# 2009

**12th Annual High School Mathematical Contest in Modeling (HiMCM) Summary Sheet**

(Please attach a copy of this page to each copy of your Solution Paper.)

**Team Control Number:** 2461

**Problem Chosen:** A

Please type a summary of your results on this page. Please remember not to include the name of your school, advisor, or team members on this page.

Our objective is to devise an effective, feasible, cost-efficient national water strategy to meet the projected needs of the United States in 2025. Thus, we first created a mathematical model to project the demand for fresh water in the United States in 2025, basing our projected needs on current trends in eight major categories of fresh water usage, namely public water, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric-power generation. We then devised a cost-efficient and plausible national water strategy in which we can meet the 2025 projected water needs of the United States through storage, movement, desalinization, and the reduction in consumption of our water resources. Within our paper, part 1 addresses the projected growth in the demand for water due to the growth in U.S population, energy demand, and industries, while parts 2-6 of the model addresses our national water strategy and details illustrating how our strategy will create a sustainable water usage plan for the years 2010 to 2025.

For our projection model, we considered current trends in the eight main categories of the total fresh water usage as recorded by the United States Geological Survey. The eight main categories were public water, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric-power generation. We created regression curves of the data given by the USGS for each of the eight categories. We then summed up the projected 2025 fresh water usage from each of the eight categories to obtain a total fresh water usage graph which projected the total United States fresh water usage in 2025.

This parameter allowed us to devise a plan that would attempt to alleviate the projected water usage through storage, movement, desalination, and conservation. In our plan, we addressed financial issues, physical and environmental effects. We took a multi-pronged approach in tackling this problem, addressing various areas of water use, such as toilet flush and canal

lining, as well as multiple ways of conserving the freshwater. Each individual plan is modeled by a sub-model and at the end, their costs and water savings are summed to create the total water saved and the total cost of our national water strategy. By minimizing waste and maximizing economic efficiency, our plan attempts to achieve a permanent sustainable national fresh water system.

In conclusion, our national water plan requires a moderate amount of funds, around 200 billion over the course of the next 15 years (13.3 billion a year), yet it greatly lessens the burden of available freshwater in the United States. By reducing the amount of fresh water consumed every year to pre-1970's level, our national water strategy creates a plan for long term sustainable usage of the United States' fresh water resources.

Dear members of the U.S. House of Representatives and the Senate:

One of the greatest challenges of our nation today is the supply of freshwater. As we grow to become a leading global power, the limited supply of freshwater that our nation has remains to be one of our greatest problems. It is projected that at the current levels of water use and availability, by 2025, we will have reached the critical point for our freshwater supplies. Thus, it is critical that we plan ahead and solve this problem before the impending catastrophe.

In this report, we present a model of our plan for water use in the United States. Through considering current trends in the freshwater usage, we estimate the projected water demand in 2025, and then design a protocol by which the United States can efficiently and cost-effectively meet these growing needs. At the same time, our model proposes approaches via which the U.S. can fulfill the effective storage, movement, desalination, and the reduction of consumption of water, thereby leading to a conservation of freshwater to also meet future demand.

Our model accomplishes these goals in several ways. The first part of our model projects the demand for fresh water in the United States by projecting trends based on data collected by the United States Geological survey. Then we use these projections, along with the ratios of fresh water use to saline water use to extrapolate the estimated fresh water usage in 2025 based on current trends. The second part of our model consists of sub-models that project the effects of various components of our national water strategy, the costs involved, and how they are able to reduce/alleviate the need for fresh water usage in 2025. Then we combine the the total water saved through our plan to extrapolate the water usage needs. The sum of the costs of the individual sub-models will represent the total cost for our national water strategy.

Our plan tackles the main areas of water storage, transportation, effective utilization and household water conservation efforts to reduce overall fresh water consumption in the United States to sustainable levels.

Through the implementation of our national water strategy, we successfully alleviate projected fresh water demands in 2025 from 364 billion gallons of water per day to 304 billion gallons of water per day; reducing overall usage/consumption of fresh water resources by 26.5% by 2025.

Sincerely, members of team 2461

## I. Introduction

Water, it is the essence of life; two hydrogen atom attached to one oxygen atom, its unique chemical properties are the perfect fit to allow life on earth. 71% of earth's surface is covered by water, yet 97% of those water are salt water. 3% of the water on earth is freshwater, and 2% of those are locked away in polar icecaps. Yet the remaining 1% of water has to support almost all terrestrial life, including humans. As the global population continue to grow, water resources around the world will get more and more scarce. By 2025, we may reach a limit on the water resource supply of the world. Thus in the interest and the continual survival and prosperity of human kind, it is Imperative to take immediate action to not only avoid this catastrophe, but to ensure the long term stability and sustainability of water resources for the next generations.

## II. Interpretation and Restatement of the Problem

As the United States continue to grow and prosper as the dominant global power, the limiting freshwater resource will become a major obstacle to the continued growth and prosperity of the U.S. While freshwater is a renewable resource, the demand for freshwater is exceeding the supply in many areas of the U.S.

Our Objectives are:

Based on current water supply and demand data, create a projection for the estimated amount of water demand in 2025. Then come up with plans in which the U.S can cost-effectively fulfill this demand while minimizing the need for fresh water resources through effective storage, movement, desalination, and reduction of consumption, there by conserving United State's limited fresh water resources.

## III. Assumptions and Justifications

1. No major natural or man made catastrophes will affect water resources during 2009-2025

   It is very difficult, if not impossible to model the unpredictable effects of large scale natural disaster such as a asteroid impact or man-made disasters such as global nuclear war on the water resources within the U.S.
2. If our plan is adopted, the American people will enact the policies stated in this model by 2025.

   Given 15 years and tax incentives as we will state later in the paper, it is reasonable to assume that the overwhelming majority of people will take such actions not only motivated by altruistic and patriotic motivations, but also by economic incentives.
3. The ratio of saline water usage to fresh water usage stays constant within various categories of water consumption.

   It is very difficult to change the usage of water from fresh water to saline water, especially considering not everyone has access to saline water if they are not living close to the coast. The only except might be desalination plants which will be addressed in our model.
4. There will be no major deviations from the expected population growth, as indicated by the US Census Projections (2008).

   For both our water demand and conservation efforts, we assume the projections by the

U.S Census are accurate.

5. There be no creation of new water-intensive industries resulting in new economic sectors with large water consumption.
   We assume that no new water intensive industries might arise due to technological breakthroughs or dramatic global economic change as these abnormalities would be very difficult, if not impossible to include into our model given the lack of pre-existing data.
6. Policies as defined in our models will be enacted regardless of politics.
   We assume that politics are out of the picture for our plans, and that they will be carried out as they are stated in the paper. To include politics, we would be introducing a new set of unpredictable variables.
7. Inflation is ignored as all costs are adjusted to purchasing power of 2009
   This would merely effect the interpretation of data for the cost of this project, adjusting for purchasing power of 2009 merely simplifies the cost data.

## IV. Justification and Design of Model

Our model is broken down to two main parts. The first part consists of an accurate model of the projected need for fresh water supply in the 8 main sectors of water consumption: public supply, domestic, agricultural, thermoelectric, industrial, mining, and aquaculture uses. Each of the 8 main sectors will be broken down and analyzed using the data from the USGS on water usage for the past 50 years. Individual growth projection functions will then be created, and will be multiplied by the ratio of fresh to saline water used in order to isolate fresh water usage for each category. In order to extrapolate total projection needs, we will create a sum function of all individual growth functions. The overall function is designed to correctly predict our projected needs in 2025.

The second part of our model consists of a plan to lower need for water that includes 5 sub-models. The first allows for reduction of public water supply needs. By conserving water in individual household units, we can improve immensely as a whole country. Our second sub-model decreases agricultural uses for water by converting irrigation systems to ones of better efficiency and by geologically distributing crops according to the respective water needs of an individual crop. The third sub-model reduces thermoelectric power plant water utilization through implementation of new technology. Our last sub-model involves legislation controlling the fresh water usage by aquaculture. We will also address the efficiency desalination.

Variables in Projected Needs Model:

1. x=the year
2. $y_{pu}$=projected public needs
3. $y_{do}$=projected domestic needs
4. $y_{ag}$=projected agricultural needs
5. $y_{th}$=projected thermal needs
6. $y_{in}$=projected industrial needs
7. $y_{mi}$=projected mining needs
8. $y_{aq=}$projected agricultural needs
9. $y_{to}$=total projected needs

**Units: Unless otherwise stated, all units of water consumption are in billions of gallons of water per day.**

In the following section, we will be addressing the projected water needs of the United States in 2025 by considering recent trends in the major categories of total water withdrawals.

PART I: PROJECTED NEEDS MODEL

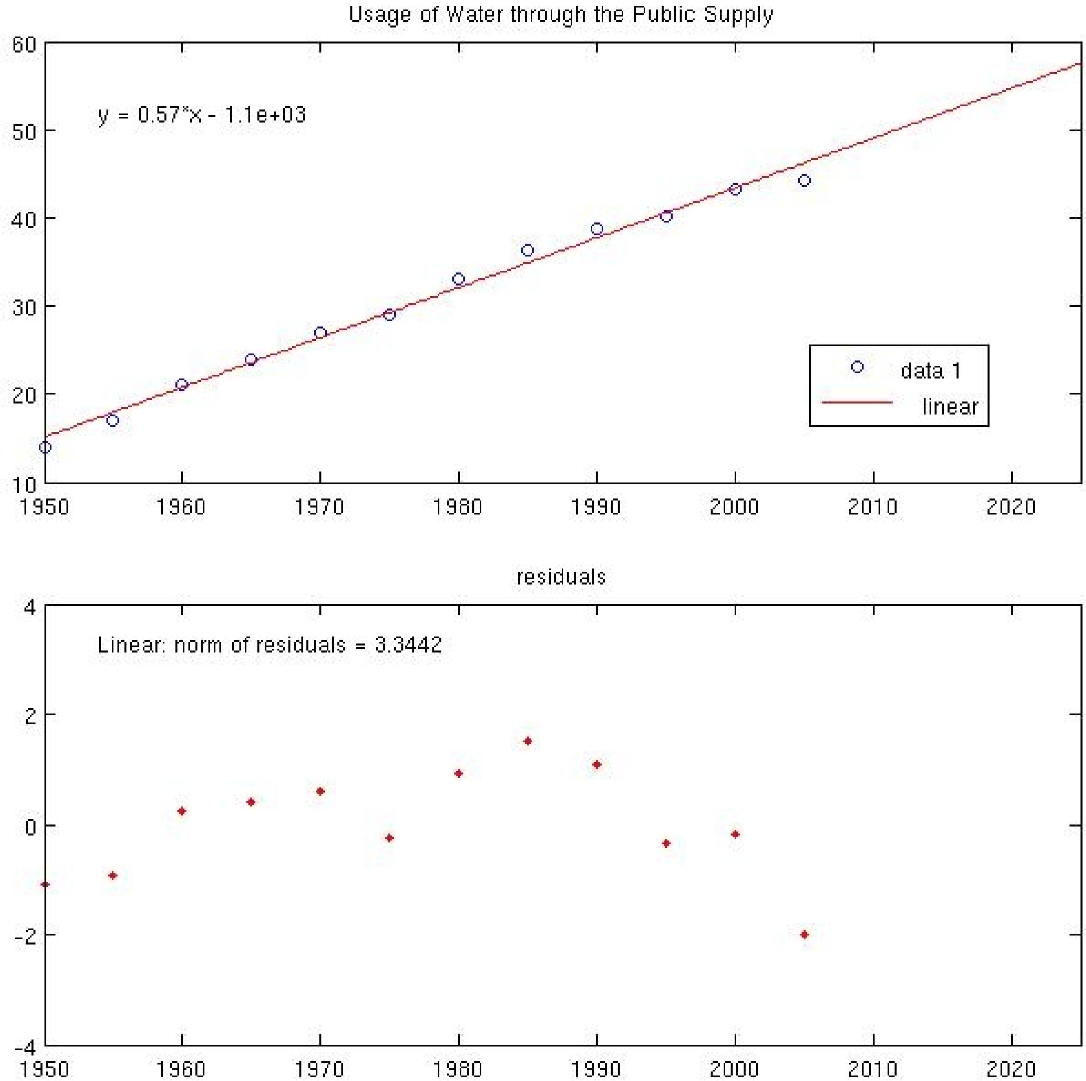
**Total Water Withdrawals of 2005**

Total water withdrawals in the United States of 2005 were estimated for eight categories of use: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric-power generation. Thermoelectric power was the largest category of water use, followed by irrigation and public supply. The remaining categories accounted for less than 10% of the total water withdrawals. Total freshwater and saline-water withdrawals were estimated to be 410,000 Mgal/d, or 460,000 thousand acre-feet per year. Freshwater withdrawals of 349,000 Mgal/d made up 85% of the total, and the remaining 61,000 Mgal/d (15%) were saline water. Most saline-water withdrawals were seawater and brackish coastal water used to cool thermoelectric power plants.

**Water Usage through the Public Supply**

Public water supply refers to water withdrawn by public and private water supplies that provide water to at least 25 people or have a minimum of 15 connections. Public-supply water is delivered to users for domestic, commercial, and industrial purposes. Public supply represents about 13% of total freshwater withdrawals, and 21 percent of all withdrawals, not including thermoelectric power. An estimated 258 million people rely on public water supplies for household use. This represents about 86% of the total US population.

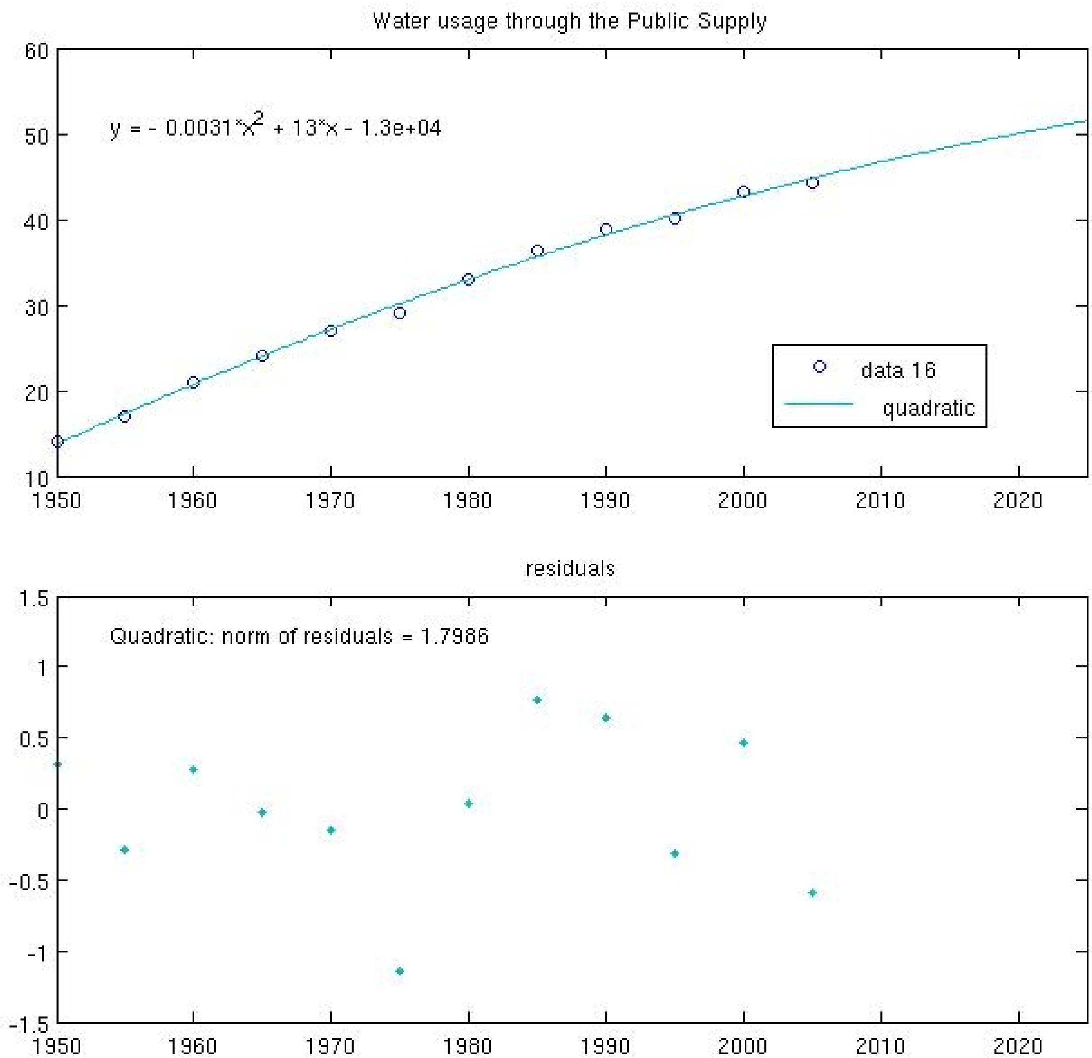
Part of the total, often unbilled, issued for public services, such as pools,parks, firefighting, water and wastewater treatment, and municipal buildings. A certain amount of public-supply water is lost because of leaks, flushing, tower maintenance, and other system losses. In our further submodels, we will address this issue by trying to minimize the water loss due to the major problems of leaks and flushing.




Linear regression model of the usage of water through public water supply based on the data from USGS 5-year reports since 1950.
$y_{pu}$ = p1*x + p2 Coefficients: p1 = 0.56545 p2 = -1087.5
Norm of residuals = 3.3442

We can see from the residual model that our linear regression line of the Public Supply consumption of water in the U.S relatively well, with the regression line falling within ±2(BG/D)

However, according to the U.S census, the U.S population is projected slow down in growth due to the increased death rate from an older population as well as decreased birthrates, thus it is completely reasonable to see that the rate of water consumption increase will decrease over time, Thus we came up with our 2nd regression line, which is a cubic regression that more accurately model a decrease in the increase of water consumption.




This quadratic regression shows a better fit both in terms of norms of residuals and the projected slowing of the increase of the population of the United States(which, according to the US census, will be 350 million in 2025). It is also foreseeable that with the gradual increase in population, land use per capita will decrease, thus there would be a decreased need per capita of water used on landscaping and aquatic entertainments like private pools.

$y_{pu}$ = p1*x^2+ p2*x + p3
Coefficients p1= 0.01372 p2 = -54.1186 p3 = 53693.6
Norm of residuals = 1.4895

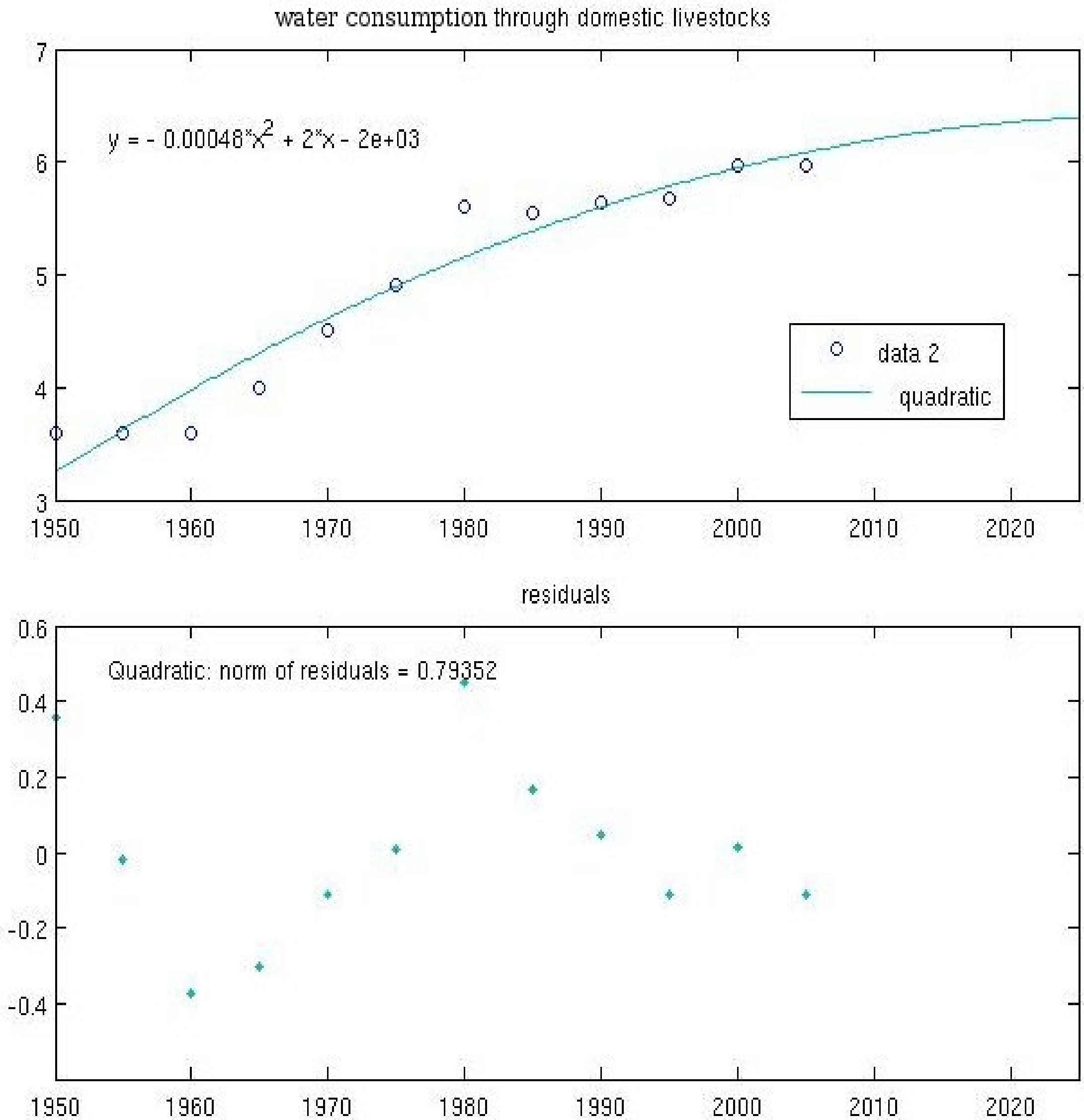
From this model, we can see that not only does our residual plot fall within ±1.2(BG/D) but that we also get a decrease in the rate of increase of water consumption. Thus we choose this model as our model for the projection of usage of water through the public supply.

When we plug in the future years into our regression function, we get the following results.

| | |
|---|---|
| 2010 | 46.7 |
| 2015 | 48.4 |
| 2020 | 50.0 |
| 2025 | 51.5 |

**Domestic(Self Supplied) and Livestock**

Self supplied domestic water are water withdrawn from a groundwater or surface-water source by a user rather than being obtained from a public supply. Majority of water for domestic use is still from the public supply, and self supplied domestic water are mostly used in rural areas, thus they are grouped with usage of water by livestock. Livestock water consumption includes water consumed by domesticated animals such as cows, pigs, chickens and other livestock. Live stock water consumption does not include water used in raising aquatic organisms such as fish and shrimp as those are included in a separate category under aquaculture.




The data for the domestic(self supplied) and livestock water consumption does not correlate well with most forms of regression lines/curves, however the quadratic regression line does give a reasonable model for predicting future domestic(self supplied) and livestock consumption of water in the United States given our assumption that there will be no major changes in the economic trend.

$y_{do}$ = p1*x^2 + p2*x + p3
Coefficients: p1 = -0.00048162  p2 = 1.9564  p3 = -1980.5
Norm of residuals = 0.79352

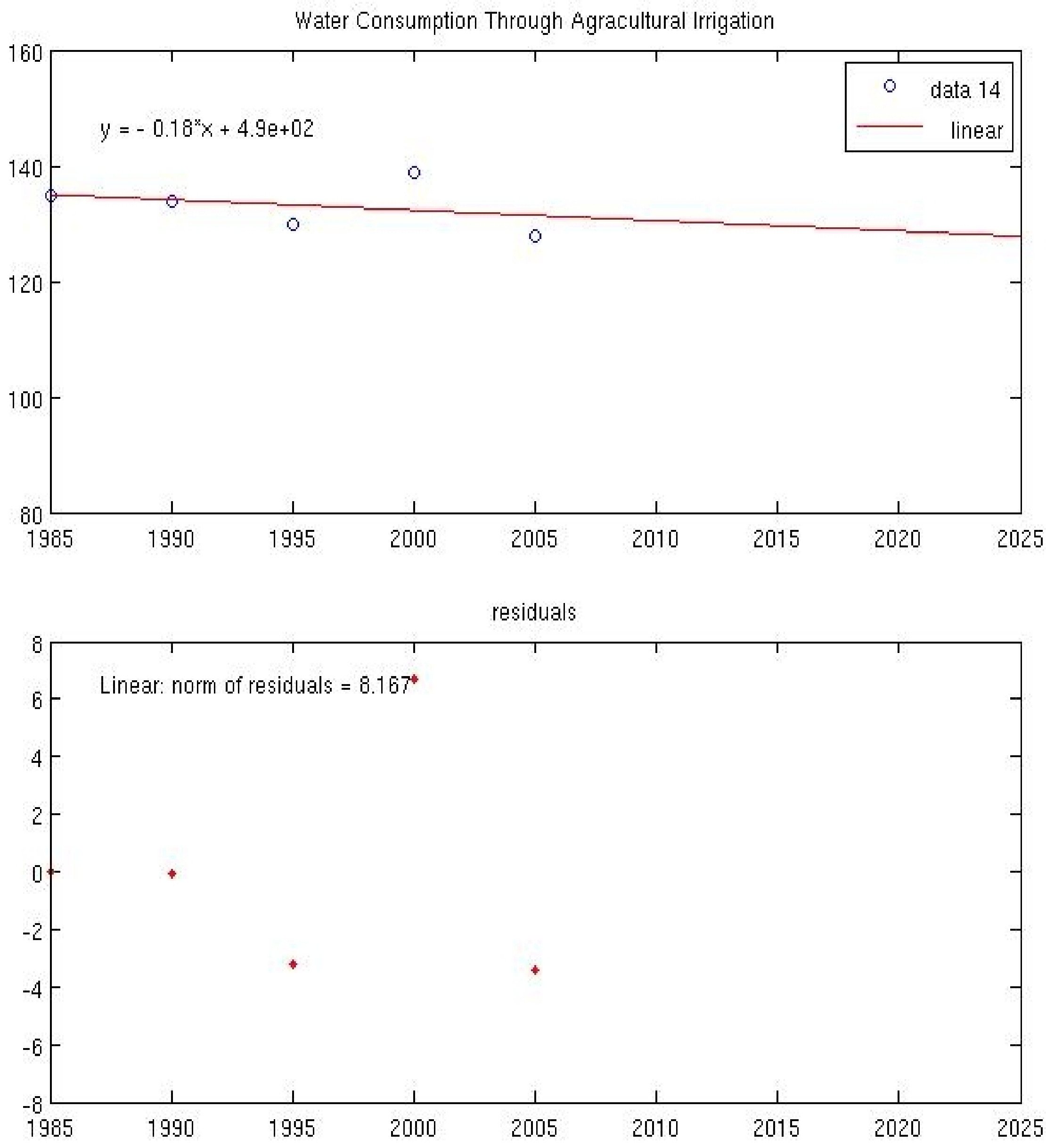
From the model, we can see that the water usage through domestic(self supplied) and livestock is projected to increase, but only at a steady rate. Again, while our Norms of residual might be relatively high in terms of error percentage, the model is still an accurate model for future water consumption through domestic(self supplied) and livestock due to the high correlation our model has with the 4 most recent data points.

When we plug in the future years into our regression function, we get the following results.

| | |
|---|---|
| 2010 | 6.20 |
| 2015 | 6.29 |
| 2020 | 6.35 |
| 2025 | 6.39 |

**Water Use Through Irrigation of Farmlands**

Irrigation water use includes water that is applied by an irrigation system to sustain plant growth in all agricultural practices. Irrigation includes the water that is applied for pre-irrigation, frost protection, application of chemicals, weed control, field preparation, crop cooling, harvesting, dust suppression, leaching salts from the root zone, and water lost in conveyance. Total irrigation withdrawals were about 128000 Mgal/d, or 144000 thousand acre-feet per year. Irrigation withdrawals were 37 percent of total freshwater withdrawals and 62 percent of total freshwater withdrawals for all categories excluding thermoelectric power.



We only use the last 5 data plots in the USGS survey of water consumption by irrigation due to the wide ranging nature of data before 1985, while the last 5 data points from 1985 onwards shows a stable trend.

$y_{ag} = p1*x + p2$ Coefficients: $p1 = -0.18$ $p2 = 492.3$
Norm of residuals = 8.167

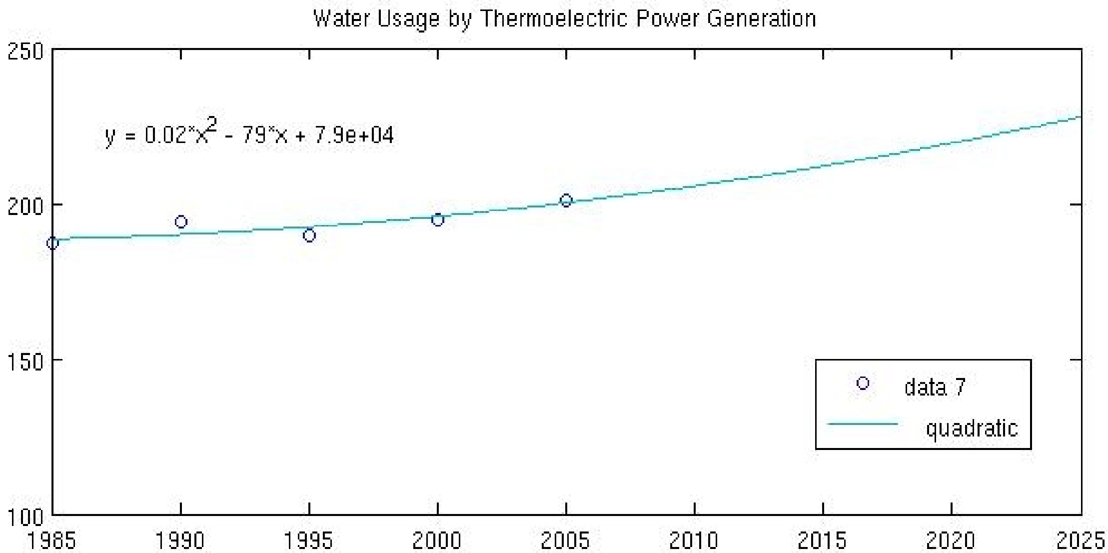
From our model, we can see that the norms of residual data are still within relatively acceptable ranges. While it is foreseeable that the demand for American agricultural products will rise both domestically and internationally, current trends towards new agricultural techniques and more eco-centric farming practices should lead to an overall reduction in the usage of water. Agricultural exports from the United States have also greatly fallen in the past few years according to data from the USDA, and it is foreseeable that other developing countries will enter in competition with the U.S on agricultural products on the international market.

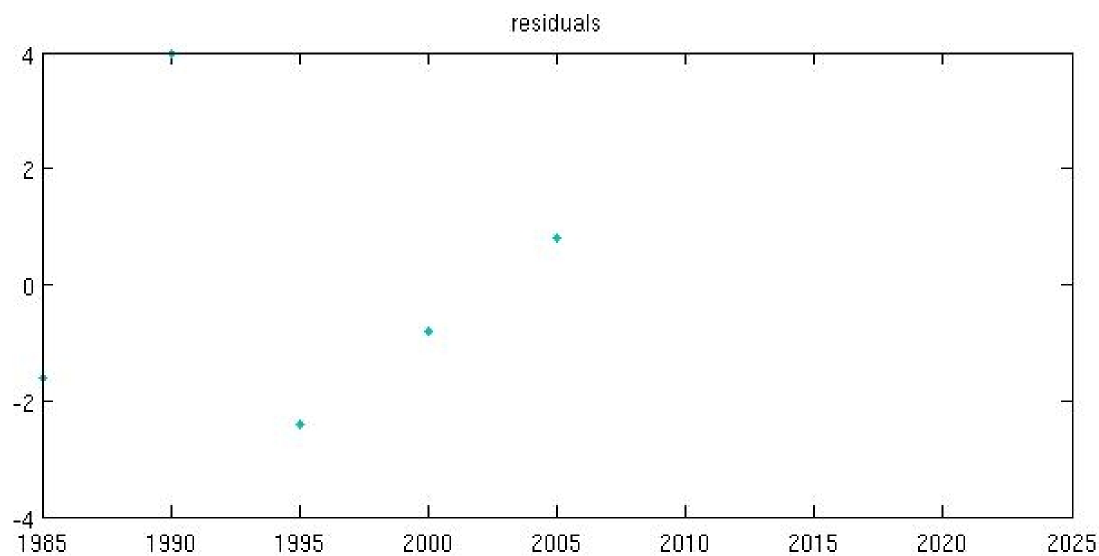
When we plug in the future years into our regression function, we get the following results.

| | |
|---|---|
| 2010 | 130 |
| 2015 | 130 |
| 2020 | 129 |
| 2025 | 128 |

**Thermoelectric Power Generation**

Thermoelectric power generation refers to any electrical generation system which utilizes heat in the generation of electrical power. As the demand for electricity rises in the United States, it is foreseeable that we're going to need more electrical power stations to keep up with power demands. However thermoelectric power generation is also one of the top users of water within the United States, using over 200 Billion Gallons of water per day. While some power plants contain water recycling systems which return used water back to the source, there are still very significant percentage of power stations which uses once-through cooling, which wastes a lot of freshwater resource as steam, given back into the atmosphere.




For the water used through thermoelectric power generation, we also only used the last 5 data points. The overall data for water usage by thermoelectric power generators shows little correlation if we include the data from pre-1985 data points. Therefore, we concluded that the model would yield more accurate predictions if we only included the past 5 data points from 1985-2005.

$y_{th}$ = p1*x^2 + p2*x + p3 Coefficients: p1 = 0.02 p2 = -79.22 p3 = 78636
Norm of residuals = 5.0596

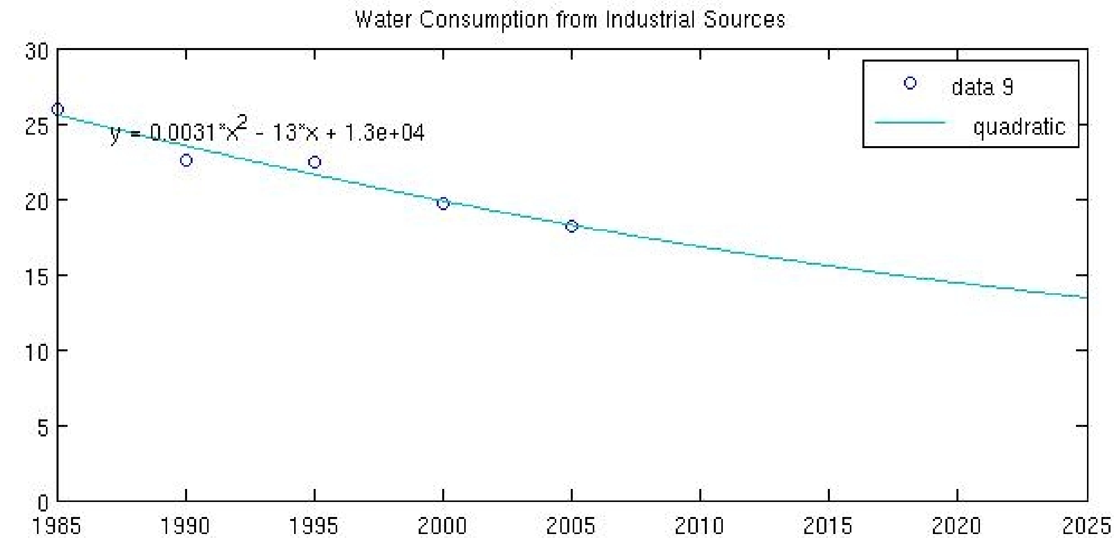
From our regression model, we can see that the usage of water by thermoelectric power generation will increase slightly in the future. The residual show good correlation between the data points and our regression function.

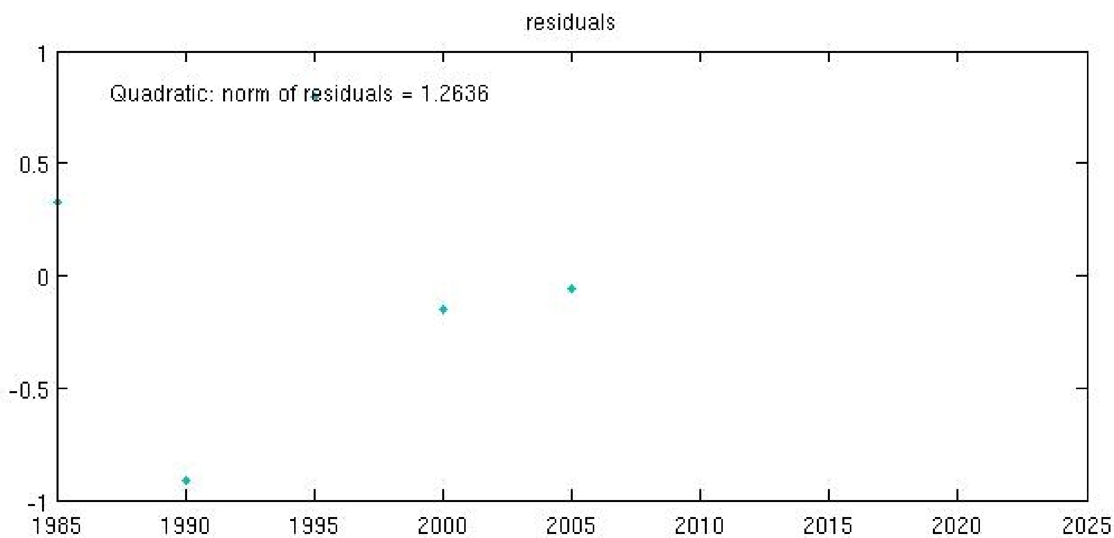
When we plug in the future years into our regression function, we get the following results.

| | |
|---|---|
| 2010 | 206 |
| 2015 | 212 |
| 2020 | 219 |
| 2025 | 228 |

**Industrial Use**

Industrial uses for water include creating, processing, dilution, cooling, or movement a product. It can also contribute to disinfection inside the production site. Industry utilizes 18,200 million gallons of water everyday, 93% of which is fresh water. The usage makes up 4 percent of total water withdrawals, and 9% of total water withdrawals excluding thermoelectric power.




For water consumed by Industrial sources, we also used the last 5 data points to allow for a well correlated regression to better model the future demand from this specific source. As the U.S follows the economic trends of developing nations, more of the economy will be centered around service based industries, while moving away from industrial production of goods. Hence this model makes logical sense in that as less and less industrial production occur in the U.S, the demand for water from industrial sources would also decrease.

$y_{in}$ = p1*x^2 + p2*x + p3 Coefficients: p1 = 0.0031429 p2 = -12.906 p3 = 13260
Norm of residuals = 1.2636

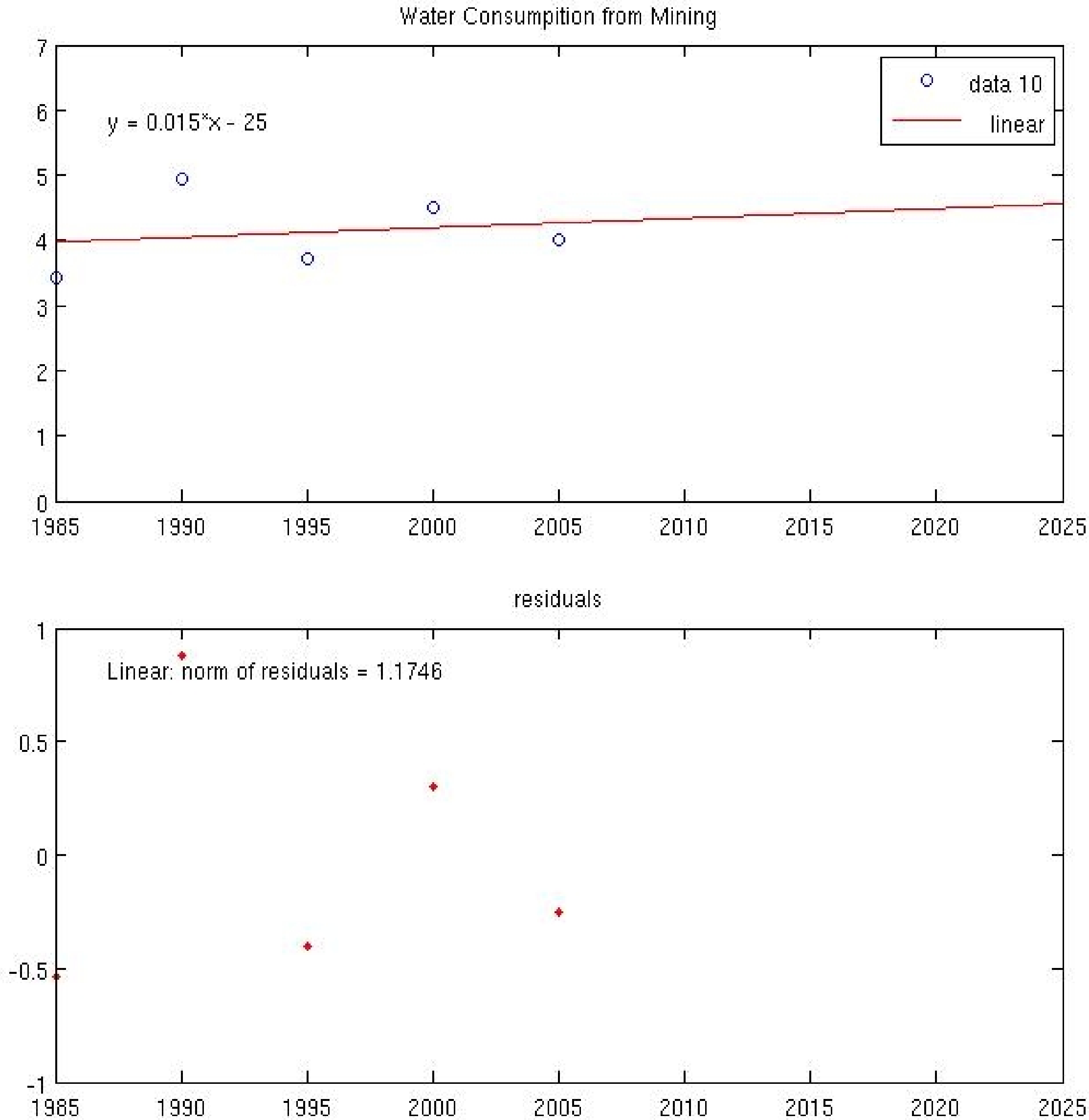
The residual graph shows relatively strong correlation and the regression line shows that future water consumption from industrial sources will gradually decrease.

When we plug in the future years into our regression function, we get the following results.

| | |
|---|---|
| 2010 | 16.8 |
| 2015 | 15.5 |
| 2020 | 14.4 |
| 2025 | 13.5 |

**Water Consumption from Mining**

Mining requires water for obtaining minerals (such as coal, iron, petroleum, and natural gas) through quarrying, and milling. The process uses an average of 4,020 million gallons per day, and around 57% of the total water used is fresh water. Mining makes up around 1% of all withdrawals, and 2% of all withdrawals excluding thermoelectric power.




For water consumption from Mining, we choose a linear model due to the sinusoidal nature of the data points. Because the sinusoidal graph centers around a linear regression line, it would be more reasonable to simply use the linear regression line instead of trying to estimate the trends of peaks and troughs, we simply use a linear regressions line to predict their expected average value.

$y_{mi}$ = p1*x + p2 Coefficients: p1 = 0.0146 p2 = -25.005
Norm of residuals = 1.1746

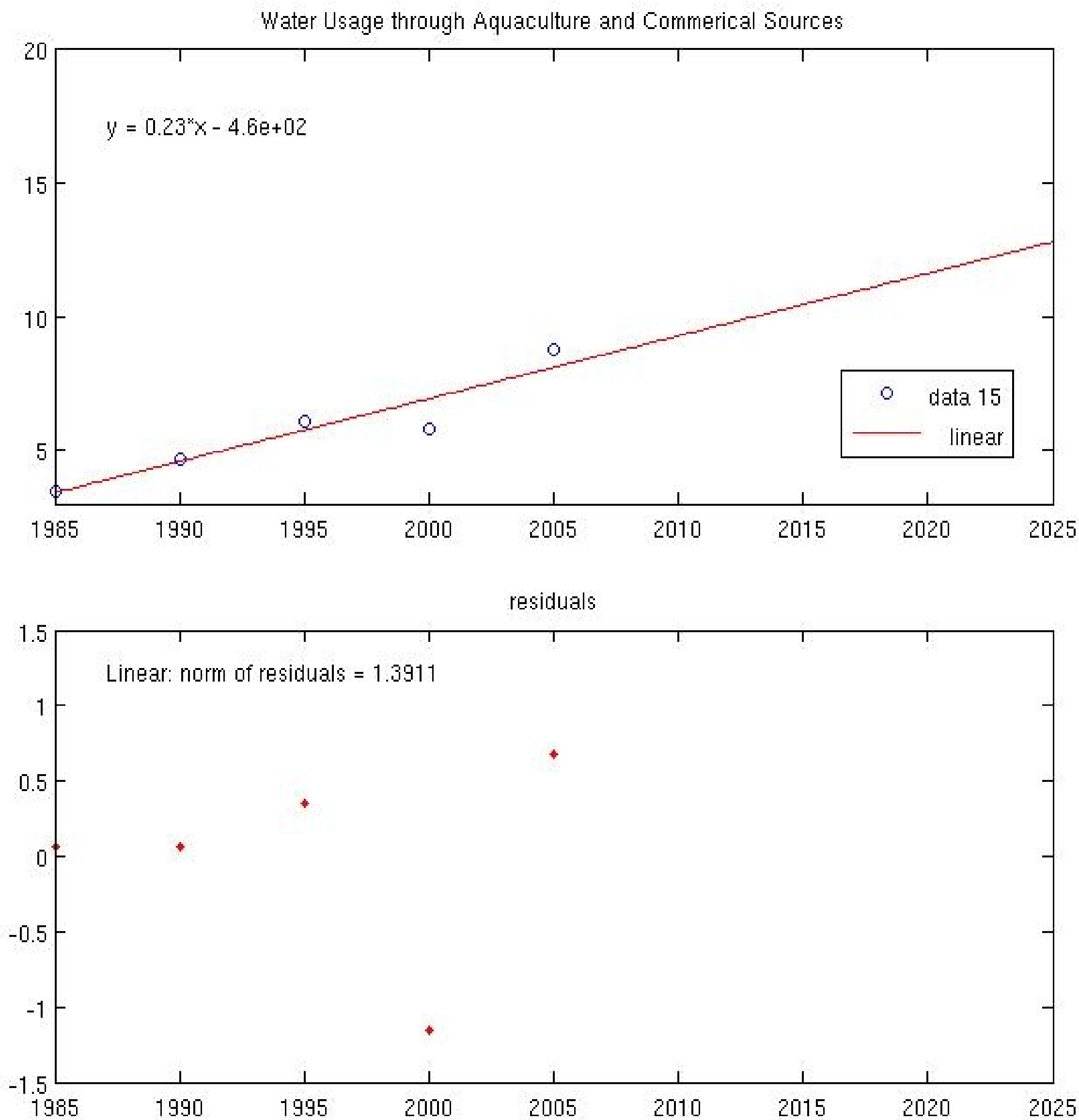
From our regression line, it shows that the water consumption by mining will rise, but only by minuscule amounts. While the residual graph does not show strong relative correlation, but linear regression of this type of dataset should yield reasonable predictions.

When we plug in the future years into our regression function, we get the following results.

| | |
|---|---|
| 2010 | 4.34 |
| 2015 | 4.41 |
| 2020 | 4.49 |
| 2025 | 4.56 |

**Aqua-cultural and Commercial Sources**

Aquaculture is the growing water-residing organisms such as fish. The goal of aquaculture is to provide a clean and controlled environment for optimize healthy growth. Therefore, to raise these aquatic beings, the US uses an average of 8,780 million gallons of fresh water per day. The water resources used constitutes 2% of total withdrawals, and 4% of total withdrawals excluding thermoelectric power. Commercial uses also make minor additions to water usage. These causes include providing resources for motels, hotels, restaurants, various commercial facilities, military facilities, off-stream fish hatcheries, etc. Commercial contributions make up less than 2% of total withdrawals, excluding thermoelectric power.




For water usage through aquaculture and commercial sources, we choose a linear regression, which fits the given data points better than other polynomial, power, exponential, or logarithmic regression curves.

$y_{aq}$ = p1*x + p2 Coefficients: p1 = 0.235 p2 = -463.07
Norm of residuals = 1.3911

Residual plot shows moderate correlation with the data points. Overall, the Water Usage through aquaculture and commercial sources will increase, at a relatively substantial percentage if it continues at the current trends.

When we plug in the future years into our regression function, we get the following results.

| | |
|---|---|
| 2010 | 9.28 |
| 2015 | 10.5 |
| 2020 | 11.6 |
| 2025 | 12.8 |

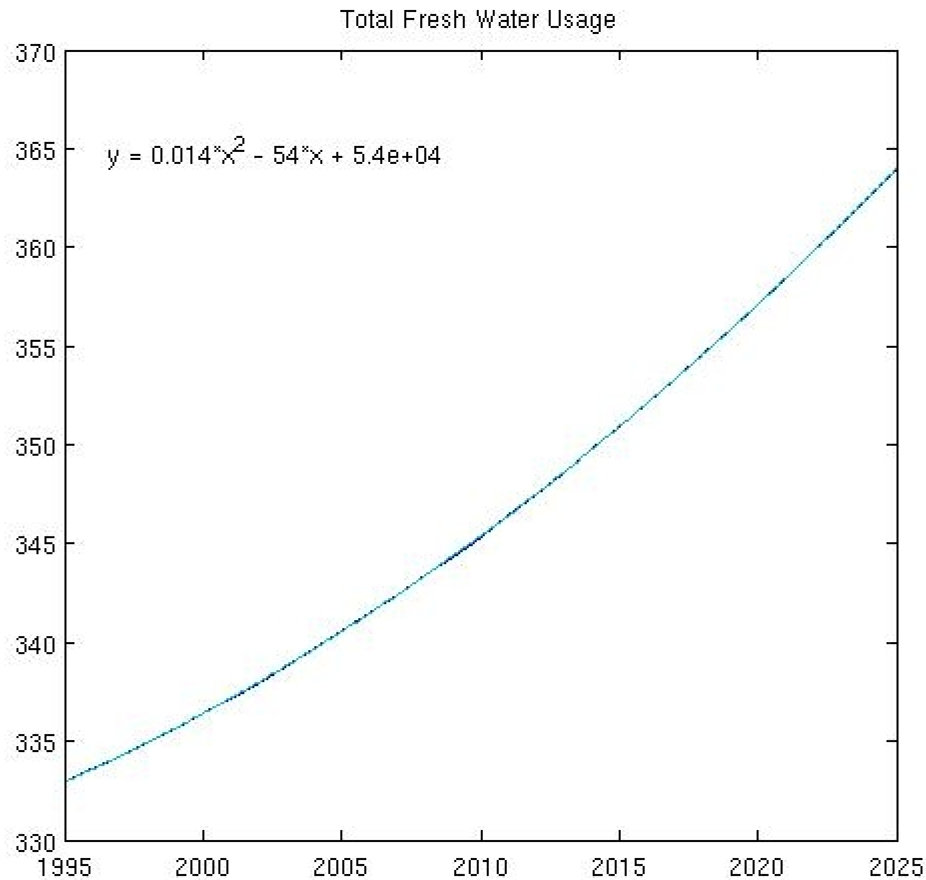
Now we have the projected usage for each individual major component of water consumption, we can not only take the regression lines to project the future water usage/consumption rates, but we can find the sum of them, which will be the projected need for water in the United States in 2025.

**Freshwater Usage/Consumption**

Not all of the water used/consumption in the United States if from freshwater sources. In the Same USGS report, break downs of how much water is from fresh vs saline sources is given for each major category above. The data for water withdraws given by the USGS report are recorded within the following chart.

| Category | Freshwater | Saline |
|---|---|---|
| Public Supply | 100%* | 0%* |
| Domestic+Livestock | 100%* | 0%* |
| Agriculture | 100% | 0% |
| Thermoelectric | 72% | 28% |
| Industrial | 92% | 8% |
| Mining | 57% | 43% |
| Aquaculture | 100% | 0% |

If given our assumption that the ratio of saline water use to freshwater use will remain constant for the course of our model, we use the regression projections of total water use/consumed and the % of freshwater usage in each of the categories to extrapolate the total freshwater used/consumption in 2025.




To obtain a model of the total projected needs of the US, we created a sum function of all fresh water consumption areas.

From our submodels, we have:

1. $y_{pu}$=-0.0030869*x^2+12.774x-13158
2. $y_{do}$=-0.000482x^2+1.956x-1980.5
3. $y_{ag}$=-0.18x^2+492.3
4. $y_{th}$=0.02x^2-79.22x+78636
5. $y_{in}$=0.0314x^2-12.9906x+13260
6. $y_{mi}$=0.0146x-25.005
7. $y_{aq}$=0.235x-463.07

Because thermoelectric, industrial, and mining categories only utilize 72%, 92%, 57% freshwater respectively, we multiplied each regression equation by .72, .92, and .57 to account for partial fresh water usage.

Thus, $y_{to}= y_{pu}+y_{do}+y_{ag}+(.72)y_{th}+(.92)y_{in}+(.57)y_{mi}+y_{aq}$=0.01372x^2+12.774x-13158

When we plug in the future years into our regression function for the sum of fresh water usage, we get the following results.

| | |
|---|---|
| 2010 | 345 |
| 2015 | 351 |
| 2020 | 357 |
| 2025 | 364 |

PART II: OUR WATER STADEGY STARTING 2010

**Public Supply Water Conservation Sub-model**

Water is used in many ways inside our households. By simply changing habits and implementing a national campaign that encourages water conservation, household water use – and therefore the public supply of water – can be significantly conserved. We will be using four different protocols for saving water in the household – preventing leakage, limiting the amount used per toilet, saving water in washing machines, and also changing amount of water flow in the shower. This will not require any change in human behavior, but we assume that by 2025, people will have switched to water-conserving appliances.

In homes, toilets consume between 25-33% of water. While legislation requires that the number of gallons per flush cannot be more than 1.6 gallons / flush, it is estimated that most toilets use 3.5 gallons per flush. We will introduce new legislation that requires that toilets use no more than 1.2 gallons of water everyday. As such, to calculate the amount of water used for toilets, we can use the model of population growth, where we assume that population grows via this following model from the Statistical Abstract of the United States (2008)

$P(t) = 0.0022675t^2 + 2.6804t + 300.760$ (where *t* is the number of years since 2007)

Where t = 18 years (2025-2007)

As such, following this model we have that in 2025 the national population is projected to be 349.7 million people.
We also assume that the national average for number of flushes per day is 5.5 flushes per capita
Thus we have that
$W_t$ = amount of water used nationally for toilets per day saved via new model
= (flushes per capita per day)(current number of gallons used per flush - number of gallons of water used per flush with new legislation)(projected 2025 population of the United States)
= (5.5 flushes per capita per day)(3.5 gallons of water per flush – 1.2 gallons of water per flush)(349.7 million people)
= 4.42 billion gallons of fresh water saved per day by this plan

Changing shower heads is also another way to conserve water. We assume that currently adults take one 12-minute shower per day, and that by 2025, legislation will require that only LF (Low-flow) showerheads, which use only 2 gallons of water minute, will be sold so that essentially all homes use this new shower system, versus conventional shower heads which use approximately 2 gallons of water per minute. Thus, assuming the previous model for population growth, we assume that the amount of water saved using the new shower system is

$W_s$ = (number of minutes spent in the shower per day)(current number of gallons used per minute in shower – number of gallons of water used per minute for new shower heads)(projected population in the United States in 2025)

= (12 minutes showered per person per day)(2 gallons of water per minute – 1 gallons of water per minute)(349.7 million people in the U.S. in 2025)

= 4.20 billion gallons of water saved per day

Leakage is another cause for much loss of public water supply. We will introduce awareness campaigns that reduce leakage, therefore conserving the public supply of water. The national average for leakage is 21.9 gallons of water per day. Thus, assuming 4.5 people per household, and following the previously stated population model, with national campaigns lowering water leakage by 50% per day, we have the amount of water saved

$W_l$ = (amount of water lost daily to leakage currently – amount of water to be lost to leakage daily in 2025)(number of households in the U.S.)

= (21.9 gallons of water – 0.5*21.9 gallons of water)(349.7 million people in the U.S.)/(4 people per household)

= 0.96 billion gallons of water saved per day

Clothes washers are another way that water usage can be reduced. The average household goes through 0.96 loads of laundry per day. Whereas conventional clothes washers use 40.9 gallons of water per wash cycle, large-capacity resource-efficient models use approximately 25 gallons per wash cycle. We propose legislation requiring that by 2025, only resource-efficient large capacity washers will be used, and that all washers have switched to these new models. As such, we model the amount of water saved as

$W_w$ = (amount of water used by conventional washers – amount of water used by cost-efficient washers) (average loads of laundry per household per day)(number of households in the U.S. In 2025)

= (40 gallons – 25 gallons)(0.96 laundry loads per day)(349.7 million people)(4 persons/household)

=1.34 billion gallons of water saved per day

As a result, the total water saved per day by implementing the water-efficient toilets, low-flow shower heads, better leakage systems, and efficient washing machines, we have

$W_p = W_t + W_s + W_l + W_w$

= 4.42 + 4.20 + 0.96 + 1.34 billion gallons

= 10.92 billions of gallons of water saved per day

**Water conservation in agriculture.**

Irrigation represents the largest usage of fresh water outside of thermoelectric power generation. Irrigation uses almost all freshwater, as plants will wilt if there is excess dissolved particles in water, losings turgidity and water due to water loss from osmosis to a hypertonic(water with excess salts) source. Irrigation comprises of 2/3rds of all freshwater withdraws in the United States and thus is a good target for water usage reduction.

One of the ways to reduce water usage through irrigation is the adoption of the conservation tillage system of farming for suitable plants. The U.S primarily grow corn, soybean, cotton, and peanuts, most of which varieties of plants are well adopted for use in conservation tillage systems. According to data provided by the USDA, an increase of 10% adaptation of conservation tillage on all compatible crops would result in the decrease of the total freshwater withdraws from agricultural irrigation sources by 4%. This technique has the added advantage of financially befitting farmers by reducing the needs for water, fertilization, and tilling, without the adverse effects of decreased crop yields. Thus this is one of the first tools we're going to use in our efforts to reduce freshwater withdraws from agricultural sources.

For our plan, we will introduce nation wide campaign to increase the use of conservation tillage to 60% by 2025. Based on current adaptation rate of 30%, this increase would reduce the total agricultural water usage by 12%.

The lessen of tillage on a field, if done correctly, not only greatly reduce water needs, but also reduces labor, machinery, chemical, and yields lower erosion rates. However, the change in farming techniques are going to require some convincing of the farmers through advertisement, and we will allocate 1 billion dollars over the period of 15 years which is 66.7million dollars a year on tax incentives and promotion of the conservation tillage system.

$C_{ir}$=1 billion dollar over 15 years.

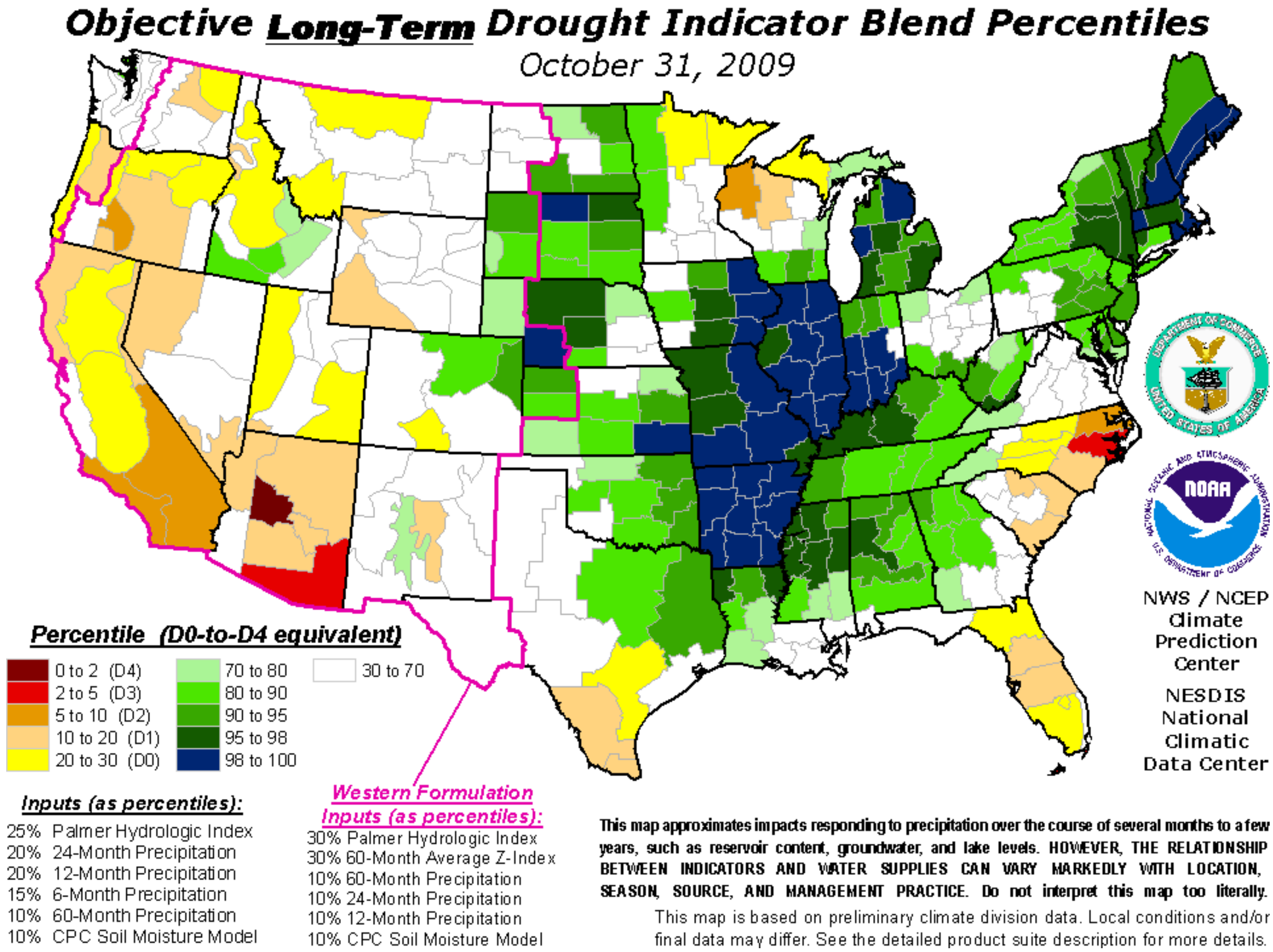
$W_c = Y_{ag} - L_i$

where W is the water saved, $Y_{ag}$ is the fresh water use originally projected in 2025, and L is projected water use after our plan has been implemented in 2025

$W_c$= 128-113

$W_c$= 15 billion gallons of water saved per day.

The second part of our plan to conserve agricultural water use is to prevent evaporator loss from water in transit in canals.




As seen by the above map, certain areas of the United States are more arid and prone to drought than others. Thus, as part of our strategy, we will allocate a certain amount of funds to building canals, aqueducts, reservoirs, and other water projects in order to distribute water more evenly throughout the country.

Much of the arid areas with droughts depend on unsustainable use of groundwater for their freshwater supplies, thus our plan is to build a system of canals and reservoirs to alleviate the states with the worst drought conditions. Thus for all our purposes, the water collected by the reservoirs in places of the nation with excess water then delivered to arid areas of the nation with the need for irrigation water will not count towards the projected fresh water withdraws.

A recent project in Arizona's Yuma County lines 25 miles of earthen and badly deteriorated canals with concrete, as well as replacing the deteriorated structures. The project allows members of an association farm to have access to over 53,400 irrigable acres, with 45,000 to 46,000 acres in production. The project costs $6,161,432 for constructing 25 miles of canal. Thus, each mile of canal costs $246457.

In a Nevada Creek Canal, the construction cost estimate was \$41000 and \$49000 was further used to reduce sediment load in the canal. The Nevada Creek Canal was 2000 feet long. Thus, the average mile of canal cost
(41000+49000)/(2000/5280) = \$237600.

Thus, we can estimate the cost of building one mile of concrete canal to be \$237000. In addition, we assume that each mile of canal built will account for 1840 acres of irrigable land. Thus, by building canals in the areas with low precipitation, we can ensure a large amount of crops to be planted in those areas. We thus will create canals to areas in the arid west to alleviate drought. A canal can provide 350,810,534 gallons of water a day to a city.
We can build canals in California, Arizona, Nevada, Texas, New Mexico, and Oregon. The area of these six states together is 876,830 square miles, which is equivalent to 561,171,200 acres. On average, 20% of this land is currently put aside for agricultural purposes. Thus, the amount of land we will consider is 112,234,240 acres. We assume that one mile of canal can provide for 45,000 acres of agriculture. We see that 2494 miles of canal should be created. In addition, we assume that half of the land is already supplied by already existing, thus, all we have to do is construct an additional 1247 miles of canal. Assuming that each mile of the canal costs \$237000, we will be spending \$295,550,165 on this project. Assuming that each canal branch is approximately 50 miles, we will be providing 25 x 350810534 gallons of water, which is 8,750,000,000 gallons of water a day. Irrigation requires 128,000 billion gallons per day according to the USGS. Thus, this system will account for 6.4% of the total irrigation water, although requiring \$295,550,000. Approximately every 3.3 miles, canal diversion points must be attached and pipeline must be installed. Polyurethane lining must also be applied. Polyurethane lining must be applied at a rate of \$1,186,666 per mile. Thus, the 1247 miles of canal and their branches and pipelines, costs an extra \$1,479,773,000. Thus, adding these two costs together, we find that the project will cost roughly \$1,775,323,000.

Fresh water for agriculture will be accounted for in arid states. The canals will be connected to suppler canals in neighboring states with higher average rainfall, a further 2 billion dollars will be allocated to the building of reservoirs collecting excess rainfall that would of otherwise be wasted. The total project cost would amount to 3.78 billion dollars

Thus Total cost of agricultural water projects from promoting conservation filling systems to building new irrigation canals comes to 4.78 billion dollars over 15 years. While the total water saved would come to 6.4% of the total irrigation water in 2005, due to the data given by USGS. Which comes to 8.19billion gallons of water per day.

$$C_{ag}=3.78+1$$
$$=4.78 \text{ billion dollars}$$

The total water saving would be

$$W_c+ 8.19= W_{ag}$$
$$W_{ag} = 23.2 \text{ billion gallons of water per day saved}$$

**Thermoelectric power generation sub-model**

Thermoelectric power generation accounts for the largest proportion by far. It accounts for 41% of all fresh water withdrawals in the United States. In 2005, 3,190,000 gigawatt-hours of energy was produced by thermoelectric power plants, using about 23 gallons of water to produce 1 kilowatt-hour of energy. Much of these water withdraws are inefficient and loses large amounts of water due to evaporative loss and leakages.

Such problems has already been a topic of research for NETL, the national laboratory for the department of energy. Under the Innovations for Existing plan, they plan to "develop cost-effective technologies for commercial demonstration by 2020 that will reduce water usage and consumption by 70%"(U.S House of Representatives committee on science and technology, subcommittee on energy and environment) However, the annual funding of 12million dollars on this project has been cut from the budget in 2010.

We believe that we should continue the funding of such R&D programs, as water usage by thermoelectric power plants consists of the overwhelming portion of total water withdraws/usage. Furthermore, we plan to invest more money as tax intensives for the power plants to adopt such technology once it becomes available.

For our model, we assume a their estimate for the actual reduction in water reduction brought on by these new technologies, an cost effective improvement of 70% decrease in the water usage and consumption in power plants by 2020. Then we assign a certain budget "$S_{te}$" to implement such technology in 20% of the largest freshwater consumption especially in the states with the scarcest such as Texas, California, Arizona, and Colorado.

This would mean for we would reduce 20% of freshwater withdraws by 70%, hence a 14% overall reduction in freshwater withdraw. Since we also implemented these water saving systems in already water-scarce areas of the nation, that would mean that these freshwater can immediately be put to use in irrigation and/or included into the public supply.

According to our model for the projection, the total fresh water use for the power plants in 2025 will be [228BG/D*.72(% of water from fresh water sources)] = 164 billion gallons of water per day.

Now with the application of our technology, we would have a 14% reduction in the overall consumption of freshwater through thermoelectric power generation. Therefore, the reduction would be 164*.14=22.96 billion gallons of water per day.

$W_{te} = 22.96$ for the freshwater saved by this plan.

For the Cost of this plan, we have the annual 12 million dollars allocated to R&D of such technology as state by the House committee plan, which the cost, in millions of dollars would be

$C_{te}$ =.012(x)+"$S_{te}$"(x) where x is the number of years from 2010 till 2025 and C is in billions of USD

For the $S_{te}$ cost, we assume that the implementation of these technologies would be equivalent to the cost of 5 million dollars per power plant (which is about 1/20$^{th}$ of the construction cost of a 350Megawatt power plant). These new technologies would be implemented during normal plant overhauls, at which time the 5 million dollars would go towards efficiency upgrades developed by the R&D team. We assume its within the normal budget of the power plants to plan for these overhauls, therefore, the 5 million is solely dedicated towards the newer technology, rather than the total overhaul cost. There are 847723 thermoelectric power plants producing 3,190,000 gigawatt hours of energy. That averages out to 376 megawatts per power plant. 10% of 847723 power plants are 84772 power plants that need to be re-renovated, which would cost 847.72 billion dollar. While this cost sounds like an outrageous amount of money, distributed over the course of 15 years, this plan would only need an annual budget of 28.8 billion dollars a year. This is a much more reasonable amount of money, and this can be easily accounted for if we just adjust the price of electricity per kilowatt hour. Current national average for the price of electricity is 9.95 cent per kilowatt hour, so if we raise the cost of electricity by .5 cent per kilowatt hour, difference in gains from selling 3,190,000 gigawatt of energy would raise the funds needed

$$S_{te}=(28,800,000,000)-(.005)(3,190,000*10^9)/(10^3)$$
$$S_{te} = 12.85 \text{ billion dollars a year}$$

Different numbers can be plugged into the original assumed amount of power plant renovated through the use of the new technology, yielding different costs and water saved, but for our model, we choose to model the 10% in the most water scarce part of the nation to minimize the transportation of the water that is saved through this process.

Our Overall Cost function for the Thermoelectric sub-model is:

$$C_{te} = .012(x)+\text{"}S_{te}\text{"}(x)$$

and specifically for the number of power plants we choose to renovate,

$C_{te}$=192.9 billion dollars over the period of 15 years.

While this number still may seem very large, however it is only a one time investment. This single investments improving the water use efficiencies of thermoelectric power plants would yield great permanent amounts of water savings.

**Aquaculture/commercial water savings sub-model**

One of the largest growing sectors of water consumption by percentage growth projections for 2025 is the growth of the aquaculture/commercial sector's water use. By our projects, Aquaculture and commercial use of water will increase by 46% (at about 2.6% per year), to 12.8 billion gallons of water used per day. While it is important that our aquacultural and commercial industries have enough freshwater to sustain their growth, but it is also necessary to conserve our precious fresh water supplies.

Therefore we propose to introduce a legislation that will cap the growth of aquacultural and commercial usage of fresh water to 1% a year, resulting in the total increase from 2005 to 2025 to be caped at 16.1%

This would still allow reasonable growth within the aquacultural and commercial sectors of the economy, but also greatly reducing the amount of water consumed by 2025.

Through the passing of this legislation and the enforcement of these policies, by 2025, the water saved would be the difference between the original projected growth and the limit of what the legislation allows.

Again, changing the cap on the growth rate can be changed, but for our model, 1% growth in the increased usage of fresh water seems very reasonable as it would force these sectors to come up with new, less water-intensive ways.

$$W_{ac} = P_{ac} - L_{ac}$$

where W is the water conserved, P is the original projected water usage, and L is the post legislation water usage. For our model:

$$W_{ac} = 12.8 - 10.2$$

$$W_{ac} = 2.6 \text{ billion gallons of water per day saved}$$

**Desalination**

We realize that large scale desalination is a recent advance in technology that has substantiated the idea of removing salt from seawater to increase water supplies in the US. Yet, in considering the costs of maintaining desalination facilities and the environmental influences, we have decided that desalinization is not a feasible water strategy to rely heavily on in future years. Thus, although our plan will continue to rely on desalinization, it will become less and less dependent on desalinization as a source of fresh water from the present to 2025.

Desalination, like many other industrial processes, has environmental impacts that must be understood and mitigated. These include effects associated with the construction of the plant and its long-term operation, including the effects of withdrawing large volumes of brackish water from an aquifer or seawater from the ocean, and discharging large volumes of highly concentrated brine. Indirect impacts associated with the substantial use of energy will be considered. Environmental impacts of desalination will also be discussed.

Desalination plants require substantial amounts of source water to produce high-quality product and for other plant operations. Most thermal seawater desalination processes require substantial amounts of cooling water and have significantly greater seawater intake flow rates than comparably sized membrane system. Such intake water designs and operations have environmental and ecological implications. Seawater is a habitat and contains an entire ecosystem of phytoplankton, fishes, and invertebrates. Large marine organisms, such as adult fish and invertebrates can be killed on the intake screen (impingement) and organisms small enough to pass through the intake screens, such as plankton, eggs, larvae, and some fish are killed during the processing of the salt water (entrainment). The magnitude and intensity of these effects depend on several factors, including the percent mortality of the vulnerable species and the mortality rate of the organism relative to the natural mortality rate. The other most significant environmental problem associated with desalination is the adequate and safe disposal of the concentrated brine produced by the plant. The most obvious characteristic of brine is the elevated salt concentration, yet desalination brines contain other contaminants as well. In addition, chemicals used throughout the desalination process are generally discharged with the brine. Chlorine and other biocides are applied continuously to prevent organisms from growing on the plant's interior, and sodium bisulfite is then generally added to eliminate chlorine. Heavy metals in the brine are discharged during the desalination process.

Biocides are responsible for resistance of bacterial populations to antimicrobial products. Bisulfite is toxic to many organisms and is responsible for the disruption of many ecosystems. Thus, in considering the harmful effects of the toxic chemicals produced in the process of desalination, perhaps the best way to reduce the effects of brine disposal is to reduce the volume of brine that must be discharged and minimize the adverse chemicals found in the brines. Several brine disposal options exist. Ocean discharge is the most common and least expensive disposal method for coastal desalination plants. However, ocean discharge assumes that the dilution of brine with much larger volumes of ocean water will reduce toxicity and ecological impacts. Although this statement remains accurate for certain brine components, namely salt, it does not apply to the others. the toxicity of persistent toxic elements, including some subject to bioaccumulation, such as heavy metals, is not effectively minimized by dilution.

In summary, there are three major negative effects that desalination has on the environment.

1. Impact of the marine habitats: the effluent in the waste is a heavily concentrated brine solution. After the brine solution is discharged, it has the potential to kill marine organisms. Although the brine solution contains natural ingredients of the seawater it may cause damage by its unnatural concentration to marine population near the outlet. Another source of concern is the chemicals from pretreatments and from membrane periodical cleaning.
2. Impact of rising water temperature: the discharged waste has the potential to raise the temperature of coastal waters near the outlet. This has adverse effect on marine life and water quality.
3. The impact to aquifer occurs mainly when there are long pipes conducting seawater and brine. In this case, there is danger of leakage and penetration of salty water to aquifer.

Economically, desalination is not an efficient national water strategy to rely heavily on. Currently, desalination accounts for .4% of the fresh water. Thus, in 2009, desalination plants produced 1377.46 million gallons per day. Currently in the US, there are 250 desalination plants that are connected to the public water supply system. Thus, we assume that the two types of desalination plants in the US are 25 MDG plants and 5 MDG plants where MDG is million gallons/day. There are 243 brackish 5 MDG plants and 7 seawater 25-MDG plants. In general, desalinated water costs are a function of capital costs, debt service, and operating costs. In general, desalinated brackish water can cost about $1.50 per 1000 gallons, whereas desalinated seawater may cost anywhere from $2.50 to $3.00 per 1000 gallons or more.

$C_{25MDG}$=(7plants)*(25,000,000gals/day/plant)(3.00 dollars/1000gals)=(7plants)*($75000/day/plant)
=$525,000/day
$C_{5MDG}$=(243plants)*(5,000,000gals/1day)(1.50dollars/1000gals)=(243plants)*($7500/day/plant)
=$1,822,500/day
$C_{total}$=$C_{25MDG}$+$C_{5MDG}$=$525,000+$1,822,500
=$2,347,500/day

Thus, desalination will cost $2,347,500 daily. This is the amount spent on 1390 million gallons of water, roughly the amount of water produced per day by desalination as put forth by our current statistics. Because of pretreatment expenses, we add $5000 to the $2,347,500 to obtain $2,352,500 for desalination on a daily basis.

In addition, the initial cost of building a desalination plant is costly and time consuming. Desalination of brackish water costs less than that of seawater because brackish water is generally cleaner and contains less total dissolved salts. A desalination plant is constructed using certain techniques keeping the substance to be filtered in mind. A 5 MGD (million gallons per day) brackish water desalination plant can cost about $40 to $50 million to build, whereas a 25 MGD seawater desalination plant can cost about $100 million or more. The cost also depends on the amount of pre-treatment and post-treatment needed. Thus, because there are 7 MGD seawater desalination plants and 243 MGD brackish water plants in the US, the cost of constructing these 250 desalination plants is 12850 million dollars, or 12.85 billion dollars.

Although the cost of desalination has fallen in recent years, it remains a high cost water option. In addition, recent increases in energy and construction costs, and diminishing potential for gains in membrane performance, suggest that further cost declines may be limited. Thus, from this we assume the following: the historical downward trend in the cost of produced water will not continue; the financial input for desalinated water will plateau out.
In conclusion, increased desalination is not a feasible method of reducing water demand as a result of its harmful environmental effects, and its immense economical necessities. While the desalination of brackish waters might be cheaper, but it causes severe damages to sensitive habituates like coastal estuaries and lagoons. Compared to alternative solutions, such as introducing water conserving household appliances that requires virtually no funding to reduce water usage desalination is not only expensive, but also creates various problems to the biosphere. Thus an increase desalination will not be included in our plan for 2025.

## PART III: EFFECTS OF OUR PLAN ON WATER DEMAND IN 2025

The demand of freshwater after the implementation of our plans in billions of gallons of water per day is:

N, where $N = Y_{sum} - W_{sum}$

$Y_{sum}$= 364 billion gallons of freshwater water per day in 2025.

$W_{sum} = W_{ac}+W_{te}+W_{ag}+W_p$

$= 2.6+ 22.96+23.2+ 10.92$

$= 59.71$ billions of gallons of water conserved per day

N=364 – 59.71=304.29 billions of gallons of water per day after the implementation of our national water strategy

## PART 4. COST OF OUR PLAN

$C_{sum}= C_{te}+C_{ag} = 192.9+4.78=197.68$ billions of dollars to implement our plan over the course of the next 15 years from 2010-2025

This is the cost of our national water strategy; it does not incorporate the current costs of programs that are already running and in place.

## ECONOMIC SURVEY AND ANALYSIS

Each sub-model has a set of economic specifications which together determines the cost of our national water strategy. For all appropriate sub-models, we assume it takes one year to get the technology settled. Thus, the statistics present in our sub-models are reasonable as of 2010. Thus, the costs of initial one time investments will not be incorporated in subsequent years (2011-2025) unless otherwise stated in the sub-model. The economic specifications as required by each sub-model are presented to be reasonable and feasible. Much of the investments spent on these programs will be invested back into the nation, thus stimulating the economy while paving the road for stable strong growth in the future.

## PART 5. CONCLUSION

In our model, we first projected the demand for water according to recent trends and data provided by the USGS. Then we created multiple sub-models to model the various parts of our plan in terms of cost and water saved. Due to the lack of data and the sheer complexity in creating a whole model of the natural water cycle of the United States, we chose to create a sustainable national water strategy by alleviating the demand for fresh water through smarter use, more efficient utilization, and strong water conservation legislations. We found that through the use of new, more efficient technology, agricultural techniques, and house-hold usage of our fresh water supply. We can supply a population of 350 million people in 2025 with the same amount of fresh water as we did in 1970 supplying a population of 200 million.

While it is difficult to tell what is the maximum amount of sustainable fresh water we can withdraw from the United States, our national water strategy did successfully alleviate the fresh water demand from 364 billion gallons of water per day to 304 billion gallons of water per day, an estimated reduction of 26.5% in water consumption.

While our plan costs a total of 197.68 billion dollars over the course of the next 15 years, a sustainable national water system is imperative to the continued growth and prosperity of the United States. The investments put into the infrastructure, agriculture, and technology will not only create jobs, but it also paves the road for further growth of the United States as the dominant global power.

## PART 6. STRENGTHS AND WEAKNESSES OF OUR MODEL

Strengths:

- Our projections are broken down into the 8 sectors, each with its own unique regression. This allows for a much more accurate projection of the water demands in 2025.
- Our project takes into account the difference in fresh water usage and saline/brackish water usage. Saline and brackish water usage is not totaled into our count for fresh water demands.
- Our multi-pronged approach to water conservation does not rely solely on one plan or another.
- Our plans are economically feasible and because it comprises of investment made into the United States infrastructure and economy, it would strengthen the United States as a whole.

Weaknesses:

- Our projections already include some of the currently made to curb water usage, and there will be some overlapping of our plans with the conservation efforts already in existence that effected our original projection model.

- We do not take into account the limit of what nature can produce in terms of total freshwater, through our research, we were unable to find sufficient data on how we can model the limit of natures ability to supply us with fresh water.
- We assumed 100% cooperation with the legislations within our model. Such obedience rarely happen in real life, and thus might be an overestimation on the amount of water we might save.

**Works Cited**

American Water Works Association. *Water Use Inside the Home,* 1998 Water Use Summary.

"ARS | Publication request: Potential Impact of Conservation Tillage on Conserving Water Resources in Georgia." *ARS : Home*. Web. 08 Nov. 2009. <http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=187847>.

*Climate Prediction Center*. Web. 08 Nov. 2009. <http://www.cpc.ncep.noaa.gov/products/predictions/tools/edb/lbfinal.gif>.

"Colorado River Aqueduct -." *Wikipedia, the free encyclopedia*. Web. 08 Nov. 2009. <http://en.wikipedia.org/wiki/Colorado_River_Aqueduct>.

Consumer Reports, *Low-Flow Shower Heads,* February, 1995.

Consumer Reports, *Low-Flow Toilets,* February 1995.

Cooperative Extension Service. *Ways to Limit Water Use to Forty Gallons Per Day.* University of Kentucky College of Agriculture. <http://www.cpc.ncep.noaa.gov/products/predictions/tools/edb/lbfinal.gif>

"Efficient Clothes Washing." *ACEEE - American Council for an Energy-Efficient Economy*. Web. 08 Nov. 2009. <http://www.aceee.org/Consumerguide/laundry.htm>.

"Environmental Protection Agency - Water & Wastewater Pricing Introduction." *U.S. Environmental Protection Agency*. Web. 08 Nov. 2009. <http://www.epa.gov/waterinfrastructure/pricing/index.htm>.

Heaton, Linda, Tom Ilvento, and Joe Taraba, *Conserving Water at Home (IP-2)*, University of Kentucky, College of Agriculture, Cooperative Extension Service, July, 1989.

Hutson, S.S., compiler, 2007, Guidelines for preparation of State water-use estimates for 2005: U.S. Geological Survey Techniques and Methods Book 4, Chap. E1, 28 p. <http://pubs.usgs.gov/tm/2007/tm4e1>

Kenny, J.F., Barber, N.L., Hutson, S.S., Linsey, K.S., Lovelace, J.K., and Maupin, M.A., 2009, Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344, 52 p.

Matlab Version 7.8.347. The MathWorks, Inc., 1984-2009. February 12, 2009.

"Population Profile of the United States." *Census Bureau Home Page*. Web. 08 Nov. 2009. <http://www.census.gov/population/www/pop-profile/natproj.html>.

"Residential end uses of water -." *Google Books*. Web. 08 Nov. 2009.

<http://books.google.com/books>.

"Residential water use summary." *Aquacraft.com*. Web. 08 Nov. 2009. <http://www.aquacraft.com/Publications/resident.htm>.

"Technology Research and Development Efforts Related to the Energy and Water Linkage" Committee on Science and Technology US House of Representatives <http://www.cpc.ncep.noaa.gov/products/predictions/tools/edb/lbfinal.gif>

U.S. Department of Energy, 2006a, Steam-electric plant operation and design report, Form EIA-767: Energy Information Administration, accessed March 9, 2009, at <http://www.eia.doe.gov/cneaf/electricity/forms/eia767/eia767.pdf>

U.S. Department of Energy, 2006b, Power plant report, Form EIA-906: Energy Information Administration, accessed March 9, 2009, at <http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html>

"Where is Earth's water located? USGS Water Science for Schools." *USGS Georgia Water Science Center*. Web. 08 Nov. 2009. <http://ga.water.usgs.gov/edu/earthwherewater.html>.