USE OF IMPAIRED WATERS in POWER PLANT COOLING TOWER SYSTEM: REVIEW OF REGULATIONS AND FEASIBILITY ANALYSIS

by

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Submitted to the Graduate Faculty of

Swanson School of Engineering in partial fulfillment

of the requirements for the degree of

Master of Science in Civil Engineering

University of Pittsburgh

2010

UNIVERSITY OF PITTSBURGH

SWANSON SCHOOL OF ENGINEERING

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In 2000, the freshwater withdrawn for industrial use in the U.S., including mining, industrial process usage, power generation, etc., has reached 45% of the total daily freshwater withdrawal of 346 billion gallons. Among these industries, thermoelectric generation is the largest freshwater user with a withdrawal of 136 BGD. Fierce competition for this valuable resource will force difficult decisions to be made about allocation priorities and water availability for electric power production. Studies have shown that impaired waters can be used as alternative water sources for certain applications, including makeup water in electric power plant cooling systems. Among all possible impaired waters that could potentially be used in power production, secondary treated municipal wastewater is the most common and widespread source.

Review of regulations that govern water reuse revealed that there are no federal regulations specifically addressing water reuse and that a number of states have implemented their own regulations. Several states were investigated for specific regulations and/or guidelines related to water reuse in power plant cooling water systems.

The geospatial analysis performed in this study was designed to evaluate the feasibility of using treated municipal wastewater for cooling in power industry. By utilizing the geoprocessing tools of a geographic information system (GIS), this study evaluated if the water demand of a particular facility can be satisfied by nearby Publicly Owned Treatment Works (POTWs). Datasets of 110 power plants proposed for development and 11785 POTWs were evaluated as part of this feasibility analysis. Estimated cooling water needs for the proposed power plants

were compared with the total wastewater flowrates discharged by nearby POTWs. Data analysis revealed that 81% of the proposed power plants would have sufficient cooling water supply from POTWs within a 10 mile radius, while 97% of the proposed power plants would be able to meet their cooling water needs from POTWs located within 25 miles from these plants. On average, 1.15 POTWs were needed to completely satisfy the cooling water demand for each of these power plants. In other words, one fairly large POTW within a reasonable distance from each power plant could meet most of its cooling water needs.

Dataset of 407 existing coal fired power plants was also evaluated using the same process. All of the existing power plants were assumed to be renovated to wet recirculating cooling systems regardless of their original design. Results indicate 49.4% of the existing power plants would have sufficient cooling water supply from POTWs within a 10 miles radius; 75.9% of the existing power plants would have sufficient cooling water supply from POTWs within a 25 miles radius. For those power plants which have sufficient water supply, an average number of 1.46 POTWs are required to satisfy the cooling water demand.

The tools developed in this study can be used to evaluate a number of scenarios for alternative cooling water supply needed for energy generation in the future. It is clear that the reclaimed municipal wastewater can and will likely play a more prominent role in this critical industrial sector.

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ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to those who have helped me make this work possible. First, I want to thank my advisor, Professor Radisav D. Vidic, for his guidance and for giving me the opportunity to participate in this research. His innovative ideas and organizational skills provided the foundation of this research and his encouragement, meticulousness and pursuit for perfection greatly enhanced its quality. It has been an honor and a life-changing experience working with him.

I would also like to thank Professor David A. Dzombak for our pertinent discussions throughout the two years. His advice and suggestions helped me to get technical and practical insights into the scope of my research. Thanks to Professor Jason D. Monnell for his insightful comments and suggestions to improve it. I also express thanks to Professor William Harbert who helped me to improve my GIS operation and gave me much needed suggestions.

I especially appreciate the diligent assistance and sincere cooperation of current members of this research project: Ming-Kai Hsieh, Heng Li and Indranil Chowdhury. I am really thankful to Ming-Kai for assisting me in collecting regulations and giving me insightful suggestions throughout this research.

I would also like to thank the United States Department of Energy, National Energy Technology Laboratory for funding this innovative research project (Grant No. DE-FC26-06NT42722) and their cooperation and support to find the alternative sources of water for cooling systems for a sustainable power plant operation.

I would like to thank the community of science and Pennsylvania Department of Environment Protection for providing solid research environment and friendly support during my study.

I am really grateful to my family members, particularly my mother A-Chin Chen, my father Li-Ching Chien and my sisters--Wei-Jan Chien and Su-Yu Chien. I could not have reached this stage of my life without their endless support and encouragement. Finally, I would like to dedicate this thesis to my parents who devoted their entire life to helping people unselfishly and encouraging me throughout my academic career.

1.0 INTRODUCTION

The issue of water shortage is becoming more prominent in the U.S. as population increases and global warming affects water supplies (Hinrichsen, Robey et al. 1996). The freshwater usage in the U.S. has increased from 341 to 378 billion per day between 1995 and 2000 (USGS 2000). The major freshwater users are irrigation (39%) and thermoelectric power generation (38%-39%). Water needs in a thermoelectric power plant include water for cooling, water for operation of pollution control devices, such as flue gas desulfurization (FGD), as well as for ash handling, wastewater treatment, and wash water.

Cooling tower operation is based on evaporative condensation and exchange of sensible heat. Depending on the technology used for cooling, the amount of water usage can be quite different. For a once-through cooling tower, 20–50 gallons of water are required to generate each kW-hour of electricity. On the other hand, modern recirculating cooling towers need 0.2 to 0.6 gallons of water to generate each kW-hour electricity (Veil 2007).

It is estimated that water demand for energy generation will increase by 50% by 2030 (USDOE 2008). Fierce competition for this valuable resource will force difficult decisions about allocation priorities and water availability for electric power production. Therefore, alternative sources of water for cooling tower operation are likely to be in even greater demand in the future.

Some potential alternative sources of cooling water include treated municipal wastewater, treated mine drainage, and ash transport water from coal-fired power plants. It has been shown that impaired waters can be used as cooling water in electric power plants (Richard 1964; Paul and Ken 2003; Veil, John et al. 2003). However, most of these reuse applications employ fairly limited addition of wastewater to cooling tower as make up water. In addition, these applications represent special circumstances (e.g., both POTW and power plant owned by the same company, close proximately of the two, demonstration project, etc.) and there is no reliable information about the true potential of these alternative water sources to meet cooling water demand of power industry.

This study was designed to evaluate key regulation incentives and obstacles for impaired water reuse in cooling applications and to provide comprehensive assessment of the availability of secondary effluent from POTWs to meet the cooling water needs of existing and proposed thermoelectric power plants. In addition, technical issues associated with the use of selected impaired waters were evaluated in both lab- and pilot-scale studies together with potential operating strategies that would ensure proper performance of these critical systems in thermoelectric power plants.

2.0 WATER SHORTAGE IN THE NEAR FUTURE FOR THERMOELECTRIC POWER PLANTS

2.1 WATER AVAILABILITY IN THE UNITED STATES

Although 70% of the earth's surface is covered with water, most of that is saltwater. By volume, only 3% of all water on earth is fresh-water, and most of it is largely unavailable (Duddin and Hendrie 1989) since it exists in the form of ice located in remote areas far away from most human habitation; only about 1% of all available water is easily accessible, surface freshwater. This is mainly the water found in lakes and rivers. In sum, only 0.007% of the world's total supply of water is considered easily accessible for human use (Lefort 1996).

The U.S. population has been steadily increasing from 1990s to 2000s. Figure 1 shows the resident population change between 1990 and 2000 in the 50 states. Among the 50 states, Nevada and Arizona experienced the highest population increase rates, which are 66 % and 40 %, respectively. The intermountain states have an average increase of 30%. Apparently, the southern states have faster population increase because of the available undeveloped territory and immigration. The future population in the U.S. is also estimated to increase by as much as 82% (from 296 to 438 million) in the U.S (Passe and Cohn 2008).

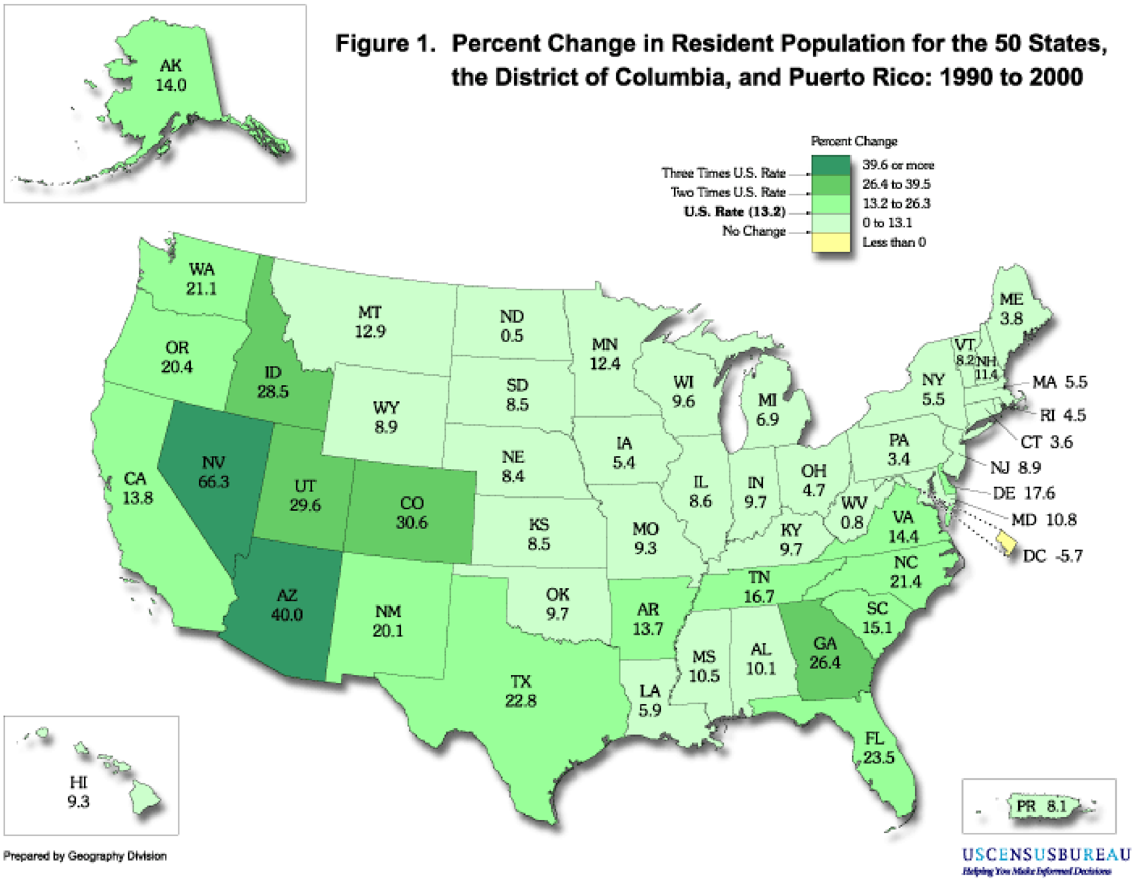


Figure 1. Population change in the U.S. from 1990 to 2000. Darker color indicates the higher increase rate (Adapted from (USCB 2000)).

Figure 2 shows the drought monitor in the U.S. in October, 2007. A comparison of Figure 1 and Figure 2 shows that the areas where the population is high also have intensive drought, especially in southwestern and southeastern U.S. It is clear that these conditions represent significant challenges for industrial water uses and that the industry will most likely have to find alternative solutions to their current water needs.

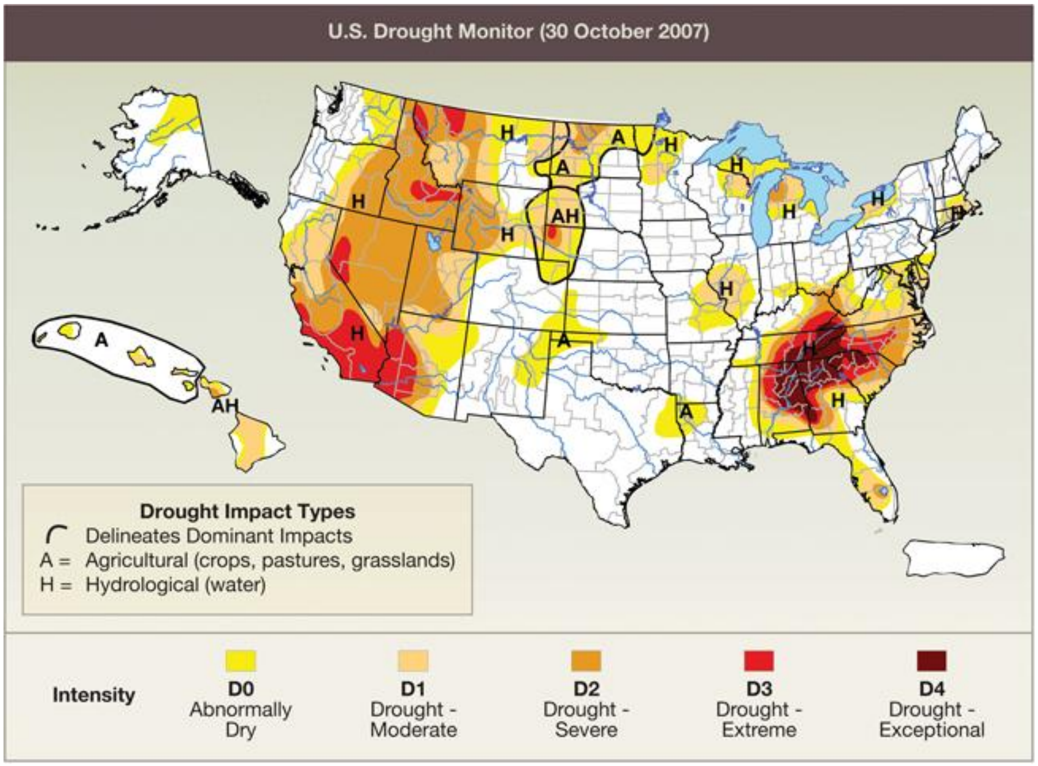


Figure 2. U.S. Drought monitor. Drought Monitor integrates information from a range of data on rainfall, snowpack, streamflow, and other water supply indicators into a comprehensible picture. (Adapted from (USGCRP 2007)).

2.2 WATER AND ENERGY ISSUES

Following rapid population growth is the increase in energy demand. In order to satisfy the developing communities and businesses, more energy will be produced; in other words, more water will be needed. Thermoelectric power generation, which represents about 91% of electrical power produced in the U.S. (Figure 3), (USEIA 2007), requires an abundance of water for its operation. In addition, the total thermoelectric generating capacity is expected to increase by nearly 18 % between 2005 and 2030. The increasing energy demand in next decades would certainly aggravate the water shortage problem, especially the availability of water used for electricity generation (USDOE 2008).

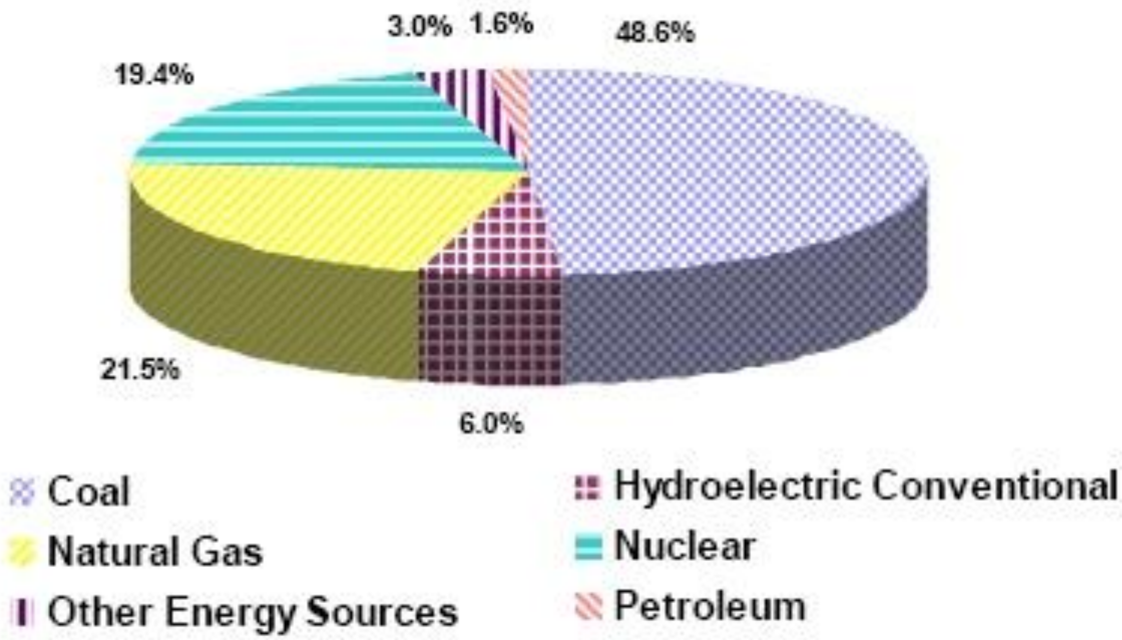


Figure 3. Net Generation Shares by Energy Source: Total (All Sectors), Year-to-Date through December (USEIA 2007).

During the electricity generation process, process water is converted to steam to drive the turbine and generate electricity. Steam is then exhausted from the turbine and condensed for reuse. Coolant, such as water, is introduced to absorb heat from the exhaust steam so that the process water can be recycled. Therefore, the design and operating parameters of the cooling system are critically important for the overall power generation efficiency. At higher condenser cooling water inlet temperatures, the steam condensate temperature is higher and subsequently turbine backpressure is higher. The turbine backpressure is inversely related to power generation efficiency (i.e., the higher the turbine backpressure, the lower the power generation efficiency).

There are three major types of wet cooling procedures currently used by thermoelectric power generation, including once-through cooling system, wet recirculating system, and a cooling pond. Once-through cooling system draws surface water from lake, river, or the ocean for one time cooling and then discharges the heated water back to the water body. For once-through cooling system, the water withdrawal is high, but the water consumption is low. However, the higher temperature effluent usually causes the changes in aquatic ecology and damages the local natural habitats. The construction of once-through cooling systems is highly restricted in many states because of 316(b) Federal regulation (CWA 2002). Clean Water Act section 316(b) introduced technology-based standards to reduce the harmful effects associated with cooling water intake structures on marine and estuarine life, such as trapping fish and small mammals against the intake screen, sucking in immature larvae and eggs, etc. In addition, the National Pollutant Discharge Elimination System (NDPES) program is involved in any point discharge source, thus making the construction of once-through cooling tower quite challenging.

In a wet re-circulating cooling system, warm water is transferred to a cooling tower and exposed to ambient air for cooling through evaporation. Contact between water and air is enhanced by the use of packing material in the cooling tower and the natural draft is used to pull air through the tower. Since the water keeps recycling in the system, the total water withdrawal decreases, but the total water consumption increases because of significant evaporative loses. Cooling pond uses the same mechanism as the re-circulating system but it relies on the natural heat transfer from the water to the atmosphere.

Dry cooling systems are also used in either direct cooling or indirect cooling arrangement. High flowrate of air is blown to the surface of an air-cooled condenser to absorb the heat via convective heat transfer, which is called direct dry cooling. Indirect dry cooling uses the same water-cooled condenser but uses air instead of water as a coolant. Therefore, both processes have no loss of cooling water and the freshwater withdrawal and consumption are minimized. However, due to significantly lower heat capacity of air as compared to water, dry cooling systems are usual larger and require significantly larger capital costs.

For wet recirculating systems, each kW-hour of electricity generation requires 20-50 gallons of water in once through cooling systems, while only 0.3-0.6 gallons of water is required to generate each kW-hour of electricity in modern re-circulating systems (Veil 2007). About 145 billion gallons of freshwater was withdrawn per day in 2004 for thermoelectric power generation, which is the highest, 41%, of the overall freshwater withdrawal in the U.S. (Figure 4, (USGS 2004)).

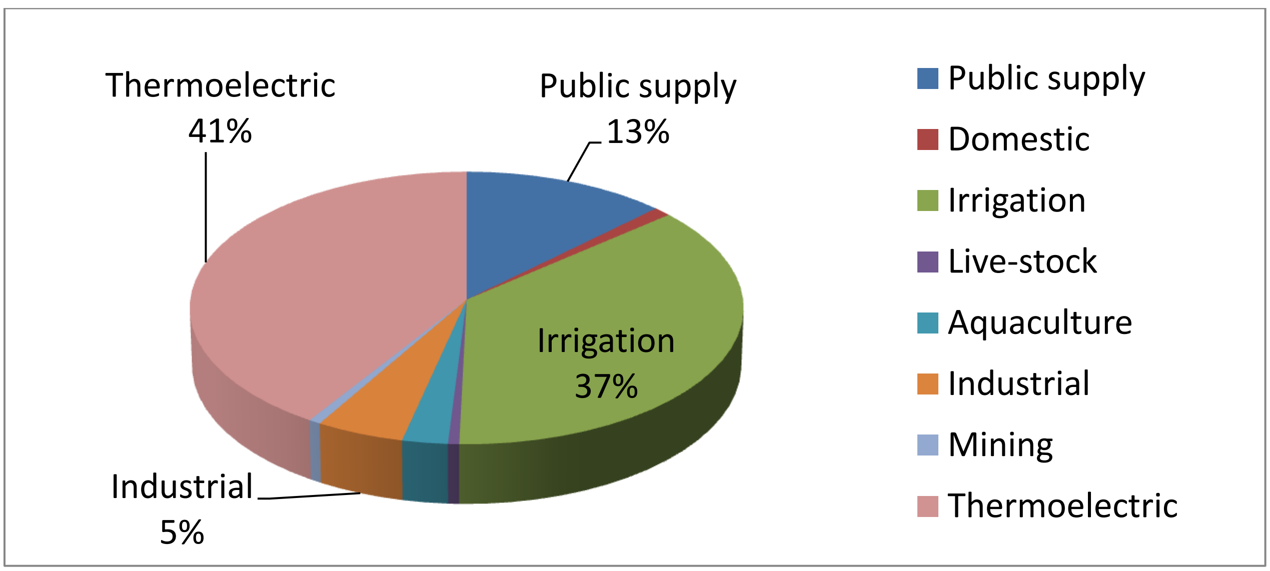


Figure 4. Daily freshwater withdrawn in the United States in billion gallons per day (USGS 2004).

In addition to water withdrawal, USGS also has evaluated the overall freshwater consumption in the U.S. (Figure 5, (USGS 2000)). The thermoelectric power generation represents 3%, (3 billion gallons per day) of the overall freshwater consumption in the U.S., while the irrigation represents the largest portion of freshwater consumption at 81%. As opposed to the huge amount of freshwater withdrawn for thermoelectric power generation, only 0.47 gallons of freshwater is evaporated per kWh of electricity at the point of end use (Torcellini, Long et al. 2003).

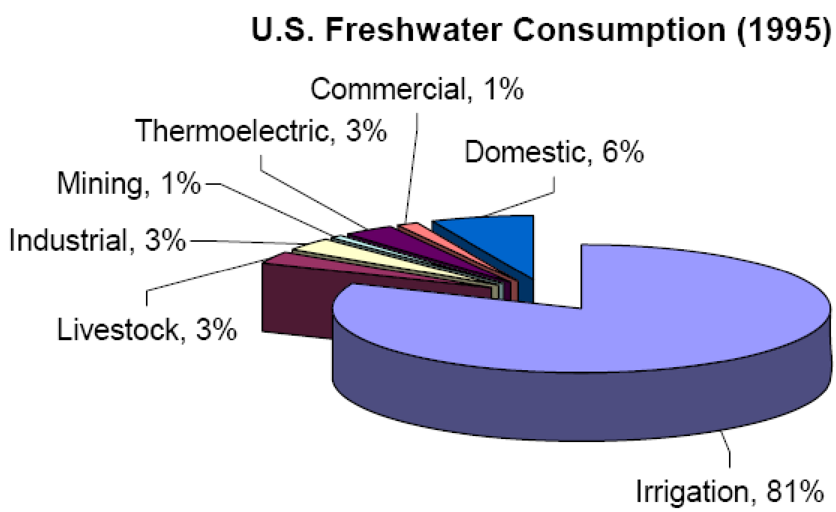


Figure 5. Freshwater consumption percentage divides into different categories in the United States (USGS 2000).

A forecast of freshwater usage in 2030 was done by National Energy Technology Laboratory using different assumptions about cooling system deployment in the U.S. (USDOE 2008). The results indicate that freshwater withdrawal will remain the same or even decrease when most aged power plants are replaced with modern generation units and recirculating cooling systems. However, the freshwater consumption in 2030 will increase by 27~49% when compared to freshwater consumption in 2005.

Existing and new power plants, including coal-based thermoelectric plants, will be faced with increasingly stringent restrictions on water use in some regions of the U.S. Figure 6 shows the Cooling Constraint Index for thermoelectric power plants (Roy, Summers et al. 2003). Indeed, the lack of available freshwater has already prevented the siting and permitting of new power plants in some regions (Feeley and Ramezan 2003; Dishneau 2007). Furthermore, Section 316(b) of the Clean Water Act limits the amount of freshwater that can be withdrawn by power plants, thereby requiring the installation of wet or dry closed-loop cooling systems.

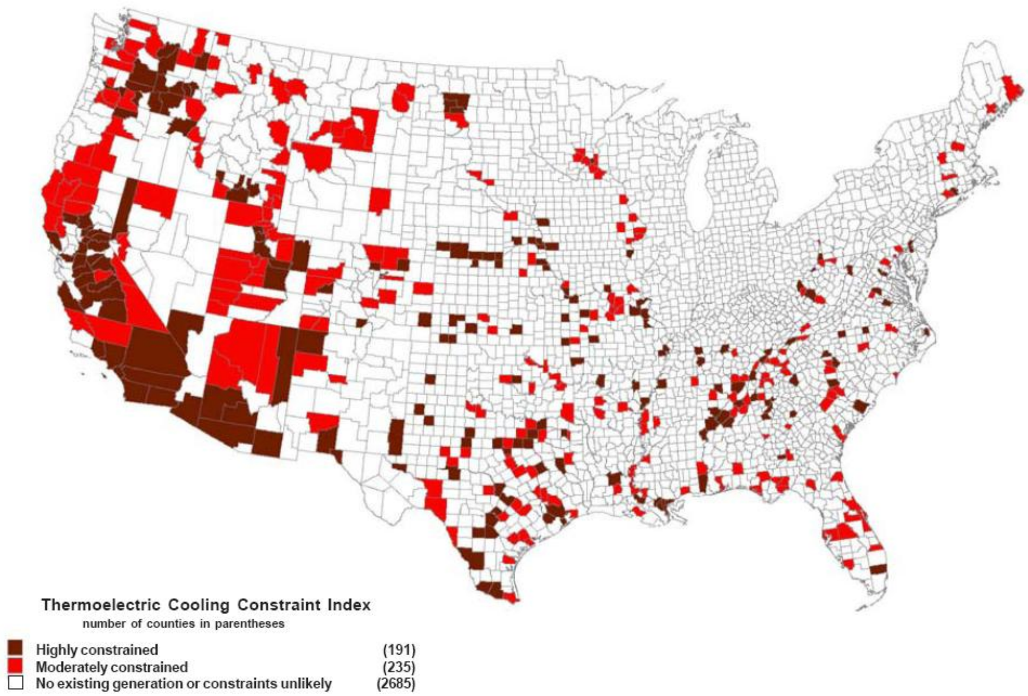


Figure 6. Thermoelectric Cooling Constraint Index. The colored areas indicate the cooling water supply is limited (Roy, Summers et al. 2003).

In conclusion, water and energy issues are intricately related and cannot be addressed in isolation. With the increasing population and energy demand, the scarcity of freshwater will become a nationwide phenomenon. Impaired waters could serve as potential alternative water sources and help meet power plant cooling needs. There is already some experience with the use of impaired waters, especially treated municipal wastewater as cooling water sources. Therefore, finding alternative water resources to replace freshwater demand for cooling purposes is inevitable and urgent.

2.3 AVAILABILITY OF IMPAIRED WATERS FOR COOLING IN POWER PLANTS

Potential alternative sources of cooling water addressed in this study include treated municipal wastewater, treated mine drainage, and ash transport water from coal-fired power plants. It has been shown that impaired waters can be used for cooling needs in electric power plants (Richard 1964; Paul and Ken 2003; Veil, Kupar et al. 2003). However, most of these reuse applications employed fairly limited addition of wastewater to cooling tower as make up water. In addition, these applications represent special circumstances (e.g., both POTW and power plant owned by the same company, close proximately of the two, demonstration project, etc.) and there is no reliable information about the true potential of these alternative water sources to meet cooling water demand of power industry.

When assessing the feasibility of using impaired waters for cooling in power plants, it is important to asses both water quality parameters and the availability of different impaired waters to meet power plant needs. Among all possible sources of impaired water that could potentially be used in power production, secondary treated municipal wastewater is the most common and widespread source in the U.S. Therefore, particular attention is given to comprehensive analysis of the quantities, availability and proximity of this impaired water for use in existing and future power plants.

2.3.1 General Water Quality and Availability of Secondary Treated Municipal Wastewater

Municipal wastewater is a complex mixture of organic waste, suspended solids, debris and a variety of chemicals that come from residential, commercial and industrial activities. Secondary treatment of municipal wastewater, the minimum standard for municipal wastewater treatment under the Clean Water Act, usually involves debris and grit removal, primary settling of particles, aerobic biological treatment for the removal of readily biodegradable organic matter, secondary sedimentation, and disinfection.

The characteristics of typical secondary effluent reported in literature were compiled in this study and the results are shown in Table 1 and Table 2. Data for secondary effluent that is currently used as makeup for cooling water systems were also included. The secondary effluent quality in Table 1 can be used as an indication of the concentration range for the constituents that are of importance if the effluent is used as cooling tower makeup water. The range of concentrations for general constituents of treated wastewater used for cooling needs is shown in Table 2.

After treatment, BOD and ammonia concentration are reduced to low levels, thus causing less adverse impact when using this impaired water in cooling systems. However, total dissolved solid and several neutral salts, such as sodium and potassium are comparatively higher than other chemicals because of less strict limitations. Organic nutrients, calcium and magnesium, which may cause biofouling, corrosion, and scaling problems, show a wide range in the treated wastewater.

Table 1. Water quality of secondary treated municipal wastewater effluent from different U.S. locations

Parameters	General Treated Wastewater Quality	
	After (Williams 1982)	After (Weinberger, Stephan et al. 1966)
pH		
Conductivity (mS/cm)		
BOD (mg/L)	11	25
COD (mg/L)	71	
TSS (mg/L)	17	
TDS (mg/L)		730
Alkalinity (mg/L as $CaCO_3$)	131	250
Hardness (as $CaCO_3$)		270
Turbidity (TU)	11	
Color (P-C unit)	29	
Forming Agent (mg/L)	0.45	
Oil and Grease (mg/L)	3.7	
TOC (mg/L)	11	
Organics (mg/L)		55
Na (mg/L)		135
K (mg/L)		15
Ca (mg/L)		60
Mg (mg/L)		25
Cl (mg/L)		130
NH_3-N (mg/L)		16
NO_3-N (mg/L)		3
NO_2-N (mg/L)		0.3
HCO_3 (mg/L)		300
SO_4 (mg/L)		100
P (mg/L)		
PO_4 (mg/L)		8
SiO_2 (mg/L)		50

Table 2. Range of chemical constituent concentrations in secondary treated municipal wastewater effluent

Parameter	Range*
pH	7 -8
BOD (mg/L)	3 – 30
TDS (mg/L)	130 – 1600
Alkalinity (mg/L as $CaCO_3$)	100 – 250
Ca (mg/L)	28 – 185
Mg (mg/L)	23 – 150
NH_3-N (mg/L)	3 – 73
HCO_3 (mg/L)	137 - 396
SO_4	60 – 293
PO_4	0.6 – 51
SiO_2	8.3 – 50

*The range of concentration is determined from

(1) General water quality gathered from (Williams 1982) and (Weinberger, Stephan et al. 1966).
(2) Sewage effluent quality used for power plant cooling water makeup from (Goldstein and Casana 1982) and (Breitstein and Tucker 1986).
(3) Specific sites from (Goldstein and Casana 1982), (Tsai 2006), and (Masri and Therkelsen 2003).

2.3.1.1 Feasibility Analysis Methodology

Regional and local wastewater availability for selected power plants was evaluated using standard geoprocessing tools. The analysis was performed using ArcGIS (Version 9.2, ESRI). Database of publicly owned treatment works with NPDES permits was extracted from EnviroMapper of Water, USEPA. Database of power plants included proposed power plants listed by Energy Information Administration, Form EIA-860, "Annual Electric Generator Report" and the existing coal-fired power plants from DOE database (USDOE 2007).

For each of the power plants in the database, the sources of treated municipal wastewater within a 10 and 25-mile radius from the plant was catalogued together with the distance and average flow characteristics. The number of POTWs required to satisfy the cooling water demand of each power plants is determined to provide an initial assessment of water distribution network needed to meet cooling water needs.

2.3.1.2 Analysis Steps

Figure 7 provides a flowchart depiction of the methodology used to conduct the analysis. Each step in the process is briefly described in the following sections while the additional details are given in Appendix A.

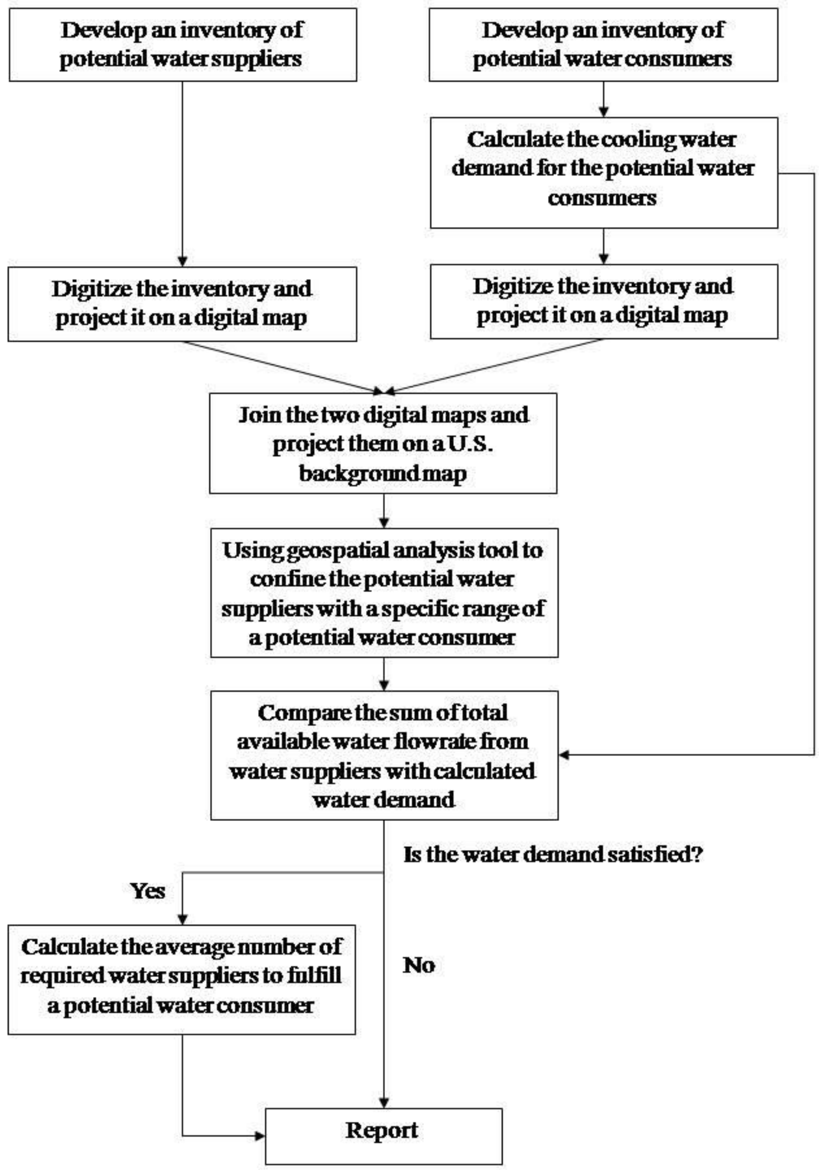


Figure 7 Methodology for the Feasibility Analysis of using secondary effluent as cooling water.

2.3.1.3 Develop an inventory of Potential Water Suppliers and Consumers

Water Suppliers – Publicly Owned Treatment Works (POTWs)

An inventory of publicly owned treatment works was developed in order to demonstrate potential water suppliers in the U.S. The first step was to acquire a database containing information about wastewater treatment facilities. Database created for the Clean Watersheds Needs Survey (CWNS), which was used in CWNS 2000 data report to congress (USEPA 2003), was chosen and the information about POTWs was extracted from the original database.

The database has a list of 33,852 wastewater discharge records and includes wastewater flow discharged from household, city sewer, treatment plant, industry, etc. However, it includes both abandoned facilities and proposed facilities to be built in the future. Therefore, the database was screened based on the following requirements:

- Reflects publicly owned treatment works,
- Minimum level of treatment is secondary treatment
- Includes latitude and longitude information
- Plant currently in operation instead of abandoned or proposed.

After the screening, the total number of POTWs that could be used for this survey was reduced to 17,864, including wastewater treatment plants, sewage treatment plants, water recycling plants, water pollution control plants, and lagoons. Data for each POTW included information about present and future discharge flowrates. Since this study was based on geospatial analysis, the geographic location and available wastewater flowrate of these POTWs would significantly affect the accuracy of the results and required data validation. First, authorized permit number by the National Pollutant Discharge Elimination System (NPDES) was related to facility name in the database. Furthermore, a number of random POTWs was verified on the GIS query tool, EnviroMapper, to ensure the reliability of the information (USEPA 2008). EnviroMapper is an online based GIS developed by EPA and can provide information about any point discharge source in the U.S. Querying with NPDES permit number, geographic information and daily discharge flowrate can be compared with information in POTW database.

Figure 8 shows an example of verifying the water supplier, Akron Lagoon, Alabama, on EnviroMapper with latitude and longitude query.

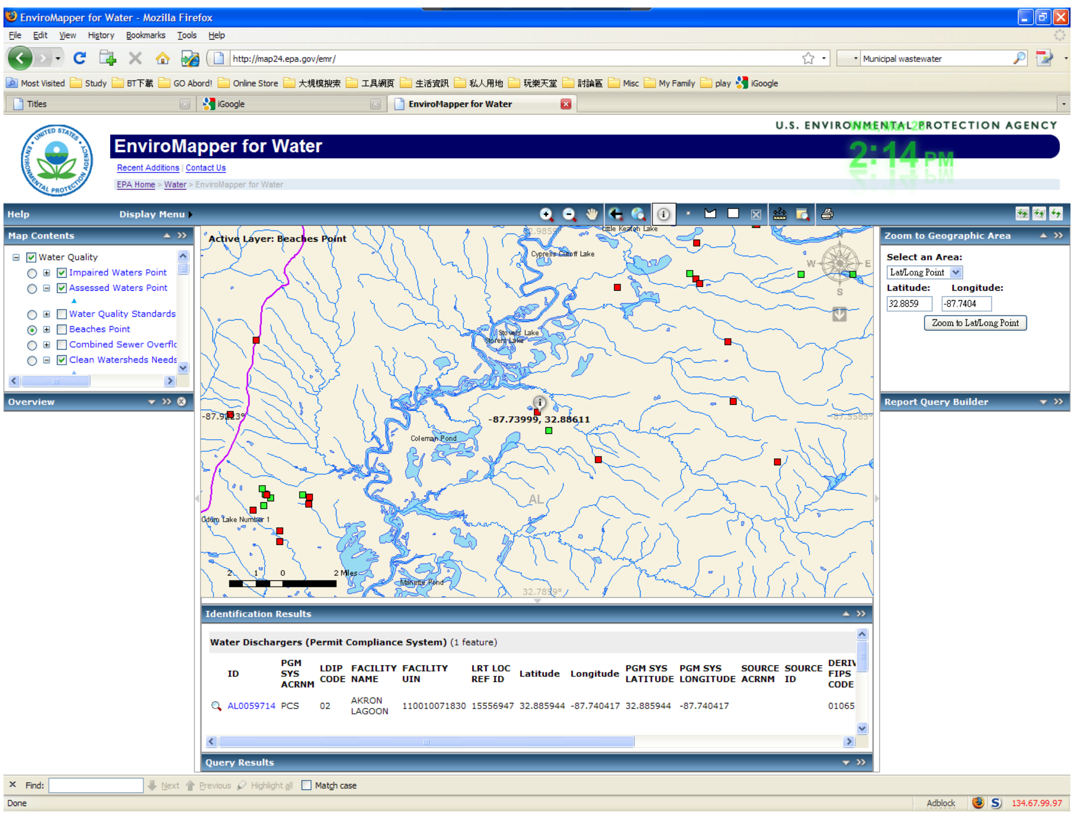


Figure 8 EnviroMapper, the online GIS query tool (USEPA 2008).

A number of POTWs were validated through this procedure and all information matched with the database used in this study. However, some limitations of the database are: (1) Both point or non-point source of discharge are included in the inventory; (2) POTWs matching the requirements listed above were included in the database regardless of discharge destination (e.g.

surface discharge, groundwater recharge, ocean discharge, etc.); (3) POTWs matching the requirements listed above were included in the database regardless when the information was last updated.

Since 1996, the water discharge data were collected and updated every four years and the latest update was in 2004. However, the database still included dated information for some facilities. According to the USEPA website, the CWNS group plans to move the data entry to the Internet to enable direct entry into CWNS 2008 by the responsible parties.

The information about 17,864 POTWs extracted from CWNS 2000 was imported into a geographic information system (GIS). ArcGIS version 9.2 was used as the software package for this study. The U.S. background was acquired from ESRI – U.S. Street Map DVD. The geographic coordinate system for the map was World Geodetic Survey 1984 (WGS 84) and the datum for the map was also WGS 84. The distribution of POTWs is shown on Figure 9. Each node represents a POTW on the map and the scale/color of the point reflects the present flowrate discharged from the POTW.

Most POTWs are located in the Eastern and middle U.S. and most large treatment facilities are located in major cities, such as Chicago, New York, etc.

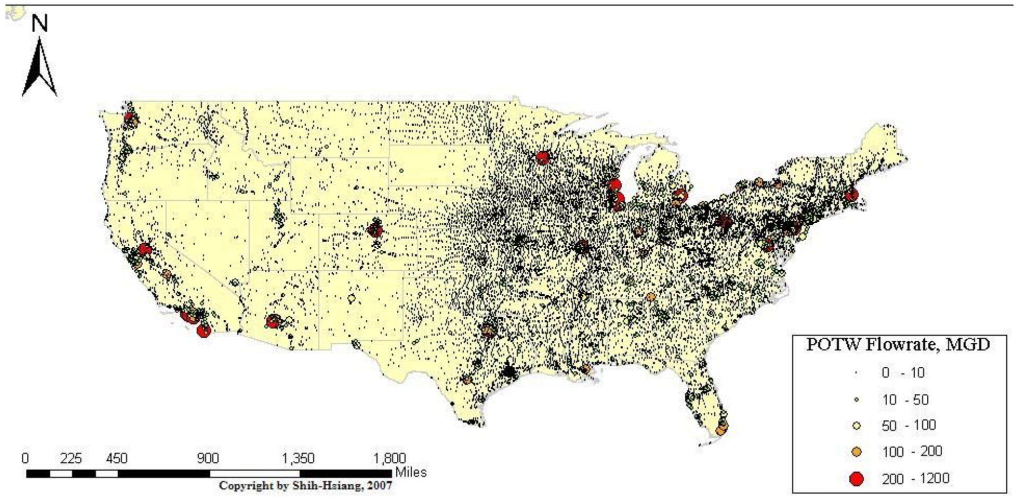


Figure 9 Publicly owned treatment works in continental U.S.

Water Consumers – Power Plants Proposed for Construction

Power plants which were proposed to start construction in 2007 were selected to represent potential water consumers in this study. The original database was compiled from the EIA-860, Annual Electric Generator Reports. The EIA-860 reports includes specific information about generators at electric power plants owned and operated by electric companies, including independent power producers, combined heat and power producers, and other industrial facilities. The file contains generator-specific information, such as initial date of commercial operation, generation capacity, energy sources, status of existing and proposed generators, proposed changes to existing generators, etc. A total number of 110 power plants proposed in 2007 were used to assess the feasibility of using secondary effluent to meet cooling water needs for new power plant.

Figure 10 depicts tentative locations of these new plants. The geographic coordinate system for the map was World Geodetic Survey 1984 (WGS 84) and the datum for the map was also WGS 84. The U.S is divided into 13 different North America Electric Reliability Council

(NERC) regions. The NREC regions were formed by the electric utility industry in 1968 to ensure that the main electric system in North America is reliable, adequate, and secure. The full name of each region is provided in Table 3.

The region boundaries used in this study were those originally established by the NERC Regional Council. Regional boundaries have been changed to include eight regions as shown in Figure 11. Due to the lack of information on new boundaries and reliable digitized maps, the analysis conducted in this study focused on the original NERC regions.

Only 11 NERC regions were included in this survey because no power plants were proposed to be built in Mid-Atlantic Area Council (MACC) and Western Electricity Coordinating Council/New England (NPCC/NE).

It is also important to note that the exact geographic locations of the proposed power plants have not yet been confirmed. As a result, the center of the city/county was designed as the location for the new plant and used in this study.

Table 3. Full name of NERC regions,

Abbreviation	Region
ECAR	East Central Area Reliability Coordination Agreement
ERCOT	Electric Reliability Council of Texas
MAAC	Mid-Atlantic Area Council
MAIN	Mid-America Interconnected Network
MAPP	Mid-Continent Area Power Pool
NPCC/NY	Northeast Power Coordinating Council/New York
NPCC/NE	Northeast Power Coordinating Council/New England
FRCC	Florida Reliability Coordinating Council
SERC	Southeastern Electric Reliability Council
SPP	Southwest Power Pool
WECC/NWCC	Western Electricity Coordinating Council/Northwest Power Pool
WECC/RM	Western Electricity Coordinating Council/Rocky Mountains AZ NM Southern NV
WECC/CA	Western Electricity Coordinating Council/California

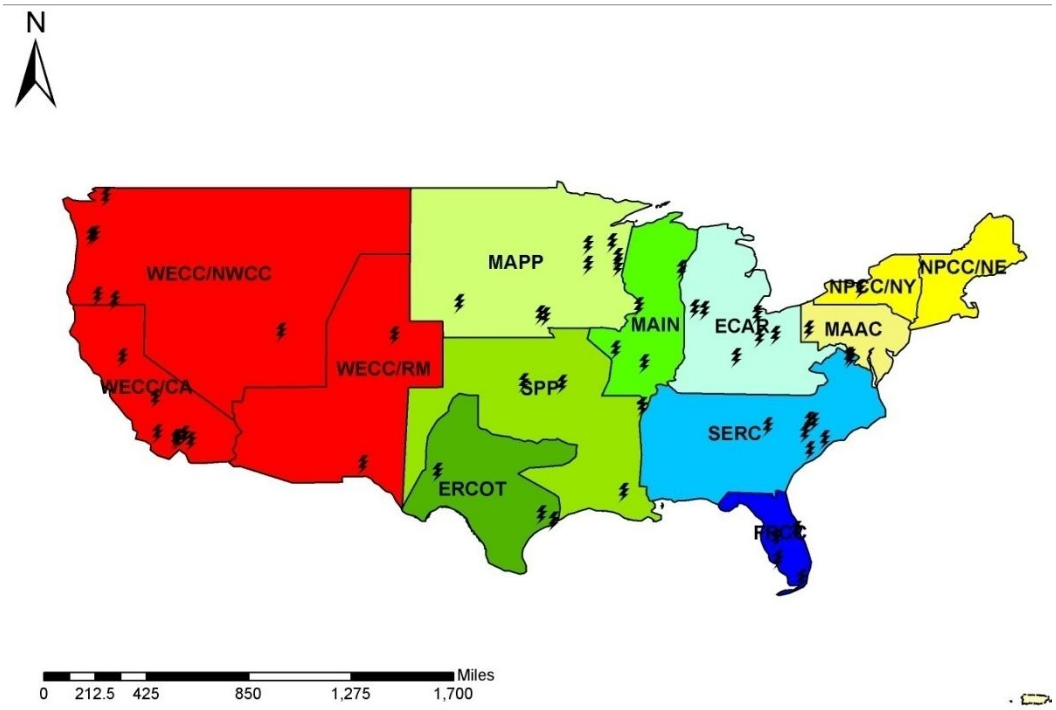


Figure 10 Power plants proposed in 2007 listed by EIA in continental US

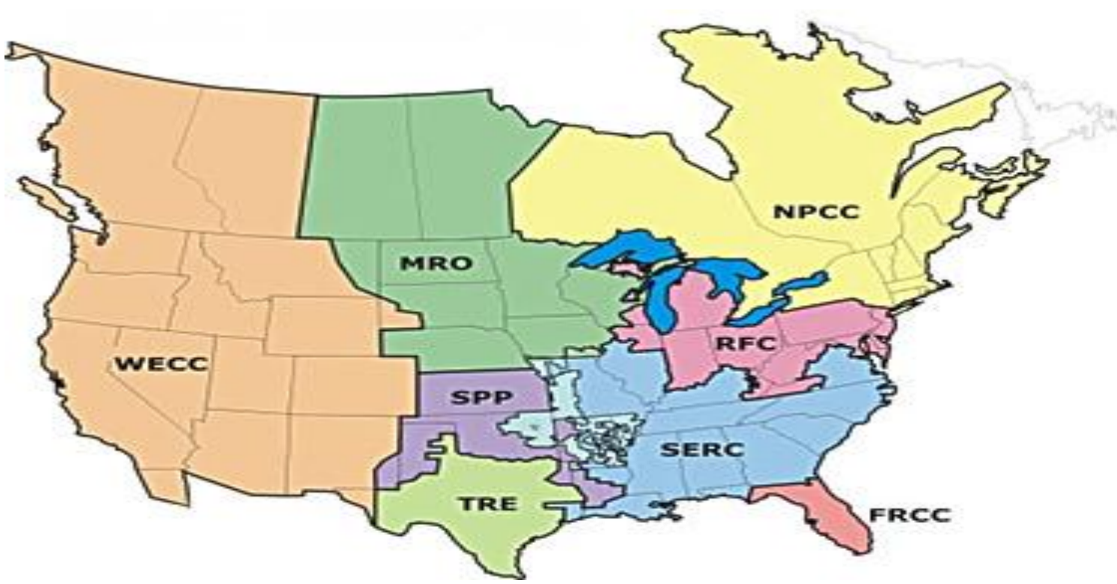


Figure 11 Latest map of the Eight NERC Regions (Starting from January 1, 2006) (USEIA 2009)

Water Consumers –Existing Power Plant Units as of 2007

To better understand the potential connection between treated wastewater and power generation, database of existing coal-fired power plants compiled by NETL (USDOE 2007) was evaluated in this study. A total of 1929 generating units were listed individually although a single power plant may have multiple generating units. The average generating capacity of existing power plants is 547 megawatts per hour. Total numbers of power plants used in the study is 407 in 43 states as shown in Figure 12. The geographic coordinate system for the map was World Geodetic Survey 1984 (WGS 84) and the datum for the map was also WGS 84.

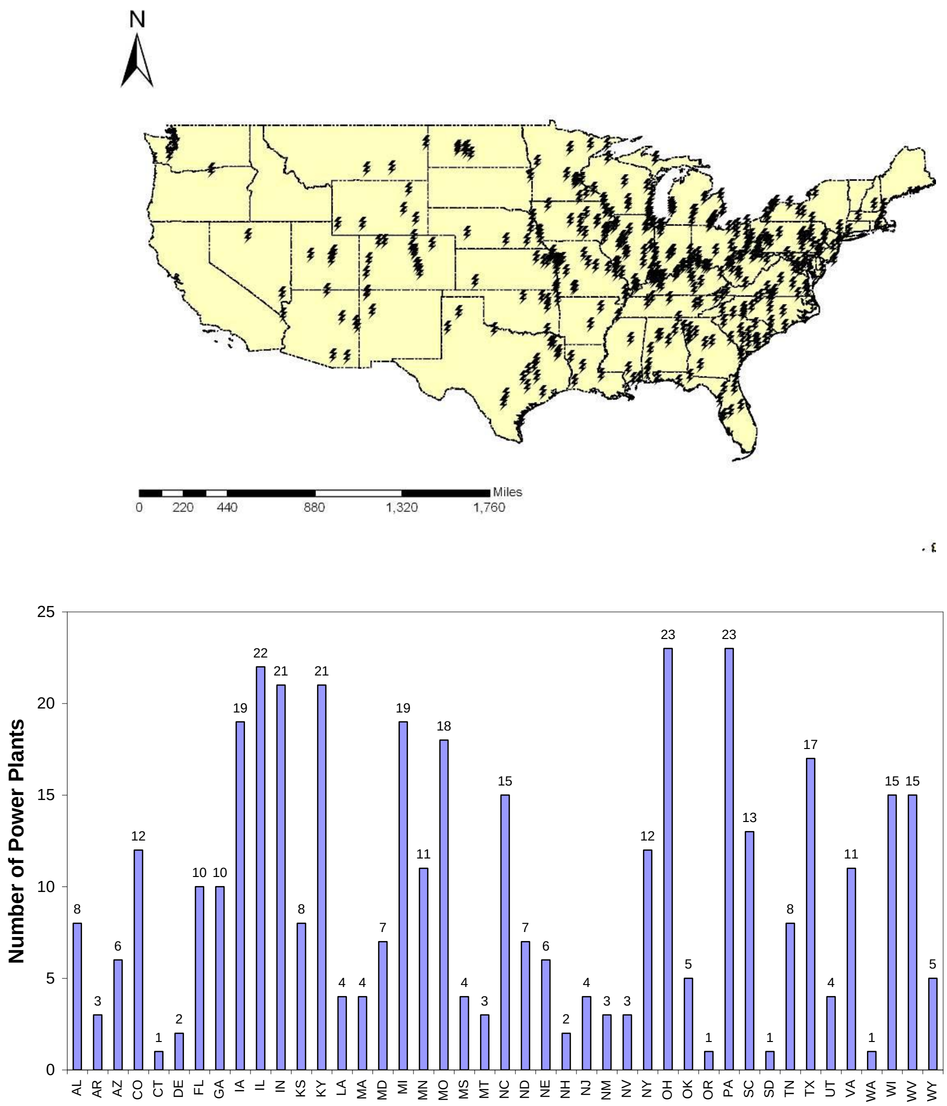


Figure 12 Existing Coal-fired power plants listed in NETL Thermoelectric Power Plant Database (USDOE 2007). A total of 407 plants are included in the database. (A) Geographical distribution of existing power plants; (B) Summation of the existing power plants in each state.

2.3.1.4 Estimation of the Cooling Water Demand

The next step was to estimate the cooling water needs for each proposed power plant so that a comparison with the total available wastewater that can be made. Two methods for estimating water needs of a specific power plant are described below.

The first method calculates water demand based on plant capacity, water to energy ratio, capacity factor and operating hours based on the following equation:

$$E = C \cdot R \cdot F \cdot T \qquad (1)$$

Where,

E = Estimated water demand, gal/day

C = Maximum generating capacity (Summer capacity), MW

R = Water to energy ratio = 1200 gal/MW*h

F = Capacity factor = 0.75 (dimensionless)

T = Operating hours, hours/day

Water to energy ratio of 1200 gallons of water per MWh of energy was derived from the EIA's report (USEIA 2007; USDOE 2008) and it is an estimate of average water withdrawal for wet re-circulating cooling systems based on the data collected in 2000. The water to energy factor has since been updated to reflect specific generation type, the boiler type, and the design of the turbine and has been renamed to withdrawal factor. Table 4 summarizes withdrawal factors adapted from NETL report, Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements (USDOE 2008). The withdrawal factor for coal-fired power plants includes: 1) boiler make-up water, 2) FGD make-up water, and 3) cooling water. Apparently, the water to energy factor of 1,200 gal/MWh used in this study is overestimating the cooling water demand by power plants, which provides a conservative assessment of water availability for cooling.

Table 4. Withdrawal factors for specific applications.

Applications	Withdrawal Factor (gal/MWh)
Freshwater, Re-circulating System, Coal-fired power plants	~600
Freshwater, Re-circulating System, Nuclear power plants	~1100
Freshwater, Re-circulating System, Non Coal-fired power plants	~250
Freshwater, Re-circulating System, NGCC power plants	~150
Freshwater, Re-circulating System, IGCC power plants	~226

Summer capacity is usually regarded as the design capacity of a power plant. The capacity factor is the average output of a power plant as a fraction of the full load of a power plant. A seventy five percent capacity factor was assumed for this analysis considering a steady, normal output condition and variations between seasons. The operating hours were set at 24 hours per day. Using this equation for the Freeport Energy Center owned by Dow Chemical Company in Texas, for example, a cooling water makeup flowrate is estimated at 3.34 MGD for this 154.80MW power plant.

The second method to estimate the water demand for cooling was to analyze the existing power plants that are using reclaimed water for cooling purposes. From the inventory of 48 plants provided in a technical report (Vidic and Dzombak 2007), it is estimated that an average of 0.0095 MGD of cooling water is required per MW of power generated per day. Using this ratio for the Freeport Energy Center (the same 154.80MW power plant used in the previous example), a cooling water make up is estimated at 1.47 MGD.

The water consumption estimated by the second method is much lower than the value derived using the first method. One possible explanation is that the second method only considers the amount of impaired water used for cooling as reported by these plants. However, not all of these 48 power plants use only reclaimed water for cooling and may add water from other sources. Therefore, the first method was selected for further analysis.

2.3.1.5 Geospatial Analysis

The goal of this study was to identify the total amount of secondary effluent discharged from POTWs that is available within a specific distance from each power plant. To accomplish this goal, several geoprocessing tools, such as buffer, overlay, select, and summary were used.

The geoprocessing steps are shown in Figure 13. Generating a buffer zone is the first operation to perform in order to create a correlation between two point attribute datasets. The buffer zone is then overlaid on the POTW layer to produce a list of POTWs contained within the buffer zone. In this way, a list of all POTWs available to meet the cooling water needs of a proposed power plant is extracted from the database.

The buffer zones selected for this study had a radius of 10 and 25 miles. The reason to limit the distance from a given power plant to 10 and 25 miles is the cost of transporting the water from a POTW to a power plant. These numbers were selected arbitrarily based on the example of Redhawk Power Plant (RPP) in Arizona. The RPP is one of the power plants that uses 100% reclaimed water for cooling proposes with an average daily cooling water flowrate of 6.48 MGD. The wastewater is transported 40 miles from a wastewater treatment facility, which is located at a higher elevation than the power plant. Therefore, it is assumed that 10-25 miles would likely be a reasonable distance for transporting wastewater in the areas where other sources of the waters are not available.

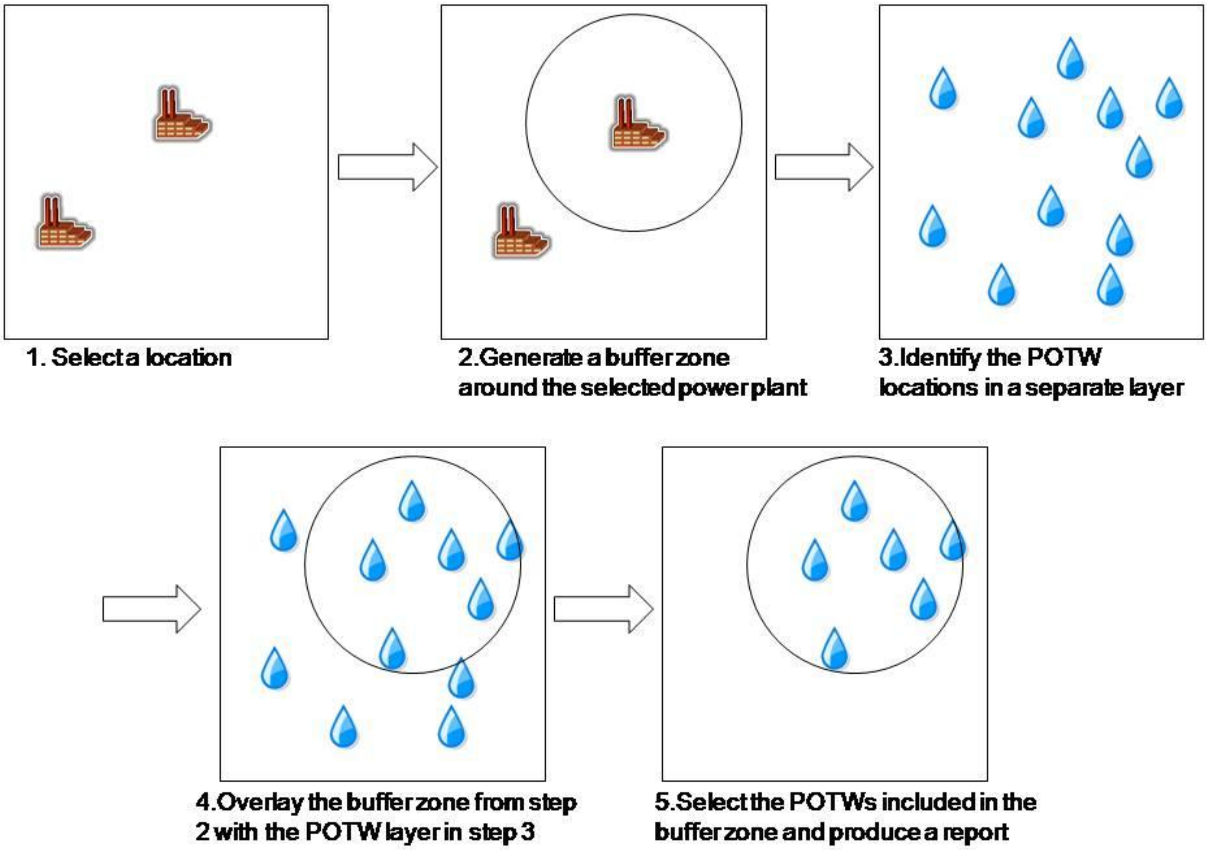


Figure 13. Geoprocessing steps used for this study.

Selected POTWs were extracted from the POTW layer and related to the proposed power plants. The total wastewater discharged from POTWs within a specified distance from the selected power plant was calculated and compared to estimated cooling water demand of the power plant.

Power plants having sufficient wastewater to meet their cooling water demand were subjected to further analysis to determine the total number of POTWs needed to meet its cooling water needs. Publicly owned treatment works within a specified distance from the power plant were ranked in a descending manner based on their flowrate. The estimated cooling water demand was compared to the summation of wastewater flowrate from the POTW series until the estimated value was less than the summation of wastewater flowrate. The total number of POTWs required to satisfy the cooling water demand for each power plant was also reported.

2.3.1.6 Wastewater Availability for Future Power Plants

Table 5 shows the total cooling water needs for all proposed power plants in each NERC region in comparison to the total secondary wastewater available in that region. The amounts of cooling water needed for proposed power plants are highest in WECC/NWCC region, followed by FRCC and SERC regions. This trend matches the projection of energy demands for water resources by Department of Energy, which states that the main increase in energy demands will be in Southeast, Southwest, and Far West (USDOE 2008). It is evident from the last column of Table 5 that the cooling water needs of the proposed power plants in most regions do not exceed 1% of the total available wastewater in that region, except for FRCC, MAPP and WECC/NWCC regions.

As mentioned earlier, there are 110 proposed power plants that were included in this survey and a large percentage of them are located in WECC, SERC, ECAR regions. The number of power plants in a given region does not accurately reflect the total cooling water needs. For example, there are only six proposed plants in the FRCC region. However, because of the 1053 MW Turkey Point Power Plant, the total daily cooling water needs in FRCC is much greater than that in ECAR, which includes 21 proposed power plants.

The average percentage of available wastewater needed for cooling is 1.10%. The real available wastewater flowrate can be higher because this survey does not include private or commercial wastewater plants. In addition, the guidelines for Water Reuse indicate that the total wastewater reuse in California and Florida only accounts for 358 MGD and 584 MGD, respectively. This indicates that plenty of wastewater is still available for further reuse.

The key outcome of this part of the study is that the amount of wastewater available in each region can easily satisfy cooling water needs of the proposed power plants.

Table 5. Comparison of total cooling water required for the proposed power plants and total available wastewater from POTWs in NERC regions.

NERC Region	Total daily cooling water needs, MGD	Total daily wastewater flow rate, MGD	Percentage of available wastewater needed for cooling, %
ECAR	27.5	4873	0.56
ERCOT	15.0	1994	0.76
FRCC	42.9	1374	3.12
MAIN	01.6	3318	0.05
MAPP	25.8	1167	2.20
NPCC/NY	00.1	1112	0.01
SERC	28.2	3915	0.72
SPP	17.5	2077	0.84
WECC/CA	22.5	3636	0.62
WECC/NWCC	44.9	1910	2.35
WECC/RM	09.3	1061	0.88

Table 6 and Figure 14 and Figure 15 provide the results of the analysis performed for individual power plants. GIS-based analysis provided information about the total wastewater flowrate available within a 10 and 25 mile radius around each proposed power plant.

The data in Table 6 show that about 81% of proposed power plants could completely meet their water needs by the POTWs within a 10 mile radius. On the same Table, it is shown that 97% of proposed power plants can satisfy their cooling water needs from POTWs within a 25 mile radius.

Figure 14 shows the percentage of power plants that can meet their cooling water needs from POTWs in each NERC region when considering wastewater available with a 10 mile radius. Only SPP and WECC/RM could not satisfy the needs of more than half of their proposed plants with the treated wastewater from POTWs within 10 mile radius, despite the fact that both SPP and WECC/RM have more than 1500 MGD wastewater available. Figure 15 shows the same analysis when considering wastewater available with a 25 mile radius. With the increase in coverage, SPP and WECC/RM could completely satisfy the water demand for their power plants with secondary effluent. This result is important because it indicates that treated municipal wastewater can be a major cooling water resource for the future power plants.

Table 6. Proposed power plants that have sufficient wastewater for cooling provided by POTWs within 10 and 25 mile radius.

Region	Number of proposed power plants that have sufficient wastewater within 10 miles	Proposed power plants that have insufficient wastewater within 10 miles	Proposed power plants that have sufficient wastewater within 25 miles	Proposed power plants that have insufficient wastewater within 25 miles
ECAR	18	3	21	0
ERCOT	5	3	8	0
FRCC	5	1	6	0
MAIN	3	1	4	0
MAPP	10	1	10	1
NPCC/NY	4	0	4	0
SERC	18	1	19	0
SPP	1	5	6	0
WECC/CA	11	0	11	0
WECC/NWCC	13	4	15	2
WECC/RM	1	2	3	0
Average Percentage	81%	19%	97%	3%

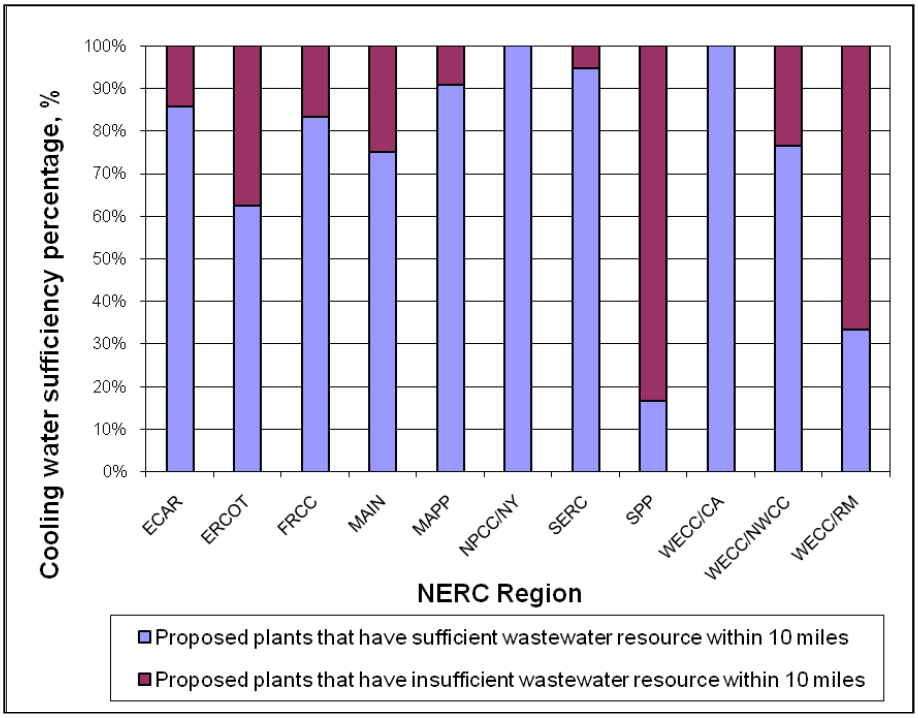


Figure 14. Percentage of proposed plants which have sufficient wastewater within 10 miles.

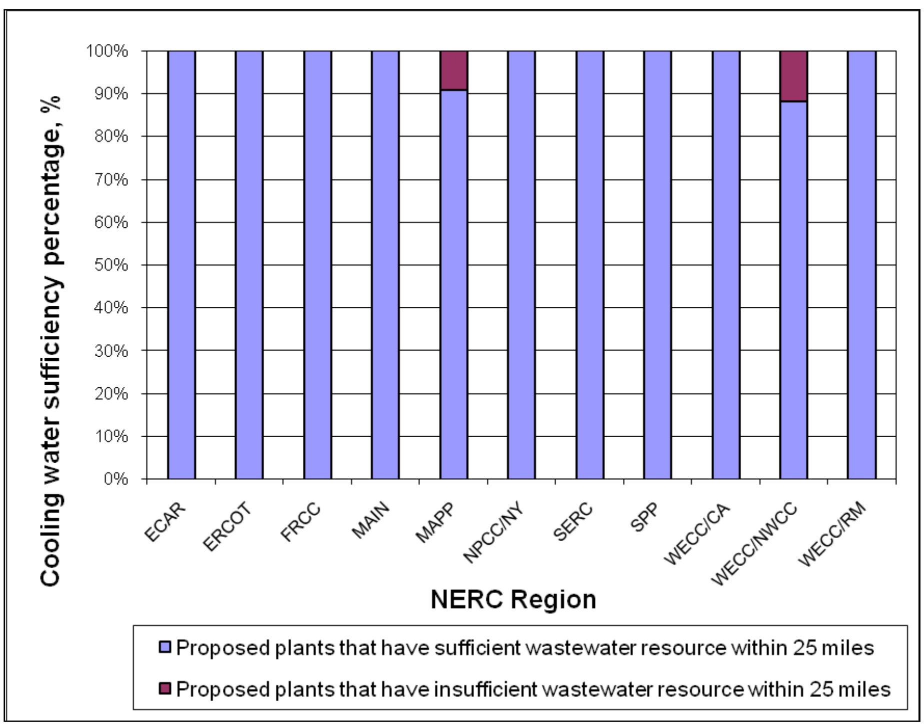


Figure 15. Percentage of proposed plants which have sufficient wastewater within 25.

Table 7 and Table 8 provide information about the ability of proposed power plants to satisfy their cooling water needs considering POTWs in each region. For both tables, column 2 provides the total percentage of all proposed power plants in a given NERC Regions that can satisfy their cooling water needs from POTWs located within 10 and 25 mile radius, respectively. Column 3 lists the average number of POTWs located within 10 and 25 mile radius from each proposed power plant, respectively. Last column provides information about the average number of POTWs with a 10 and 25 mile radius that can satisfy cooling water needs for proposed power plants in each NERC region, respectively.

The data provided in Table 7 indicate that each power plant has an average of 3.48 POTWs within a 10 mile radius. However, only 1.15 POTWs are needed to satisfy cooling water needs of the proposed power plants. If the coverage is extended to 25 miles, it can be seen in Table 8 that the proposed power plants have an average of 18.4 POTWs within that radius. However, only 1.10 POTWs are needed to satisfy cooling water needs of the proposed power plants.

Figure 16 and Figure 17 show that the MAIN region has the largest number of POTWs in either 10 or 25 mile radius around the power plants proposed for that region. On average, regions around the Great Lakes and the regions in the western part of the US have higher total wastewater flows available. In addition, in the western regions (e.g., WECC), only one POTW can satisfy water demand of the proposed power plants.

The fact that a fairly low number of POTWs (i.e., close to one) can meet the cooling water needs of the proposed power plants suggests that the cost of transporting wastewater can be kept at a minimum (i.e., only one or two pipes may be needed to transport the cooling water to each power plant). Therefore, using reclaimed water for cooling purposes can be both economical and reliable and can facilitate the development of coal-fired power plants in the regions where other water sources may not be readily available.

Table 7. Number of POTWs within 10 mile radius that can satisfy the cooling water demand of the proposed power plants.

Region	Percentage of proposed power plants that have sufficient wastewater water within 10 miles to satisfy their cooling water needs, %	Average number of POTWs within a 10 mile radius of a proposed power plant	Number of POTWs within a 10 mile radius needed to satisfy cooling water needs
ECAR	086	2.89	1.06
ERCOT	063	3.00	1.20
FRCC	083	4.60	1.40
MAIN	075	7.00	1.00
MAPP	091	3.10	1.00
NPCC/NY	100	4.00	1.00
SERC	095	2.06	1.00
SPP	017	2.00	2.00
WECC/CA	100	4.91	1.00
WECC/NWCC	076	2.85	1.00
WECC/RM	033	2.00	1.00
Average	81	3.48	1.15

Table 8. Number of POTWs within 25 mile radius that can satisfy the cooling water demand of the proposed power plants.

Region	Percentage of proposed power plants that have sufficient wastewater water within 25 miles to satisfy their cooling water needs, %	Average number of POTWs within a 25 mile radius of a proposed power plant	Number of POTWs within a 25 mile radius needed to satisfy cooling water needs
ECAR	100	20.29	1.05
ERCOT	100	09.88	1.25
FRCC	100	14.50	1.17
MAIN	100	28.50	1.00
MAPP	91	14.30	1.00
NPCC/NY	100	26.00	1.00
SERC	100	12.68	1.00
SPP	100	23.67	1.67
WECC/CA	100	20.18	1.00
WECC/NWCC	88	08.47	1.00
WECC/RM	100	24.00	1.00
Average	97	18.40	1.10

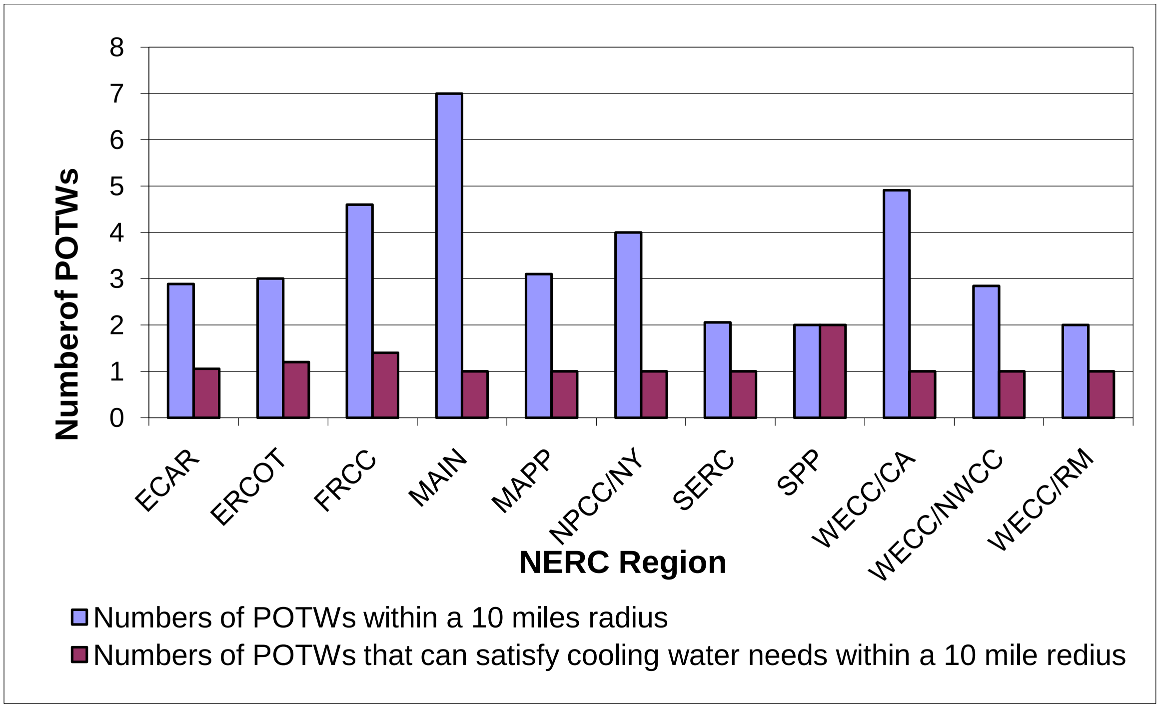


Figure 16. Total number of POTWs within a 10 mile radius and the number of POTWs that are needed to provide sufficient wastewater for cooling.

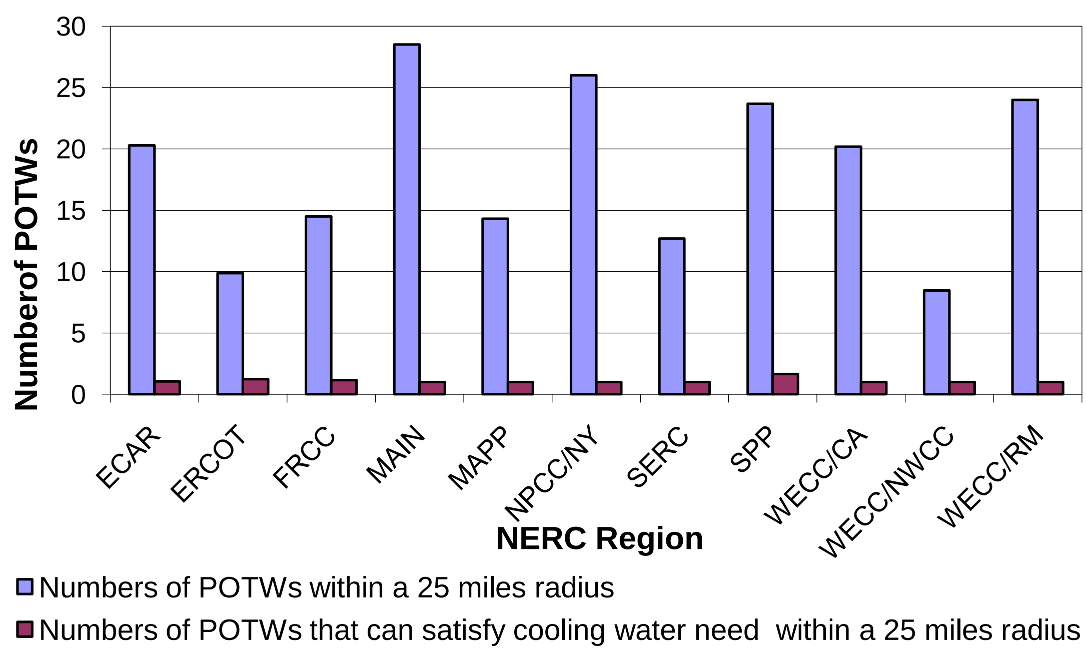


Figure 17. Total numbers of POTWs within a 25 mile radius and the number of POTWs that are needed to provide sufficient wastewater for cooling.

2.3.1.7 Wastewater Availability for Existing Power Plants

Figure 18 shows the availability of secondary effluent for power plants in each state. The cooling water demand to available wastewater ratio is the total estimated cooling water divided by the available wastewater flow in each state. On average, cooling water for existing power plants will require less than 50 % of available municipal wastewater from POTWs in most states. North Dakota, West Virginia, and Wyoming have the least available wastewater flow.

In Table 9, the average POTWs inside a 10/25 mile radius range of existing power plants is given for each state. Western states, like Arizona, New Mexico, Nevada, and Oregon, have lower number of available POTWs near the exiting power plants. On the other hand, Pennsylvania, Connecticut, Kansas, and West Virginia have the largest number of available POTWs. On average, each power plant has at least 4.9 POTWs within 10 miles and 25.3 POTWs within 25 miles.

Figure 19 shows the percentage of power plants that have sufficient wastewater to meet their cooling water demand. Results indicate that only 49.4% of existing power plants would have sufficient wastewater from POTWs within 10 miles. For these power plants having sufficient wastewater, only 1.14 POTWs are needed to meet their demand. If the range is extended to 25 miles, percentage of power plants having sufficient wastewater supply increases to 75.9% and an average of 1.46 POTWs are needed to meet their demand.

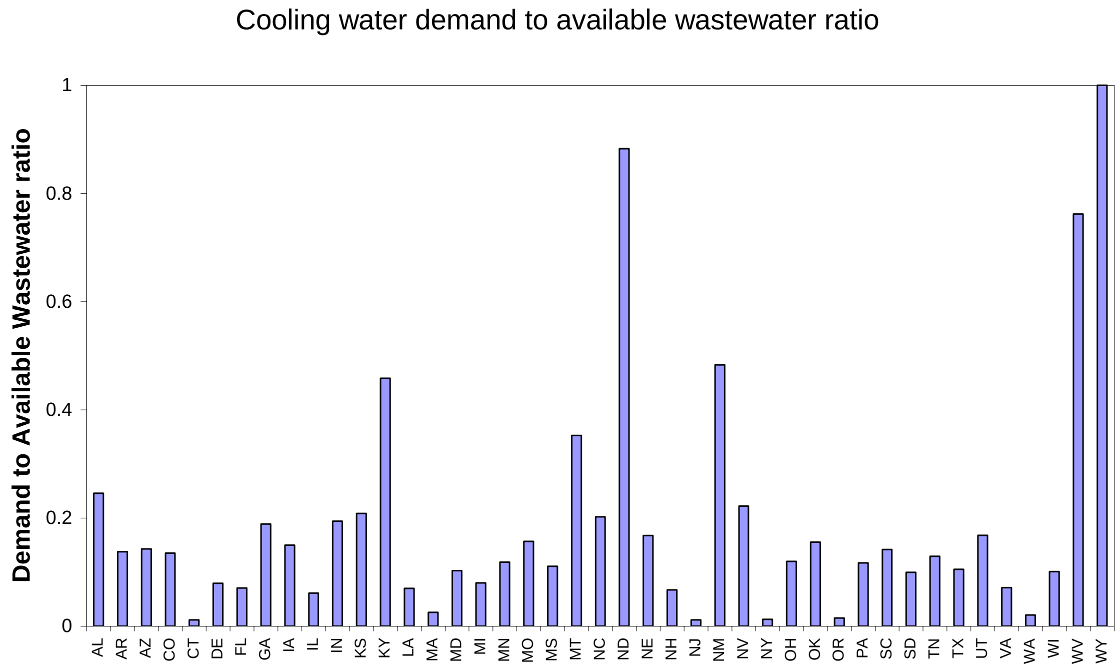
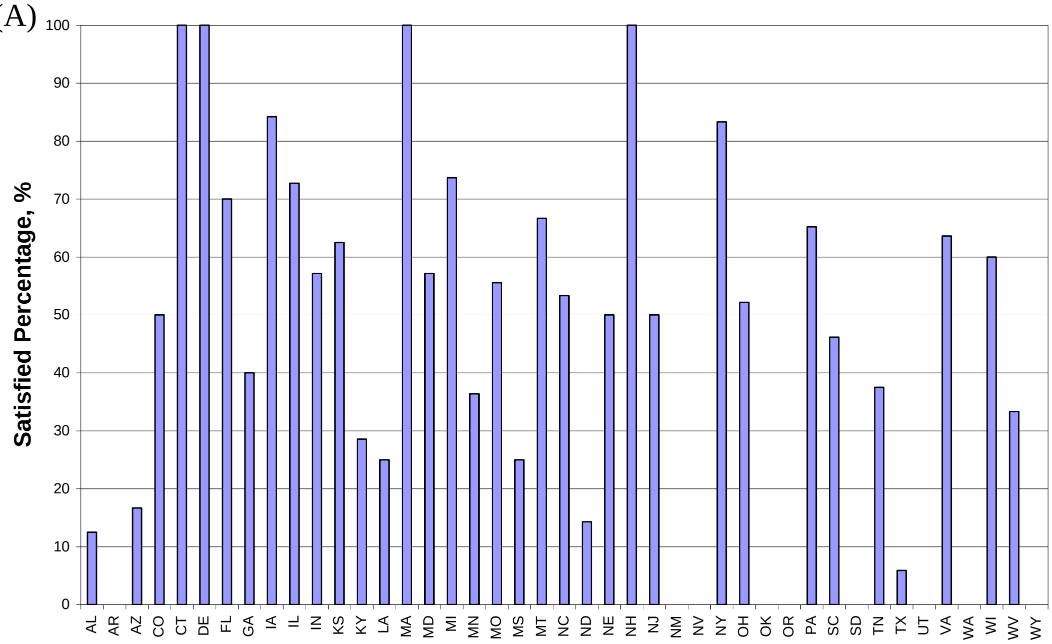


Figure 18. Total cooling water demand to total available secondary effluent in each state. Higher value indicates the scarcity of secondary effluent that can be used for cooling purposes.

Table 9 Average POTWs of existing power plants within 10 or 25 mile radius

State	Number of Power Plants	Average POTWs within 10 miles	Average POTWs within 25 m
AL	8	2.4	12.3
AR	3	3.0	20.0
AZ	6	1.8	5.2
CO	12	4.4	16.5
CT	1	5.0	43.0
DE	2	5.5	34.5
FL	10	2.9	14.3
GA	10	2.8	14.9
IA	19	4.8	31.3
IL	22	6.3	33.1
IN	21	3.9	23.2
KS	8	9.8	43.8
KY	21	3.4	20.6
LA	4	3.8	18.3
MA	4	6.8	27.8
MD	7	4.9	27.0
MI	19	3.2	12.8
MN	11	2.4	16.1
MO	18	7.9	39.6
MS	4	3.3	13.5
MT	3	1.0	3.7
NC	15	4.4	21.9
ND	7	1.6	8.1
NE	6	4.7	25.2
NH	2	6.5	25.5
NJ	4	3.5	30.8
NM	3	0.0	1.3
NV	3	1.3	4.3
NY	12	6.4	30.0
OH	23	8.1	40.7
OK	5	2.8	18.2
OR	1	0.0	4.0
PA	23	11.7	62.5
SC	13	2.2	10.6
SD	1	2.0	11.0
TN	8	3.9	15.8
TX	17	3.0	17.0
UT	4	0.8	5.0
VA	11	3.0	14.0
WA	1	2.0	11.0
WI	15	3.9	25.4
WV	15	8.8	41.1
WY	5	1.8	4.4
Average	-	**4.9**	**25.3**

(A)



(B)

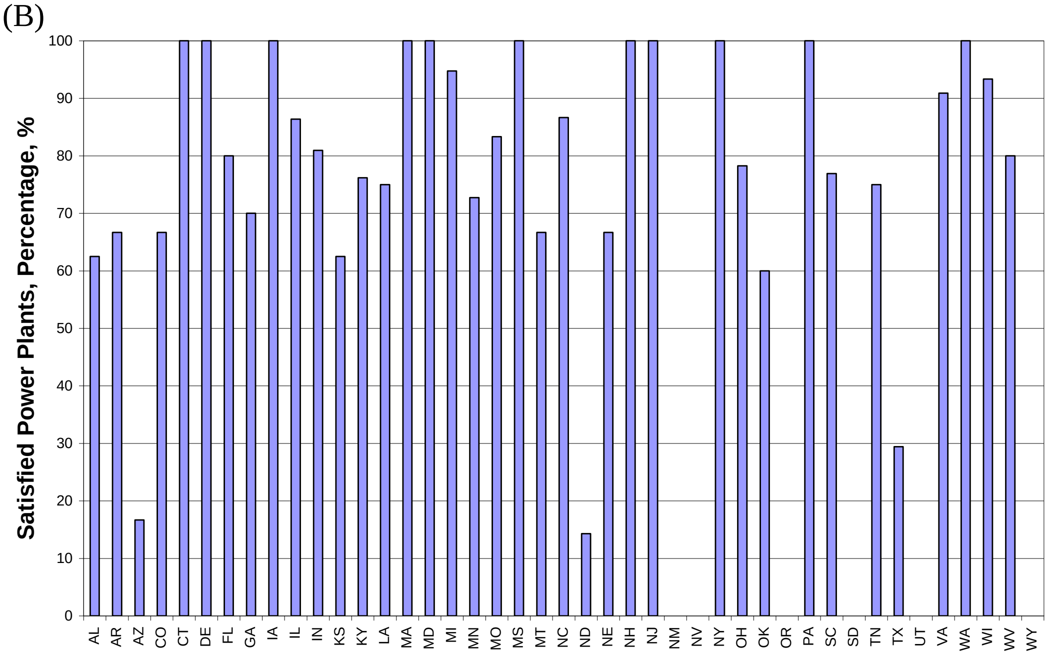


Figure 19. Percentage of existing power plants that have sufficient wastewater for cooling within (A) 10 mile radius and (B) 25 mile radius. Although extending the radius form 10 to 25 miles significantly improves availability of wastewater for cooling, the power plants in New Mexico, Nevada, Utah, and Wyoming still cannot meet their cooling needs

2.3.1.8 Results of Feasibility Analysis

Water to energy factor is introduced to estimate the cooling water demand of proposed thermoelectric power plants. This factor varies depending on the type and configuration of the power plant but the analysis performed in this study used high water to energy factors to be able to account for the worst case of cooling water demand. The total wastewater flowrate available from POTWs within a 10 or 25 mile radius from each proposed power plant was calculated and compared to the estimated cooling water demand.

Limited freshwater sources have becoming more of a public concern and the shortage of freshwater supply will inevitably impact the power industry. Wastewater availability analysis with proposed power plants demonstrated the real possibility of employing impaired water for cooling systems both in terms of quantity and proximity. Considering POTWs within 25 miles, 97 percent of the proposed power plants can meet their cooling needs by utilizing secondary treated wastewater from POTWs. Results of geospatial analysis suggest that one fairly large POTW can fulfill most of the cooling water needs for majority of the 110 proposed power plants. This implies that the cost of transporting wastewater can be kept reasonably low (i.e., only one or two pipes may be needed to transport the cooling water to the power plant).

Thermoelectric power plants are categorized as major freshwater withdrawal and consumption sources. Analysis of existing coal fired power plants revealed that the secondary treated wastewater from POTWs within 25 miles can satisfy more than 75% of their cooling water demand.

This analysis showed that using reclaimed water for cooling purposes can be both economical and reliable and can facilitate the development of coal-fired power plants in the regions where other sources are not readily available.

2.3.2 General Water Quality and Availability of Abandoned Mine Drainage

Acid mine drainage refers to the discharge of acidic water from an abandoned coal mine. Because of the oxidized iron precipitation, streams receiving AMD will have different color sediments at the bottom or on the riverside. The acidic discharge may also contain heavy metals, such as copper, lead, mercury, which will endanger the aquatic and botanic life.

The formation of AMD is the result of reactions involving pyrite, FeS_2. Once FeS_2 is exposed and reacts with air and water, sulfuric acid and dissolved iron are formed according to the following equations (Stumm and Morgan, 1996):

$$FeS_2 + \frac{7}{2}O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{\ 2-} + 2H^+ \tag{2}$$

$$Fe^{2+} + \frac{1}{4}O_2 + H^+ \rightarrow Fe^{3+} + \frac{1}{2}H_2O \tag{3}$$

$$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{\ 2-} + 16H^+ \tag{4}$$

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+ \tag{5}$$

Pyrite can be oxidized by oxygen and ferric iron, Fe^{2+}, as shown by Equation (2) and (4). The produced ferrous iron from Eq. (2) can then be oxidized by oxygen to form ferric iron, as seen in Eq. (3), which produces more ferrous iron (Eq. (4)) to keep reactions (3) and (4) active. Ferric iron can also form amorphous precipitate, hydrous ferric oxide (Eq. (5)). Those equations indicate that oxidation of pyrite contributes to the increase of acidity and that the oxygen level plays a key role in the production of AMD. Studies have shown that the production of AMD can be limited by controlling the oxygen level in water or coal system (Watzlaf 1992). Recent studies have shown that the better quality of water was observed from flooded mines than that from partially flooded or unflooded mines (Lambert, McDonough et al. 2004).

AMD has a wide range of chemical characteristics in North America and might even have different water characteristics among mines located at identical geographic locations. Typically, AMD contains elevated concentrations of sulfate, iron, manganese, aluminum, and several common elements, such as calcium, sodium, potassium, and magnesium (PADEP 1998). Different composition of these elements leads to different pH values, ranging from acidic to alkaline. The range of pH is commonly within either 3 to 4.5 or 6 to 7; however, intermediate values or extreme values might occur as well. Abandoned coal mines could reach steady-state conditions approximately 25-30 years after the mine pool flooded (Lambert, McDonough et al. 2004).

The most serious problems with acid mine drainage are confined to the coal mining areas of Western Maryland, Northern West Virginia, Pennsylvania, Western Kentucky, and along the Illinois-Indiana border (USEPA 1995). Table 10 shows the concentrations of constituents in the coal mine drainage for the U.S., Illinois, Kentucky, Maryland, and West Virginia. The concentrations of the major contaminants in the U.S. were compiled by (Wildeman, Dietz et al. 1993). The values given in Table 10 are 10 and 90 percentage concentration of AMD from 23 coal mines in the U.S. The data shown for Illinois were the median of 110 coal disposal sites in Southern Illinois, collected by (Prodan, Mele et al. 1982). The regional concentration range in Kentucky was estimated by (Caruccio, Ferm et al. 1977). The example in Maryland was from Frazee Mine (Leonardo and Paul 1999), which is the underground coal mine that was abandoned since the 1960's. The example in West Virginia was a bond-forfeited coal mine site (Upper Freeport seam) located in north central West Virginia and was collected in an underground pool and pumped to a treatment channel on the surface (Wei, Viadero et al. 2005).

Table 10 also shows that the AMDs are quite similar among these states. The pH values are about 3 and the concentration of sulfate reaches 1000 mg/L in all states. The iron concentration among all regions compares well with the values for the entire U.S. Most metals are within the values for the entire U.S. except for the concentrations of Zn and Mn in West Virginia. Factors that may influence the concentration of specific constituents include temperature, precipitation, hydraulic head, conductivity, fractures, floor leakages, etc. (Stumm and Morgan 1996).

Pennsylvania has abundant coal resources that have been mined for a very long time. Hence, there are plenty of AMD sources in PA. Studies of 136 mine discharges in the syncline were done in 1974-1975. A reevaluation of discharges in 21 out of the 136 mines was done in 1998-2000 (Lambert, McDonough et al. 2004). The results show that the AMD characteristics changed with time as the hydraulic condition changed (McDonough, Lambert et al. 2005).

Table 11 shows the concentrations of constitutes from two regularly sampled mines located in Clarion County, Pennsylvania (PADEP 1998).

Table 10. Water quality of mine drainage in North America

Substance	U.S. (1)	Illinois (2)	Kentucky (3)	Maryland (4)	West Virginia (5)
pH	3.2-7.9	3	1.8-3.5	3.6–6.0	2.6±0.1
Acidity CaCO3 (mg/L)	-	-	-	90-438	-
SO4- (mg/L)	-	1300	500-12000	620-1600	1527±12
Ca (mg/L)	-	-	-	183-489	191±10
Mg (mg/L)	-	-	-	17-48	50.5±3.9
Fe (mg/L)	0.6-220	57	57-500	28-92	162±23
Mn (mg/L)	0.3-12	6.4	-	2-5.5	203±0.21
Al (mg/L)	-	37	-	4.0-28	80.8±7.4
Cu (mg/L)	0.01-0.17	-	-	ND-0.08	0.08±0.02
Ni(mg/L)	-	-	-	0.57-1	1.01±0.15
Zn (mg/L)	0.03-2.2	-	-	0.5-3	2.72±0.34
Cd (mg/L)	0.01-0.10	-	-	-	-
Pb (mg/L)	0.01-0.40	-	-	-	-
As (mg/L)	0.002-0.20	-	-	-	-

Note: ND = non-detectable,
Reference: (1) (Wildeman, Dietz et al. 1993) (2) (Prodan, Mele et al. 1982) (3) (Caruccio, Ferm et al. 1977) (4) (Leonardo and Paul 1999) (5) Xinchao et. al., 2005 (Wei, Viadero et al. 2005).

West Virginia, Pennsylvania, and Kentucky have long history of mining and a large number of abandoned mine sites. With more than 250,000 acres of abandoned mine lands, Pennsylvania has the highest number of abandoned mines (PADEP 1997). Studies have also revealed that Pennsylvania and West Virginia have potentially 250 billion gallons of water stored in these abandoned mine sites (Veil, Kupar et al. 2003).

Table 11. Water quality of mine drainage in Pennsylvania

Mine 1. Clarion County, C & K Mines 18, 19, and 20 (lat 41°04'15" N, long 79°26'45" W)										
Site name	Depth, meters	Conduc-tance, mS/cm	pH	Acidity, $CaCO_3$	Alkalin-ity, $CaCO_3$	SO_4	Ca	Mg	Fe	Mn
LMS S2-5	1.5	4,370	7.0	0	750	2,300	560	210	0.04	6.60
LMS S1-15	4.6	3,550	6.9	0	600	1,600	610	220	1.80	19.00
LMS S2-15	4.6	3,890	6.9	0	730	1,900	650	230	5.70	7.50
WMS N2-1	17.4	2,900	6.1	64	120	2,200	320	240	30.00	59.00
WMS S4-1	20.1	2,310	6.3	30	360	1,400	410	180	0.70	16.00
WMS S1-1	28.9	2,330	6.7	0	500	1,300	380	130	0.76	5.10
Mine 2. Clarion County, C & K Mine #69 (lat 41°09'15" N, long 79°29'30" W))										
DMS 16	0	3,280	5.2	22	56	2,352	311	288	18.8	22.80
WMS 15B	16.3	5,030	2.6	1,660	0	3,457	331	287	375.0	36.10
WMB 15A	24.8	6,040	2.5	2,680	0	4,404	279	234	683.0	41.10
WUB 14A	33.2	2,960	5.4	122	54	2,251	325	229	62.8	24.10
WUB 14	33.3	3,030	5.2	136	33	2,049	308	215	63.4	26.60
WMB 15	36.4	4,840	3.4	1,604	0	3,675	353	270	477.0	48.30

The three-letter prefix of sample site name indicates sample type: W=well, L=lysimeter, M=mined, U=unmined, S=spoil, B= bedrock.

A list of 4476 water sources affected by acid mine drainages were identified by PADEP and the spatial database is available through Pennsylvania Spatial Data Access (PASDA 2010). Among the impacted water sources, only 242 sites have been reclaimed and are readily for reuse. Most sites have fairly low water flowrate, while there are only 9 reclaimed sites have flowrate higher than one million gallon per day (Figure 20). Feasibility analysis of using treated mine drainage for cooling needs at a specific site in Pennsylvania has been conducted by Donovan et al. (Donovan, Duffy et al. 2004). However, unlike municipal wastewater that is available throughout the country, acid mine drainage is available in just a few states and at specific location so that its impact in meeting the cooling water needs of thermoelectric power plants is limited.

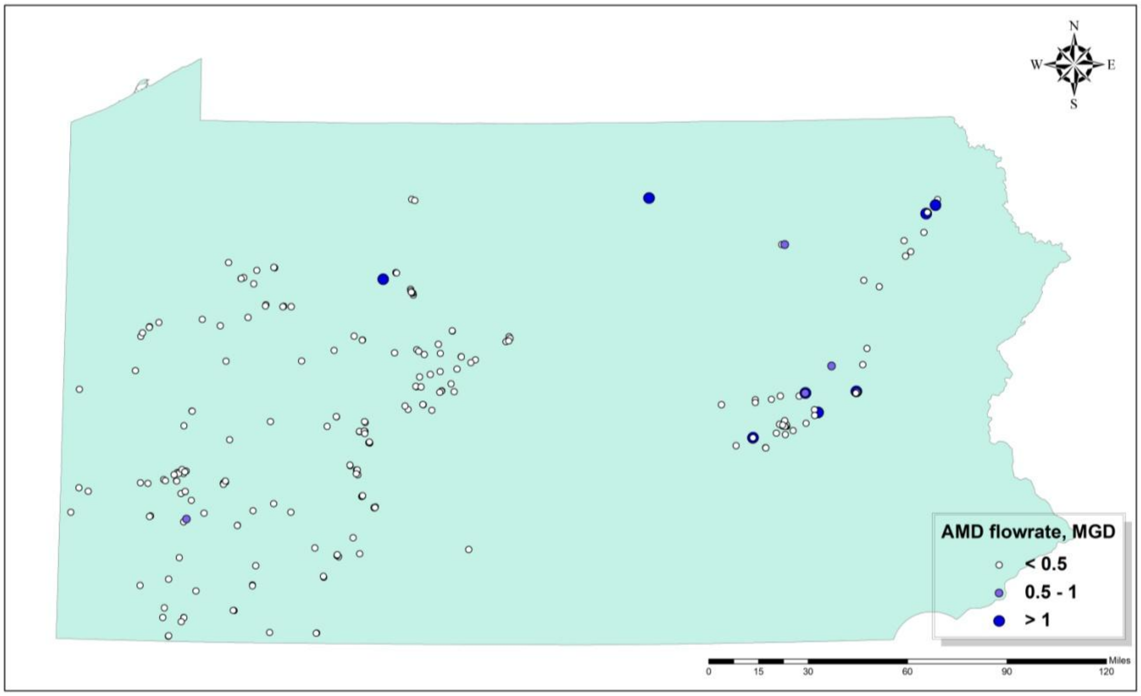


Figure 20 Treated acid mine drainages from coal mine operation in Pennsylvania (Source:(PASDA 2010)).

2.3.3 General Water Quality and Availability of Ash Pond Water

As coal is combusted, ash is generated and it either falls to the bottom of the boiler (bottom ash) or it travels together with a flue gas (fly ash). Bottom ash consists primarily of oxides of silica, aluminum, iron, magnesium, and calcium that represent over 95% of its weight. Bottom ash contains lower concentrations of trace elements, such as arsenic, beryllium, copper and vanadium, than fly ash (MDEQ 2004). Exact chemical properties of fly ash are influenced, to a great extent, by those of the coal burned and the techniques used for handling and storage.

Recent study by Nevada Division of Environmental protection showed that the total flow of ash to the ponds from Reid Gardner Station power plant (650MW), including fly ash, bottom ash, and other coal combustion by products, was 286,000 gpd (NDEP 2005). It is very common that the cooling tower blowdown is used as a water supply for the scrubbers and bottom ash transport system (EPRI 1980). When an ash settling pond is full, it is temporarily removed from service and allowed to dry so that the retained materials can be removed to the disposal site.

Fly ash transport waters are generated when the ash collected from the stack gases is mixed with water to form slurry, which is then pumped to ash settling ponds. Liquid used to transport fly ash may be either fresh water, diverted waste streams from other processes, or re-circulated slurry water from fly ash settling ponds. Table 12 summarizes the result of several studies investigating the characteristics of water in fly ash and bottom ash settling ponds.

TVA power plant uses a once-through ash pond where the fly ash is pumped to settling ponds to be removed by gravity settling so that the ash pond effluent can be treated and released to the environment. Colstrip power plant in Montana burns sub-bituminous coal and uses several ponds for disposal of fly ash and bottom ash. Water in these units comes from the ash transport water and from the wet venturi scrubbers that are used for particulate and sulfur dioxide control. The last column in Table 12 provides the average water quality from several bottom ash ponds compiled by (Lagnese 1991).

Table 13 compares the characteristics of the fly ash and bottom ash pond waters to the quality of river water (Bohac 1990). The bottom ash water quality is poorer than the fly ash pond water but these results indicate that the quality of the ash pond waters may not be that different from the quality of the river water, which is commonly used for cooling in coal-fired power plants. Such finding suggests that the ash pond water may serve the same purpose without much difficulty.

Table 12. Chemical Characteristics of fly ash pond and bottom ash pond at different plants

Parameter	TVA Fly Ash Pond (1)	TVA Bottom Ash Pond (1)	Colstrip Bottom Ash Pond 1&2 (2)	Colstrip Bottom Ash Pond 3&4 (2)	Bottom Ash Ponds (3)
Flow (gpm)	6212.5	16000	0	0	-
Total alkalinity (CaCO3)	-	85	125	268	-
Conductivity (umhos/cm)	810	322	5166	4119	-
Total hardness (CaCO3)	261	140	3768	985	-
Ph	4.4	7.2	9.5	10	6.71
Dissolved Solid	508	170	5924	3089	209
Suspended solid	62.5	60	-	-	2.4
AL	7.19	3.49	0.27	0.42	<0.15
Ammonia as N	0.43	0.12	7.2	0.34	0.06
Ar	0.01	0.006	-	-	0.006
B	-	0	21.7	2.5	<0.05
Ba	0.25	0.12	-	-	0.063
Be	0.011	<0.01	-	-	-
Cd	0.037	0.0011	<0.002	<0.001	<0.0005
Ca	136	40	550	354	46
Cl	7.12	8.38	1.13	0.51	20
Cr	0.037	0.009	-	-	0.04
Cu	0.31	0.065	0.05	0.01	0.008
Cyanide	<0.01	<0.01	-	-	-
Fe	1.44	5.29	0.03	0.03	2.38
Pb	0.058	0.016	0.03	<0.01	<0.002
Mg	13.99	5.85	518	41	9.8
Mn	0.48	0.16	1.64	0.02	0.37
Hg	<0.0003	<0.0007	<0.001	<0.001	0.002
Ni	1.1	<0.059	0.08	0.01	<0.011
Total phosphate as P	0.021	0.081	0.04	0.04	-
Se	0.0019	0.002	0.014	0.01	<0.003
Silica	12.57	7.4	-	-	3.6
Ag	<0.01	<0.01	-	-	<0.0005
Sulfate	357.6	48.75	3790	1893	103
Zn	1.51	0.09	0.05	0.01	<0.001

Unit for all concentrations are in mg/l unless otherwise indicated.
TVA: Tennessee Valley Authority
Reference (1) (EPRI 1980), (2) (MDEQ 2004), (3) (Lagnese 1991)

Table 13. Comparison of fly and bottom ash pond water in TVA plant to river water*

	River water	Fly ash supernatant	Bottom ash supernatant**
TDS mg/l			72
SS mg/l			160
Al µg/l	110	<50	2200/<50
As µg/l		130	28/22
Ba µg/l		410	160/100
Cd µg/l		1.1	0.3/<0.1
Ca mg/l	25	38	15/14
Cl mg/l	4	4.5	3.5
Cr µg/l		10	3/<1
Cu µg/l	<10	<10	<10
B µg/l		170	<50
Fe µg/l	340	2	2500/60
Pb µg/l		<1	5/1
Mg mg/l	7.9	7.8	3.1/2.9
Mn µg/l	84	32	61/22
Na mg/l	5	5.6	3.2/3.1
Li µg/l		<10	<10
Se µg/l		14	<1
Silica µg/l			2200/1700
Sulfate mg/l	26	62	22/20
Zn µg/l	<10	10	30/30

*Source: (MDEQ 2004)
** Total Concentration/Dissolved Concentration

Ash pond water is generally stored near the coal-fired power plants, which means that it is readily available for reuse in cooling systems. Newerow and Agardy showed the average volume of bottom ash pond overflow is 3,881 GPD/MW, while the average makeup water need in a recirculating cooling system is about 14,400 GPD/MW. (Nemerow and Agardy 1998; NETL 2005). These results indicate that a small portion (25%) of freshwater demand for cooling can be easily replaced by ash pond water.

3.0 REVIEW OF REGULATIONS GOVERNING THE USE OF RECLAIMED WATER FOR COOLING PURPOSES

Alternative water sources have been reviewed and the general water quality of these waters was evaluated in previous chapter. However, use of these impaired waters may cause adverse impact on the environment with improper application. Therefore, knowing the legality of using impaired water for cooing purposes and the generally acceptable water quality is necessary. Review of regulations will focus on four topics: (1) the basis of using reclaimed water in re-circulating system, (2) the discharge of utilized impaired water, (3) the air emission from cooling tower using reclaimed waters, and (4) transport of reclaimed water across regional boundaries.

All topics will be evaluated on both federal and state level and additional requirements for local government will be addressed as well. In addition to official regulatory requirements, this chapter also offers guidelines suggested by federal and state EPA offices.

3.1 FEDERAL REGULATIONS

The operation of a water reuse program must be within the framework of federal and state regulations and these must be addressed in the earliest planning stages. Currently, there are no federal regulations directly related to the practices of water reuse in the U.S., including no specific federal regulations governing the reuse of reclaimed water as power plant cooling water.

Many states, however, do have regulations pertaining to water reuse. At the federal level, the U.S. Environmental Protection Agency published “Guidelines for Water Reuse” for the benefit of utilities and regulatory agencies (USEPA 2004). “Guidelines for Water Reuse” provides an overview of (1) types of reuse applications, (2) related technical issues, (3) water-reuse regulations/guidelines established by each state, (4) legal and institutional issues, (5) funding water reuse systems, (6) public involvement programs, and (7) water reuse in other countries. For those states having no water reuse regulations/guidelines, the USEPA guideline document provides suggestions about treatment, reclaimed water quality, reclaimed water monitoring, and minimal distance between wastewater source and public area in the guidelines.

3.1.1 Water Reuse Regulations

Currently, there are no federal regulations governing water reuse in cooling systems. “Guidelines for Water Reuse” suggests treatment and desired reclaimed water quality for water reuse in industrial cooling water, including once-through cooling and re-circulating cooling towers. The reclaimed water quality for industrial reuse suggested by the USEPA is summarized in Table 14. Since the general focus of reclaimed water use is on municipal wastewater, suggested standards for cooling towers are correlated to the municipal wastewater discharge standards. Any effluent leaving the wastewater treatment plant is regulated by technology-based limits on BOD_5, TSS, and pH.

Federal regulations do not govern how the power plant uses reclaimed water inside their facility. Therefore, the water quality requirements are established by the local government based on the operational requirement. For example, the suggested guidelines for fecal coliform and chlorine residual are focused on bacteria levels in the drift, which may travel through the air and causes increased health risk.

Table 14. Summary of reclaimed water quality when used in cooling water system (USEPA 2004)

System	Treatment	pH	BOD_5	TSS	Fecal Coliform	Cl_2 Residue
Once-through cooling	Secondary, disinfection	6-9 (monitored weekly)	30 mg/l (monitored weekly)	30 mg/l (monitored daily)	•200/100 ml (weekly median, monitored daily) •800/100 ml (max)	1 mg/l (minimum, monitored continuous)
Re-circulating cooling towers	Secondary, disinfection (chemical coagulation and filtration may be needed)	6-9 (variable depends on recirculation ratio)				

3.1.2 Water Discharge Regulations

Clean Water Act rules all discharges of pollutants into the surface water. Cooling tower is regulated and referred to as a point source. National Pollutant Discharge Elimination System (NPDES) permit is required by the wastewater treatment facilities. While there are no federal regulations focused specifically on the effluent discharge of reclaimed water from industrial cooling systems, Section 402 of the Clean Water Act requires that all point source discharges of pollutants to surface waters must be authorized by NPDES discharge permits. Limits in NPDES permits can be technology-based or water-quality-related. Specific Clean Water Act regulations in the Code of Federal Regulations (40CFR423) provide effluent standards for steam electric power generating plant discharges, categorized as:

1. The best practicable control technology currently available (BPT);
2. The best available technology economically achievable (BAT);
3. New source performance standards (NSPS);
4. Pretreatment standards for existing sources (PSES); and
5. Pretreatment standards for new sources (PSNS).

As noted by the California Energy Commission (Masri and Therkelsen 2003), the only aspect of BPT that applies to any current or future power plant discharges is pH limits of 6.0~9.0. Other BPT controls are superceded by BAT. A summary of effluent standards from 40CFR423 is shown in Table 15.

Free chlorine is a generally used biocide for controlling the bacteria population in the cooling tower system. Inactivation and suppression of pathogenic microorganisms, for example, Legionella, requires a chlorine concentration level above 3 mg/L (Skaliy, Thompson et al. 1980). Therefore, the suggested chlorine residual in cooling tower system has a minimum at 1 mg/L shown in Table 8. However, elevated free chlorine concentration contributes to the production of trihalomethanes and other byproducts that are carcinogenic or mutagenic (Morris and Comstock 1993).

Other commonly regulated additives are Chromium and Zinc, which are usually used as corrosion inhibitors. Hexavalent chromium-based compounds are among the most available and efficient corrosion inhibitors for cooling towers, but have been categorized as suspected carcinogens with high toxicity (IARC 1997). Traces of zinc are not directly hazardous to human body. However, elevated concentration of Zinc will cause adverse impact on the aquatic life and cause a wide range of problems in mammals, including cardiovascular, developmental, immunological, liver and kidney problems, neurological, hematological, pancreatic, and reproductive issues (Eisler 1993; Domingo 1994).

NSPS are federal emission standards for point sources which cause or contribute significantly to air pollution, such as cooling towers. Any sources which have been constructed or modified since the proposal of the standards are regulated under this section. This act ensure the use of best air pollution control technologies in the future.

In 40 CFR 403, government proposed PSES and PSNS in order to establish responsibilities of federal, state, local government, industry, and public for the pollutant discharge. These standards regulate all non-domestic sources which introduce pollutants into POTWs and are enforced through a pretreatment program established by individual plants.

Table 15. Summary of 40CFR423 related to BPT, BAT, NSPS, PSNS, and PSES in once through cooling water and cooling tower blowdown

		pH	Free available Chlorine		Total Chromium		Total Zinc	
			One day maximum (mg/l)	Average (30 consecutive days) (mg/l)	One day maximum (mg/l)	Average (30 consecutive days) (mg/l)	One day maximum (mg/l)	Average (30 consecutive days) (mg/l)
Once through cooling water	BPT		0.5	0.2				
	BAT/NSPS ≥25MW		0.2					
	BAT/NSPS <25MW		0.5	0.2				
Cooling tower blowdown	BPT	6~9	0.5	0.2				
	BAT, NSPS	6~9	0.5	0.2	0.2	0.2	1.0	1.0
	PSNS				0.2		1.0	
	PSES				0.2		1.0	

Note:
1) For BAT, NSPS, PSNS, and PSES, the 126 priority pollutants (except chromium and zinc) contained in chemicals added for cooling tower maintenance should be in non-detectable amounts.

Another type of NPDES permit is water quality-based limits that consider the water quality of receiving water body and possible dilution factor of the water body. Limits may be set on trace metals, nutrients, organic compounds, BOD_5, etc. based on state or local regulations.

3.1.3 Air Emission Regulation

Evaporative condensation of water occurs when the warm water gets in contact with air in wet re-circulating cooling towers. Millions of small droplets, also called “drift”, are exhausted with air into the atmosphere from these towers. In “Guidelines for Water Reuse” it is recommended that when reclaimed water is used in industrial cooling, windblown spray should not reach areas accessible to workers or the public. The drift usually contains highly concentrated elements, including metals, nutrients, and microorganisms which may increase the health risk for residents in the vicinity of the power plant. Cooling tower drift can contain all the chemicals present in the recirculating cooling water . (USEPA 2004)

The federal government does not offer specific limitations on air emission from industrial cooling systems using reclaimed water for cooling purposes. Nonetheless, there are regulations related to air emissions from cooling towers. According to USEPA (USEPA 2005), cooling towers are categorized as potential point emission sources of volatile organic compounds (VOC), PM10, PM2.5, and NH_3. EPA (USEPA 1995) also provides a compilation of emission factors for these air pollutants for estimation purposes, but the values listed are neither EPA-recommended emission limits (e.g., best available control technology or BACT, or lowest achievable emission rate or LAER) nor standards (e.g., National Emission Standard for Hazardous Air Pollutants or

NESHAP, or New Source Performance Standards or NSPS). Detailed discussion of particulate emission calculations pertinent to cooling towers in the United States is given in Appendix B.

As mentioned before, chromium was commonly used as corrosion inhibitor in re-circulating cooling systems but has been banned for its toxicity to humans. The use of chromium in cooling water is regulated in 40CFR63.402 (National Emission Standards for Hazardous Air Pollutants for Industrial Process Towers): “No owner or operator of an IPCT (industrial process cooling tower) shall use chromium-based water treatment chemicals in any affected IPCT.”

3.1.3.1 Particulate Emission Regulations Pertinent to Cooling Towers in The United States

Particulate matter emissions from cooling towers are a concern primarily because they are aerosols that may be easily inhaled and deposited into the respiratory system. Drift eliminators are able to reduce the amount of cooling water lost as a drift to a range between 0.0005-0.002% of the total recirculation flow rate. However, most of the loss is as PM_{10} which is the particle size of highest concern. Regulations pertaining to cooling towers are similar to those in place for vehicles and power plants and therefore are set in terms of particle mass/airflow ($\mu g/m^3$). National ambient air quality standards (NAAQS) set particulate matter criterion, whereas each state regulates the amount of water used for cooling purposes. If the total dissolved solids in the cooling water are established, total particulate emissions can be estimated using the drift loss. If there are no data for total dissolved solids in the cooling water, particulate emissions can be estimated using PM_{10} emission factor (USEPA 1995) resulting in total drift to PM_{10} ration of 89.5:1.

3.1.3.2 National Ambient Air Quality Standards (NAAQS)

Particulate matter regulations were issued together with six criteria pollutants in 1971 and then revised in 1997 (USEPA 1997). In 1990, the Clean Air Act required EPA to set up standards for all pollutants that are considered harmful to public health and the environment, which are known as National Ambient Air Quality Standards (40 CFR part 50). Primary and secondary standards are two types of national air quality standards built to limit the potential adverse impacts. Primary standards are mainly concerned with protecting public health and secondary standards are about protecting public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings. The specific standard for total suspended particulate matter was introduced in 1987 by NAAQS, with maximum concentration in a 24-hour period of 150 μg/m^3 and annual average of 50 μg/m^3. This standard was later referred as PM_{10}. In 1997, EPA established new NAAQS for PM, which included standards for particles smaller than 2.5 μm ($PM_{2.5}$) and smaller than 10 μm (PM_{10}) (USEPA 1997). The PM criteria are listed in Table 16.

Table 16. Particulate Matter Criteria issued in NAAQS

Pollutant	Primary Standards.	Averaging Times	Secondary Standards.
Particulate Matter (PM_{10})	Revoked*	Annual (Arith. Mean)	
	150 μg/m^3	24-hour	
Particulate Matter ($PM_{2.5}$)	15.0 μg/m^3	Annual (Arith. Mean)	Same as Primary
	35 μg/m^3	24-hour	

Note:
*Due to a lack of evidence linking health problems to long-term exposure to coarse particle pollution, the agency revoked the annual PM_{10} standard in 2006 (effective December 17, 2006)
Source: National Ambient Air Quality Standards, (USEPA 2005)

3.1.4 Interbasin Water Transfer Regulations

The use of treated wastewater or other impaired waters in power plants may involve the transfer of water/wastewater from one water drainage basin to another, and perhaps even across a state boundary. Such water/wastewater transfer could raise public concern, especially in regions with limited water resources and competition for those resources. Both federal and state laws and regulations pertaining to interbasin water transfer were evaluated in this study. Regulations that govern interbasin water transfers vary from region to region, and interstate or intrastate water transfer is mainly governed by individual states. This stems from having no federal interbasin transfer regulations and the fact that many large watersheds have their own regulatory commissions. These commissions often govern water rights and have very prohibitive transfer policies between basins, such as in the Great Lakes and Colorado River regions. Previous cases show that most transfer events were evaluated on a case-by-case basis and indicate few prohibitions against water transfer.

Water rights are legal rights to possess water, use it, dispose of it and prohibit anyone else from interfering with its use for an indefinite period of time (Goldfarb 1998). In the US, the concept of water rights is divided into two different systems. States east of the Mississippi River, except Mississippi, Arkansas, Iowa, and Missouri, mostly define water rights as “riparian rights” (Getches 1997). Riparian rights are the rights held by the owners of the land along the banks of bodies of water. The western US states rely on the appropriation rules, which can be described as “the first in time, the first in right” (Getches 1997). Under this approach, a person who uses water in a beneficial and legal way can continue to do so as long as water is available. The appropriation system under the law that governs interbasin water transfer in the western US creates no fundamental barrier to taking water from one watershed to another and that water is not legally tied to the land or to the watershed. In contrast, the riparian system that prevails in the eastern US discourages interbasin transfers of water by arbitrary limitation on watershed (Goldfarb 1998).

Existing federal laws are not directly governing interbasin water transfer, but some environmental laws can influence interbasin water transfer. Table 17 shows that several laws, including the National Environmental Policy Act (NEPA), the Clean Water Act (CWA), and the Endangered Species Act (ESA), indirectly relate to interbasin water transfer. The major concern is mainly about the potential impacts on environment caused by transporting water from one basin to another. As stated in the CWA, interbasin transfers are usually governed by states except in special cases such as Great Lakes and federally authorized reclamation projects which involve interstate impacts (Craig 2007).

Table 17. Federal environmental laws that indirectly affect interbasin water transfer

Law	Description
The National Environmental Policy Act (NEPA)	Federal agencies are required to assess potential environmental impacts of proposed "major federal actions". The agencies must hold hearings that allow public participation and then prepare an "environmental impact statement" document.
The Clean Water Act (CWA)	Although the Clean Water Act does not regulate interbasin water transfer, the depletion of a stream used by the transfer of water to other basin can impact water quality negatively. Section 404 of the CWA requires the U.S. Army Corps of Engineers to review the impacts and require mitigation for the impacts of a water development on the basin of origin.
The Endangered Species Act (ESA)	The ESA prohibits any action that would jeopardize the existence of an endangered species.

3.2 STATE REGULATIONS

As summarized in “Guidelines of Water Reuse” , most states have established regulations and/or guidelines on water reuse for different purposes (USEPA 2004). Among those states, California, Florida, Hawaii, New Jersey, North Carolina, Oregon, Texas, Utah, and Washington have regulations and guidelines for industrial reuse of reclaimed water. The regulations/guidelines for reclaimed water use in industrial cooling water systems in these ten states are reviewed.

Although Arizona, Maryland, and Wyoming do not have regulations or guidelines related to reclaimed water reuse as industrial cooling water, they were chosen to illustrate the applicability of their general regulations/guidelines pertaining to reclaimed water reuse. In addition, all these states are selected for further analysis because they either have potential to severe water shortage or have documented experience with water reuse for cooling in thermoelectric power plants.

Table 18 summarizes the states having regulations and guidelines for different water reuse applications. In Section 3.2.1, pertinent regulations developed by each of the states to govern water reuse and water discharge are outlined in more details.

Another critical concern of water reuse is the expose of public or workers to reclaimed waters. When public or workers have the chance to contact the reclaimed water, higher reclaimed water quality may be required. Drift/mist/aerosol created from cooling tower is the key concern in air emission regulations because of the potential for human exposure. Pertinent regulations are also renewed in Section 3.2.1.

Interbasin water transfer regulations developed by the states are also relevant to the use of impaired waters in cooling water systems of power plants. State interbasin water transfer regulations are described in Section 3.2.2.

3.2.1 State Regulations on Water Reuse

Table 19 summarizes specific state rules and regulations governing water reuse, water discharge and air emissions in 12 states selected for further evaluations. Specific guidelines and regulations developed by these states are reviewed in the rest of 3.2.1.

Table 18. Summary of water reuse regulations and guidelines by states*

State	Regulations	Guidelines	No regulation/Guideline	Unrestricted Urban Reuse	Restricted Urban Reuse	Agricultural Reuse Food Crops	Agricultural Reuse Non-Food Crops	Unrestricted Recreational Reuse	Restricted Recreational Reuse	Environmental Reuse	Industrial Reuse	Groundwater Recharge	Indirect Potable Reuse
Alabama		●			●		●						
Alaska	●						●						
Arizona	●			●	●	●	●		●				
Arkansas		●		●	●	●	●						
California (3)	●			●	●	●	●	●	●		●	●	
Colorado	●			●	●	●	●	●	●				
Connecticut			●										
Delaware	●			●	●		●						
Florida	●			●	●	●	●			●	●	●	
Georgia		●		●	●		●						
Hawaii		●		●	●	●	●		●		●	●	
Idaho	●			●	●	●	●						
Illinois	●			●	●		●						
Indiana	●			●	●	●	●						
Iowa	●				●		●						
Kansas		●		●	●	●	●						
Kentucky			●										
Louisiana			●										
Maine			●										
Maryland		●			●		●						
Massachusetts		●		●	●		●					●	
Michigan	●					●	●						
Minnesota			●										
Mississippi			●										
Missouri	●				●		●						
Montana	●			●	●	●	●						
Nebraska	●				●		●						
Nevada	●			●	●	●	●	●	●				
New Hampshire			●										
New Jersey		●		●	●	●	●				●		
New Mexico		●		●	●	●	●						
New York		●			●		●						
North Carolina	●			●							●		
North Dakota		●		●	●		●						
Ohio		●		●	●		●						
Oklahoma	●				●	●	●						
Oregon	●			●	●	●	●	●	●		●		
Pennsylvania		●			●		●						
Rhode Island			●										
South Carolina	●			●	●		●						
South Dakota		●		●	●		●						
Tennessee	●			●	●		●						
Texas	●			●	●	●	●	●	●		●		
Utah	●			●	●	●	●	●	●		●		
Vermont	●						●						
Virginia			●										
Washington		●		●	●	●	●	●	●	●	●	●	
West Virginia	●				●	●	●						
Wisconsin	●				●		●						
Wyoming	●			●	●	●	●						

*Adapted from "Guidelines of Water Reuse", (USEPA 2004).

**States reviewed in this study are those that are shaded in this table.

Table 19. Summary of regulations and guidelines reviewed in the twelve selected states.

	Water Reuse Regulations	Water Discharge Regulations	Air Emission
Arizona	*AAC, R18-9, Article 7	• AAC, R18-9 Article 9	
California	* State Water Resources Control Board, Resolution No.75-58 * Warren-Alquist Act, Section 25602 * Water Code, Section 462 * 22CCR60306	* State Water Resources Control Board, Resolution No. 75-58	* 22CCR60306 • 17CCR93103
Florida	* FAC 62-610-668	• FAC 62-302-520 • FAC 62-660.400	* FAC 62-610-668
Hawaii	* Guidelines for the Treatment and Use of Recycled Water, III, C (Dep. of Health, 2002)		* Guidelines for the Treatment and Use of Recycled Water, III, C (Dep. of Health, 2002)
Maryland		• COMAR26.08.03.06	
New Jersey	* Reclaimed Water for Beneficial Reuse (Dep. of Env. Pro., 2005)		
North Carolina	* 15A NCAC 02T.0906 * 15A NCAC 02T.0910	• 15A NCAC 02B.0208 • 15A NCAC 02B.0211 • Thermal (Temperature) Variances to North Carolina Water Quality Standards (USEPA 2006)	
Oregon	* OAR 340-550-0012		* OAR 340-550-0012
Texas	* TAC 30-210.32 * TAC 30-210.33	• TAC 30-307.8	* TAC 30-210.32 * TAC 30-210.33 • TAC 30-113.220
Utah	* Water Reuse in Utah (UDWR 2005) * UAC R317-3-11		* UAC R317-3-11
Washington	* RCW 90.46 * Water Reclamation of Reuse Standards (WADOH and WADOE 1997)		* Water Reclamation of Reuse Standards (WADOH and WADOE 1997)
Wyoming	• WQRS Chapter 21	• WQRS Chapter 2	

Notation
* Related to reuse of reclaimed water in power plant cooling water system.
• Related to power plant cooling water system.

Arizona

In the state of Arizona, the Revised Statutes (A.R.S.), Arizona State Legislature, authorizes the Arizona Department of Environmental Quality (ADEQ) to adopt water quality standards for the direct reuse of reclaimed water. Any reclaimed water reuse is regulated by Arizona Administrative Code (AAC), R18-9, Water Quality Control and the requirement for direct use of reclaimed water is regulated in AAC R18-9, Article 7. The reclaimed water classification and relevant water quality is stated in AAC, R18-11 and the transportation of reclaimed water is regulated in AAC, R18-9 Article 6.

In the Regulation R18-9-704 G Prohibited Activities, Item 2-C, direct reclaimed water reuse is prohibited for evaporative cooling towers or misting. Using reclaimed water for cooling seems to be illegal in Arizona but there have been power plants using 100% reclaimed water for years. The answer was provided by the Reclaimed Water Office, ADEQ (Veil 2007). The definition of "direct use" opens the opportunity for the power plants to utilize reclaimed water in cooling tower systems. The Regulation R18-9-701 states that "The use of industrial wastewater or reclaimed water, or both, in a workspace subject to a federal program that protects workers from workplace exposures" is not regarded as "direct reuse" of reclaimed water. In other words, as long as the power plant could provide safety programs to the workers, the use of reclaimed water will not be categorized as direct reuse and does not require a permit for its reuse. Another case is to acquire the reclaimed water from a treatment facility and discharge the blowdown back to the treatment facility. Under this circumstance, R18-9-701-a will activate and no permit is required.

Although any discharge of pollutant is regulated by AZPDES, the power plants could avoid to be regulated by sending cooling tower blowdown back to: 1) POTWs by indirect discharge, and 2) Discharge into a privately owned treatment works. Otherwise, the discharge of blowdown back to the surface water or other water body is regulated in R18-9 Article 9.

Regulation R18-9 Article 6 regulates two types of transportation of reclaimed water, "Open Water conveyance" and "Pipeline conveyance". An open water conveyance does not include waters of the United States thus is excluded. "Pipeline conveyance" means any system of pipelines that transports reclaimed water from a sewage treatment facility to a reclaimed water blending facility or from a sewage treatment facility or reclaimed water blending facility to the point of land application or end use. In R18-9-602, F and G, the transportation of reclaimed water through pipelines should meet the minimum separation distance or have better material/joint design to ensure no contamination to drinking water. In addition, a notable sign with caution words is required; otherwise, the pipe must have light purple color.

California

California is one of the two states (the other is Florida) having comprehensive regulations about water reuse. State Water Resources Control Board and the California Regional Water Quality Control Board are the two divisions of California Environmental Protection Agency (CEPA), which administer the state water quality control. Regional boards include (1) North Coast (2) San Francisco Bay (3) Central Coast (4) Los Angeles (5) Central Valley (6) Lahontan (7) Colorado River Basin (8) Santa Ana and (9) San Diego.

・ Two major regulations related to the reuse of reclaimed water in industrial cooling tower are 1) California State Water Resources Board, resolution No. 75-58: Water quality control policy on the use and disposal of inland waters used for power plant cooling; 2)

California Health Laws Related to Recycled Water "The Purple Book" Excerpts from the Health and Safety Code, Water Code, and Titles 22 of the California Code of Regulations.

In addition to State Board Resolution No. 75-58, Warren-Alquist Act (Section 25602), and Water Code (462) also direct the administrator to evaluate water reuse in power plant cooling tower. In other words, the California government supports the use of recycled water for cooling purposes

Treated wastewater is defined as recycled water. The use of recycled water for cooling purposes is regulated by 22 CCR § 60306 (C) and recycled water used for industrial cooling that creates a mist shall be a disinfected tertiary recycled water. The recycled water quality required for cooling purposes is summarized in Table 20.

Table 20. The recycled water quality requirement for cooling water in CA

System	Treatment level	Treatment Requirement	Total Coliform	Turbidity
Industrial cooling involving cooling tower, evaporative condenser, or spraying that creates a mist	Disinfected Tertiary Recycled Water	oxidation, coagulation, filtration, and disinfection	23/100 ml (Av g) 240/100 ml (Max in 30 days) 2.2/100 ml as a weekly median	• coagulated and passed through natural undisturbed soil or a bed of filter media - 2 NTU (1-day average) - 5 NTU (not to exceed for more than 5% of 24 hr period) - 10 NTU (max) • passed through membrane - 0.2 NTU (not to exceed for more than 5% of 24 hr period) - 0.5 NTU (max)

*Adapted from "Guidelines of Water Reuse",(USEPA 2004).

In addition to the water quality requirement, the California government also suggests sampling total coliform at least once a week and turbidity continuously following filtration.

In California State Water Resources Board, resolution No.75-58, Page 5, two kinds of discharge are prohibited:

1) The discharge to land disposal sites of blowdown waters from inland power plant cooling facilities shall be prohibited except to salt sinks or to lined facilities approved by the Regional and State Boards for the reception of such wastes.
2) The discharge of wastewaters from once-through inland power plant cooling facilities shall be prohibited unless the discharger can show that such a practice will maintain the existing water quality and aquatic environment of the State's water resources.

In addition, the Regional Boards may grant exemption to these discharge prohibitions on a case-by-case basis in accordance with exception procedures included in the "Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California".

Concerning the air emission, District Rule 4201, Section 3.1 limits the emission of total suspended particulate matters (PM) to 0.1 grain/dry standard cubic foot of gas. Another concern is the hexavalent chromium compounds in the cooling tower. In 17 CCR s 93103, restrictions of chromate use in cooling towers includes: (1) Not adding any hexavalent chromium-containing compounds to the cooling tower circulating water; (2) The hexavalent chromium concentration should be less than 0.15 milligrams hexavalent chromium per liter of circulating water; (3) The concentration of hexavalent chromium should be tested every six months.

The air emission from cooling tower using recycled water is also regulated by 22 CCR § 60306 (C). Whenever a cooling system using recycled water in conjunction with an air conditioning facility utilizes a cooling tower which creates a mist that could come into contact with employees or members of the public, the cooling system shall comply with the following:

(1) A drift eliminator shall be used whenever the cooling system is in operation.

(2) A chlorine, or other, biocide shall be used to treat the cooling system re-circulating water to minimize the growth of Legionella and other micro-organisms. Moreover, the volatile organic compound emission is not expected from cooling towers in power plant facilities.

Florida

In the state of Florida, the water quality specific to cooling tower is regulated in FAC 62-610.668. Reclaimed water may be used in once-through cooling towers and open cooling towers with at least secondary treatment. Once-through cooling towers may use non-disinfected secondary effluent in a closed system and return the used water back to the domestic wastewater treatment facilities. For open cooling systems (wet re-circulating systems), reclaimed water must be at least secondary treated with a basic disinfection before use. A 300-foot setback distance shall be also provided to inform the workers and the cooling tower shall be designed and operated to minimize aerosol drift to areas beyond the site property line that are accessible to the public.

If the system design does not meet the requirements in Part III of Chapter 62-610, F.A.C., alternative requirements shall be addressed in the industrial wastewater permit, including high level of disinfection, filtration, and continuous monitoring of total suspended solids, chlorine residual, Giardia and Cryptosporidium. Moreover, total chlorine residual of at least 1 mg/l after a minimum acceptable contact time of 15 minutes is required at peak hourly flow. The water quality required for cooling systems is summarized in Table 21.

Table 21. The minimum reclaimed water quality requirement for cooling water in Florida

System	Treatment level	$CBOD_5$	TSS	Fecal Coliform	pH
Once-through cooling tower	secondary treatment (used in closed systems)	60 mg/l*	60 mg/l*	NS	6-8.5
Open Cooling tower	Secondary treatment and basic disinfection	20 mg/l	5 mg/l**	25/100 ml***	

Note: For once-through cooling tower: 1) the reclaimed water must be conveyed and used in closed systems which are not open to the atmosphere and 2) The reclaimed water must return to the domestic wastewater treatment facility.
*20 mg/l for annual average, 30 mg/L for monthly average, 45 mg/L for weekly average, and 60 mg/L for single sample.
**Single sample to be met after filtration and prior to disinfection.
***Over 30-day period, 75 percent of samples below detection limits.

Discharges from once-through cooling towers using reclaimed water must return the effluent back to the domestic wastewater treatment facility. Although no regulation is related to the effluent discharge of used reclaimed water from open cooling system, the discharges into waters of the state is still regulated by FAC, 62-302.520 regulates the thermal water discharge and FAC, 62-660.400 Effluent Limitations.

Discharges from steam electric generating plants existing or licensed by July 1st, 1984 shall not be required to be treated to a greater extent than may be necessary to assure:

1. That the quality of non-thermal components of discharges from non-recirculated cooling water systems is as high as the quality of the make-up waters; or

2. That the quality of non-thermal components of discharges from re-circulated cooling water systems is not lower than is allowed for blowdown from such systems; or

3. That the quality of non-cooling system discharges, which receive make-up water from a receiving body of water that does not meet applicable Department water quality standards, is as high as the quality of the receiving body of water.

Hawaii

Currently, Hawaii has no regulation related to water reuse. However, the Department of Health published "Guidelines for the Treatment and Use of Recycled Water" in 2002. The reuse of recycled water in evaporative cooling towers is referred to the uses of R-1 type water and the following requirements shall be met:

(1) A high efficiency drift reducer is used and the system is maintained to avoid greater rate of generation of drift than that with which a high efficiency drift reducer is associated;

(2) A continuous biocide residual, sufficient to prevent bacterial population from exceeding 10,000 per milliliter, is maintained in circulating water; and

(3) The system is inspected by an operator, capable of determining compliance with this subdivision, at least daily.

For R-1 type recycled water, a continuous recording of turbidity shall be installed after a filtration process as a measure of the coagulation-flocculation sedimentation-filtration process effectiveness and as a means of assuring a quality effluent upon disinfection. The turbidity of filtered effluent shall not exceed 2 NTU at any time.

No evaporative cooling towers can use a lower quality recycled water, R-2 type water, for cooling purposes. R-2 type recycled water does not require a filtration process; however, new R-

2 facilities constructed after May 30, 2002, will be required to install a continuous recording turbidimeter at a point after the secondary treatment. A continuous monitoring is required at this stage.

The water quality of two types of cooling systems is summarized in Table 22. Disinfected secondary-23 recycled water, means secondary treatment with disinfection to achieve a median fecal coliform limit of 23 per 100 ml based on the last seven days for which analyses have been completed.

Table 22. The least reclaimed water quality requirements for cooling water in Hawaii

System	Treatment level	Fecal coliform	Cl_2 Residue	Turbidity
Cooling water that doesn't emit drift	R-2 water: oxidized and disinfected	• 23/100 ml (7-day median) • 200/100 ml (not to exceed in more than one sample in 30-day)	0.5 mg/l (minimum; theoretical contact time 15min, actually contact time 10min)	NS
Cooling water that emits drift	R-1 water: oxidized, filtered, disinfected	• 2.2/100 ml (7-day median) • 23/100 ml (not to exceed in more than one sample in 30-day) • 200/100 ml (max)	5 mg/l (minimum; theoretical contact time 15min, actually contact time 10min)	2 NTU

In addition to the minimum reclaimed water quality requirements, continuous monitoring of daily flow, turbidity prior and after filtration procedure, fecal coliform, and chlorine residual are mandatory. Besides these, BOD_5 and suspended solids shall also be measured weekly.

Maryland

Although Maryland was mentioned in “Guidelines for Water Reuse” as having a guideline for reclaimed water reuse, there are no regulations about using reclaimed water as industrial cooling water (USEPA 2004). The “Guidelines for Land Treatment of Municipal Wastewaters” reveals that the majority of wastewater reuse in Maryland is spray irrigation systems installed for agricultural crops.

Maryland’s regulations applicable to thermal discharges and cooling water intake structures were based on the State’s then-current scientific and technical knowledge of the factors influencing the type and magnitude of impacts expected to occur, and following a logical conceptual framework. Code of Maryland, 26.08.03.06 indicates the standards for the effluent discharged from steam electric power stations using the cooling system. The biocide concentration in the cooling water is regulated to prevent adverse impact on aquatic life in the receiving water bodies. The information is summarized in Table 23.

Table 23. Standard of effluents discharge contained chlorine

System	Type (capacity)	Total residual chlorine (daily max)	Free available chlorine (daily max)
Once-through cooling tower	> 25MW	0.2 mg/l	
	<25MW	0.2 mg/l	0.5mg/l
Cooling tower blowdown		0.2 mg/l	0.5mg/l

New Jersey

The state of New Jersey does not have specific regulations regarding the use of reclaimed water as industrial cooling water. However, "Reclaimed Water for Beneficial Reuse" provides the guidelines on using reclaimed water for different purposes (NJDEP 2005). Industrial reuse for cooling equipment is listed as Type IV Reclaimed Water for Beneficial Reuse (RWBR). It is mentioned that type IV RWBR can be used as industrial cooling water but there are no established standards. Otherwise, all industrial reuse systems require a case-by-case review by NJDEP.

Non-contact cooling water, as mentioned in the document, is an example of little or no level change of treatment before use because the water has already been treated by the wastewater treatment plant. Furthermore, only workers who receive specialized training on dealing with the RWBR systems would be in contact with the reclaimed water. In addition to criteria listed in Table 24, other requirements include following the Submission of Standard Operations Procedure that ensure proper material handling and submitting a User/Supplier Agreement Annual usage report.

Table 24. The minimum reclaimed water quality requirements for cooling water in New Jersey

System	Type of Water	TSS	Cl_2 Residue	Fecal Coliform
Cooling water	Type IV RWBR, secondary treatment	Specified in the NJDEP permit for the existing treatment requirements	1 mg/L (minimum; after a minimum acceptable contact time of 15 min at peak hourly flow)	• 200/100 ml (30-day average) • 400/100 ml (max, single sample)

North Carolina

In North Carolina Administrative Code, Subchapter 02T, Chapter 15A section 0910 Reclaimed Water Utilization, the use of reclaimed water for cooling tower is approved once the following requirements are met:

(1) Notification is provided to inform the public or employees of the use of reclaimed water (Non-Potable Water) and that the reclaimed water is not intended for drinking,

(2) The reclaimed water users received appropriate education and approval from the reclaimed water generator,

(3) The distribution of reclaimed water is recorded by the reclaimed water generator, and

(4) The pathway used to transport reclaimed water from the generator to end user is reviewed and inspected.

In the Subchapter Section 0906, the North Carolina Government mentions the reclaimed water effluent standards that could be used but they are not specific to cooling purposes. The reclaimed water should be treated (filtration or its equivalent) to achieve the tertiary quality before using for storage, distribution, or irrigation. The reclaimed water criteria are summarized in Table 25. However, if the power plant has its own treatment facility, the water quality of produced reclaimed water is not required to meet the same criteria if the water is used in the industrial process and the area of use has no public access.

Table 25. The minimum reclaimed water quality requirements for cooling water in North Carolina

System	Treatment Level	BOD_5	TSS	NH_3	Total Fecal Coliform	Turbidity
Reclaimed water prior to storage, distribution, or irrigation	Tertiary treatment	10 mg/l (monthly) 15 mg/l (daily max)	5 mg/l (monthly) 10 mg/l (daily max)	4 mg/l (monthly) 6 mg/l (daily max)	14/100 ml (monthly) 25/100 ml (daily max)	10 NTU (max)

Thermal discharge requirements are regulated in 15A NCAC 02B.0208, 0211, and "Thermal (Temperature) Variances to North Carolina Water Quality Standards" (USEPA 2006). The Commission may establish a water quality standard for temperature for specific water bodies other than the standards specified in Rules 0211 and 0220 of this Section, upon a case by case determination that thermal discharges to these waters, such as industrial cooling water, provide for the maintenance of the designated best use throughout a reasonable portion of the water body.

Oregon

Generally, different classes of water quality are required in accordance to different reuse purposes (there are four reuse levels). Public access to Class A, Class B, and Class C water should be prevented and controlled, respectively, while there should be no direct public contact when using Class D water.

Oregon Administrative Rules (OAR), Title 340, Division 55 Section 0012 declares that Class C recycled water can be used for industrial cooling if the requirements are met. Typical Class C recycled water must be an oxidized and disinfected wastewater. The total coliform must be monitored once per week at a minimum and meet target level in Table 26. If aerosols are generated when using recycled water for an industrial, commercial, or construction purpose, the aerosols must not create a public health hazard.

Table 26. The minimum reclaimed water quality requirements for cooling water in Oregon

System	Type of Water	Treatment	Total coliform
Industrial Cooling	Class C	Oxidized and Disinfected	• 240/100 ml (2 consecutive samples) • 23/100 ml (7-day median)

Texas

Texas' Administrative Code, Title 30, Environmental Quality, Part 1, Chapter 210 regulates the use of reclaimed water for different purposes. For instance, two kinds of reclaimed water are:

1) Type I, reclaimed water that is used when the public may be present or the public may come in contact with the reclaimed water.
2) Type II, reclaimed water that is used when the public may not be present or the public may not come in contact with the reclaimed water.

Since Type I reclaimed water has better water quality than Type II, any Type I Reclaimed water can also be used for any of the Type II uses identified in TAC 30-210.32. Water quality requirements (TAC 30-210.33) for Type I and Type II Reclaimed Waters used in cooling systems are summarized in Table 27. The reclaimed water must meet standards for BOD_5 and fecal coliform and samplings must be conducted once per week.

Table 27. The minimum reclaimed water on a 30-day average quality requirement in Texas

Type of reclaimed water		BOD_5	$CBOD_5$	Turbidity	Fecal Coliform	Fecal Coliform (Maximum)
Type I		5 mg/l		3 NTU	20 CFU/100 ml	75 CFU/100 ml
Type II	Others	20 mg/l	15 mg/l		200 CFU/100 ml	800 CFU/100 ml
	Pond system	30 mg/l			200 CFU/100 ml	800 CFU/100 ml

The used reclaimed water discharged from cooling towers is also regulated by Texas Administrative Code, TAC, title 30, 113, 113.220 with regards to the Industrial Process Cooling Towers Maximum Achievable Control Technology standard as specified in 40 Code of Federal Regulations Part 63, Subpart Q. In addition, for once-through cooling systems, if the discharges do not measurably alter intake concentrations of a pollutant, the water-quality based effluent limits for that pollutant are not required (TAC, Title 30 Environmental Quality, Part 1, Chapter

307, Rule 307.8). Although Type II Reclaimed Water can be used in cooling tower makeup water according to TAC 30-210.32, special requirements might be needed to control the air emission.

Utah

The use of reclaimed water as cooling water is regulated by Utah Administrative Code, R317-3-11 Use, Land Application and Alternate Methods for Disposal of Treated Wastewater Effluents. There are two types of reclaimed water identified in this session, 1) Type I, use of treated domestic wastewater effluent where human exposure is likely; 2) Type II, use of treated domestic wastewater effluent where human exposure is unlikely. Apparently, reclaimed water used for cooling water makeup is classified into Type II uses. The same session and “Water Reuse in Uath”(UDWR 2005)also state that Type I effluent can also be utilized for any of the Type II uses based on its higher quality. Utah State Department of Natural Resources also published “Utah’s Water Resources Planning for the Future” (UDWR 2001) to help satisfy the need for more detailed information about water reuse and its potential in Utah.

Type II reclaimed water can be used as cooling water but use for cooling towers which produce aerosols in populated areas may have special restriction. The least requirements of water quality for cooling water is summarized in Table 28.

Table 28. The minimum reclaimed water quality requirement for cooling water in Utah

Type of reclaimed water	BOD_5	TSS	Turbidity	Daily Fecal Coliform	Total residual chlorine	pH
Type I	10 mg/l (monthly)		2 NTU (daily) 5 NTU (max)	none detected (weekly) 9 /100 ml (max)	1.0 mg/l	6-9
Type II	25 mg/l (monthly)	25 mg/l (monthly avg.) 35 mg/l (weekly avg.)		126/100 ml (weekly) 500 /100 ml (max)		

Washington

Four types of reclaimed water are classified in Revised Code of Washington (RCW) 90.46 Reclaimed Water Use:

1) Class A reclaimed water is at a minimum, at all times an oxidized, coagulated, filtered, disinfected wastewater.

2) Class B, C, and D reclaimed waters are at a minimum, at all times oxidized, disinfected wastewaters.

According to "Water Reclamation and Reuse Standards", article 4, section 15, reclaimed water used for industrial cooling purposes without creating aerosols or mist shall be class C reclaimed water or better. Reclaimed water used for industrial cooling purposes with creating aerosols or mist shall be Class A reclaimed water or better. "Water Reclamation and Reuse Standards" indicates the potential usage and the required reclaimed water quality (WADOH and WADOE 1997) as summarized in Table 29.

Table 29. The minimum reclaimed water quality requirement for cooling water in Washington

System	Type of reclaimed water	Total Fecal Coliform	BOD_5	TSS	Turbidity	Cl_2 Residue
Cooling tower with creating mist	Class A (oxidized, coagulated, filtered, and disinfected)	2.2 /100 ml (weekly) 23/100 ml (max)	30 mg/l (monthly)	30 mg/l (monthly)	2 NTU (daily) 5 NTU (max)	Minimum Cl residue of 1 mg/l after a contact time of 30-min
Cooling tower without creating mist	Class C (oxidized, disinfected)	23/100 ml (weekly) 240 /100 ml (max)				

Wyoming

The state of Wyoming has not yet developed regulations for the use of reclaimed water as industrial cooling water. However, Water Quality Division (WQD), Department of Environmental Quality, provides regulations when using reclaimed water for irrigations. “Standards for The Reuse of Treated Wastewaters,” Chapter 21, regulates the use of reclaimed water in Wyoming. Three different types of reclaimed water, Class A, B, and C are classified by relative treatment and the maximum number of fecal coliform organisms (CFU/mL).

Although there is no regulation directly related to the effluent discharge of used reclaimed water from industrial cooling systems, standards have been established to address the primary health concerns associated with the reuse of treated wastewater. According to “Water Quality Rules and Regulations, Chapter 2, Permit, Regulations for Discharges to Wyoming Surface Waters”, the potential quantitative data for the pollutants or parameters needed for cooling water discharge include major parameters, such as pH, Total Suspended Solids (TSS), Total Organic Carbon (TOC), and Fecal Coliform (if believed present or if sanitary waste is or will be discharged), etc.. Chemical parameters are Total Residual Chlorine (if chlorine is used), Chemical Oxygen Demand (COD), (if non-contact cooling water is or will be discharged), and Ammonia (as N). Moreover, temperature should be monitored during both summer and winter.

3.2.2 State Interbasin Water Transfer Regulations

Among the twelve states that have been reviewed in this study, seven states were found to have regulations that directly or indirectly relate to interbasin water transfer (Table 30). These states are Arizona, California, Florida, New Jersey, North Carolina, Texas, and Wyoming. Pennsylvania is also included in this study although there are no proposed regulations or guidelines by the state government In general, no prohibition against interbasin water transfer was found in these states.

The beneficial use of water is the main concern at the state level. California Water Code Section 109, California Water Code Sections 480-484, Pennsylvania House Bill 2005 P.N. 2707, and Wyoming Statutes Annotated Section 41-4-503 all declare the transfer will be permitted if the transfer is beneficial to the state.

Most states declare that applying for interbasin water transfer is necessary to obtain the permission, while commissions should consider the welfare of the public in the origin basin and might need to hold hearings. Most states do not have limitations on transfer certifications. The only numeric limitation is the case of North Carolina where a transfer certificate is required for a new transfer of 2 million gallons per day (mgd) or more and for an increase in the existing transfer by 25 percent or more, if the total including the increase is 2 mgd or more.

Additional issues exist about the quality of transported water and the protection of conservation districts. For example, New Jersey Statutes clearly state that no individual shall transport ground or surface water in the Pinelands National reserve, or cause it to be transported more than 10 miles from the reserve. Water quality rules in Wyoming introduce restrictions on water transport to avoid contact between transported water and contaminants.

In Pennsylvania, there are instances of both drinking water and wastewater being transported across state lines into neighboring states. There are no regulations that apply specifically to interstate transport of impaired water above those that apply to intrastate transport of water in general. However, there may be interstate commissions that may regulate the transport of water. These include the Delaware River Basin Commission, the Susquehanna River Basin Commission, and the Great Lakes Commission. These commissions have the responsibility and authority to regulate the quantity and quality of water in their respective basins, whether it is interstate or intrastate (McLeary 2007).

The transfer of water between different water regions sometimes requires certification for the right to carry out the process. An example of such a process is that implemented in North Carolina. In 1993, the Legislature adopted the Regulation of Surface Water Transfers Act (N.C.G.S. Section 143-215.22I) to regulate large surface water interbasin transfers by requiring a certificate from the Environmental Management Commission (EMC). In North Carolina, the certification process usually contains several stages. The first step is to send notification and hold a consultation to determine the original basin capacity. After a detailed evaluation, the state requests the applicant to make either an Environmental Assessment (EA) or an Environmental Impact Statement (EIS) for this event and submit a petition to Environmental Management Commission (EMC), which will evaluate the document and hold a public hearing (N.C.G.S. Section 143-215.22I). Integrating the public comments from the hearing, the applicant then completes a final EA/EIS and submit it to the EMC for final decision.

Table 30. Limitations on interbasin water transfers in eight selected states

State	Regulation	Description
Arizona	A.R.S. § 45-107	Water transfer beyond the boundary of irrigation districts subject to the approval of the district. *
	A.R.S. § 45-165	About the application for interstate operations, except as regulated by A.R.S. § 45-291 to 294, every application should not be denied.
	A.R.S. § 45-291-294	Approval is required to transport water out of state; application, criteria, hearing, and written periodic reports as required by the director.
	A.R.S. § 45-292	A person may withdraw, divert or transport water from the state for a beneficial use in other states as long as the application is approved. The annual amount of water in acre-feet for the application and studies of the probable hydrologic impact on the area from which the water is proposed to be transported are required.
	A.R.S. § 45-541 to 547	Regulate the transportation of groundwater instate.
California	C.W.C § 109	The State Water Resources Control Board should review proposed transfers to determine if they would cause an unreasonable effect on the economy in the area of origin or on fish, wildlife, or other water uses.*
	C.W.C § 480-484	The department shall seek to facilitate transaction only if the water to be transferred is already developed and being diverted from a stream for beneficial use or has been conserved.*
	C.W.C § 10501-10505.5	This code reserves for the county of origin all the water it may need for future development; this code also provides that the State Water Resources Control Board makes the determination of when, and to what extent, water is "necessary for the development of the country".*
	C.W.C § 11460-11463 (Watershed Protection Act)	The main idea of the act was to extend area of origin priorities to the entire watershed area and not limit them to the areas of precipitation.*
Florida	Florida Statutes §373.2295	This statute grants authority only to groundwater but not surface water. (Surface water inter-district transfer is not permitted under chapter 373**)
New Jersey	N.J.S. §58:1A-7.1	No individual shall transport, or cause to be transported, more than 10 miles outside the boundary of the Pinelands National Reserve, and ground or surface water there from. However, nothing in this section shall prohibit the continued transportation of any such water utilized for public water supply purposes prior to the effective date of this act.*
North Carolina	N.C.G.S. §143-215/22I	Without a certificate from the commission, no person may initiate an interbasin transfer of over than 2 MGD.*

Table 30. (continued).

Pennsylvania	House Bill 2005 P.N. 2707	This interbasin transfer of waters of the commonwealth shall be permitted only if it agrees with long-range water resource planning and proper management and use of the water resources of the commonwealth.*
Texas	T.W.C §11.085	No person may take or divert any state water from a river basin in this state and transfer such water to any other river basin without first applying for and receiving a water right or an amendment to a permit, certified filing, or certificate of adjudication from the commission authorizing the transfer.*
	T.W.C. §36.122	If an application for a permit or an amendment to a permit under section 36.113 proposes the transfer of groundwater outside of a district's boundaries, the district may also consider the provisions of this section in determining whether to grant or deny the permit or permit amendment.*
Wyoming	Wyoming Statutes Annotated §41-4-503	A special process to evaluate transfers considers potential economics losses to the community relative to the benefits of the transfer and the availability of other sources of water *
	Water quality rules and regulations, Chapter 2	The restriction of transport water is to avoid contact between transported water and contaminants

P.S. A.R.S. =Arizona Revised Statutes; C.W.C.=California Water Code; N.J.S.=New jersey Statutes; N.C.G.C=North Carolina General Statues; T.W.C.=Texas Water Code

*Integrated information from "Survey of Eastern Water Law", Janice A. Beecher, Ph.D et. al., Center for Urban Policy and the Environment School of Public and Environmental Affairs Indiana University, Indianapolis, IN, September, 1995.

**R.A. Christland. "Sharing the cup: a proposal for the allocation of Florida's Water resources, "Florida State University Law Review. 1996.

3.3 SUMMARY OF REGULATIONS

Review of state and federal regulations relevant to water reuse in power plant cooling systems shows that the federal government has not established regulations specifically related to this type of water reuse, but a number of states have done so. Among those states, California, Florida, Hawaii, New Jersey, North Carolina, Oregon, Texas, Utah, and Washington were investigated for their development of specific regulations and/or guidelines related to water reuse in re-circulating, evaporative cooling water systems at power plants. Regulations pertaining to interbasin transfer of water were also examined, as some potential sources of impaired water for power plants will be in different drainage basins, and perhaps different states, than the power plant.

The state regulations focus commonly on water aerosol "drift" emitted from cooling towers, which has the potential to contain elevated concentrations of chemicals and microorganisms and thus pose a health risk to the public. Other regulations related to use of impaired waters in cooling towers, appear to be much less limiting, if they exist at all. Drift has the same water quality as the re-circulating cooling water. The possible presence of microorganisms in drift is of primary concern. With regard to regulation of drift from cooling towers, the various state regulations and guidelines include the following provisions:

1) require the reclaimed water to be secondary treated and disinfected or tertiary treated (EPA, CA, FL, HI, NJ, NC, OR, TX, UT, WA),
2) and/or require the chlorine residual to be above a certain amount after a period of contact time (EPA, FL, HI, NJ, WA),
3) and/or require
    - the cooling tower to be equipped with drift eliminator (CA, FL, HI)
    - or a demonstration of public health assurance (OR),
    - or invoke special requirements (EPA, TX, UT, WA),
4) and/or require the fecal/total coliform to be under a certain concentration (EPA, CA, FL, HI, NJ, NC, OR, TX, UT, WA).

Thus, existing regulations pertaining to reuse of reclaimed water in evaporative cooling systems focus on potential exposure of workers and the public to drift in air emissions from the cooling tower, and especially to the potential for exposure to microorganisms in the drift.

Transferring impaired water within a state or between states is possible but also strictly regulated by local committees constituted by adjacent state governments, such as the Great Lake Commission. There is no direct federal regulation of interbasin water transfer. The request for transferring wastewater must demonstrate benefits for the states involved in the transfer. An environmental impact statement and public hearing may be required to acquire permission from the state environmental agency or multi-state environmental management-commission.

4.0 SUMMARY AND CONCLUSION

Freshwater has been considered one of the most precious natural resources in the world. The uniqueness and limited of accessibility lead to the competition for acquiring this rare resource for any applications. Thanks to the increases in population and energy demand, this problem is further aggravated in the U.S. Besides agriculture, electricity generation by thermoelectric power plants represents the largest freshwater demand. To relieve the stress in freshwater usage, studies have been initiated to evaluate the use of reclaimed waters for the cooling process. Among all possible sources of impaired water that could potentially be used in power production, secondary treated municipal wastewater is the most common and widespread source in the U.S.

4.1 FEASIBILITY ANALYSIS OF USING SECONDARY TREATED WASTEWATER FOR COOLING PURPOSES

Water to energy factor is introduced to estimate the cooling water demand. Higher water to energy ratio was used to satisfy the worse case of cooling water demand. For each power plant, coverage of 10/25 mile radius circle is drawn to include the POTWs. The total available flowrate was calculated and compared to the estimated cooling water demand.

Limited freshwater sources have been a public concern from last century and the shortage of freshwater supply will inevitably shock the power industry. Wastewater availability analysis with proposed power plants demonstrated the possibility of employing impaired water for cooling systems in quantity and proximity. Considering POTWs within 25 miles, 97 percent of these proposed power plants can have sufficient secondary treated wastewater supply for cooling towers with only 1.10 POTWs.

Results of geospatial analysis suggest that one fairly large POTW can fulfill the cooling water needs for most of the 110 proposed power plants. This implies that the cost of transporting wastewater can be kept reasonably low (i.e., only one or two pipes may be needed to transport the cooling water to the power plant).

Thermoelectric power plants are categorized as major freshwater withdrawal and consumption sources. Availability analysis of existing coal fired generating facilities was conducted and results indicate the secondary treated wastewater can satisfy more than 75% of the water demands by POTWs within 25 miles.

The fact that a fairly low number of POTWs can meet the cooling water needs of the existing power plants suggests that the modification of current cooling systems will be achievable. Therefore, using reclaimed water for cooling purposes can be both economical and reliable and can facilitate the development of coal-fired power plants in the regions where other sources are not readily available.

4.2 REGULATION REVIEW FOR USING RECLAIMED WATER FOR COOLING PURPOSES

Any water reuse program must be approved in accordance with federal and state regulations. In order to understand the legality of using reclaimed water for cooling water makeup, this study focused on four aspects, including the basis of using reclaimed water, the discharge of used reclaimed water from cooling tower, the air emission from cooling tower using reclaimed water, and conveyance of reclaimed water between watersheds and states. The federal government has not yet introduced regulations specific to reclaimed water reuse in cooling towers. However, general guidelines are published by the U.S. EPA.

Review of states regulations revealed that there are no serious impediments for widespread use of treated secondary effluent from POTWs to satisfy the cooling water needs of thermoelectric power plants. States like California and Florida encourage the reclaimed water use to lessen the drought problems. Otherwise, a case-by-case inspection and construction permit will be required before starting the reuse program.

Although there are no discharge regulations specific to the use of reclaimed water, a NPDES permit is required if surface waters are receiving the discharge no permit is required if the reclaimed water users discharge or return the utilized reclaimed water back to a wastewater treatment facility. However, if the discharges are returned to POTWs, CWA 316 (b) will be implemented and pretreatments may be required based on different cooling tower design. Chromium and zinc are major concerns in discharges from wet recirculating cooling towers.

However, states may request continuously monitoring on physic-chemical parameters to prevent adverse influences on environment. For example, in Virginia, the effluent temperature shall be continuously monitored and shall not exceed a maximum 32 ºC for discharges to nontidal coastal and piedmont waters, or 31 ºC for mountain and upper piedmont waters. This type of regulations ensures the survivability of local aquatic and botanic life in the receiving watershed.

The federal government does not provide specific limitations on air emission from industrial cooling systems using reclaimed water. State regulations focus commonly on water aerosol “drift” emitted from cooling towers, which has the potential to contain elevated concentrations of chemicals and microorganisms and may pose a health risk to the public. Small particulates, such as PM2.5 or PM10, can easily enter lungs and may even get into bloodstream thus causing heart failure, pulmonary, or coronary artery diseases. Another notable microbial infection is Legionnaire's Disease, which causes pneumonia.

The major concern with the transportation of reclaimed water is due to potential impacts on environment caused by transporting water from one basin to another. State DEPS and special watershed commissions, such as Great Lake and Colorado River commissions govern the water transfer in the region. Transporting of reclaimed water has not been prohibited; however, a case-by-case evaluation of the conveyance is required.

APPENDIX A

DETAILS OF REGULATIONS/GUIDELINES CITED

A. 1 Arizona

Regulation/Guidelines/Policy	
Water Reuse	*** *AAC, R18-9-704*** *G.Prohibited activities.* *c. Direct reuse for evaporative cooling or misting.* *** *AAC, R18-9-701*** *1."Direct reuse" means the beneficial use of reclaimed water for a purpose allowed by this Article. The following is not a direct reuse of reclaimed water:* *c. The use of industrial wastewater or reclaimed water, or both, in a workplace subject to a federal program that protects workers from workplace exposures.* *** *AAC, R18-9-602*** ***F. The following requirements for minimum separation distance apply. A person shall:*** *1. Locate a pipeline conveyance no closer than 50 feet from a drinking water well unless the pipeline conveyance is constructed as specified under subsection (F)(3);* *2. Locate a pipeline conveyance no closer than two feet vertically nor six feet horizontally from a potable water pipeline unless the pipeline conveyance is constructed as specified under subsection (F)(3);* *3. Construct a pipeline conveyance that does not meet the minimum separation distances specified in subsections (F)(1) and (F)(2) by encasing the pipeline conveyance in at least six inches of concrete or using mechanical joint ductile iron pipe or other materials of equivalent or greater tensile and compressive strength at least 10 feet beyond any point on the pipeline conveyance within the specified minimum separation distance; and* *4. If a reclaimed water system is supplemented with water from a potable water system, separate the potable water system from the pipeline conveyance by an air gap.*

A.1 (continued)

Water Discharge	* ***AAC, R18-9-701*** *1."Direct reuse" means the beneficial use of reclaimed water for a purpose allowed by this Article. The following is not a direct reuse of reclaimed water:* *a. The use of water subsequent to its discharge under the conditions of a National Pollutant Discharge Elimination System permit;* * ***AAC, R18-9-702*** *G.Exclusions. The following discharges do not require an AZPDES permit:* *2. The introduction of sewage, industrial wastes, or other pollutants into POTWs by indirect dischargers. Plans or agreements to switch to this method of disposal in the future do not relieve dischargers of the obligation to have and comply with a permit until all discharges of pollutants to a navigable water are eliminated. This exclusion does not apply to the introduction of pollutants to privately owned treatment works or to other discharges through a pipe, sewer, or other conveyance owned by the state, a municipality, or other party not leading to treatment works;* *6. Discharges into a privately owned treatment works, except as the Director requires under 40 CFR 122.44(m), which is incorporated by reference in R18-9-A905(A)(3)(d)*

A. 2 California

	Regulation/Guidelines/Policy
Water Reuse	*** State Water Resources Control Board, Resolution No. 75-58** (Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Powerplant Cooling) *It is the Board's position that from a water quantity and quality standpoint the source of powerplant cooling water should come from the following sources in this order of priority depending on site specifics such as environmental, technical and economic feasibility consideration: (1) wastewater being discharged to the ocean, (2) ocean, (3) brackish water from natural sources or irrigation return flow, (4) inland wastewaters of low TDS, and (5) other inland waters.* *** Warren-Alquist Act, Section 25602** (Public Resources Code, Section 25602) *The commission shall carry out technical assessment studies on all forms of energy and energy-related problems …* *(d) Expanded use of wastewater as cooling water and other advances in powerplant cooling.* *** Water Code, Section 462** (Action by the Department of Water Resources) *The department shall conduct studies and investigations on the availability and quality of wastewater and the uses of reclaimed water for beneficial purposes, including, but not limited to, groundwater recharge, municipal and industrial use, irrigation use, and cooling for thermal electric powerplants.* *** 22CCR60306** (California Code of Regulations, Title 22, Division 4, Chapter 1, Article 3, Section 306: Use of recycled water for cooling) *(a) Recycled water used for industrial or commercial cooling or air conditioning that involves the use of a cooling tower, evaporative condenser, spraying or any mechanism that creates a mist shall be a disinfected tertiary recycled water.* *(b) Use of recycled water for industrial or commercial cooling or air conditioning that does not involve the use of a cooling tower, evaporative condenser, spraying, or any mechanism that creates a mist shall be at least disinfected secondary-23 recycled water.* *Note:* *Disinfected tertiary recycled water: defined in 22CCR60301.225* *Disinfected secondary-23 recycled water: defined in 22CCR60301.230*
Water Discharge	*** State Water Resources Control Board, Resolution No. 75-58** (Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Powerplant Cooling) • *The discharge to land disposal sites of blowdown waters from inland powerplant cooling facilities shall be prohibited except to salt sinks or to lined facilities approved by the Regional and State Boards for the reception of such wastes.* • *The discharge of wastewaters from once-through inland powerplant cooling facilities shall be prohibited unless the discharger can show that such a practice will maintain the existing water quality and aquatic environment of the State's water resources.* • *The Regional Boards may grant exceptions to these discharge prohibitions on a case-by-case basis in accordance with exception procedures included in the "Water Quality Control Plan for Control of Temperature In the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California."*

A.2 (continued)

Air Emission	***22CCR60306** (Use of recycled water for cooling) *(c)Whenever a cooling system, using recycled water in conjunction with an air conditioning facility, utilizes a cooling tower or otherwise creates a mist that could come into contact with employees or members of the public, the cooling system shall comply with the following:* *(1) A drift eliminator shall be used whenever the cooling system is in operation.* *(2) A chlorine, or other, biocide shall be used to treat the cooling system recirculating water to minimize the growth of Legionella and other microorganisms.* • **17CCR93103** (Regulation for chromate treated cooling towers) *… not add any hexavalent chromium-containing compounds to the cooling tower circulating water, and keep the hexavalent chromium concentration in the cooling tower circulating water less than 0.15 milligrams hexavalent chromium per liter of circulating water, …*

A. 3 Florida

	Regulation/Guidelines/Policy
Water Reuse	*** FAC 62-610-668** (Florida Administrative Code, Chapter 62, Section 610-668: Cooling Water Applications) *(1) Once-through cooling.* *(a) Reclaimed water may be used for once-through cooling.* *(b) Setback distances shall be as established in Rule 62-610.662, F.A.C.* *(c) Reclaimed water, upon flowing out of the once-through, non-contact, cooling system, that is returned to the domestic wastewater facilities for additional treatment or disposal or reuse, shall be defined to be a "domestic wastewater." This definition is made solely for the purposes of classifying wastewater treatment, reuse, and effluent disposal facilities associated with the domestic wastewater facilities. This definition shall apply only if the sole change to the quality of the reclaimed water during the once-through, non-contact, cooling process is a temperature increase, and conditioning chemicals, other than chlorine and other chemicals accepted by the Department, have not been added to the reclaimed water.* *(d) Reclaimed water which has not been disinfected may be used for once-through cooling purposes at industrial facilities if the following conditions are met:* *1. The reclaimed water has received at least secondary treatment as defined in subparagraph 62-600.420(1)(b)2., F.A.C.* *2. The reclaimed water is conveyed and used in closed systems which are not open to the atmosphere.* *3. The reclaimed water is returned to the domestic wastewater treatment facility.* *(e) Water used for once-through cooling under the provisions of paragraph 62-610.668(1)(d), F.A.C., shall be considered "reclaimed water" and the use of this water shall be considered "reuse."* *(2) Open cooling towers.* *(a) Reclaimed water may be used in open cooling towers, if the requirements in paragraphs 62-610.668(2)(b), (c), or (d), F.A.C., are met.* *(b) All requirements of Part III of Chapter 62-610, F.A.C., including minimum system size requirements, shall be met.* *(c) As an alternative to the requirements in paragraph 62-610.668(2)(b), F.A.C., all of the following requirements shall apply:* *1. Preapplication waste treatment shall result in a reclaimed water that meets secondary treatment and basic disinfection.* *2. A 300-foot setback distance shall be provided from the cooling tower that receives reclaimed water to the site property line.* *3. The cooling tower shall be designed and operated to minimize aerosol drift to areas beyond the site property line that are accessible to the public.* *4. The cooling tower shall be designed, operated, and maintained utilizing best engineering practices to control biological growth.* *(d) As an alternative to the requirements in paragraph 62-610.668(2)(b), F.A.C., all of the following requirements shall be met in the facility's industrial wastewater permit:* *1. The high-level disinfection requirements of subsection 62-600.440(5), F.A.C.* *2. The filtration requirements of subsection 62-610.460(3), F.A.C.* *3. The continuous monitoring requirements of subsection 62-610.463(2), F.A.C.* *4. In lieu of the operation, staffing, and reliability provisions in Rule 62-610.462, F.A.C., operation, maintenance, staffing and reliability requirements shall be addressed in the facility's industrial wastewater permit in accordance with applicable industrial wastewater rules.* *5. The cooling tower shall be designed, operated, and maintained utilizing best engineering practices to control biological growth.*

A.3 (continued)

Water Discharge	**FAC 62-302-520** (Thermal Surface Water Criteria) **FAC 62-660.400** (Effluent limitations)
Air Emission	*** FAC 62-610-668(2)(c)3** *The cooling tower shall be designed and operated to minimize aerosol drift to areas beyond the site property line that are accessible to the public.*

A. 4 Hawaii

	Regulation/Guidelines/Policy
Water Reuse	*** Guidelines for the Treatment and Use of Recycled Water, III, B** (Uses For R-2 Water) *2. R-2 Water is suitable for, from a public health standpoint, the purposes cited under R-3 Water in these guidelines and shall be restricted to the following purposes:* *d. Use in an industrial process that does not generate mist, does not involve facial contact with recycled water, and does not involve incorporation into food or drink for humans or contact with anything that will contact food or drink for humans;* *** Guidelines for the Treatment and Use of Recycled Water, III, C** (Uses For R-1 Water) *2. R-1 Water is suitable for, from a public health standpoint, the purposes cited under R-2 Water, and R-3 Water in these guidelines and shall be restricted to the following purposes:* *j. Industrial cooling in a system that does not have a cooling tower, evaporative condenser, or other feature that emits vapor or droplets to the open atmosphere or to air to be passed into a building or other enclosure occupied by person;* *k. Supply for addition to a cooling system or air conditioning system with a cooling tower, evaporative condenser, or other feature that emits vapor or droplets to the open atmosphere or to air to be passed into a building or other enclosure occupied by a person, when all of the following shall occur:* *(1) A high efficiency drift reducer is used and the system is maintained to avoid greater rate of generation of drift than that with which a high efficiency drift reducer is associated;* *(2) A continuous biocide residual, sufficient to prevent bacterial population from exceeding 10,000 per milliliter, is maintained in circulating water; and* *(3) The system is inspected by an operator, capable of determining compliance with this subdivision, at least once per day;* *l. In the absence of one or more of the three conditions in paragraph "k" above, it is suitable for addition to such a cooling or air conditioning system when the purveyor of R-2 Water uses has demonstrated to the satisfaction of DOH that the probability of intestinal infection with virus will not exceed 1 in 10,000 under the specific conditions of use and that growth of Legionella will be controlled to avoid a concentration that could pose a significant hazard to health;* *Note:* *R-1 Water: Significant reduction in viral and bacterial pathogens* *R-2 Water: Disinfected secondary-23 recycled water, which means secondary treatment with disinfection to achieve a median fecal coliform limit of 23 per 100 ml based on the last seven days for which analyses have been completed* *R-3 Water: Undisinfected secondary recycled water*
Air Emission	*** Guidelines for the Treatment and Use of Recycled Water, III, C** (Uses For R-1 Water) *2, k, (1), (2), and (3)*

A. 5 Maryland

	Regulation/Guidelines/Policy
Water Discharge	*COMAR 26.08.03.06* *A. Biocide Residual Levels. Biocide residual levels shall be controlled in the effluents discharged to all surface waters of this State.* *C. All Other Water Use Designations. A person may not discharge any chlorine or chlorine products into Use I, I-P, II, IV, or IV-P waters of this State in excess of the limits set forth below:* *(1) For steam electric power stations using once-through cooling water from plants with total rated generating capacity of 25 or more megawatts, the limit shall be 0.2 milligram/liter daily maximum of total residual chlorine as determined using the amperometric titration method;* *(2) For steam electric power stations using once-through cooling water from plants with total rated generating capacity of less than 25 megawatts, the limit shall be 0.2 milligram/liter monthly average and 0.5 milligram/liter daily maximum of free available chlorine as determined using the amperometric titration method;* *(3) The limit for cooling tower blowdown from steam electric generating plants shall be 0.2 milligram/liter monthly average and 0.5 milligram/liter daily maximum of free available chlorine as determined using the amperometric titration method;* *(4) For any other discharge category for which the EPA has published effluent limitation guidelines, the limit shall be the limits specified in the published guidelines;*

A. 6 New Jersey

Regulation/Guidelines/Policy	
Water Reuse	*** Reclaimed Water for Beneficial Reuse, V, A** (Minimum Effluent Treatment Requirements for RWBR) *4. Type IV RWBR – Industrial Systems, Maintenance Operations and Construction Industrial RWBR involves the use of reclaimed water in industrial applications such as cooling water and/or washing operations. The uniqueness of each industrial reuse application makes it impossible to establish specific treatment standards for this general category of reuse. Prior to implementation, all industrial reuse systems require a case-by-case review by the Department. Some applications, such as the reuse of effluent for non-contact cooling water, may require very little, if any changes to the level of treatment the wastewater is already receiving at the wastewater treatment plant.* *** Reclaimed Water for Beneficial Reuse, Appendix A** (Effluent Reuse Treatment Guideline Table) *• Types of Reuse:* *RWBR Industrial Systems* *Includes closed loop system. For example, sewer jetting, non-contact cooling water, boiler makeup water.* *• Treatment & RWBR Quality:* *Permit levels must be met.* *• RWBR Monitoring:* *Submission of Standard Operations Procedure that ensures proper material handling.* *User/Supplier Agreement* *Annual usage report* *• Comments:* *Worker contact with RWBR shall be limited to individuals who have received specialized training to deal with the RWBR systems.* *Additional requirements dependant on application.* *Note:* *Type I RWBR: Public Access Systems* *Type II RWBR: Restricted Access and Non Edible Crop Systems* *Type III RWBR: Agricultural Edible Crop Systems* *Type IV RWBR: Industrial Systems, Maintenance Operations and Construction*

A. 7 North Carolina

	Regulation/Guidelines/Policy
Water Reuse	*** 15A NCAC 02T.0906** (North Carolina Administrative Code, Chapter 15A, Subchapter 02T, Section 0906: Reclaimed Water Effluent Standards) *(a) The reclaimed water treatment process shall be documented to produce a tertiary quality effluent (filtered or equivalent) prior to storage, distribution, or irrigation that meets the parameter limits listed below:* *(1) monthly average BOD_5 of less than or equal to 10 mg/l and a daily maximum BOD_5 of less than or equal to 15 mg/l;* *(2) monthly average TSS of less than or equal to 5 mg/l and a daily maximum TSS of less than or equal to 10 mg/l;* *(3) monthly average NH_3 of less than or equal to 4 mg/l and a daily maximum NH_3 of less than or equal to 6 mg/l;* *(4) monthly geometric mean fecal coliform level of less than or equal to 14/100 ml and a daily maximum fecal coliform of less than or equal to 25/100 ml; and* *(5) maximum turbidity of 10 NTUs.* *(b) Reclaimed water produced by industrial facilities shall not be required to meet the above criteria if the reclaimed water is used in the industry's process and the area of use has no public access.* *** 15A NCAC 02T.0910** (Reclaimed Water Utilization) *(b) Reclaimed water used for purposes such as industrial process water or cooling water, aesthetic purposes such as decorative ponds or fountains, fire fighting or extinguishing, dust control, soil compaction for construction purposes, street sweeping (not street washing), and individual vehicle washing for personal purposes shall meet the criteria below:* *(1) Notification shall be provided by the permittee or its representative to inform the public or employees of the use of reclaimed water (Non Potable Water) and that the reclaimed water is not intended for drinking.* *(4) The generator of the reclaimed water shall develop and maintain a program of education and approval for all reclaimed water users.* *(5) The generator of the reclaimed water shall develop and maintain a program of record keeping for distribution of reclaimed water.* *(6) The generator of the reclaimed water shall develop and maintain a program of routine review and inspection of reclaimed water users.*
Water Discharge	**15A NCAC 02B.0208** (Standards For Toxic Substances and Temperature) **15 A NCAC 02B.0211** (Fresh Surface Water Quality Standards For Class C Waters) **Thermal (Temperature) Variances to North Carolina Water Quality Standards** (Effective April 23, 2006. Information detailing variances from water quality standards for dischargers to North Carolina surface waters)

A. 8 Oregon

	Regulation/Guidelines/Policy
Water Reuse	**** OAR 340-055*** *(Oregon Administrative Rules, Title 34, Division 55 Section 0012: Regulations Pertaining to the Use of Reclaimed Water (Treated Effluent) from Sewage Treatment Plants)* *"(E) Industrial, commercial, or construction uses limited to: industrial cooling, rock crushing, aggregate washing, mixing concrete, dust control, nonstructural fire fighting using aircraft, street sweeping, or sanitary sewer flushing;"* *(G) Any beneficial purpose authorized in writing by the department* *pursuant to OAR 340-055-0016(6).* *(b) Treatment. Class C recycled water must be an oxidized and disinfected wastewater that meets the numeric criteria in subsection (c) of this section.* *(c) Criteria. Class C recycled water must not exceed a median of 23 total coliform organisms per 100 milliliters, based on results of the last seven days that analyses have been completed, and 240 total coliform organisms per 100 milliliters in any two consecutive samples.* *(d) Monitoring. Monitoring for total coliform organisms must occur once per week at a minimum.*
Air Emission	**** OAR 340-055-0012*** *(C) If aerosols are generated when using recycled water for an industrial, commercial, or construction purpose, the aerosols must not create a public health hazard.*

A. 9 Texas

<table>
<tr><th></th><th>Regulation/Guidelines/Policy</th></tr>
<tr><td>Water Reuse</td><td>

*** TAC 30-210.32**

(Texas Administrative Code, Title 30, Chapter 210, Rule 210.32: Specific Uses of Reclaimed Water)

(1) Type I Reclaimed Water Use. This type of use includes irrigation or other uses in areas where the public may be present during the time when irrigation takes place or other uses where the public may come in contact with the reclaimed water.
(2) Type II Reclaimed Water Use. This type of use includes irrigation or other uses in areas where the public is not present during the time when irrigation activities occur or other uses where the public would not come in contact with the reclaimed water. The following are examples of uses that would be considered Type II uses.
(F) Cooling tower makeup water. Use for cooling towers which produce significant aerosols adjacent to public access areas may have special requirements.
(3) Any Type I reclaimed water may also be utilized for any of the Type II uses identified in subsection (2) of this section.

*** TAC 30-210.33**
(Quality Standards for Using Reclaimed Water)
Reclaimed water quality on a 30-day average

<table>
<tr><th rowspan="2"></th><th rowspan="2">Type I</th><th colspan="2">Type II</th></tr>
<tr><th>For a system other than pond system</th><th>For a pond system</th></tr>
<tr><td>BOD5 (or CBOD5) (mg/l)</td><td>5 (or 5)</td><td>20 (or 5)</td><td>30 (or N/S)</td></tr>
<tr><td>Turbidity (NTU)</td><td>3</td><td>N/S</td><td>N/S</td></tr>
<tr><td>Fecal Coliform (CFU/100 ml)</td><td>20*</td><td>200*</td><td>200*</td></tr>
<tr><td>Fecal Coliform (max) (CFU/100 ml)</td><td>75**</td><td>800**</td><td>800**</td></tr>
</table>

Definition:
N/S: Not specified
** : Geometric mean*
*** : Single grab sample*

</td></tr>
<tr><td>Water Discharge</td><td>

TAC 30-307.8
(Texas Surface Water Quality Standards/Application Standards)
(d) Once-through cooling water discharges. When a discharge of once-through cooling water does not measurably alter intake concentrations of a pollutant, then water-quality based effluent limits for that pollutant are not required. For facilities which intake and discharge cooling-water into different water bodies, this provision only applies if water quality and applicable water quality standards in the receiving water are maintained and protected.

</td></tr>
</table>

A. 9 (continued)

Air Emission	*** TAC 30-210.32** ***(1)(2)(F)*** *Use for cooling towers which produce significant aerosols adjacent to public access areas may have special requirements.* **TAC 30-113.220** (NESHAPS/Industrial Process Cooling Towers) *The Industrial Process Cooling Towers Maximum Achievable Control Technology standard as specified in 40 Code of Federal Regulations Part 63, Subpart Q, is incorporated by reference as amended through June 23, 2003 (68 FR 37348).*

A. 10 Utah

Regulation/Guidelines/Policy	
Water Reuse	*** Water Reuse in Utah (Apr. 2005)** *** Utah's Water Resources Planning for the Future, Chapter 5 (May, 2001)** *** UAC R317-3-11** (Utilization and Isolation of Domestic Wastewater Treatment Works Effluent) *11.5 Use of Treated Domestic Wastewater Effluent Where Human Exposure is Unlikely (Type II)A. Used allowed* *5. Cooling water. Use for cooling towers which produce aerosols in populated areas may have special restrictions imposed.* *B. Required Treatment Process* *C. Water Quality Limits*
Air Emission	*** UAC R317-3-11** *11.5 A. 5. Use (reclaimed water) for cooling towers, which produce aerosols in populated areas, may have special restrictions imposed.*

A. 11 Washington

	Regulation/Guidelines/Policy
Water Reuse	*** RCW 90.46** (Reclaimed Water Use) *** Water Reclamation and Reuse Standards, SECTION 1, Article 4, Section 15** (Industrial Cooling) *(a) Reclaimed water used for industrial cooling purposes where aerosols or other mist are not created shall be at all times Class C reclaimed water or better.* *(b) Reclaimed water used for industrial cooling purposes where aerosols or other mist are created shall be at all times Class A reclaimed water or better.* *Note:* *Class A water: oxidized, coagulated, filtered, and disinfected; total coliform 2.2/100 ml (7-day mean), 23/100 ml (single sample)* *Class C water: oxidized and disinfected; total coliform 23/100 ml (7-day mean), 240/100 ml (single sample)* *** Water Reclamation and Reuse Standards, SECTION 1, Table 2** (General Requirements) *BOD and TSS: 30 mg/l (monthly mean)* *Turbidity: 2 NTU (monthly), 5 NTU (not to exceed at any time)* *Minimum chlorine residual: mg/l after a contact time of 30 minutes*
Air Emission	*** Water Reclamation and Reuse Standards, SECTION 1, Article 4, Section 15**

A. 12 Wyoming

	Regulation/Guidelines/Policy
Water Reuse	***STANDARDS FOR THE REUSE OF TREATED WASTEWATER*** ***CHAPTER 21,WQD,*** **Authority and Purpose**. *"It is the intent of these regulations to encourage and facilitate the productive and safe reuse of treated wastewater as a viable option in the management of the state's scarce water resources. The use of treated wastewater for non-potable purposes through "source substitution" or replacing potable water used for non-potable purposes is encouraged. This part contains the minimum standards for the reuse of treated wastewater as defined in these regulations."* *"These regulations establish standards that address the primary health concerns associated with the reuse of treated wastewater. The regulations establish criteria to address the risk of pathogen exposure and infectious disease risks associated with various specified uses of treated wastewater."*
Water Discharge	***STANDARDS FOR THE REUSE OF TREATED WASTEWATER*** ***CHAPTER 2, WAQS&R,*** *APPENDIX D* *Additional Requirements Applicable to* *Manufacturing, Commercial, Mining and Silvicultural Facilities* *Discharging Only Non-process Waste Water*

A. 13 Related websites for regulations

Code of Federal Regulations (CFR)	http://www.access.gpo.gov/
Arizona State Legislature (ASL)	http://www.azleg.state.az.us/
The Arizona Administrative Code (AAC)	http://www.azsos.gov/public_services/Table_of_Contents.htm
California Code of Regulations (CCR)	http://ccr.oal.ca.gov/linkedslice/default.asp?SP=CCR-1000&Action=Welcome
The Florida Administrative Code(FAC)	http://fac.dos.state.fl.us/
Code of Maryland (COMAR)	http://www.dsd.state.md.us/comar/search_all.htm
New Jersey department of environmental protection (NJDEP)	http://www.state.nj.us/dep/dwq/techman.htm
North Carolina Administrative Code(NCAC)	http://reports.oah.state.nc.us/ncac.asp
Texas Administrative Code (TAC)	http://info.sos.state.tx.us/pls/pub/readtac$ext.viewtac
Utah Administrative Code(UAC)	http://www.rules.utah.gov/main/index.php?module=Pagesetter&func=viewpub&tid=1&pid=9
Washington State Legislature (WSL)	http://apps.leg.wa.gov/RCW/default.aspx?cite=90.46
Warren-Alquist Energy Resources Conservation and Development Act	http://www.energy.ca.gov/2005publications/CEC-140-2005-001/CEC-140-2005-001-ED2.PDF
Clean Water Act (CWA)	http://www.epa.gov/region5/water/cwa.htm
New Jersey Administrative Code (NJAC)	http://michie.lexisnexis.com/newjersey/lpext.dll?f=templates&fn=main-h.htm&cp=uanjadmin
California Water Code	http://www.leginfo.ca.gov/calaw.html
Code of Maryland Regulation (COMAR)	http://www.dsd.state.md.us/comar/

APPENDIX B

AIR EMISSIONS FROM COOLING TOWERS

B.1 PARTICULATE EMISSIONS FROM COOLING TOWERS

The increase in power demand in Southeast, Southwest, and Far West will lead to the need to augment traditional cooling water sources with lesser quality water and will likely increase air emissions from the cooling systems of power plants that supply electricity in that region (USDOE 2008). The other issue is the use of reclaimed water in cooling system, which will inevitably increase the concentration of particulate matter in a cooling tower. Although the air emissions from cooling systems are not regulated by the US EPA, the EPA has formulated guidelines and established factors for industries to limit/control the emissions from their cooling towers.

B.2 EMISSIONS OF PARTICULATE MATTER FROM WET COOLING TOWERS

When air passes through the cooling tower, small liquid droplets might attach to the airflow and be carried out of the tower as aerosol drifts. Therefore, the particulate matter constituent of the drift can be classified as emission (USEPA 1995).

Part of the water loss in cooling tower is related to the amount of particulate matter (droplets) which is discharged into the air. The water loss rate, i.e., the rate of air drift production, is controlled by numerous factors, including the packing design, contact pattern for water and air, flow rate of water and air, etc. For example, excessive water flow and excessive airflow will undoubtedly increase the emissions. Also, bypassing drift eliminators can also increase drift emissions (USEPA 1995).

Cooling water used in power plant usually needs basic treatment, such as adding chlorine to control biological growth in the tower or corrosion inhibitors to reduce corrosion of pipes and heat exchanger and achieve effluent limitation for blowdown. Because the drift will contain all the constituents characteristic of the cooling water (suspended or dissolved chemicals and biological contaminants), emissions from cooling towers may cause adverse impact for local population and environment.

Large drifts can not travel for a long distance and usually deposit near the tower. This phenomenon leads to wetting, icing, salt deposition, and related problems (USEPA 2009). Small drifts may travel a certain distance before being deposited, and those drifts can be referred as PM10 emissions. PM10 are fine particulates formed by the crystallization of dissolved solids (USEPA 1995).

Although the US EPA does not regulate air emissions from industrial cooling systems, monitoring air emissions and their reporting is required. In the EPA report, "Compilation of Air

Pollutant Emission Factors; Volume I: Stationary Point and Area Sources", this offers means to calculate PM10 depending on the total dissolved solids and PM10 factor. First approach must attain the data of drift loss, total suspend solids, and cycle of concentration. For example, if a tower has recycle flowrate, 2500 gpm, operates at 6 cycle of concentration, 800ppm dissolved solids concentration, and drift loss of 0.02%, PM_{10} emissions can be calculated as:

$$\begin{aligned}
&\mathrm{PM_{10}\ Emissions}\\
&= (\text{recycling rate}) \times (\text{cycle of conc}) \times (TDS\ \text{conc}) \times (drift\ \text{loss})\\
&= (2{,}500\frac{gal}{\min}) \times (6) \times (800\,ppm) \times (0.02\%) \times \left(60\frac{\min}{hr}\right) \times \left(24\frac{hr}{day}\right) \times \left(8.34\frac{lb}{gal}\right)\\
&= 28.82\frac{lb}{day}PM_{10} = 13.08\frac{kg}{day}PM_{10} = 4.8\frac{ton}{year}PM_{10}
\end{aligned}$$

Second approach to estimate emissioning from a cooling tower is to use factors given by Source Classification Code 3-85-001-01. Assume the total liquid drift is 0.02% of the water flow, the PM10 factor is given as 0.019 lb per 10^3gallons of the water flow. For example, the annual amount of PM10 for a cooling tower with total water flow of 2,500 gal/min can be calculated as follows (USEPA 1995):

$$\begin{aligned}
&\mathrm{PM_{10}\ Emissions}\\
&= (\text{recycling rate}) \times (\text{emission factor})\\
&= (2{,}500\frac{gal}{\min}) \times 0.019\frac{lb}{1000gal} \times \left(60\frac{\min}{hr}\right) \times \left(24\frac{hr}{day}\right)\\
&= 68.4\frac{lb}{day}PM_{10} = 31\frac{kg}{day}PM_{10} = 12.3\frac{ton}{year}PM_{10}
\end{aligned}$$

Comparing the two calculations, the emission amount calculated using the PM10 emission factor is much higher than that using empirical data. Recent study shows the PM10 factor overestimates the amount of PM10 from cooling tower because of the original assumption of PM10 factor and the designs for new cooling towers which have drift that ranges between 0.0005 and 0.002 percent while typical drift loss rates for existing cooling towers range from

0.001 to 0.02% of the recirculating flow. (Micheletti, 2006). However, a conservatively high PM10 is still commonly applied when making design and operating decisions by cooling tower owners/operators.

Table B1. Particulate emissions factors for wet cooling towers

Cooling Type	Total Liquid Drift				PM-10		
	Circulating Water Flow (%)	g/10L	lb/10^3 gal	Emission Factor Rating	g/10L	lb/10^3 gal	Emission Factor Rating
Induced Draft	0.020	2.0	1.7	D	0.023	0.019	E
Natural Draft	0.00088	0.088	0.073	E	No Data	No Data	—

Note: (1) Factors are for % of circulating water flow.
(2) AP-42 emission factor quality ratings:
D — Below average. Factor is developed from A-, B- and/or C-rated test data from a small number of facilities, and there may be reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source population.
E — Poor. Factor is developed from C- and D-rated test data, and there may be reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population.
Source: AP42 Compilation of Air Pollutant Emission Factor, 5th edition, (USEPA 1995)

B.3 CONTROL OF PARTICULATE MATTER EMISSIONS

Dissolved and suspended compounds and biological contaminants found in cooling tower drift may pose significant threat to neighboring communities. Drift eliminators represent the best available technology for controlling the emissions of particulate matter from cooling towers. They are normally included into the tower design to meet requirements established by local regulatory agency. Drift eliminators are made of various materials, such as ceramics, fiber reinforced cement, fiberglass, metal, plastic, and wood and are installed in closely spaced sheets or tiles or in honeycomb assemblies (USEPA 1995). They can also include other features, such as corrugations and water removal channels, to improve the drift removal efficiency. Currently, the Best Available Control Technology (BACT) can achieve emission rate of 0.0005% of the cooling water flow rate and this standard is common requested while applying construct a new plant in most states.

Another approach for controlling particulate emissions is to reduce the concentrations of any potential pollutants in the recirculating water, thereby reducing the amount of chemical compounds that might be discharged with airflow. Specialized treatment may be needed to achieve this goal, such as adding biocide to control the number of microorganisms or using membrane to reduce suspended solids concentration.

APPENDIX C

INTRODUCTION OF GEOGRAPHIC INFORMATION SYSTEM OPERATION

In this manual, geographic information system was applied to help power industry estimate the available wastewater flowrate from publicly owned treatment works (POTWs) at any given location for existing or future power plants.

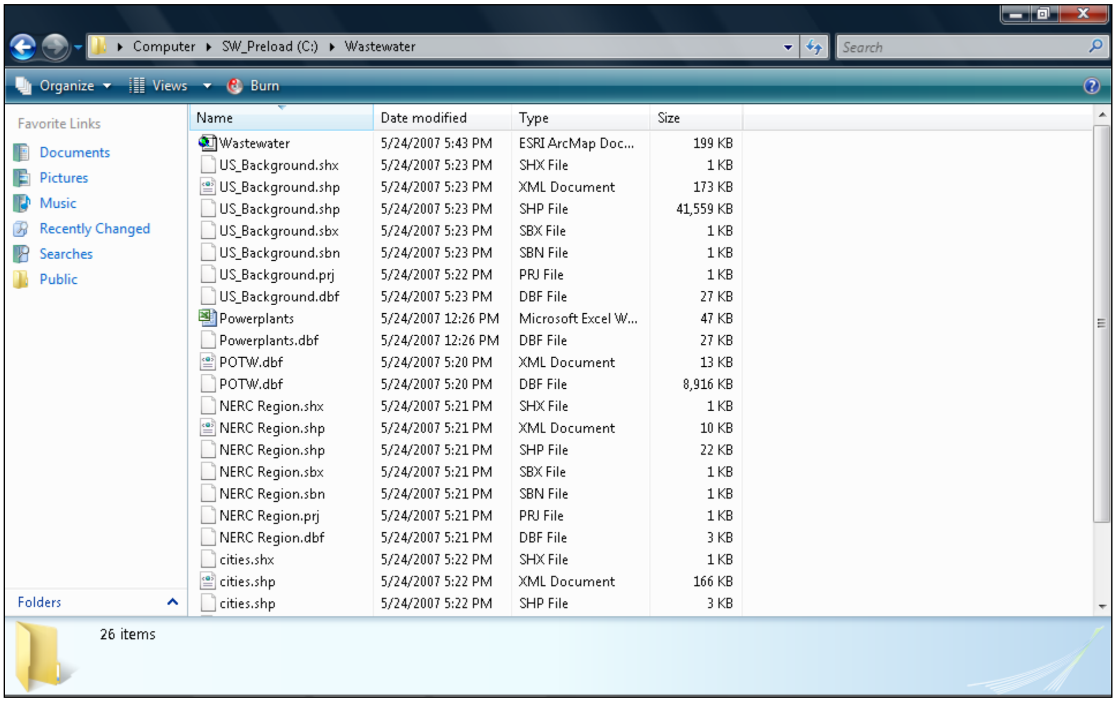
The U.S. environmental protection agency (USEPA) provides an online geographic information system (GIS), Enviromapper for Water (USEPA 2008), for publics to check the wastewater discharge from any source inside the U.S. continent. The database for Enviromapper for Water was based on Clean Watersheds Needs Survey (CWNS) and has information on publicly-owned wastewater collection and treatment facilities, facilities for control of sanitary swewe overflows, combined seweroverflows, stormwater control activities, nonpoint sources, and programs designed to protect the nation's estuaries.

Another useful tool provided by USEPA is Ask WATERs, which can help publics collect information of wastewater for a specific EPA region, state or county. Although the Enviromapper for Water and Ask WATERs provide enough information of wastewater and can help locating any treatment facility on map, those information is not detailed enough to help industries making decision. A more accurate wastewater flowrate analysis for a particular location is needed for power industry to make appropriate decision. Therefore, we extracted the information of wastewater flowrate, the name of facilities, the number of applications and geographic location (latitude and longitude), etc. from Enviromapper of Water database and combined the information into a basic GIS.

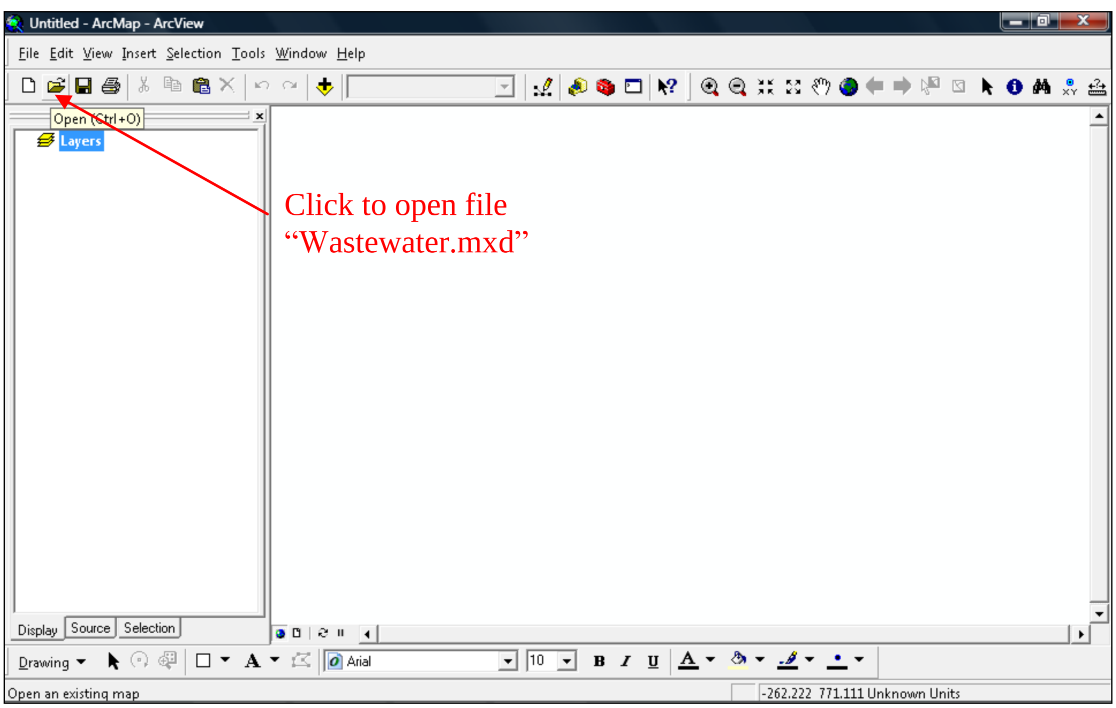
The GIS provided by us was built on ArcGIS, version 9.2, ESRI and the database was extracted from Enviromapper of Water. Wastewater facilities listed on the database are wastewater treatment plants, sewage treatment plants, water recycle plants, water pollution control plant and lagoons. Proposed power plants for example are derived from Energy Information Administration, Form EIA-860, "Annual Electric Generator Report.”, (USEIA 2007).

The following steps from next page will introduce how to use the data extracted from Enviromapper to estimate available wastewater flowrate for a specific location.

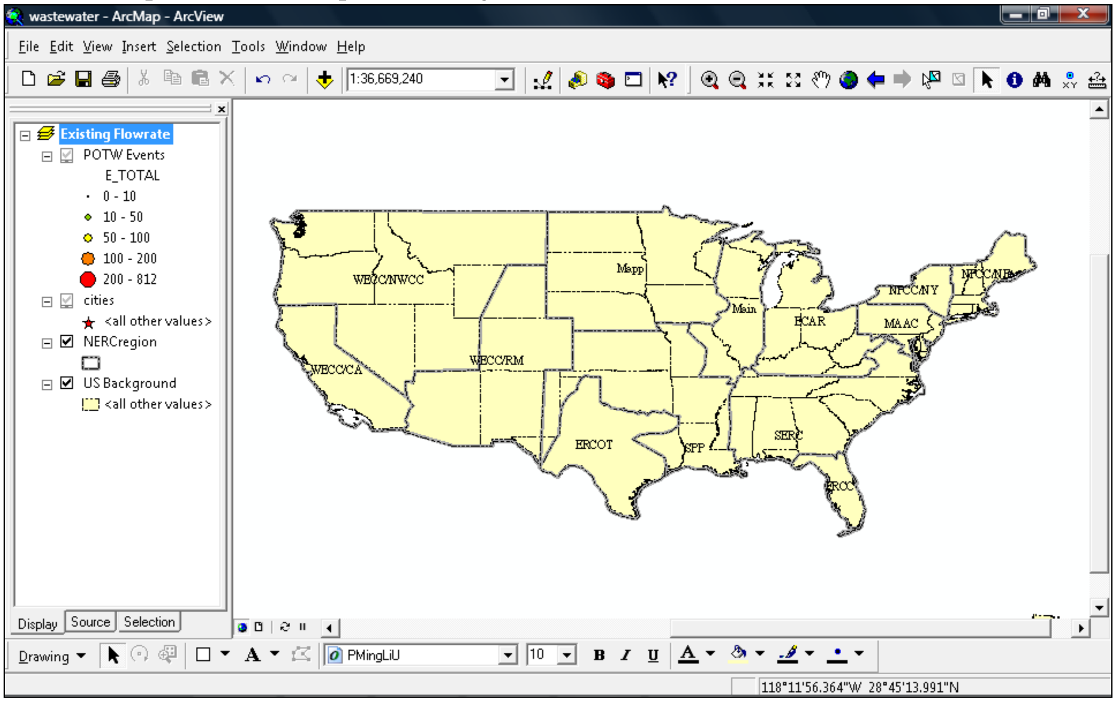
1. Preparation
    a. Download file Wastewater.zip (30.7MB) and extract this file to folder C:\Wastewater\
    b. Make sure all 26 files are saved in the same folder.



2. Open target files
    a. You can either double click on the file or open Wastewater.mxd in ArcView, which is shown below.

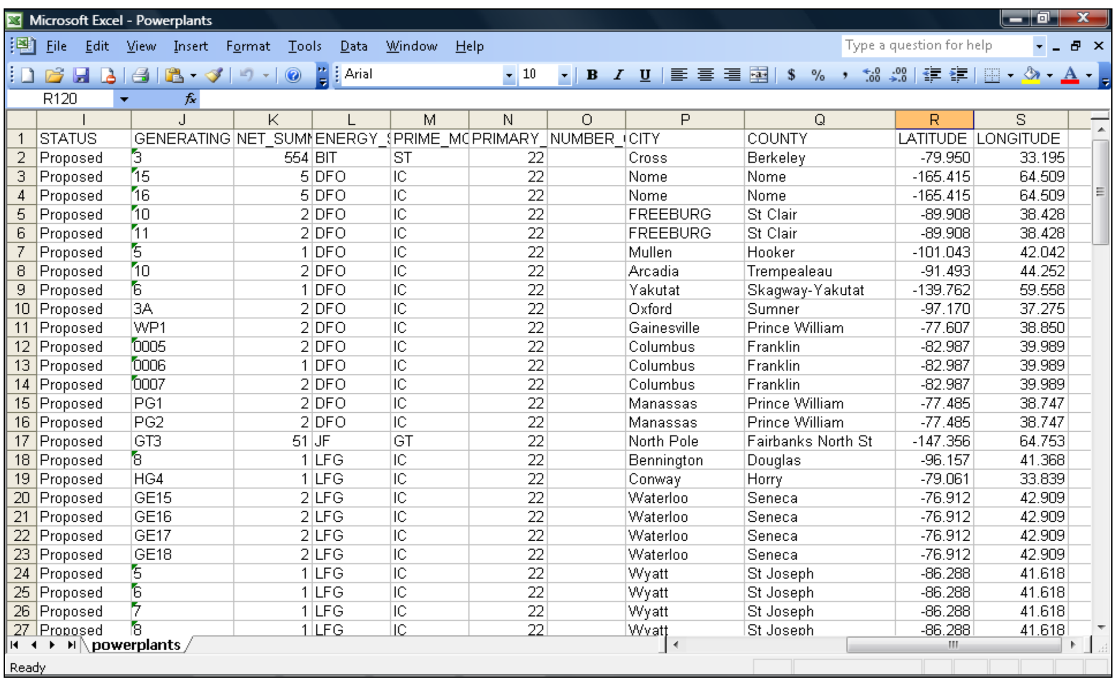


b. The U.S. base Map will appear on the screen. In addition to state boundaries, North American Electric Reliability Corporation (NERC) region boundaries are also provided to help with analysis.



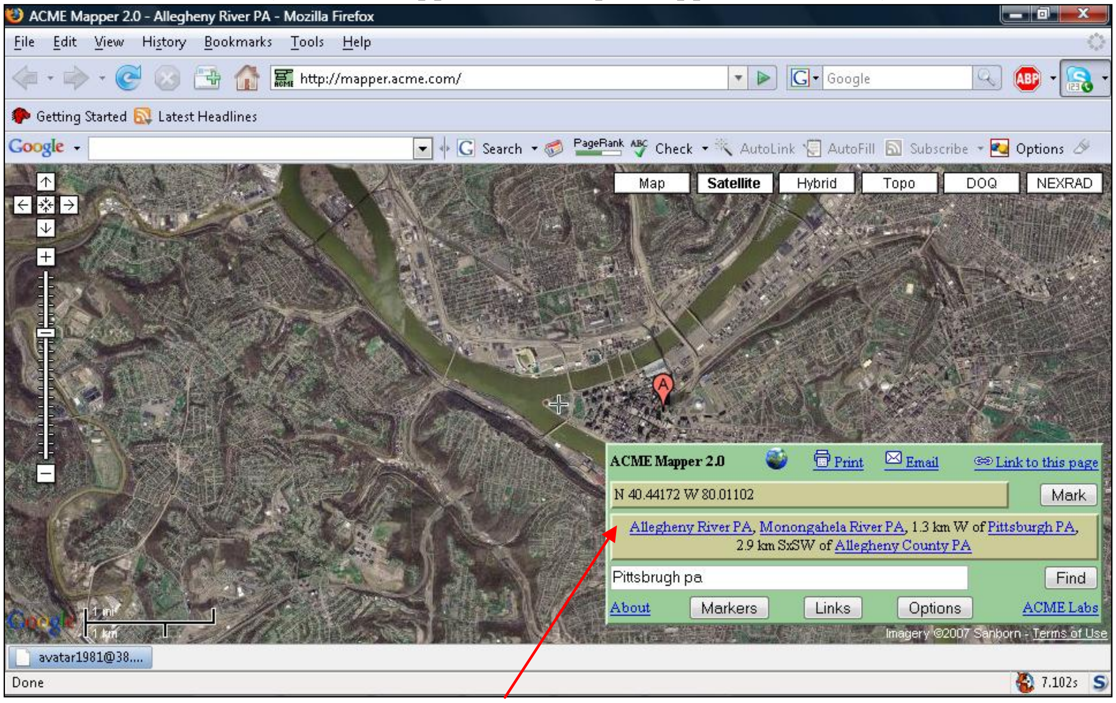
3. Add your data

a. Prepare the information for your future plant site and save it into *.txt, *.xls, or *.dbf format. Latitude and longitude of the site is needed for analysis. The file Powerplants.xls lists proposed U. S. electric generating units and your plant can be added to the list.



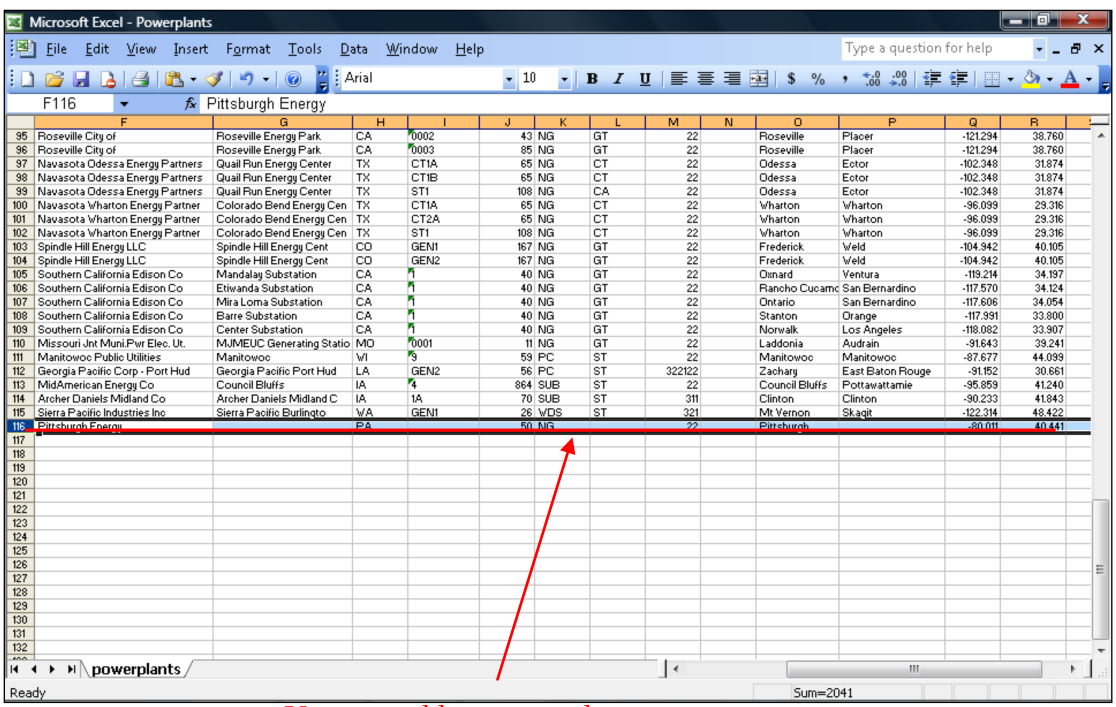
	I	J	K	L	M	N	O	P	Q	R	S
1	STATUS	GENERATING	NET_SUMI	ENERGY_S	PRIME_MC	PRIMARY_	NUMBER_I	CITY	COUNTY	LATITUDE	LONGITUDE
2	Proposed	3	554	BIT	ST	22		Cross	Berkeley	-79.950	33.195
3	Proposed	15	5	DFO	IC	22		Nome	Nome	-165.415	64.509
4	Proposed	16	5	DFO	IC	22		Nome	Nome	-165.415	64.509
5	Proposed	10	2	DFO	IC	22		FREEBURG	St Clair	-89.908	38.428
6	Proposed	11	2	DFO	IC	22		FREEBURG	St Clair	-89.908	38.428
7	Proposed	5	1	DFO	IC	22		Mullen	Hooker	-101.043	42.042
8	Proposed	10	2	DFO	IC	22		Arcadia	Trempealeau	-91.493	44.252
9	Proposed	6	1	DFO	IC	22		Yakutat	Skagway-Yakutat	-139.762	59.558
10	Proposed	3A	2	DFO	IC	22		Oxford	Sumner	-97.170	37.275
11	Proposed	WP1	2	DFO	IC	22		Gainesville	Prince William	-77.607	38.850
12	Proposed	0005	2	DFO	IC	22		Columbus	Franklin	-82.987	39.989
13	Proposed	0006	1	DFO	IC	22		Columbus	Franklin	-82.987	39.989
14	Proposed	0007	2	DFO	IC	22		Columbus	Franklin	-82.987	39.989
15	Proposed	PG1	2	DFO	IC	22		Manassas	Prince William	-77.485	38.747
16	Proposed	PG2	2	DFO	IC	22		Manassas	Prince William	-77.485	38.747
17	Proposed	GT3	51	JF	GT	22		North Pole	Fairbanks North St	-147.356	64.753
18	Proposed	8	1	LFG	IC	22		Bennington	Douglas	-96.157	41.368
19	Proposed	HG4	1	LFG	IC	22		Conway	Horry	-79.061	33.839
20	Proposed	GE15	2	LFG	IC	22		Waterloo	Seneca	-76.912	42.909
21	Proposed	GE16	2	LFG	IC	22		Waterloo	Seneca	-76.912	42.909
22	Proposed	GE17	2	LFG	IC	22		Waterloo	Seneca	-76.912	42.909
23	Proposed	GE18	2	LFG	IC	22		Waterloo	Seneca	-76.912	42.909
24	Proposed	5	1	LFG	IC	22		Wyatt	St Joseph	-86.288	41.618
25	Proposed	6	1	LFG	IC	22		Wyatt	St Joseph	-86.288	41.618
26	Proposed	7	1	LFG	IC	22		Wyatt	St Joseph	-86.288	41.618
27	Proposed	8	1	LFG	IC	22		Wyatt	St Joseph	-86.288	41.618

a. For example, assume there will be a new 50MW gas power plant in Pittsburgh, Pennsylvania and use online GIS locator to find latitude and longitude for selected location. (ACME Mapper, from http://mapper.acme.com/)



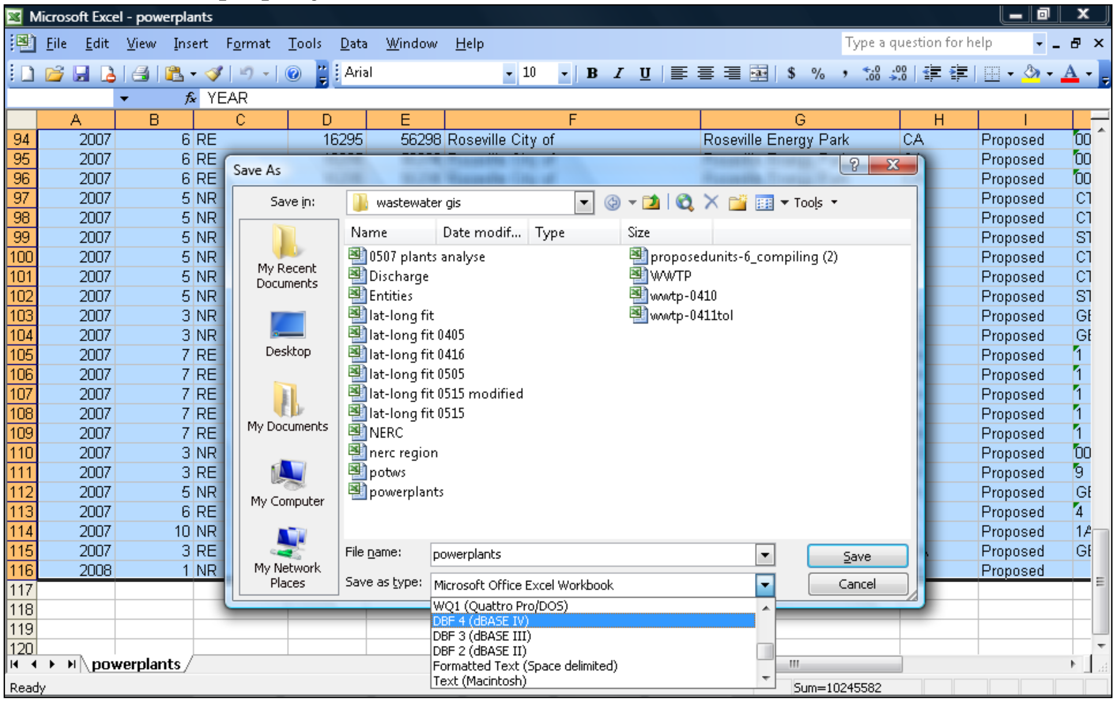
Latitude and longitude data

b. Add latitude and longitude and available power plant information into excel and save the file.

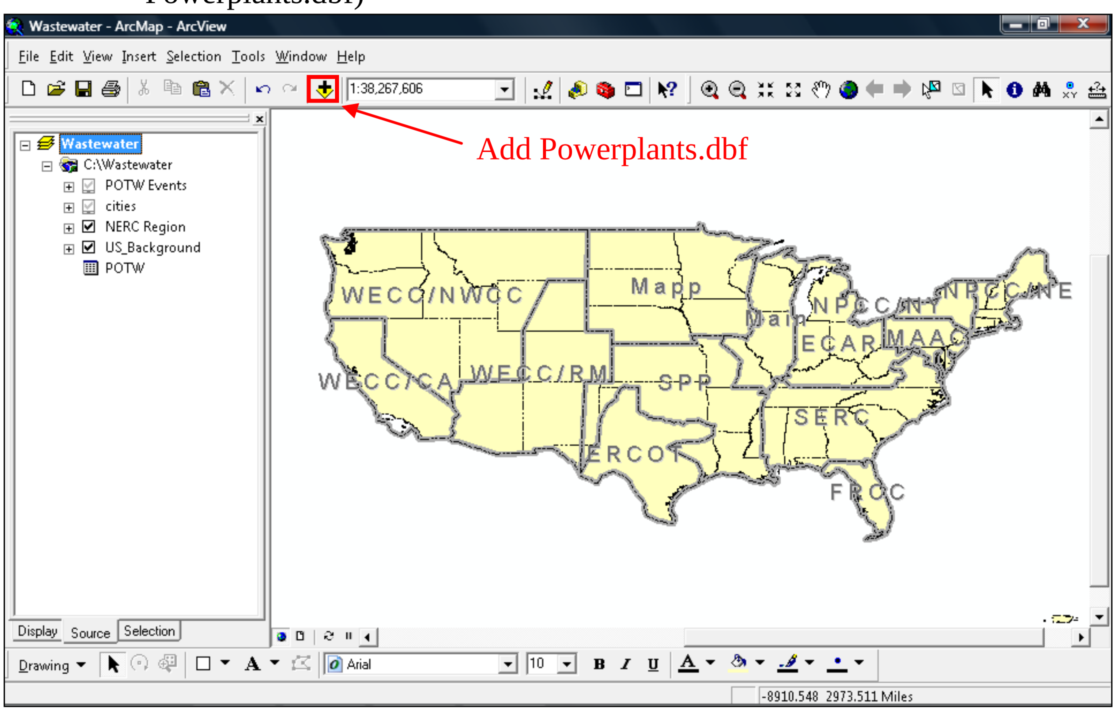


You can add as many plants as you need here

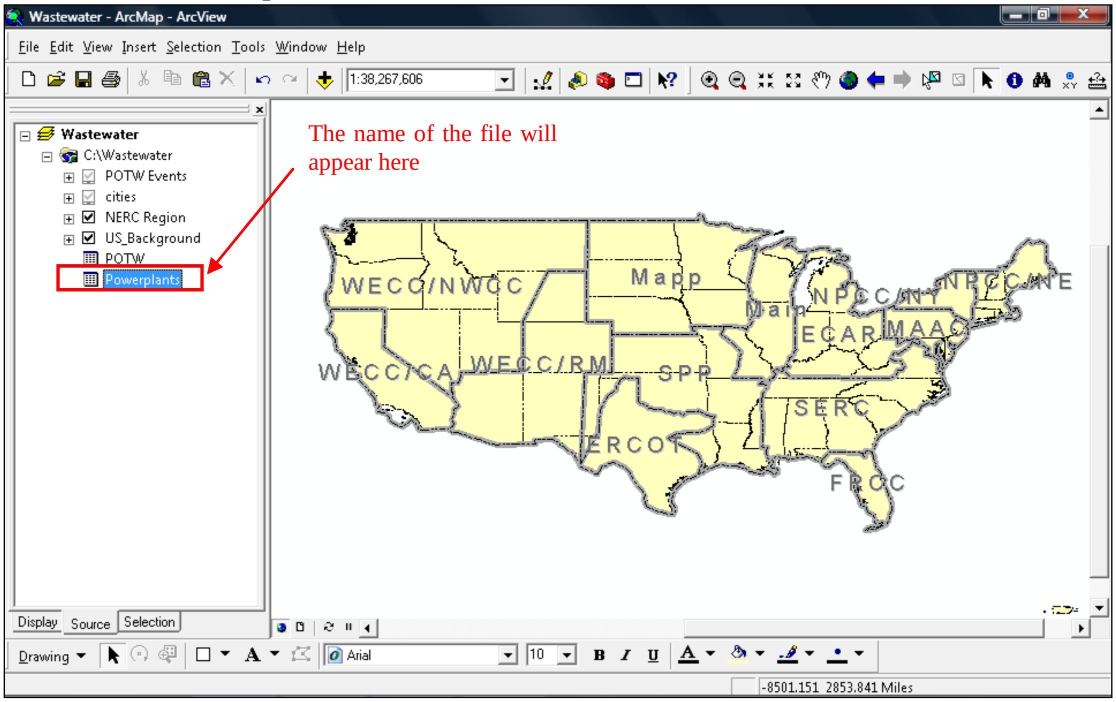
b. Save the file as “Powerplants.dbf” because only database file with .dbf extension can work properly in ArcGIS.



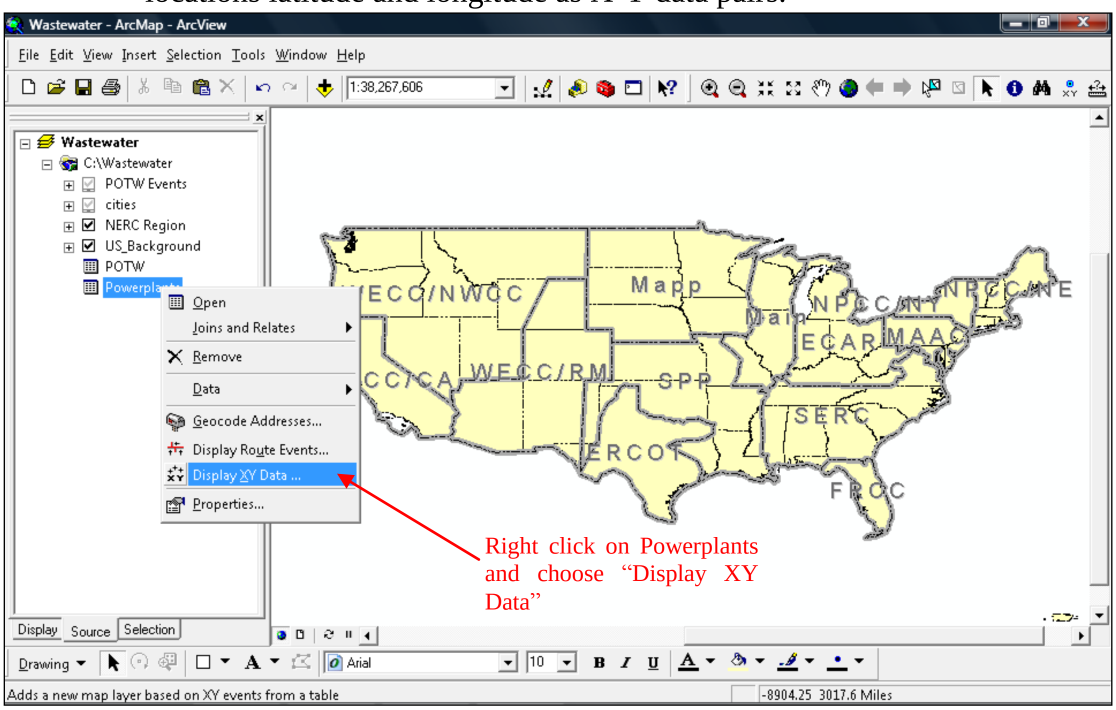
4. Link your input file with ArcGIS to be able to display location of proposed power plants.
   a. Go back to the ArcGIS program, click on “Add Data” and add the target file (e.g. Powerplants.dbf)



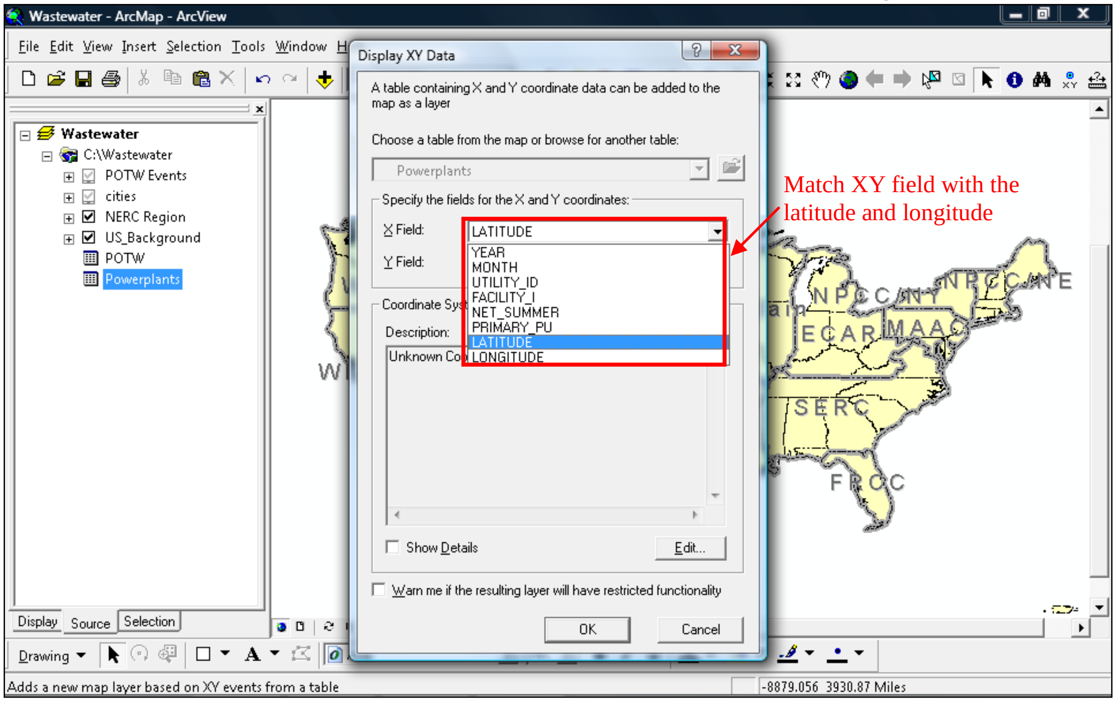
a. The file will be added as a table. You can right click on the Powerplants table and select “Open Attribution table” to check if the information is added correctely.



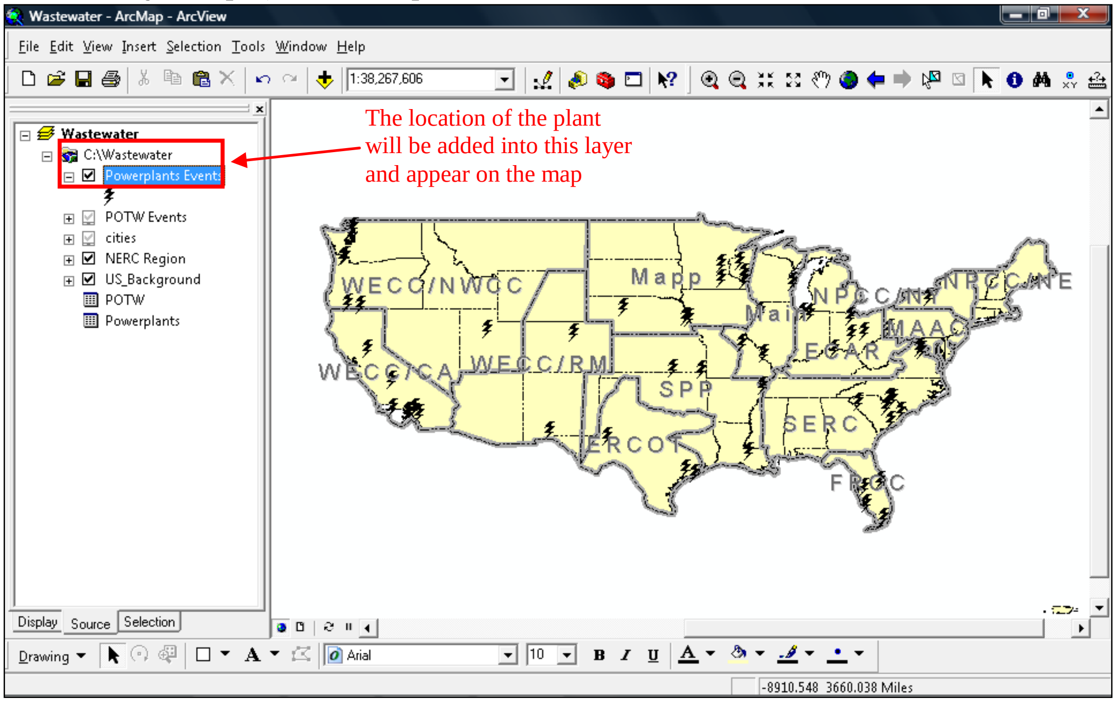
b. In order to display all power plants included in the table, it is required to import their locations latitude and longitude as X-Y data pairs.



b. Match X axis field with latitude and Y axis field with longitude.

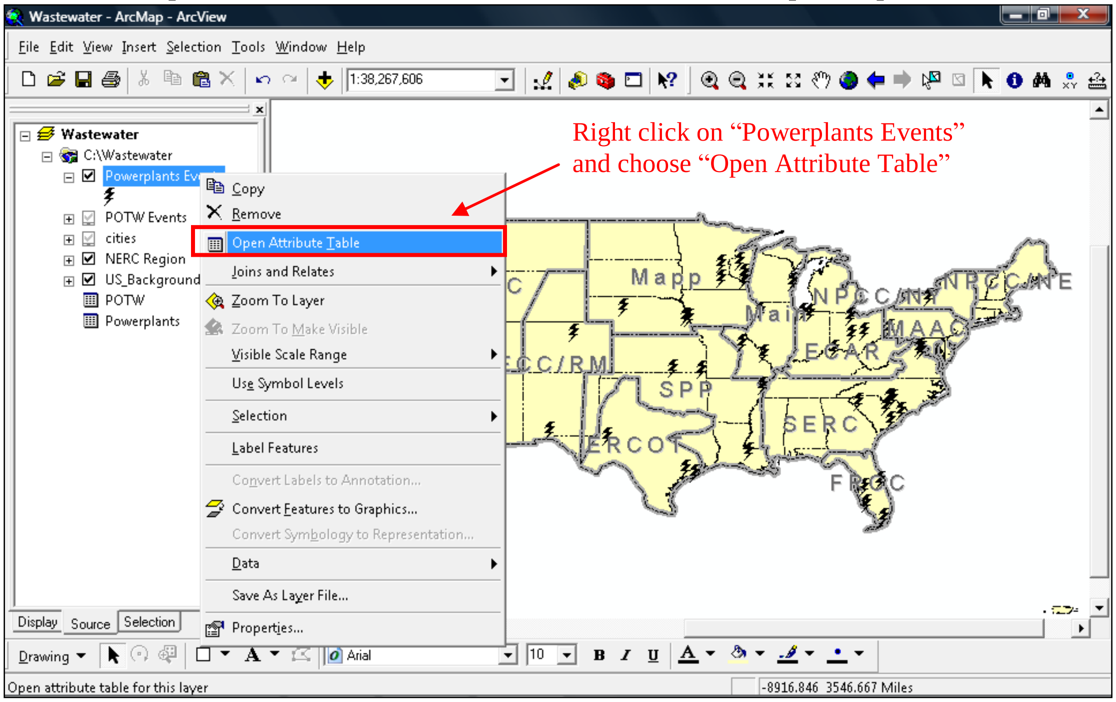


c. Each plant listed in the table will be shown as a symbol (symbols may vary each time you input) on the map.

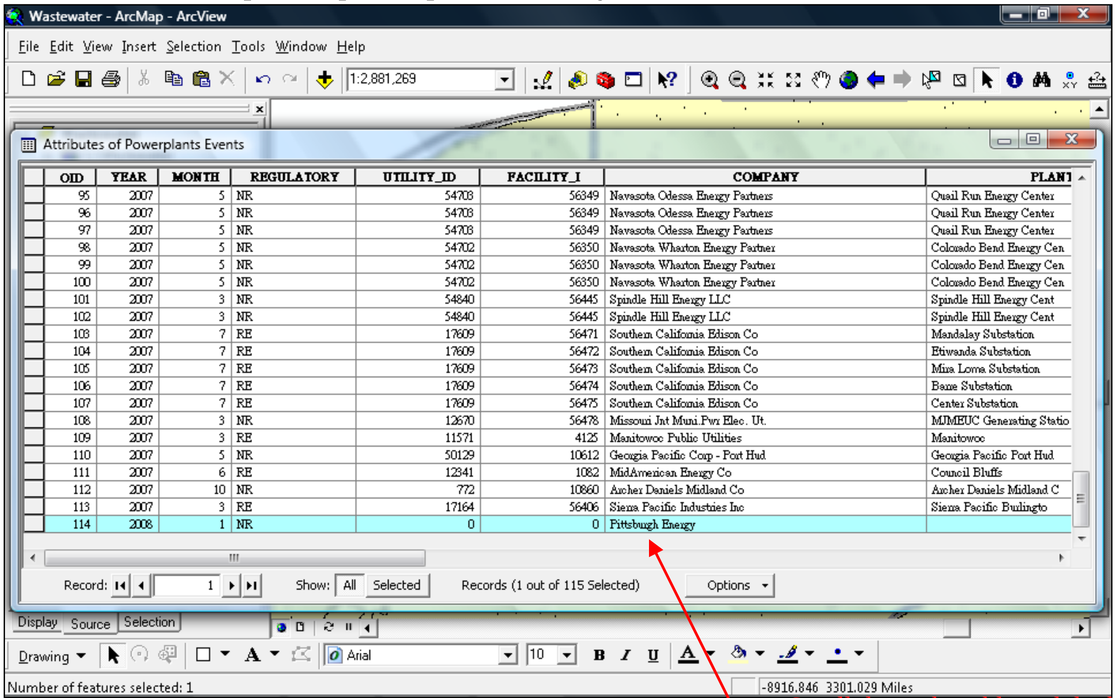


5. Determine the location of existing POTWs in the vicinity of selected power plant.

   a. Open the table that contains information about all power plants.

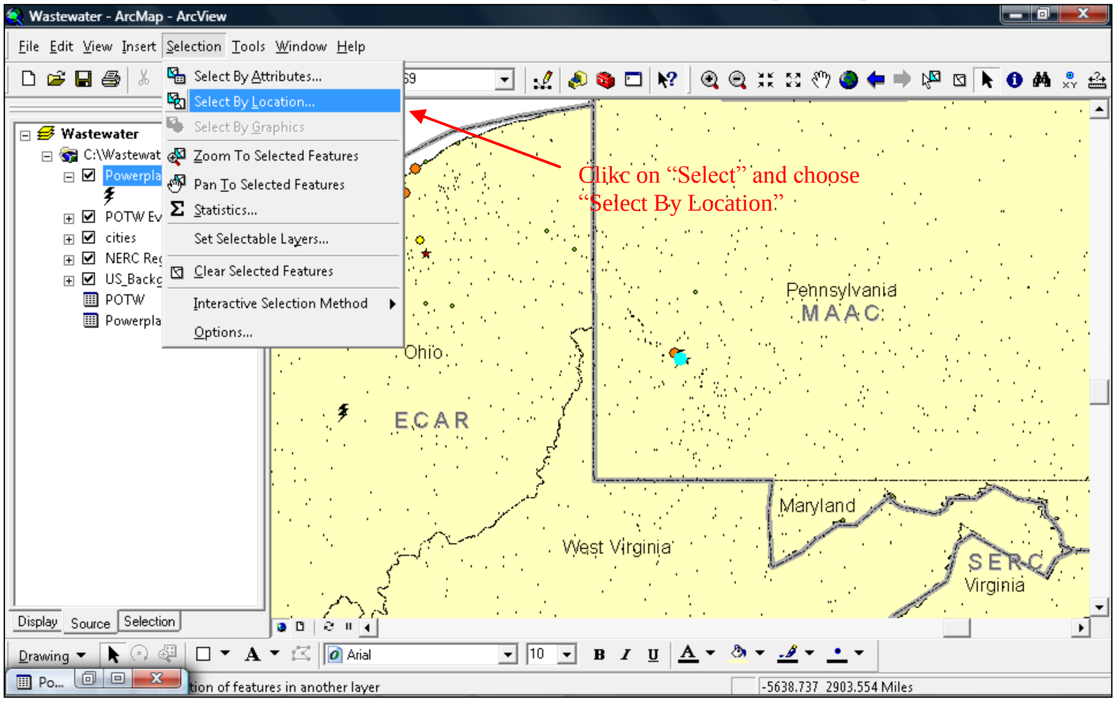


   b. Select specific power plant for analysis.

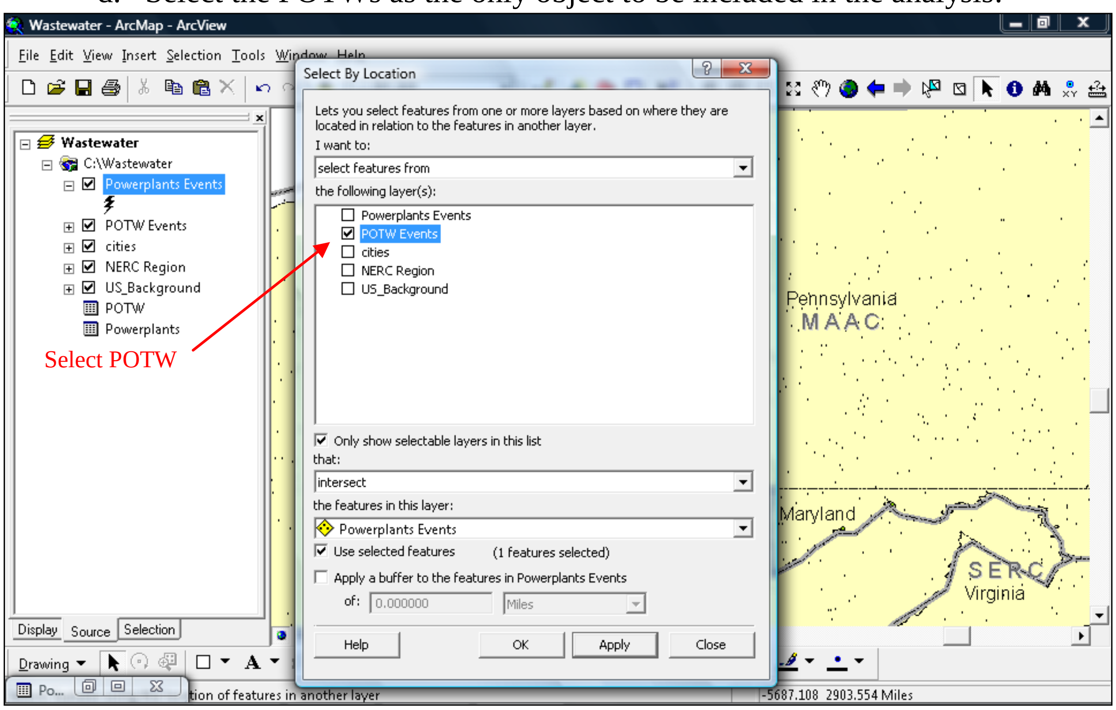


Scroll down the table and double click to select a particular power plant and then minimize the window

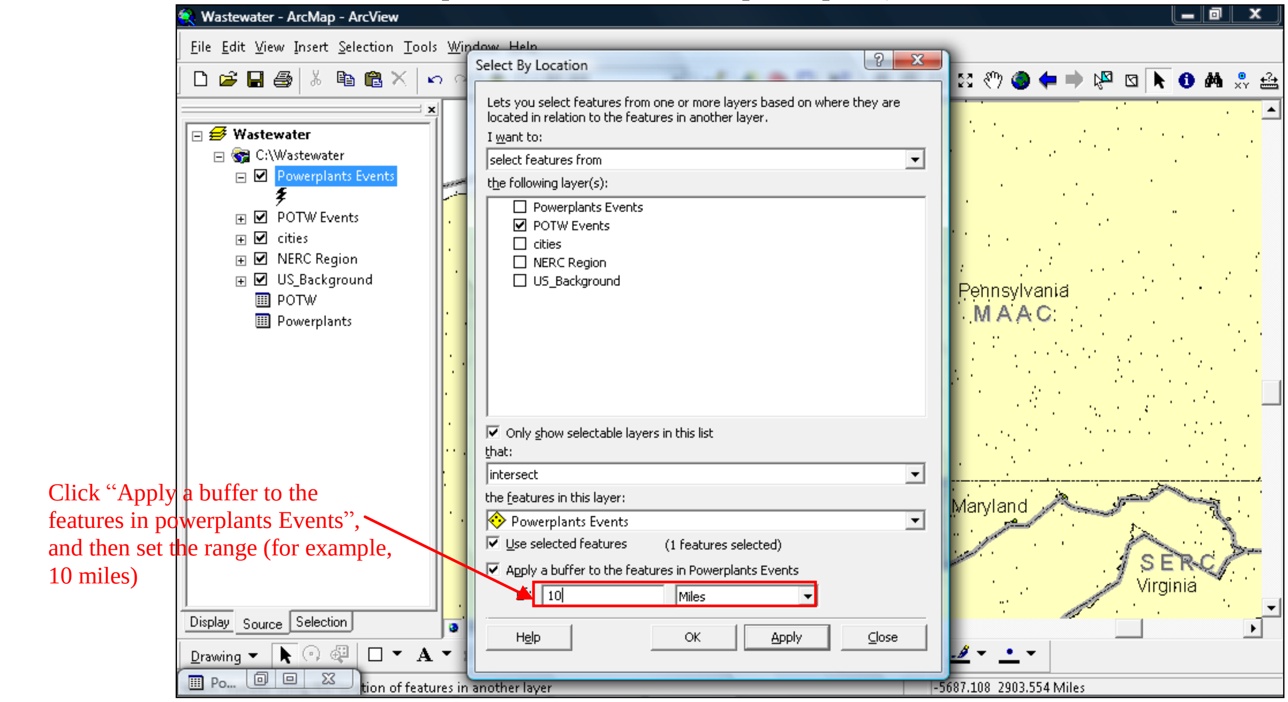
c. Extract the location of POTWs near the selected power plant location.



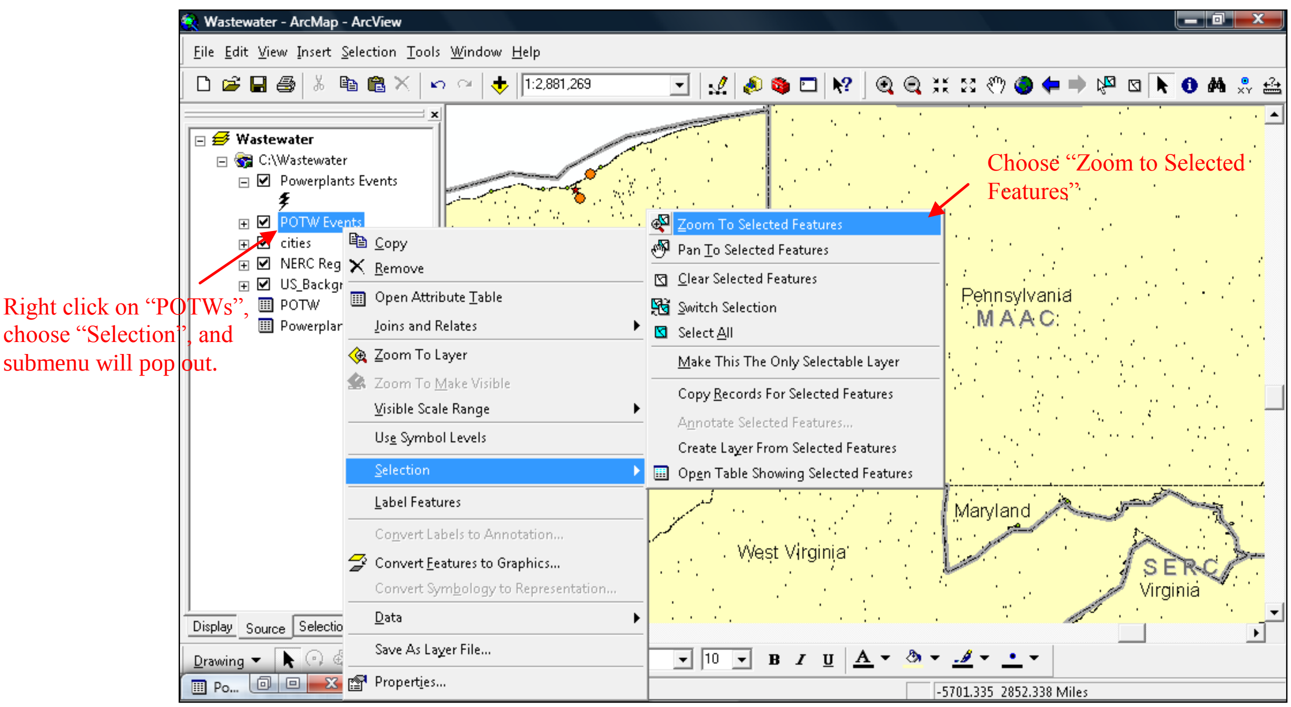
d. Select the POTWs as the only object to be included in the analysis.



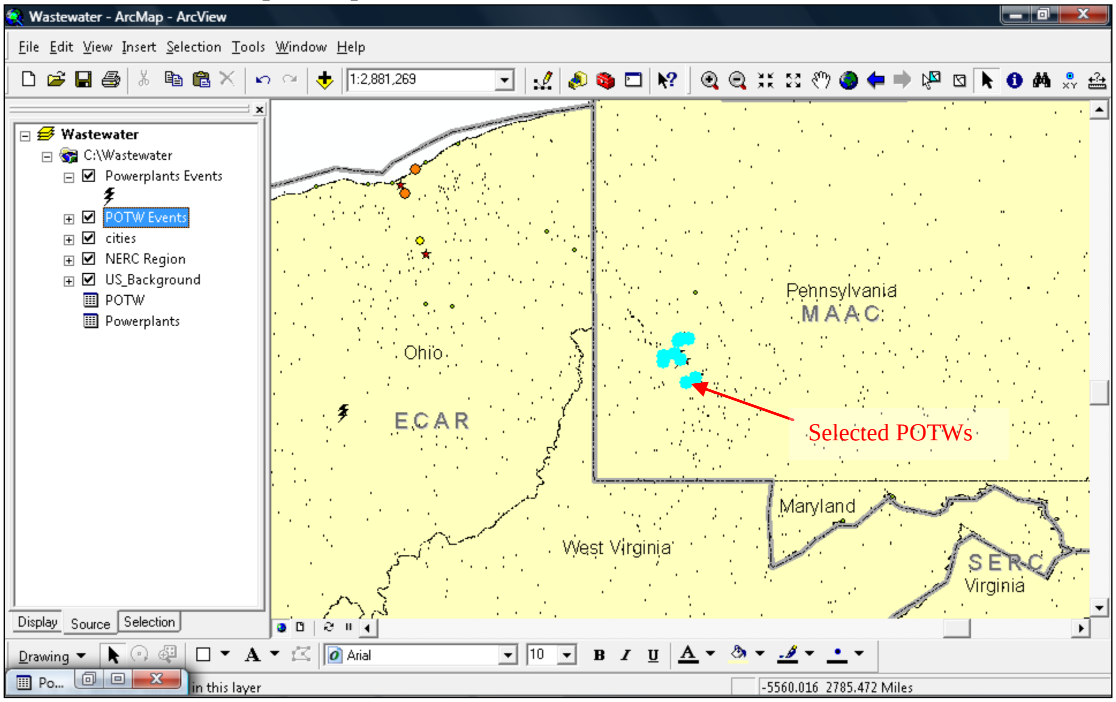
e. Set the distance from the power plant of interest for this analysis (i.e. select a POTWs within a specific distance from a powerplant).



f. In order to display those selected POTWs on the map, right click on the “POTW Events” and choose “Zoom to Selected Features” under “Selection”.

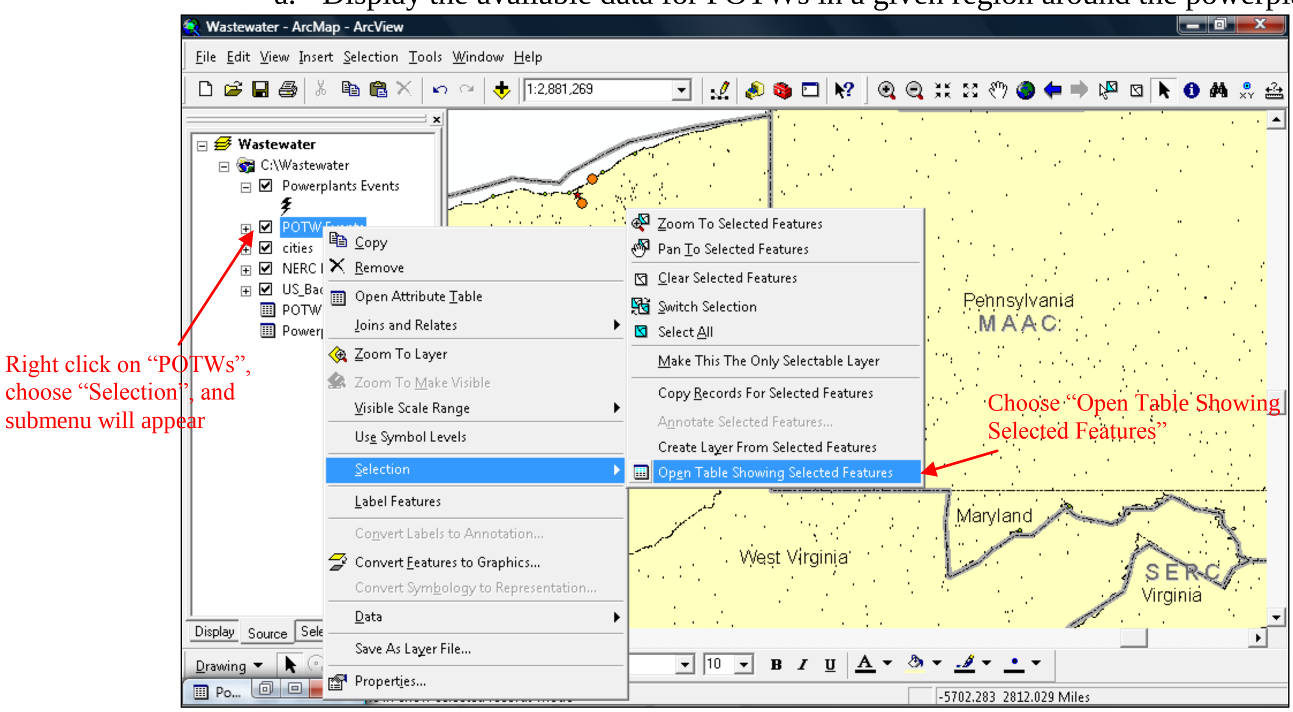


g. The software will zoom to the region and display all POTWs with a selected distance from the power plant.

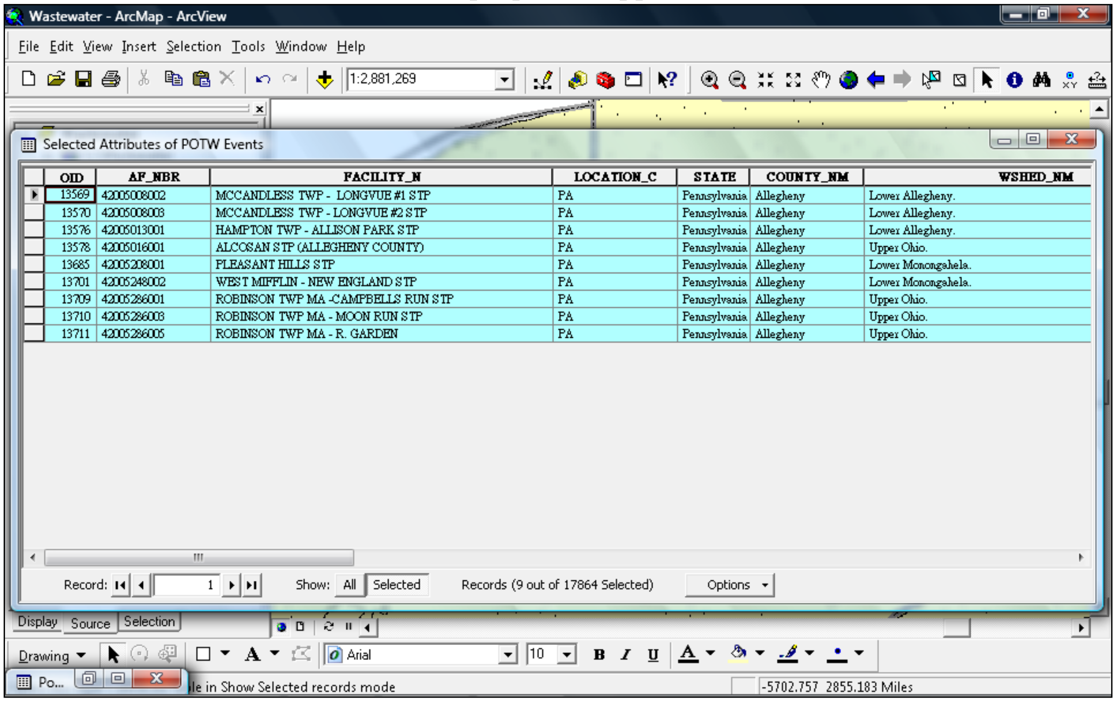


6. Extract information about selected POTWs for further analysis.

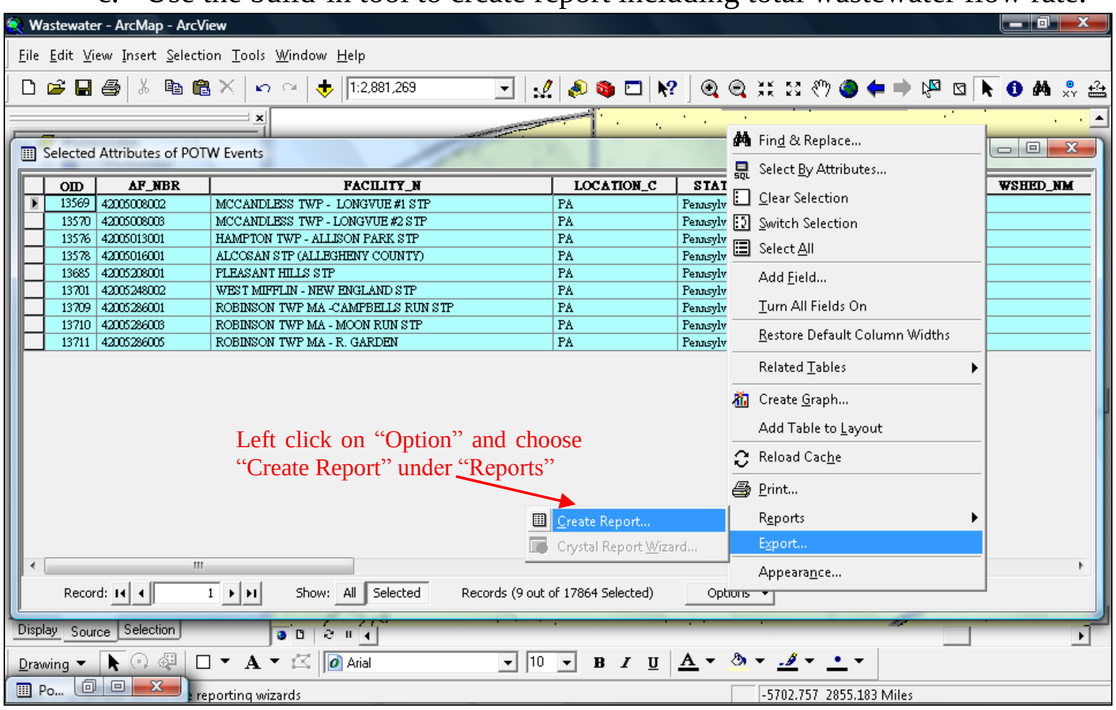
a. Display the available data for POTWs in a given region around the powerplant.



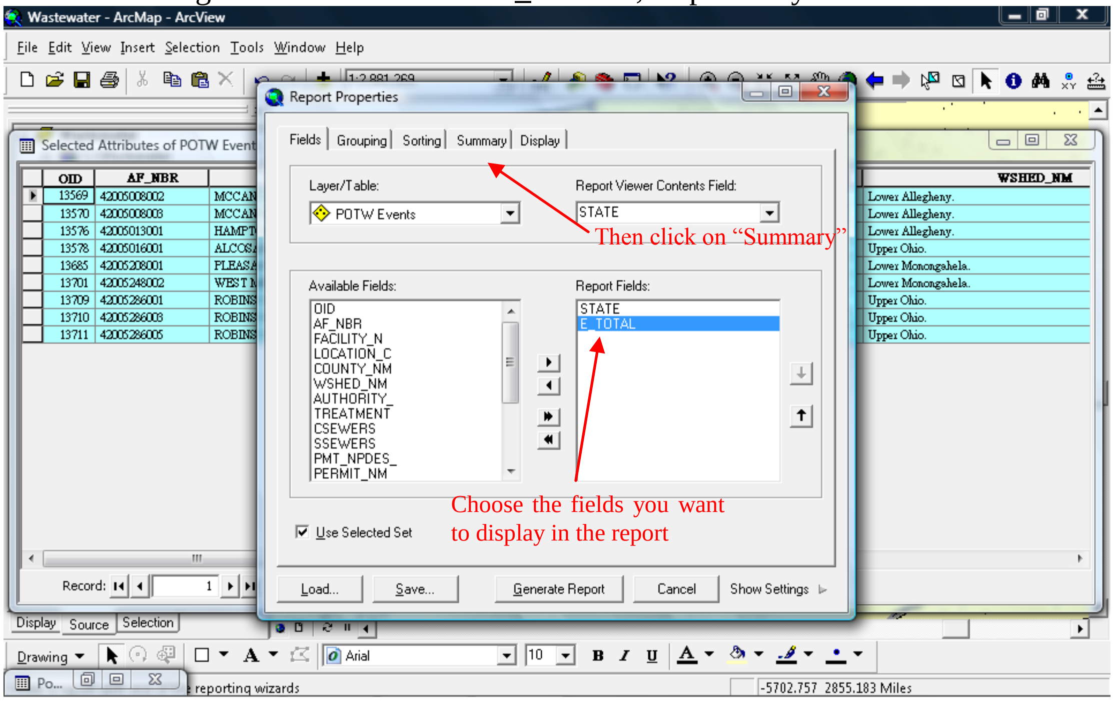
b. List of POTWs and their properties appear on the screen.



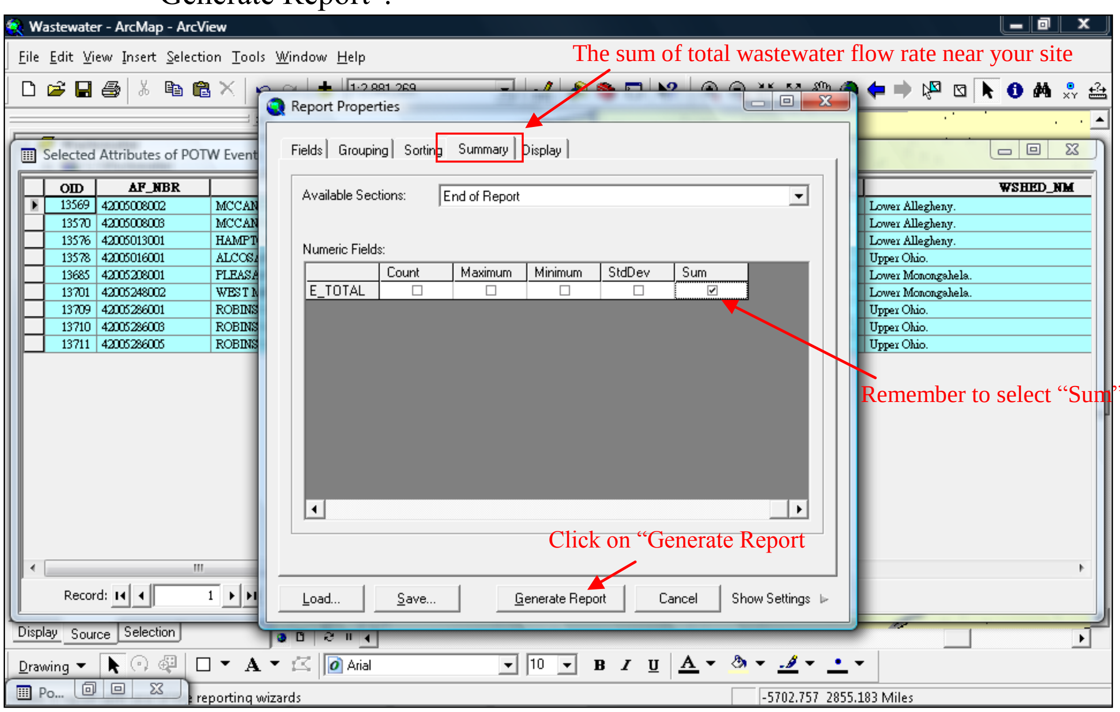
c. Use the build-in tool to create report including total wastewater flow rate.



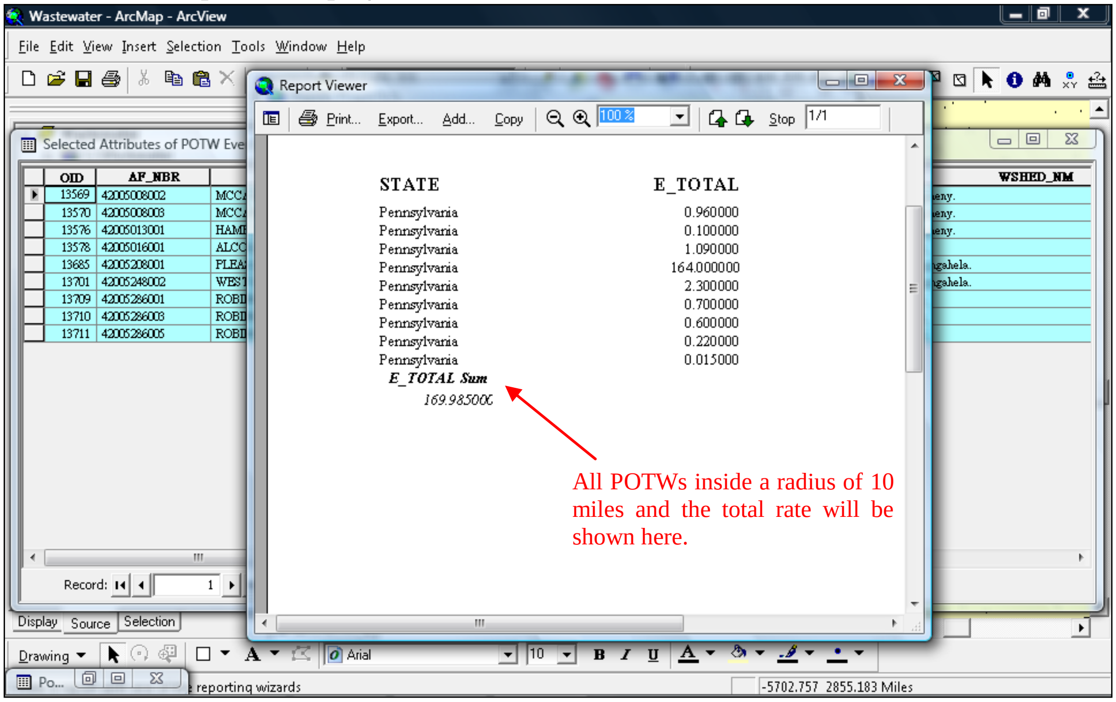
d. Select the type of information that should be included in the report, for example, state where POTWs is located and the total existing wastewater flowrate, which are categorized as STATE and E_TOTAL, respectively.



e. Use summary tool to calculate the total numbers of POTWs in a selected region, maximum and minimum wastewater flow rate, standard deviation, and total flowrate for all selected POTWs. After selecting desired features to be reported, click on "Generate Report".



f. A report is displayed on the screen.



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