Technical Review of the

Tetra Tech, Inc. Report entitled

"Evaluating Sustainability of Projected Water Demands Under Future Climate Change Scenarios"

Prepared by:

Robert Ingersoll
Principal Consultant
Tetra Tech, Inc.

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INTRODUCTION

In July 2010, Tetra Tech, Inc. (Tetra Tech) prepared a report (the Report) entitled "Evaluating Sustainability of Projected Water Demands Under Future Climate Change Scenarios" for the Natural Resources Defense Council. The report presented predictions of future water demands in the years 2030 and 2050 and compared the demands to the locally available water resources on a national level using averaged climate prediction results from sixteen climate change models as well as long-term (1934-2000) climate data. The report presented a "water sustainability index" comprised of five attributes of water use and growth that was used to compare potential impacts across regions. Maps were prepared identifying regions where potential future impacts may occur based on water availability. The objective of the report, "in addition to developing national-scale maps of potential impacts…serves as a starting point for more detailed analysis, either at more local scales, or by consideration of specific sectors of the economy that are directly dependent on sustainable water resources."

The results of the analysis were misleading, stating that "under the business-as-usual scenario of demand growth, water supplies in 70% of counties in the U.S. may be at risk to climate change, and approximately one-third may be at high or extreme risk." However, it is also stated that 'To be clear, it (the Report) is not intended as a prediction that water shortages will occur, but rather where they are more likely to occur." The following Technical Review has been prepared to review the underlying assumptions contained within this study and to assess the conclusions of the study.

The results of this technical review are presented in two sections: general comments and specific comments as to the scientific methodologies and conclusions of the Report as they pertain to Pima County, Arizona.

GENERAL COMMENTS

A review of the Report has identified a number of assumptions and calculation methodologies that raise concern about the validity of the Report conclusions, including:

- The Report fails to benchmark current conditions within the United States as it relates to the "Water Sustainability Index" developed as part of the Report. The reader is unable to understand how this Index characterizes current conditions;
- The Report fails to recognize that in the United States, particularly in the West, water rights are administered under state authority, by the State Engineer or equivalent. The State Engineer allocates the use of existing water resources (both groundwater and surface water). Water demand solely due to population growth cannot go unchecked as is assumed in the analysis;
- The Report assumes that all water is locally sourced (no importation of water) and that power will be locally generated based on current power generation (no importation of power). In many parts of the United States, these assumptions are not based in reality; and
- The Report assumes there is no increase in water usage efficiency over time, which is not a valid assumption.

The Report assumes many factors such as future population increases, future power generation, and changes to climate on a broad scale. The Report then presents projected water withdrawals and a water supply sustainability index on a county-by-county basis without an understanding of the intricacies of the current and future water supply and distribution on a local

level. The projection of future water withdrawal at the county level would lead the reader to assume a level of data accuracy and precision which is not present. It is misleading for the Report to make such county-by-county projections based on general assumptions.

A fundamental failure of the Report is that it fails to include water rights and the authority of each state (through the State Engineer or equivalent) in the allocation of existing and future water withdrawals. The Report assumes that there will be increases in withdrawals based on population growth and additional power generation; this is incorrect. For many portions of the western United States, the water withdrawals from the groundwater basins or river systems are currently capped by the water rights granted by the state. In wet years, more water can be taken from the systems; in drought conditions, there are reduced withdrawals generally based on the seniority of the water rights. The water rights and priorities will limit the amounts and locations of future withdrawals.

The Report notes that "the 2005 water use survey data at the county level (Kenny et al., 2009) forms the baseline for this analysis. Total freshwater withdrawals reported in the 2005 survey are shown in Figure 2 where the volumes of freshwater withdrawn are normalized to the county area and shown in inches per year." (Pg. 4). The reference is for Kenny, J.F., N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin (2009), Estimated use of water in the United States in 2005, U.S. Geological Survey Report, Circular 1344. As an editorial note, the USGS Circular 1344 has only water use by state, the county level use is from an associated report listed at http://water.usgs.gov/watuse/.

The Report notes that "available precipitation is defined as the difference between precipitation and potential evapotranspiration for each month of the year" (Pg. 9) and that "when precipitation is less than potential evapotranspiration for a particular month, the available precipitation of that month was counted as 0" (Pg. 11). This oversimplification of the precipitation and evapotranspiration data ignores the precipitation patterns in the western United States. There are periods of high intensity thunderstorm activity, generally in the summer months, which can produce heavy rainfall in a short period of time, with resultant overland flow and flow in normally dry arroyos. This water infiltrates into the ground and through the streambeds and recharges the local aquifers. This available precipitation and recharge is ignored in the Report because of the erroneous use of monthly data, instead of a more accurate daily (or shorter time period) dataset. If the authors of the Report purport to present the water available on a county-by-county basis; the use of the monthly data, at least for those counties in the western United States, is not scientifically valid.

PIMA COUNTY SPECIFIC COMMENTS

The Report makes current and future projections of “available precipitation and water sustainability” for Pima County using regional data sets and calculation assumptions which are not valid for projections on a county level. The projections for Pima County would lead the reader to assume a level of data accuracy and precision which is not present.

Current Available Precipitation

The Report data set has a calculated current available precipitation value for Pima County of 1.442 inches. This calculated value is not applicable to Pima County for two reasons: the use of Climate Division data and the use of monthly precipitation and evapotranspiration data.

There are seven climate divisions in Arizona, based on the “Locations of US Climate Divisions” map found at http://www.esrl.noaa.gov/psd/data/usclimate/map.html. The seventh climate division in Arizona includes Pima, Santa Cruz, Cochise, Graham and Greenlee counties. There

are substantial elevation variations (and one would suppose precipitation and evaporation differences) among the counties in this grouping. There is no scientific basis to use the precipitation and evaporation data from such a large area for the county-by-county analyses in the Report.

As previously noted, the Report is erroneous in using monthly precipitation and evapotranspiration data to define available precipitation for the climatic conditions in the western United States in general, and for Pima County specifically. To illustrate this point, an analysis of the "available precipitation" in Pima County was done using data from Tucson and using the criteria in the Report.

For the data set, the monthly precipitation for Tucson during the period from 1971 through 2000 was used; this data is from the National Weather Service at http://www.wrh.noaa.gov/twc/climate/tus.php.

The pan evaporation data is for the Tucson University of Arizona # 1 station for the period from 1982 through 2005; obtained from the Western Regional Climate Center at http://www.wrcc.dri.edu/htmlfiles/westevap.final.html.

The evapotranspiration was calculated by multiplying the pan evaporation by 0.6925. This ratio is based on the evapotranspiration at the AZMET station in Tucson of 76.92 inches; this data is from sub-table C of Table 8.5-1, Climate Data for Tucson AMA at the Arizona Department of Water Resources webpage.

Month	Precipitation (inches)	Pan Evaporation (inches)	Calculated Evapotranspiration (Inches)	Precipitation - Evapotranspiration (inches)	Available Precipitation (inches)
January	0.99	3.94	2.73	-1.74	0
February	0.88	4.68	3.24	-2.36	0
March	0.81	7.53	5.21	-4.40	0
April	0.28	10.57	7.32	-7.04	0
May	0.24	14.14	9.79	-9.55	0
June	0.24	16.51	11.43	-11.19	0
July	2.07	14.61	10.12	-8.05	0
August	2.30	12.17	8.43	-9.77	0
September	1.45	10.71	7.42	-5.97	0
October	1.21	8.05	5.57	-4.36	0
November	0.67	4.93	3.41	-2.74	0
December	1.03	3.23	2.24	-1.21	0

Based on the criteria in the Report that the "available precipitation is defined as the difference between precipitation and potential evapotranspiration for each month of the year", it would appear that there is no available precipitation in Pima County, Arizona based on the Tucson climate data. This flawed method for calculating available precipitation does not account for the groundwater recharge from the high intensity precipitation events, such as the monsoon rains which occur in southern Arizona during the summer months. As anyone who has seen a flash flood in the Arizona desert can tell you, there is a lot of water in the arroyos during the storm events. This water quickly infiltrates into the ground and recharges the local aquifers.

In summary, the Report calculates current available precipitation with an invalid method based on monthly data sets using a five county regional climate division to generate specific values for Pima County.

Pima County Water Use

The USGS county data referenced in the Report is listed at http://water.usgs.gov/watuse/. This 2005 water data shows the following uses in Pima County:

Uses	Million Gallons Per Day
Public Supply, groundwater withdrawals	159.12
Public Supply, surface water withdrawals	0.00
Domestic Self-Supplied, groundwater withdrawals	2.37
Domestic Self-Supplied, surface water withdrawals	0.00
Industrial Self-Supplied, groundwater withdrawals	0.48
Industrial Self-Supplied, surface water withdrawals	0.00
Irrigation, groundwater withdrawals	86.78
Irrigation, surface water withdrawals	20.40
Livestock, groundwater withdrawals	0.32
Livestock, surface water withdrawals	0.01
Mining, groundwater withdrawals	34.66
Mining, surface water withdrawals	0.00
Thermoelectric, groundwater withdrawals	2.62
Thermoelectric, surface water withdrawals	0.00
TOTAL	**306.76**

As can be seen, the majority of the water use in Pima County is from groundwater withdrawals. There are limited surface water withdrawals for irrigation and livestock.

The groundwater withdrawals are from the aquifers which are recharged from water infiltration during the high intensity storm events. The erroneous method for calculating available precipitation in the Report would project no available precipitation in Pima County if the Tucson climatic data were used. As can be seen, there is substantial groundwater recharge and use in Pima County.

Central Arizona Project Water

The Report also fails to account for water importation into Pima County. The Central Arizona Project (CAP) delivers water from the Colorado River to cities, counties, irrigation districts, and Native American farms both on and off reservations within the State.

It should be noted that much of the CAP water delivered to Pima County is recharged to the groundwater system for storage. As of April 2008, Tucson Water had recharged more than 350,000 Acre-Feet (AF) of CAP water since recharge activities began in 1996. An additional 70,000 AF has been recharged on Tucson's behalf by the Arizona Water Banking Authority in order to ensure Tucson's ability to access CAP water in times of canal shutdown or Colorado River shortages (Tucson Water webpage).

Future Projections of Available Water

As previously noted, the Report erroneously used the Climate Division regional data and the monthly precipitation and evapotranspiration data to calculate the available precipitation for Pima County. This same invalid methodology was used to project future available precipitation for Pima County, with results that do not make sense and further illustrate why the methodology is flawed.

The Report data files show a future projection of available precipitation for Pima County in the Year 2050 of only 0.147 inches. This is an 882 percent decrease in available water. The Report data files show a slight decrease in yearly precipitation of only 0.2056 inches, and an increase in temperature of 2.55 degrees Celsius. Using the invalid methodology for calculating available precipitation, this slight climatic change would result in an order of magnitude decrease in available precipitation for Pima County. As previously noted, much of the recharge occurs during the high intensity storm events. The fact that it is slightly warmer on an already hot day will not impact the availability of the precipitation which has recharged the local aquifers. This future prediction of an order of magnitude decrease in available precipitation further illustrates the fact that the Report methodology using monthly precipitation and evapotranspiration data and regional climatic data is in error.

Water Sustainability Supply Index

The Report shows a current available precipitation value for Pima County of 1.442 inches (as previously noted, there appears to be no valid scientific basis for this value). The Report database shows that the current use is only 0.702 inches, and will be only 1.090 inches in 2050 from increases in population and electricity generation (absent climate change impacts which also appear to have invalid scientific bases). It would appear that there is no current or future water shortage in Pima County. This seems to be at odds with the inclusion of Pima County in the "extreme" category for water supply sustainability risk in Figure 17B of the Report.

The Report apparently does not use current or future water supply and use balances for the determination of sustainability of the water supply, but uses the following five arbitrary index categories for “scoring” each county:

- Extent of Development of Available Renewable Water (> 25 percent);
- Groundwater Use Index (> 25);
- Susceptibility to Drought (summer deficit < -10 inches);
- Increased Need for Storage (summer deficit increase > 1 inch); and
- Growth in Water Demand (> 10 percent).

The Report data base shows that Pima County “scored” in each index category and is shown to be in the “extreme” category for the future (Year 2050) both with and without climate change (see Figures 17 A and 17B in the Report). The use of these index categories appears to reflect a very limited understanding of water supply in the western United States in general, and in Pima County specifically.

Like many counties in the arid West, the water use in Pima County is of course greater than 25 percent of the available renewable water. That does not mean the water supply is unsustainable. The water resource is protected through limitations on groundwater withdrawals specified in water rights. The groundwater withdrawals are supplemented by the importation of Colorado River water through the CAP. On the water use side of the equation, there are limitations on the uses of water for lawns and an extensive water reuse program. The Pima

County water districts and residents are aware of the limited water resources, and have instituted conservation programs to assure that the water supply in Pima County is indeed sustainable.

As shown in the water use table, approximately 93 percent of the water withdrawals for Pima County were from groundwater. It should be noted that much of the CAP water delivered to Pima County is recharged to the groundwater system for storage. In a desert environment, it would not be prudent to develop surface water storage reservoirs because of the evaporative losses. The inclusion of groundwater use as an index appears to be flawed as it pertains to Pima County. For the counties in the arid West, perhaps the better index would be that groundwater use of greater than 25 percent is sustainable, while use of surface water greater than 25 percent may be unsustainable because of the evaporative losses.

Both the Susceptibility to Drought (summer deficit < -10 inches) and the Increased Need for Storage (summer deficit increase > 1 inch) indices show a lack of understanding of the water supply and use in the western United States. As has been previously noted, there are periods of high intensity thunderstorm activity, generally in the summer months, which can produce heavy rainfall in a short period of time, with resultant overland flow and flow in normally dry arroyos. This water infiltrates into the ground and through the streambeds and recharges the local aquifers. This recharge generally occurs within hours after the storm event, and is not influenced by drought conditions or deficits. Furthermore, because the water is stored in the local aquifers, the presence (or absence) of a drought does not impact the availability of the water resource.

CONCLUSIONS

The Report assumes many factors such as future population increases, future power generation, and changes to climate on a broad scale and then presents projected water withdrawals and water supply sustainability on a county-by-county basis without an understanding of the intricacies of the current and future water supply and distribution on a local level.

The methodology of projecting available precipitation using monthly precipitation and evapotranspiration data is invalid in the western United States where there are periods of high intensity thunderstorm activity. The infiltration of the precipitation into the groundwater system from these storm events occurs in a short time frame, and is not influenced by the monthly evapotranspiration.

A fundamental failure of the Report is that it fails to include water rights and the authority of each state (through the State Engineer or equivalent) in the allocation of existing and future water withdrawals.

The Report projects “extreme risk” to water supply sustainability in many counties based on arbitrary index categories which show a very limited understanding of water supply in the western United States.