individuals move to the state by 2030.

Aquifer depletion is an additional problem due to the unsustainable use of groundwater. Approximately 66% of individuals in the state use groundwater for drinking (Hermanson, 1991). Almost 100% of rural residents rely on groundwater for drinking. There are a number of examples of aquifer depletion across the state, including:

- The Grande Ronde Aquifer, part of the larger Columbia Basin, has experienced annual average declines of three feet for several decades (http://www.columbia-institute.org/wsu/WSUhome/Overview.html).
- The Odessa Subarea deep aquifers have been declining since 1960, as a result of irrigation over-pumping and illegal groundwater wells (http://www.columbia-institute.org/oa/odessa/Home.html).
- In areas of the Columbia Plateau, such as the Odessa-Lind area, the water table has dropped by 10 feet a year for 20 years. However, in other areas of the Plateau, such as the Yakima River valley, excessive levels of pumping have contributed to flooding (Hermanson, 1991)

Action Needed

Washington will need to consider placing limits on the amount of water which can be withdrawn per day from surface water and groundwater sources. Charging fees for amounts of water which are withdrawn beyond a specified amount per day would also decrease total water use.

There is currently no adequate pricing structure in place and thus, there is no way to accurately track groundwater or surface water use. As a result, there is currently no incentive to conserve water. Block rate structures would reduce demand and pricing needs to be combined with water use and land use planning.

Current Approach

The City of Seattle has one of the most comprehensive water conservation programs in the state. Some of its water saving measures include:

- Increasing block rate structure for residences during peak water use season
- Plumbing fixture codes and regulations
- Customer rebates and financial incentives to encourage purchase and use of cost-effective and water-efficient equipment, such as efficient showerheads, washing machines, and commercial toilets and urinals

Thus far, these measures have been effective, as annual water consumption fell from 171 million gallons per day to 150 million gallons in the 1990s.

Seattle also has higher municipal water rates than most large cities in the country, which may encourage responsible water use. In 2007, of the 50 largest U.S. cities, Seattle had the second highest average monthly water bill ($35.30) for residential customers (7,500 gallons billable water usage).

Impending Water Policy Changes/ Conditions to Address Issue

Municipal Water Law

The Washington State Legislature passed the Municipal Water Law in 2003, which is intended to enact a Water Use Efficiency program to conserve water and reduce energy needs. This program requires municipalities to formulate goals for water conservation and to implement measures necessary to attain those goals. More specifically, water suppliers must install meters on all customer hook-ups and attain a water loss standard of no more than 10% by January 22, 2017.

However, the legality of this rule was challenged and the Washington Superior Court decided on June 11, 2008 that the requirements only apply to community water systems that are classified as governmentally-owned Class A. Private water systems were decided to be different from municipal systems and are thus exempt from the Water Use Efficiency requirements, pending a final decision.

Technology/Policies Needed

Washington State still needs a water use law requiring metering for all water systems, as opposed to requiring the metering of only Class A community water systems. Because the Washington Superior Court exempted other water systems, it is unknown how such a law or regulation would be implemented.

Availability of Technology

Groundwater monitoring technologies which would address unsustainable supply and aquifer depletion include:

- Real-time monitoring
- Multiple site/strata monitoring
- Web-enabled networked systems linked by RF or cellular technology
- Automated systems that do not rely on operator interpretation to determine results
- Leak control technologies:
  - Continuous acoustic monitoring
  - District Metered Areas (DMAs) for audit and leak control
  - Pressure monitoring
  - GIS analysis

Key Issue: High Irrigation and Outdated Water Rights

Key Dimensions

Agriculture is the largest user of water in Washington and according to Washington State University Extension, the state has 1.8 million acres of irrigated land. It is estimated that 80% of the total water use in the state is for agriculture. Approximately 75% of that water is surface water, while the remaining 25% is groundwater.

A study by the U.S. Department of the Interior (2006) stated that 170,000 acres of farm land are irrigated by groundwater in the Columbia Basin Odessa Subarea, alone.

According to the Washington State Department of Ecology, Washington's water rights involve prior appropriation ((http://www.ecy.wa.gov/programs/wr/comp_enforce/comp_enfor.html). Water rights are required to withdraw any amount of surface water and to withdraw more than 5,000 gallons per day of groundwater. However, once these rights are secured, a permit holder using water for agriculture is allowed to withdraw as much water as they desire, per day. The Washington State Department of Ecology discusses the need for water metering and provides a list of metering devices and technical requirements for those devices (http://www.ecy.wa.gov/programs/wr/measuring/measuringhome.html).

Action Needed

Because agriculture is a primary user of water in the state, it will be important to consider greater use of genetically-engineered crops which require less overall water and are more resilient in drought conditions.

Changes to water rights may be necessary to conserve water, as the current rights structure generally allows unlimited daily withdrawal of water, so long as a permit is held. Therefore, limits on water withdrawal and use by permit holders would encourage efficient and responsible use of water.

Current Approach

Due to agriculture, the aquifer in the Columbia Basin Subarea has declined to a point where new wells are being drilled between 2,100 and 2,400 feet, at a cost of $200 per foot (U.S. Department of the Interior, 2006). Powerful pumps are necessary to bring this water to the surface.

Impending Water Policy Changes/ Conditions to Address Issue

RCW 90.03.360 (Controlling works and measuring devices – Metering of diversions – Impact on fish stock) was added to the current water code in 1993. However, the Department of Ecology was sued in 2000 for not complying with the rule and was forced to create a compliance plan in 2001 (http://www.ecy.wa.gov/programs/wr/measuring/measuringhome.html). This plan only requires the top 80% of users by volume used, to meter water use. This affected approximately 1,000 utilities and large agricultural operations which only draw water in fish critical watersheds.

Technology/Policies Needed

Improved irrigation systems, such as drip irrigation, will be important to reduce the amount of water necessary for agricultural uses. Drip irrigation systems lose less water to evaporation than traditional systems such as sprinkler irrigation (http://ga.water.usgs.gov/edu/irdrip.html).

Availability of Technology

Available technologies to address high irrigation use include:

- Micro- and drip irrigation

- Water saving irrigation technologies:
  - Automated diversions
  - Gated pipe application
  - Surge valves

Key Issue: Necessity for Greater Use of Reclaimed Water

Key Dimensions
Any water used by a household, aside from water for toilets and human waste, is considered greywater (http://nmwater.nmsu.edu/pubs/_m/m-106.html). Irrigation is the primary use of greywater but steps often must be taken to ensure that the reclaimed water does not come in contact with the edible portions of crops. Application to flat areas is encouraged, to prevent runoff.

Action Needed
Public education about greywater use is needed. There is still aversion to use of such systems with regards to drinking water. For example, residents of San Francisco were surveyed about the use of reclaimed water. While over 80% felt positive about uses such as agriculture, only 18% felt positive about direct potable reuse (U.S. Environmental Protection Agency, 2004).

Current Approach
Washington's current Water Reclamation and Reuse Standards date to September 1997 (Washington State Department of Health, 1997). It includes general requirements for use, reclaimed water standards for wetlands, and direct aquifer recharge standards. Greywater standards may not currently be comprehensive but year-end adoption of the Greywater Reuse Rule should change this.

Impending Water Policy Changes/ Conditions to Address Issue
Reclaimed Water Use Amendments
The Washington State Legislature enacted ESHB 2884 in 2006 and E2SSB 6117 in 2007 to amend Chapter 90.46 RCW (Reclaimed Water Use). These amendments state that the Department of Ecology is responsible for creating and implementing rules for reclaimed water use by December 31, 2010. The Department of Ecology is also partnering with the Department of Health and the Department of Agriculture to identify stakeholder groups with knowledge of new technology advancements. The purpose of this legislation is to remove barriers to using reclaimed water, which will contribute to conservation.

Greywater Reuse for Subsurface Irrigation, Draft Chapter 246-274 WAC
This rule would "establish requirements that provide building owners with simple, cost-effective options for reusing greywater for subsurface irrigation" (Washington State DOH, 2010 draft). The draft is required to be adopted by the end of 2010. Systems covered under the rule include those with design flows of no more than 3,500 gallons per day. The greywater must not come in contact with any edible parts of the plants which are being irrigated.

Technology/Policies Needed
Examples of systems that address water recycling and reuse include greywater reuse and toilet-to-tap. Systems that will not be affected by freezing conditions will also be necessary.

Availability of Technology
Other water reuse/recycling technologies include:

- Wastewater biofiltration systems
- Membrane bioreactor technology for water reuse
- Low-pressure membranes
- Advanced water filtration for reclaimed water systems

Key Issue: Drought and Climate Change

Key Dimensions
Washington is also facing sustainable use problems because the eastern half of the state receives only 5 to 8 inches of rain annually, and most water used comes from melting snowpack. Drought is a common occurrence when snowpack levels are low, and climate change is threatening to increase drought. By 2040, 35 to 41% declines in snowpack are expected (Booth, 2008). This will cause severe water shortages and force the state to find other sources of water.

Action Needed
Washington's reliance on snowpack for drinking water means that water storage infrastructure will need to be expanded to ensure that water shortages are not severe during conditions of drought. Additionally, though Western Washington receives high annual rainfall, it is still prone to water shortages because current reservoirs and dams cannot hold enough rainfall to meet the needs of growing populations. Water conservation will thus also be important in lessening the severity of drought.

Current Approach
In 2005, the state spent $8 million on drought mitigation and exhausted its drought relief reserve account (Gregoire wants $4M, 2010). Therefore, Washington will have difficulties in providing future drought relief unless it can obtain more funds. In March 2010, Governor Christine Gregoire appealed to the Washington State Legislature for $4 million to support the exhausted reserve account. The Legislature approved the funding, but it can only be used when a drought emergency is authorized.

A Climate Change Adaptation Group meets occasionally to address how to adapt policies addressing issues such as global warming-related drought and saltwater intrusion from rising sea levels.

Impending Water Policy Changes/ Conditions to Address Issue
Washington State H.B. 1303 was passed in April, 2007. It required the comprehensive evaluation of the effects of climate change and effects on water supply were to be required in the report (The Climate Impacts Group, 2009). The resulting "Washington Climate Change Impacts Assessment" determined that the uncertain nature of climate change will mean that creation of policy and regulation will need to have greater flexibility in the future.

Technology/Policies Needed
Though there are not any impending water policy changes, Washington will need drought monitoring technology if any future policies are implemented. Barriers to halt or slow saltwater intrusion will also be needed.

Availability of Technology
Injection wells which constitute freshwater barriers have been used in states like California and Texas to protect against saltwater intrusion.

Key Issue: Aging Water Infrastructure

Key Dimensions
Aging infrastructure can cost more money to maintain than new infrastructure. Aging infrastructure can mean less efficient water treatment, leaking pipes, and groundwater contamination. Approximately 60% of communities in Washington will need to replace part or all of their water distribution systems in the next 10 years. In addition, over 50% will need to replace portions of pump stations and collection systems during the same timeframe (Association of Washington Cities, 2008). Leaking septic systems also contribute to groundwater contamination and stormwater runoff.

In 2008, the EPA released cost estimates of water infrastructure that will be needed for the state in the near future in 2008 in millions (U.S. Environmental Protection Agency, 2008):

- Wastewater:
  - Wastewater treatment: $2.4 billion
  - Pipe repair and new pipes: $1.8 billion
  - Recycled water distribution: $140 million
  - Combined sewer overflow correction: $584 million
    - Total: $4.9 billion
- Stormwater Management:
  - Conveyance infrastructure: $225 million
  - Treatment systems: $47 million
  - Green infrastructure: $35 million
  - General stormwater management: $23 million
    - Total: $329 million

More recently, the EPA has suggested that upgrades and replacement of water infrastructure over the next 20 years may total $.9.7 billion (Washington State Department of Health, 2010).

Action Needed
Washington will need to begin replacing aging water infrastructure and wastewater treatment technology with more cost-efficient and energy-efficient technology that conserves water. Wastewater treatment and pipes have the highest monetary needs but priority should be given to structures and systems which are in the poorest structural shape.

Current Approach
Twenty one drinking water systems in the state are receiving $38.5 million in funding from the 2009 American Recovery and Reinvestment Act (ARRA) (Washington State Department of Health, 2010). The loans are low-interest and will be used to rectify serious health threats posed by these systems. Projects examples are replacement of a failing reservoir, rehabilitation of another reservoir, upgrades to water treatment plants, and construction of an arsenic treatment facility.

Impending Water Policy Changes/ Conditions to Address Issue
The state currently does not have policies in place to address aging infrastructure. However, it will need to begin determining the severity of the problem and ensure that funding is available to replace pipes, plants, and other infrastructure that pose a threat to individuals due to their deteriorated condition.

Technology/Policies Needed
In June 2008, the Carnation Wastewater treatment plant in King County was dedicated. The plant uses a membrane bioreactor (MBR) system which has pores small enough to filter individual bacteria (http://www.kingcounty.gov/environment/dnrp/newsroom/newsreleases/2008/june/0602CarnationDedication.aspx). Wastewater will be treated at such a high level that reclaimed water will be used to replenish a nearby wetland. The plant also ends the reliance on aging, leaking septic systems in that area.

Leak detection technology will also be necessary because it will help in the prioritization of repairs and replacements to aging infrastructure.

Availability of Technology
There are number of available technologies that aid in the detection of water leaks. These include:

- Continuous acoustic monitoring
- Advanced metering infrastructure communication
- District Metered Areas (DMAs) for audit and leak control
- Pressure monitoring
- GIS analysis

Key Issue: Contaminated River and Lake Sediment

Key Dimensions
High levels of contaminated sediment can be deadly to aquatic life and dangerous to humans and other animals which consume aquatic organisms or come into direct contact with the sediment.

In 2007, there were 150 sediment cleanup locations in the state, and 115 of these sites were in the areas surrounding Puget Sound. The Washington State Department of Ecology’s Sediment Cleanup Status Report (2008a) estimates that there are 3,902 acres of contaminated sediment around Puget Sound.

Examples of contaminants in the sediment include (Washington State DOE, 2004):

- 2, 4-Dimethylphenol
- 2-Methylnapthalene
- Arsenic
- Copper
- Fluorine
- Mercury
- Phenol
- Pyrene
- Zinc

Action Needed

The cost to clean the contaminated sediment across the 150 cleanup locations in the state was estimated to be between $436 million and $1.86 billion (Washington State Department of Ecology, 2008a). Point source pollution needs to be identified and controlled, as this measure could be less costly than cleanup.

Current Approach

The South Puget Sound Dissolved Oxygen Study is tracking the migration of nutrients such as nitrogen and phosphorus throughout the surface water (Washington State Department of Ecology, 2009 draft). The next step is to determine nutrient loads at various points through Puget Sound.

In 1993, the Washington State Department of Ecology (DOE) created the Watershed Approach to Quality Management framework._The state was divided into 23 Water Quality Management Areas (WQMAs) "and a five step process for systematically issuing permits, assessing water quality conditions, focusing staff effort, and developing and improved basis for decision making in each WQMA" (Washington State Department of Ecology, 2008b).

Each WQMA has a continuous cycle of five steps, which are one year each. These steps include identification of water quality issues, data collection, data analysis, development of a technical report, and implementation.

In 1994, WA made it illegal to sell laundry detergent with phosphorus content greater than 0.5% by weight and dishwashing detergents with greater than 8.7%. Additionally, Washington State Senate Bill 6289 would reduce phosphorus from lawn fertilizers but won't affect fertilizer for agricultural uses (S. 6289) (http://apps.leg.wa.gov/documents/billdocs/2009-10/Pdf/Bill%20Reports/Senate/6289%20SBR%20EWE%2010.pdf)
As of July 2010, dishwashing detergent statewide is not allowed to have greater than 0.5% phosphorus.

Impending Water Policy Changes/ Conditions to Address Issue

Federal Lead and copper rule short-term revisions (Group A Public Water Systems, Chapter 246-290 WAC) "provides a more effective approach of reducing exposure to lead in drinking water" (Washington State Department of Health, n.d.). The federal requirements must be adopted by October 2011.

Technology/Policies Needed
Tertiary wastewater treatment will be an important technology in Washington, as this type of treatment removes contaminants that were missed by secondary treatment. Examples of current tertiary treatments include:

- Activated carbon adsorption
- Ion exchange
- Membrane filtration and separation
- Physical/Chemical treatment
- Reverse osmosis
- Ultraviolet disinfection

Availability of Technology
Technologies available to address surface water contamination in Washington include:

- Chemical control of nutrients in wastewater treatment plants
- Aerobic and anaerobic biological processes to mitigate heavy metal contamination
- Mercury mitigation
  - Stannous chloride reagent for in-situ air stripping
  - Slow release sequestrants - encapsulated nano-particles
  - Sodium thiosulfate to control methylation
- Technology for further reduction of atmospheric mercury emissions from power plants

Key Issue: Stormwater Runoff Contamination, Flooding, and Combined Sewer Overflows

Key Dimensions
Stormwater Runoff
Stormwater runoff contamination is especially problematic in urban areas, such as Seattle. Stormwater contaminants include lead, petroleum, mercury, and copper. It is estimated that thousands of pounds of copper from brake pads enter Washington water bodies every year (http://apps.leg.wa.gov/documents/billdocs/2009-10/Pdf/Bills/Senate%20Passed%20Legislature/6557-S.PL.pdf). Copper is problematic because it decreases the sense of smell in salmon and other species of fish.

Sustainable Conservation found that brake pads in vehicles were the largest contributors of copper to waterways in the San Francisco Bay Area (http://www.suscon.org/bpp/index.php). Many of the areas surrounding Puget Sound are heavily urban, so It is likely that brake pads also are the main contributor of copper to Puget Sound. The other sources of copper in Puget Sound are oil refineries and pulp and paper mills (LaLiberte & Ewing, 2006).

Approximately 26,600 gallons of water per year run off the roof of a single home in the Puget Sound region, into gutters and streams (Stiffler & de Place, 2010). There are approximately 1.5 million homes in the state, so there may be 39.9 billion gallons of stormwater annually, across the state. This figure would not include runoff from commercial and industrial buildings. It is estimated that $250 million per year is spent on the control and cleanup of stormwater pollution.

Flooding
From 1956 to 2006, there have been 30 Presidential Disasters declared for floods in the state (Washington Military Department Emergency Management Division, 2007). Since 1970, every county has received at least one of these declarations for flooding. Approximately 2.5% of the state's land area is comprised of floodplains and 100,000 homes are within these floodplains. Several rivers in the state flood every two to five years, including the Snohomish, Skagit, Puyallup, Spokane, Yakima, and Walla Walla.

Untreated Sewage and CSOs
Statewide combined sewer overflow figures have decreased from 3.3 billion gallons per year in 1988 to 1.3 billion gallons per year in 2002 (Washington DOE, 2002).

King County averaged 665.5 million gallons annually in combined sewer overflows from 2000 to 2007 (Washington State DOE, 2010). This amount was down from an average of 2.3 billion gallons in 1983. Plants managed by Seattle have been responsible for approximately 249 overflows, while plants managed by King County has been responsible for approximately 87 overflows per year (U.S. Environmental Protection Agency, 2009).

Fecal coliform is a main concern when considering contaminants in combined sewer overflows. On average, there are 10^7 to 10^9 colony-forming units (cfu) per 100 ml (Wang et al., 2004). In contrast, treated water contains 10^4 to 10^6 cfu/ 100 ml.

- Other contaminants include (King County Department of Natural Resources, 1999):
  - 1, 4-dichlorobenzene
  - Arsenic
  - Bis(2-ethylhexyl) phthalate
  - Copper
  - Lead
  - Mercury
  - Polycyclic Aromatic Hydrocarbons (PAHs)
  - Polychlorinated Biphenyls (PCBs)
  - Tributyltin (TBT)
  - Zinc

Action Needed
Because stormwater runoff is a major problem in urban areas of Washington, it will be important to enact more stringent stormwater rules and regulations. Best management practices should be promoted, including:

- Green roofs
- Bioswales
- Pervious pavement
- Rain barrels and cisterns

It may also be important to improve and expand municipal sewer systems to reduce the possibility of combined sewage overflows during periods of heavy rainfall.

Western Washington and Eastern Washington have their own stormwater management manuals.

- The manual for Western Washington can be found at: http://www.ecy.wa.gov/programs/wq/stormwater/manual.html#How_to_Find_the_Stormwater_Manual_on_the
- The stormwater management manual for Eastern Washington can be found at: http://www.ecy.wa.gov/biblio/0410076.html

Current Approach

Low impact stormwater management techniques are one current solution to curbing stormwater runoff. In 2008, the state ordered Seattle, Tacoma, King County, Pierce County, and Snohomish County to utilize low-impact development approaches whenever possible (http://www.martenlaw.com/newsletter/20080903-stormwater-mgmt-techniques). The University of Washington's Water Center has also published nine studies since 1998 on stormwater best management practices (http://water.washington.edu/Research/stormwater.html#bmps).

The Water Pollution Control Act (Chapter 90.48 RCW) was amended in 1985. This required municipalities to develop plans and deadlines for reducing combined sewer overflows (Washington DOE, 2002). In 1987, Chapter 173-245 WAC was implemented, which stated that municipalities should strive to have no more than one combined sewer overflow per year.

The state has handed out fines for violations in the past. For example, in 2010, the Washington State Department of Ecology fined King County $46,000 for 46 violations at four treatment plants from September 2009 to April 2010 (Washington State DOE, 2010). These violations included failure to adhere to contaminant limits, as well as failure to sample and monitor water from time to time.

King County plans to spend $388 million in stormwater and sewer system improvements through 2030. By contrast, the Milwaukee Metropolitan Sewerage District (MMSD) has averaged 1.21 billion gallons in combined sewer overflows from 2000 to 2009 and has spent over $4 billion to reduce overflows (http://v3.mmsd.com/Overflow.aspx). The Overflow Reduction Plan is in progress, at a cost of $1 billion. The major component of the plan is the construction of two new tunnels which will add a total of 116 gallons of additional capacity.

Impending Water Policy Changes/ Conditions to Address Issue

On March 8, 2010, the Washington State Senate approved SB 6557, making the state the first to place restrictions on the amount of copper in brake pads (http://apps.leg.wa.gov/documents/billdocs/2009-10/Pdf/Bills/Senate%20Passed%20Legislature/6557-S.PL.pdf). Beginning January 1, 2021, the sale of brake pads containing five percent or more of copper or copper compounds will be banned.

Technology/Policies Needed

Policies are needed which limit the amount of discharged sewage from combined sewer overflows. As a result, areas such as King County will likely need to spend far more than the $388 million that it has planned for improvements through 2030. If urban areas create deep tunnel systems, cost-effective boring technology, soil retention systems, and pipes will be needed. Sewer flow monitors are also likely to be needed so that adequate precautions can be taken during periods of heavy rainfall.

Availability of Technology
Available stormwater mitigation technologies include:

- Bio-retention ponds and bioswales
- Green roofs
- Rain barrels and rain gardens

Technology to address combined sewer overflows includes:

- Sewer flow monitors
- Bed pipe barriers to reduce the concentration of suspended solids around mining sites
- Settling ponds

Key Issue: Inadequate Groundwater Controls and Monitoring of Aquifers

Key Dimensions
Washington has a lack of groundwater limits and controls, as well as inadequate monitoring of aquifer levels and quality. The Washington State Department of Natural Resources stated that there is no comprehensive program for monitoring groundwater across the state (http://www.dnr.wa.gov/Publications/fp_hcp_feis_ch3.pdf). Current groundwater monitoring varies in methods of measurement and data quality and most of these monitoring stations only measure parts of the major aquifers in the state.

Currently, there are 9 main groundwater quality monitoring programs and 11 main groundwater level monitoring programs (http://www.ecy.wa.gov/programs/eap/groundwater/programdescription.html). Examples of existing programs include:

- Clark County
  - Water quality: Samples are taken quarterly from 29 private and public wells and tested for nitrate, inorganic compounds, and volatile organic compounds.
  - Water quantity: There are 130 private and public wells which are monitored.
- Spokane Valley Aquifer
  - Water quality: There are 15 public supply wells and 26 monitoring wells which are tested for:
    - pH (acidity and basicity)
    - Temperature
    - Calcium
    - Chloride
    - Sulfates
    - Dissolved solids
    - Total phosphorus
  - Water quantity: A total of 26 monitoring wells are tested.

Action Needed
There are 36 watersheds in the state with water plans but a statewide plan does not exist (Colo. Gov. says western, 2009). Brian Walsh of the Washington State Department of Ecology was quoted as saying that some areas of the state are still resistant to water planning. A statewide plan would provide comprehensive guidelines and recommendations that would be easier to implement and interpret than those resulting from regional and city plans. There does not seem to be a high amount of pressure to expand groundwater monitoring programs at this time.

Current Approach
The Groundwater Permit Exemption RCW 90.44.050 allows certain individuals to build wells without obtaining a permit (http://www.ecy.wa.gov/programs/wr/comp_enforce/gwpe.html). Individuals or groups that are not required to apply for a permit are those who are:

- Using water for livestock (no daily water limit applies)
- Watering a private lawn or garden of less than one half acre (no limit)
- Using water to serve one or several homes (5,000 gallon per day limit)
- Using water for industry or irrigation (5,000 gallon per day limit without an acre limit)

The Washington State Department of Ecology has nine groundwater quality monitoring programs and 11 groundwater level monitoring programs (http://www.ecy.wa.gov/programs/eap/groundwater/programdescription.html). These programs vary in size and range. For example, the Columbia Basin Groundwater Management Area performs baseline monitoring of wells every two years to measure nitrate levels while Island County (Whidbey and Camano Islands) take samples from 50 to 100 wells twice per year to measure potassium, magnesium, sulfate, sodium, nitrate, and arsenic levels.

King County is one site that measures groundwater level. Measurements are taken when private domestic wells are inspected. Pierce County measures water levels monthly in over 190 wells.

Impending Water Policy Changes/ Conditions to Address Issue
Groundwater Rule
The EPA's October 2006 Groundwater Rule is an extension of the Total Coliform Rule, which is intended to reduce fecal contamination in public groundwater sources (Washington State Department of Health, 2009) "The basic requirements of the Groundwater Rule include:

- Source water monitoring (triggered and assessment).
- Compliance monitoring.
- Sanitary surveys and corrective actions.
- Public notification."

The Washington State Department of Health is required to finish its own rulemaking and to adopt the federal rule by November 2010. The summary of rule changes states that there will be additional water quality monitoring and "increased frequency of sanitary surveys" but no mention is made of how often future monitoring would occur (http://www.doh.wa.gov/ehp/dw/RULES/GWR_summary.pdf).

Technology/Policies Needed
Groundwater monitoring technologies are necessary for the state. An example of a newer technology related to groundwater monitoring is direct push technology (DPT). DPT involves inserting hollow steel rods into the ground. Tools and probes can be attached to the ends of these rods for the collection of ground and groundwater samples, as well as continuous monitoring (U.S. Environmental Protection Agency, 2005).

Availability of Technology
Available groundwater monitoring technologies include:

- Real-time monitoring
- Multiple site/strata monitoring
- Web-enabled networked systems linked by RF or cellular technology
- Automated systems that do not rely on operator interpretation to determine results
- Units that monitor multiple contaminant classes: biological, chemical, and radioactive

Washington References

Association of Washington Cities (2008). *Washington's infrastructure in crisis*. Retrieved from http://www.awcnet.org/documents/WAInfrastructureInCrisis.pdf

Booth, D.B. (2008). Climate change impacts on water infrastructure – A Washington State update. *University of Washington and Stillwater Sciences, Inc.*

Col. Gov. says western water policies must change (2009, September 29). *The Seattle Times*. Retrieved from http://seattletimes.nwsource.com/html/localnews/2009966642_apuswatercolorado2ndldwritethru.html

Gregoire wants $4M for drought relief reserve fund (2010, March 1). *Puget Sound Business Journal*. Retrieved from http://bizjournals.com/seattle/stories/2010/03/01/daily6.html

Hermanson, R. E. (1991). Washington groundwater: A vital resource. *Clean Water for Washington*. Retrieved from http://cru.cahe.wsu.edu/CEPublications/eb1622/eb1622.html

King County Department of Natural Resources (1999). *King County combined sewer overflow: Water quality assessment for the Duwamish River and Elliott Bay*. Retrieved from: http://your.kingcounty.gov/dnrp/library/wastewater/cso/docs/WQA/80165-LAYOUT.pdf

LaLiberte, D., & Ewing, R. D. (2006, April 17). *Effects on Puget Sound Chinook salmon of NPDES authorized toxic discharges as permitted by Washington Department of Ecology*. Retrieved from http://www.ecy.wa.gov/programs/wq/stormwater/municipal/public_comments_final_draft/06bpublicemployeesforenvironmentalres.pdf

Stiffler, L. (2009, November 23). Water pollution enemy is us. *Sightline Daily*. Retrieved from http://daily.sightline.org/daily_score/archive/2009/11/23/stormwater

Stiffler, L., & de Place, E. (2010, January 21). Curbing stormwater pollution: Cleaning up Washington's toxic runoff. *Sightline Institute*. Retrieved from http://www.sightline.org/research/pollution/res_pubs/stormwater.pdf

The Climate Impacts Group, University of Washington (2009). *The Washington climate* *change impacts assessment: Evaluating Washington's future in a changing climate (Executive Summary)*. Retrieved from http://www.cses.washington.edu/db/pdf/wacciaexecsummary638.pdf

U.S. Department of the Interior, Bureau of Reclamation (2008). *Odessa Subarea special study. Environmental impact statement.* Retrieved from http://www.usbr.gov/pn/programs/ucao_misc/odessa/sept2008-scoping/report-scoping11-08.pdf

U.S. Environmental Protection Agency (2004). *Guidelines for water reuse*. Retrieved from: http://www.ehproject.org/PDF/ehkm/water-reuse2004.pdf

U.S. Environmental Protection Agency (2008). *Washington clean watersheds needs survey 2008*. Retrieved from: http://www.epa.gov/cwns/wa08.pdf

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response (2005). *Groundwater sampling and monitoring with direct push technologies*. Retrieved from http://www.clu-in.org/download/char/540r04005.pdf

U.S. Environmental Protection Agency (2009, August 26). Seattle and King County agree to step up efforts to reduce sewer overflows to Puget Sound [News Release]. Retrieved from http://yosemite.epa.gov/opa/admpress.nsf/0/EABE4B202B37FC9B8525761E0067E36F

Wang, P.F., Johnston, R. K., Halkola, H., Richter, R. E., & Davidson, B. (2004). *A modeling study of combined sewer overflows in the Port Washington narrows and fecal coliform transport in Sinclair and Dyes Inlet, Washington*. Retrieved from http://www.ecy.wa.gov/programs/wq/tmdl/sinclair-dyes_inlets/sinclair_cd/Reports/FC_TMDL_STUDY_REPORT/Appendices/AppendixF_CSO_modeling_study.pdf

Washington Military Department Emergency Management Division (2007). *Hazard profile – Flood*. Retrieved from http://www.emd.wa.gov/plans/documents/FloodNov2007Tab5.5.pdf

Washington Rivers Conservancy (n.d.). *Before the well runs dry: Water solutions for Washington*. Retrieved from http://www.warivers.org/WaterBroFinal.pdf

Washington State Department of Ecology (2002). *Focus. Combined Sewer Overflows (CSOs)*. Retrieved from http://www.ecy.wa.gov/pubs/0010080.pdf

Washington State Department of Ecology (2004). *2004 water quality assessment (final) – Category 4B sediment listings*. Retrieved from http://www.ecy.wa.gov/programs/wq/303d/2002/2004_documents/sedimentpdfs1105/sediment110205cat4b.pdf

Washington State Department of Ecology (2008a). *Sediment cleanup report*. Retrieved from http://www.ecy.wa.gov/pubs/0809046.pdf

Washington State Department of Ecology (2008b). *An overview of Washington State's watershed approach to water quality management*. Retrieved from http://www.ecy.wa.gov/programs/wq/watershed/overview.html#fivestep

Washington State Department of Ecology (2009 draft). *South Puget Sound dissolved oxygen study: South and Central Puget Sound. Water circulation model development and calibration*. Retrieved from http://www.ecy.wa.gov/programs/eap/mar_wat/Documents/SPScirculationrpt_extrevdraft_101509.pdf

Washington State Department of Ecology (2010, June 17). King County fined for

combined sewer overflow violations. [News Release]. Retrieved from http://www.ecy.wa.gov/news/2010news/2010-139.html
Washington State Department of Health (n.d.) *Rule revision to begin. Federal Lead and Copper Rule short-term revisions*. Retrieved from http://www.doh.wa.gov/ehp/dw/RULES/CR101_lead_copper.pdf
Washington State Department of Health (1997). *Water reclamation and reuse standards*. Retrieved from http://www.ecy.wa.gov/programs/wq/reclaim/advisorycommittee/standards.pdf
Washington State Department of Health (2009). *What you need to know: Groundwater Rule (GWR)*. Retrieved from http://www.doh.wa.gov/ehp/dw/Publications/331-447.pdf
Washington State Department of Health (2010 draft). *Draft rule chapter 246-274: Greywater reuse for subsurface irrigation*. Retrieved from http://www.doh.wa.gov/ehp/ts/ww/greywater/rule/draft246-274.pdf
Washington State Department of Health (2010). *Water funds stimulate Washington communities*. Retrieved from http://www.doh.wa.gov/ehp/dw/pdf/ARRAfunds.pdf

2.11 Wisconsin

Key Markets	Niche Markets
Agriculture	Phosphorus-free fertilization methods; phosphorus control mechanisms; treatment/reuse methods (digesters) for animal waste from CAFOs; monitoring technology
Wastewater Treatment	Pharmaceutical removal technologies; more effective phosphate removal/harvesting technologies; utilization of sewer sludge
Nitrate/phosphate contamination	Technologies more tightly incorporating nutrient recovery technologies into waste treatment processes; alternatives corrosion control mechanisms for pipes in homes (to prevent copper and lead leaching)
Invasive species	Technology facilitating removal of invasive species from ship hulls; ballast water disinfection technologies; technologies inhibiting spread of invasive species between bodies of water (biological, electrical, mechanical barriers, etc.)

Population Indicators

	2009 (est.)	2015	2030
Urban Population	4,338,362	-	-
Rural Population	686,386	-	-
Total	**5,654,748**	**5,882,760**	**6,420,000**

http://www.bcnys.org/whatsnew/2005/0420censuspoptable.htm

Economic Indicators

Total GSP: $216,322 (in millions)
US Rank: 21
World Rank: 46
GSP per capita: $36,822 USD (*US average - $39,138*)
http://en.wikipedia.org/wiki/Comparison_between_US_states_and_countries_by_GDP_(PPP)

Water Use
Average per capita daily use (*domestic*): 57g (US avg. = 90g)
* USGS, 2005

Withdrawals *(in thousand acre-feet per year)*

	Fresh	Saline	Total
WI Withdrawals	36,800	14,400	51,300

Summary of Key Issues
- Phosphorus in Water
- Storm water control & decontamination

- Invasive species
- Mercury contamination

Background
With over **330 watersheds** in the state, including the large population centers within the Lake Michigan Basin in the eastern region of the state, Wisconsin in a state flush in water. Nevertheless, real challenges face the state in light of climate change, increasing strain on state aquifers, as well as significant sources of point and non-point pollution throughout the state, among others. Although 25% of Wisconsin's residents enjoy the benefits of fresh water from the Lake Michigan Basin, the other **75% is dependent upon groundwater** for daily domestic needs and fully **95% of state municipalities depend on such sources for public water supplies**. Almost all water dedicated to agriculture in the state, one-third of industrial water, and half of commercial water in the state is pulled from groundwater sources.

A breakdown of water resources in Wisconsin includes:
- 6.4 million acres share of Lakes Michigan and Superior
- 95,000 acres share of the Upper Mississippi River
- More than 15,000 lakes (3% of Wisconsin's area)
- More than 13,500 miles of navigable streams and rivers
- 1.2 million billion gallons of water underground

Some 24% of WI residents live within the three southeastern coastal counties of Milwaukee, Racine and Kenosha. Fully one-third of WI residents live within the eleven counties forming its Lake Michigan coast.

With the recent passage of the Great Lakes Compact, inter-basin transfers from the Lake Michigan Basin are no longer a viable alternative to depleted groundwater sources for most communities and conservation is sure to play an increasingly important role in the state. The city of Waukesha, located west of the city of Milwaukee and outside of the Lake Michigan Basin, has recently submitted a request for transfer of Lake Michigan water, but such an agreement would require strict provisions for the treatment and return of water used, as well as levies for the communities enabling the transfers. Even so, all signing members would have to agree to such a transfer and, given the potential for establishing a dangerous precedent, it is not entirely clear that this will happen. Deficient applications have now twice been sent back to the city by the Wisconsin DNR for future revision.

The estimated population residing within the Lake Michigan Basin is over 10 million, primarily residing in the Milwaukee-Chicago corridor. The population of the entire Great Lakes Basin as a whole is estimated to be some 33 million (slightly more than one-tenth of the total US population).

Projected 20-year Need (Drinking Water Infrastructure)
A survey of water infrastructure needs by the US EPA identified the following needs in Wisconsin: transmission/distribution = $3,550.5M; Source = $385.1M; Treatment = $1,467.5M; Storage = $758.7M; Other = $24.2M; Total = $6,186M (2007)

Projected 20-year Need for Community Water Systems (CWS) Serving 10,000 residents or fewer

CWS's Serving 10,000 or Fewer People	
Transmission/Distribution	$1,193.0M
Source	$168.1M
Treatment	$459.3M
Storage	$290.7M
Other	$14.5M
Total 20-year need of CWS's serving 20 people or fewer	$2,125.6M
Total 20-year need of all CWS	$5,702.6M
% of CWS need related to systems serving 10,000 or fewer persons	37.3%

Source: EPA Drinking Water Infrastructure Needs Survey and Assessment 2007
http://wi.water.usgs.gov/lmmcc/workgroups/geninfo/lmmn.gw.draft.html

Global Compact City
In 2009, Milwaukee, Wisconsin's largest city, was designated a U.N. Global Compact City, still only one of only 14 such cities worldwide.

The list of projects pledged in Milwaukee's application include:
- Research to reduce algae in Lake Michigan and use algae as biofuel
- Disinfecting storm-water runoff and desalination of winter road salt
- Seeking new efficiencies in wastewater treatment
- Removing radium from groundwater (advancing a pilot project that began in 2009 in Waukesha)

Great Lakes Compact
The DNR is required to establish statewide administrative rules for the implementation of the Great Lakes Compact. Proposed rules are:

- **Natural Resources Chapter NR 856** (*statewide*) – *Water Use Registration and Reporting*: defines who must register and annually report water use to allow for a better understanding of the amount, location and use of withdrawals. Would affect those with the capacity to withdraw more than 100,000 gallons per day or in more in any 30-day period, as well as those diverting any amount of water from the Great Lakes Basin

  Examples of persons that would be affected by such a rule include public water systems, high capacity well owners, and certain people withdrawing water from lakes and streams **Note:** *100,000 gallons per day is equivalent to 70 gallons per minute operated for 24 hours per day)*

Key Elements of Rule:
Registration

a) Any person in state who has or proposes to have a water supply system with the capacity to withdraw an average of 100,000 gallons per day or more in any 30-day period or who diverts water in any amount from the Great Lakes Basin is required to register with the DNR
b) The rule sets forth procedures and information required for registration

Measurement

a) Any person registered must measure the volume of water withdrawn every month
b) The rule identifies a range of options for measuring withdrawals including an option that allows for tailoring a measurement process on a case by case basis for challenging situations like aquaculture facilities
c) The purchase of new metering devices is NOT required by the rule

Reporting

a) Any person in the state who withdraws an average of 100,000 gallons per day or more in any 3-day period or who diverts any amount from the Great Lakes Basin must annually report to the DNR their monthly volumes of withdrawal or diversion
b) Reporting for each calendar year is required by March 1 the following year
c) The rule provides flexibility in how the information is collected to help eliminate duplication of report to the DNR

- **Natural Resources Chapter NR 850** – *Water Use Fees*: establishes fees to be paid by those withdrawing more than 50 million gallons per year from the Great Lakes Basin. Fee would be in addition to $125 annual fee established by Wisconsin law for all registered water withdrawers statewide. Persons affected by this rule could include large dairy operations, public water systems and power companies.

Key Elements of Rule:
The rule establishes fees based on an increasing block rate structure. The fee increases as the withdrawal amount increases. Fee revenue will be used for Great Lakes Compact related programs including:

a) Building a water resources inventory
b) Developing methods to monitor groundwater and surface water quantity and to assess the impacts of withdrawals
c) Implementation of the registration, reporting, permitting and all other related requirements of the Compact

- **Natural Resources Chapter 852** - *Water Conservation and Water Use Efficiency*: establishes water conservation requirements that will be mandatory in the Great Lakes Basin for water users seeking new or increased withdrawals or diversions. Will also be mandatory in rest of state for water users with losses exceeding 2 million or more gallons per day in any 30-day period

Key Elements of Rule:

a) Water conservation not required for existing facilities at their current level of water withdrawal
b) Rule categorizes withdrawals and diversions into one of three tiers. The conservation requirements increase with each tier
c) CEMs that involve retrofitting are optional

The level of water conservation and efficiency requirements would increase from **Tier 1** to **Tier 2** to **Tier 2** to **Tier 3**:

– **Tier 1**: Includes new and increased withdrawals in the Great Lakes Basin that average 100,000 GPD or more in any 30-day period but that do not equal at least 1,000,000 GPD for any 30 consecutive days
– **Tier 2**: includes new and increased withdrawals in the Great Lakes Basin that equal 1,000,000 GPD or more for any 30 consecutive days
– **Tier 3**: includes new and increased diversions in a community or county that straddles the sub-continental divide and new and increased withdrawals statewide that would result in a water loss averaging more than 2,000,000 GPD in any 20-day period

4 Basic Conservation and Efficiency Measures

1) Conduct a water audit
2) Develop a leak detection and repair program
3) Educate staff or customers about water conservation activities
4) Measure all sources of water

http://www.dnr.state.wi.us/org/water/dwg/greatlakes/FinalRules_Factsheet_June2010.pdf
http://beta.thehindu.com/sci-tech/agriculture/article442770.ece

Key Issue: Agriculture - Manure Fertilizer Contamination/CAFO Pollution

Key Dimensions

- Number of large permitted dairy farms in Wisconsin grew from eight in 1995 to 154 by the end of 2009
- Some farms produce as much waste as small cities (a single cow produces about as much waste as 18 people). However, unlike cities, most large farms dispose of manure by spreading it on fields; only about 25% of large farms in WI use digesters or treatment systems
- In Brown County alone, dairy and livestock operations produce more than 551 million gallons of waste per year, with an additional 41 million gallons of animal byproduct spread on fields as fertilizer; in 2006, some 100 private wells in Brown County were contaminated by spring runoff
- Although the number of farms in the state has decreased, an increase in the number of Concentrated Animal Feeding Operations (including farms with at least 1,000 animals) has meant no decrease in the total number of animals

- According to an investigation by the Wisconsin State Journal, little oversight is provided for these large operations, with inspections being performed once or twice every five years
- By the end of 2010, nearly 200 mega farms will have been permitted to open or expand in the state of Wisconsin
- The Department of Natural Resources has not turned down a single application for such operations in the seven years since they first fell under its jurisdiction (Michigan and Illinois have when threats to water quality have been identified), nor has it revoked a permit once granted
- The farms are an important contributor the state's $26.5B/year dairy sector
- Review of the state's oversight of such operations has revealed a lack of inspection and monitoring (much of which is done off-site via paperwork)

Action Needed

- Stricter permitting process with an eye to CAFO effects on water supply and security
- Better, on-site monitoring; more regular review and inspection of existing operations
- Increased fees for permits (currently $345 for 5 year permit; comparable permits for municipalities run into the thousands)

Current Approach

- Digesters; treatment systems
- WI state law prohibits the application of liquid manure during winter months, thus limiting runoff accompanying thawing events in late winter/spring (the result of a particularly heinous contamination event in Brown County in 2006 in which over 100 private wells were contaminated and individuals hospitalized)
- Furthermore, the DNR has codified performance standards, including the following areas:
  - Manure management prohibitions
  - Nutrient management
  - Manure storage

Impending Water Policy Changes/Conditions to Address Issue

- Technical standards used in permitting new or expanding livestock operations will be reviewed by a Livestock Siting Technical Expert committee named by former Secretary Rod Nilsestuen, Wisconsin Department of Agriculture, Trade and Consumer Protection. The technical committee has been convened to review water quality, odor, runoff management and other standards used by local governments in permitting livestock operations under the Livestock Facility Siting Law. (6/17/2010)

  Items to be considered by this committee include:
  - Livestock structures and their location on the property which would include structural and manure storage setbacks from property lines.
  - Odor and air emissions including an assessment of odor credits for structures and manure handling practices.
  - Nutrient management which includes identifying required documentation within the nutrient management plan.
  - Waste storage facilities as well as clarifying waste generation calculations.

- Runoff management including the consideration of federal standards for controlling leachate from stored feed.
- Determining the completeness of the application materials for a siting permit.

Technology Needed

- Digesters/processes that can effectively and safely treat and dispose of large amounts of animal waste
- Field-embedded real-time sensor networks for nutrient and chemical sampling
  - Higher spatial resolution
  - Timely data acquisition
- Sensor network control of variable rate fertilizer application equipment
- Real-time nutrient mixing and balancing
- Synthetic nutrient balancing of natural fertilizers to control excess phosphorus
- "Toilet to field" systems for the production of clean sewage sludge for agricultural use

Availability of Technology

- **Anaerobic Digesters -** although technologies such as anaerobic digester are already available, they do not resolve the issue of applying fertilizer to farmland, as the final waste product still must be disposed of. Digesters also fail to solve issues related to the presence of contaminants in the waste.

Sources:
http://www.energyjustice.net/digesters/
http://aqua.wisc.edu/waterlibrary/Default.aspx?tabid=74

Key Issue: Groundwater/Surface Water - Contaminants Entering Waterways

Key Dimensions

- Nitrate is the most common contaminant found in WI groundwater, its primary source being fertilizer used for agricultural purposes
  - More than 2 billion lbs of nitrate is added to WI soil annually
  - 80% of that amount comes from commercial fertilizers, manure and legumes
  - Nitrate levels have been found to exceed state and federal standards in 10% of private wells sampled
  - 15 WI municipalities must treat water to reduce nitrate levels
- Phosphates are also a primary concern in WI because of the algae blooms and associated eutrophication they can cause, devastating to both recreational and commercial uses of the state's waterways
- More than 800 toxic contaminants have been identified in Great Lakes water and sediments
- Although arsenic occurs naturally in WI groundwater, unnaturally high concentrations have been found in 23 of the state's 72 counties
- Mercury has also been a growing concern (in 2002 an advisory was issued for all of the state's inland waters

Action Needed

- Stricter regulations on application of fertilizers containing nitrates and phosphates for agricultural uses
- Incorporation of nutrient recovery technologies in waste treatment processes (potential for offsetting high costs of meeting stricter nutrient discharge limits)
- Alternatives to phosphorus compound as a corrosion control mechanism for pipes in home to prevent copper and lead leaching
- Better farm practices that greatly reduce farm runoff

Current Approach

- Current approaches to limited undesirable nutrient loads in WI waters have focused on tightening limits on allowable amounts:
  - In 2009 WI took the step of banning phosphorus in dish detergent (effective beginning July 2010)
  - **2009 Wisconsin Act 9** - Effective April 1, 2010, the state also banned the use of fertilizers containing phosphorus or available phosphate for application to lawns or turf in Wisconsin (with the exception of certain exemptions). This measures affects: municipalities and local governments (parks, athletic fields, turf, etc.), professional lawn and landscape businesses, homeowners, golf course superintendents and other sports-turf managers, fertilizer retailers (including garden centers, hardware stores, home improvement centers and discount stores)

Impending Water Policy Changes/Conditions to Address Issue

- Proposed changes to phosphorus limits in WI for wastewater treatment facilities would limit discharge to 10 times lower than the current permitted levels (municipal sewage plants account for approximately 20% of less of phosphorus entering state water basins)
  - The proposed changes are expected to result in rate increases of up to 28% for affected communities
  - Estimated total costs for state municipalities have ranged up to $4.3B (Milwaukee Metropolitan Sewerage District could be forced to spend $500M alone)

Technology Needed

- For sewage treatment plants to meet new proposed phosphorus limits, plants would need to install new membranes or filter technologies capable of removing phosphorus.
- To offset the cost of upgrading these systems, state treatment facilities may consider the adoption of nutrient recovery technologies (such as for phosphorus, which is a limited commodity worldwide and essential to agricultural)

Availability of Technology

- Some technologies currently exist on the market that are capable of capturing nutrients such as phosphorus and nitrogen from waste product, such as a system developed by Ostara Nutrient Recovery Technologies that converts wastewater from sewage-treatment plants into fertilizer while recycling phosphorus and nitrogen
- Certain facilities already separate nutrients from effluent using bacteria in order to avoid their discharge into waterways (generally done to comply with environmental

regulations. Technologies such as Ostara's may offered value-added stages to the wastewater treatment process
- Real-time monitoring
- Multiple site/strata monitoring
- Web-enabled networked systems linked by RF or cellular technology
- Automated systems that do not rely on operator interpretation to determine results
- Units that monitor multiple contaminant classes: biological, chemical, and radioactive

http://news.cnet.com/8301-11128_3-20005648-54.html
http://www.jsonline.com/news/milwaukee/91670079.html
http://www.landscapemanagement.net/landscape-management-author/news/wisconsin-phosphorus-fertilizer-ban-goes-effect-9477

Key Issue: Storm Water

Key Dimensions

- Contaminated stormwater poses a serious threat with Wisconsin's lakes, rivers, and streams
- The 2004 Wisconsin 303(d) listing of impaired waters found impairments in 643 state waters up from 552 state waters in 1998. Of the impaired waters on the 2004 list, 316 are due to atmospheric deposition or contaminated sediments, which will require long-term cooperation beyond the state as well as cleanup of legacy contaminants in order to improve these waters. Of the remaining 327 impaired waters, 79 percent are impaired in part due to stormwater runoff (non point source pollution).
- Overflows routinely force the Milwaukee Metropolitan Sewerage District to dump sewage into Lake Michigan and rivers during heavy rains
- A study carried out by Sandra McLellan (Milwaukee Great Lakes Water Institute) attributed high levels of human waste contamination to aging, poorly maintained, leaking pipes, with waste from sewer lines leaking into storm water drains. Fixing the problem could require thousands of miles of municipal and residential pipes to be rehabbed.
- A study appearing in Environmental Health Perspectives (June 2010) points to a link between rainfall and gastrointestinal disease in children
  - 11% increase in number of visits four days after rainfall
  - Study's authors suspect culprit is sewage leaking into storm water systems
- In Milwaukee, which has three major tributaries that discharge into Lake Michigan, stormwater was found to have very high levels of E. coli (100 to 500 times higher than water quality standards)
  - Likely sources of contamination were identified as pet waste, wildlife, leaking sewer pipes and cross connections of sanitary pipes into the stormwater system
- Heavy rains frequently force the Milwaukee Metropolitan Sewerage District to discharge combined flows of treated wastewater, sewage and stormwater from the city's deep tunnel, which has only been disinfected, into Lake Michigan
  - The city is authorized to blend up to 60 million gallons a day of untreated wastewater during a storm

  - These measures allow the city to avoid overflows of combined sanitary and storm sewers
- In 2009, sewer overflows to local rivers and Lake Michigan amounted to 1.2B gallons of untreated wastewater (approx. 1.7% of total entering the regional system)
- Average annual percentage of total wastewater captured and treated since installation of Deep Tunnel in 1994 is 98.2%
- Other key issues related to stormwater in Southeast Wisconsin include:
  - Disinfecting stormwater runoff
  - Limiting stormwater overflows
  - Removing road salt from stormwater
  - Primary treatment of stormwater at discharge
  - On-site containment of stormwater
- The four primary types of stormwater pollution are:
  - Litter (cigarette butts, cans, paper, plastic bags, etc.)
  - Chemical pollution (detergents, oil, fertilizers, etc.)
  - Organic pollution (leaves, lawn and garden clippings, animal droppings, dirt, etc.)
  - Debris, pollutants and disturbed soil from construction sites

http://www.todaystmj4.com/news/local/52380387.html
http://www.iaglr.org/jglr/release/33/33_3_566-580.php
http://www.istockanalyst.com/article/viewiStockNews/articleid/4244704
http://www.jsonline.com/news/milwaukee/83511107.html
http://www.sewallspoint.org/stormwater.php?menuchoice=building_dept

Action Needed

- Increased public awareness to cut non-point sources and reduce runoff, including: disconnecting downspouts, creating rain gardens for runoff retention and minimizing fertilizer usage
- Increased use of bioswales and other mitigating techniques

http://www.iaglr.org/jglr/release/33/33_3_566-580.php

Current Approach

- To meet requirements of the Clean Water Act, WI current regulates stormwater under the Wisconsin Pollutant Discharge Elimination System (WPDES) Storm Water Discharge Permit Program (ch. NR 216, Wis. Adm. Code)
- In addition to regulatory oversight, the DNR also a number of voluntary stormwater management activities, including projects funded through the *Urban Nonpoint Source and Storm Water and Targeted Runoff Management* Runoff Grant Programs

Impending Water Policy Changes/Conditions to Address Issue

- The City of Pewaukee is currently considering the creation of a public stormwater utility to charge property owners for the costs of stormwater control projects and in order to meet federal and state clean water mandates

- The City hopes to generate a needed $1 to $1.5M per year for flood control and drainage projects, and to meet clean water requirements
- Under the utility, property owners, homeowners, businesses and churches would pay a fee for the work; businesses and tax-exempt organizations would be charged a fee based on the amount of impervious surface they have
- Property tax rates would rise by an estimated 40 cents to cover the cost of storm-water work
- Flooding in June 2008 in areas targeted by control work cost the city an estimated $18.7M in damages
- Some 70 WI communities currently charge storm-water fees (including Milwaukee)

http://www.jsonline.com/news/waukesha/98213549.html

Technology Needed

- Rain gardens
- Impervious surfaces

Availability of Technology

- A variety of technologies are currently available for addressing stormwater issues in the state of WI
- Available stormwater mitigation technologies include:
  - Bio-retention ponds and bioswales
  - Green roofs
  - Rain barrels and rain gardens
- Technology to address combined sewer overflows includes:
  - Sewer flow monitors
  - Bed pipe barriers to reduce the concentration of suspended solids around mining sites
  - Settling ponds

Key Issue: Invasive Species

Key Dimensions

- WI has approximately three dozen laws aimed at preventing the spread of invasive species
- The **Eurasian milfoil** plant, which chokes out other species by spreading from lake bottoms to the water surface and blocking vital sunlight, is now present in 539 of WI's 15,000 inland lakes
- **Viral hemorrhagic septicemia (VHS)** is a deadly fish disease that first attacks gill tissue, then internal organs and blood vessels, eventually leading to hemorrhaging in the internal organs and muscles of affected fish. Fish infected with VHS have been found in Lake Michigan, Lake Superior, Lake Winnebago and the Mississippi River. The lower Wisconsin River (Sauk City Dam to Mississippi River) is classified as a "suspect" area.
- **Zebra Mussels**: first introduced into the Great Lakes sometime during the mid-1980s, zebra mussels have not spread to inland lakes and the Mississippi River. This invasive

species has been associated with declines in mussel diversity in the Mississippi River, blue-green algae (which it does not consume) and a decline in larger fish species.
  - In 2001, the Wisconsin Electric Power Company reported expenditures of $1.2 million per year to control zebra mussels on their Lake Michigan power plants
  - Estimated annual costs for controlling zebra mussels in the Great Lakes ranges from $100 million to $400 million (NOAA Great Lakes Environmental Research Laboratory Direct Dr. Stephen Brandt)
- **Asian Carp**: this invasive species first introduced to the US in the 1970s to clear algae from fisheries spread following flooding events. Asian Carp consume 40% of their body weight in food per day and have no known predators. Their presence is associated with the loss of native fish species such as perch and there are not effective means of removing them once they have colonized a body of water.
- **Quagga Mussels**: closely related to the zebra mussels and able to live in waters ranging from warm and shallow to deep and cold. Quagga mussels are also able to tolerate brackish water and are native to Caspian Sea drainage in Eurasia. Unlike zebra mussels, which lie dormant during the winter months, quagga mussels feed year round. Some researchers have credited Lake Erie's dead zone in part to the presence of tiny quagga mussels and their perpetual feeding activity, their ability to live in deep water (they have been found at depth of up to 130m in the Great Lakes) and the excretion of phosphorus with their waste.
  - Although quagga mussels have only been found in Lake Michigan waters bordering WI, it is believed that they may be able to successfully invade inland lakes not suitable for zebra mussels

http://dnr.wi.gov/invasives/fact/quagga.htm
http://host.madison.com/ct/news/local/article_bba6c036-8d6f-11df-b4cd-001cc4c002e0.html
http://dnr.wi.gov/invasives/fact/zebra.htm

Action Needed
- Preventative measures to ensures invasive species are not transported between WI's lakes and streams
- The is generally very little that can be done to control **zebra mussel** population once established in a water body; preventive measures are therefore the primary means of control

Current Approach
- A new law passed in 2009 assigns a fine ranging from $263 to $389 for boats, trailers or other marine recreational vehicles caught with dangling plant debris while traveling down roads and interstates
- WI recently put into place new laws aimed at preventing new introductions of three specific invasive species into the Wisconsin wild. The three targeted species are wolf-dog hybrids, feral or wild swine and mute swans.
  - The Department of Natural Resources requires permits to keep any of these species in captivity.
  - Fines for the release of any of these species into the wild can be upwards of $1,100 plus restitution for any damage caused by the animals

http://www.chicagotribune.com/news/chi-ap-wi-invasivespecies-w,0,6066366.story

- Biological control (introduction of natural enemies to mitigate impacts)
- Chemical control (e.g., pesticides)
- Mechanical control
- Ecosystem management: entire ecosystem subject to regular treatment, such as fire control measures, that favors native species over exotic invaders

Technology Needed

- Technology facilitating the removal of invasive species from ship hulls
- Technology facilitating disinfection of ship ballast water
- Technology preventing the spread of invasive species from one body of water to another

Availability of Technology

Numerous technologies currently exist, including:

- Chemical control of ballast water - on-vessel
- Biocide application to water body
- Barriers
  - Sound waves
  - Electrical impulses
  - Visual deterrents
  - Physical barrier
- Predator species
- Harvesting and removal

Emerging technology and technology needs

- UV disinfection of ballast water
- Port-based ballast water control - filtration and UV (Port of Milwaukee)
- Effluent monitoring for ballast control chemical concentrations
- Innovative barrier techniques
- Control techniques for recreational vessels
- An example of technology aimed at preventing the transfer of mussels from one body of water to another is the HullMasters™ dispersal unit, which disrupts the glue used by barnacles and muscles to attach to host surfaces, including ship hulls, piers, pilings, floating docks in marinas, among other facilities http://marinebiologyoceanography.suite101.com/article.cfm/new_technology_removes_invasive_species

Key Issue: Water Treatment – Quality

Key Dimensions

Issues affecting water quality treatment in WI include:

- Removal of pharmaceuticals
  - Trace amounts of pharmaceuticals, originating from both topical and ingested medications, is a growing cause for concern in Wisconsin as
- Water softening and need for techniques not using salt

- Removal of phosphates
- Development of real-time sensor forms
- Removal of radium in ground water
- Desalination
- Need for reductions in chemicals used in treatment

Action Needed

- Mechanisms for removal of pharmaceuticals during wastewater treatment to prevent their entry into bodies of water (high levels of estrogen have been linked to increasingly effeminate behavior in fish)
- Mechanism of pharmaceuticals during drinking water treatment process

Current Approach

Pharmaceuticals

- Current best practice for managing waste drugs is through collection and high temperature incineration at licensed facilities
- Wisconsin Clean Sweep Program – program for the collection of unwanted prescription drugs offering grants to counties, regional planning commissions, cities, villages, and other municipalities for the collection of unwanted or waste chemicals such as pesticides, acids, flammable chemicals, mercury, lead paint, and solvents, as well as unwanted prescription drugs such as controlled substances, analgesics, anti-inflammatory drugs, antibiotics, gastrointestinal drugs, and antihistamines

Impending Water Policy Changes/Conditions to Address Issue

- Wisconsin will receive $38 million for the Drinking Water State Revolving Fund used for low-interest or no-interest loans to local governments building and upgrading communities' drinking water infrastructure. Again, in order to boost our economy as quickly as possible, projects that are ready to proceed to construction within 12 months get the top priority, and the provision includes a goal of 50 percent of funds going to activities initiated within 120 days. Like the Clean Water State Revolving Fund, not less than 20 percent of funds must be for projects in green infrastructure, water or energy efficiency improvements, and other innovative energy projects.

Technology Needed

- Technologies capable of effectively removing pharmaceuticals from wastewater
- Technologies capable of more cost-effectively removing items such as arsenic and salts from contaminated groundwater supplies (particularly in areas with depleted aquifers, such as the city of Waukesha)

Availability of Technology

Innovative biological treatment technologies

- Membrane bioreactors (MBR),
- Mobile bed biofilm reactor technology (MBRT)
- Integrated fixed-film reactor technology (IFAS), and
- Biological aerated filters (BAF)

- novel configurations of biological (aerobic, anaerobic, and anoxic) processes and recycle streams

Innovative technology development in the area of physical and chemical treatment processes

- Membrane filtration
- Compressible media filters
- Cloth media filters
- Disinfection processes, including ultraviolet (UV)
- Fine/Advanced grit removal system (AGRS),
- Microfiltration/Microseive,
- Ultrafiltration,
- Nanofiltration
- Biomass concentrator reactor to remove Endocrine Disrupting Compounds (EDCs)

Key Issue: Municipal Wastewater Treatment

Key Dimensions:

- In year 2003, 30 plants, about 4.5%, were rated as requiring improvements and 106 plants, about 15.8%, were rated as requiring some action. According to the Clean Water Needs Survey (USEPA, 2000), the need for municipal wastewater treatment projects exceeds $3.35 billion in Wisconsin through year 2020, or $167.5 million per year
- Current federal and state funding programs provide approximately $114 million
- Combined sewer overflows (CSOs) are a significant concern in WI. Since 1996, there have been over 1,400 CSOs/SSOs in Wisconsin (as of 2007) http://sections.asce.org/wisconsin/2007ReportCard.html (see accompanying links)

Action Needed

Municipal action needed

- Increased efficiency
- Removal of pharmaceuticals
- Removal of higher levels of phosphates
- Speeding treatment to handle larger volumes
- Utilization of sewer sludge
- Reduced chemical use in treatment
- Removing PCBs from sewer pipes

Industrial action needed

- Disposal/use of liquid farm manure
- Cleaning/recovery of food processing waste
- Utilization of sewer sludge
- Aquaculture water cleaning and reuse
- Fish farm refuse removal

Current Approach

- There is currently no process for removing pharmaceuticals from treated water

- Although most wastewater treatment facilities currently remove up to 80% of phosphorus, new regulations are aimed at significantly reducing the remaining 20% (also considered exponentially more expensive to remove)

Impending Water Policy Changes/Conditions to Address Issue

- The State Water Resources Board recently approved sweeping new regulations to limit phosphorus in state waterways
  - The regulations are aimed at improving the quality of water, reducing algae blooms and improving the habitats of fish and other aquatic life
  - Regulations will lower phosphorus limits from 10 milligrams per liter of water to just .03
  - Compliance with the new regulations are estimated to cost upwards of $1B (a business-sponsored analysis put this number at over $4B over the 2-year rollout of the regulations)
  - The state has not yet identified a way to finance a cost-sharing program
  - Compliance will be phased in over a 20-year period
  - The DNR currently considers 172 state lakes and streams as impaired due to the presence of phosphorus
  - Currently only Florida has regulations on par with those of Wisconsin, but other states are expected to follow
  - The Milwaukee Metropolitan Sewerage District (which agrees with the new regulations) estimates the cost of compliance for new equipment to be $500M or more, which will be passed on to customers
  - 70% of farmers' non-point pollution controls will be paid for by the state (for an estimated total of some $9.3M from the state and $4M from farmers to comply with the wastewater regulations)
  - The DNR estimates up to 163 municipal plants may need new filtration systems that could run a total of $300 million to $1.13 billion.
  - The rules also limit phosphorus run-off from fields to 6lbs per acre annually over an eight-year average; farmers will also be restricted from plowing within 5ft of a stream bank to prevent erosion and will be required to use equipment such as sump pumps to prevent wastewater from milk houses and feed storage structures for running off

  http://www.fdlreporter.com/article/20100625/FON0101/6250359/Phosphorus-rules-will-have-major-impact

Technology Needed

- Mechanisms for the effective removal of pharmaceuticals from water
- More cost-effective means for phosphorus removal and processes that allow for the effective harvesting of phosphorus (a limited resource essential to growing food and one projected to experience shortfalls in coming years)
- Nutrient (nitrogen and phosphorous) and emerging contaminant (pharmaceuticals and personal care products) removal are the current drivers of needs in this category. As states develop numeric nutrient criteria for surface waters, more stringent nutrient effluent standards are likely to be adopted for many wastewater treatment plants. Current trends include the utilization of more sophisticated control systems and novel

configurations of aerobic, anaerobic, and anoxic processes to maximize the performance of biological processes for nutrient removal, and innovative chemical treatment, clarifying, and filtering technologies to reach mandated effluent limits. In addition, there is a need for processes/technologies that concurrently remove emerging contaminants.

Availability of Technology

- Ostar reactors are now commercially available and are capable of harvesting phosphorus from raw sewage. The PEARL Nutrient Recycling Process makes use of a proprietary fluidized bed reactor. When installed in wastewater treatment plants, the devices removes ammonia and most of the phosphorus from untreated sewage.
  - Trial reactor in Edmonton Albert extracts over 80% of the phosphorus and 15% of the ammonia from 500,000 liters of sludge (20% of the plant's total sludge stream), and converts it to 500 kg (1,102 lbs) of ready-to-use Crystal Green fertilizer. Pilot plants have also proven successful in British Columbia, Virginia and Oregon.

  http://www.gizmag.com/ostara-harvests-phosphorus-from-raw-sewage/14685/

From EPA Report

Innovative biological treatment technologies

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Key Issue: Water/Wastewater Infrastructure Needs

Key Dimensions:

- 189 high hazard dams in WI (dam whose failure would cause a loss of life and significant property damage)
- 13 of WI's 3,653 dams in need of rehabilitation to meet applicable state dam safety standards
- 55% of WI's high hazard dams have no emergency action plan (EAP)
- Drinking water infrastructure needs investment of $5.94B over next 20 years

- In 2005, state ports handled 44M tons of waterborne traffic (20th in nation)
- According to the state's most recent Intended Use Plan and Priority List, WI requires more than $966M in wastewater infrastructure spending; the state's 2007 federal state revolving fund grant was only $28.9M (1/33rd of the state's needs)
- Other sources place WI's wastewater infrastructure needs at $3.66B
- Federal contributions to WI's clean water funding efforts have decreased by 47.8% since the Clean Water SRF was fully implemented in fiscal year 1991 (65.9% was adjusting for inflation)
- **Unaccounted-for Water** – In 2009, water loss in WI totaled 21.4 billion gallons, or 12% of total water pumped and treated. Water loss includes unauthorized consumption, meter inaccuracies, accounting errors, water main leaks, overflows, theft, and other unaccounted for water.
  - **Milwaukee**: between 2006 and 2009, Milwaukee Water Works (MWW) had an annual unaccounted for water rate of 13 to 14 percent, translating to an average loss of 5.8 billion gallons per year. Should water loss rates exceed 15 percent, the public service commission would require an investigation. MWW would risk losing a waiver to test residential water meters every 20 years and instead would be required to test them every ten years. For this reason, MWW has a vested interested in curbing water loss rates as failure to do so could potentially prove very expensive for the utility
  - **Madison**: in 2007, the City of Madison registered an unaccounted-for water rate of 9.6%

  http://documents.foodandwaterwatch.org/WI_FactSheet.pdf
  http://www.infrastructurereportcard.org/state-page/wisconsin

Action Needed

- Improved funding mechanisms for wastewater projects; more cost-effective technologies to meet state and federal wastewater standards
- Given the crippling cost of infrastructure upgrades required by the state, technologies able to reduce both up-front and maintenance costs while complying with state and federal regulations should prove highly attractive.
- The National Utility Contractors Association has estimated that for every $1B spent on water infrastructure, nearly 27,000 jobs are created

Current Approach

- Wisconsin may receive some of the $1.38 billion allocated nationally for rural communities (limited to communities of 10,000 or less) through the USDA's grant and loan programs for water and wastewater projects. The funds will be distributed in four programs: emergency community water assistance grants, water and waste disposal loans and grants, solid waste management grants, and technical assistance and training grants.
- Wisconsin will receive more than $107.5 million for the Clean Water State Revolving Fund used for low-interest and no-interest loans to local governments building and upgrading communities' waste water infrastructure. In order to boost our economy as quickly as possible, projects that are ready to proceed to construction within 12 months get the top priority, and the provision includes a goal of 50 percent of funds going to activities initiated within 120 days. The law specifies that not less than 20 percent of

funds must be for projects in green infrastructure, water or energy efficiency improvements, and other innovative energy projects.

- Wisconsin will receive $38 million for the Drinking Water State Revolving Fund used for low-interest or no-interest loans to local governments building and upgrading communities' drinking water infrastructure. Again, in order to boost our economy as quickly as possible, projects that are ready to proceed to construction within 12 months get the top priority, and the provision includes a goal of 50 percent of funds going to activities initiated within 120 days. Like the Clean Water State Revolving Fund, not less than 20 percent of funds must be for projects in green infrastructure, water or energy efficiency improvements, and other innovative energy projects. http://feingold.senate.gov/recovery/basic_invest_water.html

Impending Water Policy Changes/Conditions to Address Issue

- A bipartisan group of congressmen has proposed the creation of a $10 billion-a-year federal clean water trust fund.
  - Revenue for the trust fund would come from proposed taxes on the pharmaceutical industry, many beverages, a variety of household goods - toothpaste, detergents, face creams and other toiletries, toilet paper, water softeners and cooking oil - that are normally disposed of in residential sewers, as well as corporate profits.
  - The US Environmental Protection Agency forecasts a $534 billion gap between current levels of investment in the systems and projected needs in the next 20 years

  http://www.jsonline.com/news/milwaukee/50866627.html
- In order to address water loss in Milwaukee, in December 2009 the MWW and Milwaukee Fire Department decided to end the practice of allowing urban gardeners and landscape companies to access water from fire hydrants beginning in 2011. Although the implications of such a step are not yet fully clear, it is reasonable to assume that increased on-site storage of rain water, particularly for urban gardens, will prove increasingly attractive.

Technology/Policies Needed

- Given the crippling cost of infrastructure upgrades required by the state, technologies able to reduce both up-front and maintenance costs while complying with state and federal regulations should prove highly attractive.
- Like projects throughout the US, WI would stand to greatly benefit from the creation of an American Investment Bank modeled off of institutions such as the European Infrastructure Bank

Availability of Technology/Policies

- A new EPA water infrastructure policy released in May 2010 instructs states to adopt smart-growth principles in allocating the $3.3B in water infrastructure funding distributed by the federal government each year. States should prioritize upgrades to drinking water and wastewater infrastructure in cities over projects intended to serve new developments on the suburban fringe
- Regarding leakages in the state, some existing leakage control technologies include:
  - Continuous acoustic monitoring
  - Advanced metering infrastructure communication

- District Metered Areas (DMAs) for audit and leak control
- Pressure monitoring
- GIS analysis

2.2 Wyoming

Key Markets	Niche Markets
Agricultural infrastructure	On-site treatment for hydraulic fracturing fluids
Advanced wastewater treatment technology	On-site treatment for coal-bed methane discharge
Groundwater quality & quantity monitoring	
Surface water monitoring	
Water re-use	

Demographic Indicators

Population	2000	2009	2020
Urban Population	321,000	--	--
Rural Population	172,000	--	--
Total Population	**493,000**	**544,000**	**531,000**

Population Growth Rate	2000-2009
Total Population Growth Rate	10.3%

Source: United States Census Bureau (http://www.census.gov/population/www/projections/projectionsagesex.html)

Economic Indicators

Economic Indicator (2007)	Nominal GDP
Total GDP	$31.5 billion
GDP per capita	$39,807
GDP growth rate	0.7%

Source: United States Bureau of Economic Analysis (http://www.bea.gov/scb/pdf/2009/06%20June/0609_gdp_state.pdf)

Background and Summary of Key Issues

Wyoming is a headwaters state, and most of the water in the state comes from rainfall or melting snowpack (Wyoming Water Development Commission, 2007). This can cause drought conditions, especially in the summer months, when snowpack is low. Many of Wyoming's water issues revolve around energy production. Wyoming is one of the biggest producers of coal and also has many wells for coal-bed methane extraction and hydraulic fracturing.

- Wyoming's most severe problems are:
  - Unsustainable supply, aquifer depletion, and high irrigation demand
  - Contaminated sediment and surface water
  - Hydraulic fracturing, coal-bed methane extraction, and groundwater contamination
  - Climate change and drought
  - Inadequate monitoring of aquifer levels
  - Need to set and enforce consumption standards and rules promoting conservation
  - Outdated water rights and lack of groundwater controls and limits

Key Issue: Unsustainable Supply, Aquifer Depletion and High Irrigation Demand

Key Dimensions

In Wyoming, 80% of the population relies on groundwater for drinking water while 20% uses surface water (Groundwater Protection Council, n.d.). Approximately 317 million gallons of groundwater are used in the state per day. Agricultural irrigation accounts for 181 million gallons (57%) and mining accounts for 89 million gallons (28%).

Wyoming has an unsustainable water supply because areas of the state have experienced decreasing aquifer levels. Furthermore, low winter snowfall often causes increased drought in the later summer months, as many areas of the state rely on melting snowpack as a source of water.

- The Ogallala Aquifer has declined by 5 to 10 feet in some areas of Wyoming from 1980 to 1999 and by more than 60 feet in some areas of Texas and Wyoming (McGuire, 2001).
- Powder River Basin:
  - The Middle Tertiary Aquifer has declined 6 to 13 feet since the 1970s (http://waterplan.state.wy.us/plan/newy/techmemos/gwdeterm/gwdeterm_summ.html)
  - The Fort Union/ Wasatch Aquifer has declined 40 to 50 feet, southeast of the City of Wright

Wyoming's Green River Basin water conservation plan stated that the conveyance of water through canals and ditches is responsible for a significant percentage of water loss in agriculture (http://waterplan.state.wy.us/plan/green/techmemos/conserv.html).

- Up to 40% water loss has been measured in some areas.
- This amounts to losses of 0.27 to 2.89 acre feet of water per linear foot of canal or ditch.

Action Needed

Wyoming needs to implement a statewide aquifer monitoring system which integrates all of the existing individual aquifer monitoring programs. Such a program would give officials more comprehensive data that could potentially improve decision-making on water-use policies and laws.

Because agriculture is a major user of water in the state, it may be important to consider genetically-engineered crops which require less water overall and are more resilient in drought conditions. Irrigation ditches and canals are responsible for high levels of water loss from leaks and evaporation. Therefore, Wyoming should consider requiring the use of sprinkler irrigation or drip irrigation over ditches and canals for agricultural purposes.

Current Approach

Wyoming water planning has developed projections for agricultural, municipal and domestic, recreational, and environmental demand based on low-, mid-, and high-growth scenarios (Wyoming Water Development Commission, 2007, p.6-29). There are seven major basins included in the plan:

- Bear River Basin
- Green River Basin
- Northeast Wyoming River Basin

- Platte River Basin
- Powder/Tongue River Basin
- Snake/Salt River Basin
- Wind/Bighorn River Basin

Impending Water Policy Changes/ Conditions to Address Issue
There are no impending water policy changes to address any of the above problems. However, policies are needed that will both require the use of more efficient irrigation systems and will limit the daily amount of water consumed for irrigation.

Technology/Policies Needed
Because of water loss, more affordable and efficient irrigation technology is needed. The Green River Basin water conservation plan states that sprinkler irrigation systems can be up to 25% more efficient than flood irrigation. Low pressure sprinkler systems add another 10% in efficiency. However, drip irrigation can consume 30 to 60% less water than traditional sprinkler irrigation systems (Food and Agriculture Organization, 2003). Furthermore, higher crop yields are also often seen with drip irrigation. The problem is that drip irrigation systems cost between $485 and $1,010 per acre.

Wyoming's major crops are hay, barley, and wheat. A number of factors are involved in calculating payback periods after switching to drip irrigation. These include acres of land, types of crops grown, existing irrigation system, and cost of water per acre foot. However, there are a number of online calculators to determine time to payback (http://www.dripmicrowizard.com/). If an individual had 20 acres of sprinkler irrigated land, with a water cost of $10 per acre foot, the average time to payback after conversion to drip irrigation for the following crops would be:

- Grass hay: 14.83 years
  - Water saved would allow the irrigation of an additional 5.88 acres
- Barley: 8.21 years
  - Water saved would allow the irrigation of an additional 5.88 acres
- Wheat: 8.57 years
  - Water saved would allow the irrigation of an additional 5.88 acres

The acres of land appear to affect the amount of additional land which could be irrigated but not the time to payback. However, a higher cost of water per acre foot would decrease the time to payback. Thus, incentives or grants for new equipment would likely be needed to convince farmers to switch to drip irrigation if time to payback can be as high as 15 years.

Other water saving technologies for agriculture, mentioned in the Green River Basin plan, include (http://waterplan.state.wy.us/plan/green/techmemos/conserv.html):

- Automated diversions
- Gated pipe application
- Surge valves

Availability of Technology
Micro-irrigation systems currently are being produced, which involve low-cost drip technology and state-of the art technology

(http://www.iwmi.cgiar.org/publications/Water_Policy_Briefs/PDF/WPB23.pdf). Examples of these available technologies include:

- Low-cost
  - Pepsee easy drip technology
  - Bucket and drum kits
  - Micro sprinklers
  - Micro tube drip systems
- State-of-the-art
  - Conventional drip systems
  - Sprinkler systems

Crop yields are generally higher when drip irrigation systems are used. Additionally, users of low-cost systems, such as Pepsee systems, can begin to see returns after as little as one year. However, low-cost systems are usually more appropriate for very small landowners.

Key Issue: Contaminated Sediment and Surface Water

Key Dimensions
Wyoming has 63.9 miles of waterways with contaminated sediment (Wyoming Department of Environmental Quality, 2008a, p. 94). The primary contaminants in state waterways are selenium, chloride, and phosphates:

- 348.8 miles of selenium-contaminated waterways
- 64.8 miles of chloride contaminated waterways
- 15.4 acres of phosphate contamination

Cottonwood Creek is one example of a water body with high concentrations of both selenium and chloride. Discharge from the Hamilton Dome Oil Field may be responsible for these high concentrations. The Wyoming Department of Environmental Quality report (2008a) found that high chloride concentrations (above the acute criterion of 860mg/L) were found in surface waters in four sub-basins:

- Upper Belle Fourche
- Upper Big Horn
- Bitter Creek
- Salt Creek

Phosphates are also problematic in many sub-basins. Areas such as Twin Creek, have high levels of phosphates from mining runoff. Many other areas of the state also have phosphate mines. Nutrient contamination can cause eutrophication, which is harmful to fish and other aquatic species.

Wyoming waterways are also contaminated by other elements and compounds, including:

- Ammonia (45.4 miles of contaminated waterways)
- Cadmium (12.4 miles)
- Copper (17.0 miles)
- Silver (12.4 miles)

- Manganese (6.3 miles)

Some Wyoming water systems also contain various contaminants. Of the nine largest water systems in Wyoming, six had at least one contaminant in drinking water that was found at levels that were below legal limits but above health guidelines. The average amounts of Radium-226 and Radium-228 were found to exceed health limits in several of these water systems (http://projects.nytimes.com/toxic-waters/contaminants/wy). Other contaminants which had at least one test result fall above health limits are:

- Bromate
  - Bromate is often formed when bromide in drinking water interacts with compounds such as chlorine and sodium hydroxide that are used in disinfectant chemicals (World Health Organization, 2005). Bromate is also often found in water treated with ozone. Acute ingestion can cause side effects such as nausea, vomiting, and depression of the central nervous system.
- Combined Radium (-226 and -228)
  - Procedures which remove radium from drinking water concentrate radioactivity, making safe and proper disposal of by-products necessary (New Hampshire DES, 2004). High exposure to radium can increase one's risk of cancer.
- Total haloacetic acids (HAAs)
  - Haloacetic acids are byproducts from the treatment of drinking water with chlorine (NRDC, 2003). High levels of HAAs can cause cancer.

Action Needed

Wyoming, in partnership with the USGS, needs to continue its surface water monitoring program at the current 145 sites. The state might consider stricter regulations and penalties for companies and individuals responsible for point source pollution.

Current Approach

The main objectives of the Wyoming Water Quality Monitoring Strategy are to identify degraded waters, to identify the sources of pollution, and to determine whether water quality standards are being met (Wyoming Department of Environmental Quality, 2004).

Impending Water Policy Changes/ Conditions to Address Issue

There is no evidence that there are any impending water policy changes. However, Wyoming does have its own surface water quality rules and regulations. These regulations establish criteria for solids, fecal coliform, salinity, and heavy metals. Permits are required for point sources of pollution while best management practices are required for non-point sources (Wyoming Department of Environmental Quality, 2000). The state has the ability to directly enforce the rules and can take legal action when those rules are violated.

Technology/Policies Needed

Wyoming has created the Wyoming Nutrient Criteria Development Plan (Wyoming Department of Environmental Quality, 2008b) which states that there are currently no established criteria for total nitrogen and total phosphorus levels in surface water. Nutrient criteria for lakes, reservoirs, streams, and rivers are not expected to be fully established until 2013 or 2014. Due to the high level of phosphates in state water bodies, these criteria need to be established as soon as possible.

Availability of Technology

Current water treatment technologies include chemical treatment of nutrients, and aerobic and anaerobic biological treatment. Examples of treatment technologies available include ultraviolet disinfection, filtration, adsorption, and chlorination. Other technological solutions for nutrient control in wastewater treatment include:

- Alternatives to phosphorus addition for lead control in plumbing pipes
- Biological methods to mitigate legacy contaminants and heavy metals
- New microfiltration, ultrafiltration, nanofiltration and membrane filtration methods to remove trace amounts of PPCPs and EDCs from drinking water and wastewater
- Mercury mitigation

Key Issue: Hydraulic Fracturing, Coal-bed Methane Extraction, and Groundwater Contamination

Key Dimensions

Hydraulic fracturing for natural gas is a controversial process that contributes to groundwater contamination. Fracturing involves injecting a mixture of chemicals into the ground to break apart ("prop open") the bedrock and facilitate the escape of natural gas, which is then collected at the surface. The injected chemicals can seep into groundwater through the fractures they have helped to create.

Hydraulic fracturing has been exempt from the Safe Drinking Water Act since a 2004 study by the EPA found that no threats to drinking water existed. This exemption has meant that companies that perform hydraulic fracturing are not required to disclose the chemicals that are used to break apart the bedrock. Therefore, it is currently impossible to identify all of the chemicals that are used.

Sublette County in Wyoming is home to 6,000 of the state's natural gas wells, many of which have been subjected to hydraulic fracturing (Lustgarten, 2008). Researchers found several contaminants in well water tested in July 2008:

- The concentration of benzene was 1,500 times the level safe for humans.
- The Bureau of Land Management suspects that up to 300 compounds are used in fracturing. Of these suspected compounds, 65 are considered hazardous by the federal government.
  - Other known chemical compounds and materials include 2-butoxyethanol which can contribute to cancer and tumors, methane, methanol, diesel fuel, oil, guar gum and derivatives, isopropanol, potassium chloride, hydrochloric acid, and formic acid (U.S. Environmental Protection Agency, 2004).
- According to a 2007 written testimony by Dr. Theo Colborn, presented to the House Committee on Oversight and Government reform, in addition to benzene, methane rising to the surface after fracturing often carries along the following chemicals (United States Congress, 2007):
  - Toluene
  - Ethyl benzene
  - Xylene (BETX)

Coal-bed methane is extracted from coal seams and consists of nearly 100% methane (CH_4) (ALL Consulting, 2003). In coal seams, methane sits on top of the solid coal. There are two primary ways that the coal-bed methane is extracted. In the first type of practice, vertical and horizontal wells are drilled to access the methane (http://www.netl.doe.gov/technologies/oil-gas/futuresupply/coalbedng/coalbed_ng.html). Hydraulic fracturing is then used to create fractures which direct the gas into the wells. Pumping water out of the coal reduces underground pressure, allowing the methane to be released from the coal.

In the second type of practice, coal-bed methane is removed once the solid coal is mined. Voids are created from the absence of coal and collapse when temporary supports are removed. Methane is released into the mine when this void collapses and it can then be extracted.

Discharge of coal-bed methane water is one of the largest problems with extraction. Solutions which are injected into the ground contain many of the chemicals previously listed. This fluid is usually released directly onto the ground outside the mine. Discharged fluid often includes abnormally high levels of (ALL Consulting, 2003):

- Sodicity
- Sodium
- Barium
- Biocarbonates
- EC
- Iron

Wyoming is the third highest producer of coal-bed methane, at 0.32 trillion cubic feet (TCF) per year (U.S. Environmental Protection Agency, 2007).

Action Needed

It is important that full disclosure of all hydraulic fracturing chemicals be required. The Wyoming Oil and Gas Conservation Commission currently allows hydraulic fracturing companies to withhold the disclosure of chemicals that are considered trade secrets, while the federal Toxic Substances Control Act (TSCA) of 1976 is considered outdated and is in the process of being amended. Unless the Fracturing Responsibility and Awareness of Chemicals Act is passed, hydraulic fracturing companies likely will not be disclosing all of the chemicals that they use.

Wyoming should also consider imposing stricter fines on companies which discharge coal-bed methane liquids directly onto surfaces surrounding their wells. **see http://deq.state.wy.us/wqd/wypdes_permitting/downloads/TEMPDISCHARGE_9-6-07.pdf

Current Approach

The U.S. Environmental Protection Agency has established a non-emergency hotline for individuals to report potential illegal oil or gas-related activities (**source?).

State Hydraulic Fracturing Disclosure Rules
On June 8, 2010, the Wyoming Oil and Gas Conservation Commission approved new rules which will require energy companies to disclose the chemicals that are used in their fracturing fluids. While this is a step forward, the new rule says that under the state's open records laws, companies are not required to publicly disclose any chemical compound that is considered a "trade secret."

Impending Water Policy Changes/ Conditions to Address Issue
FRAC Act: Fracturing Responsibility and Awareness of Chemicals"
On June 9, 2009, the following Congressional bills were introduced:

- H.R. 2766: To repeal the exemption for hydraulic fracturing in the Safe Drinking Water Act, and for other purposes
- S. 1215: To amend the Safe Drinking Water Act to repeal a certain exemption for hydraulic fracturing, and for other purposes

These bills were referred to the Committee on Energy and Commerce and the Committee on Environment and public works, respectively. The purpose is to force hydraulic fracturing companies to reveal the chemicals which they inject into the ground. Knowledge of the chemicals used will help guide further policies.

Toxic Chemicals Safety Act of 2010
On January 21, 2010, the EPA announced that it would begin to reject Confidential Business Information (CBI) claims on the identity of chemicals which are known to pose health risks and are included in the Toxic Substances Control Act (TSCA) Chemical Inventory (United States Environmental Protection Agency, 2010). The TSCA was originally passed in 1976 and requires companies to notify the EPA if any chemicals used were found to pose risks to health or the environment. However, before the EPA's January announcement, companies could withhold chemical information if the chemical in question were determined to be a trade secret.

A discussion draft for the Toxic Chemicals Safety Act of 2010 was released on April 15, 2010. The act, if passed, would amend the TSCA (http://energycommerce.house.gov/Press_111/20100415/TCSA.Summary.04.15.2010.pdf). The Toxic Chemicals Safety Act would require industries "to submit to the EPA the data it needs and improves EPA's authority to compel testing by the chemical industry" (p. 1). The act would also ensure that information provided to the EPA is properly disclosed to the public.

Injection of carbon dioxide
Chapter 24 of the Wyoming Water Quality Rules and Regulations (Class VI Injection Wells and Facilities Underground Injection Control Program) is currently being drafted. This proposed rule would make it illegal to inject and sequester carbon dioxide in streams without an Underground Injection Control (UIC) permit. The rule would not apply to carbon dioxide sequestered in coal seams, basalt, or shale rock (Wyoming Department of Environmental Quality, draft for 2010, July 8 hearing).

The EPA and the Wyoming Carbon Sequestration Working Group argue that sequestration of carbon dioxide can affect underground water sources, including drinking water. This rule would help to preserve and protect drinking water quality (Wyoming Department of Environmental Quality, 2009).

Technology/Policies Needed
Alternatives to conventional hydraulic fracturing should be explored. One example of fracturing which does not use conventional chemicals is CO_2 – sand fracturing. Standard practice generally involves the injection of a water-based solution with nitrogen, sand, and other chemicals to create fractures (U.S. Department of Energy, 1997). CO_2 – sand fracturing does not use water or oil-based fluids and instead relies on liquid carbon dioxide. Alternatives that do not use harmful chemicals would avoid the possible contamination of groundwater.

Technologies that treat the discharged water from coal-bed methane extraction are also needed. One example of existing technology is the Higgins Loop continuous ion exchange technology. This process, used by EMIT (an Exterran Company) "utilizes a continuous countercurrent ion exchange (CCIX) method for removing sodium and other cations from the CBM produced water" (http://www.emitwater.com/higgins_loop.html)._Total treatment costs using this process range from $0.25 to $2.00 per barrel (ALL Consulting, 2006).

Availability of Technology
There are several available technologies for hydraulic fracturing and for the production of coal-bed methane:

- Treatment of hydraulic fracturing fluid and coal-bed methane discharge with reverse osmosis (RO) membrane filtration and electrodeionization (EDI)
- Portable on-site treatment of discharge
    - Units for the oil and gas industry have been developed by Veolia and GE Water
    - On-site treatment units which are power by natural gas from the wells
    - Hydraulic fracturing water recycling and reuse
    - Alternative gas extraction methods, such as nitrogen injection
    - Berms and fibrous construction fences to contain runoff

Key Issue: Climate Change and Drought

Key Dimensions
Wyoming is currently the fifth driest state in the country, and the state relies on slowly melting snowpack for much of its water. Desert basins in the state can receive as little as 4 to 6 inches of rain annually, while mountainous areas can receive up to 60 to 80 inches annually (Wyoming Drought Task Force, 2003). Approximately 70% of Wyoming receives an average of less than 16 inches of annual rainfall (Wyoming Vulnerable, 2010).

Wyoming climatologist Steve Gray stated that an average temperature increase of three degrees or more would result in increased rainfall and decreased snowfall during the winter (Climatologist offers sobering, 2007). Gray said that less snowpack could increase drought severity later in the summer and fall.

Action Needed
Gray recommends that Wyoming increase its water storage capacity, so that there will be larger supplies of water in conditions of drought (Climatologist offers sobering, 2007). Dams and reservoirs would be examples of possible infrastructure needed. Pipes may also be needed to move additional stored water to various areas of the state. It will also be important to improve any antiquated infrastructure that could be the source of leaks.

Finally, land-use planning and growth control will be important, as six of the ten-fastest-growing states are located within the Colorado River Basin where water is already scarce (Wyoming Vulnerable, 2010). Many downstream states use more water than they are legally entitled to. Therefore, inter-state cooperation and planning will also be necessary.

Current Approach
Wyoming has a drought plan which was created by the Wyoming Drought Task Force and revised on January 24, 2003. The drought task force was created following a drought in 2000. Drought monitoring, as stated in the plan, involves:

- Temperature and rainfall records
- Snow and stream flow prediction
- Groundwater records
- Palmer Drought Severity Index (PDSI)
  - This index ranges from -6.0 (Extreme Drought) to +6.0 (Extremely Wet).
- Surface Water Supply Index (SWSI)
  - Complements the PDSI and is computed from snowpack, stream flow, precipitation, and reservoir storage.
- Standardized Precipitation Index (SPI)
  - Measures drought based on multiple time scales.

The USGS also provides a map of real-time and seven-day average stream flow conditions within the state. Measurements of drought range from “normal to above normal” to “extreme hydrologic drought” (http://wy.water.usgs.gov/projects/drought/). The University of Wyoming has also partnered with federal and state agencies to begin watershed planning and drought monitoring (Wyoming Vulnerable, 2010).

Impending Water Policy Changes/ Conditions to Address Issue
The Wyoming State Climate Office states that it is involved in the process of adding climate change predictions to the State Water Plan (http://www.wrds.uwyo.edu/sco/climate/climate_change.html). However, there are no specific details about the process or timetable so it is likely that this project will not be completed in the near future. Wyoming does not currently appear to have other impending policy changes to address drought.

Technology/Policies Needed
There are no impending policy changes or new standards at this time and it may be several years before these are created. Once new policies are implemented, specific ideas for technologies can be generated.

Availability of Technology
Wyoming's drought plan is currently measuring surface water supply and predicting snow and stream flow. Therefore, sensors for water level monitoring are an available technology that will be needed to address drought and climate change in the state.

Key Issue: Inadequate Monitoring of Aquifer Levels

Key Dimensions
The main aquifer systems in Wyoming are structural basin aquifers, alluvial aquifers, and the Ogallala (High Plains) Aquifer system (Bedessem, Casey, Frederick, & Nibbelink, 2005). Wyoming is in the process of creating a state ambient groundwater monitoring program. Phase I mapped and targeted aquifers which are most susceptible to contamination (Wyoming Department of Environmental Quality, n.d.). This resulted in the identification of 33 priority areas within seven major basins.

Efforts have started with a partnership between the USGS, the Wyoming State Geological Survey, and the University of Wyoming's Water Resources Data System. In 2009, this partnership gathered information on the groundwater wells in the Greater Green River Basin to determine which wells should be a part of the program (http://wy.water.usgs.gov/projects/gw_monitoring/index.htm). Only alluvial or shallow bedrock wells of a depth less than 160 meters will be initially included. There is no implementation timetable, nor announced scope of the final program.

Action Needed
The state ambient groundwater monitoring plan needs to be fully implemented as soon as possible, due to the fact that chemicals used in hydraulic fracturing pose a threat to groundwater. Though a small percentage of the Ogallala Aquifer is located in Wyoming, the aquifer's future is still important to the state.

Wyoming does not appear to have addressed water monitoring in the Ogallala system but the Kansas Water Office (n.d.) has included Ogallala monitoring as part of its water plan. They aim to identify the annual rate of change by analyzing groundwater monitoring well data from the past 30 years. Regression equations will be used to estimate the average water depth. Therefore, efforts are being made to identify the scope of the problem but real-time monitoring is needed for an aquifer that is among the largest in the world at 174,000 square miles.

Current Approach
The USGS Wyoming Water Science Center has separate continuous water monitoring networks. However, there are currently only seven groundwater monitoring sites within the program (http://wy.water.usgs.gov/). The sites include:

- Surface water: 145 sites
- Groundwater: 7 sites
- Water quality: 21 sites, monitoring surface water only

Impending Water Policy Changes/ Conditions to Address Issue
To date, there are no impending policy changes to address aquifer monitoring in Wyoming. The state appears to be focused on implementing the statewide ambient groundwater monitoring program at this point.

Technology/Policies Needed
No new technology is needed at this time because there are no impending standards or policy changes. However, current water monitoring technologies are still needed to address current problems.

Availability of Technology
Water quality monitoring may be an important market for companies in Milwaukee to consider, as Bruno (2008) determined that there are fewer startup companies that focus on water quality monitoring than other areas. Technologies available include:

- Real-time monitoring
- Multiple site/strata monitoring
- Automated systems that do not rely on operator interpretation to determine results
- Units that monitor multiple contaminant classes: biological, chemical, and radioactive

Key Issue: Need to Set and Enforce Consumption Standards and Rules Promoting Conservation

Key Dimensions
Due to Wyoming's heavy use of irrigation and low population, the state's freshwater use per person, per day is 10,000 gallons (Boughton, Remley, & Bartos, 2006). In comparison, the national average use per person, per day is 827 gallons. Wyoming's total withdrawals per day in 2000 were:

- Total withdrawals: 5.16 billion gallons
  - Surface water: 4.4 billion gallons (85%)
  - Groundwater: 763 million gallons (15%)
- Water use per day by category:
  - Irrigation: 4.5 billion gallons
  - Mining: 301 million gallons
  - Thermoelectric: 243 million gallons
  - Public supply: 107 million gallons
  - Self-supplied domestic: 6.57 million gallons
  - Industrial: 5.78 million gallons

Action Needed
Water conservation education, replacement of old plumbing and fixtures, and reuse systems such as grey-water recycling will be needed, to an extent. However, the state has a higher than average water use per person because agricultural irrigation accounts for an extremely high total. Thus, specific limits need to be placed on the amount of water used or withdrawn per day, especially for agriculture. The current limit is 25 gallons per minute, regardless of use (Jacobs, Fassett, & Brosz, 1995).

Current Approach
Water conservation, involving the use of gray-water, is one current approach in Wyoming. The state allows gray-water systems without a permit if 11 specific conditions are met (http://deq.state.wy.us/wqd/www/Permitting/Downloads/GWPolicy.pdf). Gray-water is defined as any used water which does not come from the toilet and gray-water systems are intended to decrease the amount of water used in the state. Systems are not allowed to produce more than 2,000 gallons per day, on average, and must be designed so that they can withstand freezing conditions.

Impending Water Policy Changes/ Conditions to Address Issue
There is no evidence that Wyoming has any state level water conservation policies or programs. The Wyoming Water Development Commission states that it began working on the development of a conservation program with the Wyoming State Engineer's Office and the United States Bureau of Reclamation in August 1998 (http://wwdc.state.wy.us/wconsprog/wconsprog.html). The partnership resulted in the creation of a directory of agencies which provide educational, planning, and policy assistance to interested parties. However, there were no actual policies created.

Technology/Policies Needed
Policies to limit water use for all sectors, but especially for agricultural irrigation, are needed. The EPA's direct authority over groundwater is limited, as individual states are in charge of many regulations. Thus, there appears to be no EPA multi-state aquifer rules. This is something which may be necessary in western states where water shortages are common and amounts of water withdrawn are high. Multi-state aquifer rules may be necessary because individual state regulations will not be as effective without regional cooperation.

Availability of Technology
If water restrictions are placed on irrigation, micro-irrigation systems which involve low-cost drip technology and state-of the art technology will be needed. This includes micro sprinklers and conventional drip systems

Controlling water leaks in municipal systems is an important way to reduce water use, so the following leak control technologies will be helpful:

- Continuous acoustic monitoring
- Advanced metering infrastructure communication
- District Metered Areas (DMAs) for audit and leak control
- Pressure monitoring
- GIS analysis

Key Issue: Outdated Water Rights and Lack of Groundwater Controls and Limits

Key Dimensions
Prior appropriation is based on earliest use of water. Individuals who have the earliest rights are given priority over others for water in times of scarcity. Once an individual has a permit for individual or family household, lawn and garden, or stock watering for livestock, he or she can pump up to 25 gallons per minute without charge (Jacobs, Fassett, & Brosz, 1995).

There is no limit to the daily amount of water withdrawn, as long as it does not exceed 25 gallons per minute. Therefore, an individual could theoretically pump up to 36,000 gallons of water per day without any penalty or additional charges. Water rights such as these do little to promote conservation of water.

Action Needed
Changes to water rights may be necessary to help conserve water. The state might decide to amend the current rule of prior appropriation, as it does not result in equitable water distribution.

It may also be necessary to place limits on the amount of water which can be withdrawn per day or to charge fees for amounts of water which are withdrawn beyond a specified amount per day.

Current Approach
Currently, there are only two primary ways that a water right can be lost. The user can either voluntarily relinquish his or her right or can lose the right if water has not been used for a beneficial purpose for five years in a row (U.S. Bureau of Land Management, 2001).

Impending Water Policy Changes/ Conditions to Address Issue
Prior appropriation is very common in western states and there appears to be no discussion on amending this policy. In fact, it would likely be very difficult to do so. There is also the possibility that if such a change were ever to be made, individuals with existing water rights would be grandfathered under any new policies. There is also currently no discussion about placing limits on groundwater withdrawals at this time.

Technology/Policies Needed
If a future policy limiting groundwater withdrawal is implemented, the following technologies would be needed:

- More efficient crop irrigation systems to limit the need for groundwater withdrawal
- Real-time monitoring of aquifer withdrawal
- Water metering of individual water use

Availability of Technology
The technologies listed above are either being implemented or are currently available.

Wyoming References

ALL Consulting (2003). *Handbook on Coal bed methane produced water: Management and beneficial use alternatives*. Retrieved from http://www.gwpc.org/e-library/documents/general/Coalbed%20Methane%20Produced%20Water%20Management%20and%20Beneficial%20Use%20Alternatives.pdf

ALL Consulting (2006). *Feasibility study of expanded coal bed natural gas produced water management alternatives in the Wyoming portion of the Powder River Basin, phase one*. Retrieved from http://www.fe.doe.gov/programs/oilgas/publications/coalbed_methane/Final_WY_CBNG_FS.pdf

Bedessem, M. E., Casey, B., Frederick, K., & Nibbelink, N. (2005). Aquifer prioritization for ambient ground water monitoring [Electronic version]. *Ground Water Monitoring & Remediation, 25*(1), 150-158.
Boughton, G. K., Remley, K. R., & Bartos, T. T. (2006). Estimated Water Use in Wyoming During 2000. *U.S. Geological Survey*. Retrieved from http://pubs.usgs.gov/fs/2006/3099/pdf/fs2006-3099.pdf
Bruno, L. (2008, May 22). Water monitoring technology gets $8M boost in San Francisco, with more funds to come. *Green Beat: Interpreting Innovation*. Retrieved from http://green.venturebeat.com/2008/05/22/water-monitoring-technology-gets-8m-boost-in-san-francisco-with-more-funds-to-come/
Climatologist offers sobering water outlook for Wyoming (2007, October 19). *Wyoming Tribune Eagle*. Retrieved from http://www.wyomingnews.com
Food and Agriculture Organization of the United Nations (2003). *Improving irrigation technology*. Retrieved from http://www.fao.org/ag/magazine/0303sp3.htm
Groundwater Protection Council (n.d.). *Wyoming Groundwater Conditions*. Retrieved from http://www.gwpc.org/e-library/documents/state_fact_sheets/wyoming.pdf
Jacobs, J. J., Fassett, G., & Brosz, D. J. (1995). Wyoming water law: A summary [Electronic version]. *Corporate Extension Service, College of Agriculture and Wyoming Water Research Center, University of Wyoming.*
Kansas Water Office (n.d.). *Assessment of water level decline rates within the Ogallala Aquifer: Kansas*. Retrieved from http://www.kwo.org/reports%20&%20publications/Ogallala_decline_assessment.pdf
Lustgarten, A. (2008, November 13). Buried secrets: Is natural gas drilling endangering U.S. water supplies? *ProPublica*. Retrieved from http://www.propublica.org/feature/buried-secrets-is-natural-gas-drilling-endangering-us-water-supplies-1113
McGuire, V. L. (2001). Water-level changes in the High Plains Aquifer, 1980 to 1999. *United States Geological Survey*.
National Resources Defense Council [NRDC] (2003). *What's on tap? Grading drinking water in U.S. cities*. Retrieved from http://www.nrdc.org/water/drinking/uscities/pdf/chap01.pdf
New Hampshire Department of Environmental Services (2004). *Dissolved mineral radioactivity in drinking water*. Retrieved from http://des.nh.gov/organization/commissioner/pip/factsheets/dwgb/documents/dwgb-3-11.pdf
United States Bureau of Land Management (2001). *Wyoming: Water rights fact sheet*. Retrieved from http://www.blm.gov/nstc/WaterLaws/wyoming.html
United States Department of Energy, Office of Fossil Energy (1997). *Investments in Fossil Energy Technology: How the Government's Fossil Energy R&D Program Has Made a Difference.* Retrieved from http://www.fe.doe.gov/programs/powersystems/publications/General_Interest/succes97.pdf
United States Environmental Protection Agency (2004). *Evaluation of impacts to underground sources of drinking water by hydraulic fracturing of coal-bed methane reservoirs*. Retrieved from http://www.epa.gov/safewater/uic/pdfs/cbmstudy_attach_uic_ch04_hyd_frac_fluids.pdf

United States Environmental Protection Agency (2007). *EPA's Clean Water Act review of the coal bed methane (CBM) industrial sector: Stakeholder teleconferences*. Retrieved from http://www.oipa.com/page_images/1194276205.pdf

United States Environmental Protection Agency (2010, January 1). EPA increases transparency on chemical risk information [News Release]. Retrieved from http://www.epa.gov/aging/press/epanews/2010/2010_0121_1.htm

United States Congress, House Committee on Oversight and Government Reform (2007, October 25). Theo Coburn, PhD, President of TEDX, Paonia, Colorado. *Hearing on The Applicability of Federal Requirements to Protect Public Health and the Environment from Oil and Gas Development*. Retrieved from http://s3.amazonaws.com/propublica/assets/natural_gas/colburn_testimony_071025.pdf

World Health Organization (2005). *Bromate in drinking-water: Background document for development of WHO "Guidelines for Drinking-water Quality."* Retrieved from http://www.who.int/water_sanitation_health/dwq/chemicals/bromate030406.pdf

Wyoming Department of Environmental Quality (n.d.). *Addendum: Water quality monitoring strategy 2004-2008*. Retrieved from http://deq.state.wy.us/wqd/groundwater/downloads/Strategy%2004-08.pdf

Wyoming Department of Environmental Quality (2000). *Water quality rules and regulations: Chapter 1.* Retrieved from http://www.epa.gov/waterscience/standards/wqslibrary/wy/wy_8_chapter1.pdf

Wyoming Department of Environmental Quality (2004). *Water quality monitoring strategy: 2004-2008*. Retrieved from http://deq.state.wy.us/wqd/watershed/Downloads/Monitoring/4-0661doc.pdf

Wyoming Department of Environmental Quality (2008a). *Wyoming's draft 2008 305(b): Integrated state water quality assessment report and draft 2008 303(d): List of waters requiring TDMLs.* Retrieved from http://deq.state.wy.us/wqd/events/public%20notices/2008%20Draft%20305_b_.pdf

Wyoming Department of Environmental Quality (2008b). *Wyoming nutrient criteria development plan: Final*. Retrieved from http://deq.state.wy.us/wqd/watershed/surfacestandards/Downloads/Standards/Wyoming%20Nutrient%20Criteria%20Plan%20final%202008.pdf

Wyoming Department of Environmental Quality (2009). *Report and recommendations of the Carbon Sequestration Working Group to the Joint Minerals, Business and Economic Development Committee and the Joint Judicial Committee of the Wyoming State Legislature*. Retrieved from http://deq.state.wy.us/wqd/events/public%20notices/UIC/FinalReport081909.pdf

Wyoming Department of Environmental Quality (draft for 2010, July 8 hearing). *Water quality rules and regulations. Class VI injection wells and facilities underground injection control program*. Retrieved from http://deq.state.wy.us/wqd/events/public%20notices/UIC/Ch%2024%20Draft%20for%20EQC%20Hearing%20July%208,%202010.pdf

Wyoming Drought Task Force (2003). *Wyoming drought plan*. Retrieved from http://www.wrds.uwyo.edu/sco/drought/droughtplan.pdf

Wyoming vulnerable to water scarcity as planet warms (2010, January 26).

Environmental News Service. Retrieved from http://www.ens-newswire.com/ens/jan2010/2010-01-26-093.html

Wyoming Water Development Commission (2007). *Wyoming framework water plan volume I*. Retrieved from http://waterplan.state.wy.us/plan/statewide/Volume_I.pdf

Chapter 3 The US EPA Approach

Key Markets	Niche Markets
Biological Nutrient Removal controls systems & retrofits for wastewater treatment	Point of entry/point of use treatment systems
Resource recovery from wastewater	Greywater systems
CAFO pollution control & nutrient recovery	Rainwater collection
Coal-bed Methane wastewater treatment & re-use	Bilge water treatment for vessels
Hydrofracking fluid treatment & re-use	Dual distribution systems
Conservation and efficiency	Biological, chemical & radiological security
Stormwater control	
Real-time measurement, control and alert systems for drinking water and wastewater	
Distribution and collection system infrastructure replacement and repair	
Emerging contaminants	
Disinfectant Byproduct (DBP) control	
CO_2 sequestration	
Decentralized wastewater treatment (septic and cluster systems)	

While the dozen states in Chapter 2 are fairly representative of the US water problems and approaches, there are differences both in problems and approaches across the fifty states. In many instances water regulations are set by the federal government and administered by the Environmental Protection Agency. In fact, the Clean Water Act is quite explicit about that.

But the nature of the federal system also allows for local discretion on a number of topics. Thus, for example, the level of phosphorous allowed in wastewater treatment effluent is allowed to vary further, as long as it meets a national minimum. Wisconsin is currently attempting to dramatically lower the amount allowed, and this effort is entirely independent of EPA.

On the other hand, there are many issues and standards that are set by the federal government. This is done, in part, to assure safety and similarity across the country. But it is also done to contend with issues that are not contained within any one state. Thus, for example, we have issues in the Chesapeake Bay that have been caused by activities in New York, Pennsylvania, Delaware, Maryland, and Virginia. To better protect the endangered watershed, EPA has stepped in with regulations that the individual states might not endorse on their own.

One advantage of EPA involvement is federal resources. The federal government not only regulates, it helps to make change happen with the use of federal dollars. It also sponsors research to develop new approaches to solving perplexing water problems. Explication of both these topics is the subject of this chapter.

United States EPA Summary: Problems and Technologies

The US, with a population of 312 million and a gross domestic product of $14 trillion, is currently the world's largest water market, estimated at $108 billion annually. The US Environmental Protection Agency (EPA) is the primary regulatory agency for water, and also administers the majority of funding for water projects through the Clean Water State Revolving Fund (CWSRF) and the Drinking Water State Revolving Fund (DWSRF). Other federal agencies are also involved in water regulation, including the US Department of Agriculture (USDA), the Department of Energy (DOE), the Department of Homeland Security (DHS), and others. In addition, states and municipalities have responsibility for some aspects of water regulation within their jurisdictions, and often administer federal programs.

Water Infrastructure - Scale

Collection (wastewater) and distribution (drinking water) comprise the two major categories of water infrastructure. The US EPA produces quadrennial reports that project national needs over a twenty-year period in both categories. The Drinking Water Infrastructure Needs Survey and Assessment 2007 estimates that $335 billion will be needed for drinking water infrastructure through 2026, and the 2008 Clean Watersheds Needs Survey estimates that $298 billion will be needed over a twenty-year period for wastewater infrastructure. In both cases, these estimates are solely for improvements that "address a water quality or a water quality-related public health problem" for an existing population, and are confined to capital costs for infrastructure replacement projects that are eligible for Clean Water State Revolving Fund (CWSRF) or Drinking Water State Revolving Fund (DWSRF) monies. They do not include investments for things such as service expansion due to population growth, or non-capital expenditures such as ongoing operations and maintenance costs. Also specifically excluded are large water storage projects, such as dams and reservoirs, which are not eligible for DWSRF funding.

Other Long-Term Infrastructure Cost Estimates

- The Congressional Budget Office (CBO) 2002 report "Future Investment in Drinking Water and Wastewater Infrastructure," which estimates annual water system needs of $14.6 billion to $25.2 billion, or a 20-year need in the range of $292 to $504 billion

- EPA's 2002 "Clean Water and Drinking Water Infrastructure Gap Analysis," which estimated drinking water systems' 20-year capital needs in the range of $204 billion to $590 billion.

- The Water Infrastructure Network's (WIN's) 2000 "Clean and Safe Water for the 21st Century - A Renewed National Commitment to Water and Wastewater Infrastructure," which estimates water system needs of $25 billion annually, or $503 billion over 20 years.

- The US Conference of Mayors (USCM) released the "Trends in Local Government Expenditures on Public Water and Wastewater Services and Infrastructure: Past, Present, and Future" report in 2010 that estimated total spending by governments over twenty years for water projects will be in the range of $2.5 to $4.3 trillion. This estimate includes operation and maintenance costs, and includes investment for new infrastructure to meet population growth needs.

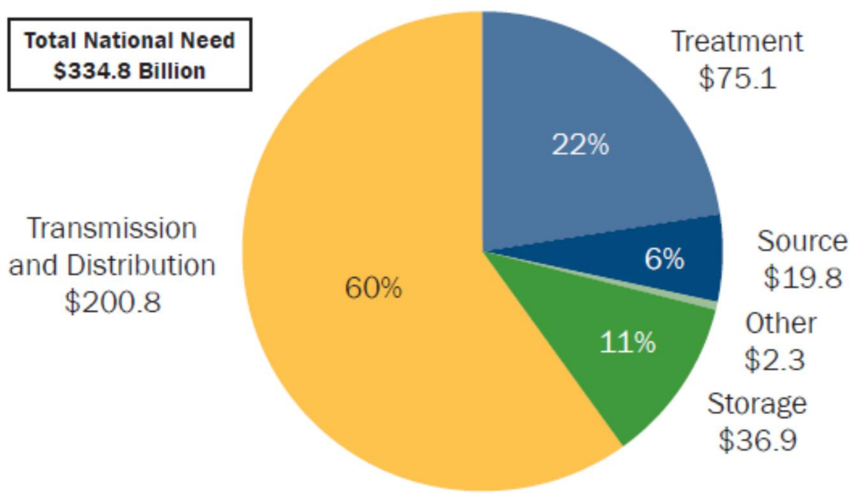
National Water Infrastructure

- 52,000 community and 21,400 non-community drinking water systems
- 1.8 million miles of drinking water pipe
- 16,000 publicly-owned wastewater treatment plants
- 100,000 major pumping stations
- 600,000 miles of sanitary sewers and 200,000 miles of storm sewers
- 1.2 million miles of wastewater pipe

Needs by Category

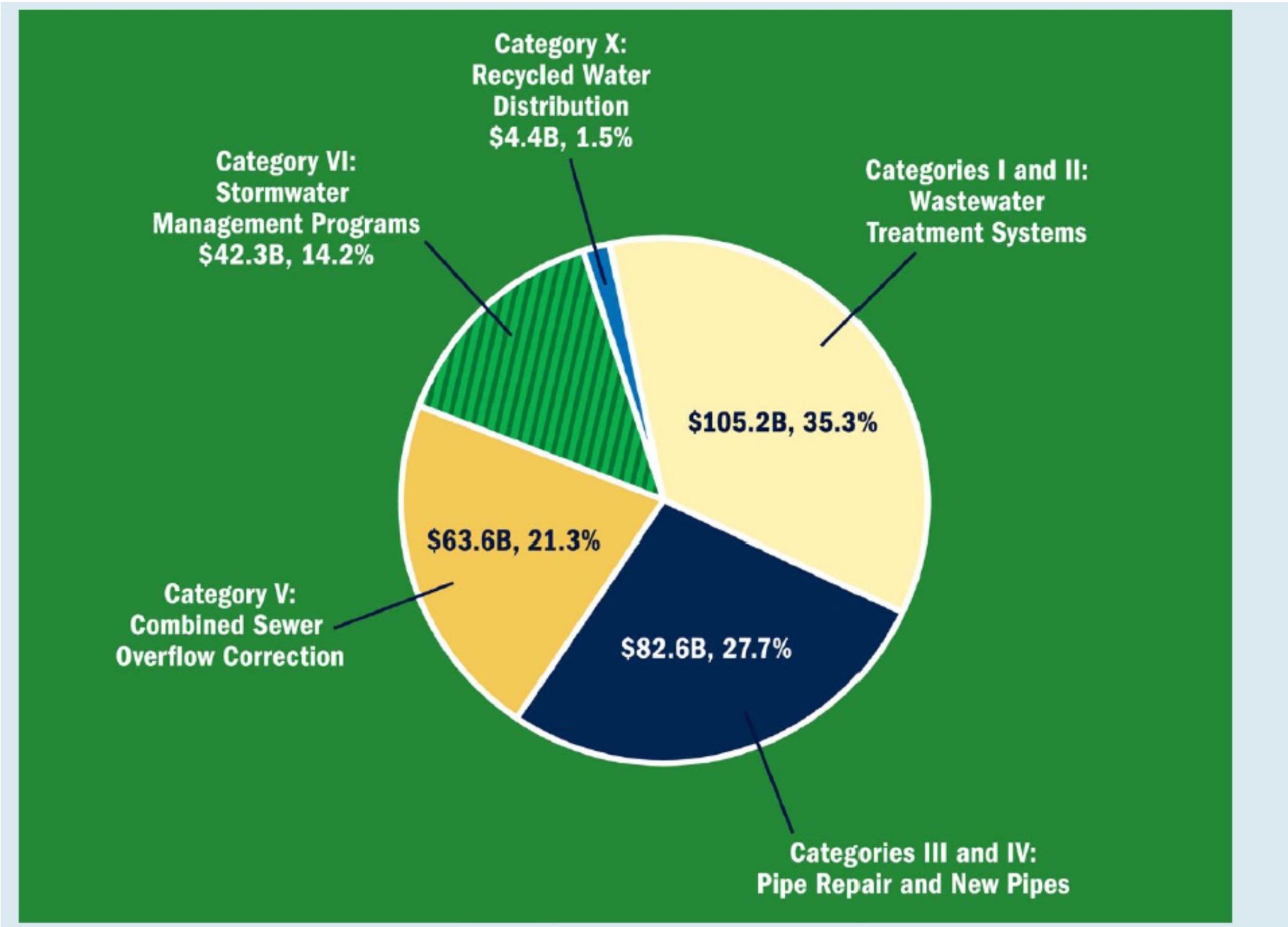
The chart below shows projected drinking water needs. Transmission and distribution is the largest category, at 60% of the total; the next largest is treatment, at 22%.

Exhibit 1.4: Total 20-Year Need by Project Type (in billions of January 2007 dollars)



Note: Numbers may not total due to rounding.

As shown below, the two largest needs for wastewater are collection (pipes and pipe repair) and treatment infrastructure. Treatment comprises the largest share, at 35%, and collection needs, at 28%, are somewhat smaller.



Drivers

- Aging infrastructure, especially in older urban centers - the annual percentage of transmission and distribution lines that require replacement is expected to increase steadily from less than 0.5% currently to nearly 2% by 2035
- Population growth rate of 0.91% annually through 2016, with growth concentrated in urban areas, and predominantly occurring in southern and western areas (infrastructure costs for growth needs are accounted for in the USCM report) - rural population is expected to decline over the same period
- Trends toward higher treatment standards (e.g., secondary and tertiary wastewater treatment) for an ever-increasing percentage of the US population
- Current treatment may not be sufficient to address emerging issues and potentially stronger regulatory requirements, especially regarding storm water runoff in developed areas, nutrient (phosphorus and nitrogen) control, and contaminants such as endocrine disrupting compounds and pharmaceuticals
- Investment in research and development has declined, creating technology gaps in the water industry

Medium and small drinking water systems, defined as those that serve less than 100,000 persons, account for a disproportionate share of the need, as indicated in the table below.

System Size	CWS Need		Water Systems		Population Served	
	$ Billions	% of CWS Need	Number of Systems	% of Water Systems	Pop. (millions)	% of Pop. Served
Large Community Water Systems (serving over 100,000 persons)	$116.3	36%	584	1%	128.6	45%
Medium Community Water Systems (serving 3,301 to 100,000 persons)	$145.1	45%	8,749	17%	130.7	46%
Small Community Water Systems (serving 3,300 and fewer persons)	$59.4	19%	41,748	82%	24.1	9%

Source: EPA 2008 Clean Watersheds Needs Survey

Drinking Water Quality

Scale and Timeframes

Of the $334 billion for drinking water needs, $52 billion, or 16% of the total, is allocated for current and future regulatory needs. Future regulatory needs are subject to revision as issues and regulatory priorities change over time, and new technologies make lower contaminant limits feasible.

Regulatory Needs (in billions)

Regulation Type	Microbial Regulations	Chemical Regulations	Total Regulatory Need
Existing Regulations	$29.4	$15.6	$45.0
Proposed or Recently Promulgated Regulations	$3.6	$3.3	$7.0
Total Regulatory Need	**$33.0**	**$19.0**	**$52.0**
Note: Numbers may not total due to rounding.			

Source: EPA 2008 Clean Watersheds Needs Survey

Four emerging rules make up the $7 billion in capital expenditures for proposed and recently promulgated regulations.

- Proposed Radon Rule: $3.3 billion
- Final Stage 2 Disinfectants/Disinfection Byproducts Rule: $1.0 billion

- Final Long Term 2 Enhanced Surface Water Treatment Rule (treatment needs only): $2.2 billion
- Ground Water Rule: $400 million

Drinking water Contaminants
Coliform, the disinfectant byproducts (DBPs) HAA5 and TTHM, nitrates, arsenic, and radionuclides are the most abundant contaminants nationwide.

US Safe Drinking Water Compliance Trends - Selected Violations 2001-2009

Category	Contaminant Name	Number of Violations by Year								
		2001	2002	2003	2004	2005	2006	2007	2008	2009
Total Coliform Rule	Coliform (Pre-TCR)	1	27	5	2					
	Coliform (TCR)	9,644	9,101	9,041	9,093	9,113	9,349	9,586	9,049	8,753
TCR Total		9,645	9,128	9,046	9,095	9,113	9,349	9,586	9,049	8,753
Disinfection By-Products	Total Haloacetic Acids (HAA5)	1	10	100	256	1,577	1,301	1,099	1,146	997
	TTHM		21	132	329	2,712	2,374	2,076	2,030	1,999
	Nitrate	452	538	610	662	730	739	788	862	830
	Nitrate-Nitrite	61	54	151	201	204	166	196	283	271
	Nitrite	4	3	6	7	9	7	11	18	26
	Arsenic	27	36	29	72	96	448	1,569	2,191	2,424
Inorganic Chemicals	Fluoride	143	334	231	252	433	322	312	304	329
k Rads	Combined Radium (-226 & -228)	252	275	515	514	707	686	740	645	531
	Combined Uranium				21	181	216	234	329	310
Not Regulated	Chloride	2	13	13	34	73	54	50	58	50

Source: SDWISFED GPRA http://www.epa.gov/safewater/databases/pivottables.html

Current and Emerging Technologies for Water Infrastructure and Drinking Water Treatment
Many treatment and control technologies are effective over a broad range of chemical and biological contaminants. While the radon, disinfectant/disinfection byproducts, surface water, and groundwater rules have some unique requirements, there is considerable overlap in treatment technology.

Proposed Radon Rule
The proposed radon rule for drinking water from has been in existence since 1999. It applies to community water systems that utilize groundwater sources, and requires states to adopt one of two contaminant limits for radon in drinking water, depending on whether the state operates an indoor air radon mitigation program. Effective means of radon removal from water include aeration and granulated activated carbon (GAC) adsorption. Advanced filtration technologies developed for other contaminants are also likely to be effective for radon removal.

Final Stage 2 Disinfectant/Disinfection Byproducts Rule
The Stage 2 D/DBPR rule was promulgated in 2005. It requires public drinking water treatment systems to begin monitoring between 2012 and 2016; the start date is dependent on system size. Each system has one year from the date that monitoring begins to reach full compliance for the maximum contaminant levels (MCLs) for disinfectant residuals and byproducts. Total trihalomethanes (TTHM) and five haloacetic acids (HAA5) are the main DBPs of concern. Switching from chlorine to chloramine disinfectant and enhanced coagulation with organic

carbon are standard DBP control methods, along with pH management. There are several advanced options as well, most of which focus on the removal of total organic carbon.

Advanced options for DBP control

- Magnetic Ion Exchange (MIEX®) - proprietary polymer bead resin with magnetic core
- Actiflo®CARB - proprietary ballasted clarification with powdered activated carbon adsorption
- Nanofiltration
- Granular activated carbon (GAC),
- Ozone/Biofiltration - biologically reactive GAC
- Automated mains flushing systems - received categorical approval from EPA in 2010

Final Long Term 2 Enhanced Surface Water Treatment Rule

The LT2 SWTR is primarily designed to control *Cryptosporidium, a pathogen that is resistant to disinfection agents. It* applies to drinking water systems that use surface water (or ground water under the direct influence of surface water) as a source. This includes about 14,000 systems serving approximately 180 million people. LT2 also applies to systems that store finished water in reservoirs.

Since filtration is relatively effective in removing c*ryptosporidium* from water, advanced filtration methods utilized for other contaminants can be utilized for crypto*sporidium* as well. Since monitoring for crypto*sporidium* can be expensive, small systems can monitor for E. coli instead; E. coli detection triggers further investigation and corrective action. Innovative technology is needed to monitor, prevent and control surface water pathogens.

Emerging technologies and needs

- Hexa-Cover® - floating tile, self-forming reservoir covering system
- Cost-effective E. coli and cryptosporidium monitoring
- Real-time monitoring systems
- Diatomaceous earth (DE) filtration
- UV treatment

Ground Water Rule

The Ground Water Rule was promulgated on December 1, 2009 and applies to public drinking water systems that use groundwater sources, which serve 70 million people in the US It requires 4 log (99.99%) virus inactivation or removal, or alternatively, groundwater monitoring. Systems that do not provide 4-log treatment are required to monitor their groundwater source(s) for fecal coliform. States must complete surveys of all public water systems that use groundwater as a source by 2014; after that, ongoing surveys must be completed on three- or five-year cycles, depending on system treatment method and historical performance.

Current treatment technology

- UV disinfection
- Filtration
- Adsorption
- Chlorination

The main challenge is maintaining treatment effectiveness throughout the distribution system, including storage tanks and water pipes, without increasing the formation of disinfection byproducts (DBPs). Recent trends in water conservation initiatives, such as EPA's Water Sense program and LEED certification standards, will exacerbate this problem by increasing water residence times in distribution networks. There are several emerging technologies that address these issues.

Emerging Technologies

- Energy efficient in-tank mixing systems that maintain a uniform water "age" in the tank and prevent thermal stratification
- Chlorine dosing systems that operate in tanks or reservoirs to maintain an effective level of disinfectant in the distribution system
- UV systems that achieve uniform dosing, even in turbid water
- Pre-treatment filters that minimize organic matter and resulting DBP formation
- Granular activated carbon (GAC) adsorbents (effective on a broad range of contaminants, including radon)
- Point of entry and point of use filtration, especially for sensitive applications such as hospitals
- Dual distribution systems that utilize separate pipes for fire hydrants and potable supply; in this arrangement, the potable supply pipes can be much smaller (typically 2" vs. 6" or larger), greatly reducing water residence time in the network. An additional benefit of dual distribution is that the water used for fire suppression may not have to be treated to potable standards.
- Real-time monitoring and instantaneous wireless notification of disinfectant residual, DBP, and biological contaminant levels at various points in the distribution network
- Alternative disinfecting agents (for example, chloramines, hydrogen peroxide, chlorine dioxide, ozone, copper and silver compounds), that may produce fewer DBPs and/or maintain effective residuals for an extended period of time

For water systems that rely primarily on groundwater monitoring to satisfy the requirements of the rule, the greatest need is for enhanced, cost-effective monitoring and control systems.

- Trend toward real-time monitoring
- Multiple site/strata monitoring
- Web-enabled networked systems linked by RF or cellular technology
- Automated systems that do not rely on operator interpretation to determine results
- Units that monitor multiple contaminant classes: biological, chemical, and radiological

Arsenic

Arsenic - the maximum contaminant level for arsenic in drinking water is .01 mg/L, with an MCL goal of zero mg/L. The limit was established in 2001, and utilities were required to be in compliance by 2006. As indicated in the violations table, MCL violations for arsenic have been increasing steadily since 2006. EPA estimates that approximately 4,000 drinking water systems supplying 13 million people need to treat their water to meet MCL targets, at a cost of $181 million (in 2001 dollars). The rise in arsenic violations suggests that these numbers have increased since the estimates were made. In addition, recent studies on waterborne arsenic in

Bangladesh indicate that concentrations as low as .01mg/L may still produce adverse health effects. For these reasons, arsenic may be a prime candidate for more stringent regulation in the future. A number of established treatment methods are used to control arsenic.

- Coagulation/Filtration
- Lime Softening
- Activated Alumina
- Ion Exchange
- Reverse Osmosis
- Electrodialysis Reversal
- Nanofiltration
- Point of Use/Point of Entry treatment

Emerging Technologies and Innovative Treatment Methods

- Ion Exchange with Brine Recycle - lowers sludge production
- Iron (Addition) Coagulation with Direct Filtration
- Iron/Manganese (Fe/Mn) Removal Processes
- Arsenic Treatment Unit (ATU) with Aqua-Bind™ alumina media- used in Bangladesh

Virtually all of these processes generate arsenic-laden sludge or waste streams, which can present disposal problems. Technology and processes that address this issue are needed. Currently, treatment for arsenic is also relatively costly, so there is a need for lower cost technologies.

Radium and Other Radionuclides

The MCL for radium is 5 pCi/L (picocuries/liter), with an MCL goal of zero. Like arsenic, radium contamination is typically more of an issue for groundwater sources, especially, deep aquifer sources. Other radionuclides, such as uranium, are regulated as well - radium is more common in Midwest aquifers, while uranium is more prevalent in the West. In 2000, EPA estimated that approximately 800 water systems serving over one million people would need to treat for radium or uranium, at an annual cost of $81 million (in 2000 dollars). The treatment methods for radionuclides are similar to those for arsenic, and the processes generate similar disposal problems. Radium-containing sludge is often diluted with soil and spread on agricultural fields. States regulate the sludge disposal process; as a result, allowed radiation levels vary widely.

Leak Control

Water leakage rates vary widely by location. The estimated overall leakage rate for US water distribution systems is 11%, which is low by worldwide standards. By 2050, one third of US counties may be facing water shortages due to climate change, and population growth in arid regions of the country. Leak control is one of the most cost effective water conservation measures. It can also increase treatment plant income by reducing “non-revenue water.” The need for leak control technologies is certain to increase in the coming years, and leak control technology has been the subject of much recent research.

Leak Control Technologies

- Continuous acoustic monitoring

- Advanced metering infrastructure communication
- District Metered Areas (DMAs) for audit and leak control
- Pressure monitoring
- GIS analysis

Emerging Drinking Water Regulations

- Long-term lead and copper revisions proposal is due in 2012 - it potentially would require the replacement of municipally-owned lead distribution lines
- By the end of 2010, EPA is expected to regulate several emerging contaminants
  - Perchlorate - a degradate of chlorine (potential MCLs - EPA: .015 mg/L, CA: .006 mg/L)
  - NDMA and other nitrosamines
- Candidate Contaminant List 3 (CCL3) - 104 chemicals and 12 microbes, several of which may be regulated in the near future
- Unregulated Contaminant Monitoring Regulation (UCMR) - round 3 is scheduled for 2013-2015

In March 2010, EPA published the results of its second six-year review of health effects, analytical methods, occurrence, and treatment data for 71 existing drinking water regulations. The review identified 18 chemicals and pathogens of concern.

Candidates for Regulatory Revision

- Acrylamide
- Epichlorohydrin
- Trichloroethylene [TCE]
- Tetrachloroethylene [PCE]

Recent or Ongoing Action

- Bromate
- Chloramines
- Chlorine
- Chlorine dioxide
- Chlorite
- Coliform
- Copper
- Cryptosporidium
- Giardia lamblia
- HAA5
- Lead
- Legionella
- TTHMs
- Viruses

Policy Trends

- Funding for infrastructure replacement is the main issue confronting the public water sector, especially for medium and small districts. A significant policy innovation to address this issue would be the removal of the current cap for private activity bonding issues for water infrastructure, a proposal which was most recently introduced (and rejected) in the 2010 congressional session. It would generate up to $60 billion in water infrastructure financing at a cost to the federal government of approximately $372 million.

- A bill has been introduced in Congress (HR 5320) that would require the EPA to begin testing at least 100 suspected endocrine disrupting chemicals. It also would establish lower lead limits for plumbing system components - to be labeled "lead-free," components could contain no more than .2% - .25% lead by weight.

- EPA is changing the way it evaluates drinking water contaminants. The agency is moving to a system in which substances are evaluated in groups, rather than individually. The goal is to speed the regulatory process. Potential classification groupings include chemical or biological similarity, treatment technology, similarity of use, and health endpoints. New treatment technologies that address a broad range of chemical and biological contaminants without generating harmful byproducts will be best suited to this new regulatory approach.

- EPA is also focusing more resources on smaller systems, where the bulk of violations occur. Smaller systems often have fiscal constraints that prevent them from adopting the latest or most effective technology. EPA is targeting several sources of funding to small systems.

- The disposal of sewage sludge, especially on agricultural fields, is becoming a public issue, particularly in regard to organic agriculture standards.

Agriculture

Background

Agriculture accounts for approximately 70% of water use worldwide, and exceeds 80% of consumptive water use in the US. In some western states, agricultural water consumption exceeds 90% of total consumptive use.

Due to increased needs for efficiency in the face of declining profit margins, agricultural processes in the US are becoming increasingly industrialized and operate on ever larger scales. Agriculture is also frequently monoculture as well, in which a single crop or animal is the major focus of a farming operation. Modern agricultural practices can have significant impacts on both surface water and groundwater. A number of issues are of particular concern to EPA and other governmental agencies.

- Concentrated Animal Feeding Operation (CAFO) Pollution
- Chemical Fertilizer Contamination
- Erosion/Sedimentation

CAFOs

Key Dimensions

CAFOs concentrate animals, feed, wastes, dead animals, and production operations on a small land area. CAFOs that meet the regulatory definition of a CAFO are considered point sources of pollution and may be regulated under the NPDES permitting program of the Clean Water Act (CWA).

Contaminants in CAFO Effluent

- Nutrients (phosphorus and nitrogen)
- Sediment
- Heavy metals
- Arsenic
- Pathogens

An emerging CAFO "contaminant" has recently been identified in groundwater near leaking lagoons at swine farm operations - bacterial DNA that confers antibiotic resistance and that can migrate among species of microorganisms. This development has potentially negative consequences for the continued efficacy of commonly used antibiotics.

Only CAFOs that discharge waste or propose to discharge are required to apply for NPDES permits. CAFOs that are required to apply for permits are also required to submit Nutrient Management Plans (NMPs), which become enforceable elements of the permits and are made available to the public for comment.

Land application of manure is an enduring practice which mimics the natural ecological order. Nitrogen and phosphorus are beneficial to plants if applied to soil at the correct concentrations and at the right times. However, manure from CAFO's often contains excessive phosphorus, which, unused by the plants, can contribute to surface water phosphorus loadings.

Timeframe and Political Attention

EPA's CAFO Final Rule was promulgated in 2008. It required compliance by February, 2009. Certain provisions of the 2008 CAFO rule were the result of a lawsuit brought by the Waterkeeper's Alliance, an environmental action group seeking to strengthen regulation of the industry.

The use of CAFOs is likely to increase to accommodate the nation's population growth, and likely to expand in such areas as aquaculture. In addition, EPA's nutrient strategy increasingly favors source control for nitrogen and phosphorus. CAFO pollution problems, especially odors, are often dramatic and generate extensive publicity. These factors, combined with states' expected forthcoming development of numeric nutrient criteria, mean that expanded regulation of CAFOs is going to remain a high priority for EPA and USDA in the coming years.

Scale and Drivers
The defining characteristics of a CAFO for regulatory purposes are the number and type of animal in the operation. The numerical thresholds for CAFO designation range from 150 for horses to 37,500 for chickens, and designation also depends on such factors as the presence of surface water, a means of conveyance (ditch or pipe) of animal waste to surface water, or a regulatory determination that the operation is a "significant contributor of pollutants."

Overall, there are an estimated 238,000 CAFOs of all sizes in the US, which generate 500 million tons of manure each year. In 2006, EPA estimated that there were approximately 19,000 medium and large CAFOs, over 14,000 of which would require NPDES permits and NMPs under the 2008 rule.

Total estimated annual load of selected contaminants from medium and large (regulated classes) CAFOs:

- Nitrogen: 786 million pounds
- Phosphorus: 371 million pounds
- Sediment: 33 million tons
- Heavy metals: 4.4 million pounds
- Arsenic: 1.7 million pounds

Current Technology

- Anaerobic treatment lagoons for partial biological waste digestion (can be unlined if built prior to late 1990s)
- Liquid manure soil injection - controls odors, usable with no-till agriculture
- Biogas capture for energy generation

Technology Needs

- Monitoring and control systems for treatment lagoons to enhance BNR processes
- Retrofit liner technology for existing lagoons
- Cost-effective high-efficiency manure treatment systems
- Nutrient recovery - especially phosphorus
- Zero liquid discharge processes for environmentally sensitive watersheds and dry fertilizer production
- Phosphorus/nitrogen balancing - for optimum fertilization efficiency without excess phosphorus
- Nutrient testing and automated blending systems to achieve appropriate nutrient concentrations for a variety of agricultural needs
- Systems for aquaculture
- Manure solids application technology for no-till agriculture
- Heavy metals and arsenic reduction technology
- Alternatives to "preventive" antibiotics use in animals
- Integrated energy/fertilizer production
- Sophisticated field-level and watershed-level modeling tools (the GIS-based Hydrologic Unit Water Quality Tool (HUWQ) and Soil and Water Assessment Tool (SWAT) are examples)

Policy Needs

- Regulations to cover a majority of small CAFOs, currently regulated only under special determinations
- Watershed-level authorities for NPDES permitting

Chemical Fertilizer Contamination

Key Dimensions

Chemical, or synthetic, fertilizers present some of the same water quality challenges as CAFOs. The primary concern is nutrient management. Heavy metals are also present in synthetic fertilizers to varying degrees, although typically at much lower concentrations than found in CAFO generated manure.

Nutrient management in agricultural applications begins with accurate and timely soil analysis, and takes crop type, topography, hydrologic modeling, and historical crop yield information into account.

The manufacture of synthetic fertilizers is heavily dependent on the use of fossil fuels, both as a source of nitrogen and to provide energy for the processing, delivery, and field application of the product. In theory, locally sourced organically-based fertilizers are a more sustainable alternative, but synthetic products offer the advantages of consistent nutrient ratios and lower heavy metal and arsenic loadings. However, most synthetic fertilizers are much more concentrated than organic materials, for ease of transportation, storage, and application. Spillage, runoff and excessive application of synthetics may have serious water quality implications.

Scale

By 2008, according to USDA estimates, synthetic fertilizers applied in the US utilized the following quantities of nutrients:

- 13 million tons of nitrogen
- 4 million tons of phosphorus
- 5 million tons of potash

Phosphorus use has remained relatively stable since the late 1960s, while nitrogen use has doubled. Overall, the quantities of synthetic nutrients used on an annual basis haven't changed significantly since the late 1970's, while yields per acre of some crops, such as corn, have nearly doubled. This is generally attributed to advances in agricultural technology and more selective application of fertilizers. The increased use of compost, dried manure, and other organic materials over this period may also have contributed to this trend.

Although usage trends for synthetic fertilizers remain flat, more stringent surface water limits for nitrogen and phosphorus are likely to make regulation of synthetic fertilizers a continuing priority for USDA, EPA, and the states.

Policy

- USDA, through its Natural Resources Conservation Service, operates the Environmental

Quality Incentives Program (EQIP). EQIP provides payments to farmers for, among other things, nutrient management practices that utilize soil tests and variable-rate fertilizer application to ensure accurate nutrient dosing for crop needs.
- States regulate fertilizer handling procedures and field application rates

Policy Needs
- Regulations limiting use of synthetic fertilizers for non-essential (ornamental) plants, including lawns
- Stringent limits on phosphate use in fertilizers
- Increased incentives for the use of natural and organic fertilization materials

Current Technology
- Determination of soil nutrient levels
  - Manual sampling
  - Lab analysis
  - Substantial time gap between sampling and results
- GIS-aided sampling for increased mapping precision

Technology Needs
- Field-embedded real-time sensor networks for nutrient and chemical sampling
  - Higher spatial resolution
  - Timely data acquisition
- Sensor network control of variable rate fertilizer application equipment
- Real-time nutrient mixing and balancing
- Synthetic nutrient balancing of natural fertilizers to control excess phosphorus
- "Toilet to field" systems for the production of clean sewage sludge for agricultural use

Erosion/Sedimentation

Key Dimensions
Soil erosion from agricultural land is one of the primary mechanisms of nutrient contamination in surface water. Cropland erosion transfers phosphorus and nitrogen from soil to water, and can also increase water turbidity and cause excess sedimentation in river and stream beds. In addition, erosion may transfer pesticide and herbicide residuals to surface waters, increasing treatment requirements where surface water is a used as a source of drinking water.

Scale and Drivers
Agricultural acreage in the US has declined significantly in recent years, while developed acreage has increased significantly to accommodate population growth.
- Cropland acreage declined from 420 million acres in 1982 to 357 million acres in 2007, a 15% decrease
- 40 million acres of land were newly developed between 1982 and 2007, bringing the national total to about 111 million acres

Several technology and policy drivers have also contributed to the decline in cropland.

- Intensive farming methods
- Incentives to remove environmentally sensitive land from production - USDA's Conservation Reserve Program accounts for half of the decline in cropland from 1982 to 2007

Agricultural erosion has also declined significantly, due in part to programs designed to reduce erosion.

- Total cropland erosion (sheet, rill and wind) declined by about 43 percent, from more than 3.06 billion tons per year in 1982 to about 1.72 billion tons per year in 2007
  - The reduction reflects USDA's Natural Resources Conservation Service's (NRCS) emphasis on working with producers and landowners to reduce erosion

Erosion control is amenable to green infrastructure solutions and best management practices.

- Cover crops
- Proper manure storage
- Riparian forested buffers
- Gutters
- Restricting winter application of manure

Technology

- Stream fencing
- Biodegradable erosion control mats

Policy

Agricultural erosion will continue to be an important regulatory issue for the foreseeable future, due in part to EPA's increasing emphases on non-point source control and green infrastructure solutions.

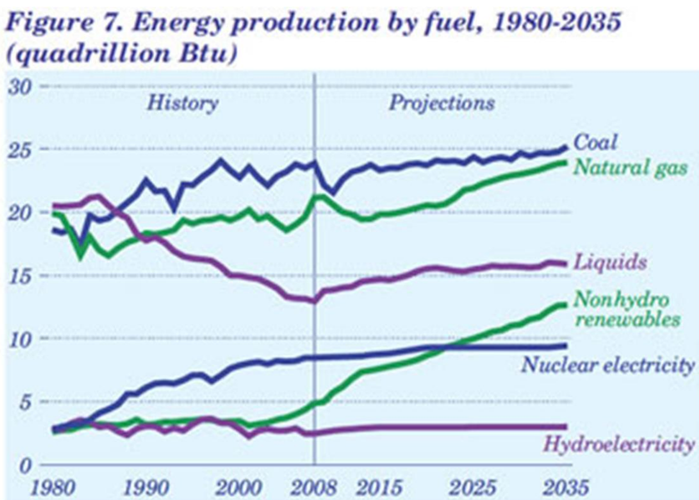
Groundwater

EPA's direct authority over groundwater and its use is limited; much groundwater regulation is left to the individual states. However, there are a number of national regulatory acts that give the EPA a great deal of indirect authority over groundwater.

- The Safe Drinking Water Act (SDWA) regulates groundwater used as a source for potable supply
  - Maximum Contaminant Levels (MCLs) for a host of contaminants.
  - Sole Source Aquifer (SSA) protection program - protects designated aquifers from projects that may threaten their viability
  - Underground Injection Control (UIC) program - regulates liquid waste injections to prevent them from affecting drinking source aquifers
  - Source Water Assessment and Protection Program
  - Wellhead Protection Program
- Aquifer recharge is governed in part by sections of the Clean Water Act
  - The National Pollutant Discharge Elimination System (NPDES) permit program protects aquifers from contamination by infiltration from surface waters

Energy Production

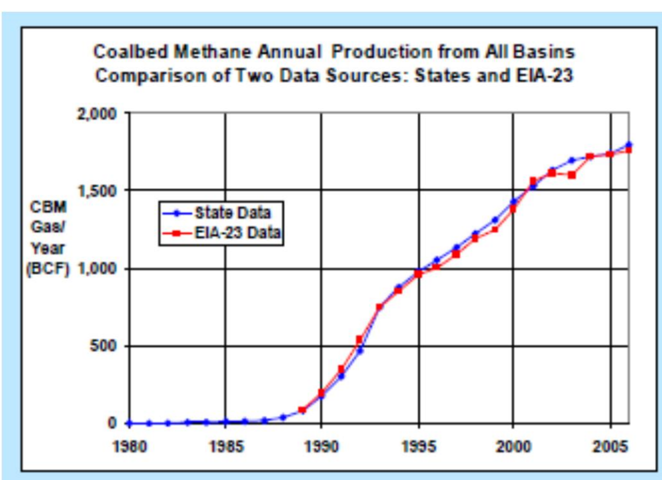
Some of the most significant recent threats to groundwater involve energy production, namely, coal-bed methane extraction and hydrofracking for natural gas extraction. Natural gas production in the US is expected to grow significantly over the next 25 years, as shown in the graph.

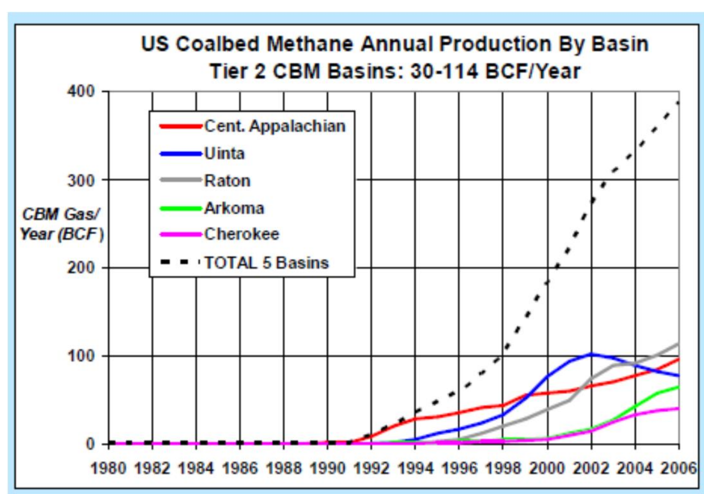


source: Energy Information Administration, US Dept of Energy
http://www.eia.doe.gov/oiaf/aeo/overview.html

Scale and Drivers

The graphs below show the expansion of coal bed methane activity over the past several decades. While overall production increased 75% from 1995 to 2006, production in the second largest category, tier 2 basins, more than quadrupled over the same period. A higher number of wells increases the need for on-site treatment, storage, and re-use technologies.





source: Energy Information Administration, US Dept of Energy www.eia.doe.gov

According to Potential Gas Committee estimates in 2008, proven and potential reserves of recoverable coal-bed methane (CBM) in the US total approximately 163 trillion cubic feet (Tcf), which is equivalent to 10% of the natural gas estimated to be in traditional reserves. The coalbed reserves cover a wide geographic area, clustered largely along the Appalachian and Rocky Mountain ranges, along the Mississippi basin and Gulf Coast, and in parts of Alaska.

Hydraulic Fracturing

Hydraulic fracturing (hydrofracking or fracking) is a process which utilizes high pressure injection of treated water to extract natural gas from underground shale deposits. Shale gas production in the US almost doubled from 2007 to 2008, increasing from 1.2 Tcf to 2.0 Tcf. As of 2008, proved reserves in the US amounted to nearly 33 Tcf. The recent discovery of gas reserves in the Marcellus shale region of Pennsylvania and neighboring states has the potential to increase shale gas production significantly. Estimates of recoverable gas in the Marcellus deposits range from 20 Tcf to 100 Tcf.

Key Dimensions

Water is a byproduct of the CBM gas extraction process. This "produced" water can be injected back into the ground, in which case it comes under UIC regulatory control, or stored in constructed or natural reservoirs and allowed to infiltrate into the ground. If it is discharged into surface waters, regulatory control is left up to the states, because gas and oil wells are exempt from NPDES permitting requirements. The quantity of produced water varies widely by location and across the life cycle of the well, but it generally ranges from 5,000 to 20,000 gallons per day for each well. Produced water is often higher in sodium and bicarbonate than either surface water or ground water used for agricultural irrigation or potable source water. The higher sodium levels make CBM produced water unsuitable for agricultural irrigation, and the high bicarbonate levels can be toxic to aquatic life. EPA announced in 2006 that it would begin studying the CBM industry sector to determine if national effluent limitation guidelines are needed. The likely outcome of the study is further restrictions on the release of produced water into surface water bodies.

The water used in hydrofracking operations is typically treated with a proprietary mixture of chemicals and compounds to aid the gas extraction process. Many of these substances are toxic, and there are numerous reports of potable well contamination in the vicinity of fracking operations. The recent expansion of shale gas operations in the US has increasingly brought this issue into public consciousness.

Marcellus Shale water use in the Susquehanna River Basin as of March, 2010

- Approximately 200 wells drilled to date
- Total Water Withdrawn (6/08 –3/10): 433.0 million gallons (Mgal). 177.2 MGal from public water supply (41%), 255.8 MGal from surface water sites (59%)
- Average Total Vol. of Fluid Used per Well: 2.8 Mgal. Average fresh water used per well: 2.4 MGal (86%)
- Average flowback reuse per well: 0.4 MGal (14%)
- Average Recovery of Fluids: 11.9% (First 30 days) reuse approx. 60 %, disposal approx. 40 %

source: *Water Resource Challenges From Energy Production,* Susquehanna River Basin Commission www.srbc.net

These numbers are expected to increase dramatically under full production.

Political and Regulatory Climate

High profile events, such as the 2010 Gulf oil spill and a blowout at a Marcellus shale gas well that sent a plume of fracking fluid and natural gas into the air for sixteen hours, have captured the public's attention and made a case for stronger regulation of gas and oil industries.

Even before these events occurred, EPA implemented several regulatory changes that will have an impact on these industries.

- January 2010: modification to the Toxic Substance Control Act (TSCA) that would reject most types of confidential business information claims - will require more complete disclosure of fracking fluid components (currently under challenge by the industry)
- March 2010: provision of free public access to the TSCA database via the internet to "empower the public with important information"
- May 2010: addition of more than 6,300 chemicals and 3,800 chemical facilities regulated under TSCA to public *Envirofacts* database
- March 2010: formation of task group to undertake a $2 million study of the environmental impacts of hydrofracking
- January 2010: creation of the "Eyes on Drilling" tip line for citizens to report non-emergency suspicious activity related to oil and natural gas development

Current Technology

Produced water and fracking fluids can be treated with some of the same technology used in desalination processes.

- Reverse osmosis (RO) membrane filtration
- Electrodeionization (EDI)

Technology Trends and Needs

- Real-time, networked groundwater quality monitoring
  - Fiber optic
  - Web-enabled
- Portable on-site treatment - Veolia and GE Water have recently developed units for the oil and gas industry
- Less energy-intensive processes and methods
- Treatment units that run on the natural gas produced by the wells
- Treatment technologies that derive process energy from the wastewater itself
- Zero liquid discharge (ZLD) processes - to avoid the need for NPDES permits for liquid concentrate disposal
- Filtration media and technologies to enable processing of water in temporary, constructed reservoirs
- Frack water recycling and reuse
- Filtration and recovery of hydrocarbons
- Potable water and irrigation water production

- Alternative gas extraction methods, including nitrogen injection
- Compost “socks” and other methods of berm construction to contain runoff at well pads

Policy Needs

- Nationwide regulatory standards for gas wells, as recommended by EPA
  - Develop regulations similar to current NDPES requirements for construction sites
  - Stormwater pollution prevention plans, erosion and sediment control BMPs, provisions for containing spills and leaks, procedures for site inspections and enforcement of control measures, sanctions to ensure compliance.
  - Require installation of berms around the down slope portion of gas well pad sites
- Better predictive contaminant migration models for regulators

Energy Consumption

Geologic Sequestration

The nexus between water and energy drives a number of regulatory issues. One of the most significant is the plan for geologic sequestration of carbon dioxide (CO_2), a greenhouse gas that is produced in industrial processes, petroleum processing, and electricity generation. According to the US Department of Energy, total annual greenhouse gas emissions from all sources in the US were estimated to be 8 billion tons in 2004. Capacity estimates of underground carbon sequestration potential in the US range from 1.3 billion tons to 4.0 billion tons. Underground injection of CO_2 for the purpose of sequestration is regulated by the Underground Injection Control (UIC) Program under the Safe Drinking Water Act (SDWA).

Potential Ground Water Effects of CO_2 Sequestration

- CO_2 leakage into aquifers
- Saline ground water intrusion into aquifers as a result of being displaced by injected CO_2

The American Power Act of 2010 (APA) regulates emissions of greenhouse gases through market-based mechanisms, efficiency programs, and other economic incentives. Subtitle C establishes the Carbon Capture and Sequestration Program Partnership Council, which is responsible for overseeing the commercialization of CCS throughout the United States. It authorizes the collection of approximately $20 billion over a 10-year period to be funded through a surcharge on electricity that is generated using fossil fuels and sold to consumers. It also includes a provision providing allowances to owners of electric power and industrial facilities that have installed carbon capture systems, and mandates that all new coal-fired plants initially permitted after 2008 meet specific performance standards limiting CO_2 emissions.

EPA is partnering with the US Department of Energy (DOE) to form the Interagency Task Force on Carbon Capture and Storage. The task force is charged with proposing a plan to overcome the barriers to the widespread, cost-effective deployment of carbon capture and storage within 10 years, with a goal of bringing five to 10 commercial demonstration projects online by 2016.

Technology Needs

- Tools to locate and assess potential sequestration sites
- Groundwater monitoring for CO_2 and saline contamination

- Monitoring systems to detect CO_2 leakage into the atmosphere from underground storage sites

Surface Water Contamination

EPA completes surveys of the conditions of the nation's surface waters by water body category on a rolling five year schedule. The most recent streams survey was completed in 2006, the coastal waters survey in 2007, the lakes and reservoirs survey in 2009, and the rivers survey is due in 2011, combined with the next streams survey. The wetlands survey is due in 2013.

Key Dimensions
The most significant contaminants found in the nation's surface waters

- Nutrients - phosphorus and nitrogen
- Heavy metals
- Pesticides
- Industrial chemicals
- Legacy contaminants - DDT and PCBs - found primarily in sediments

Emerging contaminants

- ingredients used in pharmaceutical and personal care products (PPCPs)
- endocrine disrupting compounds (EDCs), from pesticides, fungicides, plasticizers, and industrial solvents and lubricants, among other sources

PPCP contaminants may not be the most significant pollutants from a human health standpoint - they have much more significant aquatic life effects - but PPCPs are an important issue because the subject typically engenders an emotional response. The PPCP issue may be “consciousness raising” in terms of water quality issues in general.

EDCs, however, may have significant health effects even in very small doses. In addition, their effects may be additive and/or synergistic across different classes of compounds.

Scale and Drivers
Contaminant levels vary significantly by geographic location and by water body type. Emerging contaminants were not addressed in the water body surveys because research was completed before these contaminants were widely recognized.

National Lakes Assessment (NLA)

- Mercury concentrations in game fish exceed health-based limits in 49% of lakes
- Polychlorinated biphenyls (PCBs) are found at potential levels of concern in 17% of lakes
- Microcystin – a toxin that can harm humans, pets, and wildlife – was found in about one third of lakes and at levels of concern in 1% of lakes
- Nitrogen and phosphorus are at high levels in 20% of lakes
    - Poor biological health is 2.5 times more likely in lakes with high nutrient levels

National Coastal Condition Report III

- Water quality index
  - 57% rated good
  - 34% rated fair
  - 6% rated poor
- 18% of the stations where fish were caught were rated poor for the fish tissue contaminants index
- Four chemical contaminants were responsible for 92% of all fish consumption advisories in 2003
  - PCBs
  - Mercury
  - DDT and its degradation products, DDE and DDD
  - Dioxins and furans
- Sediment contaminants
  - Polycyclic aromatic hydrocarbons (PAHs)
  - Polychlorinated biphenyls (PCBs)
  - Pesticides
  - Metals
  - High levels of Total Organic Carbon (TOC) - (often associated with human, animal, and plant wastes)
- Nutrients
  - Hypoxia - the Gulf Coast zone is the second-largest area of oxygen-depleted waters in the world
  - Hypoxia also affects the Chesapeake Bay

Wadeable Streams Assessment

- 42% percent of the nation's stream length is in poor biological condition
- 32% of stream length (213,394 miles) has high concentrations of nitrogen
- 31% (207,355 miles) has high concentrations of phosphorus
- 26% of the nation's stream length (171,118 miles) has high levels of riparian disturbance (e.g., human influence along the riparian zone)
- 25% (167,092 miles) has streambed sediment characteristics in poor condition

Nutrients

Nutrients are by far the largest contaminant problem in surface waters nationwide. In 1998, EPA urged all states to formulate numeric criteria for all water body types for the following nutrients and response variables: phosphorus, nitrogen, chlorophyll-a, and turbidity (clarity). By the end of 2008, most states had formulated plans, but most have not yet adopted specific numeric standards. EPA is currently engaged in renewed efforts to assist the states to establish criteria. Several states are expected to have some criteria established by the end of 2010.

Status of State Nutrient Criteria Plans as of 2008

- One state (HI) had adopted standards for all its water body types by 1998
- 46 of 50 states have plans* which have been reviewed by EPA and are being used to

guide numeric nutrient criteria development.

- Two states (OR and SD) have not submitted a plan to EPA.
- One state (CA) submitted a plan to EPA in 2001, but is no longer using it to guide its numeric nutrient criteria development.

*Note: 43 of these plans have been mutually agreed to by EPA and the state; three of these plans have not yet been mutually agreed upon.

Once numeric limits are in place, Total Maximum Daily Loads (TMDLs) can be established for watersheds within each state. These TMDLs will drive phosphorus and nitrogen effluent regulations for wastewater treatment plants and other point sources. While conditions vary by watershed, it is widely expected that typical effluent limits for phosphorus will be in the range of 0.3 mg/L and lower, and typical limits for nitrogen will be in the range of 3 mg/L and lower.

In addition to nutrient control at centralized treatment plants, there are other significant needs for phosphorus and nitrogen mitigation. Two of the most important approaches are non-point source control and decentralized systems.

Non-point Source Pollution (NPS) Control Needs

NPS pollution sources are diffuse and can be a result of runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrological modification.

Twenty-year capital cost estimates to address non-point source pollutants: $22.8 billion.

- Change in total needs from 2004: decrease of $4.3 billion (16 percent)
- Number of states reporting needs: 38
- States with highest reported needs: New York ($5.6 billion), Michigan ($3.3 billion), Florida ($2.1 billion), New Jersey ($1.8 billion), Mississippi ($1.8 billion), Nebraska ($1.4 billion), and Oregon ($1.1 billion) accounted for 75% of the needs nationwide

Decentralized Wastewater Treatment Systems

Twenty-year capital cost estimates for the rehabilitation and replacement of on-site (septic) wastewater treatment systems (OWTS) and clustered (community) systems: $23.9 billion.

- Change in total needs from 2004: $20.3 billion (564 percent), the largest increase of any needs category reported
- Number of states reporting needs: 26
- States with highest reported needs: Florida ($10.3 billion), Maryland ($5.0 billion), New Jersey ($2.2 billion), Maine ($1.3 billion), Minnesota ($1.3 billion), and Ohio ($1.3 billion) accounted for 89% of the needs nationwide
- States with the largest percent increases since 2004: Maryland, Florida, Missouri, Maine, West Virginia, and New Jersey all reported greater than 1,000 percent increases

Current Technology

- Chemical control of nutrients in wastewater treatment plants
- Biological processes - aerobic and anaerobic

Emerging Technologies and Technology Needs
Technology solutions for nutrient control in wastewater treatment (including decentralized systems) are discussed in detail in the EPA Nutrient Control Seminar report.

- Alternatives to phosphorus addition for lead control in plumbing pipes
- Biological methods to mitigate legacy contaminants and heavy metals
- Novel microfiltration, ultrafiltration, nanofiltration and membrane filtration methods to remove trace amounts of PPCPs and EDCs from drinking water and wastewater
- Mercury mitigation
  - Stannous chloride reagent for in-situ air stripping
  - Slow release sequestrants - encapsulated nano-particles
  - Sodium thiosulfate to control methylation
- Technology for further reduction of atmospheric mercury emissions from power plants
- Alternative to dioxins and furans for industrial processes

Pesticides

Background and Key Dimensions
Pesticides in surface water come from a variety of sources, including runoff from agricultural and recreational land applications, and antibacterial cleaning and personal care products, among others. They are also applied directly to surface waters to control aquatic insects and plants, and invasive species.

Many pesticides contain endocrine disrupting compounds (EDCs), which can be toxic to aquatic life in very small concentrations, and are currently contaminants of concern for the EPA. EDC contamination is also in the public eye, and the issue has recently captured the attention of Congress.

Scale and Drivers
The US accounts for 23% of worldwide pesticide use. Approximately 2.4 billion pounds of (conventional and other chemical) pesticides are used in the US on an annual basis, which includes 797 million pounds used in wood preservatives and 117 million pounds for home and garden applications.

Atrazine, a widely used herbicide, is a significant problem in drinking water supplies across the country, especially in agricultural areas. In 1997, over 72 million pounds were applied in the US, primarily in the corn belt and sugarcane growing areas. Its use has been banned in the European Union, due to its endocrine disrupting effects and suspected carcinogenic effects. EPA has begun a comprehensive reevaluation of atrazine's ecological effects, including potential effects on amphibians, based on data generated since 2007. In 2010, 25 community water systems were added to the EPA's ongoing atrazine program, which monitors 40 watersheds for the chemical.

Technology Needs

- Alternatives to harmful chemical ingredients in pesticides
- Innovative integrated pest management (IPM) and organic/bio-dynamic methods
- Alternative no-till agricultural methods that do not utilize herbicides
- Containment and on-site bio-degradation of residues in contaminated runoff and soils

- Innovative wood preservation technologies

Policy

- EPA has recently moved to regulate surface water pesticide applications as point sources of pollution requiring NPDES permits.
- A number of communities across the US are implementing stringent controls on lawn pesticide applications, including bans in some cases

Surface Water Policy -Trends and Solutions

- EPA recognizes the need for a variety of wastewater treatment options, including centralized, on-site and clustered systems - state statutes and codes should be modified where needed to allow a mix of treatment scales and technologies
- USDA regulations that limit the agricultural use of fertilizers under conditions or in locations where runoff is a concern
- More stringent limits on nitrogen and phosphorus fertilizers for “cosmetic” uses (including lawns)
- Limits on pesticide use for non-agricultural purposes - most Canadian provinces have banned the use of pesticides on lawns

Ecological Damage - Aquatic Invasive Species

Scale and Drivers

Invasive species have the potential to permanently affect the ecology and economies of water bodies by crowding out native species and altering aquatic food chains. As of 2008, it was estimated that more than 1,000 aquatic invasive species were present in US waters. Roughly 40-50% of invasive species have caused damage to native ecosystems. Estimates of monetized damages vary widely, and range as high as $136 billion annually for the U.S.

Table 1: Estimates of Invasive Species in Several Major Water Systems		
Region	Estimated Rate of Invasion[1]	Estimated Total Invasions to Date[2]
Great Lakes	Once every 28 weeks[3]	162
Mississippi River System	Unknown	100
San Francisco Bay	Once every 24 weeks[4]	212
Lower Columbia River Basin	Once every 5 months[5]	81
Gulf of Mexico	Unknown	579

[1] Ruiz and Reid (2007) suggest that these figures may not reliably represent the true rate of introduction, as they are based on discovery data, which may not always track with the underlying rate of introduction.

[2] All figures in this column are taken from USCG 2004.

[3] NOAA (2007).

[4] Cohen and Carlton (1995).

[5] Sytsma et al. (2004).

Source: EPA 2008 Final Issuance of National Pollutant Discharge Elimination System (NPDES) Vessel General Permit (VGP) for Discharges Incidental to the Normal Operation of Vessels Fact Sheet

Policy

Invasive species are regulated under a number of laws, including the National Invasive Species Act of 1996 (NISA), the Final Vessel General Permit (VGP) of 2008, and various international treaties and state statutes applicable to ballast water. Ballast water is one of the major sources of invasive species introduction to US waters. Saltwater ports receive the majority of arrivals, as shown in the table.

Annual arrivals of ballast-capable vessels to US ports

Table 3-3: Oceangoing Arrivals				
Vessel Flag	All Saltwater Ports		Great Lakes and Upper Hudson Ports	
	Vessel Count	Arrival Count	Vessel Count	Arrival Count
Domestic	336	3,443	3	3
Foreign	6,484	35,409	34	57
Total	6,820	38,852	37	60

Source: Economic and Benefits Analysis of the Final Vessel General Permit (VGP) 2008 Abt Associates Inc. Cambridge, MA

Invasive species control at the ballast water level overlaps with other ballast water effluent standards, and is amenable to similar technological solutions. For example, the International Maritime Organization has developed standards for microorganisms in ballast water. These standards have been widely adopted by federal and state governments for waters in their jurisdictions, and apply to vessels requiring NPDES permits. For vessels built in 2012 or later, the standards apply when the vessel is placed into service, while all other vessels must meet the standards by 2016.

Table A. Biological Performance Standards for Ballast Water Treatment Technology

Parameter	Limit	Limit Type	Sample Type
Organisms > 50um in minimum dimension	<10 viable/m^3	Daily Average	Composite
Organisms 10-50 um in minimum dimension	<10 viable/ml	Daily Average	Composite
Escherichia coliform	<250 cfu/100ml	Daily Average	Composite
Intestinal enterococci	<100 cfu/100 ml	Daily Average	Composite

Source: EPA 2008 Final Issuance of National Pollutant Discharge Elimination System (NPDES) Vessel General Permit (VGP) for Discharges Incidental to the Normal Operation of Vessels Fact Sheet
cfu = colony forming unit

If numeric limits have not been established for a particular contaminant, then technology-based effluent limits are used instead, and are applied without regard to receiving water quality.

- Best Practicable Control Technology Currently Available (BPT) applies to all pollutants, and is designed to bring all sources in an industrial category up to the level of the average of the best source in that category
- Best Conventional Pollutant Control Technology (BCT) applies to biological oxygen demand (BOD), pH, fecal coliform, TSS, and oil and grease (common contaminants in cruise ship effluents)
- Best Available Technology Economically Achievable (BAT) applies to toxic and non-conventional pollutants

As innovative and cost-effective treatment technology is developed and employed, technology-based effluent standards will automatically tighten, without requiring further policy mandates. In addition, EPA will continue to develop numeric effluent standards, as it becomes feasible to do so.

Technology

- Chemical control of ballast water - on-vessel
- Biocide application to water body
- Barriers
  - Sound waves
  - Electrical impulses
  - Visual deterrents
  - Physical barrier
- Predator species
- Harvesting and removal

Emerging technology and technology needs

- UV disinfection of ballast water
- Port-based ballast water control - filtration and UV (Port of Milwaukee)
- Effluent monitoring for ballast control chemical concentrations

- Innovative barrier techniques
- Control techniques for recreational vessels

Policy Needs

- Remove moratorium on application of VGP to smaller vessels
- Ballast water reporting laws (e.g., Michigan)
- Integration of ballast water regulations with NPDES

Stormwater

Key Dimensions

- Sanitary Sewer Overflows and Combined Sewer Overflows - SSOs and CSOs can discharge untreated wastewater that contains bacteria, viruses, suspended solids, toxic chemicals, trash and other pollutants into waterways. Infrastructure deficiencies, such as broken or blocked pipes, lack of storage capacity, and poorly-designed stormwater interceptors that allow re-suspension of solids are some of the causes of SSO and CSO pollution.
- Mining - coal mining, in particular, presents a number of water quality issues
- Emerging regulations for several applications that discharge effluent into storm sewers
  - Airport de-icing
  - Construction sites
  - Drinking water treatment
  - Power plant cooling
  - Industries that discharge chlorine and chlorinated hydrocarbons (CCH)

Scale and Drivers

Due in part to extensive infrastructure investments in response to strict enforcement by EPA, the capital needs for sewer overflow correction declined by 2% from 2004 to 2008. However, needs are still significant.

- The infrastructure needs for Combined Sewer Overflow Correction over twenty years are $63.6 billion
  - Illinois ($10.9 billion), New Jersey ($9.3 billion), Pennsylvania ($8.7 billion), Ohio ($7.5 billion), New York ($6.6 billion), and Indiana ($5.0 billion) reported 74% of the needs

Stormwater management needs have increased 67% since 2004, largely due to the adoption of green infrastructure techniques, including bioswales, buffer zones, greenways, and constructed wetlands.

- The twenty year infrastructure needs for stormwater management are $42.3 billion
  - $7.6 billion for Conveyance Infrastructure
  - $7.4 billion for Treatment Systems
  - $17.4 billion for Green Infrastructure
  - New Jersey ($15.6 billion), Pennsylvania ($6.0 billion), California ($3.8 billion), Maryland ($3.8 billion), Texas ($3.1 billion), Florida ($2.5 billion), and New York ($1.1 billion) reported 85% of the needs

Coal mining, especially "mountaintop removal" processing in which valleys are filled with rubble, has significant effects on surface-water quality. Coal mining processes may alter flows in nearby rivers and streams, and may also change surface water chemistry through the addition of dissolved solids.

EPA issued a set of new guidelines in 2010 regarding the compliance of surface coal mining operations in Appalachia with the provisions of the Clean Water Act (CWA), the National Environmental Policy Act, and the environmental justice Executive Order (E.O. 12898). There is new scientific evidence that dissolved solids in drainage from existing valley fills in Central Appalachia are adversely affecting downstream aquatic systems. The new guidelines go into effect immediately, and the final guidelines will be issued by April 1, 2011.

Construction and Development Site Runoff

- EPA is promulgating effluent limitations guidelines (ELGs) and new source performance standards (NSPS) to control the discharge of pollutants from construction sites. This rule requires construction site owners and operators to implement a range of erosion and sediment control measures and pollution prevention practices. Numeric standards for turbidity in stormwater discharges will require effluent sampling by developers and contractors. This requirement will be phased in over a four year period, from 2011to 2014.
  - Sediment reduction projected to be 4 billion pounds annually
  - Annual cost of approximately $953 million
  - During the phase-in period, the estimated cost of the rule is $8 million in 2010, $63 million in 2011, and $204 million in 2012

- EPA intends to propose a rule to control stormwater from, at a minimum, newly developed and redeveloped urban sites, and to take final action no later than November 2012. A recent Next Generation Stormwater Control project in Washington D.C. set a site runoff goal of no more than 10%, requiring 90% of rainwater to be captured or infiltrated on the site. These standards, or similar, are likely to become the model for the rule being promulgated in 2012.

Wastewater Treatment and SSOs

EPA is considering two possible modifications to existing regulations.

- Establish standard National Pollutant Discharge Elimination System (NPDES) permit conditions for publicly owned treatment works (POTWs) permits that specifically address sanitary sewer collection systems and SSOs.

- Clarify the regulatory framework for applying NPDES permit conditions to municipal satellite collection systems. Municipal satellite collection systems (MS4's) are sanitary sewers owned or operated by a municipality that conveys wastewater to a POTW operated by a different municipality. EPA is also considering whether to address long-standing questions about peak wet weather flows at municipal wastewater treatment plants to allow for a holistic, integrated approach to reducing SSOs while at the same

time addressing peak flows at POTWs.
  - Develop a single set of consistent stormwater requirements for all MS4s
  - Require MS4s to address stormwater discharges in areas of existing development through retrofitting the sewer system or drainage area with improved stormwater control measures
  - Explore specific stormwater provisions to protect sensitive areas

Technology

The basic principles of gravity sewer technology were developed in ancient times. Currently, most systems are based on designs, assumptions, and calculations developed in the early 1900's. As a result, they may be over-designed in some ways and under-designed in others for their ability to meet 21st century needs. As hydrologic modeling and sewer monitoring and control systems become more sophisticated, some basic design principles may have to be modified in order to obtain better performance at lower cost.

Technology needs

- Infiltration and inflow control for collection systems
  - Interceptor devices that eliminate re-suspension of pollutants
  - "First flush" filtration for storm drains
- Collection system pre-treatment (e.g. In-Pipe bacterial injection)
- Control of hydrogen sulfide in collection systems
- Alternative chemicals/processes for airport de-icing
- Alternatives to CCH compounds
- CCH mitigation technology
- Control systems to enable temporary collection system sequestration of peak flows
- Real-time monitoring of sewer systems
- Techniques for energy recovery from wastewater
- Residential and commercial on-site solids/liquid separation for nutrient recovery and flow mitigation
- Enhanced hydrologic modeling for watersheds (e.g. NASA satellite-based precipitation measurement system)

Policy Trends

- EPA priority on green infrastructure solutions for CSOs, stormwater control, and nutrient control
- EPA has been proactive in rule making for stormwater control and aggressive in enforcing existing standards
- Flexibility in system design based on local needs - CSOs, SSOs, vacuum sewers

Water Security

Background and Key Dimensions

EPA's Office of Research and Development established the National Homeland Security Research Center (NHSRC) in 2003. It works in three major research areas: water security, rapid risk assessment, and safe buildings. EPA is the lead federal agency for water security, in partnership with the US Department of Homeland Security (DHS).

Water security has two components. One is the capability for the provision of potable water during emergency situations of varying durations. The other is the protection of the water supply and water system components from natural and man-made threats, as well as deliberate attacks.

Scale and Drivers

The provision of comprehensive security for the nation's physical water treatment, storage, distribution, and collection networks is a massive undertaking. Every pipe and appurtenance is a potential avenue for accidental or deliberate contamination. Secure valves, locks, intrusion alarms and contaminant sensors are just a few of the types of components that will be needed in large quantities to protect the nation's water supply.

The increasing recognition of the importance of the nation's water supply, especially as more areas experience scarcity, will drive the interest in preserving and protecting the nation's water resources and systems. The threat of terrorism is also likely to remain one of the principal drivers of water security measures.

Water security infrastructure testing programs were begun in Cincinnati, New York, City, and San Francisco in 2007. The results from these pilot programs are likely to provide information on the overall national need for water security technology.

Technology

In many instances, the technology requirements for water security are complementary to those of water and wastewater treatment and distribution. Sensor-based security networks for real-time contaminant and flow monitoring of potable water throughout the distribution system can provide toxicity event warnings, as well as routine operational data to water utilities. Similarly, District Metered Area (DMA) zones created for water loss monitoring and audit purposes can serve as containment areas in the case of an acute contamination event. Standard data used in water quality monitoring, such as TOC and chlorination levels, can provide valuable information about possible contamination. In many cases, standard monitoring and control processes can be adapted and enhanced for security needs, and security technology can be adapted to provide day-to-day operational data.

EPA has identified a number of technologies that will be critical in protecting the nation's water supply.

- Backflow prevention devices
- Biological sensors for toxicity
- Sensors for monitoring chemical, biological, and radiological contamination
  - Chemical sensor - arsenic measurement system
  - Chemical sensor for Toxicity (Adapted BOD Analyzer)
  - Chemical Sensor - Total Organic Carbon Analyzer
  - Chemical Sensor - Chlorine Measurement System
- Fire Hydrant Locks and Security Devices
- Hatch Security

- Manhole Intrusion Sensors and Locks
- Portable Cyanide Analyzer
- Portable Field Monitors to Measure VOCs
- Reservoir Covers
- Supervisory Control and Data Acquisition (SCADA) integration
- Toxicity Monitoring/Toxicity Meters
- Valve Lockout Devices
- Vent security for reservoirs and storage tanks

Emerging Technologies and Research Needs

- Point-of-entry/point of use filtration
  - Broad-band filters effective at removing chemical, biological and radioactive contaminants
  - Contaminated filter media disposal
- Real-time point-of-entry contaminant monitoring
- Fail-safe shutoff valves
- Critical valve protection
- Smart pipes with embedded sensor nets
- Self-contained self-powered mobile pumping and purification systems for emergency use
- Rapid toxicity detection systems for wide variety of possible contaminants
- Lock-out and containment systems for contaminated water
- Lower cost radiation monitoring - current systems for real-time alpha, beta and gamma radiation detection are cost-prohibitive

Overarching Policy Trends at EPA

EPA has recently instituted a number of general policy initiatives that will affect the content and implementation of environmental regulations, the geographic distribution of funding, and the way that agencies work together in the future.

- The creation of an Office of Sustainable Communities to encourage communities to take an integrated approach in making environmental, housing and transportation decisions.
  - A new pilot grant program designed to help three states – New York, Maryland and California – use their clean water funding programs to support efforts to make communities more sustainable
- Environmental Justice program - more funding for environmental issues in low income, minority, and indigenous population areas
- Source control and protection - increasing integration with the Clean Water Act
- There is currently a trend toward interagency partnerships - with DOE, USDA, HUD, DOT, DHS, and others - and cooperation on complex water issues like nutrient contamination, energy production, and water security.

Overall Policy Priorities for Water

There are a number of regulatory priorities for that will drive policy and technology needs in the water sector in the coming years.

- Enforcement of existing standards for contaminant levels

- Establishment of numeric nutrient standards by the states
- TMDL development for all watersheds
- Watershed authorities that cross political boundaries
- Standards and codes that support and encourage dual distribution for potable supply and fire suppression, both in new construction and for retrofitting of existing systems
- National standards for greywater systems

References

Clean Watersheds Needs Survey 2008, EPA-832-R-10-002, June 2010

Journal American Water Works Association, Vol. 102, Number 6, June 2010

Drinking Water Infrastructure Needs Survey and Assessment 2007, EPA 816-R-09-001, February 2009. www.epa.gov/safewater

Using DWSRF Funds for Transmission and Distribution Infrastructure Needs EPA 816-F-03-003 February 2003, www.epa.gov/safewater/dwsrf/index.html

FACTOIDS: Drinking Water and Ground Water Statistics for 2008 (4601M) EPA 816-K-08-004 November 2008 www.epa.gov/safewater/data

Ground Water Rule: A Quick Reference Guide EPA-816-F-08-029, July 2008, updated March 2010 http://epa.gov/ogwdw/disinfection/gwr/compliancehelp.html#quick

Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules EPA 815-R-07-017 March 2007 http://www.epa.gov/safewater/disinfection/stage2/compliance.html

http://www.epa.gov/safewater/disinfection/stage2/basicinformation.html - threehttp://www.epa.gov/safewater/disinfection/stage2/basicinformation.html - threeStage 2 Disinfectants and Disinfection Byproducts Rule, http://www.epa.gov/safewater/disinfection/stage2/basicinformation.html#three

Ground Water Rule Source Water Monitoring Methods Guidance EPA 815-R-07-019 Revised March 2008

American Water Works Association ACE10 conference proceedings and presentations, Chicago, June 21-22, 2010

Technical Fact Sheet: Final Rule for Arsenic in Drinking Water, EPA 815-F-00-016 January 2001,

http://www.epa.gov/safewater/arsenic/regulations_techfactsheet.html

Technical Fact Sheet: Final Rule for (Non-Radon) Radionuclides in Drinking Water EPA 815-F-00-013, November 2000,

http://permanent.access.gpo.gov/lps21800/www.epa.gov/safewater/rads/technicalfacts.html

2008 PGC Natural Gas Resource Estimates and Biennial Report,

http://geology.mines.edu/pgc/index.html?CMSPAGE=Research/pga/index.html

Melanie L. Clark, Kirk A. Miller, and Myron H. Brooks, US Geological Survey Monitoring of Powder River Basin Stream-Water Quantity and Quality, Water-Resources Investigations Report 01-4279, Cheyenne, Wyoming, 2001,

http://pubs.usgs.gov/wri/wri014279/html/report.htm

Amy Frykman, An Inside Look at Coal Bed Methane, Montana Environmental Information Center,

http://meic.org/water-quality/coal-bed-methane/coal-bed-methane-2014-an-inside-look

Increasing Transparency in TSCA,

http://www.epa.gov/oppt/existingchemicals/pubs/transparency.html
US Department of Energy National Energy Technology Laboratory, Carbon Sequestration, http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlas/index.html
The Economic Impacts of Aquatic Invasive Species: A Review of the Literature Environmental Protection Agency, National Center for Environmental Economics, Washington, DC, http://www.epa.gov/economics
Irrigation and Water Use, USDA Economic Research Service http://www.ers.usda.gov/Briefing/WaterUse/
Team Tracks Antibiotic Resistance from Swine Farms to Groundwater, News from University of Illinois, August 21, 2007, Champaign, IL
Common Manure Handling Systems, EPA, http://www.epa.gov/agriculture/ag101/porkmanure.html
Update on CAFO NPDES Permitting Implementation, 2007 CAFO Roundtable, Tacoma, Washington
Kitchen, N.R., Adamchuk, V.I., Sudduth, K.A. 2009. Narrowing the Soil-Sample to Fertilizer-Application Gap Using Soil Sensors [abstract]. ASA-CSSA-SSSA Annual Meeting Abstracts November 1-5, 2009, Pittsburgh, Pennsylvania
Interim Guidance on Considering Environmental Justice During the Development of an Action, EPA, http://www.epa.gov/environmentaljustice/resources/policy/ej-rulemaking.html
USDA Economic Research Service, Fertilizer Use and Price, http://www.ers.usda.gov/Data/FertilizerUse/
USDA Releases New Data on Soil Erosion and Development of Private Lands, http://www.usda.gov/wps/portal/usda/usdahome?contentidonly=true&contentid=2010/04/0211.xml
EPA, 2000-2001 Pesticide Market Estimates: Usage, http://www.epa.gov/oppbead1/pestsales/01pestsales/usage2001.htm#3_3
Water and Wastewater Security Product Guide, EPA, http://cfpub.epa.gov/safewater/watersecurity/guide/tableofcontents.cfm
EPA ORD National Homeland Security Research Center, Investigation of the Capability of Point-of-Use/Point-of-Entry Treatment Devices as a Means of Providing Water Security, 2006
Water Security Research and Technical Support Action Plan, EPA/600/R-04/063 March 2004, http://cfpub.epa.gov/safewater/watersecurity/home.cfm?program_id=9

APPENDIX A

USEPA FY 2011 Budget Request

In FY 2011, EPA continues its commitment to upgrading drinking water and wastewater infrastructure with a substantial investment of $2 billion for the Clean Water State Revolving fund and $1.3 billion for the Drinking Water State Revolving Fund. EPA, the states, and community water systems will build on past successes while working toward the FY 2011 goal of assuring that 91 percent of the population served by community water systems receives drinking water that meets all applicable health based standards. EPA's partnership investments will allow States and Tribes to initiate approximately 800 clean water and 500 drinking water projects across America, representing a major federal commitment to water infrastructure investment. These investments send a clear message to American taxpayers that our water infrastructure is a public health and environmental priority.
The FY 2011 budget request supports national ecosystem restoration efforts; $300 million is requested for the Great Lakes, the largest freshwater system in the world. This multiagency restoration effort represents the federal government's commitment to significantly advance Great Lakes protection, with an investment of over $775 million over two years. The focus is on addressing critical environmental issues such as contaminated sediments and toxics, nonpoint source pollution, habitat degradation and loss, and invasive species, including Asian carp.

We're requesting $63 million for the Chesapeake Bay program including increased funding to implement President Obama's Chesapeake Bay Executive Order. We are accelerating implementation of pollution reduction and aquatic habitat restoration efforts to ensure that water quality objectives are achieved as soon as possible. A centerpiece of EPA's FY 2011 Chesapeake Bay activity is the implementation of the nation's largest and most complex Total Maximum Daily Load (TMDL) for the entire Bay watershed. The TMDL will involve interstate waters and the effects on water quality from the cumulative impact of more than 17 million people, 88,000 farms, 483 significant treatment plants, thousands of smaller facilities, and many other sources in the 64,000 square mile watershed

In addition, the budget request includes $17 million for the Mississippi River Basin. EPA will work with the Department of Agriculture and states to target nonpoint source reduction practices to reduce nutrient loadings. EPA will also work with other Federal partners to target two high priority watersheds in the Mississippi River Basin to demonstrate how effective nutrient strategies and enhanced partnerships can address excessive nutrient loadings that contribute to water quality impairments in the basin and, ultimately, to the hypoxic conditions in the Gulf of Mexico.

The budget also proposes $10 million for green infrastructure research, more than doubling research that offers the potential to help us transition to more sustainable water infrastructure systems.

We're also proposing $9 million for Community Water Priorities in the Healthy Communities Initiative; funds that will help underserved communities restore urban waterways and address water quality challenges.

Furthermore, the FY 2011 President's Budget includes approximately $615 million for EPA's enforcement and compliance assurance program. We are also requesting $274 million, a $45 million increase over 2010, to help states enhance their water quality programs. New funding will strengthen the base state, interstate and tribal programs, address new regulatory requirements, and support expanded water monitoring and enforcement efforts.

In FY 2011, the range of research programs and initiatives will continue the work of better understanding the scientific basis of our environmental and human health problems We are requesting a science and technology budget of $847 million to enhance – among other things – research on endocrine disrupting chemicals, green infrastructure, air quality monitoring, e-waste and e-design, and to study of the effects of hydraulic fracturing on drinking water. It's important to highlight that most of the scientific research increase will support additional Science to Achieve Results (STAR) grants and fellowships to make progress on these research priorities and leverage the expertise of the academic research community. The $26 million increase for STAR includes $6 million for STAR fellowships in support of the President's priority for Science, Technology, Engineering, and Math (STEM) investments. This reflects a near doubling of the STAR fellowships program. This budget also supports the study of computational toxicology, and other priority research efforts with a focus on advancing the design of sustainable solutions for reducing risks associated with environmentally hazardous substances.

Chapter 4 International Water Markets

Introduction

The US market is obviously the world's largest and is growing at a rather rapid pace, estimated at between 10% and 14.9% annually over the next six years. That said, the US market is currently about 22% of the world market for water products and services. Its role should diminish over time, as more other countries acquire the resources and interest in spending more money on solving their myriad water problems. Because of the size and growth potential, it is extremely important that US firms have a good understanding of the market opportunities in the rest of the world.

This chapter attempts to give critical insights into global water markets by concentrating exploration on 35 different countries spread across five continents. Collectively, these countries account for over 60% of the world's water market. When combined with the US market, over 80% of the current world market is covered.

Two of these countries are located in North America, Canada and Mexico. One, Brazil, is in South America, the only country on that continent with a substantial investment in solving water problems. Europe is a primary target because 27 countries there are part of the European Union and must meet common water standards. Three others are included because of their potential.

Five countries in Africa are examined. Only one, South Africa ($6.1 B), is among those that have current water markets of at least $5 B in 2010. But others, such as Egypt, are included because of a growing role in its region. Saudi Arabia, formally in Asia, is included because it is a larger market ($8.5 B), and it is also representative of its region.

Asia is also represented by three other nations. China is a very large ($47 B) and growing market. It has incredible water challenges in water supplies, drinking-water quality and quantity, wastewater treatment inadequacies, surface and ground water contamination, and so forth. The good news is that the nation is increasingly focused on attempting to address its numerous water challenges. Korea is included because of the scale of its current market, $10 billion in 2010.

India is a smaller market to date ($5.9 B), but its economy is growing as are its middle class and the interest in the provision of more and better drinking water and greatly expanded sanitary services.

Australia ($15 B) is included because of its market size, its problems, and its solutions.
The chapter is laid out by continent in alphabetical order, starting with Africa.

4.1 North Africa (Algeria, Egypt, Morocco, Tunisia)

Water Market (Global Water Intelligence, 2010)

- Total North African market size 2010: $9.9 billion

Key Markets	Niche Markets
Water infrastructure projects, including municipal and industrial wastewater treatment plants and technology	On-site treatment of industrial wastewater
Maintenance of aging infrastructure	Low-cost, efficient agricultural irrigation systems, including micro-irrigation
Small-size seawater desalination plants and brackish water treatment plants	

Demographic Indicators

Population	2009	2016
Urban Population`	81 million	94 million
Rural Population	75 million	78 million
Total Population	**156 million**	**172 million**

Source: (Global Water Intelligence, 2010)

Economic Indicators

Economic Indicator (2008)	Nominal GDP
Total GDP	$453 billion

Source: (Global Water Intelligence, 2010)

Background and Summary of Key Issues

The North African countries of Algeria, Egypt, Morocco, and Tunisia have a combined population of approximately 155 million and a combined GDP of $453 billion. All four countries are primarily comprised of arid desert. Many areas in North Africa receive less than 2 inches of rainfall per year. However, most of the Mediterranean coastal areas receive significantly higher levels of annual precipitation than the southern deserts. For example, northern Morocco receives up to 79 inches per year while the northwest mountains of Tunisia receive 59 inches per year. There are also imbalances in water availability and water connections between rural and urban areas in the North African countries. Many rural areas do not have daily access to water, nor are they connected to sanitary sewer systems.

Seawater intrusion is a problem in some areas, due to excessive groundwater withdrawals. The Northwest Sahara Aquifer System is one of the larger aquifers in Africa, and Tunisia, Libya, and Algeria withdraw unregulated amounts of water from the aquifer. Therefore, groundwater monitoring may be an important market to consider, even though there do not appear to be talks of monitoring this aquifer.

Desalination is cost-prohibitive for these countries and is generally used only when other options are not available. However, Tunisia has a modest market for desalination and Morocco and has a strong interest in its future use. Morocco is interested in increasing its desalination and reuse capacity tenfold by 2015 and currently has nine major desalination projects planned.

The agricultural sectors in Algeria, Egypt, Morocco, and Tunisia, are responsible for the majority of annual water use. Agricultural use as a percentage of total annual water use can be as high as 86% in these countries. In many areas, ditch and canal irrigation is still used, and these methods result in high water loss through evaporation.

Aging infrastructure is also a problem in these countries, and many water connections, pipes, and sewer systems will need to be replaced or rehabilitated in the coming years. Even Tunisia, which is prided for its water infrastructure system, is facing problems due to a focus on new projects and neglect of existing infrastructure.

Water pollution is also a problem across North African countries and is often caused by industry. Many areas do not regulate the discharge of untreated industrial wastewater into nearby water bodies, so new policies will be needed in addition to on-site industrial treatment and reuse of wastewater.

The key water issues in North Africa are:

- Insufficient water supply, drought, and excessive groundwater withdrawals
- Aging infrastructure and poor access to municipal drinking water
- High agricultural demand and inefficient watering systems
- Need for increased emphasis on water reuse
- Groundwater and surface water pollution
- Inadequate wastewater treatment and sewer networks
- Unequal access to water
- High salinity levels

4.2 Algeria

Water Market (Global Water Intelligence, 2010)

- Market size 2010: $4 billion
- Growth rate 2010 – 2016: 6% to 9.9%
- Key markets:
  - Water infrastructure projects
  - Low-cost, efficient agricultural irrigation systems
  - Municipal and industrial wastewater treatment plants and technology

Demographic Indicators

Population	2009	2016
Urban Population	23 million	27 million
Rural Population	12 million	12 million
Total Population	**35 million**	**39 million**
Population Growth Rate	**2005-2010**	**2010-2015**
Urban Population Growth Rate	2.48%	2.29%
Rural Population Growth Rate	-0.31%	-0.32%
Total Population Growth Rate	1.56%	1.50%

Source: (Global Water Intelligence, 2010)

Economic Indicators

Economic Indicator (2008)	Nominal GDP	GDP at Purchasing Power Parity
Total GDP	$160 billion	$234 billion
GDP per capita	$4,588	$6,709
GDP growth rate	3.0%	

Source: (Global Water Intelligence, 2010)

Background and Summary of Key Issues

Algeria is the second-largest country in Northern Africa, with a population of 35 million in 2009 and a projected population of 39 million in 2016. More than 70% of the population is located in the regions along the coast. In 2008, the nominal total GDP was $160 billion ($4,588 per capita).

Surface water comprises a majority of Algeria's renewable resources, at 2.68 trillion gallons/yr compared to 401.5 billion gallons/yr of groundwater. Desalination and water reuse at a tertiary level or higher comprise a small amount of available water, at 6% and less than 1%, respectively.

Nationally, water demand exceeds supply many times during the average year. Agriculture accounts for 65% of annual water withdrawals, while municipal water use comprises 22% and industry comprises 13%.

Algeria's major water issues are:

- Insufficient water supply and drought
- Aging infrastructure and poor access to municipal drinking water
- High agricultural demand and inefficient watering systems
- Need for increased emphasis on water reuse
- Water pollution

Key Issue: Insufficient Water Supply and Drought

Key Dimensions
The population of Algeria has increased from 9 million to 34 million since 1962 (Global Water Intelligence, 2010). The current demand for water is 713.3 billion gallons/yr, but this is estimated to increase by 48% by 2020. At the same time, annual average rainfall has decreased by 30%. By 2030, Algeria is predicted to have only 264,000 gallons of water per person, per year and will be considered water stressed if those trends continue (Algeria seeks dynamic, 2005). Water stressed nations have less than 449,000 gallons of water per person, annually.

The country has 71 water treatment plants with a 660.4 billion gallon/day total capacity (Global Water Intelligence, 2010). However, the majority of these are located in the northern coastal area. Though meter coverage is 87%, approximately 40% of water is unaccounted for and lost through leaks or untracked usage.

Action Needed
Algeria may need to consider increasing its storage capacity in the south, where water is scarce. Though desalination technology can be expensive, the country may need to consider increased use of desalination as an alternate source of water. Finally, emphasis on water reuse and water conservation will be necessary.

Current Approach
Algeria has substantially increased its dam capacity in the last 47 years. In 1962, there were 13 dams. By 2009, there were 70 dams with 28 times greater the capacity from 47 years earlier. Currently, these dams are 64% full during times of adequate rainfall.

The Ministry of Water Resources has partnered with The German Federal Ministry for Economic Cooperation and Development (BMZ) to develop and implement an $18 million Integrated Water Management Programme (Deutsche Gesellschaft für Technische Zusammenarbeit, n.d.). The program is in its final phase and has focused on decentralizing the water utility sector, expanding water planning and regulation, promoting sustainable use of groundwater, and reducing industrial, agricultural, and municipal water demand.

Impending Water Policy Changes/Conditions to Address Issue
There are no evident impending policies to address insufficient water or drought. Policies which enforce stringent limits to daily withdrawals might require the agricultural and domestic sectors to develop and implement efficient water-saving technology. However, Algeria would likely have difficulty funding advanced technology.

Technology/Policies Needed
In 2005, Algeria launched a plan to build 13 large-scale seawater desalination plants with a total capacity of 597.0 million gallons along 870 miles of coastline (Global Water Intelligence, 2010). Currently, 10 plants (528.3 million gallon total capacity) have been contracted out. Four of these plants are already online, and AEC has plans to build another four plants which would add 105.7 million gallons of total capacity.

Algeria also has a small number of brackish water desalination plants in the south, and there are plans to build 9 additional plants which would add a capacity of 18.5 million gallons. These are expected to go online by the end of 2010.

Key Issue: Aging Infrastructure and Poor Access to Municipal Drinking Water

Key Dimensions
Approximately 92% of Algerians have access to drinking water, and the frequency of access varies from 24/7 to once every three days for a few hours. Only 60% have daily access and only 20% have 24 hour daily access. While 90% of urban residents have proper access to drinking water, only 70% of rural residents have access. Poor service is blamed on aging water infrastructure which contributes to high water loss.

In 2008, according to AdE, 245.4 billion gallons of potable water were produced while 219.0 billion gallons of water were distributed. However, only 116.2 billion gallons of water were billed. Therefore, 129.2 billion gallons were unpaid by customers or leaked out of pipes. Thus, approximately 34% of municipal water is considered unaccounted for. Algeria has inadequate water metering, so this figure may be different.

Action Needed
Infrastructure is needed that will increase access to drinking water, especially in urban areas. Many residents also need daily access to water, and upgrades need to be made to aging infrastructure that is responsible for water loss and poor service in many areas of the country. Metering also must be expanded and improved.

Current Approach
The Algerian government's current five-year plan (2010-2014) has set aside approximately $15 to $16 billion out of $150 billion for water projects. A portion of this $16 billion amount will cover new infrastructure and replacement of existing infrastructure. For example, the construction of 19 new dams will bring total storage capacity of 97 dams to almost 30% greater capacity than existed in 2009. There are also planned repairs and improvements of water and wastewater networks in 24 cities.

From 2010 to 2014, the government also has plans for the construction of four new desalination plants, bringing total capacity to 660.4 million gallons/day. Forty new wastewater treatment plants and 20 new lagoons are also planned, bringing total capacity to 195.5 billion gallons/yr by 2014.

Impending Water Policy Changes/Conditions to Address Issue
It is unknown whether Algeria has impending policy changes to address these issues. While steps are being taken to upgrade and replace aging infrastructure, new policies should address Algeria's insufficient water metering. These meters might not necessarily identify major sources of leaks but they could ensure that all connected customers are adequately billed for their water and pay for what they use.

Technology/Policies Needed
In addition to new infrastructure such as treatment plants and pipes, Algeria will need water metering and may also need technology to identify major sources of water leaks. The country may not have the finances to pay for conventional instruments which detect leaks, so inexpensive leak-detection equipment may be a niche market for Algeria.

Key Issue: High Agricultural Demand and Inefficient Watering Systems

Key Dimensions
Agriculture is responsible for 65% of Algeria's water use, yet irrigation systems lose approximately 40% of the water used. Officials also predict that agricultural production will increase in the coming years. This will not only increase water use, but add to water loss if inefficient irrigation practices continue to be used.

Action Needed
If increased irrigation efficiency and replacement of obsolete equipment occurs in the near future, water use for agriculture may decrease despite efforts to expand agricultural production. These increases in efficiency would help offset increases in agricultural production.

Current Approach
The five-year plan for 2010 to 2014 will repair irrigation systems across 49,000 acres of agricultural land and build new systems across 99,000 acres.

Impending Water Policy Changes/Conditions to Address Issue
Algeria does not appear to have any impending water policy changes to address high agricultural water use or inefficient irrigation systems. Cost prohibits the improvement of irrigation systems so efforts to solve agricultural water problems will likely need to be small-scale.

Technology/Policies Needed
Efficient systems, such as drip irrigation, are needed. These systems decrease water loss and often increase crop yields, as well. Even sprinkler irrigation would be an upgrade for areas that use ditch and canal irrigation methods that lose large amounts of water through evaporation. Unfortunately, poverty is often high in rural areas so even sprinkler systems might not be economically feasible.

Availability of Technology
Low-cost, micro-irrigation systems will be most needed in Algeria. There are a number of low-cost systems available (International Water Management Institute, 2006):

- Pepsee easy drip technology

- Bucket and drum kits
- Micro sprinklers
- Micro tube drip systems

Key Issue: Need for Emphasis on Water Reuse

Key Dimensions
The largest potential for water reuse is in agricultural irrigation but reuse is still in the early development phases in Algeria (Global Water Intelligence, 2010). Algeria primarily uses large, irrigated perimeters for agricultural production. Most areas outside of these perimeters do not have access to existing water infrastructure. Policies which limit conventional water source use and promote reclaimed water may be necessary.

Current Approach
Some projects across the country are studying the use of reclaimed water for municipal uses and fire fighting. The government's next five-year plan includes movements to expand irrigation perimeters and use reclaimed water for crop irrigation. Details do not appear to be available for plans to use reclaimed water for irrigation.

Impending Water Policy Changes/Conditions to Address Issue
Algeria might need to consider policies which use water quotas for irrigation or to specify crops which may be grown in the country. These policies could reduce agricultural water use by encouraging more responsibility of water and by reducing the amount of water-intense crops that are grown.

Technology/Policies Needed
Technologies such as greywater systems would be helpful but may not be economically feasible for Algeria. Water harvesting on a larger scale makes more sense. Simple, low-cost solutions such as rain barrels for homes could use rainwater for lawn and garden irrigation. However, because agricultural irrigation consumes the majority of water in Algeria, future water reuse technologies will need to focus on this sector.

Key Issue: Water Pollution

Key Dimensions
Industry consumes only 13% of the water used in the country. Therefore, water use is not a currently a major issue for this sector. Wastewater is a larger concern because there are currently no requirements for industries to pre-treat their wastewater. Effluent is often discharged into both the domestic network and local rivers.

Algeria has 102 wastewater treatment plants, with a design capacity of 290.6 million gallons/day or about half the water used in areas potentially served by wastewater treatment plants. Priority has long been given to drinking water systems over sanitation systems. Currently, 86% of the population is served by a sewerage network, but only 46% of the wastewater is treated to a secondary level.

Action Needed
New wastewater treatment plants and expansion of current networks may be needed to handle industrial discharge. Algeria should attempt to construct new facilities which can treat wastewater to a secondary level or higher. Industries will also need to be required to treat any wastewater which does not go directly to municipal wastewater treatment plants.

Current Approach
Approximately 40 new wastewater treatment plants are planned. These plants will be located primarily, upstream from new and existing dams, along coastal areas, and in cities with populations greater than 100,000.

Impending Water Policy Changes/Conditions to Address Issue
Algeria needs to implement policies that require industries to pre-treat wastewater to an extent that amounts which are discharged into domestic networks will not overload these systems. Policies are also needed that prohibit discharge of untreated industrial wastewater into nearby bodies of water. All policies would need to be strictly enforced.

Technology/Policies Needed
Additional municipal wastewater treatment plants, on-site industrial wastewater treatment plants, and wastewater treatment technology will be needed. Technology that is low-cost, yet efficient, would be best suited to Algeria's needs.

Market Forecast (2010 – 2016)
According to GWI, Algeria will remain an important location in water-related investments because it has the ability to finance new projects. Furthermore, the country's population is expected to increase, yet much of the water infrastructure is still not up-to-date.

Private companies have played an increasing role in the Algerian water sector, as they have built the majority of the new water sector over the past decade. Many of the new plants are run by the developer for two years before being transferred to public companies such as AdE and ONA.

Economic changes favoring domestic investment and control of projects are making foreign investment more difficult. However, the country will still need to rely on foreign consulting for major projects. In July 2009, the Loi de Finances Complémentaire (Supplementary Finance Act) was passed, which limits foreign investor stake in any given company to 49%. The remaining stake must be owned by Algerian interests. This could affect the major desalination plants, as most have a foreign majority stake.

The Préférence Nationale amendment also increases the advantage offered to Algerian bids during international bid offers from 15% to 25%. Algerian projects will not be given foreign domestic bid consideration when Algerian companies have the expertise to perform the work.

Market Summary Forecast	2010 – 2016 Annual Average (US$)
Water	
Networks	575 million
Treatment plants	191 million
Water resources/ other	448 million
Wastewater	
Networks	234 million
Treatment/ other	123 million
Utility capital expenditure	
Water utilities	1,490 million
Wastewater utilities	370 million
Utility operating expenditure	
Water utilities	985 million
Wastewater utilities	96 million
Industrial water	
Industrial capital expenditure	92 million
Industrial chemicals	51 million
Industrial services	4 million
Desalination and reuse	
Desalination	274 million
Reuse	155 million

Source: (Global Water Intelligence, 2010)

Drinking Water Capital Expenditure
In 2010, drinking water capital expenditures are expected to be $2.45 billion. However, from 2011 to 2016, expenditures are expected to be between $1.2 billion and $1.6 billion, per year. Approximately 45% of annual expenditures will be on water resources (including desalination), 45% on new construction of water distribution networks and rehabilitation of existing networks, and 10% on new construction of water treatment plants and rehabilitation of existing plants.

Wastewater Capital Expenditure
The wastewater infrastructure, like the water infrastructure, is fairly un-centralized in Algeria. Some 61 of the 102 wastewater treatment plants are managed by ONA. Most of ONA's plants are of medium capacity (2.6 million gallons/day to 10.6 million gallons/day), but the design capacity of all 102 plants is 290.6 million gallons/day. The largest plant is in Oran, with a capacity of 79.3 million gallons/day.

Annual wastewater capital expenditures are expected to vary between $230 million and $590 million from 2010 to 2016. Approximately 75% will be for the construction of new wastewater networks and rehabilitation of existing networks, and 25% will be for wastewater treatment plants.

Industrial and Municipal Capital Expenditure
Between 2010 and 2016, annual industrial and municipal capital expenditures are expected to vary between $1.5 billion and $2.8 billion. Approximately 95% of annual expenditures will be for municipal projects, while 5% will be for industrial projects.

Water and Wastewater Operating Expenditure
Annual water operating expenditures are expected to increase from $700 million in 2010 to $1.3 billion in 2016. Annual wastewater operating expenditures are projected to increase from $75 million in 2010 to $150 million in 2016. Annual expenditures on desalination are expected to be at a low of $110 million in 2011 and gradually increase to $580 million in 2016. Total annual water reuse expenditures are expected to drop from $270 million in 2011 to $40 million in 2012. Expenditures will then gradually increase to $280 million in 2016.

4.3 Egypt

Water Market (Global Water Intelligence, 2010)

- Market size 2010: $3.5 billion
- Growth rate 2010 – 2016: 6% to 9.9%
- Key markets:
  - On-site treatment of industrial wastewater
  - Low-cost micro irrigation
  - Increased public-private partnerships for new water and wastewater treatment plants

Demographic Indicators

Population	**2009**	**2016**
Urban Population	33 million	38 million
Rural Population	45 million	49 million
Total Population	**78 million**	**87 million**
Population Growth Rate	**2005-2010**	**2010-2015**
Urban Population Growth Rate	1.83%	1.98%
Rural Population Growth Rate	1.70%	1.34%
Total Population Growth Rate	1.84%	1.68%

Source: (Global Water Intelligence, 2010)

Economic Indicators

Economic Indicator (2008)	**Nominal GDP**	**GDP at Purchasing Power Parity**
Total GDP	$163 billion	$443 billion
GDP per capita	$2,162	$5,897
GDP growth rate	7.17%	

Source: (Global Water Intelligence, 2010)

Background and Summary of Key Issues

Egypt is a country of 78 million people and the population is expected to increase to 87 million by 2016. The country is bordered by the Mediterranean Sea to the southeast and the Red Sea to the east. Approximately 97% of the population lives in the more fertile Nile Valley and Delta and relies on the Nile for water. However, Egypt is a downstream user and, thus, has the challenging task of controlling water quality. Egypt also has very low annual rainfall, with an average of only 2 inches per year. Agriculture is responsible for the majority of water withdrawals (86% in 2000).

Water use across all major sectors is expected to increase from 2007 to 2017. Agricultural use is expected to increase by 15% between 2007 and 2017. Municipal use is expected to increase 38% during that time, while industrial use is projected to increase 48% and become about 2/3 of the size of municipal use.

The greatest increases in water supply from 2007 to 2017 will be groundwater (8%), irrigation reuse (4%), and wastewater reuse (278%). Water from the Nile (97% of total water supply), desalination (less than 1% of total supply), and rain water (more than 2% of total supply) are expected to remain constant through 2017. Some 98% of water is surface water and 2% is groundwater.

The primary water problems in Egypt are:

- Water demand exceeding supply and drought
- Groundwater and surface water pollution
- Inadequate wastewater treatment and sewer networks
- High agricultural water demand

Key Issues: Demand Exceeding Supply and Drought

Key Dimensions
Renewable water sources amount to approximately 15.1 trillion gallons/yr. Approximately 98% (14.8 trillion gallons/yr) of this is surface water, while only 2% (343.4 billion gallons/yr) is groundwater. Total withdrawal in 2000 was 18.0 trillion gallons/yr, which is 2.9 trillion gallons/yr or 19% higher than total renewable water sources. This combination is not sustainable.

As in most North African countries, the majority of Egypt's rainfall occurs in coastal areas (MWRIPS, 2005). The greatest annual rainfall occurs in the coastal city of Alexandria, which is less than 8 inches. In contrast, Cairo receives less than 0.5 inches per year.

Action Needed
Either demand has to be reduced or new water sources, such as desalination or water reuse, have to be developed. Currently, desalination accounts for less than 0.5% of overall use.

Current Approach
Egypt has 488 desalination plants but three of these plants alone make up 22% of the total capacity (Global Water Intelligence, 2010). The Sinai plant, which went online in 2006, is the largest (300.2 million gallon/day capacity) and uses RO. Main technologies used are reverse osmosis (RO), which is used in 87% of the treatment plants, electrodialysis (ED), multi-effect distillation (MED), and multi-stage flash (MSF).

Impending Water Policy Changes/Conditions to Address Issue
The National Water Resources Plan 2017 mentions that seawater desalination and brackish water desalination are preferred only when cheaper sources of water are not available (MWRIPS, 2005). The authors of the plan hope that Egypt will be able to cooperate with other Nile basin countries to determine how to increase the supply of water from the Nile. However, there are no detailed plans to increase cooperation. Deep groundwater development in the Western Desert, Sinai, and the Eastern Desert is desired, in addition to better monitoring, licensing, and prioritization of groundwater in the Nile aquifer.

Technology/Policies Needed
Because the National Water Resources Plan 2017 discusses the additional use of groundwater, policies may need to be created which ensure that new developments will not threaten aquifer levels. Since desalination is an expensive source of non-conventional water, policies which encourage agricultural irrigation conservation may be more appropriate.

Key Issue: Groundwater and Surface Water Pollution

Key Dimensions
The Nile River becomes more polluted as it moves north through urban areas. Problems include low flow, agricultural runoff, municipal effluent, and industrial effluent (MWRIPS, 2005). Sources of contamination include oil and grease, nutrients, and total dissolved solids. Irrigation canals which link to the river are also contaminated and total dissolved solids in various branches of the river are as high as 500 mg/l.

Groundwater quality in the Nile Delta is generally acceptable because many areas contain a clay protective cap. The Nile Delta does have some sources of contamination, including manganese and iron. Approximately 20% of groundwater in the Nile aquifer is not acceptable for drinking standards. Much of this contaminated water exists in the Nile Valley. Sources of contamination include dissolved salts from halite and gypsum, as well as nitrates from fertilizers and pesticides.

Action Needed
Measures to prevent discharge of industrial wastewater must be taken. Egypt needs to limit pollution of the Nile but must also attempt to cooperate with upstream users to reduce surface water pollution.

Current Approach
The Task Force on Water Quality Priorities and Strategies of MWRI has created geographical maps outlining the extent of pollution in drainage catchments within the Nile Delta. Catchments in the delta which have the highest levels of pollution are north of Cairo and between the Rosetta and the Damietta Branches.

Impending Water Policy Changes/Conditions to Address Issue
There are currently no impending policy changes to address groundwater or surface water pollution.

Technology/Policies Needed
Egypt encourages industries to treat wastewater as part of their own production processes (MWRIPS, 2005). However, because this is not currently required, Egypt should consider policies which require on-site treatment or which levy higher fees for industries which send wastewater to area facilities for treatment. Strict enforcement is required of laws that prohibit discharge of untreated wastewater.

Key Issue: Inadequate Wastewater Treatment and Sewer Networks

Key Dimensions
Approximately 49% of the population (39.8 million) is connected to a sewer system (Global Water Intelligence, 2010). Egypt has 70% urban coverage (30.2 million individuals) but only 25% rural coverage (9.6 million individuals).

Action Needed
From 2000 to 2008, Egypt's municipal water supply grew from 1.4 trillion gallons/yr to 2.2 trillion gallons/yr. It is likely that the majority of this increase occurred in urban areas. Current total water treatment capacity is approximately 5.9 billion gallons/day and the HCWW operates 1,568 treatment plants. Ultimately, greater efforts are needed to increase rural sewer connections.

Current Approach
In 2005, Egypt completed the National Water Resource Plan 2017. This is intended to guide development and management of the country's water resources. The plan aims to guide a move toward private investment and away from donor funding. Approximately $25.5 million will be necessary for investment in infrastructure. The proposed plan involves a 95% public sector contribution and a 5% private sector contribution.

Egypt has an expected investment of $13.2 billion in water and wastewater projects over the next several years. Planned water projects include three reverse osmosis desalination plants with a 34.3 million gallon/day capacity. Three wastewater treatment plants and a number of other small scale wastewater projects are planned, using government funding.

There are also 11 wastewater treatment projects with private sector involvement that are in the planning or construction stages. These include the construction of new plants and upgrades to additional plants. If all projects are completed, Egypt's wastewater treatment capacity is estimated to increase to between 977.4 billion gallons/day and 1.9 trillion gallons/day or 16% to 33% of current capacity.

Impending Water Policy Changes/Conditions to Address Issue
It is not apparent whether Egypt has impending water policies to address the inadequate number of treatment facilities and sewer systems. However, policies which encourage the development of treatment plants and sewer systems in rural areas will have highest importantance.

Technology/Policies Needed
Conventional wastewater technology will be needed to address urban needs but non-conventional systems which might exist may be needed for rural areas where coverage is extremely low and funding is scarce.

Availability of Technology
Low-cost water treatment and sewer technology could be a niche market for Egypt, due to the non-existing infrastructure in many rural villages and the difficulties that low-densities could pose in the construction of such infrastructure in those areas.

Key Issue: High Agricultural Demand

Key Dimensions
In 2000, approximately 15.5 trillion gallons/yr were withdrawn for agricultural purposes. This was 86% of the 18.0 trillion gallons/yr of total water withdrawn (Global Water Intelligence, 2010). Agricultural irrigation is extremely dependent on the Nile, due to low levels of rainfall throughout Egypt (MWRIPS, 2005). Major crops include grains, vegetables, fodder, fibers, and sugar.

Action Needed
Egypt might consider the use of less-water intensive crops to reduce agricultural demand. Agricultural water reuse is important, as is new, more efficient watering systems.

Current Approach
The Ministry of State for Environmental Affairs (EEAA) has implemented the National Program for Safe Use of Treated Wastewater in Afforestation (Global Water Intelligence, 2010). Under this program, 634 billion gallons/yr are reused for irrigation. An additional 1.4 trillion gallons/yr of untreated municipal wastewater, diluted with freshwater, is used for irrigation. By 2017, it is hoped that 2.2 trillion gallons/yr will be used for irrigation.

Impending Water Policy Changes/Conditions to Address Issue
Egypt should implement policies which limit the types of crops grown or place quotas on water-intensive crops, such as certain types of grain. Because the majority of land outside of the Nile Delta is desert that receives low rainfall, Egypt might also try to limit farming to areas with higher rainfall.

Technology/Policies Needed
Drip and sprinkler irrigation systems would be ideal to ensure that less water is used for agriculture and that less water is lost through evaporation that occurs with the use of ditch and canal irrigation systems. However, high rural poverty and inadequate government funds suggest that low-cost, micro-irrigation systems will be more feasible in Egypt.

Availability of Technology
Low-cost, micro-irrigation systems which could be appropriate for Egypt are (International Water Management Institute, 2006):

- Pepsee easy drip technology
- Bucket and drum kits
- Micro sprinklers
- Micro tube drip systems

<u>Market Forecast (2010 – 2016)</u>
There is expected to be increased private sector participation, driven by the success of projects such as the New Cairo wastewater treatment plant.

- New implementations are needed to move beyond standard service and build-operate-transfer contracts.

- Participation with upstream countries along the Nile will be necessary, due to factors affecting the level of the river, such as climate change.

The Central Authority for the Drinking Water and Sanitation Sector and Protection of the Consumer (CADWSSPC) was formed as a result of the increasing private sector involvement in the water industry. New public-private partnerships (PPP) for water treatment plants and wastewater treatment plants have formed since 2008.

Some projects are in the concept stage, while others "have moved to the issuance of prequalified bidders, with the request for tendering anticipated in late 2010 (Global Water Intelligence, 2010, p.648). The construction of the New Cairo wastewater treatment plant is the first example of a PPP, and it is hoped that it will be a model for the implementation of future PPPs.

Market Summary Forecast	2010 – 2016 Annual Average (US$)
Water	
Networks	505 million
Treatment plants	48 million
Water resources/ other	192 million
Wastewater	
Networks	572 million
Treatment/ other	207 million
Utility capital expenditure	
Water utilities	915 million
Wastewater utilities	791 million
Utility operating expenditure	
Water utilities	1,360 million
Wastewater utilities	667 million
Industrial water	
Industrial capital expenditure	80 million
Industrial chemicals	59 million
Industrial services	3 million
Desalination and reuse	
Desalination	170 million
Reuse	34 million

Source: (Global Water Intelligence, 2010)

Drinking Water Capital Expenditure

From 2010 to 2016, annual drinking water capital expenditures are expected to vary between $750 million and $1.35 billion. Approximately 60% of annual expenditures will be on new construction of water distribution networks and rehabilitation of existing networks, 35% on water resources (including desalination), and 5% on new construction of water treatment plants and rehabilitation of existing plants.

Wastewater Capital Expenditure
Approximately 1.7 trillion gallons of wastewater are produced annually. The HCCW manages 187 wastewater treatment plants, treating 2.4 billion gallons/day of wastewater or 876 billion gallons annually. The plants have an overall design capacity of 4.2 billion gallons/day or 89% of total wastewater production. Some 90% of wastewater is treated at a secondary level. However, there is no official documentation on tertiary treatment.

Annual wastewater capital expenditures are expected to vary between $280 million and $1.2 billion from 2010 to 2016. Approximately 70% will be for the construction of new wastewater networks and rehabilitation of existing networks, and 30% will be for wastewater treatment plants.

Industrial and Municipal Capital Expenditure
In 2000, power was the largest annual industrial user of water, consuming 71% of the total. The food industry used the second highest amount of water, at 14%.

Annual Industrial Water Demand		
Industry	**1980**	**2000**
Power	78%	71%
Chemical	8	9
Food	6	14
Textile	3	2
Metal	3	2
Others	2	2
Total	**766 billion gallons**	**1,984 billion gallons**

Source: (Global Water Intelligence, 2010)

Between 2010 and 2016, annual industrial and municipal capital expenditures are expected to vary between $1.2 billion and $2.6 billion. Approximately 95% of annual expenditures will be for municipal projects, while 5% will be for industrial projects.

Water and Wastewater Operating Expenditure
Annual water operating expenditures are expected to increase from $1.25 billion in 2010 to $1.5 billion in 2016. Annual wastewater operating expenditures are projected to increase from $550 million in 2010 to $800 million in 2016. Annual expenditures on desalination are expected to vary between $90 million and $270 million from 2010 to 2016. Total annual water reuse expenditures are expected to be between $30 million and $50 million from 2010 to 2016.

4.4 Morocco

Water Market (Global Water Intelligence, 2010)

- Market size 2010: $1.6 billion
- Growth rate 2010 – 2016: 10% to 14.9%
- Key markets:
  - New and upgraded wastewater treatment plants
  - Low-cost irrigation technology
  - New water infrastructure

Demographic Indicators

Population	2009	2016
Urban Population	18 million	21 million
Rural Population	15 million	14 million
Total Population	**33 million**	**35 million**
Population Growth Rate	**2005-2010**	**2010-2015**
Urban Population Growth Rate	1.84%	1.86%
Rural Population Growth Rate	0.40	0.22
Total Population Growth Rate	1.24	1.2

Source: (Global Water Intelligence, 2010)

Economic Indicators

Economic Indicator (2008)	Nominal GDP	GDP at Purchasing Power Parity
Total GDP	$89 billion	$137 billion
GDP per capita	$2,827	$4,362
GDP growth rate	5.6%	

Source: (Global Water Intelligence, 2010)

Background and Summary of Key Issues

Morocco is a northwest African country of 33 million people, growing from a total of less than 12 million in 1961. The current population is expected to grow to 35 million by 2016. Most of this population growth will take place in urban areas between 2010 and 2015:

- Urban population growth rate: 1.86%
- Rural population growth rate: 0.22%
- Total population growth rate: 1.2%

In 2008, the country had a GDP growth rate of 5.6%. Morocco annexed the Western Sahara in 1975 and refers to it as the Southern Provinces. Most of the major cities such as Casablanca, Rabat, and Tangiers are on the Atlantic and Mediterranean coasts.

The average annual rainfall is uneven across the country, as the north receives 79 inches/yr while the south receives less than 4 inches/yr. Morocco's network of dams has held enough water to help the country weather severe droughts. Between 2009 and 2030, the government estimates that it will cost $10 billion to meet long-term water needs of 4.4 trillion gallons/yr.

The main water challenges in Morocco are:

- Water shortage, climate change, and drought
- Inadequate infrastructure
- High agricultural use and inefficient watering systems
- Unequal access to water
- Need for water reuse

Key Issue: Water Shortage, Climate Change, and Drought

Key Dimensions

Climate changes, lower rainfall, and drought, could cause situations where demand will exceed supply. Therefore, efforts are being made to reduce demand for water, especially in the agricultural sector.

Approximately 69% (5.8 trillion gallons/yr) of Morocco's renewable water resources come from surface water, while 31% (2.6 trillion gallons/yr) is groundwater. Morocco needs to place a higher emphasis on high quality, non-conventional resources, as desalination comprises only 7.9 billion gallons/yr and tertiary reuse accounts for only 5.3 billion gallons/yr.

Action Needed

Since gaining independence in the 1960s, Morocco has embarked on an ambitious dam-building program. There are currently 116 large dams, storing 90% of all accessible water resources. In addition, there are 6 to 8 large dams and 50 small dams planned between now and 2020.

Current Approach

Desalination is cost-prohibitive and is thus only used in a last resort, especially in the arid southern half of the country. ONEP's capacity is only 5.5 million gallons/day but there are plants operated by other companies. Morocco does have a strong interest in future use of desalination, as it is interested in increasing its desalination and reuse capacity tenfold by 2015. Nine major desalination projects are planned, for a total capacity of almost 49.9 million gallons/day.

Impending Water Policy Changes/Conditions to Address Issue

Currently, there are no known water policy changes in Morocco to address water shortage, climate change, or drought.

Technology/Policies Needed

Implementation of water management technology has been difficult because there is improper coordination between the country's water sub-sectors (United Nations ECA, 2006). Therefore, it is recommended that policies are implemented which provide for increased consolidation of water sub-sectors. Technology implementation may remain difficult if this is not achieved.

Key Issue: Inadequate Infrastructure

Key Dimensions
Morocco is struggling to renovate and expand its water infrastructure (Global Water Intelligence, 2010). This problem is especially severe in major urban areas where wastewater infrastructure has failed to keep pace with the rapidly expanding population over the last 20 years. Only 10% of the 158.5 billion gallons of annual wastewater are currently treated, and less than 50% of the wastewater treatment plants work properly.

Furthermore, only 72% of the population is served by sanitation systems. A 2003 World Bank study estimated that current pollution costs Morocco $543 million annually due to water-borne diseases and the resulting public health costs. Despite this, the volume of wastewater produced is expected to increase from 158.5 billion gallons/yr in 2005 to 237.7 billion gallons/yr in 2020.

Morocco has a municipal water supply of 218.7 billion gallons/yr, and the per capita water consumption from this supply is 19 gallons/day. Approximately 92% of the network has meter coverage but 25% of water is unaccounted for.

Action Needed
Morocco produces 158.5 billion gallons of wastewater annually and it has 80 wastewater treatment plants with a total design capacity of 42.3 million gallons/day. However, only 56% of wastewater is collected and 10% of collected wastewater is treated to a secondary level. Therefore, investments need to be made to upgrade wastewater treatment plants and networks to adequate levels.

Current Approach
Twelve major water treatment plants (two of which are multi-phase) were planned by ONEP in 2008. When completed, these plants would have a 322 million gallon/day total capacity. There are also plans to spend $907.3 million on wastewater projects, including upgrades, extensions, and new plants, between 2009 and 2013. Finally, the PNA has announced intentions to build 57 new wastewater treatment plants in partnership with ONEP. There are currently six major wastewater treatment plants under development, all of which are scheduled to be online by 2012. These plants will add a total capacity of 257 million gallons/day. Total cost is estimated to be $662.9 million.

Impending Water Policy Changes/Conditions to Address Issue
The Programme National d'Assainissement's (National Wastewater Programme) goals are to connect 80% of the population to wastewater networks by 2020 and to decrease urban pollution from wastewater by 60%. The total cost of these projects is estimated to be $5.2 billion. The government's annual investment in wastewater was approximately $41.5 million in 2006 and increased to approximately $73.2 million in 2009.

Technology/Policies Needed
Treatment technology, in addition to water treatment plants and wastewater treatment plants, will be needed. Sewer system components will also be necessary in addressing Morocco's ambitious plan to expand networks within the next 10 years.

Key Issue: High Agricultural Use and Inefficient Watering Systems

Key Dimensions
In Morocco, 85-90% (2.9 trillion gallons/yr) of all water is used for agriculture. Up to 40% of this is lost through leaks or evaporation, and only 10% of irrigated agricultural land uses sprinkler or drip irrigation. In contrast to agricultural water use, municipal use accounts for only 10% of withdrawals while industry accounts for approximately 3%.

Action Needed
Sprinkler and drip irrigation systems would be the best upgrades to reduce water loss from leaks or evaporation. However, low-cost micro-irrigation technology might be more appropriate for areas where funding is inadequate.

Current Approach
The Programme National d'Economie d'Eau et d'Irrigation (PNEEI) – National program for water saving and irrigation – plans to spend $4.8 billion over 15 years to reduce agricultural water use by 20 to 40%. This is expected to help increase the use of sprinkler or drip irrigation to 48% when 1.4 million acres of gravitationally irrigated land will be converted to modern methods.

Approximately 60% of the installation costs will be subsidized, and partnerships with the food industry and farmers will establish best management practices. Water savings of 30-50% are expected, and agricultural yields are predicted to rise from 10% to 100%.

Impending Water Policy Changes/Conditions to Address Issue
The PNEEI will help to upgrade inefficient irrigation systems but there are no specific policies which will address high agricultural water use or inefficient irrigation systems.

Technology/Policies Needed
Drip irrigation would be the best technology to utilize but even low-cost micro-irrigation would be an upgrade for areas that currently use ditches and canals for irrigation.

Key Issue: Unequal Access to Water

Key Dimensions
Access to drinking water is uneven across Morocco. In large urban areas, there is 90% access while urban areas of all size have an average of 83% access. However, rural areas had only 70% access in 2007. In rural villages, fountains and wells are still common sources of water.

Action Needed
Between private concessionaires and municipal utilities, drinking water and wastewater coverage ranges from 90% to 94%. The goal is to increase drinking water coverage to 95% or higher and wastewater coverage to 90% or higher by 2013. ONEP, Morocco's national public company, is in the process of implementing a $1.5 billion investment program from 2008 to 2010. This is intended to increase rural access to drinking water from 86% access in 2008 to 92% access in

2010. Urban coverage is estimated to increase from 93% coverage in 2008 to 96% coverage in 2010.

Current Approach

The World Bank has initiated an Output-Based Approach (OBA) to subsidize initial connection fees. Operators are required to pre-finance the subsidy and then are reimbursed by the World Bank. Morocco has also planned to build large-scale systems that would transport water from the north to the south where it is scarce. However, no action has currently been taken due to scale, cost, and environmental issues.

Between 2005 and 2009, Morocco has increased its spending on urban and rural water supply and sanitation programs from 5% to 25% (World Bank hails, 2010). With the help of a $60 million rural water supply project, financed by IBRD, rural potable water access has increased from 50% in 2004 to 87% in 2009.

Impending Water Policy Changes/Conditions to Address Issue

Approximately 2 million residents still have no access to water supply and sanitation, so the Initiative Nationale pour le Développement Humain (National Initiative for Human Development) program aims to decrease poverty and provide basic services to underserved areas. In 2006, Lydec provided connections for 30,000 of 85,000 underserved households in Casablanca. An additional 6,800 are expected to soon be provided with connections but 48,000 households in Casablanca still do not have services.

Technology/Policies Needed

Because coverage rates are higher in urban areas, low-cost water connections might be most important to install in rural areas. Since Morocco experiences constant water shortage, water meters might be an appropriate technology to install along with new water connections. As with most of the North Africa countries, irrigation uses the majority of water but it will be important to monitor and regulate domestic use, as well.

Key Issue: Need for Water Reuse

Key Dimensions

Water reuse is currently extremely low, due to the low amounts of treated wastewater. There are a number of significant water reuse projects which are being planned or implemented:

- There is a proposal to treat Rabat's city green spaces with treated wastewater.
- Marrakesh's Station Nord wastewater treatment plant has a reuse component with tertiary treatment.
- The Tamouda Bay wastewater treatment plant will also employ tertiary treatment.
  - Many of these projects will use reclaimed water for golf courses and landscaping.

Action Needed

Morocco needs to consider implementing policies that would encourage greater water reuse and less reliance on conventional sources of water. Increased treatment of wastewater to tertiary or better levels may also be necessary to achieve this goal. Greywater systems should also be considered.

Current Approach
Morocco's water reuse potential is 132.1 billion gallons/yr or approximately 4% of total water use. The Secrétariat d'Etat Chargé de l'Eau et de l'Environnement (SEEE) is expected to publish a national strategy on the use of non-conventional water sources in 2010. Provisions for water reuse are to be included in the report.

Market Forecast (2010 – 2016)
Because Morocco has no oil or gas reserves, it must rely primarily on commercial and subsidized loans for financing water infrastructure. Though Morocco has been more open to private sector involvement than other Middle Eastern countries, private financing is still low. Morocco still needs significant investment in its water industry. Most of this investment is expected to go toward wastewater treatment. However, good investment opportunities exist in the area of non-conventional resources, such as desalination, reuse, and water transfers.

A number of private operators provide services in Casablanca, Rabat, Tangiers, and Tetouan. Electricity plays an important role in the financing of water-related investments. Concession contracts are required to be reviewed every five years. These contracts are intended to increase investments but also have created the negative effect of increasing water tariffs.

Lydec has a 30 year contract for operation. Since beginning operating in Casablanca in 1997, it has invested $939.0 million in water infrastructure. Network upgrades and repairs are decreasing unaccounted for water (UFW) rates, and many upgrades have been targeted for disadvantaged areas. The company is able to fund projects as a result of its electricity revenues (72% of total revenue in 2008).

Veolia Maroc obtained a 25-year contract from Redal and Amendis in Rabat- Salé and Tangier-Tetouan. As of January 2010, Redal and Amendis were still owed $92.7 million, which could negatively impact Veolia's investments. Veolia has also made investments in wastewater, including the de-pollution of the Bay of Tangiers. It intends on shifting its focus from construction to customer service in the near future.

Morocco has been considering a regional approach to government since 1976. The country is comprised of 16 regions which have been gradually gaining power. It is currently unknown how a regional approach might affect the structure of Morocco's water organization. There is also an impending merger of ONEP and ONE, which may be signaling a shift toward a multiservice approach to distribution.

Market Summary Forecast	2010 – 2016 Annual Average (US$)
Water	
Networks	127 million
Treatment plants	29 million
Water resources/ other	117 million
Wastewater	
Networks	219 million
Treatment/ other	90 million
Utility capital expenditure	
Water utilities	429 million
Wastewater utilities	319 million
Utility operating expenditure	
Water utilities	642 million
Wastewater utilities	150 million
Industrial water	
Industrial capital expenditure	28 million
Industrial chemicals	32 million
Industrial services	1 million
Desalination and reuse	
Desalination	157 million
Reuse	17 million

Source: (Global Water Intelligence, 2010)

Drinking Water Capital Expenditure
From 2010 to 2016, annual drinking water capital expenditures are expected to vary between $300 million and $640 million. Approximately 70% of annual expenditures will be on water resources (including desalination), 30% on new construction of water distribution networks and rehabilitation of existing networks, and 5% on new construction of water treatment plants and rehabilitation of existing plants.

Wastewater Capital Expenditure
Annual wastewater capital expenditures are expected to increase steadily from $205 million in 2010 to $490 million in 2016. Approximately 75% will be for the construction of new wastewater networks and rehabilitation of existing networks, and 25% will be for wastewater treatment plants.

Industrial and Municipal Capital Expenditure
Industry is responsible for only 3% of all water use in Morocco. The major industrial water consumer is the Office Chérifien des Phosphates (OCP). OCP is state-owned and a world leader in the production of phosphates. It plans to double phosphate production and triple fertilizer production by 2020. This will increase water consumption from 17.4 billion gallons/yr in 2006 to 46.8 billion gallons/yr in 2020. However, desalination capacity is expected to increase by 26.4 billion gallons/yr by 2020, which will allow the company to stop withdrawing groundwater. Its current groundwater use is estimated to be 5.3 billion gallons/yr.

Between 2010 and 2016, annual industrial and municipal capital expenditures are expected to vary between $540 million and $975 million. Approximately 95% of annual expenditures will be for municipal projects, while 5% will be for industrial projects.

Water and Wastewater Operating Expenditure
Annual water operating expenditures are expected to increase from $590 million in 2010 to $700 million in 2016. Annual wastewater operating expenditures are projected to increase from $100 million in 2010 to $205 million in 2016. Annual expenditures on desalination are expected to vary between $60 million and $405 million from 2010 to 2016. Total annual water reuse expenditures are expected to be between $10 million and $30 million from 2010 to 2016.

4.5 Tunisia

Water Market (Global Water Intelligence, 2010)

- Market size 2010: $781.3 million
- Growth rate 2010 – 2016: 10% to 14.9%
- Key markets:
  - Small-size seawater desalination plants and brackish water treatment plants
  - Low-cost micro-irrigation
  - Maintenance of aging infrastructure
  - Northwest Sahara Aquifer System groundwater level monitoring

Demographic Indicators

Population	**2009**	**2016**
Urban Population	7 million	8 million
Rural Population	3 million	3 million
Total Population	**10 million**	**11 million**
Population Growth Rate	**2005-2010**	**2010-2015**
Urban Population Growth Rate	1.66%	1.56%
Rural Population Growth Rate	-0.07%	-0.25%
Total Population Growth Rate	1.11%	1.01%

Source: (Global Water Intelligence, 2010)

Economic Indicators

Economic Indicator (2008)	**Nominal GDP**	**GDP at Purchasing Power Parity**
Total GDP	$41 billion	$83 billion
GDP per capita	$3,955	$8,002
GDP growth rate	4.65%	

Source: (Global Water Intelligence, 2010)

Background and Summary of Key Issues

Tunisia is a North African country on the Mediterranean of over 10 million people. It shares a border with Algeria and Libya. Approximately 40% of the country is comprised of the Sahara desert. Like most North African countries, the northern area of the country is temperate, with rainy winters. The south is semi-arid. Annual rainfall is somewhat unpredictable and varies across the country. For example, the Northwest mountains receives 59 inches/yr while the Southern desert receives 2 inches/yr. Groundwater accounts for 32% of annual renewable water, while surface water accounts for 68% per year.

Tunisia has the most extensive water infrastructure out of the North-African countries. It provides 100% water coverage in urban areas and 92% coverage in rural areas. The main challenge will be to maintain this infrastructure, as current water tariffs have not been enough for any kind of upgrade work.

Tunisia has a 126.8 billion gallon annual municipal water supply and 13 water treatment plants have a 211.3 million gallon/day operational capacity. The water distribution network is 28,000 mi in length with 2.15 million water connections. Approximately 82% of the network has meter coverage but 23.5% of water is unaccounted for. Per capita water consumption from municipal sources is 33 gallons/day.

Agriculture accounts for approximately 80% of water withdrawals, but this figure is projected to decline to 74% by 2030. Domestic use comprises 14% and is expected to increase to 18% in 2030. Withdrawals for industrial use and for tourism are currently 5% and 1%, respectively. Industrial withdrawals are expected to comprise 7% in 2030, while withdrawals for tourism are not expected to change.

SONEDE is the main operator of water treatment plants in Tunisia. The country's largest plants are the Ghdir El Goulla water treatment plant with a 158.5 million gallon/day capacity and the Belli water treatment plant with a 92.5 million gallon/day capacity.

Key water issues in Tunisia are:

- Inadequate water supply and excessive groundwater withdrawals
- High salinity levels
- Maintenance of water infrastructure
- Water pollution
- High agricultural demand and inefficient watering structures
- Need for increased water reuse

Key Issue: Inadequate Water Supply and Excessive Groundwater Withdrawals

Key Dimensions

Tunisia has only 132,000 gallons of annual water per resident, and this figure is expected to decline to 95,000 gallons by 2030 because of climate change. A 5% decrease in annual rainfall is also predicted over that timeframe. Flooding and drought are also expected to increase.

The arid southern areas of the country rely on water withdrawals from the Northwestern Sahara Aquifer System, which contains over 7.9 quadrillion gallons. This system is shared with Libya and Algeria, and withdrawal is unregulated. This has severely affected the annual withdrawals from the aquifer. Withdrawals have risen from 105.7 billion gallons/yr in 1950 to 660.4 billion gallons/yr in 2000. The annual recharge is estimated to be only 264.2 billion gallons/yr, resulting in a 396.2 billion gallon/yr decrease that is not currently recharged.

Action Needed

Tunisia may need to expand its water storage network by building dams and reservoirs to ensure that it will have enough water during times of low rainfall and drought. Alternative, non-conventional sources of water will also need to increase, to ensure that the Northwest Sahara

Aquifer System does not continue to decline. Finally, Tunisia, Libya, and Algeria need to decide how to regulate withdrawal from the aquifer.

Current Approach
To monitor and limit withdrawals, Tunisia, Libya, and Algeria created a partnership which took almost 10 years to achieve and is one of only two of its kind. Tunisia also plans to build additional desalination plants and increase water reuse to partially mitigate these problems.

Impending Water Policy Changes/Conditions to Address Issue
It is unknown whether there are impending water policy changes to address low water supply or excessive groundwater withdrawals.

Technology/Policies Needed
If there are not existing policies in place, the partnership between Tunisia, Libya, and Algeria, needs to set limits on groundwater withdrawals and to create policies which ensure that future withdrawals will be low enough to allow the Northwestern Sahara Aquifer System to begin to recharge to adequate levels. Therefore, water conservation policies will be important primarily for agricultural water use, but also for domestic and industrial use.

Groundwater metering technology could be important in ensuring that aquifer levels do not continue to decline to unsustainable levels.

Key Issue: High Salinity Levels

Key Dimensions
Over half of the country's water resources have a salinity level (0.13 oz/gal or more) that is too high for human use. Excessive groundwater use in the coastal areas has worsened the problem, as declining water tables have allowed seawater intrusion.

Action Needed
Tunisia will need to start finding non-conventional alternatives to groundwater or to consider investing in additional desalination technology to address high salinity levels.

Current Approach
Tunisia has been using desalination since 1983. SONEDE operates 4 brackish water desalination plants with a total capacity of 19.1 million gallons/day. These are primarily for municipal use. Private plants, used primarily for hospitality and industrial use, have a 11.9 million gallon/day total capacity. The overall capacity of public and private plants is 31.0 million gallons/day. There are plans to add an additional 75.6 million gallon/day capacity by 2020.

Impending Water Policy Changes/Conditions to Address Issue
There are no impending water policy changes to address high levels of salinity. However, under the Programme National d'Amélioration de la Qualité de l'Eau (Water Quality Improvement Programme), there are 18 small to medium-capacity brackish water desalination plants that are planned across the country. The first phase involves 10 plants, costing a total of $33 million,

which will serve areas with salinity levels of 0.13 to 0.19 oz/gal. The earliest plants are scheduled to go online by 2012.

A second phase of eight plants will be constructed in areas where salinity is under 0.13 oz/gal. The estimated cost for this phase is $43.5 million. Feasibility studies are being done for the second phase, and the winning bidder will be required to consider the use of solar power for the plants.

Technology/Policies Needed
Tunisia has a reasonable average annual market ($89 million) for desalination over the next five years, when taking into account its small population and low GDP. Therefore, it might consider policies that would encourage private investment and operation of seawater desalination and brackish water treatment plants.

Key Issue: Maintenance of Water Infrastructure

Key Dimensions
Tunisia produces 74.0 billion gallons/yr of wastewater and has 100 wastewater treatment plants with a total design capacity of 208.7 million gallons/day. The five largest wastewater treatment plants have a combined capacity of 79.4 million gallons/day. The sewerage network is 8,800 mi in length and there are 980,000 connections. Approximately 95% of wastewater is treated to a secondary level while 5% is treated to a tertiary level or better.

Since 1974, $1.2 billion has been invested in wastewater infrastructure, which is also among the best in Northern Africa. However, because of a focus on new infrastructure investment since then, older infrastructure has often not been properly maintained and output frequently does not meet standards.

Action Needed
Rehabilitation of some facilities is necessary, and the current focus has also begun to shift to connecting small rural communities to the sewage network.

Current Approach
Construction is expected to begin on four wastewater treatment plants in 2010. The combined capacity of these plants will be approximately 19.3 million gallons/day and the total cost will be $29.0 million to $36.2 million. Financing will be obtained from a number of sources, including the European Commission Neighbourhood Investment Facility (NIF) and the European Investment Bank.

The president's sanitation program for peripheral urban areas has ensured that all peripheral urban areas will be connected to wastewater systems by 2013.

ONAS also plans to invest $1 billion in wastewater treatment infrastructure over 10 years. It plans to primarily construct plants with a 4.0 million gallon/day capacity, which would be financed by international loans. The number of wastewater treatment plants is expected to increase from 123 in 2011 to 150 in 2016, with the percentage of population coverage increasing from 91% to 94% during that time. The volume of treated wastewater is expected to increase from 70.0 billion gallons/yr in 2011 to 79.3 billion gallons/yr in 2016. The goal is to reuse 47.6 billion gallons/yr of water by 2016.

Impending Water Policy Changes/Conditions to Address Issue
The Projet d'extension et de Réhabilitation (WWTP Extension and Upgrade Programme) will address aging infrastructure. The five year program, at a cost of $127 million, aims to rehabilitate and expand 19 wastewater treatment plants and 130 pumping stations. This will also result in an additional capacity of 15.9 million gallons/day, and treated wastewater is expected to be used for agricultural and landscaping.

Technology/Policies Needed
Wastewater treatment plants and treatment technology will be needed to meet Tunisia's water infrastructure needs.

Key Issue: Water Pollution

Key Dimensions
A major problem in Tunisia is water imbalance and industrial pollution. The northern part of the country has over 85% of the higher quality water. Poor infrastructure and pre-treatment noncompliance has added to industrial pollution.

Action Needed
An increase in wastewater treatment capacity is necessary to ensure that all industrial water effluent is treated properly. Industries must not be allowed to discharge untreated water directly into streams, rivers, and lakes. Violators need to be held accountable.

Current Approach
Industry accounts for 13% of water withdrawals in 2010. This is expected to increase to 18% in 2030. Under the Projet de Valorisation des Effluents Industriels (Quality of Industrial Effluents Project), five industrial zones are targeted for a system where industrial effluent would be treated separately from domestic effluent. Feasibility studies are expected to be completed by the end of 2010, with tenders granted by 2011. $10.6 million in initial financing has been obtained for the project.

Impending Water Policy Changes/Conditions to Address Issue
There are no known impending policies which would address Tunisia's problems of water pollution.

Technology/Policies Needed
Tunisia should consider policies that encourage on-site treatment and reuse of industrial wastewater. Industries could simply be required to treat effluent on site or could be charged higher rates to have effluent treated at municipal plants. Higher rates might indirectly increase on-site treatment. Regardless, companies which dump untreated wastewater into nearby water bodies need to be held accountable.

Key Issue: High Agricultural Demand and Inefficient Watering Structures

Key Dimensions
While agriculture currently accounts for almost 80% of the country's water use, inefficiencies in irrigation are as high as 40%. Tunisia has begun to produce more crops that are less water-intensive. A goal is to save 30% of all sectoral consumption by 2030.

Action Needed
As with other North African countries, Tunisia needs to explore the use of less water-intensive crops, begin to use reclaimed water for agriculture, and upgrade existing ditch and canal irrigation systems to sprinkler and drip systems. Drip irrigation would be the most efficient option.

Current Approach
In 1995, the Programme d'Economie d'Eau à la Parcelle (Agricultural Water Saving Programme) was formed to provide state subsidies for upgrading irrigation equipment. As a result of the program, approximately 90% of all irrigated land uses modern techniques and equipment in the country. Water efficiency has, on average, improved from 50-60% to 70-85% and crop yields have increased 70%.

Impending Water Policy Changes/Conditions to Address Issue
Tunisia does not appear to have any impending water policies to address high agricultural irrigation demand for water or inefficient water structures.

Technology/Policies Needed
Tunisia is planning a $434.8 million North-South Reclaimed Water Transfer Project (Projet de Transfert des Eaux Épurées Nord-Sud). Reclaimed wastewater effluent from the north would be transported to the central plateau for agricultural use. The project includes four networks, spanning various regions. The project is being conducted in stages and is expected to be fully implemented by 2021. The transfer project could potentially irrigate up to 63,000 acres with 26.9 billion gallons/yr of water and contribute to an aquifer recharge volume of 8.0 billion gallons/yr.

Key Issue: Need for Increased Water Reuse

Key Dimensions
Reclaimed water is expected to increase from 5% of the country's water resources to 10% by 2030. This increase does take into account decreases in groundwater and rainfall, however.

Water reuse was not common until the 1980s. The primary uses for this type of water are agricultural and landscape irrigation. However, reuse has leveled off since 2006, at 25 to 30% of treated wastewater. The reason for this is that the quality of reclaimed water can vary widely from day to day. The wastewater treatment plants have difficulty treating industrial discharge. As a result, many farmers refuse to use it when color and smell are poor.

There is also a geographical supply and demand mismatch that affects water reuse with regard to agricultural production. Agriculture accounts for 80% of total water use, yet approximately 40% of wastewater is produced in North Tunisia where there is little agricultural land and the need for reclaimed water is low.

Action Needed
Desalination may need to be greatly expanded as an additional source of water, as it currently accounts for only 10.6 billion gallons of annual use. Tunisia's annual market average from 2010 to 2016 for desalination ($89 million) is very modest in comparison to the annual desalination market average for other countries, but it is a fairly significant figure when taken into account the low population and low GDP of Tunisia. However, water reuse in most cases is less expensive than desalination, so this market should continue to be explored, as well.

Current Approach
Of the 60.8 billion gallons/yr of wastewater in 2008, approximately 70% was treated but not reused. Only 30% was treated and reused. The majority of treated, reused wastewater was for agricultural purposes.

There are plans to increase the amount of reclaimed water use by three times by 2016, amounting to 60% of projected wastewater production. To protect against further aquifer depletion, the country plans to use reclaimed water to recharge aquifers.

Impending Water Policy Changes/Conditions to Address Issue
While Morocco has plans to increase the use of reclaimed water, it is not evident that the country is in the process of implementing any policies that would set standards for volume of reuse or the types of reuse permitted.

Technology/Policies Needed
Policies that limit water use and that, in tandem, encourage water reuse, should be created. Some desalination technology will be needed but other technologies such as on-site industrial wastewater treatment will be needed, as this will reduce demands on municipal treatment plants and possibly make farmers more open to using this reclaimed water.

Market Forecast (2010 – 2016)
Tunisia has one of the most extensive and well-managed water systems in the North African region. It plans on continuing to invest in new projects and is dedicated to modernization, seeking alternative methods of finance, and increasing water reuse. Types of technologies being pursued include:

- Reverse osmosis
- Solar power
- Gas recovery

Tunisia is exploring new methods of financing because private sector involvement had been primarily limited to construction contracts and studies. The private sector also played a very minimal role in the operation and maintenance of wastewater plants and infrastructure.

The first two 25-year build-operate-transfer contracts will be awarded between 2010 and 2011. The first contract is for a 13.2 million gallon desalination plant in Jerba, while the second contract is for two wastewater treatment plants in Greater Tunis (26.4 million gallon m^3/d total capacity).

A proposed 52.8 million gallon desalination plant may become an additional build-operate-transfer project. OAS also has plans to transfer 50% of operating and maintenance to the private sector by 2021.

Market Summary Forecast	2010 – 2016 Annual Average (US$)
Water	
Networks	73 million
Treatment plants	6 million
Water resources/ other	23 million
Wastewater	
Networks	100 million
Treatment/ other	27 million
Utility capital expenditure	
Water utilities	191 million
Wastewater utilities	130 million
Utility operating expenditure	
Water utilities	326 million
Wastewater utilities	69 million
Industrial water	
Industrial capital expenditure	12 million
Industrial chemicals	21 million
Industrial services	0.6 million
Desalination and reuse	
Desalination	89 million
Reuse	21 million

Source: (Global Water Intelligence, 2010)

Drinking Water Capital Expenditure
From 2010 to 2016, annual drinking water capital expenditures are expected to vary between $100 million and $340 million. Approximately 70% of annual expenditures will be on water resources (including desalination), 27% on new construction of water distribution networks and rehabilitation of existing networks, and 3% on new construction of water treatment plants and rehabilitation of existing plants.

Wastewater Capital Expenditure
Annual wastewater capital expenditures are expected to be between $75 million and $175 million from 2010 to 2016. Approximately 80% will be for the construction of new wastewater networks and rehabilitation of existing networks, and 20% will be for wastewater treatment plants.

Industrial and Municipal Capital Expenditure
Between 2010 and 2016, annual industrial and municipal capital expenditures are expected to vary between $210 million and $530 million. Approximately 97% of annual expenditures will be for municipal projects, while 3% will be for industrial projects.

Water and Wastewater Operating Expenditure
Annual water operating expenditures are expected to increase from $300 million in 2010 to $360 million in 2016. Annual wastewater operating expenditures are projected to increase from $55 million in 2010 to $85 million in 2016. Annual expenditures on desalination are expected to be between $10 million and $215 million from 2010 to 2016. Total annual water reuse expenditures are expected to vary between $20 million and $35 million from 2010 to 2016.

North Africa References

Algeria seeks dynamic solutions to water shortages (2005, March 17). *Magharebia*. Retrieved from http://www.magharebia.com/cocoon/awi/xhtml1/en_GB/features/awi/features/2005/03/17/feature-01

Deutsche Gesellschaft für Technische Zusammenarbeit (n.d.). *Integrated water management programme.* Retrieved from http://www.eau-algerie.org/index.php?id=27&L=2

Global Water Intelligence (2010). *Global water market 2011: Meeting the world's water and wastewater needs until 2016*. Oxford: Media Analytics Ltd.

International Water Management Institute (2006). Promoting micro-irrigation technologies that reduce poverty. *Water Policy Briefing, 23*.

MWRIPS – Ministry of Water Resources and Irrigation Planning Sector, Arab Republic of Egypt (2005). *Water for the future: National water resources plan 2017*. Retrieved from http://www.wldelft.nl/cons/area/rbm/wrp/pdf/nwrp2017.pdf

United Nations Economic Commission for Africa (2006). *Water, environment and sustainable development in North Africa*. Retrieved from http://www.uneca.org/sros/na/documents/Water.pdf

World Bank hails Morocco's water, sanitation policy (2010, March 11). *MENAFN – Morocco Business News*. Retrieved from http://www.menafn.com/qn_news_story_s.asp?StoryId=1093313013

4.6 South Africa

Water Market

- Market size 2010: $6.1 billion
- Growth rate 2010 – 2016: 6% to 9.9%

Key Markets	Niche Markets
Wastewater treatment	Non-conventional solutions to providing water and sanitation services to underserved rural areas affected by poverty
Reclaimed water	Industrial wastewater treatment
Upgrades to and replacement of municipal water and sanitation infrastructure to curb water loss	

Demographic Indicators

Population	**2009**	**2016**
Urban Population	30 million	33 million
Rural Population	19 million	18 million
Total Population	**49 million**	**51 million**
Population Growth Rate	**2005-2010**	**2010-2015**
Urban Population Growth Rate	1.35%	1.17%
Rural Population Growth Rate	-0.67%	-0.92%
Total Population Growth Rate	0.56%	0.40%

Source: (Global Water Intelligence, 2010)

Economic Indicators

Economic Indicator (2008)	**Nominal GDP**	**GDP at Purchasing Power Parity**
Total GDP	$277 billion	$494 billion
GDP per capita	$5,685	$10,136
GDP growth rate	3.06%	--

Source: (Global Water Intelligence, 2010)

Background and Summary of Key Issues

South Africa is the fourth largest country in Africa and has a population of 49 million. The population is expected to grow 0.4% by 2016 to 50.5 million, and all of this growth is predicted to occur in urban areas:

- 2010-2015 urban population growth rate: 1.17%
- 2010-2015 rural population growth rate: -0.92%

South Africa is a newly industrialized country with a modernizing infrastructure, including 500 dams. In 2008, South Africa had a total nominal GDP of $277 billion and a GDP growth rate of 3.06%. There are many natural resources including gold, coal, and metal ore. Major industries include mining, manufacturing, finance, and transportation.

Surface water is expected to decline from 77% of South Africa's water supply in 2008 to 72% in 2025. Groundwater will increase from 8% to 10% during that time span, and return flows and reuse will increase from 15% to 19%. Finally, desalination is expected to grow from less than 1% of overall supply in 2008 to 5% in 2025.

South Africa has a municipal water supply of 1 billion gallons/yr. The water distribution network is 20,000 mi in length, with 6.2 million water connections. Per capita water consumption from municipal water sources is 58 gallons/day. Some 1,100 plants treat the water in South Africa. Approximately 64% of the network has meter coverage, and 29% of water is unaccounted for.

The South African DWA has formulated a multi-year strategic plan (2009/10 – 2013/14) which outlines numerous goals for water. Major goals include:

- Increased measures to improve conservation and management of water demand.
- The creation of a Climate Change Response Strategy.
- Increasing support for municipalities with inadequate capacity.
- Building new infrastructure; renovating dams and pumping stations.

Major opportunities which are expected to arise from this plan include:

- Municipal water and sanitation infrastructure
- Wastewater treatment and discharge monitoring
- Desalination construction
- Water metering and pollution management

The South African Constitution also "guarantees basic water provision for all residents, defined as access to some form of water infrastructure and a minimum of 6.6 gallons per day of free water per person (depending on financial need)" (Global Water Intelligence, 2010, p. 169). The major water problems facing South Africa are:

- Drought and climate change
- Water scarcity, urbanization, and inequitable access to water
- Lost water and aging and inadequate infrastructure
- Water quality
- High agricultural use
- Wastewater treatment and sanitation

Key Issue: Drought and Climate Change

Key Dimensions

Approximately half of South Africa is comprised of arid and semi-arid areas. Changes in rainfall, caused by drought, have a negative impact on these areas (RSA Environmental Affairs, n.d.). A Department of Water Affairs News release (2010 January, 20) stated that the Eden

District Municipality in the Western Cape has experienced the lowest rainfall over a 12 month period since 1921. The area received approximately 19 inches of rainfall in 2009, which was only 63% of the annual average amount.

Areas of the Eastern Cape are also experiencing drought. Uitenhage had only 14 inches of rainfall in 2009, which was 69% of annual average precipitation. Major dams such as the Garden Route Dam and the Wolwedans Dam are at 30% and 37.1% storage, respectively. These amounts are 60% to 70% below median storage levels.

Action Needed

South Africa needs to place a strong emphasis on water conservation, water reuse, and alternative sources of water. Desalination is an expensive technology, and Global Water Intelligence (2010) states that there is virtually no market for desalination between 2010 and 2016. However, this is something which still may need to be explored because the country has many miles of ocean coastline and several major coastal cities. The development of lower-cost desalination technology for South Africa may be an opportunity for water companies.

Groundwater monitoring programs and surface metering programs need to be expanded in the country. There are 800 river flow monitoring stations (1 station per 579 mi^2) and approximately 1,000 surface water monitoring points (Department of Water Affairs and Forestry, 2004). However, the National Water Resource Strategy considers these number of stations inadequate for a country that has low availability of water.

Current Approach

To address current drought conditions, the Eden District Municipality is imposing water use restrictions and is also redirecting sewage water to treatment plant, as well as increasing seawater desalination to increase water availability (Department of Water Affairs, 2010 January, 20).

In the Nelson Mandela Bay metropolitan area, a $69.4 million pipeline is being constructed to supply the area with 71.3 million gallons of water per day (http://www.greywatersystems.co.za/2010/02/23/drought-relief-for-nelson-mandela-bay-in-the-pipeline/). Many areas of the city are currently only receiving water from catchment areas. The pipeline is intended to be completed by 2013, but the city's water supply would only last until the end of 2010 if no more rain were to fall during that time period.

South Africa has begun catchment basin studies (Berg River, Thukela Basin, Breede River Valley) to determine the future impacts of climate change on water availability (Energy & Development Research Centre, 2003). The report states that across South Africa, only 9% of rainfall reaches rivers and streams due to high water extractions for agriculture purposes such as sugarcane irrigation.

Impending Water Policy Changes/Conditions to Address Issue

<u>New Partnership for Africa's Development (NEPAD)</u>

NEPAD has a number of objectives, including ensuring safe and clean water for everyone, especially disadvantaged groups, planning for water on regional and national levels, increasing international cooperation for shared rivers, and to address climate change threats (Energy &

Development Research Centre, 2003). This partnership is intended to include the formation of a task force to address negative impacts of climate change.

Southern African Development Community (SADC) Plans and Objectives
The SADC is aiming to foster continued cooperation among members in the management of water resources. A Regional Strategic Action Plan has been created to manage and develop regional water sources and intends to initiate the design and development of various infrastructure projects.

Technology/Policies Needed
Greywater recycling is necessary because South Africa is the 30th driest country, receiving an annual average rainfall of 18 inches, compared to a global average of 34 inches (http://www.waterrhapsody.co.za/2010/02/16/drought-report-for-south-africa-december-dwaf/). However, these systems likely are too expensive for many municipalities and homes to install. Therefore, low-cost, simple alternatives such as rain barrels could still harvest water to use for personal irrigation.

The National Water Resource Strategy states that new infrastructure, such as dams, pumping stations, and pipelines will be needed to ensure adequate water during times of drought (Department of Water Affairs and Forestry, 2004). The strategy states that a national agency may be developed to oversee national and multi-sector infrastructure, while local municipalities would address local infrastructure.

Key Issue: Water Scarcity, Urbanization, and Inequitable Access to Water

Key Dimensions
The metropolitan population of South Africa increased from 57% in 1994 to 60% in 2008 (Global Water Intelligence, 2010). The Department of Water Affairs (DWA) has estimated that 60% of the poor live in rural areas where it can be difficult to deliver safe water.

The country has struggled to expand services in various areas due to factors such as poverty, after-effects of Apartheid, population growth and illegal immigration, and the distance between some rural villages.

Groundwater comprises only 9% (1.3 billion gallons/yr) of total water resources, yet 74% of rural areas completely rely on groundwater. Renewable surface water comprises 12.7 trillion gallons/yr. The country is comprised of 19 water management areas (WMAs) based on geography, and five of these have had water shortages. Future mild to moderate shortages are predicted for many metropolitan areas. Water restrictions will be necessary during these times.

Action Needed
The DWA has suggested that pilot plants be constructed and feasibility studies be done on the treatment and reuse of water. Some cities sell portions of their reclaimed water to industries. For example, Southern Sewage Works in Durban sells approximately 2.4 million gallons per day of reused water to a paper mill. An additional plant provides 7.9 million gallons per day of

reclaimed water to other industries. Another opportunity involves indirect potable reuse, where treated wastewater is returned to the surface or the ground and used in potable water systems.

Current Approach
South Africa is in the planning and construction phases of several projects that will attempt to slow or halt an impending water crisis. From 2004 to 2006, there were nine major projects costing a total of $172 million. Through 2012, there are 15 major planned projects under construction estimated to cost $2.7 billion. Examples of these projects are dams, water treatment plants, and pipeline construction.

Due to Apartheid, previous government water policies resulted in the granting of subsidies which primarily benefited whites who owned large amounts of land (Energy & Development Research Centre, 2003). The Raw Water Pricing Strategy of 1999 was passed to provide more equitable access to water by ensuring that subsidies did not benefit one group more than another.

Impending Water Policy Changes/Conditions to Address Issue
It is unknown whether South Africa has impending water policy changes to address water scarcity or inequitable access to water.

Technology/Policies Needed
Desalination currently provides 1% of the overall water (Global Water Intelligence, 2010). However, interest in desalination is beginning to increase. The South African DWA has approved studies to determine the feasibility of desalination plants in all major coastal cities. It hopes to increase output to 7-10% of the total supply by 2030. Plants are being proposed primarily in the major coastal cities, such as Cape Town, Durban, East London, and Port Elizabeth. The DWA is expected to decide whether to proceed with construction in 2010.

Key Issue: Lost Water and Aging and Inadequate Infrastructure

Key Dimensions
One of South Africa's main water supply problems involves water loss. Approximately 29% of municipal water is lost through leaks, inadequate billing, and illegal hook-ups (Global Water Intelligence, 2010). For example, the major port city of Durbin is losing approximately 23.8 million gallons of water per day, due to aging water pipes (South Africa: Durbin Moves, 2010).

South Africa's water infrastructure includes 422 major dams (8.45 trillion gallon total capacity) and 13 interbasin transfer systems (1.6 billion gallon/yr total capacity) (Global Water Intelligence, 2010). Approximately 2.1 million people (4%) still do not have access to standard water infrastructure, despite the fact that 1.3 million gained access to infrastructure in 2007-2008. The Free Basic Water Programme (FBW) serves 86% of the population and has made it possible for 96% of the population to receive proper water access. It is estimated that overall bulk infrastructure needs $8.2 billion (Department of Water Affairs and Forestry, 2009).

Action Needed
Municipal water metering seems to be badly needed, to determine where leaks are occurring and to identify illegal hookups. There is no mention of such metering in the National Water

Resource Strategy. South Africa will also need to prioritize spending on new infrastructure and on infrastructure upgrades. For 2008-2009, $61.8 million was allocated for bulk infrastructure projects (Department of Water Affairs and Forestry, 2009). South Africa will have difficulty replacing and adding infrastructure when taking into consideration that total needs.

Current Approach

There are eight major dams and bulk water projects which are expected to be completed between 2011 and 2019 (Global Water Intelligence, 2010). Twenty other projects are scheduled for completion between 2009/10 and 2012/13. Under the DWA's Dam Safety Rehabilitation project, 38 existing dams will be upgraded at a cost of approximately $199 million.

In 2009, Durbin spent $5.1 million on 16 projects to reduce water loss and is projected to spend $8.9 million in 2010 (Durban Moves, 2010). Examples of projects include the Asbestos Cement Pipe Replacement program, the replacement of 3,020 water meters with new, more accurate meters, and water pressure management. Water pressure management is expected to save up to 18.5 million gallons of water per day.

Impending Water Policy Changes/Conditions to Address Issue

While South Africa has a number of planned or ongoing projects to address aging infrastructure and lost water, it does not appear that there are any impending water policy changes to address these issues.

Technology/Policies Needed

It is estimated that new dams and additional groundwater withdrawal may provide an additional 1.4 trillion gallons/yr of water (Global Water Intelligence, 2010). Urban, irrigation, and industrial effluent return could provide an additional 501.9 billion gallons/yr. Proposed water reuse projects include supplying proposed power plants around Gauteng with treated effluent and supplying the expansion of Sasol coal-to-liquid fuel plants with treated effluent. Meters and related equipment for household and municipal supply monitoring may also be necessary.

Key Issue: Water Quality

Key Dimensions

Salinity, excessive nutrient levels, and contamination from bacteria are the major water quality issues in South Africa (Department of Water Affairs and Forestry, 2004). Mining and irrigation are responsible for high pollution levels, while excessive levels of phosphates and nitrates have contributed to algae blooms which exacerbate the eutrophication of waterways. Agricultural fertilizer and poorly maintained sanitation systems add to this buildup of nutrients. Poorly maintained sanitation systems also foster bacterial growth, as does the pollution of water from animal waste.

An additional problem is the difficulty of replacing retiring workers with a new, properly trained workforce in the water sector. For example, before 1994, there were 20 professional engineers per 100,000 people. Yet, since 2005, there have been only 3 professionals per 100,000. A shortage of skilled workers at all levels has affected the operation of wastewater treatment plants, which has in turn, resulted in poorer quality of discharged water (South Africa releases, 2010, June).

Action Needed
The government needs to consider more regulations governing the use and discharge of water for agriculture and mining. Water which is contaminated or has high salinity levels needs to be treated, instead of being discharged directly into nearby water bodies. Agricultural fertilizers which have low level of phosphates may need to be used and riparian buffers need to be utilized to control agricultural runoff.

However, The Department of Water Affairs and Forestry (2004) stated that many areas surrounding existing buffers are over-utilized. Overuse decreases the effectiveness of these buffers so land management practices may also be necessary.

Finally, more efforts need to be made to encourage younger generations to pursue careers in water technology and educational programs may need to be tailored to meet this need. An influx of new professionals might ensure that water plants and systems are properly operated and maintained.

Current Approach
The South African National Standards (SANS) has set basic water quality criteria which urge WSAs to deliver adequate quality water to at least 70% of households (Global Water Intelligence, 2010). Approximately 52% of water service authorities (WSAs) are in compliance with service quality criteria (Department of Water Affairs and Forestry, 2009). This means that they have the appropriate number of staff, a customer service operation, and ability to respond to service calls within 24 hours.

An electronic water quality management system (eWQMS) was also created to provide more effective monitoring. At least 90% of WSAs are entering data from 3,200 sampling locations into a national database. Thus far, the quality of samples from 94% of the locations has fallen within national health standards. However, many water treatment plants still do not have the proper capacity to remove all contaminants (Global Water Intelligence, 2010).

Impending Water Policy Changes/Conditions to Address Issue
In September 2008, The Department of Water Affairs and Forestry introduced the Blue Drop Certification Programme (Department of Water Affairs and Forestry, 2009). This addresses water quality through incentive-based regulations and approximately 70% of water services were assessed from November 2008 to January 2009.

Technology/Policies Needed
Policies are needed which would require a greater percentage of WSAs to comply with service quality criteria. Policies might also be needed which require responsible agricultural practices, such as the use of riparian buffers. Simply outlining best management practices does not ensure compliance.

Key Issue: High Agricultural Use

Key Dimensions
Agriculture is responsible for 60% of the annual water used (Global Water Intelligence, 2010). In 2007-2008, overall recorded water use increased 0.6% from 4.6 trillion gallons the previous year. Additionally, annual water demand increased in 14 of the 19 WMAs. Yet, approximately 65% of South Africa does not receive enough rainfall to sustain water-intensive crops, making 14 million people susceptible to food shortages. The South African average annual rainfall is approximately 18 inches while the global average annual rainfall is approximately 34 inches.

Some areas of the country have highly efficient irrigation systems, but other areas of the country have less efficient, leaking systems which may account for high volumes of water loss. One estimate states that only 60% of water for irrigation actually reaches the roots of crops (Department of Water Affairs and Forestry, 1999 draft).

Action Needed
Due to water shortages and inadequate rainfall in many areas, future agricultural production will need to use less water through more efficient irrigation or through the use of less water-intensive crops. Replacement or retrofitting of inefficient watering systems will be important.

Current Approach
Conservation, pricing, and management of demand are attempts to address water shortage. The Department of Water Affairs and Forestry (n.d.) has considered allowing a system of water trading where one user who is over quota could borrow or buy portions of another individual's allocation.

The 1st Africa Agriculture and Water Dialogues will be help in Cape Town in March, 2011 (http://www.awdialogue.org/). Discussions will be held on climate change, sustainable land and water management, and storage infrastructure. The event seeks to foster cooperation among agriculture departments across the continent and to discuss solutions to water shortage for agriculture.

Impending Water Policy Changes/Conditions to Address Issue
There do not appear to be impending water policy changes in South Africa which would address agricultural water use.

Technology/Policies Needed
Policies which limit the amount of water per capita used for agriculture may be eventually needed. Upgrades to existing irrigation infrastructure will also ensure that less water is lost from leaks and evaporation. Technologies such as sprinkler irrigation and drip irrigation are also appropriate.

Key Issue: Wastewater Treatment and Sanitation

Key Dimensions

Aging wastewater treatment infrastructure, substandard collection, and lack of experienced workers has made it difficult to maintain the country's wastewater network (Global Water Intelligence, 2010). South Africa has 7.22 million wastewater connections and 1,274 wastewater treatment plants which collect 78.2% of the 935 billion gallons/yr of wastewater produced. Approximately 38% of the wastewater collected is treated to a secondary level. The DWA's 2007 survey of 166 wastewater treatment plants across 166 WSAs revealed:

- 57% of WSAs did not have the proper licenses or permits for operation.
- 75% of WSAs were not abiding by the condition of the licenses or permits.
- 30-40% operate at levels above capacity, do not take into account the amounts of discharge, or do not perform wastewater analysis.
- Approximately 60% of plants are in need of maintenance or other work.

Lack of access to proper sanitation has decreased in current years but is still a major problem. The number of individuals which have lacked sanitation access which meet specific criteria is:

- April 2009: 12.1 million (24%)
- 2008: 13.4 million
- 1994: 20.4 million

Action Needed

The South African Green Drop report was recently issued and outlines the status of wastewater systems in the country (South Africa releases, 2010, June). The authors of the report assessed 449 wastewater treatment plants and found that only 32 are eligible for Green Drop status. This means that 32 plants meet international standards.

South African Water Affairs minister Buyelwa Sonjca stated that the country would need between $3 and 6 billion to fix wastewater problems. There are only data for half of South Africa's plants, so the amount needed to fix all plants is likely higher than $6 billion. Many plants discharge poorly-treated wastewater into surrounding bodies of water, yet only two municipalities were charged with dumping untreated wastewater.

Bluewater Bio International, based out of the United Kingdom, estimates that 60% of a registered 1,610 wastewater treatment plants in the country need upgrades. However, the DWA has not conducted its own study to determine how many plants need upgrades.

Current Approach

The percentage of individuals with basic sanitation access has increased to 76% since 1994, but only 55% are currently connected to a sewer system (Global Water Intelligence, 2010). The Free Basic Sanitation Programme (FBS), a partner of the FBW program, is expected to be introduced in 2010.

According to the Green Drop Report, cumulative risk rates (CRR) were developed for wastewater treatment plants to create a priority matrix for funding (Department of Water Affairs, 2009). Cumulative risk rates were based on design capacity, current capacity, compliance and non-compliance of regulations, and supervising and maintenance. A CRR of 1 signifies the lowest risk, while 48 is the highest. Plants with a CRR greater than 18 are considered higher risk and should be first in line for funding. Of 852 wastewater treatment facilities inspected in the country, 160 (19%) were considered high risk with a rating higher than 18.

Impending Water Policy Changes/Conditions to Address Issue

There do not appear to be any impending water policy changes to address wastewater treatment and sanitation in South Africa.

Technology/Policies Needed

Bluewater Bio signed a three-year license agreement with Headstream Water Holdings in 2009 to design and install new wastewater treatment plants and upgrade existing plants. The contract can be extended in two-year increments.

Bluewater Bio's "HYBACS" process will be used, which biologically treats nitrates, phosphates, and other contaminants from wastewater. The projects are intended to take place in underserved areas, as well as in areas surrounding mines. Carbon credits and sale of treated effluent could account for 70% of the cost of upgrades.

Market Forecast (2010 – 2016)

The primary future trends which are expected to be seen in South Africa are:

- Repairing, upgrading, and expanding the country's 1,200 wastewater treatment plants as well as municipal water and sanitation infrastructure.
- Increasing greatly the use of reclaimed water (through desalination and treatment of effluent).
- Increasing levels of sewage treatment.
- Reducing water loss from current 29%.
- Implementing non-conventional solutions to providing water and sanitation services to rural areas affected by poverty.

The South African DWA aims to provide full access to basic water and sanitation by 2014 and wants water infrastructure investment to be at least $208 billion.

Market Summary Forecast	2010 – 2016 Annual Average (US$)
Water	
Networks	984 million
Treatment plants	422 million
Water resources/ other	399 million
Wastewater	
Networks	661 million
Treatment/ other	423 million
Utility capital expenditure	
Water utilities	1,800 million
Wastewater utilities	1,130 million
Utility operating expenditure	
Water utilities	2,610 million
Wastewater utilities	732 million
Industrial water	
Industrial capital expenditure	167 million
Industrial chemicals	102 million
Industrial services	12 million
Desalination and reuse	
Desalination	N/A
Reuse	N/A

Source: (Global Water Intelligence, 2010)

Private Sector Participation

The future role of private companies in the water industry is in limbo. Many controversial concession contracts were granted in the 1990s and as a result, build-operate-transfer contracts are becoming more popular. No major concession contracts have been signed since 1999, as a result of political and public opposition.

The Water and Sanitation Services South Africa (WSSA) have signed at least five management contracts with various private companies since 1992. The most well-known contract was a $10 million deal between WSSA and Johannesburg Water Management to run Johannesburg Water Ltd for five years. The contract resulted in decreased costs as well as improved services and water and wastewater quality for 3.2 million people.

A number of desalination plants are also being built with private sector involvement. Examples of these plants range in size from 396,000 gallons/day to over 29.9 million gallons/day. Construction costs are as low as $2.1 million and as high as $220 million.

Drinking water capital expenditure

From 2010 to 2016, drinking water capital expenditures are projected to be between $1.5 billion and $1.9 billion per year. Approximately 55% of annual expenditures will be on new construction and rehabilitation of existing water distribution networks, 25% on new construction and rehabilitated of existing water treatment plants, and 20% on water resources (including desalination).

Wastewater capital expenditure
Annual wastewater capital expenditures are expected to increase from approximately $1 billion in 2010 to $1.35 billion in 2016. 60% of annual expenditures will be for the construction of new wastewater networks and rehabilitation of existing networks, while 40% will be for wastewater treatment plants.

Industrial and municipal capital expenditure
South Africa's industrial sector is the fastest growing in the country, employing over 25% of the workforce. It is also responsible for 11% of the overall water use. Examples of major products are "chemicals, metal products, food and beverages, electrical machinery, automobiles, and textiles" (GWI, 2010, p. 178).

South Africa mines more gold than any other country in the world. It also exports diamonds and metals such as platinum and vanadium. Water transportation is important because most mines are located in inner arid areas of the country and thus, are not near water sources. Mining is the largest industrial/commercial user of water, at 102.5 trillion gallons in 2004. Aluminum smelters, beverage producers, and golf courses are other major industrial users of water.

Water used for energy consumption has been reduced by approximately 40% and accounts for 2% of overall water use in the country. Eskom is the main supplier of energy, generating 95% of all electricity. Due to its large use of water, it has switched from "wet-cooled" to "dry-cooled" processes. This transition has lowered the average amount of water needed by nine times but an increase in supply will still be necessary. New proposed coal-fueled power plants will further increase the need for water.

Between 2010 and 2016, annual industrial and municipal capital expenditures are projected to be between $2.9 billion and $3.25 billion. 90% of annual expenditures will be for industrial capital projects, while 10% will be for municipal capital projects.

Water and wastewater operating expenditure
Annual water operating expenditures are expected to increase from $2.3 billion in 2010 to $2.85 billion in 2016. Annual wastewater operating expenditures are projected to increase from $600 million in 2010 to $900 million in 2016.

South Africa References

Department of Water Affairs (n.d.). *Water for growth and development in South Africa: Version 6*. Retrieved from http://www.dwa.gov.za/WFGD/documents/WfGDv6Nov21.pdf

Department of Water Affairs (2009). *Green drop report 2009. Version 1: South African waste water quality management performance.* Retrieved from http://www.pmg.org.za/files/docs/100429GreenDropReport.pdf

Department of Water Affairs (2010, January 20). Drought report for South Africa December

– DWAF [News Release]. Retrieved from http://www.waterrhapsody.co.za/2010/02/16/drought-report-for-south-africa-december-dwaf/

Department of Water Affairs and Forestry (1999 draft). *Water conservation and demand management national strategy framework*. Retrieved from http://www.info.gov.za/view/DownloadFileAction?id=70484

Department of Water Affairs and Forestry (2004, September). *National water resource strategy: First edition*. Retrieved from http://www.wrc.org.za/Knowledge%20Hub%20Documents/Other/NWRA%20Sept04.pdf

Department of Water Affairs and Forestry (2009). *Annual report: 1 April 2008 to 31 March 2009*. Retrieved from http://www.dwaf.gov.za/documents/AnnualReports/ANNUALREPORT2008-2009.pdf

Durbin moves to curb water losses. (2010, January 15). *South Africa: The Good News*. Retrieved from http://www.sagoodnews.co.za/infrastructure/durban_moves_to_curb_water_losses.html

Energy & Development Research Centre, University of Cape Town (2003). *Sustainable development and climate change in South Africa: Two case studies for the development and climate change project.* Retrieved from http://www.developmentfirst.org/Studies/SouthAfricaCountryStudies.pdf

Global Water Intelligence (2010). *Global water market 2011: Meeting the world's water and wastewater needs until 2016*. Oxford: Media Analytics Ltd.

Republic of South Africa, Department of Environmental Affairs (n.d.). *State of the environment: Effects of climate change.* Retrieved from http://soer.deat.gov.za/174.html#3561

South Africa releases Green Drop report. (2010, June). *Water 21: Magazine of the International Water Association,* 8.

Asia / Middle East

4.7 China

"We have a water shortage, but we have to develop, and development is going to be put first."
-Wang Yongli, Senior engineer at Shijiazhuang's Water Conservation Bureau (Yardley: 2007)

Water Market

- Market size 2010: $47 billion
- Growth rate 2010: 6 to 9.9%

Key Markets	Niche Markets
Water treatment	Decentralized water treatment & purification
Wastewater treatment	Water pollution remediation
Water reuse	Industrial wastewater treatment
Desalination	Water efficiency solutions at all scales
Network rehabilitation	Power plant cooling water treatment

Demographic Indicators

Population	**2009**	**2016**
Urban Population	590.33M	699.67 M
Rural Population	751.49M	697.51M
Total Population	**1,341.83M**	**1,397.18M**
Population Growth Rate	**2005-2010**	**2010-2015**
Urban Population Growth Rate	2.70%	2.37%
Rural Population Growth Rate	-1.00%	-1.08%
Total Population Growth Rate	0.59%	0.55%

Source: (Global Water Intelligence, 2010)

Economic Indicators

Economic Indicator (2008)	**Nominal GDP**	**GDP at Purchasing Power Parity**
Total GDP	$4,327.4 billion	$7,926.5 billion
GDP per capita	$3,259	$5,970
GDP growth rate	9.01%	--

Source: (Global Water Intelligence, 2010)

Background and Summary of Key Issues

Unable to raise capital to meet infrastructure needs, China began privatizing water systems in the 1970s. In 2002 China formally opened its water supply, wastewater treatment and distribution network to foreign investment. Public-Private Partnership (PPP) models, including Build-

Operate-Transfer (BOT), Transfer-Operate-Transfer (TOT), and joint ventures (JV) are becoming more common in China's water sector. Profit margins of foreign companies operating in China are around 21%, due mainly to advantages in land rent, tax policy, and loan availability over local and state-owned companies. (GWI)

Competition among foreign investors is driving huge premiums for distribution networks and joint ventures with municipal authorities. Premiums can be as high as three times the value of the asset, supporting the view that investors see huge potential in such partnerships. Reasons for the potential growth include: GPD growth, supportive local governments that will facilitate tariff increases, population growth within the existing system, potential for multiplying efficiencies, and expansion opportunities. (Weir:2008)

- In 2008, private companies, foreign companies, and local companies participated in 20% of water utilities and 70% of wastewater utilities in China. (GWI)
- In large cities, foreign firms have been successful participating in state-owned water supply companies, with a share not exceeding 50%. Generally, the government retains ownership rights, while the private partner has operating rights. (GWI)
- In small cities and medium-sized cities, there are no formal restrictions on ownership of water and wastewater pipe networks. (Weir:2008)
- New water regulations (enacted July 1st, 2007) will require an estimated 1,500 WTPs to invest in upgrades to comply with new regulations. (Weir:2008)
- Investment in capacity is often hindered due to the inability of local pipe networks to supply water, leaving some plants short of water to treat. Joint ventures can work with local contractors to expand distribution capacities.
- Industrial users in China reuse only 25% of water (compared to an average of 85% in developing countries).
- From 2006 to 2010 the Chinese government is estimated to have spent $44.3 billion on sewage and water reclamation projects, and $14.8 billion on water supply and infrastructure. (Gleick:2009)
- Rapid urbanization, 18 million people annually, will drive the need to expand water networks.
- Performance improvements can be realized by improving revenue issues such as leakage, lack of metering, and billing.
- The same goes for WWTPs: the Ministry of Construction estimated in 2006 that 278 cities in China did not have any wastewater treatment facilities. (Weir:2008) Moreover, there is no system to charge for sewerage.

Growing domestic funding sources will compete with foreign investors for infrastructure projects. In 2007, Chinese pension and insurance funds were allowed to invest in long-term projects, such as infrastructure projects. Although every transaction has to be approved, the water sector is viewed as an ideal investment for long-term funds. In addition, the development of the domestic bond market, while it is not likely to be fully functional for a few years, will provide a low-cost source of funding for municipalities. These two changes will likely have a dramatic effect on how infrastructure is procured at the municipal level in China. (Weir:2008)

Water has traditionally been heavily subsidized, though that may be changing in an effort to curb severe shortages. In Beijing, water for certain commercial uses such as car washing, is priced 10 times higher than for domestic use. Local officials in Shenzhen are pushing to adopt a new pricing structure that encourages recycling and rainwater harvesting. Some regions in southern China have adopted a base rate for the average household requirement, with a surcharge if use goes above. (Gleick:2009)

Water Use by Sector	**Demand**	**Volume (km^3/yr)**
Agriculture	62.1%	362
Industrial	23.6	138
Domestic	12.5	73
Replenishment	1.8	10
Total	100.0%	583

Urban Water Supply	
Municipal water supply	50.5 km^3/yr
Municipal water demand	40.4 km3/yr
No. of WTPs	3,400
No. of connections	120 million
Unaccounted-for water	36%
Meter Coverage	90.8%
Length of distribution network	480,084 km

Urban Wastewater	
No. of WWTPs	1,521
Design capacity of WWTPs	90.92 million m^3/day
Wastewater collected	70.2%
% treated to secondary	36.5%
% treated to tertiary	7.2%
Length of sewer network	315,200 km

Water Use by Industry

Industry	Value	Notes
Paper	$27.89 billion	China is the world's largest paper manufacturer, with 3,500 plants across the country. Currently, water consumption by the paper industry in China is 10 times higher per unit of production than in developed countries.
Chemicals	$119.08 billion	China has 21,000 chemical manufacturers, though 80-90% have revenue of less than $7.38 million. Half of these manufacturers are located along the Yangtze River and Yellow River.
Textile	$79.98 billion	China has 50,000 enterprises in the textile industry, though 99.5% are small businesses. A recent trend is a move in location from the south-east to the north-west.
Power Generation	$141.51 billion	The largest consumer of water by industry, 87% of power in China comes from coal-fired plants.
Food and Beverage	$142.10 billion	Targeted by the central government to reduce consumption and pollution, there will be a market for efficiency and reuse in this sector.

Overview of challenges

"In Israel, people regard water as more important than life itself," he said.
"In Shijiazhuang, it's not that way. People are focused on the economy." (Yardley 2007)

Pollution

Water is in direct competition with China's main goal- economic growth. Industry in China, unhindered by environmental regulation, is notoriously inefficient and polluting. (Roberts 2009) It is difficult to describe the amount of pollution and contamination in China's waters. The list of disasters is seemingly endless; chemical, oil, nutrient, and heavy metal contamination events seem almost routine. It is estimated that 70% of China's lakes and rivers are contaminated, half of Chinese cities have significantly polluted groundwater, and one-third of China is affected by acid rain. Images showing canals in cities heaping with refuse, lakes colored neon green by algae, and dozens of chemical-filled barrels floating down a river are easy to find. The Yangtze River has been called "cancerous" by Chinese experts, and a third of surface water samples taken from the river were considered severely polluted. (Gleick 2009) Some examples of pollution incidents:

- A broken oil pipeline in Yan'an contaminated the water supply reservoir of a city of 2.5 million. (Gleick 2009)
- An estimated 20,000 chemical factories are dumping uncontrolled or marginally controlled wastewater.
- In 2006, half of China's major cities did not meet state drinking water standards (OECD China Environmental Performance Review 2007)

- One-quarter of the water sampled from China's two largest rivers, the Yangtze and Yellow, were found unsafe even for irrigation. (Gleick 2009)
- In 2005, an explosion at a petrochemical plant caused the spill of 100 tons of pollutants into the Songhua River, forcing the downstream city of Harbin to shut down its water supply system for four days. That same factory has released more than 150 tons of mercury into Songhua. (Sekiguchi 2006)
- According to the World Bank, some 53.7 billion tons of untreated waste were dumped into China's lakes and rivers in 2006.
- Chinese authorities responded to 48 large-scale environmental emergencies in 2008. (Roberts 2009)

Water Efficiency

- China uses 3 to 10 times the amount of water for similar industrial processes as developed countries. (GWI)
- Of the 65% of water that goes to agriculture, only half actually reaches the crops due to leaks, evaporation and other losses.
- A 2003 study showed that 465 cubic meters of water were used to produce $1480 worth of GDP, 20 times that of Europe and Japan. (Gleick 2009)
- Facing water shortages in the north, it is likely that China will turn to stricter controls on water efficiency to reduce demand.

Water Scarcity

With 20% of the world's population and only 6% of the world's total water resources, the UN lists China as one of 13 countries experiencing serious water scarcity. The situation is compounded by an uneven distribution of water within the country: four-fifths of the supply is in the south. (Yardley 2009) Annual precipitation ranges from $1/8^{th}$ of an inch to almost 80 inches. Every year, 37.8 million acres of farmland face drought, 13% of the total acreage. (Water crisis) Four hundred Chinese cities are facing water shortages, including 100 that may experience serious shortages. China would need another 40 billion m^3/yr of water to meet the needs of urban users. (Yardley 2009)

The shortage is especially acute in the North Plain, where the average rainfall is 7.9 to 15.8 inches per year. The North Plain is home to Beijing (17 million inhabitants) and Tianjin (12 million), produces half the nation's wheat, (NYT) and is where most heavy industry is located. (GWI) Northern China has 2/3 of China's cropland, 43% of its population, and only 14% of its water. (Sekiguchi 2006) There are two large aquifers that run under northern China, but so much water is being withdrawn that levels are dropping up to three meters a year. Hebei province in northern China has lost 969 of its 1,052 lakes. Water shortages cause direct economic losses of $35 billion annually in China, more than twice that of floods. (Sekiguchi 2006)

Beijing alone used 650 million m^3/water in 2009 or 18% of China's water withdrawals. According to GWI, the municipal government claims it will be able to add 900 million m^3/year to Beijing's water supply by treating wastewater for reuse. Currently, four plants in Beijing are able to treat 390,000 m^3/d for reuse, with upgrades planned for four others.

Water Treatment
About a quarter of China's population, 300 million, drink contaminated water every day. Almost two-thirds of these fall ill. Water has been blamed for recent high rates of cancer, stunted growth, low IQs, miscarriages, and birth defects. **(**Sekiguchi 2006**)** Typhoid is endemic in southern China, and OECD Environmental Indicators reported in 2007 that an estimated 30,000 rural children die from diarrhea caused by polluted water. The WHO reported a 108.4 per 100,000 mortality rate from diarrhea-related illness in 2002, compared to less than 11 per 100,000 in Vietnam and less than 5 per 100,000 in Thailand.

Flooding
The Chinese Minister of Water Resources said the annual direct economic losses from floods since the 1990s averaged $16.3 billion, almost two percent of GDP. In contrast, flood losses in the US are estimated at 0.25% of GDP. The same Minister also predicted that by 2020 forty-one percent of China's population will be exposed to flood risks, and 67% of the country's GDP will come from vulnerable areas.

Environmental Policy
China's relationship to water is changing. Decades of policy focused on economic growth have resulted in massive and unregulated pollution, devastating floods and crippling shortages. In many ways, environmental protection is in its infancy in China; compliance with environmental regulations is estimated to be as low as 10 percent. (asiawaterproject.org) However, environmental regulations are growing stronger, enforcement is becoming more common, and a grassroots response to pollution is driving the government to respond. If China effectively enforces environmental standards, the demand for technology to meet those standards is enormous.

New regulations
The government of China is responding, passing new environmental regulations and enforcement mechanisms. Three provinces in China established environmental courts between 2007-2008, which have legal jurisdiction over environmental issues and the power to enforce fines and sanctions on violators. Two provincial high courts have supported extending the jurisdiction of the environmental courts beyond administrative boundaries in cases that involve environmental harm.

Recent water policy (from http://www.asiawaterproject.org/regulatory-trends/litigation/)

- Circular Economy Law (January 2009). The government will stringently monitor high water consumption and emission industries, specifically steel manufacturing, oil refining, paper, textile, chemical and non-ferrous metal processing. It vaguely requires that industries adopt water conservation plans and technologies, offering tax incentives for industries that comply.
- Revision of Law of the People's Republic of China on Prevention and Control of Water Pollution (June 2008). The regulation vaguely states that authorities will factor water into planning and regulation decisions. It does, however, contain some significant controls-
  - Revised monetary sanctions for pollution violations,

- Up to $150,000 for illegal operation and up to 50% of the previous annual income for extraordinarily serious pollution incidents.
- For serious incidents, enterprises may be fined up to 30% of direct damages from pollution incidents with no maximum limit.
- For ordinary or relatively serious pollution incidents, up to 20% of direct damages with no maximum limit.
- Provision for class action suits to be filed against large-scale polluters.
- More control over effluent standards, with the ability of the government to set specific location and industry standards.

* Measures for Opening the Environmental Information (May 2008).
  - Mandate disclosure of environmental information by government and administrative parties.
  - Maintain the rights of citizens to obtain environmental information
  - Promote the public's involvement in environmental protection.

Enforcement

Representatives of SEPA (State Environmental Protection Agency) have said that tougher standards for drinking water would be adopted by 2010, and that by 2009 all new enterprises which discharge pollutants would have to obtain permits to operate. In July of 2007, SEPA requested that local authorities along the country's four major rivers change the priority from economic development to environmental protection. In three months, the campaign has led to the closure, suspension, or renovation of 700 enterprises. Whether these changes are permanent or temporary is unknown.

China also set new standards for drinking water, encompassing 106 parameters to be implemented by 2012. When Taihu Lake, near Shanghai, became so polluted by algal blooms it forced 5 million people to rely on bottled water, the government ordered mass closures of chemical plants around the lake. Cleanup plans are estimated to cost up to $14 billion over 5 to 10 years. Again, although the Chinese government is capable of effective action, consistent enforcement is rare.

Grassroots pressure

Pressure to crack down on pollution is growing at the grassroots level. In 2005, there were 50,000 environmentally related protests reported by the Chinese government. (Gleick 2009) An article in the Economist pointed toward a new trend of holding polluting companies responsible by a documenting new website in China that identifies polluters and violations. "Multinationals like Adidas, GE, Nike, and Wal-Mart can see which of their suppliers are repeat offenders, and may put pressure on them to clean up."

Water Policy and Goals

The 11th five-year plan in China which laid out goals and funding for wastewater projects for 2006-2010. The goals were:

* Water Supply
  - Urban coverage rate of 95%
  - Add 40 million m^3/day to supply capacity
  - Urban water supply pipes over 50 years old should be rehabilitated

- Urban leakage rates should be kept below 15%
- Budget- $29.52 billion

- Water reuse
  - Reuse 10-15% of treated wastewater in northern cities with less than 3,000 m^3 of water resources per capita (20-25% by 2015)
  - Reuse 5-10% of treated wastewater in southern seaside cities with less than 3,000 m^3 of water resources per capita (10-15% by 2015)
  - Add 6.8 million m^3/day of reclaimed water to 2005 capacity
- Wastewater treatment
  - Add 45 million m^3/day to the 2005 capacity
  - Build 1,000 WWTPs
  - Price WW tariff above $0.12/$m^3$
  - Invest $44.2 billion in wastewater infrastructure
- Seawater desalination
  - Total capacity of 800,000-1,000,000 m^3/day for municipal and industrial uses.
  - Any revenue from seawater desalination projects will be free of income tax

China is pursuing two massive water projects to increase supply and reduce flooding. The first is the Three Gorges Dam, largely completed in 2009 (still ongoing) at a cost of over $25 billion. The dam generates 18.2 million MWs, one ninth of China's energy consumption. It will create a reservoir 375 miles long, displace 1.3 million residents and force farmers onto higher, less productive, soil. The government claims that the power produced by the dam will reduce coal usage by 50 million metric tons. The second massive water project is the South-North water diversion, an attempt to engineer three new waterways to bring water to northern China. The projected cost is $60 billion, dislocating 200,000 people. The project will funnel 45 billion m^3/year from the Yangtze River basin. However, the project is not expected to be completed for decades and is facing growing resistance.

Private Sector Participation
Initially, China opened its water market to private investment in 1992 to relieve local governments of the economic burden of building infrastructure. Now, the main reason is the ability of private companies to improve operational efficiency. Profit margins for foreign companies in 2007 were 21%, compared to 4% for local private companies and -0.5% for state-owned companies. One reason for this is that foreign companies benefit from the lowest tax burden- only 11% for foreign companies compared to 22% for local private companies.

Water supply- since state-owned companies monopolize the water sector, the most common approach for foreign investors is to buy a less-than 50% interest in a state-owned company. The foreign partner usually takes over operation and maintenance. Joint ventures are also common, with Veolia, Beijing Capital and Suez being the main companies participating.

Wastewater treatment- there is a shift toward TOT (Transfer-Operate-Transfer) and O&M (Operate and Maintain) models and away from BOT (Build-Operate-Transfer), as local governments realize that efficiency is more important than capital investment.

Water reuse- most plants or upgrades are financed by local governments, who issue contracts to private companies for EPC (Engineer, Procure, Construct) contracts. Origin Water, GE, OMEX, Sino-Dutch are among the many active companies in this sector

Current and Future Projects

Desalination- GWI is tracking four projects that are under construction or recently finished, ranging from 50,000-150,000 m^3/day. Three are industry related; only one plant is for domestic use. Only two projects have identified foreign partners, both using Norwegian firms (Aqualyng and Aker Solutions). Veolia is working with the city of Tianjin to build multi-stage flash distillation plant, using heat from a local power plant. The water will be blended with local supplies.

Water Reuse- The largest projects are in Beijing, with plans to upgrade a total of eight WWTPs for reuse. Reclaimed water is mainly used from industrial, recreational, and other non-potable uses. Projected capacity will be 1.66 million m^3/day. One Dutch company, Norit, has been identified as a foreign partner.

Water supply- Since over 90% of urban areas are covered by existing supply, most investment in this area will occur in rural supply and urban operation.

Wastewater Treatment- On average, 100 to 200 WWTPs are built every year. A wide range of recent projects are identified, although the majority are for operation contracts only and none have identified foreign partners. Sizes range from 20,000-120,000 m^3/day.

Companies

Veolia is expanding rapidly by acquiring local plants. The company signed a 25-year contract with Beijing Yanshan PetroChemicals to treat and recycle industrial wastewater and acquired a 49% stake in Lanzhou Water Group of Gansu province to become the sole water supply firm in the city. (RiteSite 2009)

United Water Corporation established a second water treatment facility in China, with full support from local government by making UWC a member in the local water management committee. This gives UWC substantial say in setting local standards and prices. (Investment opportunities)

UV Pure of Toronto secured a deal to supply 1,000 Chinese hotels with water purification units. The Chinese Ministry of Commerce announced a plan to build 10,000 green hotels by 2012, units that will include the latest in clean technology.

Market Forecast

"It's not well known that China has set aside more money for the adoption of clean technologies than any other country on the planet. This is possibly the best time to be doing business in China as a clean-tech company." Dallas Kachan, managing director of Cleantech Group in San Francisco, Special report NYT

The current water market in China is valued at $47.8 billion. The two largest sectors are utilities (80%- $42b) and industrial (4.6%- $2.1b). Of the utility market, 40.6% is drinking water capital expenditures and 33.4% is wastewater capital expenditures, and the remaining 25.9% are operating expenses.

Capital expenditure in drinking water is expected to grow steadily, from $17 billion in 2010 to $32.5 billion in 2016. Wastewater capital expenditure will increase slightly, from $14 billion to $18 billion. Municipal capital spending will increase from $31 billion to $51 billion, industrial capital spending will double but reach only $2 billion. Desalination will increase from $200 million to $950 million by 2015, and then taper off.

Niche Markets	
Decentralized industrial waste water treatment	As environmental regulation increases, individual firms may move to ensure compliance before large scale, centralized, treatment is developed.
Decentralized water treatment	As incomes rise, it will become more common for residential buildings and hotels to incorporate water treatment systems as selling point.
Water efficiency	Industrial users may be restricted in the northern, water-short, areas.
Municipal infrastructure	Large profits are available for companies that contract with Chinese municipalities for both water supply and waste water treatment. Requires additional capabilities and in-country connections.
Water reuse	Increasing industrial and municipal water reuse is a major goal for Chinese water policy, will be a key to meeting future water demands

Utility Water Capital Expenditure (GWI) in millions	**2010**	**2016**	**Growth factor**
Network rehabilitation	$8,871.3	$14,446.7	1.63
New water networks	$2,015.6	$4,861.4	2.41
Water treatment plants	$2,869.0	$4,229.6	1.47
Water resources (w/o desal)	$3,120.9	$8,027.4	2.57
Desalination	$210.7	$872.3	4.14
Total drinking water utility capex	$17,087.5	$32,437.5	1.90

Utility Wastewater Capital Expenditure (GWI) in millions	**2010**	**2016**	**Growth factor**
Network rehabilitation	$3,153.3	$3,279.2	1.04
New water networks	$3,535.1	$6,245.5	1.77
Treatment plants	$6,562.6	$7,591.5	1.16
Total wastewater utility capex	$14,066.7	$18,557.4	1.32

Industrial Water Capital Expenditure (GWI) in millions	**2010**	**2016**	**Growth factor**
Power Generation	$364.9	$593.7	1.63
Food and Beverage	$152.8	$254.0	1.66
Pulp and Paper	$72.3	$152.4	2.11
Chemicals	$54.1	$96.8	1.79
Microelectronics	$53.8	$108.4	2.01
Total industrial capex	$1,191.8	$1,919.8	1.61

Capex = Capital expenditures

Industrial and Municipal Capital Expenditure (GWI) in millions	**2010**	**2016**	**Growth factor**
Pipes	$6,747.5	$11,932.1	1.76
Pumps	$3,384.0	$6,041.6	1.78
Standard Process Equipment	$1,828.8	$2,259.6	1.23
Sludge Management	$1,142.3	$1,934.4	1.69
Meters	$508.8	$937.2	1.84
Disinfection systems	$494.5	$676.5	1.36
Intakes/headworks/screens	$423.9	$649.3	1.53
Media filtration	$418.8	$593.2	1.41
Control systems/chemical feeds	$315.1	$526.8	1.67
Low pressure membranes	$127.2	$328.1	2.57
High pressure membranes	$40.3	$116.9	2.90
Ion exchange/electroionisation	$32.6	$75.5	2.31

China References

Gleick, Peter. 2009. *The World's Water 2008-2009: The Biennial Report on Freshwater Resources. Chapter Five- China and Water.* Island Press: Washington, DC.

Global Water Intelligence. 2010. Global Water Market 2011: Meeting the world's water and wastewater needs until 2016. Oxford, The United Kingdom.

RiteSite. 2009. Investment Opportunities in China Wastewater Treatment. Available online at http://rightsite.asia/en/article/investment-opportunities-china-wastewater-treatment&urlhash=On1N&trk=news_discuss

Roberts, Dexter. 2009. *China Faces a Water Crisis*. Bloomberg Business Week: April 15, 2009. Available at: http://www.businessweek.com/print/globalbiz/content/apr2009/gb20090415_032220.htm

Sekiguchi, Rylan. 2006. *Water Issues in China.* Published by Stanford Program on International and Cross-Cultural Education. Available online at: http://iis-db.stanford.edu/docs/113/10000shovelswater.pdf

Weir, Andrew. 2008. *The Water Business in China: Looking below the surface.* Published by KPMG International. Available at http://www.kpmg.com/CN/en/IssuesAndInsights/ArticlesPublications/Documents/water_business_china_0803.pdf

Yardley, Jim. 2007. *Beneath Booming Cities, China's Future is Drying Up*. New York Times, September 28, 2008.

4.8 India

"There is an opportunity for private sector to invest and participate in water resources more aggressively."

-Shri Panjiar, Secretary to the Government of India, Ministry of Water Resources, at Singapore International Water Week 2010

Key Markets	Niche Markets
Water Resources	Small-scale water treatment & purification
Water distribution	Controlled application of pesticides
Water Treatment	Industrial wastewater treatment & regulation
Waste Water Treatment Plants	Water efficiency solutions at all scales
Wastewater Collection	Low-cost solutions to fluoride, arsenic, & nitrates in well water

Background

India's water economy can be characterized as highly informal and based on local self-supply. A 2003 survey of 4,646 villages showed that only 8.8% had a public/community water supply system, though that number is greatly dependent on local wealth. (Tushaar 2005) A survey of cultivators showed that of the 76.2% of villages reported irrigating land, but only 17.3% had access to a public irrigation system. The rest depend mainly on wells and tube wells (64.3%), tanks and streams. While this shows the potential for improving local water supplies, this example illustrates the difficulty of implementing enforceable top-down water quality standards.

One of the key questions is to what degree water will be allowed to be privatized in India. In 2005, a World Bank proposal to privatize a limited amount of the New Delhi municipal water supply "provoked a public outcry." There is a general resistance to privatizing water supplies and little ability to pay for water. (Wonscott 2007) Water tariffs in major Indian cities range from $0.04-0.17 per cubic meter of water, among the lowest in the world. (GWI) However, increasing shortages and the inability of the government to meet infrastructure needs will provide a window for private investment.

Demographic Indicators

Population	**2009**	**2016**
Urban Population	357.82 million	426.00 million
Rural Population	844.02 million	893.75 million
Total Population	**1,201.84 million**	**1,319.75 million**
Population Growth Rate	**2005-2010**	**2010-2015**
Urban Population Growth Rate	2.39%	2.50%
Rural Population Growth Rate	1.07%	0.77%
Total Population Growth Rate	1.51%	1.35%

Source: (Global Water Intelligence, 2010)

Economic Indicators

Economic Indicator (2008)	Nominal GDP	GDP at Purchasing power parity
Total GDP	US $1,206.7 billion	US $3,297.8 billion
GDP per capita	US $1,017	US $2,780
GDP growth rate	7.35 %	

Source: (Global Water Intelligence, 2010)

Market

The GWI report estimates the size of the water market in India to be $5.9 billion in 2010, growing at 10-14.9%. While the market is not particularly large, it is rapidly growing and open for investment. The Indian government has openly called for investment and private partnerships to meet their infrastructure needs. (Shri 2010) A report from the International Water Management Institute identified three long-term, driving forces behind India's water market. (Amarasinghe 2007).

- Large and growing population: Projected increase by 500 million by 2050 to 1.66 billion.
- Economic growth and increasing consumption patterns
- Spatial mismatches of population and water resources. Delhi and Chennai receive water from rivers that are 250 Km and 450 Km away, respectively.

In the short, the GWI identified the following trends in urban water usage:

- 3 major growth areas: desalination, wastewater treatment, and electrical generation
- Major urbanization is occurring in small and medium cities (20,000-100,000)
  - Current water service provides 70 l/c/d (liters per capita per day), government policies plan to increase to 135 l/c/d.
  - Large urban centers (25% of population) receive 57% of total domestic water supply, as large water utilities are located in urban centers.
  - Sewerage in small and medium cities (20,000-100,000) is not widespread. As sewerage increases, water needed to flush wastewater pipes will increase demand.
  - Heavily-groundwater-dependent areas are facing water quality problems that will put increasing pressure on surface water.
  - Small and medium cities lack managerial, financial, and technical capabilities when it comes to water utilities. This is an opportunity for Public-Private Partnerships (PPPs).
  - Coastal regions with groundwater depletion and saltwater intrusion will increase demand for surface and desalinated water (Gujarat, Tamil Nadu, Andhra Pradesh)
  - Power Generation
    - National Electric Policy (2005) set the target of increasing capacity from 132,000 MW to 232,000 MW by 2012
    - Most use is not consumptive, so treatment technologies for effluent and coastal locations (where saltwater is available) will increase
    - According to the International Energy Agency, electricity generating capacity will increase from 20.58 trillion kWh in 2010 to 31.78 trillion kWh in 2030, the bulk of the growth coming from India and China.

Water Supply and Uses

Infrastructure

There are 4,100 water treatment plants in India, with a capacity of 70 million m^3/day. By contrast, the US has 73,500 water treatment plants with an operational capacity of 202.64 million m^3/day. India's municipal water supply is 26.5 billion m^3/year, with 63-72 million connections. Meter coverage is less than 10%, and 11-25% of municipal supply is unaccounted for. (GWI) Many water plants in India are off-line or operating below capacity due to a lack of knowledge and resources and face serious challenges to adequately treat highly variable surface water. (Global water resources)

A survey of waste water treatment plants (WWTPs) found high variability in operating procedures, record keeping, monitoring, and overall functionality. (Sengupta 2007) India has 1,144 wastewater treatment plants, with a design capacity of 35.91 million m^3/day. The US has 16,000 WWTPs with a design capacity of 185 million m^3/day. Only 40% of wastewater in India is collected, and of that only 24% receives secondary treatment. The length of sewerage network is 161,300 km. (GWI) Only 15% of the population is connected to sewerage networks, primarily in large urban areas. In small towns and villages WWT is practically nonexistent. In the 499 cities with a population between 50,000 and 100,000, only 3.7% of wastewater is treated. For cities above 100,000 people (of which there are 423), only 29.2% of wastewater is treated. (Grail Research 2009) The use of improved sanitation coverage in rural areas of India was 7% in the year 1990, and this increased to about 21% in 2008. The urban sanitation coverage was 49% in 1990 and increased to about 54% by the year 2008. (Shri 2010) The government plans to treat 100% of urban wastewater by 2012. (GWI)

Key Performance Indicators (GWI)

- Access to improved water supply
  - Urban 91%
  - Rural 75%
- Imbalance favoring large urban sectors. New Delhi and Chandigarh supply water to 80-85% of population.
- Per capita supply varies from 40 l/c/d in Chennai to 342 l/c/d in Goa.
- 74% of rural areas receive at least 70 l/c/d; 89% of rural areas receive at least 10 l/c/d.
- 80% of domestic water demand in rural areas and small towns is met through groundwater sources. These sources are overwhelmingly private, small scale, and not connected to larger networks.
- Total domestic water supplied by utilities in all of India is estimated to be only 60% of total water used for domestic purposes.

Desalination

Desalination is a growing sector in India, especially in water-stressed areas in western and southern India such as Kutch, Saurashtra, Chennai, and Lakshadweep Islands. Large scale desalination projects generally involve private sector participation. Current total capacity is estimated around 1.22 million m^3/day, nearly 2% of total water supplied by utilities. The market for desalination is expected to expand at 12-15% annually. The capacity of current projects is 0.40 million m^3/day, most using multi-effect distillation and seawater reverse osmosis.

One particular source of growth is an increasingly affluent middle and upper class, which is becoming more concerned with water quality as it relates to health. The demand for small-scale desalination units, mainly using RO technology, is expected to grow. One particular area of growth is the number of residential developments incorporating a central water supply. Another growing market is household water purifiers. The market in 2008 was estimated at $370m, and total output of household based purifiers (RO and UV) estimated at 0.5 million m^3/day. (GWI) According to the CEO of Tata Chemicals, only 6% of urban and 1% of rural households use water purifiers. Tata hopes to greatly increase this number by increasing awareness and affordability of purifiers. (Wonscott 2007)

Power generation projects are increasingly using desalination to avoid closures during surface water shortages. At present more than six major power projects have shifted to desalination for water needs. One plant at Krishnapatnam is using two 800 MW nuclear power plants for water treatment. (GWI)

Water reuse is small, given that adequate treatment levels are rare. Chandigarh Municipal Corporation uses 57,000 m^3/day in a separate network to irrigate public open spaces. Only a few major institutions reuse water with tertiary treatment. There is strong public resistance to reuse for drinking water. (GWI)

Water Use by Sector

Agriculture is the dominant sector for water use, accounting for almost 80% of total water withdrawals. Rapid economic growth has significantly changed food consumption patterns, increasing demand for oil crops, vegetables, fruits, and animal products. Combined with rapid urbanization, this will significantly increase demand on irrigation. (Amarasinghe 2007) The figures below are based on estimates by the Central Water Commission; however GWI suggests that demand for industrial use and energy production is under-estimated.

Surface Water

Uses (km^3/yr)	2010	2025	% Total	% Change
Irrigation	334.5	345.5	74%	3%
Domestic	23.5	33.0	5	40
Industry	26.0	47.0	6	81
Power	14.5	25.5	3	76
Inland Navigation	7.0	10.0	2	48
Ecology	5.0	10.0	1	100
Evaporation losses	42.0	50.0	9	19
Total Surface	***452.5***	***521***	***65.0%***	***15.1%***
Groundwater				
Irrigation	215.5	240.5	86%	12%
Domestic & municipal	19.0	25.5	8	34
Industry	11.0	20.0	4	82
Power	4.0	6.5.0	2	63
Total Groundwater	***249.5***	***292.5***	***36%***	***7%***
Total use				
Irrigation	550.0	586.0	78%	7%
Domestic	42.5	58.5	6	38
Industry	37.0	67.0	5	81
Power	18.5	32.0	3	73
Inland Navigation	7.0	10.0	1	43
Ecology	5.0	10.0	1	100
Evaporation losses	42.0	50.0	6	19
Total	***702.0***	***813.5***	***100%***	***16%***

Water Problems

Water Gap

India faces a 50% projected water deficit by 2030. The deficit is estimated at 754 billion m^3 (total usage 1508 billion m^3). The main driving forces are an increasing demand for irrigation (rising population and caloric intake), limited supply infrastructure, and climate change. Climate change may increase availability temporarily as Himalayan glaciers melt (which feed western rivers such as Indus). The flow will increase, but in long run it is likely to decrease by 30-50%. Projected municipal and domestic water demand will also double to 108 billion m^3 (7% of total demand) as population and incomes increase. Projected demand for industry will quadruple to 196 billion m^3 (13% of total demand).

- Solutions
  - Increase agriculture efficiency

- Expand water storage, including dams, groundwater recharge, storage tanks, rainwater harvesting
- Increase water re-use
- Adopt efficient water usage, pumps, pipes, sprinklers, appliances, etc.

Waterborne Diseases
Waterborne diseases are one of the biggest health risks in the country. It is estimated that India loses 90 million days a year due to sickness caused by waterborne diseases, causing significant production losses and treatment costs. Monitoring is not effective, and the results of tests are generally not made public. Reports from two major municipalities found that 10% (Maharashtra) and 14% (Mumbai) of water samples collected were contaminated. (McKenzie 2009) After draining the drinking water supply pool in Kalkaluru, cleaners found drowned rats and bloated lizards. A survey of residents found that half still preferred free water from the pool over a locally-available, purified water. (Wonscott 2007)

- Solutions
  - Improved coverage and quality of treatment and distribution networks
  - Technology- small scale water treatment and water purification. This represents a large and growing market, and may be a key area for US companies to focus. There are examples of communities in India that have adopted relatively sophisticated wastewater treatment programs that allow treated water to be reused (see Seshadri 2009).
    - WaterHealth India has set up a for-profit network of 220 water purification plants using UV technology. Finance had to be guaranteed by a non-profit venture capital firm, but the venture has been successful. http://www.indiawaterportal.org/node/11237
    - Swatch water purifier, made by the Tata Group, uses a filter made from rice- husk ash and impregnated with nano-silver particles. The firm expects to sell millions of units in the first year. The unit sells for about $21.
    - Eureka Forbes offers a unit named ‘AquaSure’ for about $60, and is developing a low-cost purifier to compete with Tata.
    - The current market leader, Hindustan Unilever, recently launched a new low-cost model, the ‘Compact,’ which sells for $26. The new unit replaces a five-year-old model (the ‘Pureit’) which sold for $43, demonstrating the market drive to lower the cost of household water treatment.

Surface Water Pollutants

- Agricultural
  - Use of pesticides. Pesticide content of soft drink brands Coca Cola and Pepsi have been found at thirty times greater than the European Union’s legal limit. One study found that pesticide residues in farmers in four Punjab villages to be 53-135 times higher than samples taken in the US by the CDC. (Center for Science and Environment- India)
  - Use of fertilizers has increased for .55 Kgs/hectare in 1950 to 90.12 Kgs/hectare in 2001-2002.

- Domestic
  - Based on biological oxygen demand levels, 14% of total river length in India is severely polluted, and 19% is moderately polluted. (Grail Research 2009)
- Industrial
  - Account for 6.2 billion liters of untreated wastewater every day
  - Thermal power plants and steel plants are the highest contributors.

Groundwater

- India is draining groundwater at an astonishing rate. A satellite study that measured the gravitational pull of groundwater estimated that from 2002 to 2008 over 109 billion cubic meters of water disappeared from aquifers in northern India. In the 1970s the country switched to a flat rate for electricity due to the difficulty and cost of metering and billing the vast number of local irrigation pumps. Agricultural lobbies have kept the rates from rising, resulting in heavily subsidized power and overexploitation of groundwater. (Tushaar 2005) The Central Ground Water Authority (CGWA) manages usage, but administratively and politically it is difficult to enforce limitations on withdrawals. The CGWA annually monitors 15,000 observation wells.
- Over-extraction in 2/3 of country
  - Demand increased from 20 km^3/yr in 1960 (to 249 km^3/day) due to:
    - Rise in population
    - Increase in the use of tubewell technology, as of 2006 there are an estimated 19 million wells in India.
    - Subsidized electricity allows cheap operation of wells.
    - Inadequate surface water infrastructure.
    - Ineffective water management.
  - Saltwater intrusion
    - In some areas of Rajasthan and Gujarat, ground water salinity is so high that the well water is directly used for salt manufacturing by solar evaporation. (from Central Ground Water Board)
    - Salinity problems have been observed in a number of places in most of the coastal states of the country. Problem of salinity ingress has been conspicuously noticed in Minjur area of Tamil Nadu and Mangrol – Chorwad- Porbander belt along the Saurashtra coast. (from Central Ground Water Board)
  - Fluoride
    - High concentrations (above 1.5 mg/l) of fluoride can have severe health effects and can cause changes in shape and color of crops if used for irrigation. The recommended level of fluoride is below 1.5 ppm. Groundwater samples in six Indian states exceeded 13 ppm. As of 2003, almost 25 million people in 150 Districts were affected by "Endemic fluorosis."
    - Some estimates find that 65% of India's villages are exposed to fluoride risk (Kumar:2005)
  - Arsenic
    - Levels above 50 ppb are found in the alluvial plains of the Ganges, covering six districts of West Bengal. In Bihar, 32% of wells sampled had arsenic levels above 10 mg/L, 17.75 % above 50 mg/l, and 6.5% above 300 mg/l. The highest

concentration found was 2100 mg/l. The EPA standard for arsenic is 0.010 mg/L. (http://www.soesju.org/arsenic/groundwater_bihar.htm)
    - India has spent $3m on arsenic removal plants, using ferric salts. Only 20% of the plants are functioning well, as villagers are not being trained to maintain the plants. Of the 2000 arsenic removal plants installed in West Bengal, 4 out of 5 are either abandoned or deliver odorous and discolored water. Plants failed due to lack of local knowledge, resources, and awareness. (Sengupta 2007)
  - Nitrate
    - A study by Greenpeace in Punjab found 20% of wells had nitrate levels above 50mg/l, the WHO health limit. The high levels were blamed overuse of synthetic fertilizers. (http://www.india-server.com/news/excessive-chemical-fertilisers-led-to-16867.html)
- The Government has constituted an Advisory Council for Artificial Recharge of Ground Water in April, 2006 to popularize the concept of Artificial Recharge among all stake holders. As per recommendation made by the Advisory Council in its first meeting, the first Ground Water Congress was organized by the Central Ground Water Board (CGWB) under the auspices of Ministry of Water Resources at New Delhi on 11th September 2007 with a view to provide a platform for interaction among scientists, engineers, planners, policy makers and representatives of industries.

Infrastructure

No major Indian city has a 24-hour supply of water, the average supply ranges from 4 to 5 hours. In Delhi, a survey of homes with in-house connections found that 40% had 24 hour supply, while 25% had under fours hours. A 1995 study in Delhi estimated the average household spent 5.5 times more money coping with an unreliable water supply than they paid for municipal water services. A common solution is to install storage tanks and pumps to draw more water out of supply lines, increasing the risk of contamination and decreasing water pressure for other users. (McKenzie 2009) Municipal megacities have exploited the cheapest available water. New demand will have to be met by:

- Efficiency
- Demand management
- Water reuse
- Desalination
- Long-distance transport
- Private involvement in water collection, treatment, and distribution in megacities

- Smaller urban areas may see high growth, grassroots level government sponsored reform
  - Move toward decentralizing water authority from state level (PHEDs) to local level (Panchayati Raj Institutions); generally, the state does overall planning and investment
  - Swajaldhara scheme- a pilot program launched by the Department of Drinking Water Supply that shifts water supply to a demand-based system. Local units (generally village level) assist in the planning of projects, share initial capital costs (at least 10%), and assume 100% of operation and maintenance of the system. The program is hindered due to the difficulty of cost recovery and implementation programs and has had limited success.

- Micro-finance has been successful in some areas, though the scale is limited compared to the scope of the problem. The NGO Water Partners International is the major player, offering small revolving loans to communities in five Indian states.

Climate variability

- Monsoon is the primary water source.
  - 80% of water is delivered in a very short and intense season, making capture difficult
  - Increasing climate variability is making monsoons less predictable and reliable
- Increasing floods and droughts, both of which create opportunities.

Government Water Policy

The National Water Policy was drafted in 2002. It outlines the basic framework the country is using to approach water issues. The components of the plan are outlined briefly below:

Issues

- Floods
- Droughts
- Environmental Sustainability
- Public health
- Dam safety
- Resettlement and rehabilitation of project-affected people
- Time and cost overruns on projects
- Soil salination
- Equity and social justice
- Groundwater overuse

Goals

- Increase water for irrigation
- Meet increasing demands of rural areas
- Meet demand for hydro and thermal power
- Improve water quality through science and technology
- Financial and physical sustainability (rates to cover costs)
- Participatory approach to planning
- Hydrological base for approaching issues

Solutions

- Intensify R&D in water technology
- Encourage private sector participation Control groundwater overuse, especially on coast
- "Polluter pays" for quality issues
- Implement standardized, real-time data and information network
- Periodical reassessment of groundwater potential
- Focus on developing non-conventional methods for water utilization
  - Inter-basin transfer
  - Artificial recharge of ground water
  - Desalination
  - Rainwater harvesting

Planning	° Provision of drinking water a primary consideration ° Special effort to benefit socially weak or disadvantaged groups	° Minimize adverse impact on environment and ecology ° Include impact assessment with socio-economic and environmental components	° As far as possible, projects should be multipurpose ° Multidisciplinary approach

Because the private water market is severely limited by the ability and willingness of the majority of the population to pay for water, the majority of the infrastructure projects will be government funded. The following is a list of current programs (From GWI unless otherwise noted).

- Accelerated Urban Water Supply Program (AUWSP) 1993
  - For towns of less than 20,000, of which there are 2,844 as of 2001 census
- Accelerated Irrigation Benefits Program
  - Financial assistance to states for creation of irrigation potential. The program funded 265 major/medium irrigation projects and 9,852 minor surface water irrigation projects. Total funding for 2008-2009 was $1.63 billion. (Ministry of Water 2009 Annual Report)
- Jawaharlal Nehru National Urban Renewal Mission (JNNURM) 2005-2006
  - Fund $21.2 billion from central funds, leveraging $10.6 from state nodal agencies and the private sector, for 7 years.
  - Priority for water supply and sanitation, 40% of total funds.
  - 63 cities identified: 7 over 4 million, 28 between 1-4 million, the rest because of tourism or historical/religious reasons.
  - Central grant of 35% to 80% of project cost, based on capacity of urban local body.
- Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT) 2005-2006 running for 7 years
  - Covers all towns not covered under JNNURM
  - Subsumed the AUWSP
  - Funding based on 80:10:10 (central, state, local)
  - State Pooled Finance Entities (SPFEs) manage revolving funds in all states, soft loans or grants, ensuring 25% of central and state assistance goes back to the revolving fund
  - Project Implementation Agencies
    - o Leverage finance from private sector, capital markets and financial institutions
  - Pooled Finance Development Scheme (PFDS)
    - o Small and mid-sized ULB do not have credit or expertise to prepare projects
    - o Fund of $85 million to facilitate ULB to develop bankable infrastructure projects, access capital markets, and boost credit enhancements for municipal bond market
    - o North Eastern Urban Development Programme (NERUDP)

Develop water and sewerage facilities in north-eastern region of country.
70% of loan from Asian Development Bank
Phase I $285.7 million (2009-2015) Phase II 2010-2018 $629 million

Private Sector Participation
PPP is a mainstream procurement model that is growing significantly but represents only 4% of water investment. There are a number of private sector projects currently in operation and discussion. The majority are for water supply and treatment, as well as operation and network rehabilitation. According to GWI, one of the primary restrictions is that water and sewerage decisions are made by Urban Local Bodies (ULBs), many of which do not have the capacity to deal with PPP. Private water supply in villages is actively encouraged, ranging from non-profit to commercial enterprises. In many states governments are encouraging the private sector to set up village-level WTPs (mainly RO) to supply drinking water, with capacities ranging from 5 m^3/day to 50 m^3/day.

Large scale desalination projects are generally private sector, with Indian companies as partners to expand local capabilities. There are currently eight desalination projects being tracked by GWI. Half are in the 5,000-14,000 m^3/day range; the remaining four average 160,000 m^3/day. The majority is industry related, including power generation; only two are municipal with a total planned capacity of 24,000 m^3/day.

Capital Expenditure
Capital expenditure is projected to increase significantly through 2016. Drinking water capital expenditure is projected to increase from $1,500 million to $2,900 million annually, with most growth occurring in water resources (including desalination) and water distribution networks. Wastewater capital expenditure is projected to increase from $400 million to over $1,000 million, split evenly between treatment plants and wastewater networks. Growth in municipal capital expenditure will outpace industrial capital expenditure, increasing from $1,700 million to $4,000 million ($400m to $660m for industrial).

Utility Water Capital Expenditure (GWI)	**2007-2010 Average**	**2016**	**Growth factor**
Network rehabilitation	260.8	629.3	2.41
New water networks	312.9	755.2	2.41
Water treatment plants	156.2	377.6	2.41
Desalination*	189.9	426.4	2.26
Total drinking water utility	1,389.2	2,943.7	2.12

Utility Wastewater Capital Expenditure (GWI)	**2007-2010 Average**	**2016**	**Growth factor**
Network rehabilitation	335.4	361.9	1.08
New water networks	122.6	309.3	2.52
Treatment plants	92.9	314.7	3.39
Total wastewater utility capex	491.2	1058.0	2.15

Industrial Water Capital Expenditure (GWI)	**2010**	**2016**	**Growth factor**
Power Generation	97.9	151.6	1.55
Food and Beverage	71.2	108.9	1.53
Pharma	53.8	79.2	1.47
Oil and Gas	8.6	31.9	3.71
Automotive	6.2	19.1	3.08

Industrial and Municipal Capital Expenditure (GWI)	**2010**	**2016**	**Growth factor**
Pipes	511.2	1070.1	2.09
Pumps	332.6	583.7	1.75
Standard Process Equipment	118.7	208.5	1.76
Sludge Management	22.9	85.3	3.72
Membranes	37.0	73.4	1.98
Zero Liquid Discharge	13.8	46.4	3.36
Disinfection systems	34.2	69.1	2.02
Meters	21.6	72.7	3.37
Pipe rehabilitation	265.7	502.7	1.89

India References

Amarasinghe, U. A.; Shah, T.; Turral, H.; Anand, B. K. 2007. *India's water future to 2025-2050: Business-as-usual scenario and deviations*. Colombo, Sri Lanka: International Water Management Institute. 47p. (IWMI Research Report 123)

Chang, Arlene. 2010. *Tata Creates Inexpensive Water Purifier.* The Wall Street Journal, July 6. Available http://online.wsj.com/article/NA_WSJ_PUB:SB10001424052748704293604575343340396637802.html#printMode

Grail Research. 2009. *Water: The India Story.* Available at http://www.grailresearch.com/pdf/ContenPodsPdf/Water_The_India_Story.pdf

Kumar, Dinesh and Tushaar Shah. 2005. *Groundwater Pollution and Contamination in India: The Emerging Challenge.* Published by International Water Management Institute, South Asia Regional Programme, India Project Office.

McKenzie, David and Isha Ray. 2009. *Urban water supply in India: status, reform options, and possible lessons*. Official Journal of the World Water Council- Water Policy 11 (2009) 442-460.

Panjiar, Shri. 2010. Address at India Business Forum, Singapore International Water Week. July 1st.

Sengupta, Dr. B. 2007. *Status of Water Treatment Plants in India*. Central Pollution Control Board, Ministry of Environment and Forests, Government of India. http://cpcb.nic.in/upload/NewItems/NewItem_103_statusofwaterqualitypackage.pdf

Seshadri, Ajit. 2009. *Decentralized Wastewater Management applying concept "Waste to Reuse"- An overview of community initiatives in rural and urban sector.* Published by The Vigyan Vijay Foundation. Available online at http://sanitation.kerala.gov.in/pdf/workshop/Decentralized_Wastewater_Management.pdf

Shah, Tushaar. 2005. *The New Institutional Economics of India's Water Policy.* Presented at "African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa. Available at http://www.nri.org/projects/waterlaw/AWLworkshop/SHAH-T.pdf

Shah, Tushaar. 2005. *The New Institutional Economics of India's Water Policy*. Paper presented the international workshop on 'African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa. Available online at http://www.nri.org/projects/waterlaw/AWLworkshop/SHAH-T.pdf

Wonscott, Peter. 2007. *Behind One Effort to Tap Into India's Water Market*. Wall Street Journal, August 14 pg. B1.

4. 9 Republic of Korea

Key Markets	**Niche Markets**
WWT – Rural	Desalination efficiency
WT - domestic and industrial	Water reuse options
Water reuse	Water efficient devices
Water efficiency	Green infrastructure
Desalination	

Demographic Indicators

Population	**2009**	**2016**	**2020**
Urban Population	39.6 million	41.0 million	-
Rural Population	8.9 million	8.2 million	-
Total Population	**48.5 million**	**49.2 million**	**49.5 million**
Population Growth Rate	**2010-2015**		
Urban Population Growth Rate	0.62%	-	-
Rural Population Growth Rate	-0.41%	-	-
Total Population Growth Rate	**0.40%**	-	-

Source: (Global Water Intelligence, 2010)

Background

The Republic of Korea (South Korea) has a population of nearly 49 million. GDP (PPP) is $1.3 trillion, with a projected growth rate of 2%. Per capita GDP (PPP) is $28,000.

Over 80% of the population is urban, with modest growth expected through 2016. Rural population is expected to decline over the same period, resulting in overall population growth of 0.2%. Over the longer term, Korea's population is expected to grow steadily through 2030, with a decline thereafter.

Korea is a highly industrialized country with a high population density. The country may experience water shortages in the future, due to growth in population and industry. Domestic per capita water consumption is 94 gallons per day, and accounts for a significant percentage of overall water use. Water supply shortages through 2020 may be as high as 132 billion gallons annually, if current trends continue.

Key Dimensions

Ninety-three percent of the Korean population is connected to a public water supply, of which 97% is metered. Wastewater treatment coverage is 89%, with 100% of treated wastewater receiving secondary treatment or better. Wastewater coverage is nearly 100% in urban areas and less than half that in rural areas.

Surface water accounts for 90% of water resources, and groundwater for 10%. Domestic use accounts for 36% of water withdrawals, while agriculture accounts for 48%, and industry accounts for 16%. Water loss in the public supply network averages 18%.

Desalination, and especially, water reuse, are becoming increasingly important components of the country's water strategy. Reuse has increased steadily, from 3% in 2000 to over 11% in 2008, with half going for agricultural use. In addition, there are water conservation initiatives targeted at reducing domestic consumption; methods include rate reform and eco-labeling of efficient appliances and fixtures.

Market Scale

Korea's overall annual water market is estimated to be in excess of $10 billion, and is expected to grow moderately (2.9% annually for the utility sector) in the coming years. Municipal capital expenditure for water is expected to remain flat at $1.5 billion annually from 2010 to 2016. Utility capital expenditure for wastewater is projected to rise over the same period, from $3.6 million in 2010 to $4.9 billion by 2016, driven by growth in wastewater networks and treatment plants to expand services in rural areas.

Korea has just over 500 water treatment plants with a capacity of 4.2 billion gallons per day. There are nearly 2,400 wastewater treatment plants, with the capacity to treat 4.5 billion gallons of wastewater per day. There are 94,000 miles of water infrastructure and 63,000 miles of wastewater infrastructure.

The country will invest at least $3 billion through 2012 in water and wastewater infrastructure as part of a Ministry of Environment 5-year capital plan to improve water quality. The plan encourages increased private sector participation in the water sector.

Policy

The Ministry of Environment has overall responsibility for water policy in Korea. The Korea Water Resources Corporation (K-water) is the public works authority for the country, with broad responsibilities for water resource development and infrastructure construction, technical support and operations.

Water Vision 2020 is a public-private initiative to address water shortages, especially those related to climate change. It covers water supply and flood control for the country's four major river basins.

The National Water Resources Plan is focused on increasing water use efficiency, and stream management and green infrastructure through 2020.

Markets

The need for additional water supplies is growing. But overall expected expenditures for water are flat. Without some additional allocations or stronger forces, this does not appear to be a target market. If energy prices increase, there will be greater interest in a variety of technologies to meet the growing demand for water.

Republic of Korea References

Global Water Market 2011, Global Water Intelligence, Media Analytics Ltd., The Jam Factory, Oxford, UK, 2010.

United Nations World Population Prospects: The 2008 Revision Population Database, http://esa.un.org/UNPP

Per capita domestic consumption, Korean Ministry of Environment, www.oecd.org /dataoecd/41/60/43181268.pdf

4.10 Saudi Arabia

Key Markets	Niche Markets
Desalination	Design-Build-Operate contracts
New water infrastructure	Water conservation technologies
Wastewater treatment	Irrigation efficiency
Network rehabilitation	Leak detection & pipe rehabilitation

Demographic Indicators

Population	2009	2016
Urban Population	21.1 million	24.9 million
Rural Population	4.7 million	5.0 million
Total Population	**25.8 million**	**29.9 million**
Population Growth Rate	**2005-2010**	**2010-2015**
Urban Population Growth Rate	2.51%	2.31%
Rural Population Growth Rate	1.05%	0.81%
Total Population Growth Rate	2.38%	2.16%

Source: (Global Water Intelligence, 2010)

Economic Indicators

Economic Indicator (2008)	Nominal GDP	GDP at Purchasing power parity
Total GDP	US $469.4 billion	US $592.9 billion
GDP per capita	US $18,855	US $23,814
GDP growth rate	4.45%	

Source: (Global Water Intelligence, 2010)

Background

Saudi Arabia has been over reliant on "fossil" water, groundwater reserves that are not being replenished. Agricultural water demand has been a historic driving force, which has been compounded by the pressures of a rapidly growing urban population. Average domestic water use is currently about twice that of European countries. A high percentage of unaccounted-for water, representing the inefficiencies of current infrastructure, is also a major factor. In an effort to drive economic growth, seven new cities are being founded. This will provide both opportunities for investment and increased pressure on water resources. Further investment opportunities being created by the Saudi government, which is moving strongly to privatize water and wastewater systems in an effort to reduce national capital expenditure and increase efficiency.

The major challenges facing Saudi Arabia include:

- Groundwater overuse
- Increasing urban population
- High agricultural water use

- Poor public water sector performance
- Aging and inefficient infrastructure

Sector	% Withdrawal	Volume (km^3/yr)
Agriculture	88%	20.83
Municipal	9	2.13
Industrial	3	0.71
Total	100%	23.67

Challenges

Freshwater overdraw
Saudi Arabia has annual freshwater resources of 2.4 km^3, only 1 km^3 of which recharges groundwater aquifers. Current water withdrawals are 22 km^3 per year, resulting in a substantial deficit. Almost 84% of water comes from non-renewable groundwater, 5.5% from desalination and 9.8% from renewable surface water and shallow aquifers. The remaining 1.1% comes from treated water effluents. (GWI) Work on public awareness campaigns and scaling back agricultural production show a willingness to address these issues, but increasing population and economic growth will make significant changes different. The solution will most likely come from increased desalination, increasing network and irrigation efficiency, and individual water conservation technologies.

Agricultural Demand
Agriculture in Saudi Arabia was driven by a national goal of food self-sufficiency. Although abandoned in 2008, the policy resulted in large vested interests in the agriculture industry that are making new policies difficult to adopt. Water intensive crops, especially wheat, contributed to the high level of water consumption. In 1992, annual wheat output was 4.7 million tons, despite the fact that national demand was only 1.3 million tons. This figure was reduced by 75% in 1993 and continued to fall during the 1990s. Saudi Arabia intends to import its entire wheat needs by 2016. Annual water use for agriculture increased from almost 489 billion gallons (79% of all water use) in 1980 to more than 5.3 trillion gallons (90% of total use) in 2004. The additional water needed for agriculture was largely drawn from non-renewable groundwater resources. Irrigation techniques are largely inefficient, but the price of water may need to increase significantly before refitting systems is economically viable. Reducing irrigation demand is a key component to ensuring a sustainable water supply. (GWI)

Urban Water Supply
The urban population in Saudi Arabia is projected to grow rapidly, from 21.11 million in 2009 to 24.9 million in 2016 (18%). Even with metering at 100%, approximately 35% of water is unaccounted for. Urban water supplies come from groundwater or desalination. Groundwater quantity and quality are declining, and many desalination facilities are reaching the end of their useful life. In addition, public water supplies in Saudi Arabia are 237 l/c/d, around twice the European average. Water conservation is a high priority and should see improvements from privatization and public awareness campaigns. Water in Saudi Arabia is among the most expensive in the world, estimated to cost $6.00 per cubic meter (for desalinated water) when,

transportation, energy costs, capital costs, and loss is accounted for. Most customers pay $0.03 per cubic meter due to massive subsidies. Religious and political pressures make increasing tariffs extremely difficult. This will be an area of significant growth; as municipalities privatize networks the incentive to increase efficiency will drive demand for new products.

New Economic Cities

The government of Saudi Arabia has proposed building seven new cities to diversify the Saudi economy and accommodate the growing urban population. Each city will need new infrastructure, though only one desalination plant has been tendered so far. It was originally intended to be a design-build contract, but was later changed to a design, finance, build, operate model. This speaks to the growing opportunities private companies will have in Saudi Arabia. Four Economic Cities are already under construction: King Abdullah Economic City (KAEC), Knowledge Economic City (KEC), Prince Abdulaziz bin Mousaed Economic City (PABMEC), and Jizan Economic City (JEC). The estimated combined population of KEC, PABMEC, and JEC will alone be 2.5 million. It assumed that any utilities will be privately financed and owned, as all the cities are also being developed privately. (GWI) Whether this growth occurs in new cities or by expanding existing municipalities, services will be extended to a growing Saudi population. The private sector investment will provide a strong market for efficient and long-term cost saving products.

Public Water Management

Poor performance of the public system is a significant factor in overconsumption. A high rate of unaccounted-for-water is a major problem, which in Riyadh is officially at 31% and possibly higher. A new contract with Veolia is targeted to bring the rate down to 15% by 2013, the eventual goal is 5% by 2026. National government water organizations, such as the Saline Water Conversion Corporation (SWCC) and the Ministry of Water and Energy (MOWE), are overstaffed and inefficient. This is being remedied by increasing privatization.

There are three major players in the public water market. The MOWE is responsible for public water provision in Saudi Arabia. The National Water Company (NWC) is a holding company for the MOWE's infrastructure assets, and also acts as a joint-stock-exchange company and possibly a commercial venture in the future. Finally, the SWCC is responsible for water production and transmission. It supplies water to the MOWE for retail distribution at no cost. The SWCC owns 24 water protection facilities, as well as pipe networks linking to major cities. The SWCC employs 9,000 people, most living in self-contained communities owned by the corporation. These present a significant barrier to privatization. The total budget for SWCC in 2007 was $1.05 billion, of which $102 million went to parts, $36 million for maintenance, and $74 million on rehabilitation contracts. However, the figure is low, as the SWCC's power costs are heavily subsidized. Privatization is occurring through the Water and Electric Company (WEC), an LLC owned jointly by the SWCC and the Saudi Electric Company. The WEC is responsible for setting up contracts for new power and water plants with private companies.

Key Performance Indicators

Water Supply Infrastructure	
Municipal supply	2,088 million m^3/yr
No. of WTPs	50
Design capacity of WTPs	5.39 million m^3/yr
No. of water connections	1.5 million
Length of distribution network	40,000 km
Unaccounted-for water	35%
Meter coverage	100%

Wastewater Infrastructure	
No. of WWTPs	32
Design capacity of WWTPs	2.55 million m^3/day
Wastewater produced	4.60 million m^3/day
Treated to tertiary level	14%
Collected in central system	40%
Collected in septic tanks	60%

Of the 444 billion gallons of annual wastewater produced, only 40% is collected in central sewer systems. Approximately 100% of collected wastewater is treated to a secondary level, while 14% is treated to at least a tertiary level. Wastewater treatment is not a problem in areas which are served by central sewer systems. However, 60% of the annual wastewater produced is held in septic tanks, and an unknown amount of untreated septic wastewater is discharged into lagoons or designated areas of the desert. For example, Jeddah's wastewater lagoons have a capacity of 2.6 billion gallons. Riyadh's Manfouha plant discharges untreated water into the Riyadh River, while the treatment plants in Jeddah discharge untreated water directly into the sea. Following current trends, improvements in wastewater treatment are likely to be driven by private sector investment.

Desalination and Reuse

There are approximately 1,420 desalination plants in the country, with a total capacity of 2.7 billion gallons per day. Of the 1,420 plants, 63 are considered large (over 5.3 million gallons per day) and 1,357 are considered small (less than 5.3 million gallons per day).

Saudi Arabia's capacity for advanced water reuse is expected to increase from 296 million gallons in 2012 to 581 million gallons in 2016. No reclaimed water is used for drinking, and this is not expected to change soon. However, there is significant potential for increased water reuse networks for non-potable uses, which has been explored in a number of feasibility studies by the NWC. There is a concurrent scheme under development by the NWC to sell treated wastewater on a commercial basis, sharing investment costs with parties that will use the water. There are currently five companies interested in or formalizing arrangements to use a total of approximately 100,000 m^3/day.

While there currently do not appear to be any policies regarding household water conservation, the Minister of Water and Electricity is promoting conservation in attempt to decrease average daily municipal use. In 2008, over 34 million free water saving devices were distributed to the public , and 2 million devices were installed in public buildings, such as schools and government offices (Saudi Arabian Monetary Agency, 2009).

Water use for irrigation is presumably much more expensive in Saudi Arabia than in other countries, as vast areas of the country are desert and many of these areas have been turned into farmland through an extensive network of dams and expensive technologies such as desalination (Royal Embassy of Saudi Arabia, n.d.). Desalinated water is often required to be pumped long distances, requiring large amounts of energy, and ultimately, water to create the needed energy.

Market Forecast 2010-2016

Market Forecast Summary	2010 – 2016 Annual Average (US$)
Water	
Networks	670 million
Treatment plants	6 million
Water resources/ other	121 million
Wastewater	
Networks	952 million
Treatment/ other	755 million
Utility capital expenditure	
Water utilities	2,393 million
Wastewater utilities	1,730 million
Utility operating expenditure	
Water utilities	2,667 million
Wastewater utilities	506 million
Industrial water	
Industrial capital expenditure	237 million
Industrial chemicals	133 million
Industrial services	24 million
Desalination and reuse	
Desalination	1,596 million
Reuse	475 million

Saudi Arabia's population is expected to double from approximately 26 million in 2010 to 50 million in 2050. Thus, companies addressing alternate sources of water should see great opportunities in Saudi Arabia because declining groundwater and freshwater resources are not able to keep up with population growth. Saudi Arabia's New Cities program will also increase the need for new water infrastructure.

There is strong interest in desalination and water reuse, but desalination currently is more established than reuse. Private sector involvement is encouraged in the country, and there are 16 ongoing desalination projects which will increase current capacity by more than 660 million gallons per day. Cost figures for most of these projects are not listed but the largest is the Ras Azzour plant with a 270.8 million gallon per day capacity and a cost of more than $4 billion. Approximately 4 ongoing water reuse projects would increase daily capacity by 821 million gallons per day.

The market for water utilities is less than ideal. Many municipal utilities are very inefficient, and there is not the needed political support to increase tariffs to a proper level. While this sector greatly depends on public subsidies, privatization is beginning to gain some support. However, because unemployment is already high in Saudi Arabia, there likely would be opposition to the cost-saving downsizing that private organizations would want to perform if they took over operations of existing utilities.

Private Sector Participation

A national privatization program was approved by the Superior Economic Council in 2002. The primary strategy was adopted in 2006 by the Ministry of Water and Electricity. Major cities involved in the program are Riyadh, Jeddah, Dammam/Khobar, Madinah, and Makkah/Taif. Projects with private participation include desalination, sewerage, and wastewater treatment plants. As a result, GWI predicts an increase in private investment from bi-lateral lenders, especially from Japanese, Korean, and Chinese banks.

The sale of SWCCs production assets may attract financing from infrastructure-fund investors, largely because expensive capital outlays on infrastructure have already been made. This will create opportunities for companies to rehabilitate or increase the efficiency of existing plants, though it will require cooperation from local parties to accurately evaluate the condition of local assets. The NWCs strategy is to increase performance-based management contracts in major urban areas; two contracts have already been awarded to Veolia Water and Suez Environment.

The following table estimates the extent of private-sector participation in capital and operating expenditure:

Sector	**2009 Capex***	**2009 Opex****	**2020 Capex***	**2020 Opex****
Desalination plants	New plants	New plants	All plants	All plants
Long-distance transmission	No	No	Maybe	Maybe
Drinking-water distribution	No	Some	Some	Yes
Sewerage	No	Some	Some	Yes
Wastewater treatment plants	New plants	New plants	All plants	All plants
Groundwater resources	No	No	Maybe	Maybe

*Capex = capital expenditures ** Opex = operating expenditures

Drinking water capital expenditure

Drinking water capital expenditures are expected to fall from $2.7 billion in 2010 to $1.5 billion in 2011. Expenditures will then gradually increase to $3.3 billion in 2016. Approximately 75%

of annual expenditures will be on water resources (including desalination), 25% will be on new construction and rehabilitation of existing water distribution networks, and less than 1% will be on new construction and rehabilitation of existing water treatment plants. There are currently seventeen water production projects being monitored by GWI. The majority of capacity is being developed in water and power projects, as shown in the approximate capacities below.

Type	Capacity
Sea-water Reverse Osmosis	337,000 m^3/day
Water only	100,000 m^3/day
Water & Power	2,825,000 m^3/day

Wastewater capital expenditure
Annual wastewater capital expenditures are expected to increase from approximately $750 million in 2010 to $2.5 billion in 2016. About 55% of annual expenditures will be for the construction of new wastewater networks and rehabilitation of existing networks, while 45% will be for wastewater treatment plants

Industrial and municipal capital expenditure
Annual industrial and municipal capital expenditures are projected to fall from $3.6 billion in 2010 to $2.8 billion in 2011. Annual expenditures will then increase to $6.2 billion by 2016. Some 95% of annual expenditures will be for municipal capital projects, while 10% will be for industrial capital projects.

Water and wastewater operating expenditure
Annual water operating expenditures are expected to increase from $300 million in 2010 to $800 million in 2016. Annual wastewater operating expenditures are projected to increase from $2.2 billion in 2010 to $3.3 billion in 2016. Annual expenditures on desalination are expected to vary between $900 million and $2.2 billion from 2010 to 2016. Annual water reuse expenditures are expected to vary between $300 million and $650 million from 2010 to 2016.

<u>Saudi Arabia References</u>

Global Water Intelligence (2010). *Global water market 2011: Meeting the world's water and wastewater needs until 2016*. Oxford: Media Analytics Ltd.

Royal Embassy of Saudi Arabia (n.d.). *Agriculture and water*. Retrieved from http://www.mofa.gov.sa/Detail.asp?InSectionID=2820&InNewsItemID=103852

Saudi Arabian Monetary Agency (2009). *Forty fifth annual report: The latest economic developments*. Retrieved from http://www.sama.gov.sa/sites/samaen/ReportsStatistics/ReportsStatisticsLib/5600_R_Annual_En_45_2009_08_31.pdf

4.11 Australia

Water Market

- Market size 2010: $15 billion
- Growth rate 2010 – 2016: 6% to 9.9%
  - Water systems capital expenditure growth (2010-2016): $2.6 billion to $3.6 billion
  - Wastewater capital expenditure growth (2010-2016): $1.2 billion to $1.75 billion (Australian Trade Commission, n.d.)

Key Markets	**Niche Markets**
Water distribution networks (piping) and water treatment plants	On-site industrial wastewater treatment
Wastewater networks and treatment plants	Water recycling for public and private purposes
Desalination	
Irrigation systems (upgrades)	

Demographic Indicators

Population	**2009**	**2016**
Urban Population	18.8 million	20.4 million
Rural Population	2.3 million	2.2 million
Total Population	**21.1 million**	**22.6 million**
Population Growth Rate	**2005-2010**	**2010-2015**
Urban Population Growth Rate	1.22%	1.13%
Rural Population Growth Rate	-0.60%	-0.60%
Total Population Growth Rate	1.04%	0.97%

Source: (Global Water Intelligence, 2010)

Economic Indicators

Economic Indicator (2008)	**Nominal GDP**	**GDP at Purchasing power parity**
Total GDP	US $1,013.5 billion	US $799.1 billion
GDP per capita	US $46,824	US $36,918
GDP growth rate	2.35%	

Source: (Global Water Intelligence, 2010)

Background and Summary of Key Issues

Australia is an ethnically and geographically diverse country of approximately 21 million people. The majority of individuals live in urban areas, and the states of New South Wales, Victoria, and Queensland are home to a majority of Australians – 17.1 million. Over 80% of citizens live within 31 miles of the coast. From 2010 to 2015, the population is expected to experience modest growth, at 0.97% per year.

Australia receives most of its water from reservoirs, rivers and aquifers (Global Water Intelligence, 2010). Surface water comprises 83% (116 trillion gallons/yr) of renewable water while groundwater accounts for 17% (19 trillion gallons/yr). Only 10% of rainfall reaches water bodies, and large reservoirs held approximately 22 trillion gallons in June 2005.

In 2004-2005, total consumption was 5 trillion gallons. This figure is far lower than total renewable water resources of 135 trillion gallons/yr. However, Australia is still susceptible to water shortages due to drought and vast areas with an arid climate. Population increase is also a concern, because an estimated additional 8.5 million people in urban areas by 2050 would require an increase 273 billion gallons/yr of water (Australian Trade Commission, n.d.).

Agricultural irrigation accounts for 65% (3.2 trillion gallons/yr) of all use (Global Water Intelligence, 2010). Water for used for irrigation decreased from 69% to 65% of total use from 2000 to 2005. Residential water use has also decreased, primarily due to drought conditions and imposed water restrictions Residential water use decreased by 14% from 2000-01 to 2004-05, and residential water use in urban areas decreased by 21% from 2002-03 to 2007-08.

In 2004-05, domestic use was 557 billion gallons/yr. Utilities and water suppliers provide 90% of domestic water, while rainwater tanks and direct household withdrawals from boreholes or surface water provide 10%.

From 2004 to 2005, the largest industrial user of water was manufacturing (156 billion gallons /yr). Mining accounted for 108 billion gallons/yr while electricity and gas accounted for 71 billion gallons/yr. Many industrial users utilize recycled water from municipal plants, such as BlueScope Steel, which uses 5.3 million gallons/day of water from the Wollongong Recycled Water Plant.

Sectoral Water Use in Australia	**2000-01**		**2004-05**	
	Bil. gal/yr	**%**	**Bil. gal/yr**	**%**
Agriculture	3,960	69.1	3,220	64.9
Forestry and fishing (includes some agricultural services, hunting, and trapping)	10.6	0.2	13.2	0.3
Mining	84.5	1.5	108.3	2.2
Manufacturing	145.3	2.5	155.9	3.1
Electricity and gas (consumptive use only)	68.7	1.2	71.3	1.4
Water supply (sewerage and drainage services, water losses)	573.3	10.0	739.7	11.1
Other industries	290.6	5.1	280.0	5.6
Households	602.3	10.5	557.4	11.2
TOTAL	**5,735.3**	**100.0**	**5,145.8**	**100.0**

Source: (Global Water Intelligence, 2010)

Though desalination (132 billion gallons/yr) and water reuse (71 billion gallons/yr) are still small markets, there is strong future potential in desalination. Two desalination plants have recently been completed with additional plants being planned or constructed. Additionally, recycled effluent rose from 9% in 2006-2007 to 11% in 2007-2008. Agriculture and industry are currently the primary users of reclaimed water.

Australia comprises 3 million mi^2 and is divided fairly equally between tropical and temperate climates. The tropical climate zone is 40% of the land area, while the temperate climate zone is 60%.

The main water issues in Australia are:

- Climate change, drought, and urbanization
- Aging infrastructure
- Water shortages and aquifer withdrawal
- High irrigation demand
- Need for desalination
- Need for use of reclaimed water

Key Issue: Climate Change, Drought, and Urbanization

Key Dimensions
Australia is the second driest continent, behind Antarctica, as 65% of land is semi-arid to arid and 35% is desert. Inconsistent rainfall creates the extreme conditions of both droughts and floods. The annual rainfall across the country has ranged from approximately 13in to 28in (http://www.bom.gov.au/announcements/media_releases/climate/change/20100105.shtml). Drought has been a major problem across the country since 2000 but has been especially severe in the southeast portion of the country, where the majority of the population is located. The Murray-Darling Basin has seen below average rainfall since 2002.

Action Needed
Water storage infrastructure such as dams and reservoirs may be needed, but many parts of the country are so dry that such infrastructure would likely be storing water at far under capacity during times of drought. Drought contingency plans are needed, and water conservation needs to be encouraged. Smart growth may also be necessary, as more energy is often needed to pipe water to outlying suburbs. An increased need for energy results in an increased need for water.

Current Approach
Water Smart Australia has been providing a total of $1.6 billion from 2005 to 2010 to assist in the design and implementation of water smart technologies (Australian Trade Commission, n.d.). Projects which qualify receive a minimum of $1 million and can receive assistance for up to four years.

In 2009 the Water for the Future plan, costing $11.8 billion, was introduced. The 10-year plan includes funding for “State governments, utilities, irrigators, and private investors” (Global Water Intelligence, 2010, p. 214). It is intended to address and protect against water shortage from climate change by increasing more effective water use, securing water supplies, and protecting watersheds. Public ownerships will continue and public-private partnerships (PPPs) will be introduced.

Impending Water Policy Changes/Conditions to Address Issue
Many capital cities have imposed strict water restrictions in an attempt to ease drought conditions. For example, Melbourne, as well as the State of Victoria, have water saving rules, including restrictions on hosing down paved areas (Dueñas, 2009). Residents can be fined $414 or have their water supply reduced to an extremely low amount if they are found watering lawns or using drinking water to wash vehicles or hose down pavement.

T155 is an additional program, introduced in November 2008, whose goal is to reduce daily water consumption to 41 gallons (155 liters) (Dueñas, 2009). Average per capita consumption in May 2009 was 37 gallons, down from 111 gallons in the 1990s.

Technology/Policies Needed
Desalination plants, greywater systems, and wastewater reuse will be needed to ensure that Australia will have enough water to meet the needs of its growing population.

Key Issue: Aging Infrastructure

Key Dimensions
Australia's municipal water supply is 536 billion gallons/yr, and there are 267 water treatment plants (Global Water Intelligence, 2010). Of these 267 plants, 92 serve 100,000 people or more. The distribution network is 85,000 miles long with 8.05 million water connections. Per capita water consumption from municipal sources is 70 gallons/day. Approximately 95% of the network is metered, but 18% of water is unaccounted-for (Global Water Intelligence, 2010). Much of this unaccounted water is due to leaking pipes and infrastructure (IBM Australia, 2010).

Australia has approximately 523 billion gallons of wastewater annually (Global Water Intelligence, 2010). There are 356 wastewater treatment plants, which collect 100% of the wastewater. Approximately 38% is treated to a secondary level, while 62% is treated to a tertiary level or better. The sewerage network is 73,000 miles long and consists of 7.23 million wastewater connections. At least 81 of the 356 plants serve 100,000 individuals or more.

Municipal and agricultural irrigation systems are severely outdated and inefficient, due to leaks. However, many systems are both challenging and costly to repair or improve. An extreme example of aged infrastructure involves the irrigation channels, weirs, and dams in the Murray-Darling Basin, which covers four Australian states. Many of these irrigation structures are over 90 years old. Cost figures for replacement of aging infrastructure are difficult to uncover, but it is estimated that current maintenance of such infrastructure costs $4.5 billion annually (http://www.csiro.au/science/Urban-Water.html).

Action Needed
The Australian government will need to produce cost estimates for the replacement and rehabilitation of aging water infrastructure, since the only figures which seem to be available address maintenance only. If annual maintenance costs are $4.5 billion alone, the government will need to prioritize structures for replacement and maintenance.

Current Approach
The National Water Security Plan for Cities and Towns is a plan formed by the government that will allocate $254.8 million over five years to municipalities with populations under 50,000 (Australian Trade Commission, n.d.). The funds will provide pipe and water system upgrades and will also install new infrastructure. These projects are expected to reduce water loss through leaking pipes and aging infrastructure.

Impending Water Policy Changes/Conditions to Address Issue
There do not currently appear to be any impending policy changes to address this issue.

Technology/Policies Needed
Policies should be created which prioritize the replacement of infrastructure. The oldest and most dangerous structures need to be replaced first. Secondary and tertiary wastewater treatment technology will be needed because fairly low percentages of all wastewater are currently treated to these levels or higher.

Key Issue: Water Shortages and Aquifer Withdrawal

Key Dimensions
The Murray-Darling Basin is the largest water basin in Australia. Approximately 386,000 mi^2 (7%) of land in Australia is within the basin (http://www.environment.gov.au/water/locations/murray-darling-basin/index.html). The three longest rivers (Murray, Darling, and Murrumbidgee) are part of the basin, as are approximately 30,000 wetlands. Approximately 85% of Australia's irrigation takes place in this basin, supporting agriculture that accounts for $9 billion per year.

Over-allocation of water withdrawals is problematic and the southern portion of the basin has been experiencing severe drought and low water levels for the past decade.

Action Needed
The Water Act of 2007 also requires that an integrative basin plan be created. This is important because it will set limits on the withdrawal of surface and groundwater, identify risks, such as climate change, and ways to manage those risks, set rules for transfer of water rights, and introduce a plan to manage water quality and levels of salinity (http://www.mdba.gov.au/basin_plan).

Australia needs to set limits on water withdrawals and look for alternate sources of water, such as desalination and water reuse. Emphasis also needs to continue to be placed on water conservation for rural areas involved in irrigation, as well as for urban areas.

Current Approach
The Water for the Future program has committed $3.1 billion for the purchase of water in the basin over 10 years (Australian Trade Commission, n.d.). Water withdrawal from the basin is currently excessive, and the purchase of water is intended to decrease the over-allocation of water.

The Living Murray Initiative is another program which was implemented to improve the ecosystem of the River Murray, which is a large tributary in the Murray-Darling Basin (Australian Trade Commission, n.d.). The Murray-Darling Basin Ministerial Council also allocated $500 million from 2004 to 2009 to recover 132 billion gallons of water per year to replenish the basin. The council also allocated $150 million to construct infrastructure in the area which would facilitate water recovery. In the 2006-2007 Federal Budget, the Australian government allocated $500 million for further work in the area.

"Restoring the Balance in the Murray-Darling Basin" is part of the Water for the Future program and is purchasing water rights from willing farmers (Department of the Environment, Water, Heritage, and the Arts, 2010).

Impending Water Policy Changes/Conditions to Address Issue

The 2008 Council of Australian Governments Intergovernmental Agreement on Murray-Darling Basin Reform controls management of water in the basin (Global Water Intelligence, 2010). A basin management plan is required and regulation of water pricing and the water market is overseen by the Australian Competition and Consumer Commission (ACCC).

The states of Victoria, New South Wales, and South Australia finalized an agreement on water distribution in the southern portion of the basin for 2009-10 (http://www.environment.gov.au/water/locations/murray-darling-basin/index.html). This agreement ensures that each state will be able to secure enough water for critical use for the following year. No information is available as to what amount this constitutes.

Technology/Policies Needed to Meet New Standards/Conditions

The government intends to spend more than $600 million in water meters that will be required to be accurate to within a +/- 5% error. It is likely that more accurate metering will give officials a better idea of the amount of water being used, which will assist in policy implementation and potential water withdrawal limits.

Key Issue: High Irrigation Demand

Key Dimensions

Agricultural irrigation is responsible for approximately 65 to 70% of annual water use. It is estimated that approximately 3.2 trillion gallons/yr is used for agriculture. Around 85% of all irrigation happens in the Murray-Darling Basin (Australian Trade Commission, n.d.). The over-allocation of water entitlements and drought have contributed to a situation where irrigators are seeing restricted entitlements and availability of water.

Action Needed

Different crops require different amounts of water and studies may need to be done to determine the daily maximum amount of water per acre, per crop needed. This could be used to decide whether farmers are using inefficient irrigation methods or crop choices. Australia's high summer temperatures make evaporation highly likely, so drip irrigation systems should be used whenever necessary.

Current Approach
The On-Farm Irrigation Efficiency (Pilot Projects Program) is intended to promote more sustainable use of water in rural areas (Australian Trade Commission, n.d.). This program is part of the Sustainable Rural Water Use and Infrastructure program, with total funding of $5.8 billion. This program is expected to test products which will be most water efficient for farm and agricultural use.

The Water for the Future strategy also has plans to upgrade to more efficient irrigation infrastructure and to begin the mandatory use of metering.

Impending Water Policy Changes/Conditions to Address Issue
There are currently no impending policies to address high irrigation demand. The Sustainable Rural Water Use and Infrastructure program, and the Water for the Future strategy are currently the main programs to address the issue.

Technology/Policies Needed
Policies requiring efficient irrigation systems, as well as best management practices are needed. Policies which regulate the use of crops and encourage low water-intensive crops are also important.

Availability of Technology
The Australian Trade Commission (n.d.) stated that Australian companies design and manufacture some of the best irrigation technology in the world. However, Australian companies are not large enough to be involved in large projects which would require many different technologies and products. Therefore, this might be an opportunity for irrigation technology companies which have this kind of capacity.

Key Issue: Need for Desalination

Key Dimensions
Australia has two desalination plants for municipal use. The Perth Desalination Plant (Kwinana, Western Australia) was completed in 2006 at a cost of $337 million (Global Water Intelligence, 2010). It has a 37 million gallon/day capacity and treats 12 billion gallons/yr, providing 17% of Perth's domestic supply.

Perth was one of the first cities in Australia to invest in major desalination projects (Stedman, 2010, June). The Kwinana plant was the first large-scale plant built in Australia and at the time, was the largest saltwater desalination plant outside of the Middle East. Notably, the Kwinana plant is also the largest in the world to use renewable sources of energy. An 82MW wind farm provides energy, and the plant is considered the greenest desalination plant in the world. A second plant in Perth will be completed in 2011 and is also expected to be run using renewable energy. A third plant is planned for 2015.

The Gold Coast Desalination Plant (Tugun, Queensland) was completed in 2009 at a cost of AUD 1.2 billion (Global Water Intelligence, 2010). It has a 34 million gallon/day capacity and is expected to provide 15% of South East Queensland's domestic supply. There are also an unspecified number of brackish-water treatment plants under construction as part Western Corridor Project in Queensland.

Sydney Water is also building one of the largest reverse osmosis plants which, at full capacity, will produce approximately 500 MLD or one third of Sydney's water (Stedman, 2010, June). The plant is expected to purchase renewable energy for its operation. In addition to Australia's major desalination plants, there may be up to 500 smaller plants which provide water for mining and power, food and beverage, small communities, and medical needs.

The Perth Desalination Plant and Gold Coast Desalination Plant use public-private partnerships (PPPs) (Global Water Intelligence, 2010). The Perth Desalination Plant is currently operated by Degrémont on a 25-year contract. The Gold Coast Desalination Plant is operated by the government and was publicly financed but was built by the Gold Coast Desalination Alliance (Veolia, John Holland, Sinclair Knight Mertz, Cardno, Gold Coast Water, and the Queensland State Government).

Action Needed

Australia might want to consider continuing to utilize PPPs in the construction and operation of desalination plants.

Current Approach

In 2008, desalination accounted for 79.3 million gallons/day (0.6%) of total use in Australia but this figure is expected to increase to 554.8 million gallons/day by 2013 (Stedman, 2010, June). Seven major desalination plants are expected to go online between 2010 and 2012 (Global Water Intelligence, 2010). The largest project, the Victorian Desalination Plant, is expected to cost $3.2 billion and will have a capacity of 108 million gallons/day. All seven plants are expected to have a total capacity of approximately 428 billion gallons/day. Two of the plants could be expanded in the future, adding an additional 100 million gallon/day capacity. The total cost of these six projects is expected to be $7 billion. Three other plants are in the planning phases.

Impending Water Policy Changes/Conditions to Address Issue

There are no current impending water policy changes or conditions to address desalination in Australia.

Technology/Policies Needed

Desalination is still an expensive process, and because Australia is investing more in desalination than many other countries, less costly procedures may become necessary. Makers of membranes and other types of filtering equipment might see an opportunity in this market.

Key Issue: Need for Use of Reclaimed Water Use

Key Dimensions

Despite plans for or construction of desalination plants in most states, recycled water will also be necessary. The main urban water utilities recycled approximately 9% of water annually in 2005-06 (Australian Trade Commission, n.d.).

Reclaimed water is used mainly in agriculture, mining, and other industries. Agriculture has used the largest amount of reclaimed water across all sectors. Domestic use is low but increased from 53 million gallons/yr in 2000-2001 to 476 million gallons/yr in 2004-2005 (Global Water Intelligence, 2010). Reclaimed water supply in major utilities increased 117% from 20.3 billion gallons/yr in 1999 to 43.6 billion gallons/yr in 2007.

Reclaimed Water Use (Sector) **In trillions of gallons/yr**	**1996-97**	**2000-01**
Agriculture	10.0	111.7
Water supply, sewage, & drainage services	1.1	6.1
Manufacturing	1.3	4.5
Forestry & fishing	0.8	1.8
Mining	11.1	1.3
Electricity & gas supply	1.8	1.3
Household	--	44.9
Other	9.2	9.5
Total	**24.2**	**181.1**

Source: (Global Water Intelligence, 2010).

Action Needed

Some utilities have begun to increase future targeted amounts of recycled water. Sydney Water has set a goal of 18.5 billion gallons by 2015, and SEQ Water in Queensland is finishing The Western Corridor Recycled Water Project for urban and industrial use (Australian Trade Commission, n.d.). The Western Australian Government has set a goal of 20% recycled wastewater by 2012, so more municipalities need to set their own goals for recycled water to ensure that this goal is met.

Current Approach

Out of $11 billion in water resources, the Australian government recently allocated $7.3 billion for water reuse (Global Water Intelligence, 2010). Still, infrastructure cost is the primary factor prohibiting water reuse. The average water reuse project costs $15.86/gallon/day while the average desalination project costs $12.07/gallon/day.

Melbourne has used wastewater for several applications since 2003 (Dueñas, 2009). City West Water (CWW) is one of three major companies providing treated and reused wastewater. CWW's treated water is treated to Class A standards, which is very close to drinking water standards. The company supplies reused water to large customers such as golf courses, as well as to reused water reticulation networks for domestic purposes.

Impending Water Policy Changes/Conditions to Address Issue

By 2006, all states had signed on to the Council of Australian Governments National Water Initiative (NWI) which provides policy guidelines for water reform and management practices (Global Water Intelligence, 2010). Each state and territory is required to outline how they will adhere to the NWI. Following NWI plans and showing adequate progress toward goals makes governments eligible for funds. Examples of NWI programs include:

- Establishing national water markets.

- Advocating consumption-based and full-cost recovery water pricing.
- Improving water accounting, metering, and information gathering.

The NWI is intended to increase efficient water use, which will help increase investment in the water industry (Australian Trade Commission, n.d.).

Technology/Policies Needed

Wastewater treatment plants which are capable of treating water to high standards are needed to ensure that reclaimed water can be used for irrigation, as well as numerous domestic purposes such as laundry, water for tubs and sinks (not including drinking water), and lawn and garden irrigation.

If wastewater systems are used across the country, such as the one managed by CWW in Melbourne, separate water networks may need to be created to ensure that reclaimed water of slightly lower standards is separated from drinking water. A third pipe reticulation system, which would carry recycled water to residences, has been planned for new housing developments (Australian Trade Commission, n.d.). Sydney's Rouse Hill water recycling plant provides 502 million gallons per year of recycled water to 16,500 homes. An expansion of this system to 1.24 billion gallons per year, costing $47.4 million, was expected to be completed in 2009.

Capabilities and Opportunities

Australian capabilities are often based on the varying natural conditions across the country. Major capabilities are (Australian Trade Commission, n.d.):

- Agriculture
  - Underground drip and in-ground hydroponics irrigation technology, moisture meters, soil additives to prevent evaporation, reclaimed water for irrigation, the creation and use of more water efficient crops, and advanced farming equipment
- Industrial, resources, and energy
  - Recycling of industrial wastewater, water analysis technology, membrane separation processes, water purification, water saving technologies, rainfall catch tanks, and pipeline transportation systems
- Urban and domestic
  - Municipal and household water purification, monitoring, desalination plants.
- Environmental
  - Fish ladders to assist in fish migration
- Government
  - Innovative policy adjustment

Market Forecast (2010 – 2016)

There will be support for private sector involvement and PPPs in new projects, but the Federal Government Water for the Future initiative ensures a greater amount of public investment in projects (Global Water Intelligence, 2010).

Drought has increased the focus on methods of water supply which do not rely on rainfall:

- Desalination and water recycling for indirect potable use.
- Managed aquifer recharge for indirect potable use and agriculture.
- Industry reliance on municipal water is changing to private on-site water treatment plants.

These may be major opportunities for water technology companies; however, because Australian companies are already working on many of their own solutions, it might be somewhat difficult to enter this network without innovative products that are not currently being manufactured or developed in the country.

Market Summary Forecast	2010 – 2016 Annual Average (USD)
Water	
Networks	1.11 billion
Treatment plants	438.4 million
Water resources/ other	721.1 million
Wastewater	
Networks	712.5 million
Treatment/ other	684.2 million
Utility capital expenditure	
Water utilities	3.08 billion
Wastewater utilities	1.51 billion
Utility operating expenditure	
Water utilities	4.66 billion
Wastewater utilities	4.14 billion
Industrial water	
Industrial capital expenditure	340.6 million
Industrial chemicals	167.5 million
Industrial services	22.7 million
Desalination and reuse	
Desalination	816.5 million
Reuse	330.2 million

Source: (Global Water Intelligence, 2010)

Private Sector Participation

The public sector has majority control of the water market, and there is little support for large-scale privatization of water. The most common PPPs are build-own-operate-transfer (BOOT), build-own-operate (BOT), design-build-operate (DBO), and design-build-finance-operate (DBFO).

In 2008, CoAG stated that PPPs should be considered for all projects costing more than $45 million. Most state-level governments also have policies and programs to facilitate PPPs. Most PPPs involve major international companies such as Veolia, Suez Environment (Degrémont), Earth Tech, and EGL Water Operations. Public-private setups are becoming more common in industrial water reuse and desalination.

Drinking water capital expenditure

From 2010 to 2016, drinking water capital expenditures are projected to be between $2.6 billion and $3.55 billion per year. Approximately 65% of annual expenditures will be on water resources (including desalination), 25% on new construction of water distribution networks and rehabilitation of existing networks, and 10% on new construction of water treatment plants and rehabilitation of existing plants.

Wastewater capital expenditure
Annual wastewater capital expenditures are expected to be between $1.2 billion and $1.75 billion from 2010 to 2016. Approximately 50% will be for the construction of new wastewater networks and rehabilitation of existing networks, and 50% will be for wastewater treatment plants.

Industrial and municipal capital expenditure
Between 2010 and 2016, annual industrial and municipal capital expenditures are expected to be between $4.2 billion and $5.5 billion. Approximately 90% of annual expenditures will be for municipal projects, while 10% will be for industrial projects.

Water and wastewater operating expenditure
Annual water operating expenditures are expected to increase from $4.2 billion in 2010 to $5.2 billion in 2016. Annual wastewater operating expenditures are projected to increase from $3.7 billion in 2010 to $4.6 billion in 2016.

Desalination and water reuse expenditure
Annual expenditures on desalination are expected to be between $120 million and $305 million from 2010 to 2016. Annual water reuse expenditures are expected to be between $40 million and $280 million from 2010 to 2016.

Australia References

Australian Trade Commission, Australian Government (n.d.). *The Australian Water Industry*.

Department of the Environment, Water, Heritage, and the Arts (2010). *Water for the future: Restoring the balance in the Murray-Darling Basin*.

Dueñas, M. C. (2009). Country water action: Australia dousing Melbourne's dry spells with recycled water. *Asian Development Bank*. Retrieved from http://www.adb.org/water/actions/aus/melbourne-recycled-water.asp

Global Water Intelligence (2010). *Global water market 2011: Meeting the world's water and wastewater needs until 2016*. Oxford: Media Analytics Ltd.

IBM Australia (2010). *White paper: Water optimization through intelligent infrastructure*. Retrieved from http://www-07.ibm.com/solutions/au/government/downloads/Water_Asset_Management_Paper_Australia.pdf

Stedman, L. (2010, June). Australia's explosive growth in desal. *Water 21: Magazine of the International water Association*, 16-21.

4.12 Europe

Key Markets	**Niche Markets**
Distribution system component replacement and upgrades to meet stringent lead limits	Cost-effective real-time multi-contaminant testing for swimming water pathogens
Cost-effective BNR retrofits for existing chemical process plants	Point-of-use/point-of-entry drinking water treatment systems
Advanced filtration to remove emerging contaminants from drinking water	On-site biological treatment plants for animal waste
Nutrient (nitrogen and phosphorus) control for wastewater	Small footprint biological nutrient removal WWTPs for small communities and industrial sites
Nutrient recovery and energy generation from wastewater	Coastal water monitoring
Mitigation of heavy metals from wastewater	
Wastewater treatment infrastructure and technology for new member states	

The European continent is home to 50 recognized countries. Europe's population is 841 million, including Russia and Turkey, which span two continents. Population growth rates vary widely by country but are generally low, typical of developed areas of the world. The most significant water technology markets are found in some of the 27 member nations of the European Union (EU).

European Union Background

EU member states have a combined population in excess of 500 million (2009). Gross Domestic Product at Purchasing Power Parity (PPP)[4] was $15 trillion in 2009, or over 20% of worldwide output, making the EU the world's largest economy, just ahead of the US.

The EU is a supranational and intergovernmental body with significant regulatory authority over water. The Environment Directorate General (DG Environment) is responsible for establishing, implementing, and enforcing standards and regulations for water and wastewater. Its role is similar to that of the Environmental Protection Agency in the United States. DG Environment is supported by the European Environmental Agency (EEA), which provides independent, standardized data for the development, implementation, and evaluation of environmental policy within and across national boundaries. EEA membership includes all 27 EU member states, as well as Iceland, Liechtenstein, Norway, Switzerland and Turkey. In addition, six West Balkan nations, are EEA "cooperating countries:" Albania, Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia, Montenegro and Serbia. European countries also have national environmental protection agencies, which are generally responsible for the operational implementation of environmental policies in their respective jurisdictions.

4 Purchasing Power Parity is the adjustment to nominal economic data that allows meaningful comparisons across national and regional boundaries. It takes into account the relative costs of a standard bundle of common goods and services in a particular country or region compared to worldwide averages.

EU Water Policy and Timeframes
The history of water regulation in the EU has many parallels to water regulation in the US. The first significant EU water quality directives were enacted in the 1970's, and established standards for surface water, groundwater, bathing water, and drinking water. By the late 1980's, specific policy directives included the Directive on Urban Wastewater Treatment (UWWT), which requires member states to treat sewage in urban areas, the Nitrates Directive, which controls the application of nitrogen fertilizers to fields, and the Directive on Integrated Pollution Prevention and Control (IPPC), which regulates pollutants discharged from industrial sites.

By 2000, the benefits of a watershed-based approach to regulation were becoming apparent. In that year, the EU adopted the Water Framework Directive (WFD) as a means to integrate water regulations across policy areas and watersheds. The WFD led to the establishment of river basin management plans. The WFD also established a combined approach for regulation of point and non-point sources of contaminants and set specific compliance deadlines for a number of regulations. WFD environmental program assessments are scheduled for 2012-2015, 2021, and 2026

WFD Related Directives

- Bathing Water (76/160) (now replaced by 2006/7)
- Drinking Water (80/778, as amended by 98/83)
- Urban Wastewater Treatment (91/271)
- Nitrates (91/676)
- Integrated Pollution Prevention & Control (96/61, codified as Directive 2008/1/EC).
- Sewage Sludge (86/278)

AquaMoney, funded by the European Commission's Directorate General - Research, brings together 16 European research institutions to develop and test practical guidelines for the assessment of environmental and resource costs and benefits of the WFD. With the exception of Ireland (where domestic water is provided at no charge), and certain developing areas of the EU, the WFD requires rate structures to be set at full cost recovery as of 2010.

Bathing Water Directive 2006/7/EC
The Bathing Water Directive sets biological (coliform, streptococci, e coli) and aesthetic contaminant limits for beaches. Ongoing testing of turbidity, pH, and salinity (for coastal waters) provides timely indicators of possible contamination. The directive was revised to apply stricter biological standards beginning in 2006, with limits of 100-200 intestinal enterococci and 250-500 e coli bacteria per 100 ml. of water. The directive requires review of bathing waters on two or four year cycles, depending on compliance history at each site. Current compliance is in the range of 92-98% for the minimum standards, with a goal of 100% compliance by 2015.
Technology Needs for Bathing Water Directive

- Real-time monitoring and reporting systems
  - Sensor networks
  - Automated testing systems for turbidity, pH, and salinity
  - Cost-effective multi-contaminant testing for pathogens
  - Cellular, satellite, and radio frequency (RF) interfaces

Drinking Water Directive (80/778, as amended by 98/83)
The DWD largely follows World Health Organization (WHO) guidelines, which are based on a human health risk assessment and management model. The DWD establishes Maximum Admissible Concentrations (MACs) for 66 microbiological and chemical parameters, and specifies monitoring and sampling techniques for drinking water. Compliance dates for newer EU member states range from 2013 to 2018.
The number and type of substances regulated is under review through 2013, which will likely reduce the number of regulated contaminants and bring the DWD closer to WHO guidelines. Areas subject to revision include:

- Bacteriological contamination
- Chemical substances including construction products (pipe materials, etc.) in contact with drinking water
- Small water supplies
- Risk assessment and risk management

One significant provision requires the gradual reduction of lead levels to 10 *u*g/L by 2013, which will necessitate the extensive replacement of lead distribution mains and domestic service laterals. Another policy goal, formulated as part of the sixth environmental action program (2002-2012) is the stricter regulation of pesticides. A preliminary standard of 0.1 *u*g/L has been established for pesticides in water.

DWD standards are also likely to be affected by the Registration Evaluation and Authorization of Chemicals (REACH) program, which seeks to evaluate over 100,000 chemicals between 2007 and 2018 for toxicity and to establish consistent regulatory standards for their use. Of particular concern are substances that have potential endocrine disrupting effects.
Technology Needs for DWD

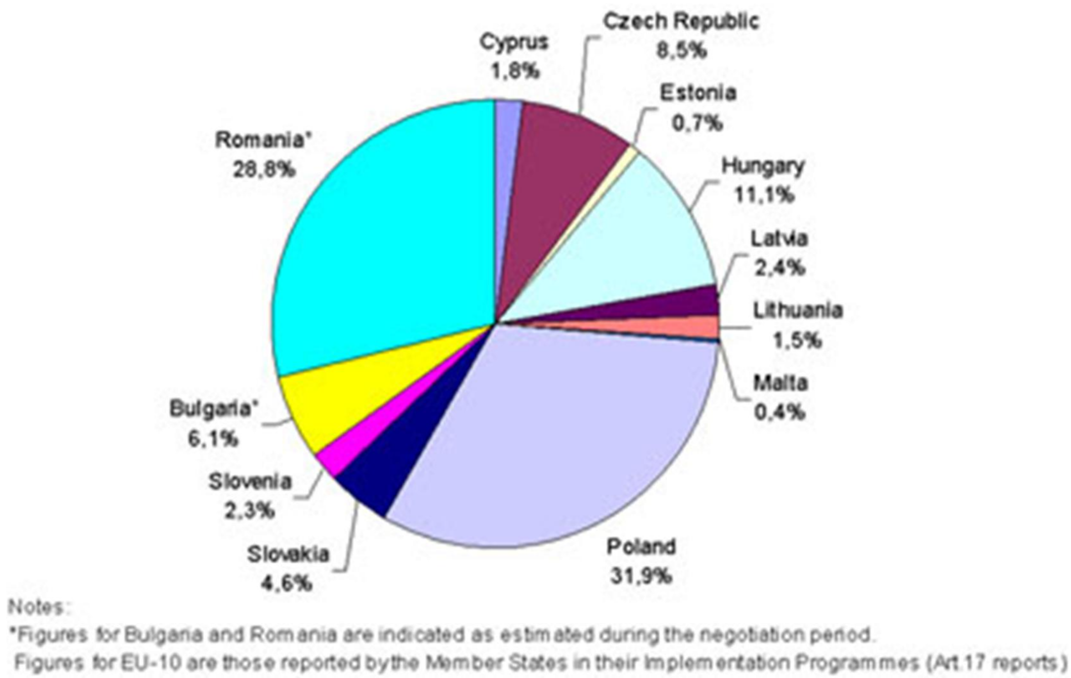
- Real-time multi-contaminant (chemical and biological) testing and alert systems
- Micro/ultra/nano-filtration membranes and materials
- Cost-effective treatment plant upgrades for small water treatment systems
- Low-lead and zero-lead valves, piping, meters, and related products
- Cost-effective pipe replacement and lining systems
- Point-of-use/point-of-entry treatment systems

Urban Wastewater Treatment (91/271, as amended by 98/15)
UWWT requires at least secondary (biological or chemical) treatment of all urban wastewater for cities with a population of 150,000 and over, and additional treatment (coagulation, filtration) if discharged to “sensitive areas,” which designation is based on ecological factors and population density. Similar standards are to be phased in for smaller cities; compliance dates vary by city size and date of the country's admission to the EU. EU-15[5] countries had to be in compliance by 2005, while target dates for EU-12[6] countries range from 2008 to 2018.

5 EU-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom
6 EU-12: Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia

As of 2009, the following segments of the European population had access to wastewater treatment: northern and southern European countries: 80%, Central Europe: > 90%, Eastern Europe: 50% (2002 data), South-eastern Europe (Turkey, Bulgaria and Romania): 35%. Portugal, Finland, and Eastern European countries will be especially affected by UWWT provisions, although most EU countries are currently not in full compliance with UWWT standards. Across the EU, total daily effluent needing treatment is 671 million p.e (population equivalent - the organic biodegradable load generated by one person per day).

Due to the generally low level of compliance with UWWT standards, especially among systems serving smaller communities and among new member states, significant investment in wastewater treatment technology will be required by 2015. Approximately $46 billion in investment will be needed to enable EU-12 countries to meet the standards of the UWWT Directive.



Source: European Commission -Environment, http://ec.europa.eu/environment/water/water-urbanwaste/implementation/factsfigures_en.htm

Technology needs for UWWT

- Optimization and control systems for existing wastewater treatment plants (see Nutrient Control report)
- Small footprint biological nutrient removal (BNR) plants for small communities and industrial sites
- Cost-effective BNR retrofits for existing chemical process plants
- Advanced filtration to remove emerging contaminants

Nitrate Directive (91/676)

The nitrate limit or drinking water is 50 *u*g/L, which is exceeded at 15% of groundwater monitoring stations and 3% of surface water monitoring stations (2007). Nitrate levels in water are strongly tied to agricultural practices, so the directive also sets a limit of 170kg of nitrogen per hectare per year from livestock manure. A corollary goal is to reduce ammonia emissions to soil, water, and air 14% by 2020 compared to the levels in 2000. The goals of the Nitrate Directive are reflected in the EU's Common Agricultural Policy, which provides direct support and rural development programs for farmers. The proposed Soil Framework Directive, which seeks to preserve and protect soil, is also likely to play a large role in nutrient regulation. Technology needs are closely related to those for UWWT, with additional agricultural needs detailed below.

Technology needs and methods for agricultural nitrate control

- Manure processing
- Cost and space-effective manure storage
- Advanced livestock feeding management for lower excretions
- Low nitrogen feed blends
- Biogas generation
- Advanced irrigation systems
- On-site biological effluent treatment
- On-site membrane filtration effluent treatment

Integrated Pollution Prevention & Control (96/61, codified as Directive 2008/1/EC)
IPPC requires permits for industrial sites and other point sources of pollution. The integrated permit program applies to air, water, and ground emissions. Under proposals being debated in 2010, combustion sites would be subject to stricter limits on sulfur dioxide and nitrous oxide emissions beginning in 2016, with some exemptions through 2020. (There is growing awareness that wastewater treatment plants may generate significant quantities of nitrous oxide, which may lead to regulation of treatment plants, especially large urban plants, in the future.)

Sewage Sludge Directive (86/278)
In Europe, treated sewage sludge is used extensively for agricultural purposes. On average, approximately 40% of sludge produced in the EU is applied to fields, with considerable variation by country. The Sewage Sludge Directive encourages such use and sets limits for allowable levels of seven heavy metals. It also specifies testing protocols and record keeping requirements. Several EU member states have set stricter limits and expanded the regulated substance list to include other contaminants and nutrients.

The Sewage Sludge Directive is currently under review (as of 2010). Probable outcomes of the review:

- More stringent limits on heavy metals
- Regulation of organic contaminants
- Regulation of other chemicals

Methods and Technologies for Land Application Sludge Stabilization

- Mesophilic anaerobic digestion
- Aerobic digestion
- Polymer Treatment
- Dewatering

    - Filter pressing
    - Vacuum filtration
    - Centrifuging
- Long-term storage
- Lime conditioning
- Thermal drying
- Composting
- Resource recovery - metals
- Partial resource recovery - nutrients (for fertilization nutrient balance)

Landfill of Waste Directive 1991/102/EC, 1993/275/EC,1991/31/EC
One of the goals of the Landfill Directive is to lower the percentage biodegradable waste disposed of in landfills to no more than 35% of total waste. Most countries had to comply with this directive by 1999. The dates for Greece, Ireland, Portugal, and the UK to achieve full compliance have been extended to the period from 2016-2020, due to their high initial rates of biodegradable materials landfill disposal.

Waste Incineration Directive 98/558/EC, 2000/76/EC
The directive applies to the incineration of sewage sludge, among other applications. It regulates atmospheric and effluent emissions of heavy metals, dioxins and furans, carbon monoxide (CO), dust, total organic carbon (TOC), hydrogen chloride (HCl), hydrogen fluoride (HF), sulphur dioxide (SO2), nitrogen monoxide (No) and nitrogen dioxide (NO2).

The sewage sludge, landfill, and incineration directives may require future policy integration as countries strive to balance the potentially conflicting requirements of these regulations. Agricultural land application of sewage sludge seems like the most environmentally sustainable method of disposal, provided that contamination issues can be addressed. Technology needs will converge on those indicated for agricultural land application.

Priority Substances List 2001/17/EC - Directive 2008/105/EC
Historically, the EU has been more aggressive than the US in banning the production and use of toxic substances. Thirty-three substances or group of substances are on the list of priority substances, emissions of which are to be phased out by 2021. The list is subject to revision every three years, and includes selected existing chemicals, plant protection products, biocides, pesticides, metals, and other groups like Polyaromatic Hydrocarbons (PAH) that are mainly incineration by-products and Polybrominated Biphenylethers (PBDE) that are used as flame retardants. The 2008 directive establishes limits, or Environmental Quality Standards, for the priority substances, as well as for eight additional previously regulated pollutants.

Priority substances
Alachlor, Anthracene, Atrazine, Benzene, Brominated diphenyletheriv, Cadmium and its compounds Chloroalkanes, Chlorfenvinphos, Chlorpyrifos (Chlorpyrifos-ethyl), 1,2-Dichloroethane, Dichloromethane, Di(2-ethylhexyl)phthalate (DEHP), Diuron, Endosulfan, Fluoranthenevi, Hexachlorobenzene, Hexachlorobutadiene, Hexachlorocyclohexane, Isoproturon, Lead and its compounds, Mercury and its compounds, Naphthalene, Nickel and its compounds, Nonylphenols, Octylphenols, Pentachlorobenzene, Pentachlorophenol, Polyaromatic

hydrocarbons, Simazine, Tributyltin compounds, Trichlorobenzenes, Trichloromethane(chloroform), Trifluralin

Certain Other Pollutants
Carbon-tetrachloride, DDT total, para-para-DDT, Cyclodiene pesticides, Aldrin, Dieldrin, Endrin, Isodrin,Tetrachloro-ethylene, Trichloro-ethylene

Technology needs, for mitigation of these contaminants in water, mirror those of the Drinking Water Directive. In addition, since use of the priority substances is to be phased out, there is a need for less toxic substitutes.

Marine Strategy Framework Directive 2008/56/EC
The Marine Strategy Framework Directive mirrors the intent of the Water Framework Directive, in that it forms a holistic and comprehensive approach to achieve “good ecological health” of the EU's coastal and marine environments. The directive was promulgated in 2008, largely in response to concerns about climate change, and establishes a 2020 deadline for achievement of its goals. The European Commission is to issue recommendations on criteria and methodologies in 2010, and member states, working in cooperation with neighboring EU and non-EU countries, must submit measurement criteria and baseline data, and set goals, by July 2012. Baseline data must include economic and social analyses of the costs of marine degradation.

Technology needs for the MSFD

- Monitoring systems for marine environments
- Modeling systems to establish economic and social costs

Flood Risk Management Directive 2007/60/EC
Since 1998, Europe has experienced over 100 catastrophic floods, which have resulted in hundreds of deaths, displacement of over half a million people, and economic losses in excess of $33 billion.[7]

Climate change is expected to increase the frequency and magnitude of flooding events. In response, the Flood Risk Management Directive requires member states to make assessments of areas at risk and draw up plans to mitigate damage. The initial deadlines are given below, after which each step is to be reviewed in six year cycles corresponding with the WFD.

- 2011 - preliminary flood risk assessment of river basins and associated coastal zones
- 2013 - development of flood hazard maps and flood risk maps for such areas, to identify:
  - Likelihood of flooding
  - Expected water depths
  - The number of inhabitants potentially at risk
  - Economic activity damage potential
  - Environmental damage potential
- 2015 - establishment of flood risk management plans for these zones, to address:
  - prevention (*i.e.* preventing damage caused by floods by avoiding construction of houses and industries in present and future flood-prone areas or by adapting future

7 The exchange rate used for all monetary measures in this report is €1 = $1.32 (8/8/2010)

developments)
  - protection (by taking measures to reduce the likelihood of floods and/or the impact of floods in a specific location such as restoring flood plains and wetlands)
  - preparedness (e.g. providing instructions to the public on what to do in the event of flooding).

In light of the local variability of flooding events, the member states are given significant flexibility on flood control objectives and measures.
Technology Needs for FRMD

- Hydrologic modeling systems
- Flood control
  - Pumps
  - Barriers
- Flood resistant building construction methods

Climate Change
The EU is a participant in the Kyoto Protocol, and established the European Climate Change Program II in 2005 to address climate change issues. The EU has committed to reducing its greenhouse gas emissions 20-30% by 2020. Climate changes concerns, in part, drive a number of EU water regulations, including the Flood Risk Management Directive and the Marine Strategy Directive. In addition, water scarcity due to climate change is a concern. In 2007, seven policy options were identified to address water scarcity and drought issues:

- Putting the right price tag on water
- Allocating water and water-related funding more efficiently
- Improving drought risk management
- Considering additional water supply infrastructures
- Fostering water efficient technologies and practices - Eco-Design Directive
- Fostering the emergence of a water-saving culture in Europe - Ecolabel for efficient products
- Improve knowledge and data collection

Overall, climate change initiatives are expected to cost $79 billion to $105 billion annually in the EU.

Technology Needs for Climate Change Initiatives

- Energy efficient water and wastewater treatment processes
- Energy generation from wastewater
- Resource recovery from wastewater
- Efficient pumping and water transport systems
- Water reuse technologies
- Waste heat recovery from industrial and power plant cooling processes
- Water efficient power plant cooling

Development
The EU is committed to achievement of the UN's Millennium Development Goals, and has a priority on those specifically related to water and sanitation in developing countries. The EU

Water Initiative (EUWI) aids developing countries with their water and sanitation programs, with a current focus on Africa. EUWI has established a water research network (SPLASH), which includes 16 government and non-governmental organizations from 11 countries. EUWI programs may provide access to non-European water markets for US water technology companies, if European countries do not produce appropriate technology.

EU Funding for Water

One difference between water regulation in the EU and US is that there are wider variations in conditions across the EU. Cultural, economic and environmental differences, as well as the level of technological development in each county and its length of tenure in the EU lead to highly variable rates of compliance with EU regulations. As a result, the EU has committed to reducing these variations among its member states. EU Structural and Cohesion Funds for water and wastewater infrastructure will total $29 billion from 2007 to 2013. The majority (60%) of funding will go to the EU-12 countries, with the remainder going to poor regions of the EU-15 countries. As a condition of fund acceptance, member states, with some exceptions, must comply with the WFD requirement to establish full-cost recovery pricing for water.

Scale

The five largest water markets in Europe are Germany, France, Italy, the United Kingdom (UK), and Spain. Collectively, they account for an estimated $93 billion, or nearly 20%, of the annual worldwide water market. All five are members of the EU. Other EU countries with annual markets in the $5 billion range include Poland, the Netherlands, and Belgium - non-EU countries in Europe with significant water markets include the Russian Federation and Switzerland. The water technology needs in these countries will largely follow those outlined for the major EU water directives. Additional technology needs specific to each country are noted at the end of their respective sections.

4.13 Germany

Key Markets
Conversion of Industrial WWTPs from chemical to biological (BNR) processes
Power plant cooling water efficiency and reuse

Demographic Indicators

Population	**2009**	**2016**	**2020**
Urban Population	60.8M	61.1M	-
Rural Population	21.6M	20.6M	-
Total Population	**82.4M**	**81.7M**	**80.4M**
Population Growth Rate	**2010-2015**		
Urban Population Growth Rate	0.07%		
Rural Population Growth Rate	-0.73%		
Total Population Growth Rate	-0.13%		

Source: (Global Water Intelligence, 2010)

Background

Germany's population of 82 million makes it the largest member of the EU by population rank, and its GDP (PPP) of $2.9 trillion makes it one of the world's largest economies. Per capita GDP (PPP) of $36,000 is in the upper range for EU countries.
Approximately three-quarters of the population is urban, with very slight growth expected through 2016. Rural population is expected to decline more significantly over the same period, resulting in a negative net growth rate. The UN projects a long-term decline in Germany's population.

Germany has plentiful water resources, along with an extensive infrastructure network to treat and transport water anywhere it is needed throughout the country. It achieves very high levels of water and wastewater treatment for virtually its entire population. The expected decline in population, combined with the trend toward lower domestic per capita water consumption (currently 31 gallons per day), may result in lower revenues in the future. The main challenges facing the country will be maintaining high water quality levels and meeting future EU standards, including initiatives related to climate change and nutrients, in an environment of declining consumption.

Key Dimensions

Over 99% of the German population is connected to a metered public water supply, and wastewater treatment coverage exceeds 95%. Most of the country is classified as a "sensitive" area for purposes of the EU's UWWT Directive. Consequently, 98% of treated wastewater gets tertiary treatment (biological treatment with additional nutrient removal), while 99% receives at least secondary treatment (biological treatment). A very small proportion of the country's public treatment plants use chemical processes for secondary treatment.
Two-thirds of the public water supply is from groundwater sources, and one-quarter is from surface water, with the remainder sourced from springs. Public supplies account for 16% of water withdrawals, while agriculture, mining and industry, combined, account for 22%. The

largest share of water withdrawal, 62%, is used for power plant cooling. Water loss in the public supply is estimated to be just over 7%, a very low number.

A large percentage of industrial users is not connected to the public supply. More than 94% produce their own water, mostly from surface water sources. It is unclear how much of this use is metered. In addition, there are approximately 3,300 industrial wastewater treatment plants, two-thirds of which utilize chemical (rather than biological) treatment processes.

Market Scale

The overall water market is the largest in the EU, estimated at nearly $30 billion annually, though this figure is expected to decline in the future (see above). Annual municipal capital expenditure for water is expected to decline steadily from $2.1 billion in 2010 to $1.8 billion in 2016. Municipal capital expenditure for wastewater is also projected to decline from $6.9 to $3.3 billion annually, with the sharpest decline coming between 2014 and 2015.

Germany has just over 13,000 public water treatment plants and nearly 10,000, public, wastewater treatment plants, with the capacity to treat 3.7 billion gallons of water and 7.3 billion gallons of wastewater per day. There are 310,000 miles of water infrastructure and 345,000 miles of wastewater infrastructure.

Water technology is highly advanced, reflecting high levels of investment and engineering expertise.

Policy

Germany is a federation of sixteen states. The provision of public water and wastewater services is left up to local municipalities, while standards are generally set at the state and federal levels, in conformance with EU directives and national priorities.

There is an increasing trend toward public-private partnerships for the provision of water services in Germany. There is a large degree of participation by private companies in the water sector, but the partnerships are typically under majority control of the municipalities. Forthcoming EU concession directives that are expected to mandate competitive bidding for public procurement in the water sector have the potential to alter this situation to the benefit of the private sector.

Germany is already at the forefront in meeting EU water directives for contaminant levels in drinking water, bathing water, and wastewater. It has a relatively small amount of coastline compared to other large European countries, so the Marine Strategy Framework Directive is likely to have a lesser impact there than in other countries. However, Germany is home to a multitude of significant river basins, including the Oder, the Danube, the Rhine, the Weser, and the Elbe. Ongoing compliance with the provisions of the Flood Risk Management Directive is likely to consume a larger share of water development resources in the future.

Technology Needs - Germany

- Industrial WWTPs - conversion of chemical plants to biological processes to meet more stringent effluent nutrient standards

4.14 Italy

Key Markets	Niche Markets
Distribution system water loss (leakage) analysis and control technology	Coastal water monitoring
Distribution and collection system infrastructure replacement	
WWTP upgrades	

Demographic Indicators

Population	2009	2016	2020
Urban Population	40.2 million	41.1 million	-
Rural Population	18.7 million	17.9 million	-
Total Population	**59.0 million**	**59.0 million**	**60.4 million**
Population Growth Rate	**2010-2015**		
Urban Population Growth Rate	0.31%		
Rural Population Growth Rate	-0.72%		
Total Population Growth Rate	-0.01%		

Source: (Global Water Intelligence, 2010)

Background

Italy has a population of nearly 60 million, the fourth largest in the EU. Its GDP (PPP) of $1.8 trillion makes it one of the world's largest economies, while per capita GDP (PPP) of $31,000 is in the middle of the range for EU-15 countries.

Approximately two-thirds of the population is urban, with slight growth expected through 2016. Rural population is expected to decline more significantly over the same period, resulting in flat population growth overall. Over the longer term, Italy's population is expected to grow slowly through 2025 and then decline to 2000 levels by 2050.

Italy's water resources vary by region. The northern part of the country has plentiful freshwater supplies, while southern regions and island areas experience periods of water stress. The country's relatively high per capita water consumption of 98 gallons per day may be attributed in part to the high average loss (leakage) rate of 32% in the distribution network. Water loss rates exceed 40% for several large cities; in one (Bari), the loss rate is 52%. Given these rates, infrastructure rehabilitation and replacement is a significant need in Italy. The country's high proportion of coastline relative to its area makes the provisions of the EU Marine Strategy Framework Directive and climate change initiatives especially relevant.

Key Dimensions

Over 95% of the Italian population is connected to a metered public water supply. Wastewater treatment coverage exceeds 84%, but the country has had difficulty complying with the EU's UWWT Directive. As of 2009, at least 800 cities across the country did not meet required standards.

Surface water comprises four-fifths of potential resources, while groundwater comprises the remaining one-fifth. Lack of storage and distribution networks limits currently exploitable resources to approximately 40% of total potential resources. Public supplies account for 18% of water withdrawals while agriculture accounts for 45%, and industry accounts for 37%. As mentioned above, water loss in the public supply network is significant, and averages 39% if losses in the raw-water transfer system are included.

Most drinking water is from groundwater sources requiring varying levels of treatment. A significant percentage requires no treatment. Contaminants such as arsenic, fluoride, magnesium, and sodium present problems, especially in smaller and remote communities.

Market Scale

Italy's overall annual water market is estimated to be nearly $17 billion, and is expected to grow significantly (6.8% annually for the utility sector) in the coming years. Annual municipal capital expenditure for water is expected to rise from $1.3 billion in 2010 to $2.7 billion in 2016, with growth in all categories. Capital expenditure by municipalities for wastewater is also projected to rise from $1.2 to $2.5 billion annually, with the most rapid growth in network expansion and rehabilitation, and treatment plants.

Italy has 2,000 public water treatment plants and nearly 17,000 public wastewater treatment plants, with the capacity to treat 2.1 billion gallons of water and 4.2 billion gallons of wastewater per day. There are 109,000 miles of water infrastructure and 102,000 miles of wastewater infrastructure.

Policy

Italy's current water utility framework is based on 92 territorial areas (ATOs in Italian) created as a result of the Galli Law of 1994. These administrative units are responsible for the provision of water and wastewater services within their jurisdictions, which overwhelmingly are provided by public utilities.

The Ronchi Decree of 2009 requires gradual public divestment in water utilities, to 40% or less by 2013 and 30% or less by 2015. This legislation, combined with the potential EU public procurement legislation, may increase the opportunities for private sector participation in Italy's water sector. However, both the Italian and EU measures are controversial and subject to modification or reversal.

Overall, Italy has extensive needs in the areas of infrastructure replacement and expansion, and water and wastewater treatment, in order to meet current EU and national standards. Meeting the upcoming requirements of the Flood Management and Marine Strategy Directives, and climate change initiatives, will result in further product and technology needs.

Technology Needs - Italy

Italy has a national requirement to upgrade to smart meters for electricity. There may be an opportunity for similar initiatives in the water sector to help reduce the country's significant water losses.

- District metered areas for loss control
  - Valves
  - Piping
  - Meters
  - Monitoring and control systems

4.15 United Kingdom (UK)

Key Markets	Niche Markets
Distribution system water loss (leakage) analysis and control technology	Desalination
Distribution and collection system infrastructure replacement	Wastewater treatment systems for rural areas
Metering for urban areas and Northern Ireland	Water re-use

Demographic Indicators

Population	2009	2016	2020
Urban Population	55.2 million	57.2 million	-
Rural Population	6.0 million	5.9 million	-
Total Population	**62.3 million**	**63.0 million**	**65.1 million**
Population Growth Rate	**2010-2015**		
Urban Population Growth Rate	0.51%		
Rural Population Growth Rate	-0.56%		
Total Population Growth Rate	0.41%		

Source: (Global Water Intelligence, 2010)

Background

The UK is one of the most populous member states of the EU, with 62 million people. GDP (PPP) is $2.2 trillion, while the per capita GDP (PPP) of $37,000 is in the upper range for EU countries.

Approximately 89% of the population is urban, with slight growth expected through 2016. Rural population is expected to decline over the same period, resulting in a net growth rate of 0.41%. Long-term, the population of the UK is expected to increase steadily through 2050.

The UK has a sufficient water resources overall, but high population density in many areas makes regional water shortages a potential for as many as 17 million people. The UK largely meets the requirements of current EU water directives for drinking, bathing, and wastewater. It achieves adequate levels of water and wastewater treatment for the vast majority of its population. Per capita domestic water consumption is relatively low at 38 gallons a day. The main challenges facing the country are modernization of its distribution and collection infrastructure, metering and conservation, and compliance with coming EU water standards, including potential initiatives related to climate change.

Key Dimensions

Nearly 100% of the population in the UK is connected to a public water supply, but only 23% of connections are metered. Thames Water, which serves London, has set a goal to have 100% of the city's buildings metered by 2020, but goals for other areas of the UK are unclear. Wastewater treatment coverage exceeds 96% in the UK, with nearly 99% receiving at least secondary

treatment. Rural areas and Northern Ireland have the lowest rates of wastewater treatment coverage.
Public water supply accounts for 48% of water withdrawals, power plant cooling for 28%, and industry for 12%. Aquaculture accounts for 10%, although this has been declining in recent years, while agriculture (including spray irrigation) accounts for just 0.3% of withdrawals, no doubt due to the plentiful precipitation the region is known for. Water loss in the public supply is estimated to be nearly 21%, a relatively high number for a developed country, which, in part, reflects the advanced age of most of the UK's water infrastructure, as well as the lack of extensive metering infrastructure to aid in pinpointing leaks and to encourage conservation.

The UK has started to pursue desalination as an answer to potential water shortages in the densely populated southeast section of the country. The Thames Gateway Water Treatment plant, with a capacity of 39 million gallons per day, was brought on-line in 2010 at a total project cost of $356 million. The project is controversial, as some believe that wastewater re-use would be preferable from energy use and related greenhouse gas emissions standpoints.

Market Scale
The overall water market is significant, estimated at nearly $13 billion annually, with modest growth expected. Annual capital expenditure for water network rehabilitation is expected to rise steadily from $1.5 billion in 2010 to $2.0 billion in 2016. Overall annual capital expenditure by municipalities for water will range from $2.2 billion to $3.1 billion over the same period. For wastewater, annual municipal expenditure estimates range from $1.3 to $1.7 billion for network rehabilitation and from $2.7 to $3.4 billion overall.

The UK has just over 1,500 water treatment plants and over 9,000 wastewater treatment plants, with the capacity to treat 5.4 billion gallons of water and 3.2 billion gallons of wastewater per day. There are 254,000 miles of water infrastructure and 245,000 miles of wastewater infrastructure. Water and wastewater treatment has been almost full privatized since the adoption of legislation in 1989 which privatized water providers in England and Wales. The legislation did not apply to Scotland and Northern Ireland, but the trend in those areas has been toward privatization as well.

Policy
The UK has three main regulatory bodies with authority over water: the Department for Environment Food and Rural Affairs (defra) in England and Wales, the Scottish Parliament in Scotland, and the Northern Ireland Assembly in that country. In addition, the Office of Water Services (Ofwat) regulates the economic aspects of water provision in England and Wales, with authority over rates for services and utility rates of return. A similar function is provided by the Water Industry Commission for Scotland (WICS) in that country. Currently, Northern Ireland does not charge for domestic water.

The UK has adopted EU water directives as required, except for the full-cost recovery mandate in Northern Ireland.

The Marine Strategy Framework Directive and the Flood Risk Management Directive are likely to consume an increasing share of water development resources in the future, due to the UK's maritime location and susceptibility to climate change effects.

Technology Needs - UK
Increasing pressure for operational efficiencies and water conservation is likely to result in an increased rate of metering, up from the current 23%. Increasing costs for infrastructure replacement, combined with the opportunity to install metering equipment concurrently with infrastructure construction, may also have similar effects in encouraging increased metering of water.

- Meters and metering infrastructure

4.16 France

Key Markets	Niche Markets
Distribution system water loss (leakage) analysis and control technology	Rainwater collection
Secondary/Tertiary wastewater treatment	Decentralized wastewater treatment systems (septic and clustered)
Water re-use	Coastal water monitoring

Demographic Indicators

Population	**2009**	**2016**	**2020**
Urban Population	48.2 million	50.7 million	-
Rural Population	14.0 million	13.3 million	-
Total Population	**62.0 million**	**64.0 million**	**64.9 million**
Population Growth Rate	**2010-2015**		
Urban Population Growth Rate	0.70%		
Rural Population Growth Rate	-0.71%		
Total Population Growth Rate	0.40%		

Source: (Global Water Intelligence, 2010)

Background

France's population of 62 million and its GDP (PPP) of $2.1 trillion are on par with the UK. Since France is the largest country in the EU by area, average population density is significantly lower. Per capita GDP (PPP) of $34,000 is average for EU-15 countries.

Approximately three-quarters of the population is urban, with slight growth expected through 2016. Rural population is expected to decline at a similar rate over the same period, resulting in a net annual growth rate of 0.40%. The UN projects slowing population growth through 2050.

Even though France's population is growing, demand for water has been declining, in line with other highly developed areas where access to efficient water saving appliances and fixtures is increasing. Per capita water consumption is currently 74 gallons per day. The main challenges facing the country are bringing hundreds of smaller wastewater treatment plants into compliance with EU standards and meeting future water EU standards, including initiatives related to climate change.

Key Dimensions

In France, 99% of the population is connected to a public water supply, and virtually all connections are metered. Wastewater treatment coverage is 80%, with 29% of treated wastewater receiving at least secondary treatment, and 18% receiving tertiary treatment. Nearly one-fifth of the population, mostly in rural areas, relies on decentralized wastewater treatment, such as septic systems.

The private sector provides most of the water (71% in 2008) and wastewater (56%) service in France. The country is home to three of the largest water technology companies in the world, Veolia, Suez, and Saur, which dominate these markets. There is ongoing pressure from municipalities to continue the trends of increasing competition and lower rates. This will be especially important in coming years, as contracts are coming up for renewal in some of the country's largest cities.

Four-fifths of the public water supply is from groundwater sources, with the remainder sourced from surface water. Public supplies account for 15% of water withdrawals, agriculture for 13%, and industry for 22%. The largest share of water withdrawal, 62%, is used for energy production, including power plant cooling for France's numerous nuclear facilities. Water loss in the public supply is estimated to be 27%, a fairly significant number.

France is at the forefront of water reuse initiatives in Europe. It has developed guidelines and regulations for agricultural and other irrigation uses, as well as for rainwater harvesting, most recently in 2008. Reuse for irrigation is already common, and several large rainwater harvesting projects are in the works, most notably for the city of Toulouse.

Market Scale

The overall water market is estimated at nearly $23 billion annually, with annual increases of about 2%. Annual municipal capital expenditure for water is expected to rise steadily from $3.1 billion in 2010 to $3.7 billion in 2016. Municipal capital expenditure for wastewater is also projected to rise from $4.0 to $5.4 billion annually, with the most rapid growth in network expansion and rehabilitation, and for treatment plants.

France has just over 15,000 public water treatment plants and over 17,000 public wastewater treatment plants, with the capacity to treat 6.0 billion gallons of water and 1.3 billion gallons of wastewater per day. There are 527,000 miles of water infrastructure and 155,000 miles of wastewater infrastructure.

Relatively low proportions of wastewater infrastructure and capacity exist for the country's large land area and population. Since several hundred, mainly smaller, wastewater treatment plants currently fail to achieve secondary treatment standards, as required by the EU's UWWT Directive, there is currently a national priority for wastewater treatment. Estimates of the investments required to bring the country into compliance for wastewater are in the range of $6.6 billion annually.

Water and wastewater technology is highly advanced, in part reflecting the presence of large global water services companies. Aquaviva, a WWTP in Cannes that utilizes membrane bioreactor technology, is the first carbon-neutral project of its kind. These types of projects will become more critical as France and other EU countries strive to meet Kyoto Protocol regulations to combat global warming. France has 82 desalination plants.

Policy

Decisions for the provision of public water and wastewater services are left up to local municipalities. As noted above, many municipalities contract with private sector companies for service provision.

Regulations are generally set at the national level by the Ministry of Ecology (MEDAD) and the French National Agency for Water and Aquatic Environments (ONEMA) in conformance with EU standards. There are eight catchment area committees and six regional water agencies responsible for zoning, water quality and financial management.

The country has a relatively large amount of coastline, along with a major island, Corsica, and shares *la Manche* (the English Channel) with the UK, so the Marine Strategy Framework Directive is likely to have a significant impact. France is also home to a large number of river basins, including the Seine, Loire, Rhône, Garonne, Dordogne, and Gironde. In addition, there are several extensive canal systems, including the Burgundy, du Centre, and du Midi. As a result, compliance with the provisions of the Flood Risk Management Directive is likely to consume a significant share of water development resources in the future.

Technology Needs - France

- Cost and energy efficient wastewater plants for small municipalities
- Decentralized wastewater treatment systems (septic and clustered)
- Greywater technology
- Rainwater harvesting systems for indoor and outdoor water applications

4.17 Spain

Key Markets	Niche Markets
Distribution system water loss (leakage) analysis and control technology	Coastal water monitoring
Desalination	
Water re-use, conservation, and efficiency	
Wastewater treatment for small municipalities	
Drought mitigation for agricultural areas	

Demographic Indicators

Population	**2009**	**2016**	**2020**
Urban Population	34.6 million	36.2 million	-
Rural Population	10.2 million	10.0 million	-
Total Population	**44.8 million**	**46.2 million**	**48.6 million**
Population Growth Rate	**2010-2015**		
Urban Population Growth Rate	0.62%		
Rural Population Growth Rate	-0.41%		
Total Population Growth Rate	0.40%		

Source: (Global Water Intelligence, 2010)

Background
Spain has a population of nearly 45 million, with a GDP (PPP) of $1.4 trillion. Per capita GDP (PPP) of $31,000 is in the middle of the range for EU-15 countries.

Approximately three-quarters of the population is urban, with modest growth expected through 2016. Rural population is expected to decline over the same period, resulting in overall population growth of 0.40%. Over the longer term, Spain's population is expected to grow steadily through 2050.

Of the five largest EU countries, Spain is the most susceptible to drought conditions, especially in the southeastern region where precipitation is minimal. Domestic per capita water consumption is 82 gallons per day. The country's extensive coastline, including its large islands, makes the provisions of the EU Marine Strategy Framework Directive and climate change initiatives especially relevant.

Key Dimensions
Ninety-three percent of the Spanish population is connected to a public water supply, of which 95% is metered. Wastewater treatment coverage is 80%, with 96% of treated wastewater receiving secondary treatment or better. However, many municipalities are out of compliance with the EU's WFD. In 2007, the National Wastewater Quality Plan was announced, with the goal of complete compliance by 2015.

Surface water accounts for a large share of water resources. The country has built dams to capture and store surface water for its needs, and it has the highest number of dams per capita in the world. Public supplies account for 13% of water withdrawals, while agriculture accounts for 68%, and industry accounts for 19%. Water loss in the public supply network averages 24%, a significant figure given the country's supply shortages. Over-pumping of groundwater has led to seawater intrusion of coastal aquifers in some areas.

In addition to a number of small existing desalination plants, Spain has built several large plants since 2002 to augment freshwater supplies. The six largest plants have a combined capacity of nearly 300 million gallons per day. More projects are planned, but due to the high energy requirements for desalination, recent attention has also been focused on water reuse.
Water reuse is governed by 2007 legislation. Currently, 119 billion gallons of wastewater are reused annually, with the majority going for agricultural use.

Market Scale
Spain's overall annual water market is estimated to be in excess of $11 billion, and is expected to grow significantly (8.8% annually for the municipal sector) in the coming years. Annual municipal capital expenditure for water is expected to rise from $1.1 billion in 2010 to $1.7 billion in 2016, driven by growth in resource development and treatment plant categories. Capital expenditure by municipalities for wastewater is projected to rise dramatically over the same period, from $400 million in 2010 to $2.9 billion by 2016, with rapid growth in all categories.

The number of water treatment plants in Spain and their capacity are not known with certainty, but current output is more reliably estimated at 3.3 billion gallons per day. Estimates of the number of public, wastewater treatment plants range from 1,800 to 3,600 Collectively, they have the capacity to treat 5.6 billion gallons of wastewater per day. There are 83,000 miles of water infrastructure and 56,000 miles of wastewater infrastructure.

Nearly half of water and wastewater services are provided by state-owned companies, 7% by municipal companies, 32% by private sector companies, and 12 by public-private partnerships. The ambitious National Wastewater Quality Plan is expected to cost $25 billion between 2007 and 2015. However, Spain fared poorly in the recent worldwide economic downturn, and further investments in the plan are highly dependent on the state of the country's economy.

Policy
Governance in Spain is highly decentralized as a result of the Constitution of 1978, which created regional autonomous communities that are responsible for most governmental functions. There are currently 17 autonomous communities. The central government's Ministry of the Environment oversees the country's Water Directorate Council. There is also a representative National Water Council, with advisory and cross-jurisdictional functions.

Municipalities are responsible for the provision of water and wastewater services within their jurisdictions, with the authority to enter into contracts and partnerships with the private sector.

To address water scarcity, Spain has set up centers for the exchange of water rights, which encourage the establishment of water banks and trading of water rights to promote conservation and efficiency.

4.18 Poland

Key Markets
Distribution system water loss (leakage) analysis and control technology
Wastewater treatment infrastructure and technology

Background
Poland has a current population of nearly 38 million, with a GDP (PPP) of $670 billion. Per capita GDP (PPP) of $18,000 is in the upper range for EU-12 countries. GDP is projected to grow at a 5% rate.

Approximately three-fifths of the population is urban, with slight contraction expected through 2016. Rural population is also expected to decline over the same period, resulting in an overall negative growth rate of -0.17%. Over the longer term, Poland's population is expected to decline steadily through 2050.

Poland's very low level of water reserves, combined with loss rates of 30-40% in the distribution network, may lead to future water scarcity. This possibility may be mitigated by the trends of declining per capita consumption and expected long-term population loss. On the wastewater side, significant investments are needed to bring the county into compliance with the UWWT by 2015. Approximately 35% of existing plants are not using biological treatment methods and may be candidates for conversion to enhanced biological processes.

Key Dimensions
Eighty-six percent of the Polish population is connected to a metered public water supply. Wastewater treatment coverage is 80%, with 86% of treated wastewater receiving secondary treatment or better. Public supplies account for 18% of water withdrawals, while agriculture accounts for 9%, and industry accounts for 73%.

Market Scale
Poland's overall annual water market is estimated to be nearly $7 billion and is expected remain relatively stable through 2014, with a decline thereafter. Poland will require almost a third of the $46 billion total required to bring EU-12 countries into compliance with the UWWT, or nearly $15 billion by 2015. Approximately 1,000 wastewater treatment plants and 13,000 miles of collection system infrastructure are planned. As a new EU member state, Poland is eligible for a high proportion of EU structural and cohesion funding for water projects.

A $660 million wastewater project in Warsaw is slated for completion in 2010, with additional projects planned for Krakow, Gdansk, and Wroclaw. The combined cost estimate for these projects is approximately $500 million.

Policy
Significant government programs currently in force include the National Program for Municipal Waste Water Treatment and the Infrastructure and Environment Operational Program. They are coordinated with various other national and European initiatives to modernize and expand wastewater treatment across the country.

4.19 The Netherlands

Key Markets	Niche Markets
Wastewater treatment infrastructure and technology	Alternatives to chlorination for drinking water treatment
Small scale wastewater treatment plants for industrial applications	

Background
The Netherlands has a population of 16 million. Its GDP (PPP) of $680 billion gives it a per capita GDP (PPP) of $41,000, which is in the upper range for EU-15 countries. GDP is projected to grow at a 2% rate.

Over four-fifths of the population is urban, with growth expected through 2016. Rural population is expected to decline substantially over the same period. Overall net growth for the period is estimated to be 0.15%. Over the longer term, growth is expected through 2040, with a decline thereafter.

Key Dimensions
The entire population of The Netherlands is served by water utilities, and 93% - 96% of supply is metered. Excessive nutrients and copper are contaminants of concern in surface waters. Wastewater coverage exceeds 99%, with 98% of wastewater receiving secondary treatment or greater. The entire country is classified as a sensitive area under the UWWT Directive, in part due to its high population density (the highest in Europe). Water loss in the distribution system is extremely low, at 5%.

As much of the country is below sea level, flooding is a significant threat. Dikes and canals are used to control seawater and surface water, while the use of groundwater is limited (regulated by fees) due to the threat of land subsidence. EU flood management and marine strategy directives will play a significant role in the development of future policy in the Netherlands, and the country's success in managing surface water is likely to serve as a model for other EU countries as they develop their own plans in these areas.

Partial pre-treatment of wastewater by industrial users is becoming more common as companies seek alternatives to public wastewater fees. Several hundred WWTPs cater to this market. Desalination is used to augment freshwater supplies, employing a variety of advanced technologies including ultra-filtration, ultraviolet, and hydrogen peroxide treatment.

Water reuse is currently employed for groundwater recharge, industrial supply, and firefighting, among other applications. Reuse is likely to grow in importance as an alternative to the generally more energy-intensive desalination processes.

Market Scale
The overall water market in The Netherlands is estimated at $5.4 billion annually, with slight growth expected through 2013 followed by a moderate decline through 2016. Wastewater network expansion and wastewater treatment plants will drive most of the growth.

Ten Public Limited Companies, owned by municipalities and provinces but operated like private sector companies, provide public water service. Private sector participation in industrial supply is significant.

Policy
The 2009 Water Act is the major piece of legislation governing water in the Netherlands. It takes an integrated approach to water management, in line with the intent of the EU's WFD.

A 2006 regulation restricts chlorine use.

Technology Needs

- Alternatives to chlorine for drinking water disinfection
- Small scale WWTPs for industrial applications

4.20 Belgium

Key Markets	Niche Markets
Secondary/Tertiary wastewater treatment	Desalination of brackish water
Water re-use and resource recovery from wastewater	

Background

Belgium has a highly urbanized population of 11 million. GDP (PPP) is $700 million, and per capita GDP (PPP) is $37,000, in the upper level of EU-15 countries.

Just 3% of the population is classified as rural. Following the general pattern in Europe, urban population is expected to increase, while rural population is expected to decline, in Belgium's case, leading to a 0.2% overall growth rate through 2016. GDP is expected to grow at a 1% pace over the same period.

Belgium is a highly industrialized country with a poor record of compliance with EU standards for water, particularly UWWT and WFD. It may be subject to EU sanctions if performance does not improve sufficiently to meet standards.

Key Dimensions

Water service coverage exceeds 98%, and 90% of public supply is metered. Domestic water consumption is very low, at just 26 gallons per capita per day. However, industrial users, particularly the energy sector, account for over 90% of water demand. Water loss is estimated at 19%.

Wastewater coverage is 86%, but just 60% of treated wastewater receives at least secondary treatment. The entire country is a sensitive area under the UWWT Directive. Belgium has been adding wastewater treatment capacity, but still has a way to go to achieve compliance.
There are nearly two dozen desalination plants in the country, mostly to treat brackish water, rather than seawater. Water reuse is increasing in importance (see policy section).

Market Scale

The total annual water market is $4.5 billion, with 3.6% annual growth expected in the utility sector through 2015. Wastewater network and treatment plants will experience the most growth, along with supply network expansion and rehabilitation.

Policy

Belgium will need to focus its water policy more intently on achieving compliance with EU directives, particularly those concerning wastewater and surface water quality.
Belgium is participating in Project Neptune, an EU initiative to increase water reuse and resource recovery from wastewater. Reuse projects are likely to figure more prominently in the country's future efforts to achieve wastewater compliance.

Technology Needs

- Water reuse technologies

Non-EU Markets

4.21 Switzerland

Key Markets
Power plant cooling water efficiency and reuse
Emerging contaminants
Pathogen detection and control for surface and groundwater

Background

Switzerland has a population of nearly 8 million, and its GDP (PPP) is $300 billion. GDP (PPP) per capita is $42,000, placing it in the top tier of European countries. Estimated annual growth in GDP through 2016 is nearly 2%.

Three-quarters of the population is urban, with slight growth expected through 2016 and a decline in rural population over the same period, leading to an overall growth rate of 0.3%. Switzerland has ample freshwater resources, a large percentage of which requires minimal or no treatment. Though it is not an EU-member-state, it meets or exceeds virtually all EU standards for water and wastewater. It also coordinates with neighboring EU countries on watershed level projects that span national borders.

Key Dimensions

Virtually the entire population is connected to a metered supply, and wastewater coverage is 97%, with 100% receiving secondary treatment and 40% receiving tertiary treatment. Water loss in the distribution system is just 12%. All water and wastewater services are provided by publicly-owned utilities.

A large percentage of the country's energy needs is supplied by hydro-electric and nuclear generation, both of which require large amounts of water. Increasing concerns about the effects of dams on the environment, along with various climate change scenarios, may lead Switzerland to re-evaluate its energy options in the future.

The country has large chemical manufacturing and pharmaceutical sectors. Recent concerns over emerging contaminants detected in the country's water, such as endocrine disrupting chemicals and pharmaceuticals, has led to plans for modifications of water and wastewater treatment plants to address the issues. Activated carbon, nanofiltration, and ozone technologies are being used to treat water and wastewater.

Concern over pathogens is leading to increased adoption of UV technology as a precautionary measure for treatment plants that use surface water as a source.

Flood control is an issue, in light of climate change predictions.

Market Scale

The annual Swiss water market is $4.4 billion, with an estimated growth rate of approximately 1% through 2016. Growth is evenly spread among all categories, reflecting the generally high level of current performance in all sectors. Needs will come in the form of enhancements to existing systems as more efficient and effective technology is developed.

There is a trend toward consolidation of services to larger plants to take advantage of economies of scale, as the latest enhancements are typically rolled out to the largest treatment plants first and may be cost-prohibitive for smaller plants.

Wastewater treatment plants will receive upgrades to control emerging contaminants, starting with the largest plants. By 2022, plants serving at least half of the country's population will have the upgraded (ozone treatment) systems.

Policy

Government water policy generally adheres to the EU framework, to include cooperation with EU member states.

Recent regulatory actions have tightened standards for pathogens and emerging contaminants, as detailed above.

Technology Needs

- Pathogen control methods
- Filtration for emerging contaminants

4.22 Russian Federation

Key Markets
Distribution system expansion
Distribution system water loss (leakage) analysis and control technology
Wastewater treatment infrastructure and technology

Background
Russia's population of 141 million is 75% urban and largely concentrated in the European section of the country. Steady population declines are projected for the short and long terms. GDP (PPP) is $2.3 billion, with a per capita GDP (PPP) of $16,000. A robust annual GDP growth rate of 5.6% is projected.

Russia has extensive freshwater resources, but the majority of water and wastewater infrastructure is in need of repair or replacement. Up to 60% will need timely rehabilitation while 30% must be replaced.

Key Dimensions
In 2008, Russia formulated a national plan to improve water and wastewater services. The Clean Water Program is to be implemented in two phases, 2009 to 2012, and 2012-2017. Goals of the program include:

- Increasing the percentage of the population with access to a public supply from 78% to 90%,
- Reducing system losses from 19% to 15%
- Increase the portion of wastewater that fully meets standards from 40% to 68%.
- Improve drinking water quality
- Increase utilities' capital spending from 15% of expenditures to 40% of expenditures

Market Size
The overall water market in the Russian Federation is estimated to be $4.5 billion annually. Utility sector growth is expected to be 2% through 2016, with water and wastewater treatment plants accounting for most of the increase.

A wastewater treatment project is currently underway in St. Petersburg, estimated to cost $3.9 billion. Expected completion is in 2012.

Increasing affluence is expected to drive future growth in Russia's water market, despite a decline in population.

Policy
Recent initiatives include the encouragement of more private sector participation in the water and wastewater markets.

4.23 Smaller, High-growth European Markets

There are a number of smaller European countries experiencing high growth in their water markets for a variety of reasons. In some cases it is due to population growth or a dramatic increase in the standard of living. In others, the reason is recent or anticipated admission into the EU, in which case funding is available to help new member states meet EU water standards. For example, EU-12 countries are eligible for up to $46 billion in EU funds over the next few years to meet the requirements of the UWWT Directive. Other sources, such as World Bank Urban Infrastructure Funding and funding from other international development programs, may also be available.

Although their individual water markets are relatively small, even tiny in some cases, these countries may provide ground-floor or niche opportunities for water technology companies. A brief overview of the scale of these markets is presented here.

	Pop. (millions)	Per Capita GDP (PPP)	Annual Utility Water Market	Utility Market Growth Rate
Lithuania (EU)	3.6	$19,000	$209 million	19.0%
Romania (EU)	22.7	$13,000	$866 million	18.0%
Bulgaria (EU)	7.3	$12,000	$473 million	14.0%
Croatia	4.5	$19,000	$496 million	12.1%
Latvia (EU)	2.2	$17,000	$199 million	12.0%
Ukraine	46.4	$7,000	$886 million	8.3%
Hungary (EU)	9.9	$20,000	$1.7 billion	7.4%
Portugal (EU)	10.7	$22,000	$1.7 billion	6.9%
Greece (EU)	10.7	$31,000	$856 million	6.9%
Ireland (EU)	4.2	$43,000	$925 million	6.9%
Slovakia (EU)	5.5	$22,000	$358 million	6.1%
Estonia (EU)	1.3	$21,000	$249 million	6.0%
Kazakhstan	15.6	$11,000	$703 million	5.6%
Slovenia (EU)	2.0	$30,000	$215 million	5.2%

European Union References

Global Water Market 2011, Global Water Intelligence, Media Analytics Ltd., The Jam Factory, Oxford, UK, 2010
EU Aquamoney, http://www.aquamoney.ecologic-events.de
http://www.worldatlas.com/webimage/countrys/europe/eur.htm
http://en.wikipedia.org/wiki/European_Union
EU Environment Directorate General, http://ec.europa.eu/dgs/environment/directory.htm
United Nations World Population Prospects: The 2008 Revision Population Database, http://esa.un.org/UNPP
Water Information System for Europe (WISE), http://water.europa.eu/en/welcome
European Commission Eurostat, http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/
EU waste incineration, http://europa.eu/legislation_summaries/environment/waste_management/l28072_en.htm
EU Priority Substances, http://ec.europa.eu/environment/water/participation/notes_en.htm
EU marine strategy framework, http://ec.europa.eu/environment/water/marine/index_en.htm
EU flood risk management, http://ec.europa.eu/environment/water/flood_risk/implem.htm
http://www.guardian.co.uk/environment/2007/mar/28/europeanunion.climatechange
EU Water Initiative, http://www.euwi.net/
http://unfccc.int/kyoto_protocol/items/2830.php
European Water Initiative, http://www.euwi.net/news/eu-realign-development-aid-towards-water
EU public procurement legislation, http://europa.eu/legislation_summaries/energy/internal_energy_market/l22010_en.htm
Per capita consumption: Data 360, http://www.data360.org/dsg.aspx?Data_Set_Group_Id=757
Rivers of France: Discover France, http://www.discoverfrance.net/France/DF_waterways.shtml

North America

4.24 Canada

Key Markets	Niche Markets
Wastewater infrastructure	Decentralized water treatment & purification
Water treatment infrastructure	Leak detection and remediation
WWT/WT plants	Waste stream value extraction
Network rehabilitation	Oil production wastewater treatment

Demographic Indicators

Population	2009	2016
Urban Population	26.92 million	28.86 million
Rural Population	6.53 million	6.62 million
Total Population	**33.44 million**	**35.49 million**
Population Growth Rate	**2005-2010**	**2010-2015**
Urban Population Growth Rate	1.01%	0.99%
Rural Population Growth Rate	0.43%	0.17%
Total Population Growth Rate	0.92%	0.85%

Source: (Global Water Intelligence, 2010)

Economic Indicators

Economic Indicator (2008)	Nominal GDP	GDP at Purchasing power parity
Total GDP	US $1,499.6 billion	US $1,300.4 billion
GDP per capita	US $45,085	US $39,098
GDP growth rate	0.41 %	

Source: (Global Water Intelligence, 2010)

Background

The forecast for water investment in Canada is good. New policies at the federal and provincial level are expected to drive higher standards, with federal funding providing a strong source of financing. The drinking water capital expenditure market is expected to grow from $1 billion in 2010 to approximately $1.33 billion by 2016. Wastewater capital expenditure is predicted to grow from $500 million in 2010 to $790 million by 2016. Industrial and municipal capital expenditure is predicted to grow from $2.1 billion to $2.8 billion, with industrial making up about $800 million in 2016. The largest equipment sectors include pipes, pumps, standard process equipment and media filtration. The fastest growing equipment sectors are membranes, sludge management, and zero-liquid discharge management. (GWI)

Water Quality
Overall water quality was measured in the 2008 Canadian Environmental Sustainability Indicators report. Freshwater quality was measured at 379 sites, 48% were 'good' or 'excellent', 30 percent were 'fair,' and 22% were 'marginal' or 'poor." The St. Lawrence river basin, which includes the Great Lakes, has the highest percentage of 'poor' rated sites, most of which occurred in the Windsor-Quebec corridor. Phosphorus was the largest driver of index ratings, 40% of sites frequently exceeded water quality standards (Environment Canada)

Water Usage

Water Use by Sector	Km^3/year	Percent of Total	1996-2005
Thermal power	32.1	63.0	12%
Manufacturing	7.8	15.0	29%
Agriculture	4.8	9.4	17%
Mining	0.5	1.0	-11%
Municipal	4.8	9.4	2%
Rural	0.9	1.8	N/A
Total	51.0	100.0	

Water Supply	
Municipal supply	6,49 m m^3/day
Population covered	90.6% (mostly urban)
Per capita demand 2004	609 l/c/d (down 4.4% from 1999)
No. of WTPs	2,158
Design capacity WTPs	27.75m m^3/day
Operational capacity	17.79m m^3/day
Distribution network	187,000 km
Unaccounted-for water	13%
Meter coverage	63.3%

Wastewater	
Population served	89%
No. of WWTPs	1,265
Design capacity	48m m^3/day
Wastewater produced	16.45m m^3/day
Collection rate	98.5%
Collected treated to secondary	6.0%
Collected treated to tertiary	67.9%
Network length	101,012 km

Treatment level	Manufacturing	Mining
Not treated	35.1%	60.8%
Primary (mechanical)	19.2	30.0
Secondary (biological)	37.8	4.4
Tertiary	7.8	4.7

Municipal reuse is relatively new and not widespread. One water treatment plant in Edmonton included a feasibility study for a reuse system capable of 40,000 m^3/day. British Columbia reuses approximately 3% of water for non-potable uses. Water reuse in 2006 was estimated at 5,000 m^3/day. Industrial water discharge by treatment type, 2005 (GWI)

Water Tariff

Water financing is determined at the municipal level. As meter coverage increases, the use of flat rate and indirect pricing is decreasing (23% in 2004). Volume-based pricing is becoming more common, which a shift from declining block rate (8% in 2004) to increasing block rate (23% in 2004). Constant unit charge remains the most common, at 46%. The average price for municipal water in 2004 was $1.62 per cubic meter, up from $1.04 per cubic meter in 1991. In 2004, an average of 47% of the water bill was for wastewater, up from 38% in 2001.

Challenges

Untreated Sewage

Every year Canada dumps 200 million m^3 of raw sewage into surface water bodies. A 2010 study found that 399 cities and towns in Canada are directly flushing raw sewage. Montreal alone dumps 900 million m^3 of effluent into the St. Lawrence River every year, most receiving only minimal primary treatment. Victoria, a city of 210,000, screens out particles larger than six millimeters, then pumps sewage directly into the ocean. For decades the city defended the practice as environmentally sound. Only under recent pressure from environmental groups and the federal government did Victoria approve a $1.2 billion plan to treat 128,000 m^3/day of sewage. Generally, only cities that have no convenient means to flush wastewater into major water bodies treat water to an acceptable level, such as Calgary and Edmonton. A lack of political will and few enforceable regulations is largely responsible for the problem. There are no national standards on water treatment, although in 2009 a set of minimal requirements has entered a formal comment period. (MacQueen)

Cruise ships dump vast quantities of waste into British Columbia waters, as regulations are far more lax than in US waters. Between 25 and 27 cruise ships travel through Canadian waters each week. A single ship generates on average 40,000 gallons of sewage, 450,000 gallons of grey water, 4,000 gallons of oily bilge water and 19 tons of solid waste each day. While regulations do exist, there is no monitoring. (Chai) This may be a niche market, if more stringent enforcement is agreed upon.

Infrastructure Deficit

In 2007, the Federation of Canadian Municipalities released a study showing a water infrastructure deficit of $31 billion. An additional $56.6 billion will be needed to meet the demands of population growth and increased regulatory requirements. Current regulations in Canada allowed sewer overflow to bypass treatment plants and go directly into water bodies, or pump raw sewage directly into the ocean. As a consequence, treatment levels near the coast are far worse than those inland. Canada will be focusing a great deal of infrastructure spending getting coastal areas up to an acceptable level. Another area of significant investment will be existing infrastructure remediation, current leak rates were estimated at 13-30%. (Bitti) Toronto has 1,400 water main breaks a year, where the average pipe is fifty-five years old and 17% are over eighty years old. Key technologies needed are leak detection, pipe rehabilitation and low-impact replacement, and energy efficient wastewater treatment systems.

In addition, 550 sewage treatment systems across the country will have to be fixed or replaced. This estimate is based on new regulation currently in a public comment period (see Government Policy below). The upcoming regulations would allow the worst treatment systems ten years to meet new regulations, and the rest up to thirty years. Funding infrastructure continues to be a major problem, as Canada's water is priced far below recovery costs. Possible solutions include decentralized solutions, a shift away from large-scale built infrastructure, and innovations that increase conservation and reduce demand such as rainwater harvesting, low-flow fixtures, industry water audits, and universal metering. (Canada Gazette)

Drinking Water Contamination

Canada has a history of large epidemics that were traced to contaminated drinking water. In 2000, seven people died in the community of Walkerton, Ontario when their drinking water was contaminated with E. coli virus. In 2001, more than 7,000 people were sickened during a three-month period by parasite- infected water in Battleford, Saskatchewan. In 2005, residents of Kasechewan, a Cree community in Ontario, were forced to evacuate their homes because of water contamination. In April of 2008 there were 1,766 boil-water advisories in place in Canadian municipalities. (Council of Canadians) Technology solutions include energy efficient disinfection systems, as well as network monitoring systems. Leak detection, especially if infiltration is a cause of disease, will address efficiency and safety.

Private water systems, which serve and estimated 12% of Canadians, are more susceptible to disease outbreak than public drinking water systems. An Ontario study found that only 8% of private water supplies were met provincial recommendations for frequency of testing. A review of 288 water-related infectious disease outbreaks in Canada over a 27 year period found that 2/3 were associated with private or semi-private water systems. Another study of 1292 drinking water wells in Ontario found that 40% had at least one contaminant above recommended provincial levels. (Canadian Medical Association Journal) Household level purification and disinfection technology is needed to address this problem, as well as cost-effective testing methods to ensure safety.

Oil Sands Production

The Athabasca Oil Sands in northern Alberta contain one of the largest known reserves of oil in the world. According to Energy Alberta, in 2008 the tar sands industry used 184.3 million m^3 meters of water. Only about 10% is returned to water bodies, the rest is collected in basins that currently cover an area 2/3 the size of Milwaukee (65.7 sq. miles), despite a commercially demonstrated reclamation method. Toxic substances in the tailings include oil and grease, naphthenic acids, cyanide, phenols, arsenic, cadmium, chromium, copper, lead, and zinc. A study of water quality near oil sands operations found high levels of Polycyclic Aromatic

Compounds. Scientists claimed they were a direct result of oil operations, while industry and government representatives claim they are the result of natural seepage. Progress has been slow to address problems and enforce regulations. (Dagg) Technology needed includes on-site filtration and treatment systems, or networks to transfer wastewater to a centralized processing center.

Government Policy
In 2009 the Canada-wide- Strategy for the Management of Municipal Wastewater Effluent was proposed and has entered a formal comment period. The regulation establishes a secondary treatment requirement for all systems with an effluent volume of 10 cubic meters or greater. The substances regulated will be biochemical oxygen demand, suspended solids, total residual chlorine, and un-ionized ammonia. The regulations are projected to cost $5.9 billion in 2010 dollars ($3.2 billion for capital costs). Effluent monitoring requirements will begin with the passage of the act, with actual effluent requirements phasing in 2-3 years later. Treatment locations will be allowed to apply for transitional permits, those systems deed a high environmental risk will have 10 years to comply, while lower risk systems will have up to 30 years. Standards are (Environment Canada)

New Effluent Standards	Standard (mg/l)
Carbonaceous Biochemical Oxygen Demand	25
Total Suspended Solids	25
Total Residual Chlorine	0.02
Un-ionized ammonia	1.24

Implementing these standards will cost approximately $10-12.7 billion over thirty years. Of that, $7.3-9.06 billion going to capital costs and a majority of the remaining will go towards annual monitoring. The difference is due to the level of projected inflation, currently between 2-4%. The majority of spending (85%) is expected to occur between 2015-2030, with only $486 million between 2010 and 2015. The Gas Tax Fund, valued at $1.94 billion, is available to municipalities for water and wastewater infrastructure. It will be available until at least 2014. The Building Canada Fund, worth $8.528 billion over seven years. It will fund up to 50% of municipal projects, 35% typically and only 25% if the private sector involved.

The regulatory structure for drinking water in Canada is highly fragmented between Federal, Provincial, and Municipal levels of government. At the federal level, the Guidelines for Canadian Drinking Water Quality are non-binding recommended limits for a variety of contaminants. The Federal government also provides a significant source of capital to provincial and municipal water systems. The Provincial governments are responsible for legislating specific standards, enforcement, testing, and capital funding. Municipal governments are largely responsible for construction, operation, and maintenance of water treatment facilities, testing, and collecting tariffs. Only Alberta strictly follows the Federal recommendations, though most provinces require some number of parameters to be met. (drinking water legislation)

Competition from Canada

In March of 2010, the government of Ontario announced plans to position the province as North America's "clean water technology capital." The province is close to passing the Water Opportunities and Water Conservation Act. It includes the Water Technology Acceleration Project which would facilitate the creation and growth of globally competitive companies and high value jobs in the water and wastewater sector. Ontario claims to currently have 22,000 jobs in the clean water sector. It will also provide a forum for governments, the private sector, academia and others to exchange information and ideas on how to make Ontario a leader in the development and commercialization of innovative water and wastewater technologies.

During an interview of five speakers from the Canadian Water Summit, industry leaders offered the following predictions of where Canadian markets will be successful long term:

- Retrofitting aging treatment plants within existing footprints for those that don't have room or capital to expand or site new plants.
- Non-invasive leak detection and pipe remediation technologies
- Metering that facilitates cost-recovery (low-cost, easy to install)
- Real-time nano-, optical-, and biotech-sensors for detection and analysis of contaminants.
- Technology for reducing water use intensity in oil and gas industry, especially shale gas and oil sands. A commercially viable method for oil-sand water reclamation is urgently needed
- Decentralized water management solutions and process optimization
- Advanced filtration and disinfection technologies for water reuse
- Energy nexus- creating energy from wastewater and reducing energy used for treatment

Private Sector Participation

The majority of water in Canada is supplied by public utilities. Only two cities have created PPPs, and one has already switched back to a public utility model due to public outcry. A few programs do exist, selected projects include:

- Winnipeg Wastewater System- currently investigating partners to expand and upgrade they city's wastewater system. The model is expected to be Design, Build, Finance and Maintain over 30 years. Companies under consideration include Black and Veatch, CH2M Hill, and Veolia Water Canada.
- Brockton Water and Wastewater Services- moved to PPP with Veolia Water Canada in 2006. The O&M contract is valued at $2.43 million, and serves approximately 7,000 customers.

Toronto Water Cluster

Competition Snapshot

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A study about the potential for PPPs in Canada was not optimistic about the potential for solutions. Only a limited number of PPPs are in existence, the majority serving fewer than 50 people. In Ontario, where privatization became a major provincial objective in 1996, only between 30 and 52 of the 672 water systems have some private sector involvement in 2002. (Ouyahia)

Current and Future Projects

- Lakeview WTP upgrade- The plant will be the largest of its kind to use ozone, BAC and ultrafiltration.
- McBride, BC- A new storage cell to increase retention time and capacity. The provincial government is contributing 50% of funding, municipality 50%. Total cost of $1.34 million.
- Sainte-Agathe-des-Monts Quebec- Plant upgrade including new storm sewer, increased capacity at pumping station, and improvements to grit removal system. Total project cost $19.5 million, funded roughly 40:40:20 (federal, provincial, municipal).
- Mont-Joli Quebec- New drinking water reservoir. Total cost $2 million, funded roughly 25:25:50 federal, provincial, municipal.

Market Forecast Tables
All figures in 1,000s of US dollars

Utility Water Capital Expenditures (Capex)	**2010**	**2016**	**CAGR**
Water Network Rehab	162.5	219.5	6.2%
New Water Networks	415.5	567.2	6.4%
Water Treatment Plants	312.9	448.9	7.5%
Water Resources- excluding desal	115.1	98.9	-3.0%
Desalination	0	0	0
Total	**1,005.9**	**1,334.5**	**5.8%**

Utility Wastewater Capex	**2010**	**2016**	**CAGR**
WW Network rehab	102.4	130.8	5.0%
New WW networks	220.2	281.6	5.0%
WW Treatment Plants	185.8	331.5	12.3%
Total	**512.2**	**787.1**	**9.0%**

Industrial Water Capex	**2010**	**2016**	**CAGR**
Pulp and Paper	141.2	196.0	6.8%
Food & Bev	121.9	148.5	4.0%
Oil and Gas	76.2	119.5	9.4%
Refining	26.8	38.4	7.5%
Mining	28.7	37.2	5.3%

Equipment Capex	2010	2016	CAGR
Pipes	467.8	594.8	4.9%
Pumps	268.2	391.3	7.8%
Standard process equipment	204.4	254.2	4.5%
Media filtration	90.6	114.3	4.8%
Membranes	35.6	92.8	21.1%
Intakes/headworks/screens	60.6	84.5	6.9%
Sludge management	26.3	76.3	23.7%
Control systems/chemical feeds	53.5	74.4	6.8%
Disinfection systems	40.2	59.8	8.3%
Zero liquid discharge	19.7	59.6	24.8%
Meters	31.4	43.3	6.6%
Valves	12.1	17.3	7.4%
Ion exchange	8.2	17.2	16.0%
Total equipment	**1,485.2**	**2,101.6**	**7.2%**

Chemicals (Industrial and Municipal)	2010	2016	CAGR
Coagulants & Flocculants	92.0	109.3	3.5%
Ion exchange	45.2	53.2	3.3%
Corrosion/scale inhibitors	45.1	54.0	3.7%
Biocides	58.4	69.6	3.6%
Activated carbon	46.4	57.0	4.2%
pH and other	47.4	57.0	3.8%
Total Chemicals	**334.6**	**400.0**	**3.6%**

Canada References

Environment Canada. 2009. Canada Water Act Annual Report for April 2008 to March 2009. Available at http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=4911B367-108D-4FD5-9D75-7B542DF7EB19

MacQueen, Ken. 2005. Canada Dumping Raw Sewage into Its Waterways. Maclean's Magazine, October 17 2005. http://www.canadianencyclopedia.ca/index.cfm?PgNm=TCE&Params=M1ARTM0012832

Chai, Carmen. 2010. B.C. Waters a 'Toilet Bowl' of Raw Sewage. Vancouver Sun, August 21, 2010.

Bitti, Mary Teresa. 2010. Facing Canada's Water Woes. Financial http://www.financialpost.com/Facing+Canada+water+woes/2660041/story.htmlal Post, March 8, 2010.

Department of the Environment. 2010. Regulatory Impact Analysis Statement. Canada Gazette, Vol. 144, No. 12.

The Council of Canadians. 2009. Why Canada Needs a National Water Policy. Available at http://www.canadians.org/water/issues/policy/index.html

Canadian Medical Association Journal (2010, April 6). Private drinking water supplies pose challenges to public health. Science Daily. Retrieved August 20, 2010, from http://www.sciencedaily.com/releases/2010/03/100315125545.htm
Dagg, Jennifer. 2010. Northern Lifeblood. Pembina Institute, July 21, 2010. http://pubs.pembina.org/reports/northern-lifeblood-report.pdf
Ouyahia, Meriem Ait. 2006. Public-Private Partnerships for Funding Municipal Drinking Water Infrastructure: What Are the Challenges. PRI Project, Sustainable Development. http://policyresearch.gc.ca/doclib/DP_SD_PPP_200605_e.pdf

4.25 Mexico

Key Markets	Niche Markets
Water/Wastewater treatment	Parts for WWTPs not operational due to lack of needed parts;
Water Conservation	Particularly regarding Mexico City - Smart/sub-metering technologies; low water-use technologies; graywater systems; technologies enabling acquisition of new supplies (such as cloud-seeding or moisture accumulation technologies)
Water/Wastewater storage	Cisterns/catch-basins for collection of rain water; storage solutions for waste, particularly in Mexico City
Infrastructure	Technologies reduce up-front and maintenance costs for infrastructure

Key Issues

- Water and wastewater treatment
- Water contamination (much of which originates from low levels of wastewater treatment)
- Inadequate water infrastructure
- Spatial variability of rainfall

Water Market

- Market Size: $7.3 billion
- Growth Rate (2010-2016): 6% - 9.9%
- Key Markets & Niche Markets

Demographic Indicators

Demographic Indicator	**2009**	**2016**
Urban Population	84.51 million	93.01 million
Rural Population	24.50 million	23.88 million
Total Population	**109.02 million**	**116.89 million**
Population Growth Rate	**2005-2010**	**2010-2015**
Urban Population Growth Rate	1.52%	1.34%
Rural Population Growth Rate	-0.2%	-0.39%
Total Population Growth Rate	1.16%	0.99%

GWI Report

Economic Indicators

Economic Indicator (2008)	**Nominal GDP**	**GDP at PPP**
Total GDP	$1,088.1 billion	$1,550.5 billion
GDP per capita	$10,200	$14,534
GDP growth rate	1.35%	

Background
Mexico comprises a total area of 1.96km^2 and is at the same elevation as the Sahara and Arabian deserts. Approximately two-thirds of its territory is classified as arid or semi-arid. Politically, it a country still marked by significant gaps between adopted regulations and effective enforcement of those regulations.

Water Challenges
Mexico currently faces a host of water challenges, many of which originate in the enormous population growth over the last decades. In addition to constraints on existing supplies and the need to procure more supplies to meet growing demand in the country's driest regions, low levels of wastewater treatment also pose a serious threat to the country.

As part of the National Water Program, CONAGUA has identified the following goals:

- Improve agricultural water productivity
- Increase access to and quality of potable water sources, sewerage and sanitation
- Promote integrated and sustainable use of water in basins and aquifers
- Improve technical, administrative and financial development of Water Sector
- Evaluate the effects of climate change on the hydrological cycle

Outdate technology continues to be an issue affecting agricultural irrigation, as well as high levels of non-profit water (NPW), largely due to inadequate infrastructure.
Wastewater treatment has also proven a chronic problem, particularly in areas such as the Valley of Mexico, where only 7-8% of wastewater produced by a population of 20 million is treated.

Water Supply
The primary sources of water for municipal supplies in Mexico come from local water catchments, water from shared catchments with neighboring countries, indirect reuse of treated wastewater, and seawater desalination. Approximately 63% of water used in Mexico comes from surface sources, with the remaining 37% coming from groundwater sources. Average total renewable water resources are 458.1km3 per year.

Sectoral Use of Water

	Gallons/year	**%**
Agriculture	13.4 trillion	77%
Public Supply	2.4 trillion	14%
Thermoelectric	858 billion	5%
Self-Supplying Industry	704 billion	4%
Total Water Use	**17.4 trillion**	**100%**

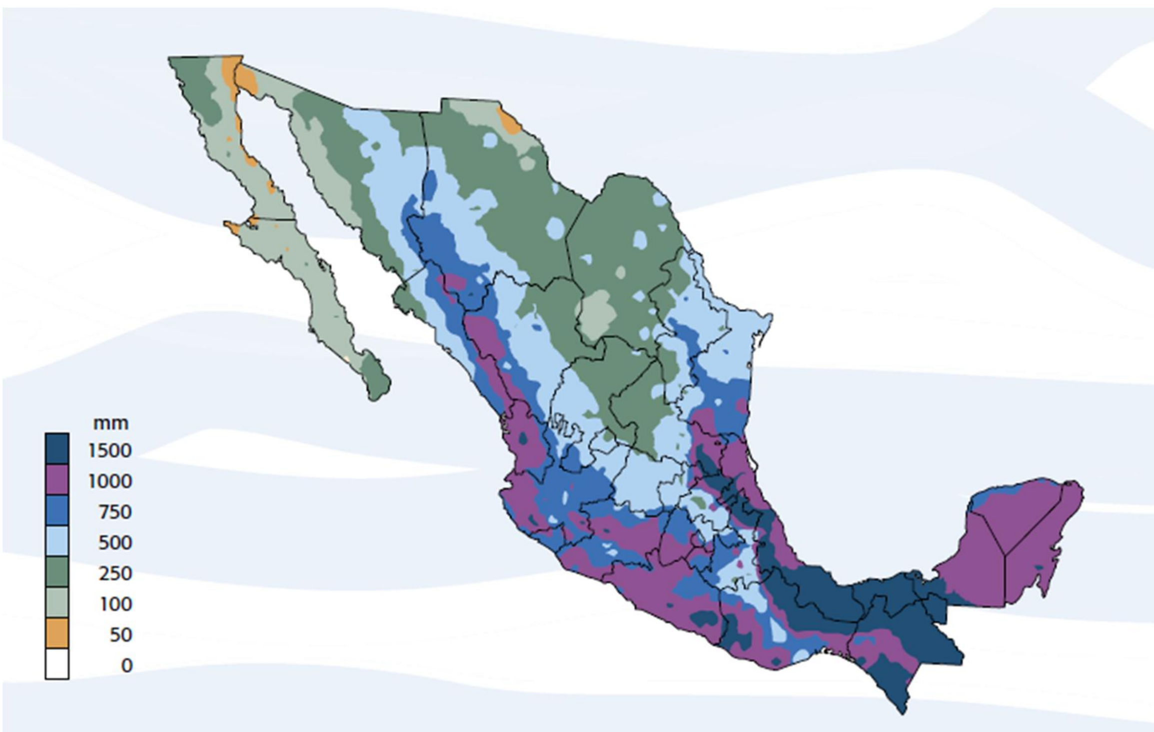
GWI

Two main factors further contribute to issues related to population growth in water-scarce areas: 1) low use efficiency (33-55% in agriculture; 50-70% in urban areas); 2) lack of public education on proper use, conservation and appropriate pricing. The National Water Program 2007-2012 calls for including water information in school textbooks, promoting water conservation via ad campaigns and implementing water awareness programs at the state level.

Water stress (percentage of water used for off-stream uses compared to average total renewable water resources) in Mexico is considered moderate, with a nationwide average of 17%. Nevertheless, the central, northern and northwest areas of the country show higher levels, with Greater Mexico City region and State of Mexico having very high water stress levels.

Spatial Variability of Rainfall
Spatial variability of rainfall is one of Mexico's main water challenges, with some states receiving as little as 8 inches per year (Baja California), while others receive as much as 95 inches per year (Tabasco). Furthermore, due to the concentration of 67% of annual precipitation during the months of June to September, infrastructure must be constructed for the collection and storage of rainfall for other periods of the year.

Distribution of Average Monthly Precipitation in Mexico



Source: Estadísticas del Agua en México, edición 2007. Comisión Nacional del Agua

Desalination
As of 2006, there were 234 desalination plants in Mexico (IMTA National Inventory of Desalination Plants), with nearly half being located on the Yucatan Peninsula (107). Baja California has the second highest number of plants (70) and is also home to the Los Cabos desalination plant, the country's largest. That particular plant has a capacity of 17,280m^3/d and is operated under a 20-year concession. The price of water produced is MXN10.5/m^3 (US$0.80). Most desalination plants in Mexico are privately owned (64%) and operate in areas where water tariffs are sufficiently high as to make them economically viable. Total national design capacity is 113,734m^3/d, while operational capacity is 67,988m^3/d. The primary means of desalination is reverse osmosis (93%).

Most desalination plants in Mexico, however, are abandoned due either to a lack of spare parts – ostensibly attributable to a 50% import rate for desalination equipment – or a lack of need due to sufficient water supply.

Water Reuse
At this time water reuse does not appear to be a viable option given the country's low levels of wastewater treatment. As such, standards for its reuse are not likely to be needed or developed for some time.

Government Water Strategy
The government's strategy is organized around **National Water Programs**, which operate on a six-year basis, coinciding the presidential terms. For the **2007-2012 National Water Program** there are eight base objectives that focus on improving water productivity, increasing access to drinking water, sewerage and sanitation services, streamlining management and assessing the effects of climate change.

Each objective itself consists of a number of strategies. An example of one such objective is future investment, which includes strategies for increasing wastewater treatment from 36.1% to 60%, drinking water coverage from 89.6% to 95%, and sewerage coverage from 86% to 88%.

- **Water Agenda 2030** – launched in 2008, this program contains a series of broad goals, including expanding drinking and sewerage coverage to 100%, reducing river contamination, and improving water reuse in order to balance withdrawals from and replenishment of aquifers and river basins.

Other large-scale government initiatives include:

- **Program for Drinking Water, Sewage and Sanitation in Urban Areas (Apazu) –** This program is aimed at funding improvements to infrastructure and services in towns with populations of over 2,500. In 2008, Conagua reported that MXN 14.2 billion (US$1.1 billion) had been invested in the Apazu program.
- **Program for Reimbursing Duties (Prodder)** – This program encourages infrastructure projects by returning federal income from water use to service providers. In 2008, Conagua reported MXN 3.8 billion (US$292 million) had been invested in the program.
- **Water Utility Modernization Project (Promagua)** – This program encourages public-private partnerships for the delivery of water services and infrastructure. In 2008, Conagua MXN 1.5 billion (US$115 million) had been invested in the program.
- **Valley of Mexico Sanitation Program** – This program is aimed at radically overhauling water management in the Valley of Mexico. The project budget – subject to constant revision – was set at MXN 40 billion (US$3.1 billion)

Private Sector Participation
Due to the high costs and pressing needs for infrastructure overhaul in Mexico, most large infrastructure projects (treatment plants, desalination plants, etc.) include some kind of partnership between national and foreign companies. The establishment of the **National Infrastructure Fund** has made private sector participation more attractive thanks to the availability of significant investment funds. Among this policy's objectives are: enabling more

rapid solutions to Mexico's troubled water infrastructure crisis, counterbalancing current difficult credit conditions and generating employment in the face of the global crisis.

Private sector participation generally involves specific requirements for individual projects, ranging from small scale goods and services to design, construction and operation of major projects. Additionally, private sector participation is becoming increasingly crucial to efforts to increase utility efficiency and moves have been made to open various stages of the water management process to private concessions.

Some cities, such as Cancun and Aguascalientes have fully privatized water services. Partial privatization concessions were scheduled to begin in Mexico City in 2010 in an effort to reduce NPW.

- **INTERPAS** – this is an inter-municipality water utility project that encourages private sector participation in day-to-day water service provision. INTERPAS includes 10 sub-projects open to private sector participation and is aimed at increasing utility revenues and infrastructure and administrative efficiency. The contract scheme is designed to ensure the private sector pays for itself and includes incentives and bonuses for meeting or exceeding set goals and objectives.

Market Forecast

GWI considers Mexico to be a growing water market with increasing opportunities for private companies on medium and large scale projects. Specifically, the period leading up to the end of current president Calderon's term in 2012 is considered key for water infrastructure projects as the government seeks to meet its stated targets.

Infrastructure projects identified as priorities in 2010 include the construction of desalination plants in Hermosillo, Ensenada, La Paz and Rosarito and Conagua's sub-director has underlined the importance of private sector participation in meeting these goals.
In December 2009, Conagua's director indicated that agencies available budget would be MXN 36B.

Given Mexico's increased interest in garnering private sector participation to assist in meeting the country's staggering water needs, opportunities for participation by private water companies, both national and foreign, stand to greatly increase over the coming years. This process has already been aided by communities benefiting from such private sector participation, activities that have help to remove the stigma traditionally attached to the privatization of such a vital resource.

Market Summary Forecast	2010 – 2016 Annual Average (USD)
Water	
Networks	581
Treatment Plants	279.2
Water resources / other	386.3
Wastewater	
Networks	191.3
Treatment / other	377.4
Utility Capital Expenditure	
Water utilities	1,345.1
Wastewater utilities	597.2
Utility Operating Expenditure	
Water utilities	1,425.8
Wastewater utilities	2,107.7
Industrial Water	
Industrial capital expenditure	257.2
Industrial chemicals	153
Industrial services	26.1
Desalination and Reuse	
Desalination	98.7
Reuse	287.6

Source: (Global Water Intelligence, 2010)

Water and Wastewater Treatment

Key Dimensions

Water Treatment

In Mexico City, 14.39% of the city's population - 1,255,326 people – lack potable water supply to their homes and an additional 443,000 individuals received water in an irregular fashion according to a study by the National Autonomous University of Mexico (UNAM). Furthermore, approximately 1.62% of the city's population – 138,480 individuals – have to wait more than a week to receive potable water at home.

According to the IMTA National Inventory of Desalination Plants (2006), there are 234 desalination plants in Mexico, most of which are privately owned and located in coastal areas where high water tariffs make desalination an economical option. The increasing acceptance of PPP financing models has helped to assuage concerns about the high capital cost of desalination. The total national capacity for desalination is 113,734m^3 per day, with an operational capacity of 67,988m^3 per day. Some 64% of desalination plants are privately owned, with reverse osmosis being the most common treatment method.

Over half of national installed desalination capacity serves the tourism industry in Mexico, with key desalination areas located in the coastal regions of Baja California peninsula and the Caribbean coastal state of Quintana Roo. Making up 14% of the national GDP, tourism and its reliance on desalination will ensure that this remains a vital and key market in the Mexican water sector.

Action Needed

- Expansion of water delivery capacity and water treatment
- Measures to bring 79 WTPs currently out of operation back into operation
- Improved maintenance at existing water treatment plants needed to lower number of non-operational facilities
- Aggressive expansion of wastewater treatment network to meet 60% goal laid out by the Mexican government. This will involve more than a 100% increase over Mexico's current rate of wastewater treatment

Current Approach

- 2007-2012 National Water Program (see above)
- Program for Drinking Water, Sewage and Sanitation in Urban Areas (Apazu) (see above)

Technologies/Policies Needed to Meet New Standards/Conditions

- In northern areas of the country, which experience significantly less rainfall than the south, desalination will play an increasingly important role

Availability of Technology

- Most of Mexico's water treatment needs could be met using existing technologies. Some existing, albeit more innovative, technologies that could potentially be used to address Mexico's wastewater problems include:
  - Membrane bioreactors (MBR);
  - Mobile bed biofilm reactor

Key Issue: Wastewater Treatment

Key Dimensions

Approximately one third of domestic wastewater and 16% of industrial wastewater is treated, a state of affairs that has been credited with a 32.5% pollution rate (more than 40mg/l chemical oxygen demand) for national surface water resources. The Mexican government has set a goal of 60% wastewater treatment by 2012.

Most wastewater in Mexico is discharged into surface or groundwater sources. 1.1 million m^3/d is used for agricultural irrigation, 460,000 m^3 as cooling water, and 354,600 m^3 for irrigation of green areas.

There are 604 operational treatment plants in Mexico, with an additional 79 plants currently out of operation. As of 2004, only 10% of Mexico City's wastewater was being treated. Although there are some 27 operating plants, they generally operate under capacity owing to a lack of available wastewater storage space. The remaining 90% of untreated went is sent out of the Basin of Mexico.

The Federal District has a primary drainage network of some 756 miles and a secondary network of 7,642 miles. Due to the closed nature of the basin's hydrological city, Mexico City has had few options other than to export wastewater, most of which is sent to the semi-arid Mezquital Valley in the neighboring state of Hidalgo.

Action Needed

- Massive expansion of wastewater collection and treatment
- Part of any effort to ramp up wastewater treatment in Mexico will invariably involve brining back on line the country's 79 inactive wastewater treatment plants
- Increases in wastewater storage capacity, which will also contribute to greater utilization of wastewater treatment capacity
- Increased wastewater treatment capacity also has the potential to help alleviate water shortage issues in the Greater Mexico City region. Currently much of the wastewater produced in the region is exported outside of the basin.

Technologies/Policies Needed to Meet New Standards/Conditions

- Policies aimed at ending the practice of direct application of sewage to farmland, a practice which further exacerbates water quality problems throughout Mexico; however, any attempt to limit the use of untreated sewage for agricultural application should also seek to ensure supply of water to farmers, particularly in the Valley of Mexico, where much of the country's produce is cultivated.

Impending Water Policy Changes/Conditions to Address Issues

- Environmental degradation from the application of untreated wastewater from Mexico City to farmland in the state of Hidalgo has become a primary concern and in January 2010 a 25-year BOT wastewater service agreement was concluded between a coalition of national and international companies and the National Water Commission of Mexico. The established project company will be responsible for providing wastewater treatment service for a period of 25 years and involves the construction of the world's largest wastewater treatment plant with a capacity of 3,600,000 tons/day at Atotonilco (Hidalgo), approximately 55 miles northeast of Mexico City. The plant is expected to sanitize about 60% of wastewater from the Mexico City metropolitan region (pop. 20 million), which will contribute to raising treatment rates in Mexico from 36% to 60%.

Availability of Technology

Innovative biological treatment technologies

- Membrane bioreactors (MBR),
- Mobile bed biofilm reactor technology (MBRT)
- Integrated fixed-film reactor technology (IFAS), and
- Biological aerated filters (BAF)
- Novel configurations of biological (aerobic, anaerobic, and anoxic) processes and recycle streams

Innovative technology development in the area of physical and chemical treatment processes

- Membrane filtration
- Compressible media filters
- Cloth media filters
- Disinfection processes, including ultraviolet (UV)
- Fine/Advanced grit removal system (AGRS),

- Microfiltration/Microseive,
- Ultrafiltration,
- Nanofiltration
- Biomass concentrator reactor to remove Endocrine Disrupting Compounds (EDCs)

Key Issue: Water Infrastructure

Key Dimensions
Sources of water for municipal water supply in Mexico are made up of water from local water catchments, water from eight shared catchments with neighboring countries (such as the USA, Guatemala and Belize), indirect reuse of treated wastewater and seawater desalination.

About 63% of Mexico's water comes from surface sources and 37% from groundwater sources. Average total renewable water resources are 458.1km^3 per year.

Action Needed
Given the variability in precipitation throughout different regions of Mexico, the country would stand to benefit from policies that more effectively tailor solutions to each region's given conditions – an approach that would allow the country to avoid unnecessary expenditures on infrastructure that is not needed, such as desalination plants in areas with abundant alternative supplies of water.

Mexico City, as the country's largest urban center with a metro population of over 21 million, will continue to be a focal point as the government seeks to carry out the Valley of Mexico project and provide water to a population far exceeding the carrying capacity of the local basin.

Infrastructure facilitating the collection and treatment of domestic and industrial wastewater will see heavy investment as Mexico works towards government wastewater treatment goals.

Current Approach (see above for description of initiatives)
- Program for Drinking Water, Sewage and Sanitation in Urban Areas (Apazu)
- Program for Reimbursing Duties (Prodder)
- Water Utility Modernization Project (Promagua)
- Valley of Mexico Sanitation Program

Impending Water Policy Changes/Conditions to Address Issue
The National Water Program 2007 – 2012 calls for an efficiency improvement in 80 water utilities with more than 20,000 inhabitants. Those improvements are aimed at addressing outdated technology and lack of expertise that result in a significant proportion of duties billed not being collected. Unaccounted-for Water (UFW) is also a major concern in Mexico.

Total investments in the water sector by the Mexican government are expected to increase from MXN 16 billion (US$1.2 billion) per year in 2006 to MXN 38 billion (US$2.9 billion) per year by the end of the 2007-2012 period.

Conagua strategies affecting future investment include an increase in the treatment of wastewater from the 2006 value of 36.1 % to 60 % in 2012, an increase from 89.6% to 95% in drinking water coverage and an increase from 86% to 88% sewerage coverage.

Additionally, as part of the **Water Agenda 2030** program launched in October of 2008, stated goals include drinking water and sewerage coverage of 100%, reduction in river contamination and improved water reuse to help to balance withdrawals and replenishment of aquifers and river basins.

Technologies/Policies Needed to Meet New Standards/Conditions
Given the low levels of wastewater collection and treatment throughout the country, policies aimed at ramping up funding for water infrastructure projects will play a key role in meeting the country's stated goals. Recently, construction on four plants in the Valley of Mexico Hydric Sustainability Program was frozen following the completion of the Atotonilco WWTP tender due to competition for federal subsidies for infrastructure projects and the constraints placed on those subsidies by the global financial crisis.

Key Issue: Water Demand and Population Growth

Key Dimensions
Mexico's primary water challenge is in meeting the demand of a population that grew four-fold between 1950 and 2005, from 27,741M to 105,330M. During that same period the urban population grew from 11 million to 79 million, with per capita water availability dropping from 17,742m^3 per capita per year to an estimated 4,242m3 in 2010.

Population growth has tended to be concentrated in areas with lower water availability, particularly in the North and central regions, which are home to 77% (87% of the GDP) of the population despite having only 31% of available water resources. Additionally, the population is expected to grow by an additional 30% by 2050, to some 150M.

Water stress – the percentage of water used for off-stream uses as compared to average total renewable water resources – is considered moderate in Mexico with a nationwide average of 17%. Nevertheless, the central, northern and northwest areas of the country suffer much higher levels of stress. The areas surrounding Mexico City and the State of Mexico are the only regions defined as having very high water stress. However, encompassing a quarter of the country's population, to be successful, any water strategy will need to address these areas.

Action Needed
Action needed to address the water needs of Mexico's growing population will surely involve a variety of approaches, including increased desalination of seawater and water conservation, primarily in water-scarce areas such as Greater Mexico City (which as of 2005 had wholly 19% of Mexico's total population).

Part of meeting this increased water demand will undoubtedly involve massive upgrades to water and wastewater infrastructure, which will also be an important stepping stone towards large-scale water reuse.

Population growth and the accompanying growth of urban centers is also linked to decreases in natural areas leading to environmental problems such as soil degradation, a process manifested through soil erosion and desertification and which adversely affects aquifer recharge.

Current Approach (see above for project descriptions)

- Program for Drinking Water, Sewage and Sanitation in Urban Areas (Apazu)
- Program for Reimbursing Duties (Prodder)
- Water Utility Modernization Project (Promagua)
- Valley of Mexico Sanitation Program

Technologies/Policies Needed to Meet New Standards/Conditions

Population growth has been exacerbated by two main factors: low use efficiency (33%-55% in agriculture and 50%-70% in urban areas) and lack of awareness of proper use, conservation, and the true cost of water.

The National Water Program 2007-2012 calls for including water themes in elementary school textbooks, promoting conservation through advertising campaigns and implementing water culture programs at the state level.

Availability of Technology

There are number of available technologies that aid in the detection of water leaks. These include:

- Continuous acoustic monitoring
- Advanced metering infrastructure communication
- District Metered Areas (DMAs) for audit and leak control
- Pressure monitoring
- GIS analysis

Key Issue: Water Pollution

Key Dimensions

Only 2% of Mexico's surface waters are classified as "high quality" and in a UN survey evaluating water quality in 122 countries, Mexico ranked 106 (behind Guatemala, Egypt and China). Contaminated water is the second leading cause of infant mortality in the country, with untreated wastewater from homes and industries being the main causes.

An estimated 150,000 residents of Mexico City drink water with dangerously high levels of arsenic and "black water" – untreated wastewater – is commonly used to irrigate crops in rural regions outside of Mexico City.

The leading source of water pollution in Mexico is the agribusiness sector. An estimated 6,000 residents of Mexico City consume water containing harmful amounts of pesticide. According to the National Water Commission (CONAGUA), in 2000 wastewater from sugar mills generated 6.2 tons of biochemical oxygen demand, considered a reliable measure of the amount of fecal and other organic matter in water. Pig farms are also the source of massive amounts of excrement entering the country's waterways.

The risks associated with water pollution have also taken a toll on the country's wildlife. Over 8,000 migratory birds died near the town of Tequisquiapan after drinking from contaminated ponds and streams.

Action Needed

The primary obstacle to improving water quality in Mexico is the low-level of wastewater treatment and collection and expanding capacity is one of the federal government's main goals. Additionally, stricter control of the agribusiness industry will be an important component of efforts to improve the quality of Mexico's waters.

Technologies/Policies Needed to Meet New Standards/Conditions

Given the magnitude of the work to be done, massive outlays of resources and money from the government will be a necessary component of any approach. In 2001, the National Water Commission called for US$77 billion in new federal government funding over a period of two decades to build new treatment plants to increase the water supply available for human consumption and agricultural irrigation. Some experts have warned that without those investments, by 2025 water availability levels in Mexico could fall to levels considered "dangerously low" by the World Bank.

Stricter enforcement of environmental regulations – Political will appears to be lacking for the effective enforcement of the country's environmental laws. Although hundreds of companies receive fines in any given month for violations, few of them take the fines seriously. During the first six months of 2003, for example, nearly 5,000 companies were cited for environmental violations, but only 737 of them actually paid those fines.

Mexico References

Contreras, Jose. Circle of Blue (2010, February 23). *Divining Destiny: Water Challenges in Mexico's Tehuacán Valley.* Retrieved from http://www.circleofblue.org/waternews/2010/world/tehuacan-divining-destiny/

Gutiérrez, Arlette. El Sol de México (2010, August 4). *Carecen de agua un millón 250 mil capitalinos.* Retrieved from http://www.oem.com.mx/elsoldemexico/notas/n1732852.htm

Mimorelia.com (2010, August 2). *Discutirán en México retos y esquemas de cooperación frente al cambio climático: CONAGUA.* Retrieved from http://www.mimorelia.com/noticias/noticias.php?id=53735

Poder Edomex (2010, April 6). *Urbanización y crecimiento poblacional afectan recarga de mantos aquíferos.* Retrieved from http://poderedomex.com/notas.asp?id=56403

South America

4.26 Brazil

Key Markets	Niche Markets
WWT and Collection	On-site treatment; rural treatment systems
Water resources, treatment, & distribution	WWT, desalination, & leak repair
Flooding	Urban flood control; flood control for irregular settlements (favelas)
Water infrastructure	Water distribution networks, large scale treatment systems – and corresponding mechanical/chemical technologies - for urban areas

Key Issues

- Water and wastewater treatment
- Basic sanitation infrastructure
- Flooding, particularly in urban areas

Water Market

- Market Size: US$15 billion
- Growth Rate (2010-2016): 10% - 14.9%
- Key Markets & Niche Markets

Demographic Indicators

Demographic Indicator	2009	2016
Urban Population	169 million	188 million
Rural Population	27 million	24 million
Total Population	**196 million**	**212 million**
Population Growth Rate	**2005-2010**	**2010-2015**
Urban Population Growth Rate	1.80%	1.48%
Rural Population Growth Rate	-1.89%	-1.64%
Total Population Growth Rate	5.08%	1.11%

Economic Indicators

Economic Indicator (2008)	Nominal GDP	GDP at PPP
Total GDP	$1,572.8 billion	$1,984.5 billion
GDP per capita	$8,295	$10,466
GDP growth rate	5.08%	

Background and Summary of Key Issues
Occupying approximately 44% of the South American landmass, Brazil is easily Latin America's largest country, as well as the fifth-largest country in the world (were it not for Alaska, it would inch ahead of the US as number 4). It is also home to some 12% of the world's total freshwater resources and a water flow of some 15,510.18 million m^3 per day – also the world's largest. There are twelve major river basins in Brazil, as established by the National Council of Water Resources: Amazon, São Francisco, Tocantins-Araguia, Paraná, Parnaíba, Western and Eastern northeast Atlantic, East Atlantic, Southeast Atlantic, South Atlantic, Uruguay and Paraguay.

Operating under a federal system, one of only two Latin American countries to do so together with Argentina, standards and policies can often vary from region to region. In accordance with the Brazilian constitution, water service provision is the responsibility of Brazil's 5,560 municipalities. Nevertheless, state water and sewer companies are in charge of some 3,887 municipalities, comprising approximately 75% of Brazil's urban population with water connections (approx. 103M people). State water and sewer companies are also in charge of sewer services in some 893 municipalities, comprising approximately 55% of the population (approx. 45M people).

Operating efficiency for Brazilian water companies can be volatile, with **non-revenue water (NRW)** estimated to vary between 21% and 81%. In 2006 the average level of NRW for Brazil was 39.8%. The cost of water from new production is estimated to be two to three times higher than that gained from reducing and controlling losses (http://dcnonl.com/article/id39265). The World Bank estimates that non-revenue water losses cost developing countries about $5.8B in revenue per year.

Furthermore, Brazil is also home to the world's largest known aquifer, the Guarani, which occupies more than 1.2 million km^2 (with 840,000 km^2, 58,500 km^2 and 58,500 km^2 found in Brazil, Paraguay and Uruguay, respectively). It is believed that the aquifer could contain as much as 40,000 km^3 of water. Throughout its territory, Brazil contains a total of some 112,000 km^3 of groundwater.

Pollution
According to GWI's report on Brazil, 90% of domestic sewage (70% of collection sewage) and 70% of industrial wastewater are discharged into waterways without prior treatment of any kind. Such practices can be observed in cities such as São Paulo and Recife, which are surrounded by rivers that are no longer safe for potable supply due to pollution levels. As a result, these cities are forced to procure water from distant basins or alternative sources such as wells.

According to a representative of the Brazil chapter of WWF, 70% of hospitalizations in Brazil are the results of diseases spread through contaminated water.

Overview of Business Opportunities in Brazil
Business Opportunities in Infrastructure and the World Cup
A report by the Director of International Relations for the Associação Brasileira da Infrastrutura e Indústrias da Base (Abdib) indentified various potential business opportunities flowing from

the country's preparations for the World Cup to be held there in 2014. The Brazilian government has stated it will commit US$18.7 billion to improvements in infrastructure as it prepares to host the 2014 World Cup.

Municipal Water and Wastewater Treatment Market

Strong growth is expected for the Brazilian municipal water and wastewater treatment market for the period 2009-2015. Technology suppliers are expected to greatly benefit from the steady development of market opportunities in the coming years and heavy investments in the municipal sector in Brazil are also expected for this period. Most construction or upgrades of new water and wastewater treatment plants will be financed under the 'Programa de Aceleração e Crescimento' (PAC).

Among the new municipal water and wastewater treatment projects across Brazil are secondary, sludge, and tertiary treatment processes. Tighter discharge standards set forth under new environmental legislation – CONAMA 357 and 375 – will be a driving force behind investments in sophisticated technologies, which will foster the growth of Brazil's advanced treatment system market for the removal of nitrogen and phosphorus.

A report by the consulting firm Frost & Sullivan suggest that international companies wishing to successfully enter the high potential municipal sector in Brazil consider forming strategic alliances and partnerships with local participants, or that they acquire reputable Brazilian companies.

PPPs in Brazil

In December of 2005, the International Development Bank approved a US$2.4 million grant to Brazil to support the National Program for the Institutional Development of Public-Private-Partnerships. Recent projects funded PPPs in Brazil include the Jaguaribe Ocean Disposal System - for the treatment and final disposal of sewage from the city of Salvador (total value of R$205 million) – and the Alto Tietê Production System (maintenance of dams; inspection and maintenance of tunnels and channels; treatment and final disposal of sludge resulting from water treatment; support services related to water delivery; expansion of water station treatment capacity; building of water mains and other utilities) at a total value of R$310 million.

Due to peculiarities of Brazilian law (specifically Federal Law No. 11.079 of 2004), PPPs in Brazil more closely resemble the British system of Private Finance Initiatives (PFI) than PPPs proper.

Further Market Potential

Sub-metering Technologies

The Brazilian Economic Affairs Commission (CAE) recently voted to modify the Sanitation Law (Law 11.445 of 2007) stipulating that water and sewage services can only be charged for on an as-used basis. The change was aimed at ending the practice of charging based on the potential availability of such services, regardless of whether or not they were actually provided. The changes are currently under consideration and will ultimately be determined by the CAE.

Deep well technology
A recent article appearing in the publication of the Brazilian Groundwater Association (ABAS) points to deep wells as a market with strong potential for future growth. Although deep well drilling is not new to Brazil, it is not yet widely practiced. Average costs for drilling of deep wells in Brazil (from 400 to 2,000 meters in depth) are R$1,300 (US$741) per meter.

Key Issue: Water Use

Key Dimensions
Ground Water
Although the quality of groundwater is generally considered to be very good, among the items that have been identified as compromising that quality are: contamination due to a lack of sanitation; over-pumping of coastal wells, which has led to salt water intrusion; leakage from fuel storage tanks; and use of agricultural products, among others.

Recent studies suggest that despite what has traditionally been believed, the Guarani (with a volume of 45,000km^3) is not in fact Brazil's largest aquifer, an honor which may belong to the Alter do Chão aquifer (estimated at a volume of 86,400km^3). A 2007 study calculated that an annual transfer of 8 trillion liters from the aquifer supports an agricultural GDP of between US$50 and US$60 billion, or 20% of the Brazilian GDP.

Estimates place the number of wells in Brazil at 400,000 or more. Some 16% of Brazil's population relies solely on groundwater. With the exception of aquifers located near the county's capitals, information on the quality of groundwater is scarce, and few studies have been conducted on the chemical and microbiological quality of groundwater in Brazil.

Although desalination is not yet widely used in Brazil, it is used for the treatment of brackish groundwater in the semi-arid northeast region of the country. Some 1,500 communities rely on groundwater with high levels of salinity. In 2004, as part of the Fresh Water Program, more than 3,000 small desalination units were installed.

Brazil currently lacks any specific legislation aimed at regulating the use of groundwater or the construction of new wells. As a result, excessive groundwater withdrawals are increasingly an issue. Additionally, urban expansion into groundwater recharge areas and the use of non-porous materials have further compromised groundwater in some regions of the country.

Surface Water
One of Brazil's primary challenges will be expanding its ability to monitor the quality of its waterways. The lack of adequate measures has been identified as a key issue by the National Water Resources Plan (PNRH). Areas identified as critical by the IQA are located near the larger metropolitan regions and are most heavily affected by domestic sewage. Indeed, this has also been identified as the single-biggest threat to water quality at the national level.

Other problems related to pollution identified as affecting the country-at-large are mining, industrial effluents, non-point urban and agricultural pollution, and solid waste, which affect virtually all of Brazil's hydrographic regions to some extent.

Action Needed

- Many of Brazil's water quality concerns are intimately linked with the rate of wastewater treatment and as such any discussion of water treatment in Brazil will invariably involve a discussion of wastewater treatment.
- Greater controls and restrictions on industrial/agricultural impacts on surface and groundwater quality
- Innovative policies/approaches for provision of clean water to irregular communities in urban areas and to under-served communities in rural areas

Technology/Policies Needed to Meet New Standards/Conditions

Given that much of the contamination experienced by Brazilian waters derives from the lack of widespread collection and treatment of sewage, primarily in urban areas, technologies and policies aimed at addressing this issue will stand to have a great impact on the quality of Brazil's waters in general.

Availability of Technology

Many of these issues can currently be addressed using existing technologies, which a particular emphasis on on-site treatment technologies for irregular communities, or shantytowns, which constitute a very large portion of the country's urban population (as much as one-third of the population of Rio de Janeiro).

Available groundwater monitoring technologies include:

- Real-time monitoring
- Multiple site/strata monitoring
- Web-enabled networked systems linked by RF or cellular technology
- Automated systems that do not rely on operator interpretation to determine results
- Units that monitor multiple contaminant classes: biological, chemical, and radioactive

Water Resources, Treatment and Infrastructure

Sectoral Use of Water

Total water withdrawal in 2006 was 8.34 km^3/yr, approximately 16% above estimated total withdrawals for 2000 (7.23 km^3/yr). Irrigation accounts for wholly 47% of water demand at 3.91km3/yr.

The two basin regions with the highest demand are the Parana and South Atlantic basins, at 27% and 15%, respectively. The highest demand for water in metropolitan areas and large cities is for urban water supply and industrial uses. For the south, the highest demand is for irrigation purposes (primarily flood irrigation). (GWI)

Water Infrastructure -

Compared with other infrastructure sectors, such as energy and telecommunications, Brazil's sanitation sector rates low in technological dynamism and variety of services. Recife, for example, has a WSS system with some water mains dating back to the first outbreak of cholera in the country in 1915.

Poor Distribution of Water Resources
Despite large amounts of natural water resources, Brazil ranks 23rd for water availability. Most of Brazil's water resources are concentrated in the North region, which is home to 70% of all water resources in Brazil, but only 7% of the total population. The southeast, on the other hand, which is home to 43% of the county's population, has only 6% of total water resources. The Northeast, a region stricken with frequent drought and poverty, is home to 29% of the population and a mere 3% of water resources. (GWI)

According to the National Water Resource Plan (PNRH), only 64% of Brazilian homes are served by the water distribution network, with large variability according to geographic region. Most water in the network (93%) receives some type of treatment before being distributed. In the case of wastewater treatment, however, Brazil has been slow to progress. Between 1989 and 2000, the number of municipalities whose waste water is treated increased a mere 5%, from 47% to 52%. Of that total, only 20% both collect and treat the wastewater, while the remaining merely collect it.

Action Needed
Given the concentration of Brazil's population in regions with relatively low shares of national water resources, policies/technologies aimed at improving the efficiency of water use in population centers will become increasingly important, as will those enabling local agencies and authorities to identify and locate breaches to the system, whether due to mechanical failures or illicit tapping.

Additionally, technologies enabling Brazil's different regions to better utilize local extant water supplies will continue to grow in importance. In some regions, such as the semi-arid northeast, this will likely imply more programs along the lines of the 1 Million Cisterns Program and technologies helping those communities to better address brackish groundwater issues.

In more water-abundant regions, such as the Amazon and Southeast, providing access to water will still require solutions addressing the low quality of urban waterways due to inadequate wastewater collection and wastewater treatment.

Technologies/Policies Needed
- Brazil's primarily challenge continues to be the degraded quality of water resources, a reality that has forced large urban conglomerations to procure more distant sources.
- Another serious challenge facing Brazil as it pursues upgrades in infrastructure involves the effective disbursement of funds. In 2009, despite a commitment to a disbursement of R$10.314 billion for improvements to basic sanitation, only R$6.699 billion were effectively disbursed.

Availability of Technology
There is already an array of existing technologies capable of meeting many of Brazil's water needs. However, given the prevalence of irregular settlements throughout the country, particularly those found within and around urban centers, technologies able to address water provision and treatment shortfalls on smaller scales and for communities lacking formal infrastructure will undoubtedly play an important role in the coming years.

Key Issue: Water Treatment -

Key Dimensions
As of 2000, 116 Brazilian municipalities were not connected to the general water supply network (2% of all municipalities), most of which are located in the country's poorer and less-populated North and Northeast regions.

Although in 2006 the number of homes connected to the water network rose to 83% (Pnad), large disparities by region were still found to exist. Only 56% of homes in the North were connected, compared with 92% of homes in the Southeast region. Similar trends were found to exist within the wastewater system, with 71% of homes nationally receiving this service in 2006, up from 70% in 2005. Nevertheless, only 49% of homes in the North were connected, compared with 88% of homes in the Southeast region.

Water Distribution Coverage

Coverage Index	**2000**
Water Distribution Network	
Urban Households	90%
Rural Households	18%

Source: 2006 National Water Resource Plan

São Paulo
In São Paulo, not only Brazil's largest city but, at a metro population of some 20 million people, also the largest city in the Southern Hemisphere, the need for chemicals necessary to make water potable has increased 51% over the last five years, as illegal settlements along its rivers and environmental degradation have compromised the quality of its waters.

Rio de Janeiro
Although Rio de Janeiro, Brazil's second-largest urban conurbation, is expected to have no issues related to water-supply quantity through 2025, the quality of the city's water is a concern. Among the primary threats to the quality of Rio de Janeiro's water sources is untreated runoff of water used by the population. This is particularly acute in the Gaundú basin and has worsened as the citizenry has grown westward from the coast. Other issues include garbage dumped along rivers and pollution from industrial users attracted to the abundance of water in the region.

Action Needed
- Massive expansion of water treatment and distribution network
- Stricter controls on sewage dumping into waterways, a practice that threatens the quality of water supplies

Impending Water Policy Changes/Conditions to Address Issue
- Infrastructure has become an increasingly central topic for presidential candidates in the upcoming election to be held on October 3, 2010. Candidate Marina Silva has cited a figure of **R$20 billion (US$11.3 billion)** for the amount that needs to be invested in basin sanitation in Brazil.

- Presidential candidate Dilma Rousseff has stated that if elected she will work to instate a federal program aimed at ensuring universal access to water, primarily for families living in the semi-arid Northeast region.

Market Prospects

- Disinfection – the Brazilian disinfection market, which includes water treatment chemicals, was valued at US$13.5 million in 2008 and it is predicted that the planned work program will allow it to grow at a compound annual growth rate of 11.5% until 2015.

Key Issue: Wastewater Treatment

Key Dimensions

Certainly the most pressing issue Brazil faces is in increasing the percent of wastewater treated. Figures place the current rate of wastewater treatment somewhere in the area of 20%. Although a higher percentage of municipalities (47%) have a wastewater collection system, most of the water collected is returned to waterways without treatment.

Brazil continues to struggle to effectively enforce its own legal frameworks, particularly as regards wastewater standards. Legislation in Brazil may, in fact, be too strict, and most WWTPs are unable to cope with the high standards in place. Furthermore, the quality of the regulatory framework in place is poor as regards targets, the setting of rates, and transparency. Because water resources management is decentralized under the responsibility of Basin Committees, the quality of management can vary significantly across different regions.

A recent study by the Applied Economic Research Institute (Ipea) shows that 16 Brazilian states have as of yet failed to reduce by 50% the number of people without access to the sewage network or septic tanks in urban areas. In rural areas, only 6.5% have access to sewage collection systems. It is not likely that these states will meet this goal by 2015, as established by the UN. Additionally, nine Brazilian states failed to reduce by 50% the number of families in urban areas without access to piped water.

Sewage Network Coverage

Coverage Index	**2000**
Sewage System	
Urban Households – sewage network	56%
Urban Households – septic tank	16%
Rural Households – sewage network	3%
Rural Households – septic tank	10%

Source: 2006 National Water Resource Plan

Action Needed

- Massive expansion of sewage network; greater use of on-site or community treatment systems

- Better public awareness campaigns about the importance of sanitation and being connected to municipal wastewater collection systems
- Federico Basañes, of the Inter-American Development Bank, believes that increased pressures on fresh water supplies, such as population growth, increasing pollution and climate change, will force Latin American countries to expand upon traditional treatment techniques (coagulation-flocculation and disinfection processes) to include more specialized technologies such as activated carbon, ion exchange, and desalination processes.
- Investment mechanisms enabling more rapid development of wastewater treatment facilities and infrastructure facilitating the collection of waste
- Higher efficiency wastewater treatment processes

Current Approach

- PRODES *(Programa Despoluição de Bacias Hidrográficas)* program – Introduced in 2001, this innovative program was developed by the National Water Agency and is designed to finance wastewater treatment plants while providing financial incentives to properly operate and maintain the plants. Under the plan, the federal government pays utilities (mostly public state or municipal water and sanitation companies) for treating wastewater based on certified outputs. Up to half of the investment costs for wastewater treatment plants are eligible for reimbursement over a period of three-to-seven years so long as the quality of the wastewater discharged meets federal standards. If a plant fails to meet norms during one trimester, a warning is issued. If in the following trimester the plant still does not meet federal standards, payment is suspended. If norms are not met in a third semester, the service provider is excluded from the program.

This program has the added benefit of ensuring that operational risks are assigned to service providers. As a means of preventing over-investment, treatment plants have to be included in basin plans adopted by water basin agencies as a necessary condition to be eligible for financing under the program.

Between 2001 and 2007, PRODES leveraged investments worth US$290 million, with subsidies and subsidy commitments of US$94 million. A total of 41 wastewater treatment plants in 32 cities were financed via this program, serving a total of some 2 million people. The program's portfolio included an additional 52 projects serving 5.7 million people.

Impending Policy Changes/Conditions to Address Issue

2007 Sanitation law no. 11445 is aimed at universalizing water access in Brazil. Under this law Brazil is expected to continue to invest in the expansion of water supply and sanitation coverage. It is estimated that R$11B (US$6.3B) in investments will become available from federal sources beginning in 2011. For the period 2009-2012, BNDES has estimated some RS$37-40 (US$21-23B) will be available. In mid 2010 the government began the second phase of the Program for Acceleration Growth for basic infrastructure and expansion of water supply.

Availability of Technology

- Enclosed anaerobic upflow reactors have seen increased use in Brazil

- Natural systems (particularly for small towns and rural communities) – stabilization pond systems, constructed wetlands and floating aquatic plant systems
- Overland flow system – some rural communities and towns in Brazil have had success with this alternative to wastewater treatment and in many cases effluent quality has been high enough for reuse in agriculture

Key Issue: Flooding

Key Dimensions
Flooding in urban areas is primarily related to inadequate drainage systems, an issue affecting mainly low-income areas. In some city, such as Rio de Janeiro, flooding conditions are also frequently accompanied by landslide events within the city itself (one such event claimed the lives of 158 people in Rio de Janeiro in April 2010). Such events typically strike the *favelas*, or shanty towns, found in most larger Brazilian cities where housing is generally precariously built and formal drainage systems are absent. Furthermore, high population density in these areas, which tend to be informally built up on slopes or floodplains, means there is little to no room to latter instate mitigating mechanisms without displacing large numbers of poor individuals.

In accordance with a report by the Univervidade Federal do Rio de Janeiro, the primary causes of urban flooding in Brazil are: intense rains; impermeability of surfaces; insufficient drainage; irregular occupation of land (i.e., *favelas*, etc.). The primary consequences of urban flooding, as outlined by that report are: leptospirosis; material damage; and disruptions to transit.

Action Needed
Solutions can be divided into four primary categories as follows:

Category	***Solution/Action Needed***
Hydraulic	Improved drainage systems
Hydrological	Rainwater capture; retention basins; infiltration basins; permeable surfaces; restoration of riparian vegetation to riverways
Environmental	Measures preventing further deforestation and increasing green areas; revitalization of rivers
Legal	Municipal Master Plan; Forest Code; Agenda 21

Additionally, there is a real need for a systemic approach to managing urban flooding. Since Brazil's urban flooding issues are inextricably linked to the lot of its poorer strata, many necessary actions will likely involve the eventual displacement of that population. Some cities, such as Curitiba, have successfully done just that, and areas that had become subject to irregular occupation decades ago have been restored to forest and parkland that acts as a crucial mitigating factor during flooding events.

Current Approach
One study analyzed the effectiveness of a wide range of different flood control measures in the Joana River watershed located in the northern region of Rio de Janeiro (city). The study found that distributed detention/retention reservoirs located at upstream reaches, parks and public squares, as well as at urban sites, served as vital alternative flood-control measures. The same

study also concluded that reforestation of slope areas, many of which are occupied by lower income communities, was a desirable flood-control mechanism. Furthermore, the study stressed the need for traditional flood control measures working together with these newer flood-control measures.

This same study found that distributed or on-source control measures are significantly less costly than end-of-pipe solutions. The cost reduction was found to vary from 25 – 80% and was found to be more significant in plain watersheds.

Technology/Policies Needed to Meet New Standards/Conditions

- Policies aimed at restoration of traditional flood plains in urban areas or installation of formal drainage mechanisms in irregularly occupied territory (i.e., territory not served by formal utility services)
- Policies/programs aimed at reforestation of slope areas that serve a crucial mitigating function in urban areas
- Greater use of permeable surfaces and distributed or on-source control measures

Availability of Technology

Numerous flood control techniques are currently available, including permeable surfaces that can be used in urban areas. However, the density and extent of many unregulated urban communities overwhelms the potential contribution of modest measures of "greening" solutions.

Brazil References

Correio Braziliense (2010, August 19). *CNBB pede a Dilma universialização de acesso à água.* Retrieved from http://www.correiobraziliense.com.br/app/noticia182/2010/08/19/noticia_eleicoes2010,i=208659/CNBB+PEDE+A+DILMA+UNIVERSALIZACAO+DE+ACESSO+A+AGUA.shtml

Filho, Flavio Machado (2009). *Business Opportunities in Infrastructure and the World Cup 2014.* Retrieved from http://investimentos.desenvolvimento.gov.br/arquivos/Japao%20-%20Jetro%20-%20Seminario%20-%20apresentacao%20-%20ABDIB%20-%20english.pdf

Financial Times (2010, May 6). *Water and sewage: Tap turns on but there's trouble with the pipes.* Retrieved from http://www.ft.com/cms/s/0/dba87ed0-571c-11df-aaff-00144feab49a,dwp_uuid=b9c736f0-5715-11df-aaff-00144feab49a.html

Gazeta Digital. *Brasil e saneamento.* Retrieved from http://www.gazetadigital.com.br/materias.php?codigo=268120&codcaderno=10&GED=6842&GEDDATA=2010-08-23&UGID=88df3245b932b8a426d76c65004388a7

International Journal of Technology Management and Sustainable Development (2006, January). *Wastewater treatment in Brazil: Institutional framework, recent initiatives and actual plant performance.* Retrieved from http://www.atypon-link.com/INT/doi/abs/10.1386/ijtm.5.3.241/1

Inter-Press Service (2006, October 31). *Eye on Urban Water Pollution*. Retrieved from http://ipsnews.net/news.asp?idnews=35308

Instituto para o Desenvolvimento Ambiental – IDA (2009, March 20). *Brasil: Muita água, péssima distribuição.* Retrieved from http://www.ida.org.br/artigos/38-recursoshidricos/140-brasil-muita-agua-pessima-distribuicao

Marcondes, Adalberto Wodianer. Desenvolvimento Nordestino (2007, April 23). *Tecnologias sociais garantem água, peixe e criação no semi-árido.* Retrieved from http://desenvolvimentonordestino.wordpress.com/2007/07/11/projeto-agua-doce-muda-a-face-do-sertao/

Ministério de Meio Ambiente (2006). *Plano Nacional de Recursos Hídricos.*

Moreira, Marli. Agência Brasil. *Marina critica falta de investimentos em saneamento básico.* Retrieved from http://jbonline.terra.com.br/editorias/pais/eleicoes2010/temporeal/ye17088106.asp

National University of Singapore (August 2009). *Getting Things Done: Bureaucratic and Entrepreneurial Approaches to the Practice of Participatory Water Management Reforms in Brazil and India.* Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1464691

Pernambuco.com (2010, August 17). *Pernambuco não cumpriu as metas de água encanada e esgoto sanitário*. Retrieved from http://www.pernambuco.com/ultimas/nota.asp?materia=20100817101455&assunto=71&onde=VidaUrbana

Revista Água e meio ambiente subterrâneo (2010, June/July). *Poços Profundos Ainda Mais Profundos, Uma Nova Realidade.* Retrieved from http://www.abas.org.br/imagens/revista16.pdf

Teoria e Prática na Engenharia Civil (2009, May). *Tratamento de esgotos de pequenas comunidades pelo método do escoamento superficial no solo.* Retrieved from http://www.editoradunas.com.br/revistatpec/Art8_N13.pdf

Water Executive Forum 2009. *Water Infrastructure in Latin America: Key Challenges and Business Opportunities in 2009.*

World Meteorological Organization (May 2007). *Urban Flood Management.* Retrieved from

Mapa Mental dos Problemas das Enchentes. Retrieved from http://www.ufrrj.br/institutos/it/de/acidentes/mma10.htm

Planning and Design of Urban Flood Control Measures: Assessing Effects Combination. Retrieved from http://scitation.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=JUPDDM00013500000300010000001&idtype=cvips&prog=normal

Chapter 5: Nutrient Control Technologies Update

EPA WWTP Nutrient Control Seminar 2010

Problems and General Dimensions

High levels of nitrogen (N) and phosphorus (P) in wastewater effluent cause eutrophication and hypoxia, conditions which are toxic to aquatic life and ecosystem diversity. These conditions threaten the health of surface waters in virtually every state. Threatened coastal waters include the Gulf of Mexico, much of the Eastern Seaboard, including the Chesapeake Bay, and areas near densely populated areas along the West Coast. In 2006, the EPA documented over 3 million acres of lakes, reservoirs, and ponds, 75,000 miles of rivers and streams, nearly 900 square miles of bays and estuaries, and over 70,000 acres of wetlands whose water quality was impaired due to nitrogen and phosphorus pollution. Forty-nine States have Clean Water Act (CWA) Section 303(d)-listed impairments for nitrogen and phosphorus pollution. States have listed over 10,000 nutrient related impairments.

- Most states had not set numeric limits for N and P for all classes of surface waters by 2009, as recommended by the U. S. EPA beginning in 1998. The EPA is currently engaged in renewed efforts to advance this process, and expects most states to establish numeric limits within the next five years. These criteria are expected to drive the adoption of stringent nutrient limits for effluent at wastewater treatment plants across the country.
- Turbidity (clarity) and chlorophyll-a are response variables that indicate high levels of N and/or P in surface waters; the EPA recommends that states also adopt numeric standards for these.
- If states have not established numeric criteria, explicit policies or regulations interpreting the states' narrative criteria may be utilized, but the EPA's preference is for states to establish explicit numeric criteria whenever practicable.
- Nitrogen loading in the Gulf *decreased* 21% from 2001 to 2005, while phosphorus loading increased 12%. These findings mean that more stringent phosphorus limits are likely to be the primary focus of nutrient control plans in the future.

The Hypoxia Action Plan for the Mississippi Atchafalaya River Basin (Gulf of Mexico) is likely to become a model for the rest of the nation regarding effluent limits for N and P.

- Recommended Total Nitrogen (TN) effluent limit: 3mg/L
- Recommended Total Phosphorus (TP) effluent limit: 0.3mg/L

The latest release (for 2008, published June 2010) of the EPA's quadrennial Clean Water Needs Survey (CWNS) estimates that capital needs for wastewater treatment in the US over the next twenty years will exceed $105 billion (2008 dollars), or in excess of $5 billion annually. Wastewater treatment is the single largest category in the needs survey, accounting for 35% of clean water expenditures. This estimate does not include pipe replacement, repair, and rehabilitation, which is estimated to cost an additional $83 billion.

Nutrient Control Techniques

There are two significant technologies currently in use to control N and P in wastewater treatment plants: biological nutrient removal (BNR) and chemical nutrient removal. Nutrient removal solely through chemical processes can be utilized in smaller treatment plants but is not cost effective for larger operations. Other methods include reverse osmosis, adsorption filters, and microfiltration processes, but these tend to be used less frequently or used in combination with the BNR and chemical processes because of their generally higher cost.

- The table below shows the typical effluent P concentrations that can be achieved using various combinations of these control methods at current limits of technology. (BPR: biological phosphorus removal)

Effluent TP mg/L	How can it be met
<1	BPR and good clarifiers
<0.5	BPR, good clarifiers and filtration
<0.1	BPR, filtration and chemicals
<0.05	BPR, Post chemical plus filtration
<0.01	BPR, Chemical, Adsorption, membranes

- The 0.3 mg/L P limit that is likely to be adopted broadly as a regulatory standard is just outside the range achievable without the use of chemicals, utilizing currently available technology and methodology.

- More efficient biological systems and processes are needed to reduce the need for chemical "polishing," both to reduce costs and avoid chemical disposal problems.
  - Metal salts (iron or aluminum) or the mineral lime are utilized in the chemical precipitation process. Lower effluent P levels require geometrically higher levels of chemical addition, which increases treatment costs dramatically.
  - The removed P is bound to the chemical salts, which makes resource recovery more difficult and increases the volume of biosolids requiring disposal.

- Where chemical treatment is still required in order to meet existing or emerging regulatory standards, there is a need for new technologies to make the process more efficient and to enable efficient resource extraction from the resulting biosolids.

- The EPA's long-term strategy favors "sustainable" nutrient removal technologies, which tend to be based primarily on combined biological and filtration processes. Filtration "finishing" processes have the added benefit of reducing other pollutants, such as EDC's and PPCP's from the effluent stream.

Technology Trends

BNR

There are a multitude of configurations available for biological nutrient removal, all consisting of some combination of aerobic, anaerobic, and anoxic processes. These BNR processes may take place in separate tanks, or may occur sequentially in the same tank (sequential batch reactor). Ideally, configurations are optimized for the particular influent characteristics and effluent requirements of each wastewater treatment plant's (WWTP) location. Current trends in BNR include experimentation with new types of configurations, process enhancements, and more precise process control in order to achieve the highest possible nutrient reduction under varied diurnal, seasonal, weekly and wet-weather flow conditions.

Innovative BNR technologies and processes

- Integrated fixed-film activated sludge (IFAS)
- Membrane Bioreactor (MBR)
- novel BNR process configurations
- Nitrification/denitrification processes
- external bioaugmentation - seeding the activated sludge process with an external source of nitrifying bacteria
- in situ bioaugmentation -making process improvements to increase the activity of or enrich the nitrifier population
- sidestream processes to grow nitrifiers onsite - many proprietary systems
- Moving Bed Biofilm Bioreactors (MBBR) - have a smaller footprint and better cold weather performance than activated sludge processes, so they are the technology of choice for chemical removal plant retrofits and cold weather climates. Sensors and controls are critical for MBBR processes. They require precise control systems for the following parameters.
  - Temperature
  - Dissolved oxygen (DO)
  - pH and alkalinity
  - Carbon sources (alternatives to methanol needed)
  - Flow equalization in response to wet weather events
  - Control of heavy metals and other inorganic compounds which can compromise bacteria

Emerging technologies and technology needs

- Fermentation processes to produce volatile fatty acids (VFA's)
- Fermentation in force mains for VFA production
- VFA addition at critical points to achieve high rates of P reduction
- Methods to control the balance between acetic, proprionic, and isovaleric acids
- Systems to control instantaneous COD:P ratio
- Control of glycogen accumulating organisms (GAO's)
- Hydraulic flow balancing control
- Organic load balancing control
- Precision mixing to retain suspension without introducing oxygen

- Selective control of aeration processes
- Precision recycle and return stream control
- Alkalizing (pH) control
- VT2 process - can achieve < 0.25 mg/L effluent P levels w/o chemicals or filtration
- Oxidation ditches - many patented variations
- Step feed - need to control DO and influent flow splitting
- Small-footprint BNR technologies for retrofit of existing chemical treatment plants
- Conservation of carbon to avoid the need to import it

Decentralized Systems

Currently, approximately 25 percent of the US population is served by on-site septic or decentralized systems. There is a growing movement toward decentralized or clustered wastewater treatment systems to reduce cost, to provide groundwater recharge near the source, and for speed and ease in siting, since they are generally located underground. The use of residential cluster development is gaining in popularity across the US as a means to permanently protect open space, preserve agricultural land, and protect wildlife habitat.

- Community drain fields
- Irrigation systems
- Aerobic tanks
- Sand filters
- Constructed wetlands
- Package plants

The Sequential Batch reactor (SBR) process is a sequential suspended growth (activated sludge) process in which all major steps occur in the same tank in sequential order. The SBR system is typically found in packaged configurations for on-site and small community or cluster applications. Package plant SBRs are suitable for areas with little land, stringent treatment requirements, and small wastewater flows. Major components of the package plant:

- Batch tanks
- Decanter device (fixed or floating)
- Process control system
  - Timers
  - Pumps
  - Piping
  - Appurtenances
  - Diffused air aeration
  - Mechanical aeration
  - Level sensors
  - Mixer
  - Microprocessors

At least one commercial package employs a thermal processing step for the excess sludge produced and wasted during the “idle” step.

Emerging on-site technologies

- About 80 percent of the nitrogen and 50 percent of the phosphorus in wastewater are derived from urine. “No Mix technology,” utilizing specially designed toilets and dual waste streams, can separate urine from solid waste. The nutrients can be extracted on-site and used as fertilizer. These systems are currently operational in several EU countries and in India.
- Another (experimental) systems consists of a basement sewage plant where domestic wastewater is treated in a membrane bioreactor so that it can be reused for flushing the toilets or watering the garden, and the sewage sludge is composted.

While studies of consumer attitudes and acceptance appear to be positive, technological improvements are still needed to prevent clogging in pipes, to identify best treatment options that can be applied in practice, and to identify how and where to convert urine to fertilizer.

Chemical Treatment

Chemical treatment is still a necessary part of nutrient removal at many WWTP's. With stricter effluent regulations, its use may even be increasing over the near term. As with BNR processes, technology is needed to enhance the efficiency and effectiveness of chemical methods. Current trends include:

- Multiple additions at varied “dosing points” in the wastewater treatment process can improve efficiency.
- Effective mixing of the chemicals to fully incorporate them into the treatment stream is also critical
- Control systems that maintain sufficiently low pH levels (<9) during chemical treatment, to ensure that biological processes work effectively.

The effectiveness of chemical P removal is directly related to the solids separation process, which precipitates the chemically bound P from the effluent. The two solids separation processes commonly used are clarification (solids settling tanks and systems) and filtration. High rate clarifiers have a smaller footprint and can be also used during wet weather events to treat influent stormwater to help prevent sanitary and combined sewer overflows.

Emerging Technologies

- Coagulants injected in a rapid mix basin
- Ballasted (including magnetic) precipitation systems - ballasted systems utilize weighted particles to increase the rate of solids separation
- High rate clarifiers that rapidly remove solids from the effluent stream
- Less toxic alternatives to ferric and aluminum salts

Filtration

The use of membranes as tertiary filtration is an area that has recently expanded. Research continues on various membrane configurations along with topics such as pre-treatment, membrane cleaning, and removal of emerging contaminants. Other issues include potential for membrane bio-fouling and increased pumping (energy) costs, and the potential for concurrent removal of Endocrine Disrupting Compounds (EDC's) and Pharmaceutical and Personal Care products (PPCP's).

Innovative and emerging filter technologies

- Fuzzy Filter®
  - Synthetic fiber spheres
  - Compressible media (density can be adjusted)
  - Flow rate up to 30 gallons per minute
- Specialized filter media
  - Nitrate-reactive media
  - Biologically active granulated activated carbon
  - Thread filters
  - Disc filters
- Iron-rich intermittent sand filters (ISF)
- Trickling filter Fixed Film Systems (FFS)
- Air scour techniques to reduce buildup on membranes
- Re-circulating sand filters (RSF)
- Reductive iron dissolution and mineralization of phosphorus
- Attached growth airlift reactor technology
- Reverse osmosis to achieve very low nutrient levels
- A variety of proprietary membrane and bioreactor technologies, many using improved fixed-film processes

Resource Recovery

There are many potentially valuable byproducts of the wastewater treatment process, such as energy extracted from anaerobic digestion, construction materials such as bricks, biodegradable plastics, and nutrients such as phosphorus and nitrogen that can be extracted from sludge and used as fertilizer.

Energy recovery processes

- Sludge to biogas
- Sludge to syngas
- Sludge to oil
- Sludge to liquid

Phosphorus Recovery

Phosphorus recovery from wastewater is a high priority. Phosphorus is a finite and rapidly declining global resource. The global market price has increased six-fold in recent years, reflecting its increasing scarcity and the recognition that supplies are finite. Climate change effects are expected to accelerate the severity of the problem. Global resources are projected to last 90 years, while US stocks will run out in 40 years. The two countries with the largest phosphorus stocks are China and Morocco.

Phosphorus can be recovered from wastewater processing, but the ease of recover depends on the removal method used. For example, phosphorus removed from wastewater using chemical processes is chemically bound with metal salts. Research is needed to determine the bio-availability of this chemically-bound phosphorus to plants, if used as a fertilizer, as well as the potential toxicity to plants of the remaining metals.

Methods to more effectively separate phosphorus from the biosolids produced in biological nutrient removal processes is an area of current research. Several different processes have been proposed that rely on precipitation of the phosphorus as either struvite (ammonium magnesium phosphate) or calcium phosphate, among other processes.

Phosphorus recovery processes

- P-precipitation using a CSH (calcium silicate hydrate) substrate
- BoironTech process using iron reducing bacteria
- Ozonation and phosphorus adsorbent
- Using ochre from mine water treatment
- Using zinc aluminum layered double silicates
- RGU + RoHM Seaborne sludge treatment process, where anaerobically stabilized sludge is treated with sulphuric acid, solids are incinerated, and the soluble part is treated to remove heavy metals by precipitation prior to P-recovery by struvite precipitation
- Using scum-forming filamentous bacteria which widely appear in BNR (biological nutrient removal) plants

Nitrogen Recovery

Nitrogen, an abundant resource, still requires energy to "fix" it into a form that can be utilized in industrial and agricultural applications. The nitrogen fixed in the wastewater treatment process represents a significant energy savings (and lower carbon footprint) compared to dedicated nitrogen production methods, and nitrogen recovery reduces the volume of biosolids that must be disposed.

Currently, nitrogen recovery is used primarily in industry. It is not yet common at municipal wastewater treatment plants (WWTP's).

Innovative nitrogen recovery processes

- ThermoEnergy Ammonia Recovery Process (ARP)
- Ammonium absorption of nitrogen to vermiculite
- Optimizing anoxic – aerobic processes in waste water treatment for nitrogen recovery

Measurement and Assessment Tools

Regulations that specify lower effluent limits for nutrients have generated the need for increasingly accurate, cost-effective and portable measurement tools and technologies. For example, phosphorus concentrations in the range of .03-.05 mg/L can be difficult to measure accurately and consistently, even in a laboratory setting. Development work is needed to design and produce advanced monitoring and test devices.

Ongoing Research

In 2007, A total of 25 priority areas were identified in a workshop conducted by the Water Environment Research Foundation (WERF). WERF will also be developing a Nutrient Compendium (www.werf.org/nutrients) that describes the current knowledge of regulatory and technological nutrient removal issues. The document will describe the key knowledge areas affecting nutrient removal to very low levels and identifies knowledge gaps related to nutrient removal.

Seven topics have been selected as the top priority.

- Effluent dissolved organic nitrogen
- Alternative carbon sources
- Regulatory issues for low-level nitrogen and phosphorus
- Operations
- Biological treatment processes for achieving low nitrogen and phosphorus effluent levels
- Low phosphorus concentration measurements
- Tertiary phosphorus removal

Bibliography and Sources

Nutrient Control Design Manual State of Technology Review Report EPA/600/R-09/012
The Cadmus Group, Inc, 57 Water Street Watertown, MA 02472, January 2009
Municipal Nutrient Removal Technologies Reference Document EPA/832/R-08/006, September 2008
Ryujiro Tsuchihashi, Operation and Control Compendium, Water Environment Research Foundation, November 2008, http://www.werf.org/nutrients/
EPA Region 5 Nutrient Control Technology Transfer Seminar presentations, May 25-26, 2010, Chicago, IL. Copies of presentations available upon request.
Fuzzy Filter®, http://www.schreiberwater.com/html/equipment/fuzzyfilter.html
Fixed-film processes, http://www.epa.gov/nrmrl/pubs/625r00008/html/tfs2.htm
International Conference on Nutrient Recovery From Wastewater Streams Vancouver, 2009,

http://iwawaterwiki.org/xwiki/bin/view/Articles/InternationalConferenceonNutrientRecoveryFromWastewaterStreamsVancouver2009

APPENDIX A Technology Selection for Nutrient Removal Matrices

Table 5-5. Technology selection matrix: nitrogen removal

Process	Site factors						Wastewater factors	Operation factors		
	Footprint	Building needed	Construction in existing aeration basin	Piping and pumping	Extra head needed	Secondary process recycle streams	Additional carbon source needed	Extra electricity	Chemicals needed	Add'l sludge
Denitrification filters	Small	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes
MBBR	Medium	No	Maybe[1]	No	No	No	Maybe	No	Maybe	Maybe
SBR/cyclic activated sludge	Medium	No	Yes	No	Maybe	No	Maybe	Yes	Maybe	Maybe
MLE/3-stage Westbank	Medium	No	Maybe	Yes	No	Yes	Maybe	Yes	Maybe	Maybe
Phased isolation ditch	Large	No	Maybe	No	No	No	Maybe	Yes	Maybe	Maybe
4-stage Bardenpho	Large	No	Maybe	Yes	No	Yes	Maybe	Yes	Maybe	Maybe
A^2O	Medium	No	Maybe	Yes	No	Yes	Maybe	Yes	Maybe	Maybe
Anoxic zone following aeration(Blue Plains)	Medium	No	Maybe	No	Maybe	No	Yes	Yes	Yes	Yes
Biological aerated filtration	Medium	Maybe	No	Yes	Yes	Yes	Maybe	Maybe	Maybe	Maybe
Step-feed AS	Large	No	Yes	Yes	No	Yes	No	No	No	No
IFAS	Medium	No	Maybe[1]	No	No	Yes	Maybe	Maybe	Maybe	Maybe

Notes:
[1]Installation of media retention screens, as needed.
Additional carbon source and chemical needs: To obtain sufficient carbon for anoxic reaction, use either external source (methanol) or step-feed activated sludge.
Construction needs: External filters require extra space and could require a building depending on conditions.
Adjustments in basins include walls to section off anoxic basins and, potentially, piping to accommodate step-feed activated sludge.
Additional sludge generation is partially dependent on the need for addition of a carbon source.
Selection factor designations are general guidelines and may not apply for all site-specific conditions.

MBBR = moving bed biofilm reactor; SBR = sequential batch reactor; MLE = modified Ludzack-Ettinger system; A^2O = anaerobic-anoxic-oxic; AS = activated sludge; IFAS = integrated fixed-film activated sludge

Table 5-6. Technology selection matrix: phosphorus removal

	Site factors						Wastewater factors	Operation factors			
									Chemicals needed		
Process	Footprint	Building needed	Construction in existing aeration basin	Piping and pumping	Extra head needed	Secondary process recycle streams	Additional carbon source needed	Extra electricity	C add'n	Chem P rem	Add'l Sludge
A/O	Medium	No	Yes	No	No	No	Maybe	Yes	Maybe	Maybe	No
SBR/CAS	Medium	No	Yes	No	Maybe	No	No	Yes	No	Maybe	No
VIP/modified UCT	Medium	No	Maybe	Yes	No	Yes	Maybe	Yes	Maybe	Maybe	No
Chemical precipitation	Small	Yes	No	Yes	No	No	No	Minimal	No	Yes	Yes
Tertiary clarifier/tertiary filter	Medium	Maybe	No	Maybe	Yes	Yes	No	Yes	No	Yes	Yes
PhoStrip	Small	No	No	Yes	No	Yes	No	Yes	No	Yes	Yes
5-stage Bardenpho	Large	No	Maybe	Yes	No	Yes	Maybe	Yes	Maybe	Maybe	Maybe
3-stage Westbank	Medium	No	Maybe	Yes	No	Yes	Maybe	Yes	Maybe	Maybe	Maybe
EBPR with VFA addition and filters	Medium	Maybe (Filters)	Maybe	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe
MBR	Small	Yes	Yes	Yes	Yes	No	Maybe	Yes	Maybe	Yes	Yes
Phased isolation ditch	Large	No	Maybe	No	No	No	No	Yes	No	Maybe	Maybe
Membrane filter	Small	Maybe	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes
CoMag	Medium	Maybe	Maybe	Yes	Yes	Yes	No	Yes	No	Yes	Yes
Infiltration basin	Large	No	No	No	Yes	No	No	Minimal	No	Yes	Yes

Notes: CAS = cyclic activated sludge; VIP = Virginia Initiative process; EBPR = enhanced biological phosphorus removal; VFA = volatile fatty acids
See "Tertiary clarifier/tertiary filter" row for information that applies to specialty filters.
Selection factor designations are general guidelines and may not apply for all site-specific conditions.

A/O = anaerobic/oxic process; SBR = sequential batch reactor; UCT = University of Capetown process; MBR = membrane bioreactor; CoMag = proprietary ballasted solids precipitation process utilizing magnetite

Table 5-7. Technology selection matrix: nitrogen and phosphorus removal

	Site factors						Wastewater factors	Operation factors			
									Chemicals needed		
Process	Footprint	Building needed	Construction in existing aeration basin	Piping and pumping	Extra head needed	Secondary process recycle streams	Additional carbon source needed	Extra electricity	C Add'n	Chem P Rem	Add'l sludge
Step-feed with selector	Medium	No	Yes	Yes	No	No	No	No	No	Maybe	Maybe
IFAS with selector	Medium	No	Maybe[1]	No	No	Maybe	Maybe	Maybe	Maybe	Maybe	Maybe
A^2O	Medium	No	Yes	Yes	No	Yes	Maybe	Yes	Maybe	Maybe	Maybe
SBR/CAS	Medium	No	Yes	No	Maybe	No	Maybe	Maybe	Maybe	Maybe	Maybe
VIP/modified UCT	Medium	No	Maybe	Yes	No	Yes	Maybe	Yes	Maybe	Maybe	Maybe
Phostrip II	Medium	No	No	Yes	No	Yes	No	Yes	No	Yes	Yes
3-stage Westbank	Medium	No	Maybe	Yes	No	Yes	Maybe	Yes	Maybe	Maybe	Maybe
5-stage Bardenpho	Large	No	Maybe	Yes	No	Yes	Maybe	Yes	Maybe	Maybe	Maybe
EBPR with VFA addition	Medium	No	Maybe	Yes	Maybe	No	Yes	Yes	Yes	Maybe	Maybe
MBR	Small	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Yes	Yes
Chemical precipitation	Small	Yes	No	Yes	No	No	No	Minimal	No	Yes	Yes
Filtration	Medium	Maybe	No	Maybe	Yes	Yes	No	Yes	No	Yes	Yes
Denitrification filter	Small	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Maybe	Yes
Phased isolation ditch	Large	No	Maybe	No	No	No	No	Yes	No	Maybe	Maybe

Notes:
[1] Installation of media retention screens, as needed.
Additional carbon source: To obtain sufficient carbon for anoxic reaction, use external source (methanol) or step-feed activated sludge.
Construction needs: Adjustments in basins include walls to section off anoxic basins and, potentially, piping to accommodate step-feed activated sludge.
Selection factor designations are general guidelines and may not apply for all site-specific conditions

IFAS = integrated fixed-film activated sludge; SBR = sequential batch reactor; A^2O = anaerobic-anoxic-oxic; SBR = sequential batch reactor; UCT = University of Capetown process; MBR = membrane bioreactor; EBPR = enhanced biological process removal; CAS = cyclic activated sludge; VIP = Virginia Initiative process; VFA = volatile fatty acids

Chapter 6 Examples of Current Products

Selected Products from ACE 10 Technology Show, Chicago, June 2010

Virtually all of the products listed below were exhibited at the ACE Technology Show at McCormick Place in Chicago in June 2010. The list is not inclusive, as the exhibit section was extremely large. The examples are given because they attracted our attention and covered a variety of the problems facing communities. The products largely address water treatment and water distribution issues.

Oasis Filter International, Calgary, Alberta. Manz Slow Sand Filter & Polishing Filter
www.oasisfilter.com

- Low pressure backwash preserves beneficial aerobic biofilm at top of filter
- Quick backwash process – 30 minutes
- System maintains 5cm water layer when flow is paused to keep biofilm viable
- Filter removes particulates, spores, bacteria, viruses, TOC/DOC
- With pre-treatment, removes heavy metals, arsenic, fluoride
- Inventor of Biosand Filter
- Filters are readily fabricated worldwide using indigenous materials

Brentwood Industries, Reading, PA. Thermoformed PVC Trickling Filters
www.brentwoodprocess.com

- 2-3x surface area compared to rock filters
- 95% void volume, compared to 50% for rock filters
- Cross-flow media on top, vertical-flow on bottom
- For BOD roughing and nitrification
- Energy efficient process – pumping and recirculation only (no aeration, etc. needed)
- Submerged fixed film process also uses structured sheet PVC media
- Simple dome controls odors

Earthtec, Bentonville, AR. Copper-based Algicide/Bactericide
www.earthsciencelabs.com

- Bioactive formula (Cu^{++}) penetrates polysaccharide sheaths
- No known DBPs produced
- Fully soluble
- Low pH
- For pre-treatment and groundwater applications

Neptune Technology Group, Tallassee, AL. Metering Systems
www.neptunetg.com

- Lead-free bronze construction
- 8-digit flow registration helps to detect leaks
- AMI – advanced metering infrastructure
- Rolling 96-day period of hourly data available
- Fixed network data collection

- RFI or cellular
- Energy and labor-saving alternative to handheld and mobile Automated Meter Reading

- Permalog acoustic leak sensing
- SEER – statistical model to predict meter accuracy in order to optimize rehabilitation and replacement cycles

Atlantium Technologies, Bet Shemesh, Israel. Hydro-Optic Disinfection (UV)
www.atlantium.com

- Quartz tube reflection chambers achieve even UV distribution
- Non-immersion design for ease of maintenance
- UV dose adjusted in real-time – lamp intensity, water flow, and transmissivity
- Ultrasonic cleaning mechanism
- Medium pressure lamp operates over broad spectrum with high density
- Meets USEPA LT2 - achieves 5 log (99.99%) reduction of pathogens
- HOD has lowest energy cost per gallon treated

Fairmount Water Solutions, Chardon, OH. Macrolite (Ceramic), Sand, & Silica Filtration Media
www.fmwater.com

- Macrolite
  - Uniform particle size, shape, sphericity, & density
  - Higher flux - smaller footprint
  - Higher surface area compared to aggregates
  - Surface composition promotes colloidal attachment
  - Enhances iron, manganese, and arsenic removal
- On-site piloting of filtration systems

Adsorbent Carbons, Chennai, India. Activated & Impregnated Carbon Media www.carbons.in

- Coconut shell – micro-pores absorb gaseous molecules
- Silver & KoH impregnated carbon
- Wood based powder – pharmaceutical grade

EP Minerals, Reno, NV. Nanocrystalline Adsorptive Media www.epminerals.com

- NXT-2 lathanum-based media
- Removes arsenic. Also phosphate chromium, selenium, fluoride, antimony, lead, etc.
- High surface area – lowest treatment cost
- Will not release bound arsenic - non-hazardous waste

Sewerin, Golden, CO. Leak Detection Technologies www.sewerin.net

- Aquaphon acoustic leak detection – test rod/ground microphone
- Combiphon acoustic plastic pipe locator
- Correlator – uses DSP techniques to eliminate background noise effects
- Noise recording loggers to detect leaks 24/7

GP Piping, Tustin, CA. Valves, Sensors. www.gfpiping.com

- Improved diaphragm valve reduces pressure drop and increases flow volume by reducing turbulence

GE, Process Water Treatment for Mining www.ge.com/energy

- Allows 99% process water re-use (coal mining application)
- Ultrafiltration, RO, brine-evaporation, & salt crystallization

US Pipe, Birmingham, AL. www.uspipeinnovation.com

- Innovative new product that promises to reduce leaks, save energy and increase efficiency – coming fall 2010

Pureline, Irvine, CA. Chlorine Dioxide www.pureline.com

- 2.5 times the oxidizing capacity of chlorine
- Does not chlorinate organic materials
- No THMs, HAAs, etc.
- No harmful effects on membranes, equipment, or pipes

Airvac, Oldsmar, FL. Vacuum Sewer Systems www.airvac.com

- Small diameter, shallow piping reduces installation, expansion, and maintenance costs
- No infiltration or inflow
- O & M costs competitive with gravity systems
- Fewer lift stations – leaves more land available for development

Nitron, Yehud-Monosson, Israel. Selective Electro-Dialysis for Nitrate Removal www.nitron.co.il

- SED uses 60% less energy than RO
- 95% of water is output, compared to 80% for RO
- Very low chemical use – used only in concentrate stream

C-Valves, Rosh Pina, Israel. www.cvalves.com

- Linear-flow, linear-control piston valves
- Glass-fiber reinforced nylon materials
- Low pressure drop
- Low noise
- Negligible cavitation
- Soft closure – no "water hammer"
- Security valve
  - Normally closed, spring actuated
  - Actuator protected by surrounding valve assembly and pipe
  - Accumulator pressure tank allows valve opening in the absence of line pressure

CheckLight, Qiryat-Tiv'on, Israel. Water Contaminant/Security Monitors www.checklight.biz

- Luminous bacteria technology
- Detects a wide range of contaminants

- Detects organic and non-organic toxins
- Real-time portable and fixed monitors

Flexim, Edgewood, NY. Non-Invasive Flow Measurement www.flexim.com

- Transit time difference correlation principle - ultrasonic pulse injected into flow by upstream transducer and received by downstream transducer

Inopor, Veilsdorf, Germany. Ceramic Membranes for Micro-, Ultra- and Nanofiltration www.inopor.com

- Chemical, mechanical and thermal stability
- Steam sterilization and back flushing capable
- High abrasion resistance
- High fluxes
- High durability
- Bacteria resistance
- Possibility of regeneration
- Dry storage after cleaning

Blue Earth Labs, Las Vegas, NV. Scale Removal Chemicals www.blueearthlabs.com

- Clearitas - proprietary oxidized chlorine
  - Neutral pH
  - Removes organic and inorganic scale from pipes and equipment
  - Non-toxic
  - Lowers disinfectant demand and resulting DBPs

Technical Associates, Canoga Park, CA. Chemical, Biological, and Radiation Sensors www.tech-associates.com

- Real-time monitoring for radio-nuclide, chemical, and biological contaminants
- Portable, self-contained units
- Comprehensive monitoring

Utility Service Company, St. Louis, MO. Tank Management and Maintenance www.utilityservice.com

- Active mixing systems to eliminate thermal stratification and icing
  - Six-inch impeller (designed using bio-mimicry) can mix up to seven million gallons
  - Energy efficient (300 watts)
- Chemical bio-film removal from tank walls for lower disinfectant demand

Filtronics, Anaheim, CA. Filtration and Backwash Cleaning Systems www.filtronics.com

- Electromedia - proprietary mineral blend media for removal of arsenic, radium, iron, manganese and other metals
- Backwash filter cleaning system allows reclamation of 99% of filter wash water
- Backwash to filtration ratio less than 1%

Miya, Luxembourg. Leak Detection www.miya-water.com

- District Metered Areas - relatively new approach in North America
  - Measure inflow & outflow within distinct boundary areas to detect leaks
  - Accurate metering required
  - Utilizes valves to set boundaries and manage pressure
- Non revenue water (NRW) management software
- Theft and illegal connection identification

Goodman Ball, Menlo Park, CA. Portable Water Purification System www.goodmanball.com

- Military, humanitarian, industrial systems
- Metered chlorination with diatomaceous earth (DE) filtration (for oocyst removal)
- DE capable of 6 log (99.9999%) removal, depending on media grade
- Meets USEPA LT2 Rule requirements for Cryptosporidium
- Electric/diesel powered
- Future units will offer desalination

Performance Pipe, Plano, TX. High Density Polyethylene Pipe www.performancepipe.com

- Flexible
  - Tight bend radius
  - Immunity to freeze, fatigue, and surge damage
  - Sliplining applications
- Low flow resistance
- Installation methods
  - Direct burial
  - Horizontal directional drilling
  - Planting
  - Plowing
  - Pulling

Nicor, Healdsburg, CA. Polymer Manhole Covers and Meter Pit Lids www.nicorinc.net

- RF transparency for AMR/AMI applications
- Custom sizes, colors, graphics
- Lightweight

Arad Technologies, Yokneam Elit, Israel. Automated Meter Reading www.aradtec.com

- Fixed based combined utility (electric, gas, water) systems
- Fly-by remote controlled drone AMR
- Internet-based AMR network

MIOX, Albuquerque, NM . On-site Chlorine Generation www.miox.com

- Process uses salt and electricity
- Produces "fresh" hypochlorite or mixed oxidants
  - More potent
  - Fewer degradation products (chlorate and perchlorate)
- Lower transportation and storage costs

- Hydrogen byproduct - must be vented
- Hand-held to industrial sizes

Orica, Melbourne, Australia. MIEX Polymer Bead Resin www.miexresin.com

- Magnetic ion exchange
- Proprietary resin with magnetic center for pre-treatment dissolved organic carbon removal
- Lowers DBP's by reducing disinfectant demand

Primayer, Denmead, Hampshire, UK. Multi-point Correlation System for Acoustic Leak Location

- Enigma correlating logger
  - Narrow band filtering
  - Advanced noise rejection
  - 24 bit processing
  - Simultaneous leak detection and location
  - Works in large mains
  - Pipe schematic map overlay capability
  - Multiple leak detection

ADS, Huntsville, AL. Flow Monitors www.adsenv.com

- Flowshark Triton
  - Cross-checking of multiple depths and velocities
  - Four sensor options

Industrial Test Systems, Rock Hill, SC. Exact LEADQuick Photometer www.sensafe.com

- Direct read parameters: lead, mercury, cadmium
- eXact® Strip/Photometer reagent delivery system
- 0.01 ppm (mg/L) precision with no visual color matching required
- Waterproof, floating meter
- Autocalibrating

McGard LLC, Water Security Products, Orchard Park, NY. www.mcgard.com

- Smart Shield
- Wireless tamper alarm for manholes, etc.
- E-mail and cellular text notification

Sigelock Systems, LLC, Melville, NY. Secure Hydrants www.sigelock.com

- Spartan high security hydrant
- Fully enclosed nozzles and valve nut
- Tamper resistant
- Innovative valve design resists freezing, debris and root growth
- Optional “urban” sprinkler cap - fire department can allow youth to cool-down without danger of street flooding

Solarbee, Inc., Dickinson, ND. Chlorine Boosting System www.solarbee.com

- Potable water in-tank mixing with hypochlorite injection
  - Reduces nitrification
  - Maintains chlorine residual

Amiad Filtration Systems, Oxnard, CA. www.amiad.com

- Microfiber thread reusable filters - alternative to disposable cartridges
- Suction-scanning automated filter cleaning
- Grooved disc filter - telescoping core separates discs to facilitate cleaning

Wedeco (ITT), Charlotte, NC. www.wedeco.com/us/

- Advanced oxidation process for micro-contaminants (NDMA, PPCP's, etc)
  - Ozone + hydrogen peroxide
  - UV + hydrogen peroxide
  - Utilizes OH radical - powerful oxidant

Bibliography and Sources

Journal AWWA, Volume 102 Number 6, June 2010
www.awwa.org/Publications/JournalCurrent.cfm

On-Site Generation of Disinfectants, Spring 2009, Vol. 9, Issue 1, National Environmental Services Center (NESC) West Virginia University Morgantown, WV
http://nesc.wvu.edu/techbrief.cfm

Manufacturer brochures and websites

Product demonstrations at ACE 10 conference and exposition, Chicago, June 21-22, 2010

Chapter 7 Next Steps

The preceding chapters have revealed a good deal about the issues and markets surrounding access to water, treatment and distribution of water, efficient and inefficient use of water, collection and treatment of waste water, real-time monitoring of ground and surface water for both quantity and quality, special markets - such as confined animal feeding operations (CAFOs) or specific industries like electric power generation and oil and gas exploration and production, water reuse, and a host of other challenges. There are many needs across the U.S. and the world. And there are some well-developed and accessible markets that should be and can be served by firms located in the greater Milwaukee region.

The Milwaukee Water Council (WC) must develop the mechanisms to best distribute this knowledge to interested companies and researchers in the region and connect the industries with the appropriate markets. The insights are on the written page, but few firms or researchers will spend the time to explore its many pages without some additional assistance. So, an important task is deconstructing what is contained in this report and parsing it out to firms and researchers who may have an interest in particular parts.

STEP ONE
Some of these connections between identified markets and local firms and researchers will be relatively easy to make because the WC staff knows who has what interests or products that relate to some of what is needed in specific states or nations. Making the connections and educating the firms and researchers that are known to have related interests will be step one.

STEP TWO
Step two involves a further deconstruction of the information in the report. The many details on markets in the different geographies are difficult to access by those pressed by time constraints. To make this information more accessible to all, the WC will make the explicit effort to construct a large-scale matrix that breaks out by location the water conditions (quality and quantity) extant, the current issues that have risen to be of greatest concern, the potential solutions identified to address the specific issues, and the industries most likely to be working on or providing the solutions. There will also be an assessment of the current market strength in each geographic area for solutions to the identified problems. The intent is to create a "super summary" that will inform readers more quickly and lead them to more details, should they want to pursue them.

Part of step two, as just mentioned, will be the construction of more specific assessments of product and process markets in each of the several geographies covered in this report. As the reader can attest, the market analysis in many cases has been taken pretty far already. What would assist the WC effort is to go a bit further in the specific assessment of the market growth rate for each geographic area, be it state or nation, among the markets that have been identified as most important to address. Some of these markets are important but are not likely to receive the financial attention they deserve; others are important and will likely be funded at higher levels going forward. Such distinctions will be helpful to the regions' firms and researchers, as they prioritize their subsequent activities.

Another part of step two will involve utilizing the many insights that EPA provides on both its appraisal of water problems in the U.S. and its assessment of technologies that have promise. Two chapters in the report cover these topics, but again a more direct route to topics of particular firms and researchers will be developed to speed distribution of this useful information.

STEP THREE
Step three will involve making connections between market knowledge and regional firms and researchers who are not yet aware that some of this information is likely to be of great interest to them. This is a much more difficult assignment. To work, what is required is greater knowledge of what are the updated interests of the water related firms and the research applications of the water researchers. WC staff will have to learn more from firms and researchers both to be better able to make connections and better use what has been learned about developed and developing markets.

STEP FOUR
A fourth step will be an effort to gather the knowledge from the region as it tries to meet the growing domestic and foreign water-policy and water-technology needs. What markets have proven to be approachable and which are not? What are the potential markets in which collaboration of local firms could develop competitive solutions? These are questions whose answers will help steer WC actions.

STEP FIVE
The fifth step will take a larger focus. As is already clear, the WC is getting increasingly involved in global water issues, not just domestic, regional or national issues. To truly contribute to solutions, the region must help to answer the larger question of what it will take for the U.S. to be more competitive globally in water solutions. This will be based on an assessment of the experiences of local companies as they have tried to become involved in the national and international arenas and analysis of what it is that needs to be done differently to generate greater success. This effort is aimed at learning what it is the WC can do to help its members become truly competitive and to show the solutions to others in the U.S.

STEP SIX
The sixth step is one that is likely to be concurrent with several others because it can help further develop markets for water solutions. The step is the testing and wide application of the “Blue Footprint™” concept. This effort to drive behavior the same way analysis of one’s carbon footprint can by combining water, energy and economics into a Blue Footprint™ may well increase global interest in a range of water policy and technology solutions. If true, that will open more markets to the region and to the U.S for the development of solutions that are applicable in a range of situations around the globe.

There is more than ample opportunity in the water sector. This report spells out many of the particulars. But to be more useful, it behooves the WC to spend time and energy attempting to help its members better grasp the opportunities and better understand the contributions of research and policy to better meet market needs. If these connections are made, the region’s water actors will generate additional jobs and incomes in the region.