Chapter 3
DRAFT Supply

3 Supply

1.0 Introduction

The Albuquerque Bernalillo County Water Utility Authority (Water Authority) is updating its 2007 Water Resources Management Strategy (WRMS). Because an understanding of future water supply is critical to any water resources management strategy, these efforts include an update to prior estimates of future water supply. Water supply projections developed as part of this effort will be incorporated into the WRMS.

Historically the Water Authority relied solely on groundwater to meet demands. Implementation of the 1997 and 2007 strategies has vastly expanded the Water Authority's supply portfolio with the goal of providing a reliable and sustainable resource for its customers. The portfolio now includes groundwater, surface water through both the San Juan-Chama (SJC) Drinking Water Project (DWP) and the North I-25 Non-potable project, reuse, and aquifer storage and recovery. Likewise the Water Authority has drastically reduced its overall water usage rate (measured as gallons per capita day [gpcd]) thorough conservation.

As part of the 1997 and 2007 strategies, the Water Authority used historical Rio Grande flow to estimate future surface water availability and subsequently the Water Authority's ability to utilize San Juan-Chama (SJC) water. Surface water availability, when coupled with demand, is the key parameter in estimating the quantity of other existing or possible new supplies needed.

As with demand, the Water Authority recognized the inherent uncertainty in surface water availability and the need to plan for a range of possible futures. Therefore, the Water Authority is considering multiple supply projections. Each of these projections is represented as a variation in future surface water supply, both Rio Grande and SJC.

This document summarizes historical and recent projected surface water supply and other considerations related to current water supply projections through 2120. While each of these supply sources and potential supply sources is discussed independently, many are interconnected either through direct or indirect relationships (e.g. demand to wastewater volume, wastewater requirements for surface water use). Likewise, individual water supply scenarios will be dependent on projected water availability and regulatory limitations on these supply sources as well as overall demand.

2.0 Supply Projections from the 1997 and 2007 WRMS

Historical planning efforts as well as the New Mexico Office of the State Engineer (OSE) permitting process for the San Juan-Chama (SJC) diversion (SP-4830) used a modified version of the 1971 to 1998 streamflow sequence at Central as representative of the longer historical record.

As part of the development of the OSE permitting process for SP-4830, surface water supply projections were completed for the period from 2006 to 2060. The 1971-1998 gage record was utilized and repeated over the planning period. The average native[1] flow over this period is roughly equivalent to the longer previous historical record (1900-1970). However, the 1971-1998 period did not include a drought as severe as that of the 1950s. Therefore, a three-year artificial drought was added to the sequence by repeating the 1972 flow record back to back (CH2M HILL, 2003). The resulting sequence was then used to estimate when SJC water could be diverted and subsequently how much groundwater and other supplies would be needed to meet projected demand.

[1] Water Authority SJC water was removed from the gaged record to arrive at a "native" flow for the 1971-1998 record. This removal was completed for comparison to the historical record and to avoid double counting this water in subsequent predictive scenarios.

Figure 1. Historical Water Rio Grande Flow at Otowi 1900-1998

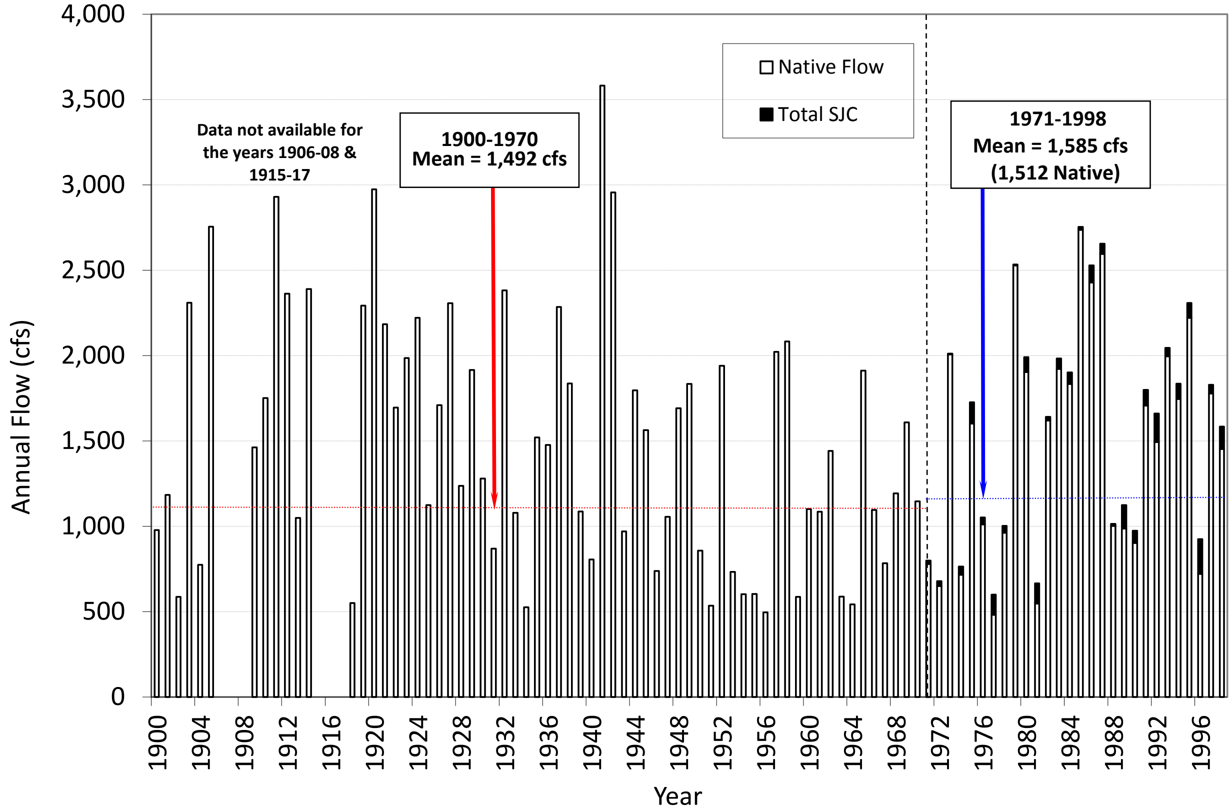


Figure 2. 1995 and 2007 WRMS Projection of Rio Grande Flow

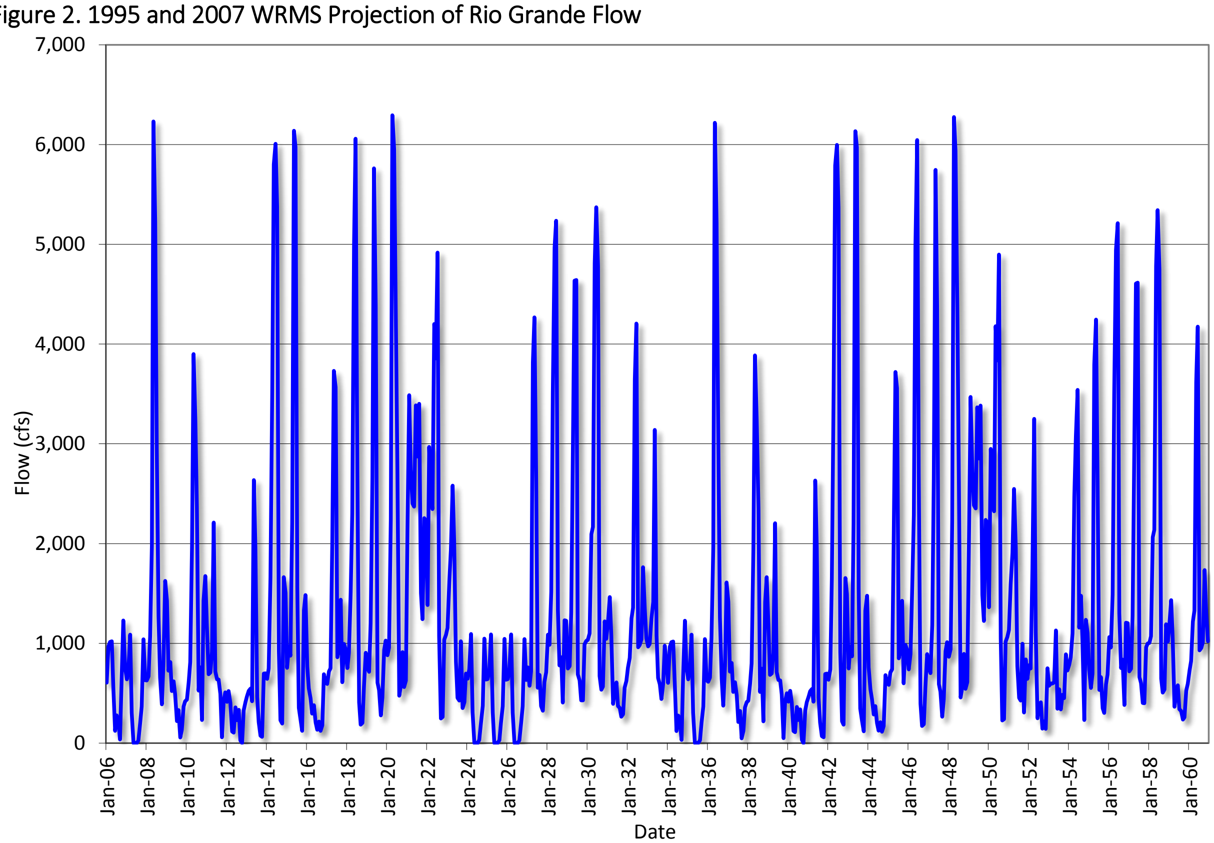


Figure 1 shows historical Rio Grande flow at Otowi that was utilized in previous planning efforts. Note that the average "native flow" of the 1900 to 1970 period is within about 1 percentage point of the native flow in the 1971-1998 period, making the two periods roughly equivalent on a surface water supply basis. Figure 2 shows the resulting 2006-2060 Rio Grande flow sequence used in the 1997 and 2007 WRMSs. The artificial drought (repeat of 1972 hydrology) occurs in the 2024 to 2026 timeframe.

The remainder of this document summarizes development of updated supply projections, for the 2017 WRMS.

3.0 Current Sources of Supply

Current supply sources include surface water and groundwater. Surface water includes native Rio Grande water, SJC water, and wastewater, each used directly through diversion or reuse and/or indirectly for offsets of groundwater pumping impacts. Surface and groundwater sources are interrelated via both the connection of the aquifer to the river and return flow of groundwater to the surface water system.

The following sections describe all current water supply sources. These supply sources are also summarized in Table 1. Figure 3 shows the historical makeup of supply sources through 2014.

3.1 Surface Water

Native Rio Grande water rights and SJC Project water are both utilized via the Rio Grande. In addition, because wastewater is currently used to offset effects of groundwater pumping on Rio Grande flow, it is included in this section as a surface water supply.

3.1.1 Native Rio Grande Water Rights

The Water Authority has two types of native water consumptive rights on the Rio Grande: vested and acquired, totaling about 26,390 acre-feet per year (afy). These water rights, along with treated wastewater flows, are currently used to offset effects on Rio Grande flows caused by the Water Authority's groundwater pumping.

Vested water rights were granted to the City/Water Authority in 1956 when the State Engineer declared the Middle Rio Grande basin. The amount granted was based on historical groundwater pumping prior to the declaration of the basin. Vested rights are a "right to deplete" and have been applied to offset effects of groundwater pumping on the Rio Grande for more than 50-years (vested rights[2] do not allow for direct diversions from the Rio Grande). The Water Authority has 17,875 afy of vested native Rio Grande rights.

The remaining 8,515 afy of the Water Authority's Rio Grande rights have been acquired over time, including about 1,261 afy acquired recently through the New Mexico Utilities purchase. All of these acquired rights are currently used to offset groundwater pumping.

[2] Vested rights were granted based on an estimate of historical pumping and are directly tied to groundwater production. As such, they are not available for direct surface diversion.

Table 1. Source Summary

		Diversion Right, Water Right, or Resource (afy)	**Comments**
Surface Water			
DWP	SP-4830	96,400	Total surface water diverted combination of SP-4830 and SP-4819). Actual diversions permitted up to about 94,000 afy (130 cfs), provided return flows to the Rio Grande are at least half of total diversion at all times along with many other conditions.
Non-potable project	SP-4819	3,000	3,000 afy are permitted for non-potable surface water reclamation project which is also used for the Bear Canyon ASR project.
Wastewater	Municipal discharge	60,000	Currently used to offset effects of groundwater pumping on Rio Grande and to return the native portion of the DWP diversion. The native portion of the DWP is up to about 47,200 afy.
	Municipal reuse	2,000	Uses a portion of the available wastewater for Non-potable irrigation demand
Groundwater			
Albuquerque Basin	RG-960 et al.	155,000	Surface water effects to be offset with wastewater return, vested and acquired rights, and/or SJC water
	RG-4462 (Previously New Mexico Utilities)	10,000	Surface water effects to be offset with wastewater return, vested and acquired rights, and/or SJC water.
ASR - Recovery Water	USR-01 (ASR)	varies	Storage of excess surface (SJC) supply for later extraction

Consumptive Water Rights			
Native Rio Grande	vested rights	17,875	Currently used to offset effects of groundwater pumping on Rio Grande.
	acquired rights	8,514	
San Juan-Chama		48,200	Currently directly diverted as part of the DWP (SP-4830), and the Non-potable Project (SP-4819). Stored SJC water is also used for groundwater pumping offsets. SJC water has been stored through SP-4819 for ASR.

Figure 3. Historical Supplies Meeting Demand (1970-2014)

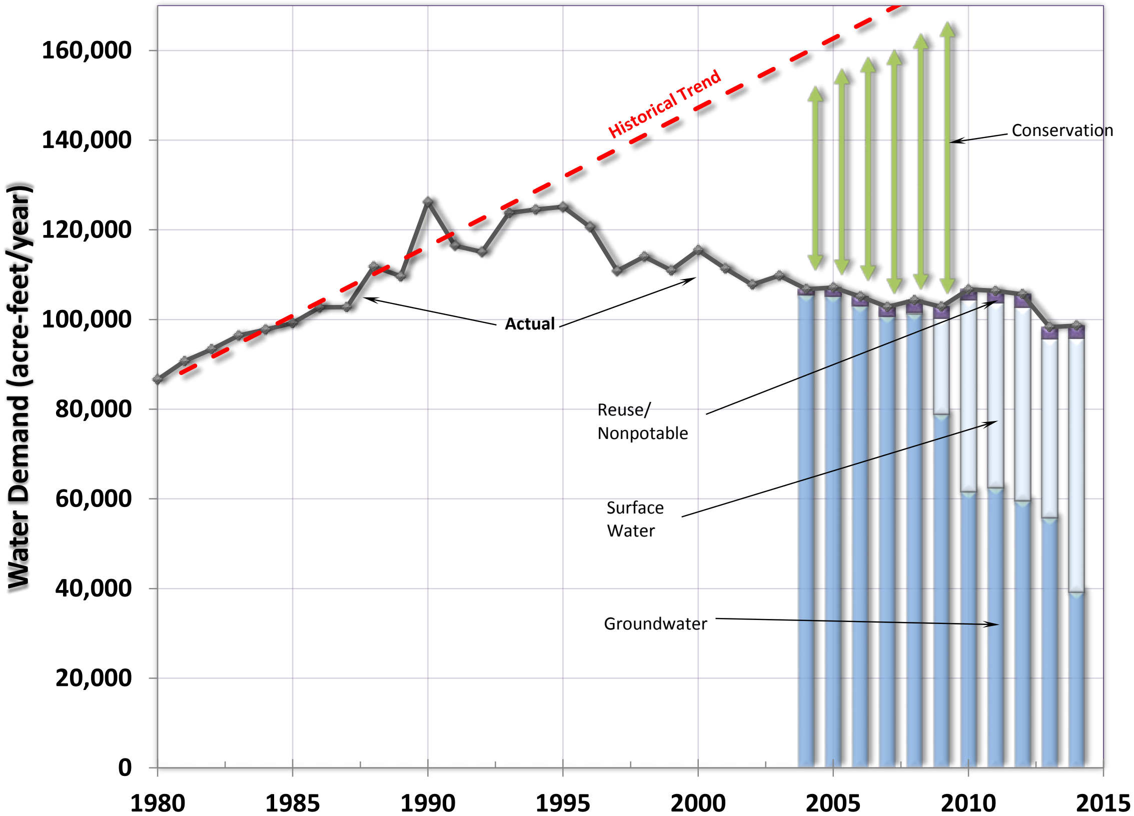
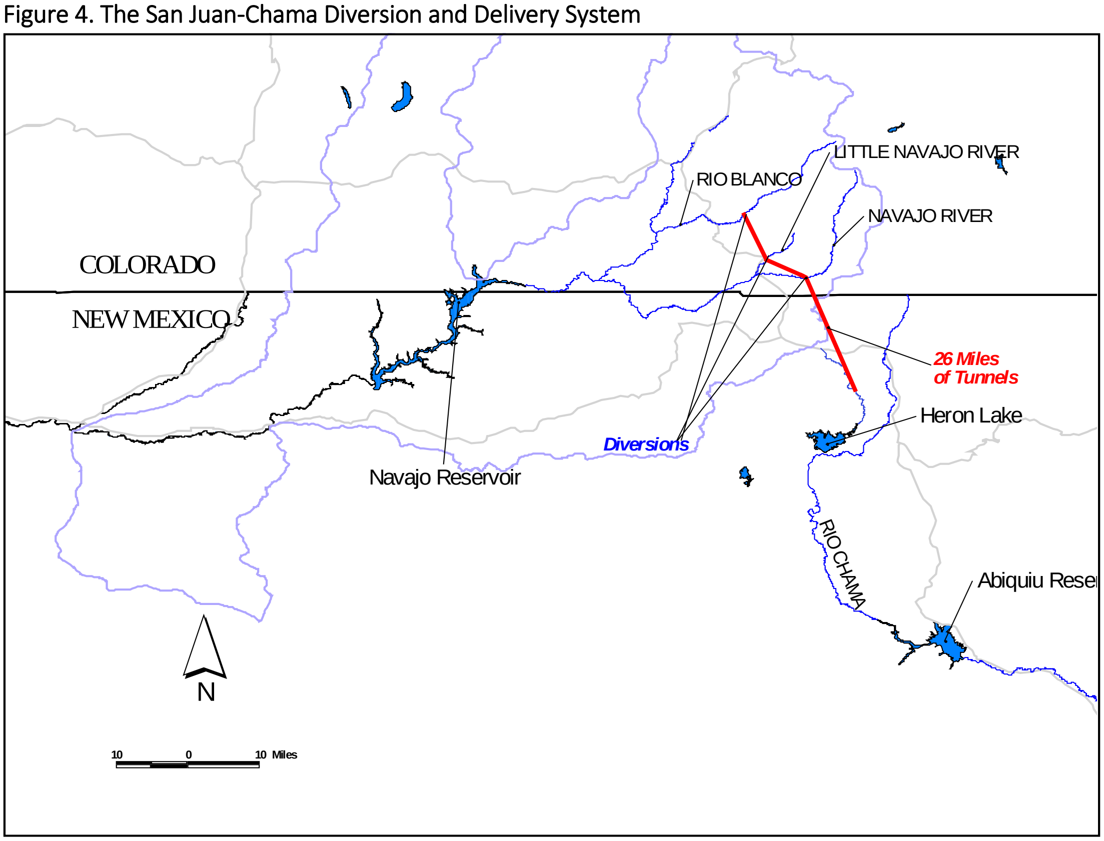
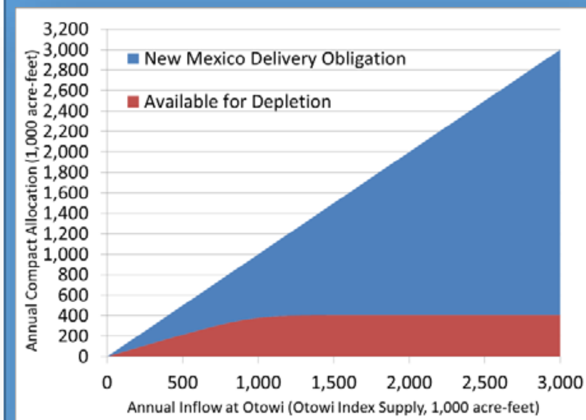


Figure 4. The San Juan-Chama Diversion and Delivery System



The Rio Grande Compact and Water Rights?

The State of New Mexico entered into an interstate compact with Colorado and Texas in 1938. This Compact apportioned the amount of Rio Grande flow and established delivery obligations for the States of Colorado and New Mexico. The Rio Grande Compact is a delivery compact, requiring each upstream state to deliver a certain amount of water to the downstream state. The amount of delivery is based on the amount of supply in a given year. For the middle Rio Grande, New Mexico's delivery obligation is dictated by the native flow passing Otowi gage (see Figure below). Any water entering into the Rio Grande downstream from Otowi gage and upstream of Elephant Butte Reservoir is also available for consumption.



Flows were apportioned based on how much the States were using at the time of signing. As can be seen, for lower inflows, the portion of the inflow that New Mexico must deliver is reduced. Once the inflow exceeds about 1 million acre feet, New Mexico's must deliver all flow in excess of 400,000 acre feet. Historical Rio Grande Flow at Otowi has averaged, from 1895 through 2014 (some data missing), about 1,450 cubic feet per second (cfs) or 1.06 million acre-feet per year. This volume of flow results in a New Mexico delivery amount of about 600,000 acre-feet. However, since 2011 flows have been below 1,000 cfs with only 755 cfs in 2013 or about 550,000 acre-feet. This volume of flow resulted in a delivery obligation of about 300,000 ac-ft and the ability to deplete 250,000 ac-ft plus water entering the system below Otowi, for all uses in the Middle Rio Grande (defined per the Compact as from Otowi gage to Elephant Butte). Depletions come from uses of Rio Grande water by native Rio Grande rights holders including agricultural, municipal and industrial users and from evapotranspiration, including evaporation associated with Elephant Butte Reservoir. The Water Authority holds about 25,000 ac-ft of native rights or just over 5 percent of the maximum depletion.

New Mexico delivers water to Elephant Butte Reservoir resulting in "Project Storage". The Compact allows for New Mexico to over or under-deliver its annual requirement. But, there are limits on how much of a deficit can be accrued (200,000 acre-feet) and annual limits on the amount of credit received (150,000 acre-feet).

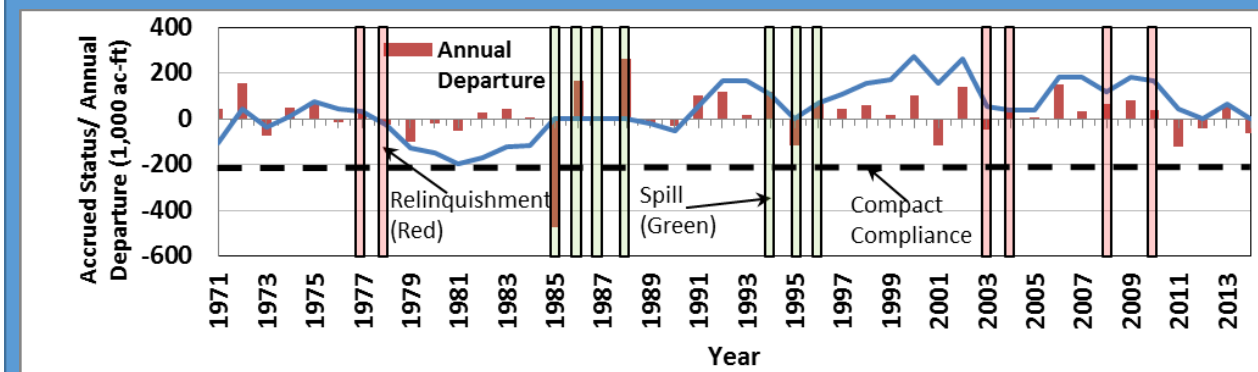
An operational spill (which can be "actual" [water actually spilled from a full Elephant Butte] or "hypothetical" [when water would have spilled had releases been made]) in system reservoirs resets the accrued status to zero (or reduces the accrued credit proportionally to the amount of the spill).

When Project Storage at Elephant Butte drops below 400,000 acre-feet, New Mexico cannot increase the amount of water in storage in upstream reservoirs. Likewise, water in storage can be called for by the downstream state when the state is in accrued debit status.

On occasion, New Mexico has relinquished ("releases") some of its stored credit water to Texas. The relinquishment amount is allocated and made available to upstream users who are then able to store a like amount of native water. Relinquishment allows for storage of native water even when project storage drops below 400,000 acre-feet. Relinquishment makes water available to New Mexico users and ensures that water is not ultimately lost due to a spill. In total, the State has relinquished almost 400,000 acre-feet of water since 2003. For example, in 2003 175,500 acre-feet of water was relinquished and allocated to the US Bureau of Reclamation, Middle Rio Grande Conservancy District, and the City of Santa Fe for storage or use (see Table for recent history).

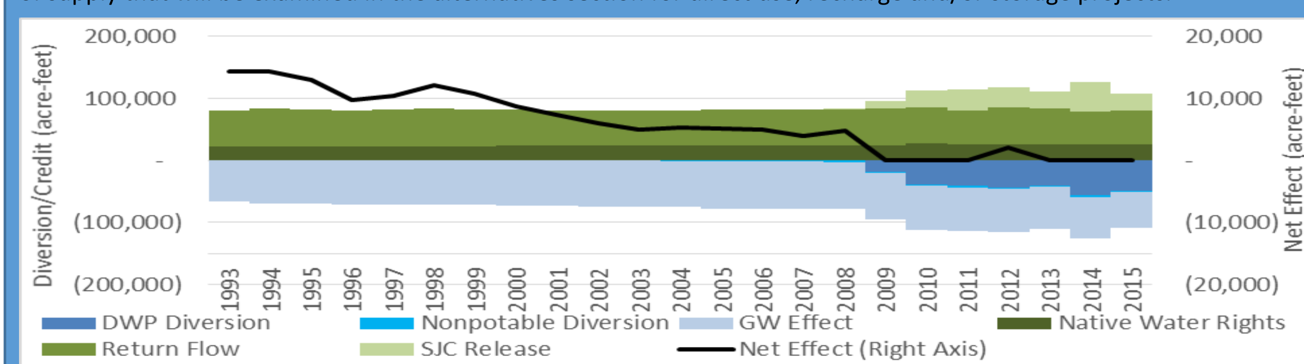
	2003	2008	2010	2011[a]	2012	2013[b]	2015	Total Used/ Stored	Available for Storage
RELINQUISHED	175,500	125,000	80,000	0	0	0			
ALLOCATIONS									
United States	56,483	25,517	0	9,000	0	0	19,000	82,584	27,416
MRGCD	112,965	37,035	0	21,000	0	20,000	58,000	171,744	77,256
City of Santa Fe	6,052	1,448	0	1,000	0	0	0	1,293	7,207
State of NM	0	0	0	0	6,000	0	7,000	0	13,000
Total Allocated	175,500	64,000	0	31,000	6,000	20,000	84,000	255,621	124,879
Total Unallocated	0	61,000	141,000	110,000	104,000	84,000	0		

In the 1950s, the State was judged to be out of compliance with the Compact for a number of years, largely due to structural problems in making deliveries. The State acted to reduce the structural problems including construction of a pilot channel through accumulated sediment at the inlet to Elephant Butte Reservoir. The State has been fully in compliance with the Compact since the late 1960s. The figure below shows the annual compact departure as well as years where spills (green bars) and relinquishment (red bars) have occurred.



To receive a permit for ground or surface water diversion, the applicant must show that they will not impact the Compact in excess of their rights or their ability to offset impacts. If the State believes that granting a permit is not neutral with respect to its impact on the Compact, the permit may not be granted. The State is able to check for compliance once a permit is issued through reporting, accounting, and administration.

Historically, the net effect of the Water Authority's permits has been positive with respect to the Compact as shown below (providing more water than required – surplus). Since 2009, the Water Authority's impact has been neutral or positive as we are fully using all of our water rights and return flows in addition to supplemental releases of SJC water thereby keeping the river whole, as per OSE Permit requirements. This change from consistent surplus is due to the lingering effects of historical groundwater production at the start of utilizing surface water. As the groundwater system balances and the aquifer rebounds, projections indicate that the Authority may once again surplus the Rio Grande with groundwater. This surplus water will be an additional source of supply that will be examined in the alternatives section for direct use, recharge and/or storage projects.



3.1.2 San Juan-Chama Project

Another surface water source is water from the San Juan-Chama (SJC) project. The SJC Project consists of a transbasin water transfer from the San Juan River Basin (tributary to the Colorado River) to the Rio Grande Basin. Water diverted from three tributaries of the San Juan River (Navajo River, Little Navajo River, and Rio Blanco) is imported into the Rio Grande through a series of tunnels to Heron Reservoir (401,320 acre-feet capacity) where it is allocated to SJC contractors (see Figure 4). The SJC project has a firm yield (defined as the amount of water that can be drawn annually without shortage based on a historical hydrologic sequence, see Figure 5) of about 96,200 afy and a contracted delivery amount of a little over 86,000 afy with the remaining difference allocated to future settlements but not contracted. Carry-over storage in Heron is not allowed and as such contractors must take delivery of their annual allotment. In some years, Federal waivers allow storage in Heron until April 30th and as late as September 30th. Evaporative losses are not accrued in Heron for SJC contractors. Figure 5 presents the historical delivery to Heron Reservoir as well as the estimated firm yield[3]. Limitations of SJC deliveries include:

- SJC diversions are subject to "minimum bypass"[4] requirements (Table 2) to protect Colorado fish and aquatic life,
- Physical diversion limitations (950 cubic feet per second capacity Azotea tunnel),
- SJC diversions are subject sharing of shortages in addition to Colorado/Upper Colorado River Basin Compact limitations by declaration of the Secretary of Interior.

The Water Authority has consumptive rights to 48,200 afy of SJC water and takes delivery from the outlet of Heron Reservoir. SJC water is typically released from Heron to Abiquiu Reservoir where the Water Authority has 170,900 acre-feet of storage. An additional 50,000 acre-feet of storage is available in Elephant Butte Reservoir and is accessed for use by the Water Authority through exchanges with native Rio Grande water. Transit losses, or estimated losses of water due to evaporation and seepage, are applied as water flows downstream to Elephant Butte for storage. The Water Authority is charged evaporative losses for storage in both Abiquiu and Elephant Butte Reservoirs.

The Water Authority diverts its SJC water under OSE permits SP-4830 and SP-4819 for the SJC DWP and the North I-25 Non-potable Project, respectively. The Water Authority may divert up to 94,000 afy for the SJC DWP, provided return flows to the Rio Grande are equal to at least half of the total diversion at all times AND that native Rio Grande flows are above 122 cfs at the point of diversion. Below 195 cfs, diversions are curtailed by 1 cfs for every 1 cfs drop in flow (USFWS, 2004). Diversions are also limited. See Appendix A for a copy of the OSE permit SP-4830 including a list of conditions.

Figure 6 presents the monthly Rio Grande flow data at Central. Monthly average Rio Grande flows less than 130 cfs occurred approximately 7 percent of time from 1942 through 2010. Figure 7 presents low flow frequency curves for the Rio Grande at Central. The plot shows the 1, 7, 14, 30, and 60 day average low-flow curves and how often they occur. For example an individual day flow of 100 cfs will occur about once every three years, whereas a 60 day average low-flow of 100 cfs will occur about every 17 years.

A portion of SJC water, 3,000 afy, is permitted for diversion as part of the North I-25 Non-potable Project (SP-4819).

3.1.3 Wastewater

Less than half (about 40 percent) of the water used by the Water Authority is used consumptively (water that evaporates, transpired

[3] Firm yield is defined as the long-term average supply that a reservoir of a given size could produce every year given the expected input flow. Note that in some years input flow will be greater or less than the firm yield due to natural variability.

[4] Minimum bypass flows are amounts that must pass the diversion point. For example, if a minimum bypass flow is set at 100 cfs and 120 cfs is flowing, then the maximum diversion would be 20 cfs.

by vegetation, or otherwise "lost"). The rest – currently about 60,000 afy – is discharged as treated wastewater to the Rio Grande. This effluent is currently used, along with native surface water rights, to offset effects on Rio Grande flows due to groundwater pumping. In addition, up to about 2,000 afy of return flow can be diverted prior to discharge and used as part of the Southside Reuse Project to irrigate large turf areas in southeastern portion of Albuquerque. This project began operation in 2012.

Figure 8 shows historical Water Authority demand (ground and surface water) and return flow. Return flow has remained relatively constant in volume since the mid-1990s while demand has decreased significantly.

A small amount of industrial wastewater has also been used as non-potable reuse in the North I-25 Non-potable Project.

Figure 5. SJC Annual Inflow to Heron

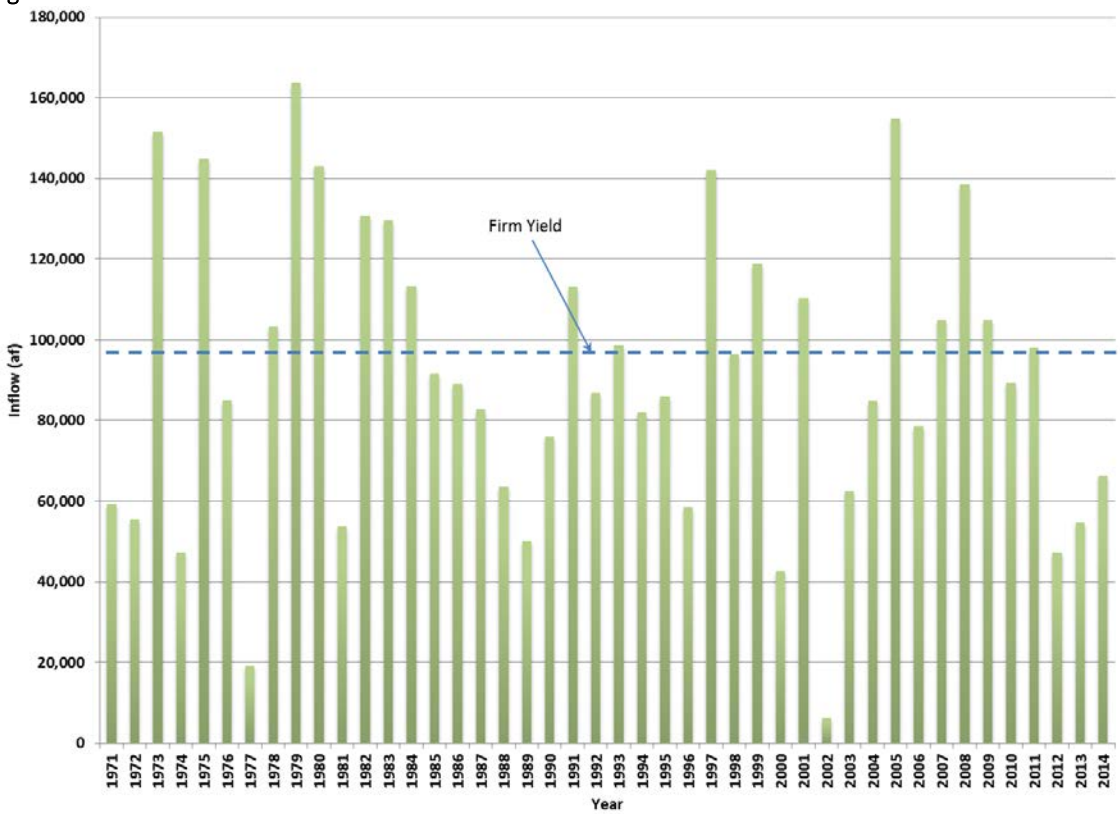


Figure 6. Monthly Rio Grande Flow at Albuquerque (1942-2014, See Appendix E for larger size)

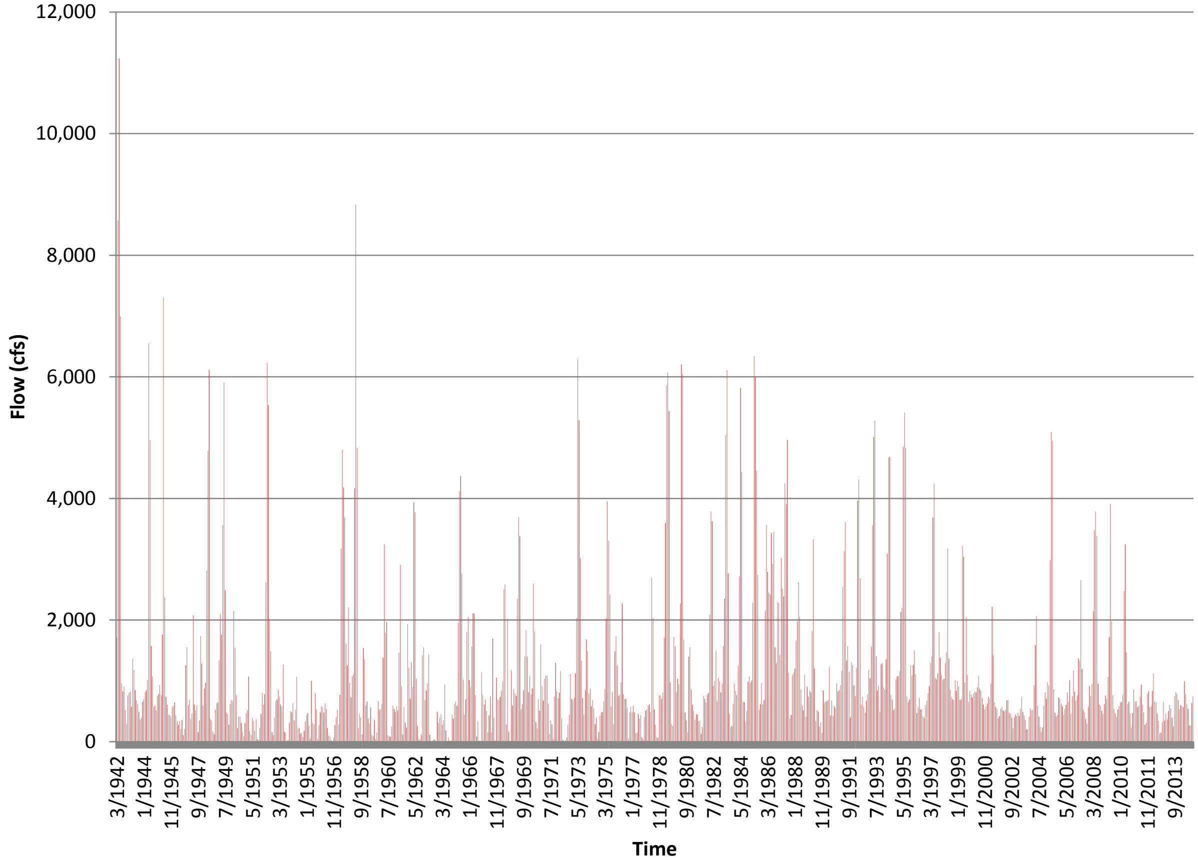


Table 2. Minimum Bypass Flows for San Juan Chama Diversions (cfs)

	Rio Blanco	Little Navajo River	Navajo River
January	15	4	30
February	15	4	34
March	20	4	37
April	20	4	37
May	40	27	88
June	20	27	55
July	20	27	55
August	20	27	55
September	20	27	55
October	20	4	37
November	20	4	37
December	15	4	37

Figure 7. Low Flow Frequency at Albuquerque, based on 1971-2014 hydrology

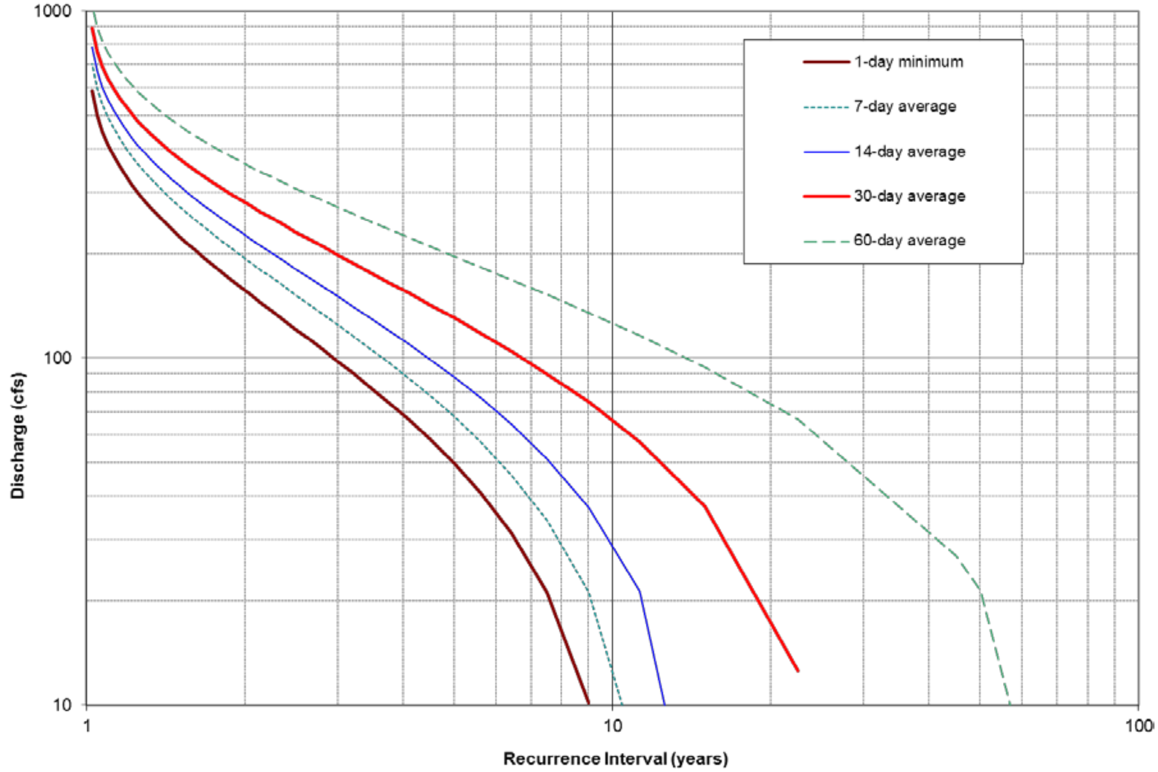
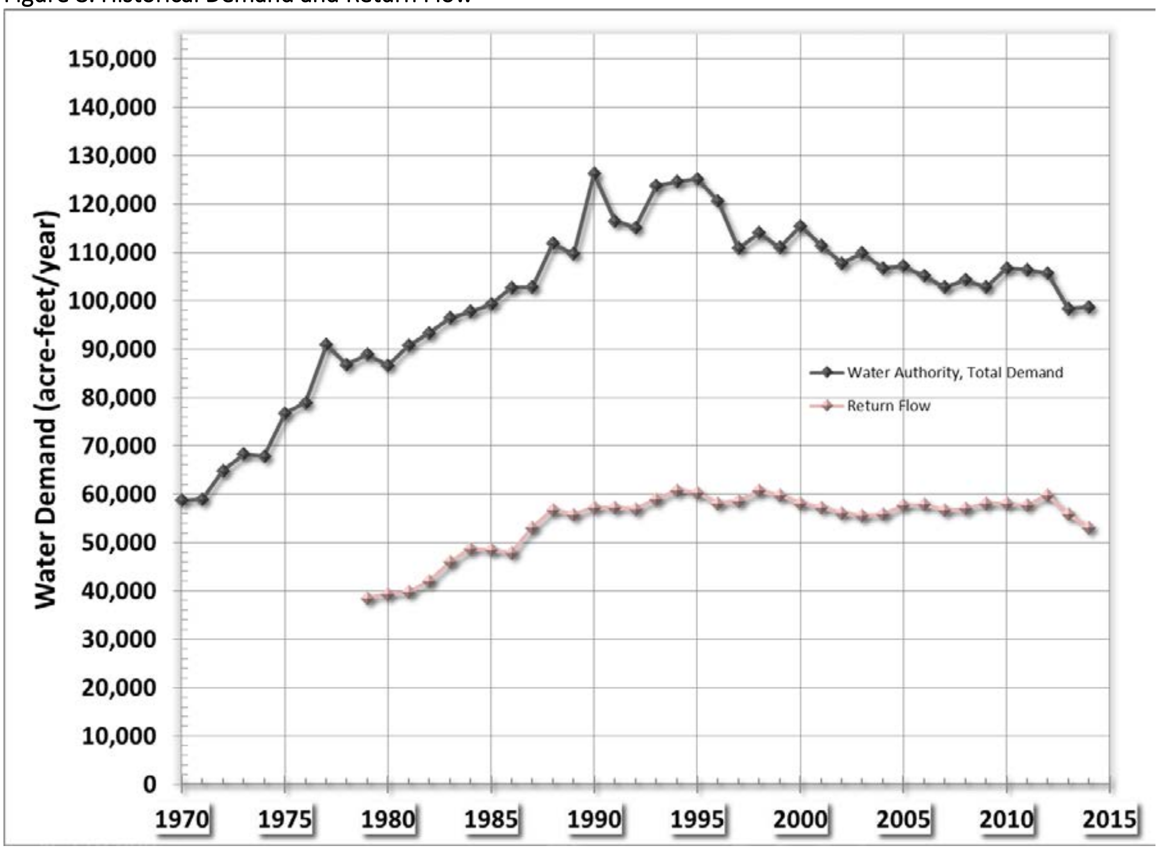


Figure 8. Historical Demand and Return Flow



3.2 Groundwater

The Water Authority currently pumps groundwater from the Albuquerque Basin aquifer, comprised of extensive sand and gravel deposits beneath the Rio Grande Valley and adjoining mesas. These deposits extend from north of Bernalillo to south of Belen. A map of the basin extent is shown in Figure 9.

The Water Authority currently has a total demand of about 100,000 afy. Until December of 2008, most of this demand was met through groundwater pumping. At this time, the Water Authority began phasing in utilization of its SJC surface water. Since December of2008, groundwater production has steadily declined from near 100,000 acre-feet to about 40,000 acre-feet in 2014 (see Figure 3).

The Water Authority has two groundwater permits issued by the OSE: one originating from the City of Albuquerque (RG-960 et al.), and one originating from New Mexico Utilities Inc. (NMUI, RG-4462), which the Water Authority acquired in 2009. The maximum pumping from both permits combined is 165,000 afy.

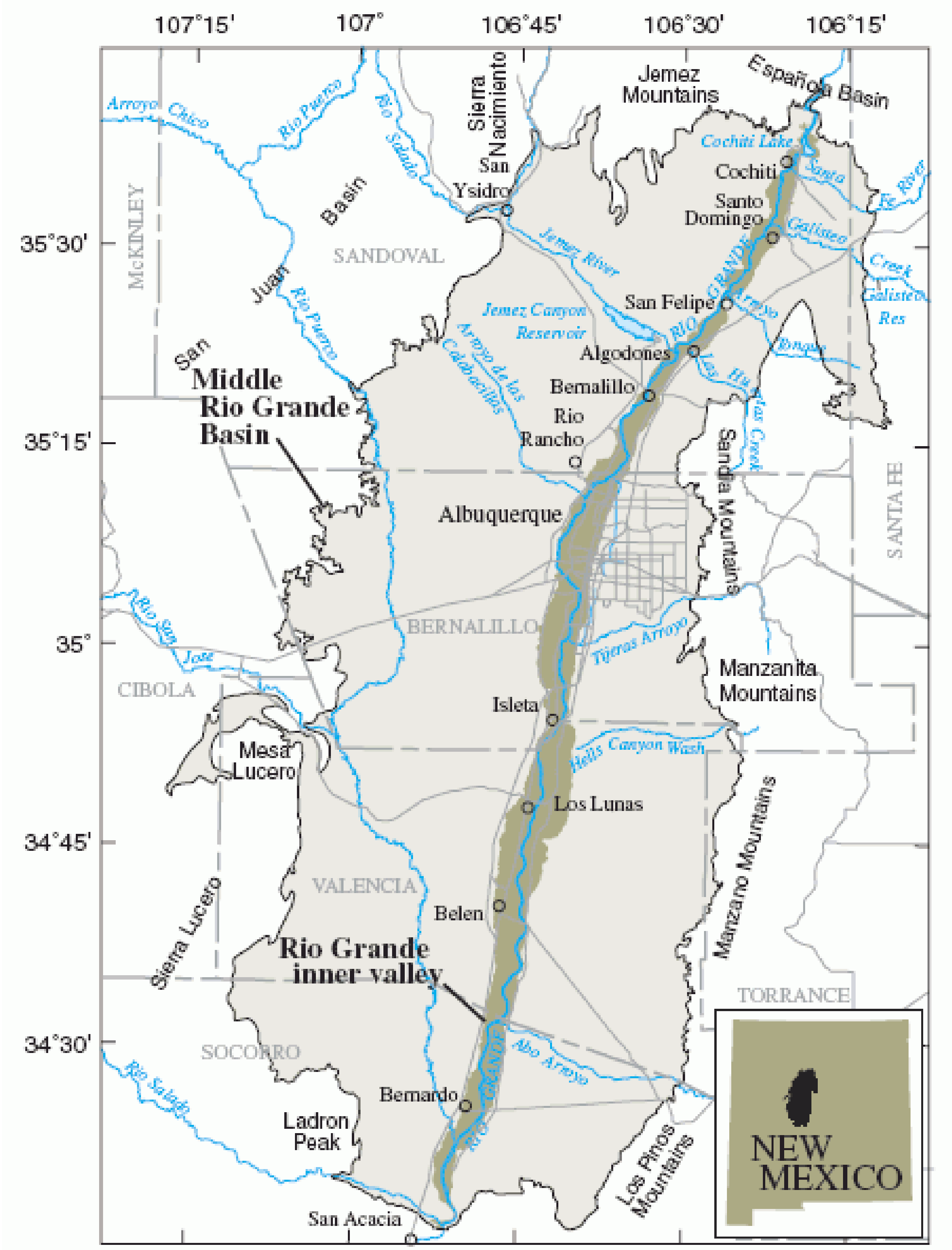
RG-960 allows pumping of up to 155,000 afy of groundwater so long as the effects of that pumping on the flow of the Rio Grande are offset. The maximum amount of allowable pumping is pro-rated over time from 132,000 afy currently to the eventual maximum of 155,000 afy noted previously. Table 3 lists the permitted maximum groundwater pumping over time. Existing well capacity from the Water Authority's more than 90 wells is sufficient to pump the full amount of its groundwater diversion rights.

The required surface water offset varies over time depending on historical and current pumping. Offset requirements are determined by the New Mexico Office of the State Engineer updating its Administrative Area Model for the Middle Rio Grande. Offsets are met through a combination of treated wastewater effluent discharged to the Rio Grande, native surface water rights, and, if necessary, releases of stored SJC water. Historical groundwater production is shown in Figure 10.

The NMUI acquisition included 10,000 afy of groundwater diversion rights, and historical production has nearly reached that amount. Offsets associated with exercise of these rights are computed using the Glover-Balmer method. Offsets are met through a combination of treated wastewater effluent discharged to the Rio Grande and native surface water rights. Since acquisition, the NMUI system has historically discharged wastewater to the Water Authority system, but diversions and return flow credits under permit RG-4462 are administered separately from RG-960. The NMUI system is currently interconnected with the Water Authority's distribution system.

Future groundwater production will be used to make up for demand not met by surface water or other sources.

Figure 9. Middle Rio Grande Basin

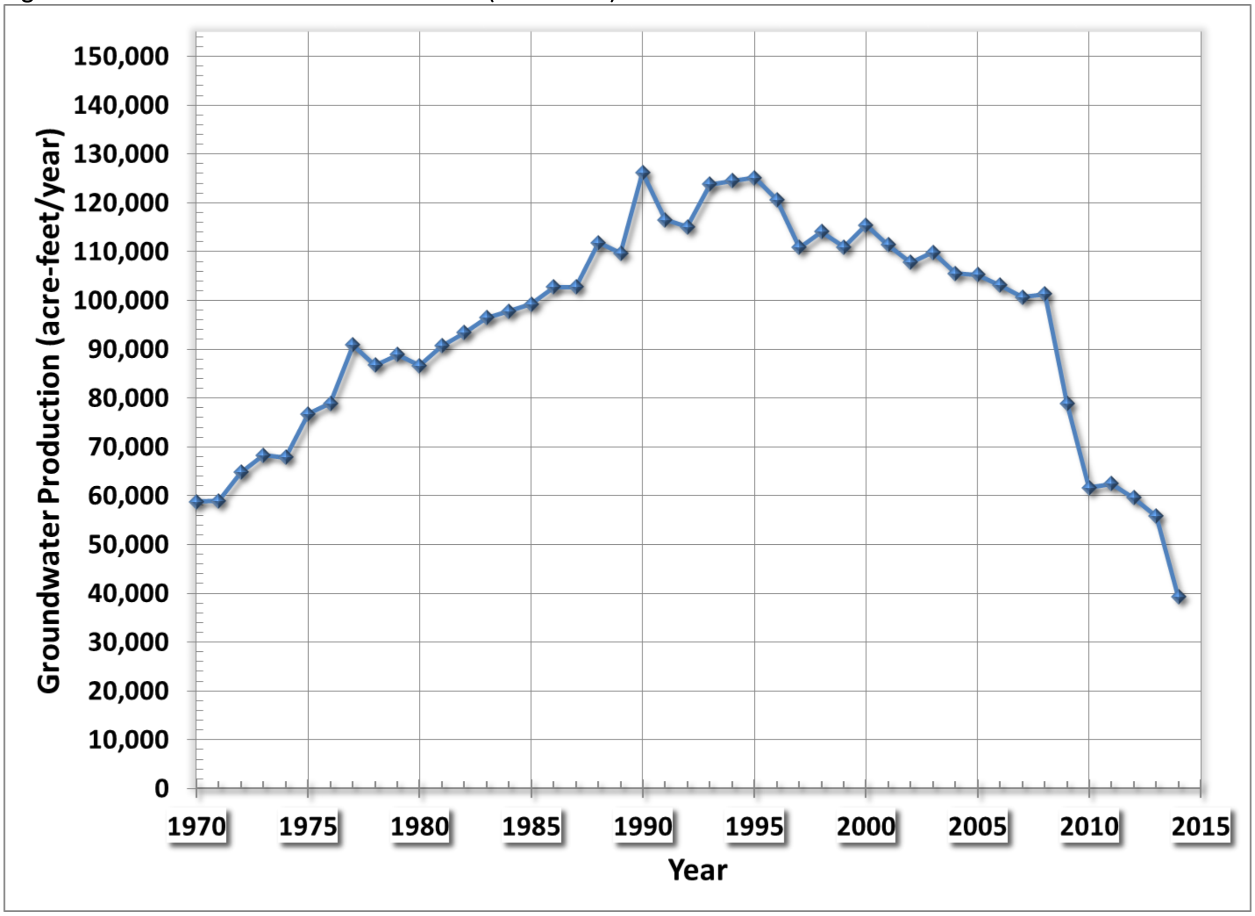


Source: USGS, http://nm.water.usgs.gov/projects/middleriogrande/images/basin.gif

Table 3. RG-960 Diversion Limits

Years	Diversion Limit (acre-feet)
Thru 2015	132,100
2016 thru 2029	142,900
2030 and thereafter	155,000

Figure 10. Historical Groundwater Production (1970-2014)



4.0 Supply Projections

Previous WRMSs included historical Rio Grande flow to represent future potential for supply variability. While this sequence is appropriate for capturing the variability associated with the observed record, it does not include the greater variability associated with either the paleo record or with more recent work on anticipated climate change.

For the current WRMS, the Water Authority is mitigating this uncertainty in future streamflow by considering a range of future conditions. A series of "Low", "Medium", and "High" streamflow/supply projections were developed based on:

1. Updating the historical Rio Grande flow sequence from 1971-1998 to 1971 to 2014 (which includes recent drought)
2. Utilizing modified US Bureau of Reclamation-provided flow sequences

(see Appendix B) for the Rio Grande and San Juan River to reflect projected climate variability.

This variability is focused entirely on surface water availability. Note that other supply sources are generally immune from variability and are either dependent on surface water availability (groundwater - demand increases directly with reduction in surface water) or completely independent of surface water (reuse/wastewater sources).

The remainder of this section presents the chosen surface water sequences and provides a discussion of how groundwater is potentially impacted by the projected hydrologic variability.

4.1 Surface Water Projections

Average and median flow over the planning period were compared for the historical record and the five Reclamation climate sequences (see Table 4). Three sequences were selected from these that describe the range of potential flows for Low, Medium, and High projections.

Table 4. Available Hydrologic Sequences, Flow in cfs 2015-2120

	Average	Median
Warm-Dry	910	583
Warm-Wet	1,216	745
Hot-Dry	778	513
Hot-Wet	952	607
Central	961	613
Historical (71-2014)	1,251	766

Note that while the Warm-Wet sequence from Reclamation results in more average flow over the planning period than the historical record, it was appropriate to utilize the historical record as it is relatively high and can be easily compared to past experience.

The following sections discuss the Low, Medium and High projections for both Rio Grande and San Juan-Chama flows and ultimately supply.

4.1.1 "High" supply - Historical Hydrology (1971-2014)

Rio Grande

As part of previous planning efforts the 1971 to 1998 hydrologic record was analyzed and subsequently chosen as representative of the longer hydrologic record (CH2M HILL 2003). This record was chosen because it is representative of the long-term (>100-year) record and the current operational regime for reservoirs, river facilities, and SJC water importation and use began in 1971.

The 1971-98 streamflow record was adjusted and aligned so that 1971 became 2006, 1972 became 2007, etc. to simulate future hydrologic conditions. Adjustments to the historic record included:

- Removal of the historical (1971-98) Water Authority SJC water that was in the river at Central based on a detailed evaluation of Federal, State, and Water Authority records.
- Addition of a simulated 3-year drought to the record based on three 1972s placed 'back to-back' in the baseline so as to depict an extended drought similar to that experienced in the 1950s. Such a drought is otherwise missing from the 1971-98 period.

As described in detail in Appendix C, this process was utilized to update the sequence through 2014, resulting in a "High" supply sequence consistent with the recent historical record (1971-2014). Figure 11 presents the resulting sequence, repeated to cover the period from 2015 to 2120. Average monthly flows vary significantly from near zero to over 6,000 cubic feet per second (cfs).

San Juan-Chama

San Juan-Chama water diverted to Heron Reservoir is constrained by minimum bypass requirements, and varies year to year. However, Heron Reservoir has a capacity of over 400,000 af, compared with the firm yield of about 96,000 afy. Historically, the capacity of Heron Reservoir has been sufficient to act as a buffer to supply variability (see Figure 5). Accordingly, San Juan-Chama supply is assumed to be 48,200 acre-feet/yr under "High" flow projections, corresponding with historical hydrology.

4.1.2 "Low" and "Medium" - Climate Change Projections

Rio Grande

As discussed above, surface water supply is likely to be influenced by climate change. Five Climate Change sequences have been developed for use in water supply planning by Reclamation. Two of these sequence, "Hot-Dry" and "Central", were chosen to represent Low and Medium supply conditions, respectively. The Low (Hot-Dry) sequence reflects the top 25 percent of climate traces for both temperature increase and precipitation decrease. The Medium (Central) sequence reflects the central tendency of climate traces for temperature and precipitation. Appendix B presents additional detail on the development of the climate change sequences. Figure 12 shows Rio Grande flow under the Low, Medium and High Supply projections for monthly flow, annual flow (with a 10-year running average) and monthly average flow. Table 5 provides summary statistics for flow over the planning period. Appendix D provides a discussion that compares the chosen sequences to the palo record as reconstructed from tree-ring data.

Figure 11. High Sequence, 2015-2120

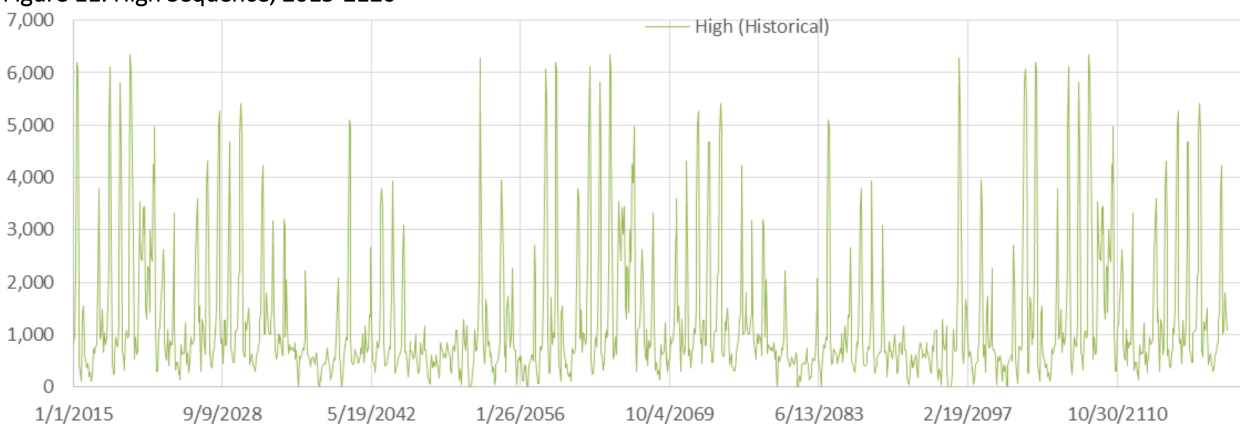


Table 5. Historical and updated Annual Rio Grande Flows (cfs)

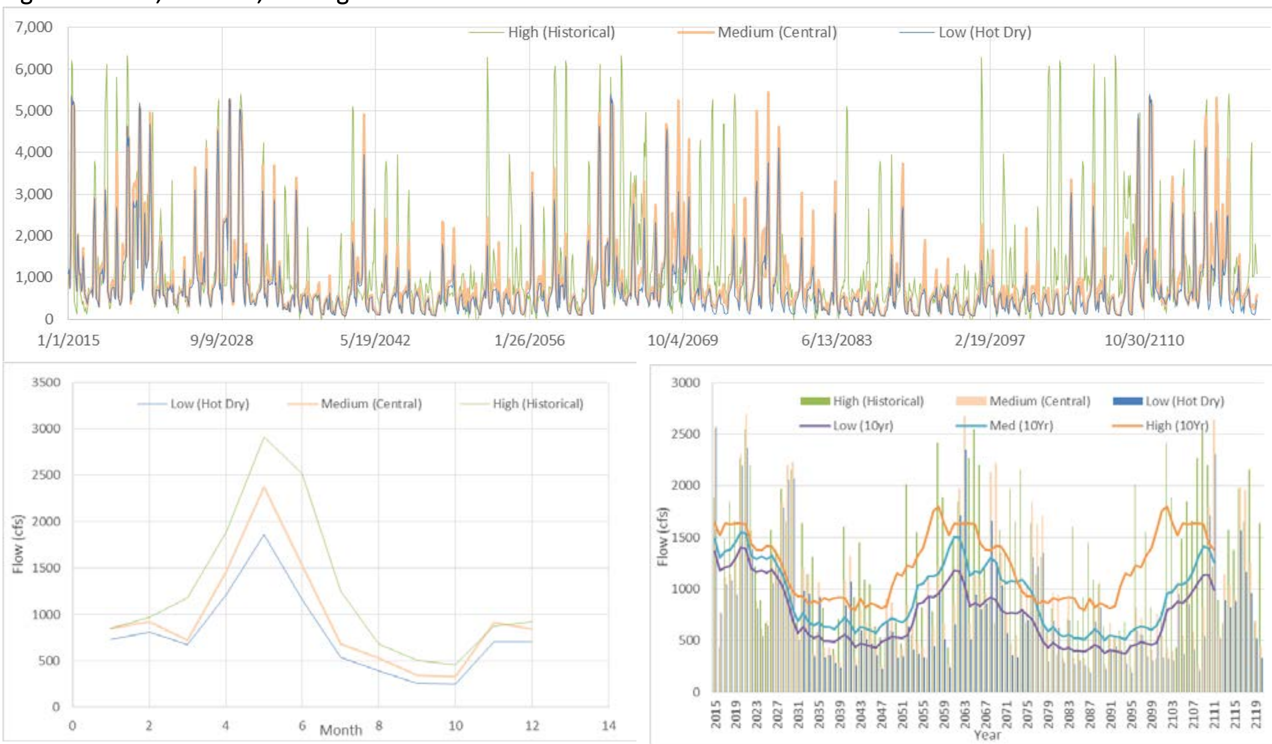
2015-2120	Average	Median
WRMS 2007[1]	1,362	816
High (Historical)	1,251	766
Medium (Central)	1,077	677
Low (Hot Dry)	973	621

[1] The 2007 WRMS is averaged over the planning period from 2006 to 2060

San Juan-Chama

For San Juan-Chama supply, each climate change sequence noted for the Rio Grande also results in a sequence of Azotea tunnel inflow. These projections can be used with evapotranspiration data (also adjusted to reflect warmer temperatures with climate change) to estimate available SJC water for the Water Authority. Table 6 presents the amount of SJC supply available under each of the three projections. As can be seen, even under relatively extreme assumptions about future climate, SJC is still a significant component of future supply.

Figure 12. Low, Medium, and High Flow



Note: These figures are intended to show data trends and not individual data points. For more detail see Appendix E, where larger versions are presented.

Table 6. Average SJC Supply 2015-2120

Projection	Percentage of normal flows
High Supply (Historical)	100%
Medium Supply (Central)	88%
Low Supply (Hot Dry)	75%

4.2 Groundwater

Under the “High” projection (historical Rio Grande hydrology), groundwater usage is expected to be reduced from other projections. It is assumed that groundwater production will increase in drought years, but that the aquifer will continue to be recharged similarly to historical recharge at the mountain front and proportional to groundwater pumping for river recharge.

For the “Low” and “Medium” projections, groundwater production will also fluctuate based on available surface water with drought years requiring grater production. However, the sustainability of groundwater production could potentially be affected by climate change through changes in local precipitation affecting mountain front recharge and/or through regional changes that impact the amount of water flowing in the Rio Grande.

The “Low” and “Medium” projections will generally result in less water flowing in the Rio Grande, resulting in more frequent curtailment of surface water diversions and subsequent greater reliance on groundwater to meet demands. In addition, less water in the river will result in lower seepage rates and therefore more reliance on groundwater from storage in the short-term. That said, additional pumping will result in additional drawdown and ultimately river recharge over a larger area, making up for the reduction in flow.

It is anticipated that the primary impact of climate change to the groundwater resource will be greater reliance on this resource with a small change in reliability due to change in recharge. Likewise, it is anticipated that this change will be small when compared to potential surface water impacts and the buffering capacity of the aquifer (storage) and will not be considered at this time.

5.0 References

CH2M HILL. 2003. *Hydrologic Effects of the Proposed City of Albuquerque Drinking Water Project on the Rio Grande and Rio Chama Systems*. Prepared for City of Albuquerque Public Work Department, October.

USFWS, 2004. Biological Opinion on the Effects of Actions Associated with the Programmatic Biological Assessment (BA) for the City of Albuquerque Drinking Water Project. February.

USGS gaged data Central

Reclamation. 2011. *West Wide Climate Assessment*.

Reclamation. 2014. *URGIA*.

Reclamation. 2014. Dagmar data

Appendix A

SP-4830

BEFORE THE NEW MEXICO STATE ENGINEER

IN THE MATTER OF THE APPLICATION BY	)	
CITY OF ALBUQUERQUE PUBLIC WORKS	)	**Hearing No. 02-017**
DEPARTMENT TO DIVERT SURFACE	)	
WATER FROM THE RIO GRANDE BASIN	)	**OSE File No. 4830**
OF NEW MEXICO	)	

REPORT AND RECOMMENDATION OF THE HEARING EXAMINER

This matter came on for hearing before Victor Kovach, the State Engineer's designated Hearing Examiner, on December 3 through December 6 and December 9 through December 13, 2002, in Santa Fe, New Mexico, and on February 24 through February 27, 2003, in Albuquerque, New Mexico. The parties appeared as follows: Jay F. Stein, Esq., and James C. Brockmann, Esq., represented the Applicant City of Albuquerque Public Works Department; Peter Thomas White, Esq., Mary Humphrey, Esq., and Connie Odé, Esq., represented Protestants Amigos Bravos, Rio Grande Restoration, Sierra Club, New Mexico Public Interest Research Group (NMPIRG), Socorro Soil and Water Conservation District (SSWC), John Carangelo, and the Assessment Payers Association of the MRGCD (hereinafter referred to collectively as the "Coalition Protestants"); and William D. Teel, Esq., represented the Water Resource Allocation Program (WRAP) of the Office of the State Engineer (OSE). An appearance, at the beginning of the hearing, was made by Lester K. Taylor, Esq., for the Pueblo of Isleta, Gary Horner, Esq., for B.J. Resources, Inc., and Ray A. Garcia, *pro se*.

Having considered the pleadings and evidence of record, the Hearing Examiner recommends the following Findings and Order.

FINDINGS

1. The State Engineer has jurisdiction of the parties and subject matter.
2. On May 18, 2001 and again on June 26, 2001, the City of Albuquerque (City) Public Works Department filed Application No. 4830 with the State Engineer for Permit to divert surface water from the Rio Grande for municipal, industrial and related

purposes for the City's Drinking Water Project (DWP). The City proposes to divert approximately 94,000 acre-feet per year (afy), on a yearly average, at a near constant rate of about 130 cubic feet per second (cfs), with peak diversions of up to 103,000 afy at a rate of up to 142 cfs, generally comprised of 50 percent San Juan-Chama Project water, which will be fully consumed within the City's water service area, and 50 percent 'native' Rio Grande Water, which will be returned to the Rio Grande. The Application and legal notice identify three alternative diversion points, all of which are located on land owned by the Middle Rio Grande Conservancy District (MRGCD).

3. The City's preferred diversion alternative, and focus of its presentation at hearing, is a new surface water diversion facility to be located in the vicinity of the Paseo del Norte Bridge in Albuquerque, New Mexico, within a 500-foot radius of a point where X=382,500 feet and Y=1,525,800 feet NMCS Central Zone, NAD 27. The facility would consist of an adjustable-height (from 0 to 3.5 feet) inflatable dam to be installed on the Rio Grande approximately 2,500 feet north (upstream) of the Paseo del Norte Bridge. At Rio Grande stream flow rates up to approximately 10,000 cfs, the adjustable-height crest gates would be raised or lowered as required to maintain an average water surface elevation of approximately 4,992.9 feet, which is about 2.9 feet above the existing river bottom. At flow rates greater than 10,000 cfs, the gates would be maintained in the lowered position. The proposed diversion facilities include a sluice channel, raw water intake and fish screens along the east bank of the Rio Grande, a 50-foot-wide, low gradient, fishway on the west side of the river, and a pump-station and pipeline to convey water to the City's proposed treatment plant near Chapell and Osuna Roads in northeast Albuquerque. The 'native' Rio Grande water diverted by the City would be returned to the river at the City's Southside Water Reclamation Plant (SWRP) wastewater outfall, located below the Rio Bravo Bridge at a point where X=373,900 feet and Y=1,462,000 feet New Mexico Coordinate System (NMCS), Central Zone, North American Datum (NAD) 27.

4. Affidavits of Publication indicate that legal notice of the Application was published in the following newspapers: *Albuquerque Journal; Las Cruces Sun-News; News Bulletin* of Valencia County, New Mexico; *The Herald*, Truth or Consequences, New Mexico; and, *El Defensor Chieftain*, Socorro, New Mexico. Protests to the granting of the Application were filed by the MRGCD, the City of Farmington, the San Juan Water Commission, the Hammond Conservancy District, the Navajo Nation, the Pueblo of Isleta, the Frankie S. Carruthers Trust, the Alliance for the Rio Grande (by and through Amigos Bravos, Rio Grande Restoration, Sierra Club, NMPIRG and only these entities), SSWC, John Carangelo, Chairman, in his official capacity and as an individual, the Assessment Payers Association of the MRGCD, B.J. Resources, Inc., Robert E. Oxford, Bette J. Oxford, and Ray A. Garcia.

5. Several Protestants objected to the priority date claimed by the City for the San Juan-Chama Project water in the Application and legal notice. San Juan-Chama Project water is imported into the Rio Grande Basin from the San Juan River Basin and is not subject to priority administration within the Rio Grande Basin. Any potential priority administration with respect to such water can only occur in the San Juan River Basin, and not in the Rio Grande Basin. Any priority date for Applicant's San Juan-Chama Project water will properly be adjudicated by the district court for the Eleventh Judicial District in the pending general water rights stream adjudication for the San Juan River. Accordingly, by stipulation, and limiting order of the State Engineer entered on November 8, 2002, the priority date for the City's San Juan-Chama Project water is not an issue for determination in this administrative proceeding and any decision entered in these proceedings shall not be construed as establishing a priority date for said SJCP water.

6. The protests of the MRGCD, the City of Farmington, the San Juan Water Commission, the Hammond Conservancy District, the Navajo Nation and the Frankie S. Carruthers Trust were withdrawn prior to hearing and these entities were dismissed from further proceedings.

7. The protests of Robert E. Oxford and Bette J. Oxford were dismissed by Order entered in this matter on September 23, 2002.

8. The Coalition Protestants moved to dismiss the Application for lack of jurisdiction. The Hearing Examiner's Order, entered on November 7, 2002, denying Coalition Protestants' Motion to Dismiss Application for Lack of Jurisdiction is incorporated herein by reference.

9. On December 3, 2002, at the beginning of the hearing and prior to the presentation of witnesses, the protests of the Pueblo of Isleta, B.J. Resources, Inc., and Ray A. Garcia were withdrawn and these parties were dismissed from the proceedings by order entered on the record.

10. The remaining parties who participated at hearing include the City, the Coalition Protestants and the WRAP of the OSE.

11. San Juan-Chama Project (SJCP) water is diverted from three tributaries of the San Juan River, a tributary of the Colorado River, and imported into the Rio Grande Basin to provide for beneficial consumptive use of a part of New Mexico's entitlement to Colorado River water under the Colorado River Compact, 45 Stat. 1057, 1064 (1928) and the Upper Colorado River Basin Compact, 63 Stat. 31 (1949).

12. The diversion works for SJCP water, located in southern Colorado, are as follows: the Blanco Diversion Dam diverts surface waters from the Blanco River; the Little Oso Diversion Dam diverts surface waters from the Little Navajo River; and, the Oso Diversion Dam diverts surface waters from the Navajo River. The SJCP water is transmitted via approximately 26 miles of tunnels, into Willow Creek, a tributary of the Rio Chama, and stored in Heron Reservoir in northern New Mexico.

13. 48,200 afy of SJCP water is expressly allocated to the City for municipal purposes in accordance with Contract No. 14-06-500-810 between the United States Department of the Interior, Bureau of Reclamation and City of Albuquerque, dated June 25, 1963 and Amendment No. 1, dated July 6, 1965. The City estimates that it has invested more than $45,000,000 to develop its supply of SJCP contract water.

14. The City has a permit to consume up to 3,000 afy of SJCP water under OSE File No. 4819 for its Nonpotable Surface Water Reclamation Project (NSWRP). It wishes to reserve the right to use said 3,000 afy under either the DWP or NSWRP

and proposes to coordinate such use with the OSE.

15. The City takes delivery of its SJCP water at the outlet works of Heron Reservoir. After release from Heron Reservoir, the City's SJCP water is stored in Abiquiu Reservoir. The City has 170,900 acre-feet of storage space leased in Abiquiu Reservoir.

16. The general operating plan for the City's DWP, set forth in Exhibit A, Pages A-4 & A-5, of Application No. 4830, provides for a constant release of about 67 cfs of City SJCP water from Abiquiu Reservoir in most years. The City estimates that after incurring conveyance losses between Abiquiu and Albuquerque, 65 cfs of SJCP water will reach the diversion facility at Paseo del Norte. A constant diversion of 130 cfs, comprised of 65 cfs SJCP water and 65 cfs ‘native’ water, would occur at the diversion facility as long as flows at the diversion works are at or above a specified 'threshold flow' of 200 cfs. The 'threshold flow' level was determined based on the following: a diversion rate of 130 cfs comprised of 65 cfs of SJCP water and 65 cfs 'native’ water; a fishway bypass flow of 50 cfs; and a flow of 20 cfs at the sluiceway outlet to provide for downstream movement of sediment and fish past the intake screens, as follows:

Total Stream Flow Above Diversion Works
200 cfs (Native + SJCP)

Native Stream Flow			**SJCP**
135 cfs			65 cfs

At Diversion Works

50 cfs	20 cfs	65 cfs	65 cfs
Fishway	Sluiceway	DWP -------------->	DWP ----------->

Below Diversion Works
70 cfs Native Stream Flow

As proposed, a minimum of 135 cfs of 'native' flow would have to be present in the Rio Grande at the point of diversion for full operation of the DWP.

17. When 'native' flows fall below 135 cfs at the diversion point (total flow of 200 cfs with the 65 cfs SJCP water in the river) the City proposes to begin curtailing the quantity of the diversion, to ensure proper operation of the sluiceway and fishway facilities and to minimize depletion effects in the reach of the Rio Grande between the point

of diversion and return flow at the SWRP. The City will continue to release 67 cfs and divert 65 cfs of SJCP water, but will begin curtailing the total quantity (native + SJCP water) of the diversion by 1 cfs for each 1 cfs drop in native flow below 135 cfs. When 'native' flow drops to 70 cfs at the point of diversion DWP diversions would cease and releases of City SJCP water at Abiquiu would be cut off.

18. The DWP is a primary component of the City of Albuquerque's Water Resources Management Strategy (AWRMS) and 40-Year Water Development Plan (hereinafter "40-Year Plan").

19. Municipalities are allowed a water use planning period not to exceed forty (40) years and applications for appropriation of water by municipalities are to be based upon a water development plan for reasonably projected water demands within the forty-year planning period. The City's population and demand projections are set forth in its 40-Year Plan dated August 2002 (City Exhibit No. 11).

20. Three different population projection data sets for the City's water service area are included in Table 2 of the City's 40-Year Plan as follows: the Bureau of Business and Economic Research (BBER) estimates a population of 752,294 in the year 2040; the Middle Rio Grande Council of Governments estimates a population through 2010 at 603,760; and the City's Continued Current Growth Trends (CCGT) estimates a population of 868,800 in the year 2040. The City's CCGT population projection is based on past water use and the growth in the number of utility accounts. All three projections are reasonable.

21. Based on its population estimate of 868,800 for the year 2040, and its expectation that annual average per capita water use will be reduced from 205 to 175 gallons per capita per day (gpcpd) by 2010, the City projects that demand for its service area in the year 2040 will be approximately 170,000 afy (175 gpcpd x 365 days = 63,875 gallons per capita per year ÷ 325,851 gallons per acre-foot = 0.196 afy per capita x 868,800 = 170,284.8 afy).

22. Estimated demand for the City's service area in the year 2040, based upon the BBER population estimate of 752,294, would be approximately 147,450 afy using similar methodology.

23. Estimated demand for the City's service area in the year 2040, using the City's population estimate and a gpcpd figure of 155 would be approximately 150,800 afy.

24. Andrew Lieuwen, Ph.D., WRAP's expert in water rights, water planning and water conservation, reviewed the City's 40-Year Plan and determined that it was acceptable.

25. The City proposes to meet anticipated water demand through transition from dependence on groundwater as its sole source of supply to conjunctive use of SJCP water under the DWP and groundwater permitted under OSE File No. RG-960 et al. Presumably, the amount of the City's annual groundwater diversions under RG-960 et al., would decrease by an amount commensurate with its annual DWP surface water diversions.

26. The City's prior strategy was to meet water demand by continued and increasing diversion of ground water under its existing Permit No. RG-960 et al., and to use its allocated SJCP water to offset the effects on the flows of the Rio Grande that result from those groundwater diversions. The City now proposes to fully consume its SJCP water through direct surface water diversion. Such transition may be permissible provided that the City can meet its obligations under RG-960 et al., that there will be no impairment to existing water rights, that its proposal will not be contrary to the conservation of water within the state and that its proposal will not be detrimental to the public welfare of the state of New Mexico.

27. As a condition of approval under its existing Permit No. RG-960 et al., the City is required to offset the depletion effects of its groundwater diversions on the surface flows of the Rio Grande. OSE records and testimony of WRAP's witnesses indicate that the City uses what it has termed 'vested' and 'acquired' water rights, return flow credit and SJCP water to do so.

28. Although the City proposes to decrease its diversion of groundwater under RG-960 et al., upon implementation of the DWP, it would nonetheless remain obliged to offset the net surface water depletions on the flow of the Rio Grande associated with past groundwater diversion (residual effects) and to offset the effects of continuing groundwater diversions under RG-960 et al. In Table 4-1 of City Exhibit 23, the City

estimates that it needs to have at least 91,000 acre-feet of SJCP water stored in Abiquiu to offset anticipated residual effects during the years 2006 through 2016, or the first ten years of operation. The City also notes that additional storage of SJCP water would be needed to offset evaporation and seepage losses at Abiquiu (26,000 acre-feet), and to meet other obligations (29,000 acre-feet), during that same ten-year period. The Coalition Protestants' technical expert adjusted the City's calculations upward and estimated that the amount of water needed to offset residual effects for the first ten years of operation could be as high as 132,382 acre-feet (Coalition Exhibit 4, Page A-4).

29. The City's calculation of additional releases of SJCP water, for offset purposes during the first ten years of operation, are derived from Table E2 of its Exhibit 23. Certain discrepancies in the listing of estimated net effects (column 17) and the consequent estimated additional SJCP releases (column 20) were recognized at hearing. The estimates of additional releases of SJCP water are calculated by comparing net effects on Rio Grande flow to the amount of water the City describes as its vested and acquired rights: 23,347 afy. The net effects for the majority of years covered by Table E2 are apparently calculated by subtracting groundwater return flows (column 11) from the river effects calculated using the OSE model (column 16). However, net effects entries for the years 2006 through 2016 are not consistent with this methodology. Adjusted entries for the years in question and the corresponding adjusted figures for additional SJCP releases are as follows:

Col. (1) Year	Col. (16) OSE River Effects	Col. (11) Groundwater Returns	Col. (17) Net Effect	Col. (20) Additional SJCP Releases
2006	65,092	17,287	47,805	24,458
2007	64,451	27,142	37,309	13,962
2008	59,050	11,870	47,180	23,833
2009	57,145	16,741	40,404	17,057
2010	53,676	11,679	41,997	18,650

2011	52,197	16,546	35,651	12,304
2012	52,517	27,385	25,132	1,785
2013	49,402	20,600	28,802	5,455
2014	46,301	15,482	30,819	7,472
2015	43,878	16,433	27,445	4,098
2016	42,203	17,547	24,656	1,309
			Total:	130,383

Based on the adjusted entries above, the City's estimate of the amount of additional releases of SJCP water needed for the period of 2006 through 2016 would be approximately 130,383 acre-feet. Additional releases of SJCP water in the amount of 97,960 acre-feet would be required for offset purposes during the first five years of operation of the DWP, as those operations are described and simulated in City Exhibit 23.

30. Prior to initial diversion of SJCP water for the DWP, the City should have at least 130,000 acre-feet of SJCP water stored in Abiquiu reservoir. Thereafter, the City should maintain SJCP water storage in Abiquiu reservoir at levels sufficient to ensure that its obligations under other permits, including its obligation concerning offset of residual and anticipated upcoming effects to the Rio Grande, resulting from its diversion of groundwater under RG-960 et al., will be met.

31. The City's SJCP water in excess of the amount determined by the State Engineer to be needed for offset purposes under RG-960 et al., would be available for release for the City's DWP. SJCP water released for the City's DWP, less conveyance losses, would be available at the DWP diversion point.

32. For purposes of estimating the annual quantity of SJCP water available for diversion at Albuquerque, the City utilized incremental loss methodology. Incremental loss methodology assumes that non-native water is riding on top of native flows. The SJCP water incurs losses caused by evaporation from the larger surface area of the flowing water, but no seepage or other losses.

33. The City considers a factor of 2.5% appropriate for computing conveyance losses of SJCP water from Heron reservoir to the Paseo del Norte diversion site. The City's

proposed factor is derived from loss factors for SJCP water used by the United States Bureau of Reclamation. Table D-5 of City Exhibit 23 reflects a loss rate of 2.35% from Heron reservoir to the Jemez River (Table D-5 of City Exhibit 23). The City adds an additional conveyance loss rate of 0.15 % for the remaining distance to the Paseo de Norte diversion site. According to the City's calculations, approximately 47,000 afy of SJCP water would be available for appropriation at the diversion point for the DWP ((48,200 afy – (0.025 x 48,200 afy) = 46,995 afy)).

34. More conservative, monthly conveyance loss rates for SJCP water from Heron reservoir to Albuquerque were provided in Tables D-6a & D-6b of City Exhibit No. 23, as follows:

	Table D-6a	Table D-6b
January-March	0.97 (3.00%)	0.97 (3.00%)
April	0.96 (4.00%)	0.94 (6.00%)
May	0.95 (5.00%)	0.91 (9.00%)
June	0.93 (7.00%)	0.88 (12.00%)
July – September	0.92 (8.00%)	0.85 (15.00%)
October	0.95 (5.00%)	0.91 (9.00%)
November – December	0.97 (3.00%)	0.97 (3.00%)

WRAP's experts utilized conveyance loss rates from Table D-6b of City Exhibit 23, in evaluating the subject Application. In order to ensure a conservative analysis of depletion effects on streamflows under the DWP, the City utilized the loss rates in Table D-6a of its Exhibit 23, in model simulations.

35. Underestimation of conveyance losses could result in the diversion of native water without a corresponding accounting for such diversion. Monthly, incremental conveyance losses for SJCP water between Heron reservoir and the City's point of diversion should be determined based upon a study, approved by and acceptable to the State Engineer. The results of said study should be adopted for determination of conveyance loss rates for SJCP water under the DWP. In the interim, for purposes of determining the amount of SJCP water delivered to the proposed point of diversion for the DWP, the monthly conveyance loss factors from Table D-6a of the

City Exhibit 23, referenced in Finding 36, above, should be utilized. Assuming a constant rate of release of SJCP water of 4,017 acre-feet monthly (48,200 afy ÷ 12), and no diversion of SJCP water under the City's NSWRP, total SJCP water available at the proposed point of diversion for the DWP would be 45,792 acre-feet calculated as follows:

Month	CLF	SJC (monthly release)	Available at diversion
January	0.97	4,017	3,896
February	0.97	4,017	3,896
March	0.97	4,017	3,896
April	0.96	4,017	3,856
May	0.95	4,017	3,816
June	0.93	4,017	3,736
July	0.92	4,017	3,696
August	0.92	4,017	3,696
September	0.92	4,017	3,696
October	0.95	4,017	3,816
November	0.97	4,017	3,896
December	0.97	4,017	3,896
Annual		48,200	45,792

The above calculations should be adjusted downward to the extent that SJCP water is diverted for the City's NSWRP under Permit No. 4819.

36. The City proposes to fully consume the available SJCP water diverted under the DWP by diverting an equivalent amount of 'native' Rio Grande water and returning the full amount of that 'native' water to the Rio Grande at its SWRP discharge point.

37. The reach of the Rio Grande between the proposed DWP diversion point at Paseo del Norte and the SWRP return flow point, referred to at hearing as the 'depleted reach', is approximately 15-miles long. There are no existing surface water right holders with diversion works on the Rio Grande within the length of the 'depleted reach'.

38. The first immediate downstream surface water diversion below the SWRP return flow point is the MRGCD's Isleta Diversion Dam used for delivery of water to lands within Isleta Pueblo and to lands of individual members of MRGCD. The MRGCD and Isleta Pueblo entered into settlement agreements with the City and withdrew their protests to the granting of this Application.

39. Provided that 100% of the amount of 'native' water diverted under the DWP is timely returned to the Rio Grande, there should be no decrease in the amount of 'native' water available to existing water right holders downstream.

40. The City submitted expert testimony and exhibits reflecting that, in time, estimated depletions on the Rio Grande under the DWP conjunctive use AWRMS strategy would be less than the effects that would result from continued reliance on groundwater under RG-960 et al., as its sole source of supply.

41. City Exhibit 23 includes an analysis of the hydrologic effects of a baseline scenario, wherein the surface water depletion effects of groundwater diversions under RG-960 et al., are simulated, with annual ground water diversions increasing up to 162,354 afy in 2040 and 194,875 afy in 2060, and an analysis of the surface water depletion effects under the DWP, wherein surface and groundwater are used conjunctively (89,883 afy ground & 72,000 afy surface water in 2040 and 100,777 afy ground & 94,000 afy surface water in 2060).

42. The City's hydrologic baseline was developed in three steps as follows:
    a. Align the 1971-98 streamflow and reservoir gage records for the Middle Rio Grande (MRG) and Rio Chama Basins so that 1971 becomes 2006, 1972 becomes 2007, etc., and adjust the records by removing historic City SJCP water.
    b. Subtract the effects of historical City groundwater pumping from the adjusted 1971-98 record and account for the effects of SWRP returns on river flows. This is based on running the OSE interim groundwater model to estimate historical pumping-induced river seepage and using the City's record of wastewater return flows.

c. Subtract or add to the flows determined in subpart (b), above, the projected future effects (2006 through 2060) of continued, full-scale, groundwater pumping (using the OSE interim model) and SWRP return flows on river flows. Also included in the baseline are: variable SJCP water releases made for existing City leases (up to 2,600 afy) through termination in about 2011, approximately 3,000 afy in SJCP water releases for the NSWRP (through 2060), and beginning in 2050, releases of SJCP water to offset pumping effects (amounts increase from about 220 afy to 6,100 afy over the 2050 to 2060 time period), and a simulated 3-year drought.

43. The 1971-98 period provides an acceptable basis for examining the effects of the DWP and RG-960 alternatives on streamflow conditions in the MRG.

44. The City used the OSE interim groundwater model of the Albuquerque basin aquifer, coupled with an interactive 'spreadsheet model' of Rio Grande flows (built upon the adjusted 1971-98 hydrologic record). The two models, so coupled, are an acceptable tool for evaluation and comparison of the hydrologic effects of the DWP and RG-960 alternatives in this matter.

45. Computer simulations for the period 2006 (City's anticipated DWP start up date) through 2060 reflect that the DWP and RG-960 groundwater diversion alternatives will have similar effects on overall streamflow conditions in the MRG. In general, the simulations indicate that relative to RG-960 groundwater diversions, the DWP alternative results in more water (about 60 cfs) in the river above the diversion point at Paseo del Norte, somewhat less water (10 to 25 cfs) in the reach between the diversion point and the City's wastewater return flow point, and essentially no change in flows at the MRGCD's Isleta Diversion Dam.

46. The overall quality of water discharged to the Rio Grande at the City's SWRP will improve under the DWP.

47. The evidence presented at hearing reflects that if the full amount of 'native' Rio Grande water diverted under the DWP is returned at the SWRP outfall, the effects on existing downstream surface water rights, under the DWP, would be no greater than the projected effects under RG-960 et al.

48. In order to prevent impairment to downstream users, diversions of 'native' water under the DWP could never be greater than 50% of the DWP diversion, and said diversion of 'native' water would have to cease at any time the City's return flows to the Rio Grande at its SWRP outfall are less than 50% of the DWP diversion.

49. The amount of the City's return flows to the Rio Grande that are considered return flows of 'native' surface water under its DWP, would not be available to offset depletion effects or to otherwise increase the City's diversion of groundwater under RG-960 et al.

50. The expert testimony and model simulations reflect that the DWP will have less effect on the Albuquerque area aquifer and upon existing groundwater rights within the basin than the RG-960 alternative. By 2040, estimated drawdowns from pre-development water levels under simulated RG-960 conditions are greater than 200 feet in areas of west, northeast and southeast Albuquerque. Under the DWP alternative, estimated drawdowns in 2040 are generally less than 150 to 175 feet in the same areas.

51. As compared to the RG-960 alternative, the DWP will have a positive effect on the aquifer.

52. The City has taken significant steps with respect to water conservation, beginning with the establishment of a Water Conservation Task Force in July of 1990. In May of 1992, the City passed Resolution R-49-1992 adopting a Short-Term Water Conservation Program that included appointment of a Water Conservation Officer, and research and development of a Long-Term Water Conservation Strategy to include specific per capita consumption goals and water rate modifications. In March of 1995 the City adopted its Long-Term Water Conservation Strategy through Resolution R-40-1995 and the Landscaping and Water Waste Ordinance O-18-1995.

53. The City adopted the following water use reduction goals in R-40-1995: reduction of overall per capita usage of 250 gallons per capita per day (gpcpd) by 30% to achieve 175 gpcpd by 2004; reduction of summer outdoor usage by 25%; reduction of current year-round indoor usage by 33%; and reduction of peak day usage by

20% within six to ten years. Since that time the City has maintained a multi-faceted program to encourage conservation and has reduced water usage within its service area by more than 20% to 205 gpcpd.

54. Other southwestern cities of comparable size and climate have successfully reduced their water usage to significantly less than 175 gpcpd. City Exhibit 17 contains a table at page 2, which reflects a gpcpd of 155 (combined residential & non-residential) for El Paso, Texas and Tucson, Arizona.

55. The City's Exhibit 17, page 3, reflects that, in 1950, water use in the City averaged 148 gpcpd.

56. Jeanne Witherspoon, the City's former Water Conservation Officer and its expert in water conservation, testified that the City has achieved significant reductions in water usage in a relatively short period of time and that with continuing and sustained effort, the City can achieve a gpcpd of 150.

57. By utilizing practically available technology and resources, the City can significantly reduce its per capita water usage. Prior to diverting any 'native' water under its DWP, the City should be required to reduce its combined residential and non-residential water usage level to 175 gpcpd. The City should be able to achieve a water usage level of 155 gpcpd or less within a reasonable period of time and continued diversion of 'native' water under the DWP should be contingent upon the City's filing of regular conservation progress reports demonstrating that it is diligently pursuing reductions in water usage levels to the maximum extent practical and showing continuing reductions consistent with achieving a water usage level of 155 gpcpd within twenty (20) years.

58. The City's water conservation program should be modified and updated to include a drought management plan acceptable to the OSE.

59. The Coalition Protestants presented several witnesses who testified about the intrinsic cultural and environmental value of maintaining flows in the Rio Grande throughout the 'depleted reach' and related concerns as to the effect that diminution of those flows might have on the riparian ecology and aquatic habitat.

60. A Draft Environmental Impact Statement (Draft EIS), City of Albuquerque DWP, June 2002, was admitted into evidence as Coalition Protestants' Exhibit 9. The Draft EIS reflects that 189 miles of river channel of the Rio Grande is likely to experience average annual flow increases of 65 cfs under the DWP with a 15-mile stretch experiencing depleted flows. Table 3.16-1 of the Draft EIS (Coalition Protestants Exhibit 9) compares the projected effects that the DWP and no action (RG-960) alternatives would have over time to historical flows measured in the Albuquerque reach of the Rio Grande. The projections are based upon an average annual gpcpd of 175. The projected incremental differences in streamflows in cfs at the Albuquerque Central Avenue gage (hereinafter 'Albuquerque gage'), and additional depletions under the DWP as opposed to the no action alternative, are as follows:

Year	No Action	DWP	Additional Depletions
2006	-47	-68	21
2012	-56	-77	21
2020	-61	-94	33
2030	-68	-99	31
2040	-78	-89	11
2050	-85	-109	24
2060	-90	-119	29

The average of the above projected additional depletions on Rio Grande streamflows under the DWP, measured at the Albuquerque gage, is 24.29 cfs (21 + 21 + 33 + 31 + 11 + 24 + 29 = 170 ÷ 7 = 24.29 cfs).

61. The DWP should be operated in a manner that minimizes additional depletions through the 15-mile 'depleted reach' of the Rio Grande, as much as practicable.

62. Table C-3, Appendix C of City Exhibit 23, sets forth historical data on monthly Rio Grande flows measured at the Albuquerque gage. The data reflect that the median of annual average flows for 1943 through 1998 is 1,116 cfs. The median of annual average flows for 1943 – 1970 (pre SJCP) is 936 cfs. The lowest reported median of monthly average flows is 122 cfs and the minimum annual average flow

measured was 293 cfs recorded in 1964.

63. To the extent that 'native' flows are available above the proposed point of diversion, the DWP should be operated so that flows in the channel of the Rio Grande between the point of diversion and the Albuquerque gage are no less than the lowest reported median of monthly average flows: 122 cfs. Allowing 130 cfs of flow to pass through the diversion works should be adequate to maintain said flow level.

64. The 'threshold flow' level and curtailment strategy, set forth in the general operating plan for the City's DWP and described in Findings 16 and 17, should be adjusted upward to reflect the difference between the 70 cfs of 'native' flow the City originally proposed to pass through the diversion works and the 130 cfs referenced in Finding 63, above. Accordingly, diversion of 'native' water would be curtailed when 'native' flows fall below 195 cfs (130 cfs that remains in the channel immediately below the point of diversion + 65 cfs DWP diversion), measured immediately above the storage pool at the proposed point of diversion, by 1 cfs for each 1 cfs drop in 'native' flow, and would be suspended when 'native' flow drops to 130 cfs or lower at the same point.

65. Other regulatory agencies, including the United States Fish and Wildlife Service and the Bureau of Reclamation, have regulatory oversight under the National Environmental Policy Act to ensure that the City's operation of the DWP complies with environmental requirements.

66. The City's plan for conjunctive use of water resources constitutes a reasonable use and development of water resources, especially as compared to reliance on groundwater as its sole source of supply, that will extend the life of the aquifer, and allow for flexibility of operations during times of low flow or drought.

67. Evidence was also presented at hearing concerning the public benefit that would be realized from the DWP.

68. The United States Environmental Protection Agency (EPA) has promulgated a new maximum contaminant level for arsenic in drinking water of 10 *u*g/L. The City's proposed Surface Water Treatment Plant under its DWP will enable it to meet the arsenic standard in a cost-effective fashion by applicable compliance dates. In

addition to the public health benefits associated with meeting the EPA drinking water standard, cost savings to the City were estimated at approximately $160,000,000 ($200 million for groundwater treatment versus $40 million for surface water treatment).

69. The use of surface water will result in a lower concentration of Total Dissolved Solids (TDS) in the water supply as compared to use of groundwater under RG-960 et al., and in the water discharged to the Rio Grande at the City's SWRP.

70. The overall quality of the water supplied to the public within the City's water service area will improve under the DWP as will the water discharged to the Rio Grande at the City's SWRP.

71. The City's continued reliance on groundwater as its sole source of water supply could result in significant land surface subsidence over large areas of the Albuquerque Basin. The City's transition to conjunctive use of water resources under the DWP will reduce the risk of land surface subsidence.

72. F. Lee Brown, Ph.D., Economic Consultant, estimates that direct economic benefits to the City resulting from the DWP will be approximately $1,371,000,000.00 as follows: $127,000,000.00 reduced well costs + $221,000,000.00 reduced subsidence costs + $260,000,000.00 reduced arsenic and desalinization costs + $763,000,000.00 creation of a drought reserve.

73. The City has demonstrated that it needs a transition from reliance on groundwater under Permit RG-960 et al., as its source of municipal water supply, to conjunctive use of surface and ground water as a matter of public health and welfare.

74. The evidence presented at hearing establishes that granting Application No. 4830 will facilitate the City’s transition to conjunctive utilization of its SJCP water under the DWP and groundwater under RG-960 et al., and that if properly conditioned, there will be no increase in depletions to the Rio Grande, no impairment to existing water rights, no detriment to the public welfare of the state and conservation of water will be enhanced.

75. The hearing adjourned on February 27, 2003. The record was held open through April 25, 2003 for the limited purpose of allowing the parties opportunity to file proposed findings, conclusions and recommended conditions. On April 25, 2003, the Coalition Protestants filed proposed findings and also filed a Motion to Recuse the State Engineer. Said motion should be and is denied.

76. Application No. 4830 should be approved, subject to conditions.

ORDER

THEREFORE, Application No. 4830 for Permit to divert surface water from the Rio Grande is approved, subject to conditions, as follows:

Permittee: City of Albuquerque

OSE File No.: 4830

Date of Application: Application filed May 18, 2001 and June 26, 2001

Point of Diversion: New surface water diversion facility located on the Rio Grande within a 500-foot radii of a point where X=382,500 feet and Y=1,525,800 feet, New Mexico Coordinate System (NMCS), Central Zone, North American Datum (NAD) 27 and approximately 2,500.0 feet north (upstream) of the Paseo del Norte Bridge

Source of Water: Colorado River water apportioned to New Mexico for beneficial consumptive use by the Colorado Compact, 45 Stat. 1057, 1064 (1928) and the Upper Colorado River Basin Compact 63 Stat. 31 (1949) and allocated to the City of Albuquerque by Contract No. 14-06-500-810 between the United States Department of the Interior, Bureau of Reclamation and the City of Albuquerque, dated May 25, 1963, and Amendment No. 1, dated July 6, 1965, for San Juan-Chama Project Water.

Surface waters of the Rio Grande

Amount of Water:

Diversion – Up to 48,200 afy of San Juan Chama Project water, less conveyance losses as determined in accordance with Conditions of Approval, below, measured at the point of diversion. 'Native' Rio Grande surface water may be simultaneously diverted, in accordance with the conditions of approval below and in an amount not to exceed the amount of San Juan-Chama Project water diverted at any time, provided such water is timely returned directly to the Rio Grande, in full, at the SWRP outflow.

Consumptive Use – Up to 48,200 afy of San Juan-Chama Project Water less conveyance losses as determined in accordance with Conditions of Approval, below. Diversion of 'native' Rio Grande surface waters is for non-consumptive use only and 100% of the amount diverted shall be simultaneously returned to the Rio Grande.

Purpose of Use: Municipal, industrial and related purposes for the City of Albuquerque Drinking Water Project

Place of Use: Service area of the City of Albuquerque water system

CONDITIONS OF APPROVAL

1. Permit No. 4830 shall not be exercised to the detriment of valid existing water rights or in a manner that is contrary to the conservation of water within the state or detrimental to the pubic welfare of the State of New Mexico.
2. The total annual combined diversion of surface water under this permit and Permit No. 4819 shall not exceed 96,400 afy, less conveyance losses as determined in accordance with Conditions of Approval 6 and 7 below.
3. Prior to initial diversion of surface water from the Rio Grande for start-up of the DWP, the City shall demonstrate to the satisfaction of the State Engineer that it has 130,000 acre-feet of San Juan-Chama Project water in storage at Abiquiu reservoir available and reserved for offsetting residual and ongoing effects to the Rio Grande as a result of its groundwater diversions under RG-960 et al.
4. The City shall submit to the State Engineer, by the first day of each of the quarterly periods January through March, April through June, July through September, and October through December, or such other time period as may be determined acceptable by the State Engineer, information concerning the upcoming period sufficient to determine that the amount of San Juan-Chama Project water the City has in storage is adequate to meet offset requirements and anticipated DWP diversions, including the following: (a) projected average daily total surface water diversions and projected total ground water diversions from the City's wells; (b) projected return flows from surface water diversions and from ground water diversions from the City's wells; (c) projected deliveries of the City's San Juan-Chama Project water; (d) the amount of the City's acquired Rio Grande surface water rights;(e) the amount of the City's vested and acquired groundwater rights and the amount of the City's dedicated surface water rights; (f) projected amount of

MRGCD or BOR water in storage available for repayment to the City; and, (g) the amount of San Juan-Chama Project water the City has in storage and available to meet its projected obligations, including offsets for residual and ongoing effects under RG-960 et al., and its projected diversion under the DWP.

5. If the information provided pursuant to Conditions of Approval 3 & 4 does not adequately establish that sufficient San Juan-Chama Project water is available in storage, the State Engineer may take such action as he deems necessary, including but not limited to, ordering that the City suspend its diversion of surface water under the DWP.

6. The City shall propose a study of incremental loss rates for delivery of San Juan-Chama Project water to the point of diversion, to be undertaken by the City within two (2) years from the date of approval of this permit, and to be conducted in a manner acceptable to and approved by the State Engineer based on existing and anticipated Rio Grande channel conditions for each month of the year and for all levels of native streamflow.

7. The amount of San Juan –Chama Project water diverted under this Permit shall be determined monthly based upon the amount of water released from upstream storage less conveyance loss rates as determined by the study required by Condition of Approval 6 and accepted by the State Engineer. Until said study is completed and the results accepted by the State Engineer, the monthly conveyance loss rates shall be as follows: January thru March 3.00%; April 4.00%; May 5.00%; June 7.00%; July thru September 8.00%; October 5.00%; and, November thru December 3.00%.

8. The City's total mean daily surface water diversion rate shall not exceed 130 cfs. The amount of native Rio Grande surface water diverted under this Permit shall not exceed 50% of the total amount of water diverted at any time.

9. An amount of water equivalent to the amount of native surface water diverted under this permit shall be simultaneously returned directly to the Rio Grande at the City's SWRP wastewater outfall as verified by accounting methodology acceptable to the State Engineer. The amount of water considered to be return flows of 'native'

surface water under this Permit shall not be available for offset purposes, or to increase diversions of ground water, under the City's other permits.

10. Prior to any diversion of 'native' Rio Grande surface water under this permit, the City shall reduce its average per capita water usage to 175 gpcpd, computed in accordance with standards and methodology described by and acceptable to the State Engineer's Water Conservation Bureau. Continued diversion of 'native' Rio Grande surface water under this permit shall be contingent upon the City's demonstrating to the satisfaction of the State Engineer that it is utilizing the highest and best technology available to ensure conservation of water to the maximum extent practicable to reduce average annual per capita water usage to 155 gpcpd, computed in accordance with standards and methodology described by and acceptable to the State Engineer's Water Conservation Bureau, as soon as practicable and no later than twenty (20) years after initial diversion of 'native' Rio Grande surface water. By March 1st of each year, the City shall submit to the State Engineer a report of its average per capita water usage for the prior calendar year, computed in accordance with standards and methodology described by and acceptable to the State Engineer's Water Conservation Bureau.

11. The City shall submit progress reports on its 40-Year Plan and Water Conservation Plan on or before January 10, 2007, and every 5 years thereafter, showing that the City is diligently pursuing and achieving reduction of its average per capita water usage in accordance with Condition of Approval 10, above.

12. The City shall regulate its surface water diversion rate under this permit and Permit No. 4819 to maintain, in so far as 'native' flow is available at and above the point of diversion, streamflows of not less than 122 cfs in the channel of the Rio Grande between the point of diversion and the Albuquerque Central Avenue gage.

13. Diversion of 'native' water from the Rio Grande under this permit shall be curtailed when 'native' flow in the channel of the Rio Grande is less than 195 cfs, measured immediately above the storage pool at the point of diversion, by 1 cfs for each 1 cfs drop in 'native' flow below 195 cfs. Diversion of 'native' water from the Rio Grande under this permit shall be suspended when any of the following situations exist: the

amount of return flow to the Rio Grande at the City's SWRP outfall is less than the amount of 'native' water diverted; 'native' flow in the channel of the Rio Grande is equal to or less than 130 cfs, measured immediately above the storage pool at the point of diversion or immediately below the point of diversion; streamflows in the channel of the Rio Grande fall below 122 cfs, measured at the Albuquerque Central Avenue gage; or the State Engineer determines that suspension is necessary to meet compact obligations or to protect existing water rights.

14. Prior to diversion of any surface water from the Rio Grande under this permit, the City shall install, in a manner acceptable to the State Engineer, stream gages of a type approved by the State Engineer, at locations acceptable to the State Engineer sufficient to adequately measure and monitor streamflows above the point of diversion and throughout the reach of the Rio Grande from the point of diversion to the Southside Water Reclamation Plant wastewater outfall. The total diversion of surface water under this permit and flows returned directly to the Rio Grande shall be measured with totalizing meters of a type and at a locations approved by and installed in a manner acceptable to the State Engineer. All meters and gages shall have continuous data recorders. The data, on a real-time basis at intervals acceptable to the State Engineer, shall be made available to the public and the State Engineer. The City shall provide in writing, the make, model, serial number, date of installation, initial reading, units, and dates of recalibration of each meter and gage, and any replacement meter or gage used to measure stream flows, diversion of water and return flows to the Rio Grande. At a minimum, all meters and gages shall be calibrated in accordance to industry standards annually and the results shall be submitted to the Office of the State Engineer.

15. The City shall submit final plans for construction of the DWP diversion works and impoundment structures to the State Engineer for approval, prior to construction. Prior to any diversion of surface waters from the Rio Grande under this permit, the City must arrange for the State Engineer's inspection and approval of the diversion works, impoundment structures and the meters and gages required pursuant to Condition of Approval 14.

16. On or before the 10th day of January, April, July and October, or such other times as may be determined acceptable by the State Engineer, the City shall submit to the Office of the State Engineer, a comprehensive report, both in writing and electronically, which includes the following data concerning the preceding three-month period, or such other time period as may be determined acceptable by the State Engineer: the total amount of San Juan-Chama Project water released from Heron and/or Abiquiu reservoir(s) for its DWP and for offset of depletions on the Rio Grande caused by the exercise of permit RG-960 et al.; the total amount of water diverted from all sources; the measured streamflows throughout the reach of the Rio Grande from above the point of diversion to the Southside Water Reclamation Plant wastewater outfall; and the total flow returned directly to the Rio Grande.

17. Proof of Completion of Works shall be filed within four (4) years from the date of this order.

18. The State Engineer shall retain jurisdiction over this permit for the purpose of ensuring that exercise of the permit does not violate the forgoing Conditions of Approval, is not detrimental to existing water rights, is not contrary to the conservation of water within the State and is not detrimental to the public welfare of the State of New Mexico.

Respectfully submitted July 8, 2004**.**

__________________________	__________________________
Victor Kovach Hearing Examiner	Louis D. O'Dell Technical Advisor

I ACCEPT AND ADOPT THE REPORT AND RECOMMENDATION OF THE HEARING EXAMINER THIS _______ DAY OF ______________ 2004.

____

JOHN R. D'ANTONIO, JR., P.E.
NEW MEXICO STATE ENGINEER

Appendix B

Discussion of Climate Change Data

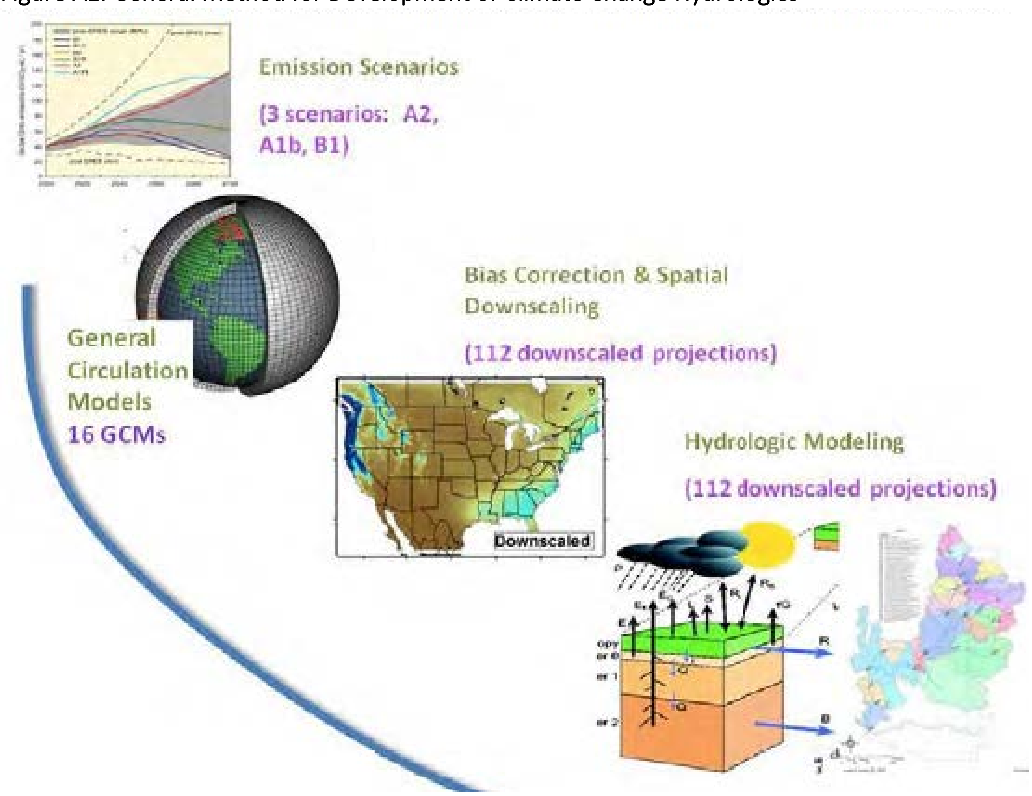
Climate Change

Projections of streamflow with the effects of climate change for the Western United States were developed by Reclamation as part of the West Wide Climate Assessment (Reclamation 2011). These projections were derived from work completed by the World Climate Research Program's (WCRP) Coupled Model Intercomparison Project Phase 3 (CMIP3) (Maurer et al., 2007). The CMIP3 data were produced using general circulation models (GCM) that project global changes in atmospheric temperature and precipitation based on changes in greenhouse gas emissions. These global projections were used to develop the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report (IPCC ,2007). For regional planning purposes, the global projections were downscaled by Reclamation using the Bias Correction and Spatial Disaggregation (BCSD) approach.

The approach was used with three different carbon emissions scenarios (B1 [low], A1B [middle], A2 [high]) to produce 112 different equally likely climate traces. The general approach to develop the Downscaled GCM Projected sequences is shown graphically in figure A1. The downscaled climate information is then fed into the Variable Infiltration Capacity (VIC) model. The VIC hydrology model used the climate projections along with land cover, soils, elevation, and other watershed information to simulate hydrologic fluxes. The result of this approach was 112 unique sequences of natural flow under a range of future climate projections.

The same Downscaled GCM Projected scenario was also employed to develop the results described in the *SECURE Water Act Section 9503(c) – Reclamation Climate Change and Water 2011* (Reclamation, 2011c) Report, the Colorado River Basin Study (Reclamation 2012), the Upper Rio Grande Impact Assessment (Reclamation 2014), and other studies.

Figure A1. General Method for Development of Climate Change Hydrologies

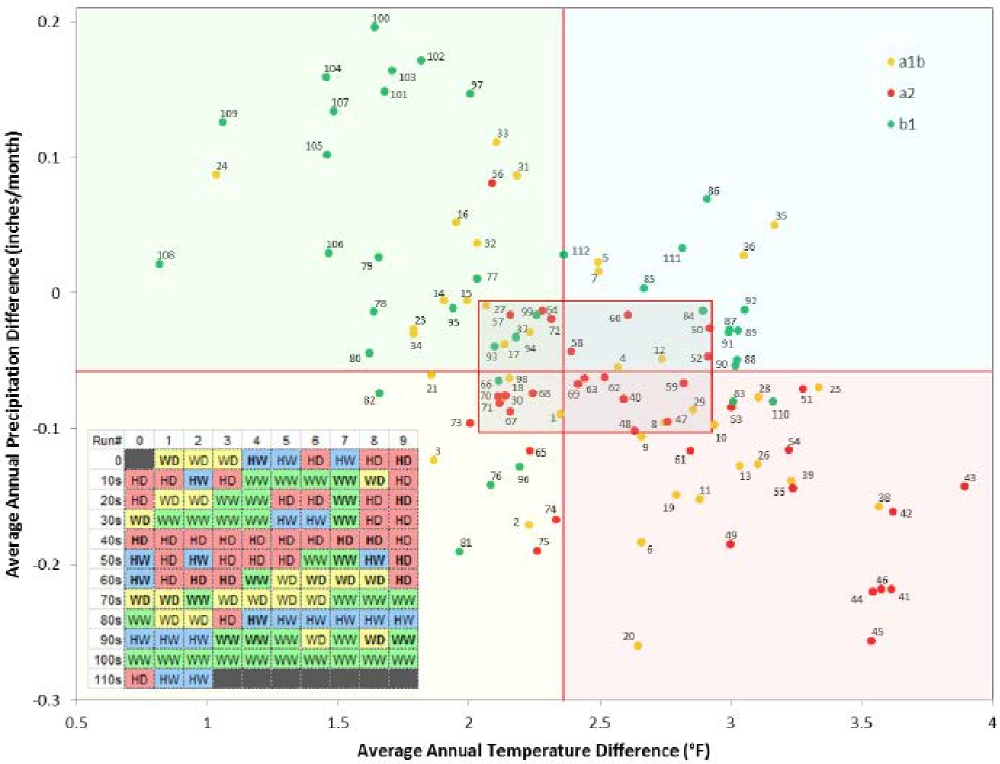


Source: Modified from the CRBS
NOTE: Higher resolution image being developed.

West-wide Climate Team Modifications for Local Use

For the purpose of water planning in the Middle Rio Grande, Reclamation organized the 112 climate traces into 5 "ensembles" by percentile of temperature and precipitation using a hybrid delta ensemble method (HDe). The "central tendency" group include all traces which fall within the 25th and 75th percentile for both precipitation and temperature change. The remaining four groups are based on the 50th percentiles of precipitation and temperature change and are referred to as hot-dry, hot-wet, warm-dry, and warm-wet (Figure A2). The HDe method uses the average of temperature and precipitation change across all traces within each ensemble for three projection points in time, 2020s, 2050s, and 2080s.

Figure A2. Grouping of the 112 Climate Traces into Five Ensembles



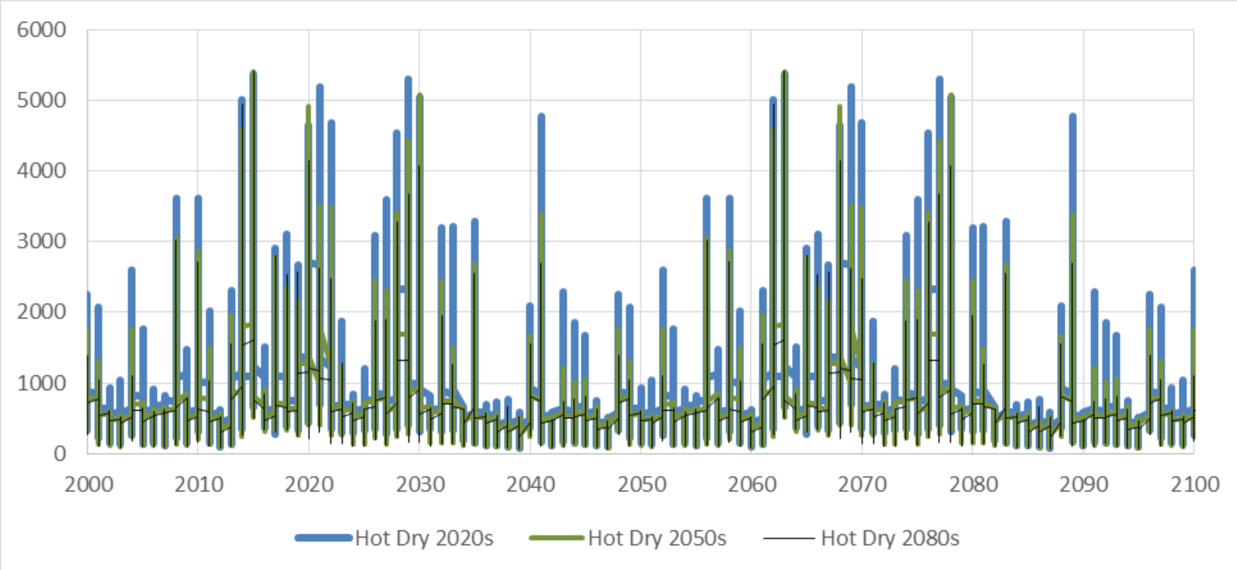
Run#	0	1	2	3	4	5	6	7	8	9
0		WD	WD	WD	HW	HW	HD	HW	HD	HD
10s	HD	HD	HW	HD	WW	WW	WW	WW	WD	HD
20s	HD	WD	WD	WW	WW	HD	HD	WW	HD	HD
30s	WD	WW	WW	WW	WW	HW	HW	WW	HD	HD
40s	HD	HD	HD	HD	HD	HD	HD	HD	HD	HD
50s	HW	HD	HW	HD	HD	HD	WW	WW	HW	HD
60s	HW	HD	HD	HD	WW	WD	WD	WD	WD	HD
70s	WD	WD	WW	WD	WD	WD	WD	WW	WW	WW
80s	WW	WD	WD	HD	HW	HW	HW	HW	HW	HW
90s	HW	HW	HW	WW	WW	WW	WD	WW	WD	WW
100s	WW	WW	WW	WW	WW	WW	WW	WW	WW	WW
110s	HD	HW	HW							

Source: Santa Fe Basin Study HDe Data Memo

So, for example, for the 2080s period the temperature and precipitation data from the above process were taken from the 2070 to 2099 period and compared to the simulated historical period (1950-1990). The difference in precipitation and temperature for the two periods was taken to create the 5 ensembles. The average difference for each ensemble was then used as a "delta" to modify the historical precipitation and temperature for each ensemble for the 2080 period. The same method was employed for each of the projection periods and the resulting climate data were run through the VIC model to arrive at streamflow.

The resulting monthly HDe hydrologic sequences were developed for the Water Authority by the West Wide Climate Risk Assessment Team, part of the Basin Study Program under the SECURE water act. These sequences have also been provided to the Middle Rio Grande Council of Governments and utilized as part of the Santa Fe Basin Study. Figure A3 shows the resulting hydrologic sequences for the Hot Dry ensemble. The sequences are plotted so that you can easily see that streamflow clearly reduces from 2020s (blue) to 2050s (green) to 2080s (black).

Figure A3. Example Streamflow Sequence, Hot Dry



Modifications Made as Part of this Study

Each hydrologic sequence developed using the HDe method reflects streamflow as if the climate were stable for each time-period. Thus, for a 2080s Hot-Dry ensemble, the resulting hydrologic sequence reflects a time series of streamflow for only the 2080s change over the entire sequence. Therefore, time series flows in 2000 or 2020 or 2090 all reflect a 2080s climate. As such, when planning using these data, any time prior to the 2080s will over represent the impact of climate. Likewise, for a 2020s sequence, any time after the 2020s will under-represent the impact of climate. To alleviate this ambiguity, the sequences were modified to interpolate the streamflow over time. For example, the “hot-dry” sequence was interpolated over time between the 2020s, 2050s, and 2080s to result in a single sequence that gradually changes over time. Figure A4 shows the factors used to interpolate the sequences. Figure A5 shows an example of the resulting Hot-Dry streamflow used in this study. Note that the red line associated with the interpolated sequence tracks with the blue 2020s line through about 2030, the green 2050s line through about 2060, and the black 2080s line through the rest of the sequence. The same methods were used for each of the ensembles.

Figure A4. Factors Applied to 2020s, 2050s, and 2080s Projections to Arrive at a Single Sequence

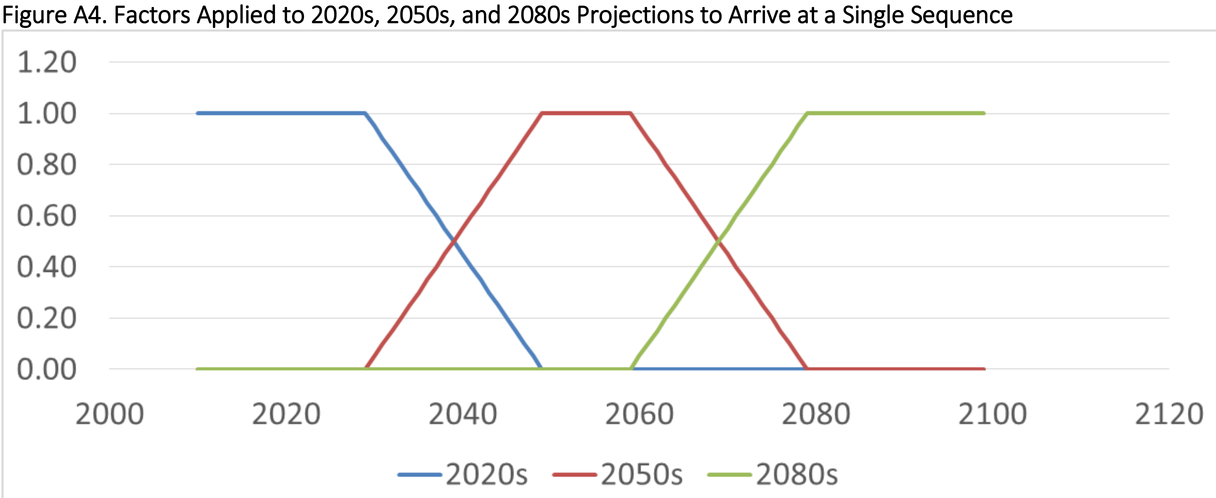
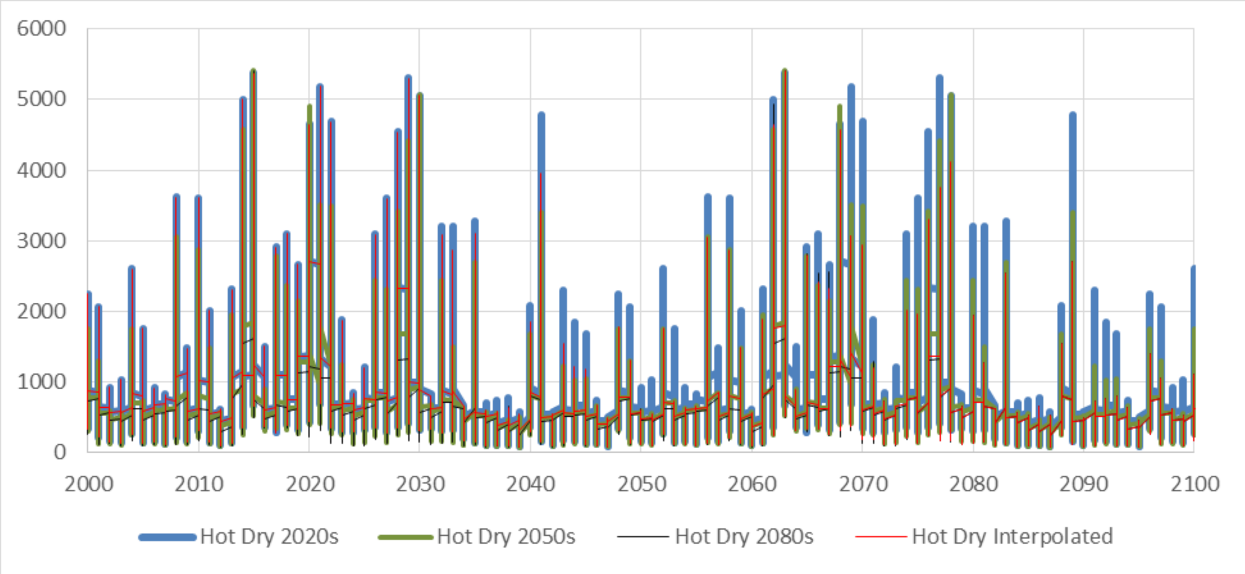


Figure A4. Factors Applied to 2020s, 2050s, and 2080s Projections to Arrive at a Single Sequence



Appendix C

Update of the Historical Rio Grande Flow Sequence

Historical Rio Grande Flow (High Supply)

As part of previous planning efforts the 1971 to 1998 hydrologic record was analyzed and subsequently chosen as representative of the longer hydrologic record (CH2M HILL 2003). This record was chosen because it is representative of the long-term (>100-year) record and the current operational regime for reservoirs, river facilities, and SJC water importation and use began in 1971.

The 1971-98 streamflow record was adjusted and aligned so that 1971 became 2006, 1972 became 2007, etc. to simulate future hydrologic conditions. Adjustments to the historic record included:

- Removal of the historical (1971-98) City SJC water that was in the river at Central based on a detailed evaluation of Federal, State, and City records.
- Addition of a simulated 3-year drought to the record based on three 1972s placed ‘back to-back’ in the baseline so as to depict an extended drought similar to that experienced in the 1950s. Such a drought is otherwise missing from the 1971-98 period.

A similar process was undertaken to update the streamflow sequence through 2014. Analysis of historical SJC records was undertaken to estimate SJC water at the Central Avenue gage. Water Authority SJC water was removed from the historical record to ensure that SJC water was not “double counted.” In this way, historical releases of SJC water for say supporting the Rio Grande Silvery Minnow would not be reflected in the gaged flow that determines future operating conditions. This process was completed by examining official Reclamation reported “SJC” water at Otowi along with Water Authority releases from upstream reservoirs and considering OSE permitted loss rates.

Pumping-induced effects on the Rio Grande also affect measured flow at the Central gage. These effects could be added back into the gage readings to reflect something closer to a “natural” flow. However, unlike SJC releases, these impacts are on-going and reflect pumping over a number years rather than a discrete event (i.e. a dedicated release). It is anticipated that while the magnitude of the effect will fluctuate, future flows at Central will continue to be affected by groundwater pumping. For future diversion planning purposes, it is assumed that adding the groundwater pumping effects back into the gaged record will over-represent the water available and therefore was not completed as part of this update.

Because the update includes a historic drought period, the simulated 3-year drought used in the previous streamflow sequence was removed.

Drinking Water Project (DWP) diversions began in December 2008. As per the OSE permit, these diversions remove both the released SJC water and a like amount of native water that is returned at the Southside Wastewater Reclamation Plant. Because this diversion occurs upstream of the Central gage and return flow occurs downstream of the Central gage, flows are reduced at the gage by the amount of “borrowed” native water. Diversions since 2008 were added back into the gage reading to reflect the flow at Central without DWP diversion.

Figure C1 shows the raw Central gage data overlain with the adjusted 71-98 data (including the artificial drought) and the updated adjusted 71-2014 data. Where there are small amounts of SJC water at the gage there is little if any discernable difference in the lines. However, when significant portions of the total flow are from SJC water, the lines clearly deviate from one another. Note that the artificial drought is clearly shown in the 1989-1991 timeframe. This artificial drought was 1972 repeated over three consecutive years. Also note that this artificial drought is not included in the newly updated 1971-2014 update. The adjusted 1971-2014 line, shown in blue, clearly deviates from the raw data in 2000, 2002, and 2004 when significant quantities of the Water Authority's SJC water were provided for the Rio Grande Silvery Minnow.

Figure C2 shows the individual monthly adjustments that were applied to the raw USGS data for the Central gage. The blue columns represent Water Authority SJC water that was subtracted from the gaged flow. The orange columns represent the total diversion that was added to the gaged flow.

Table C1 presents summary statistics for the original adjusted 1971-1998 period (with artificial drought and resulting model sequence (2006-2060) compared to the updated adjusted 1971-1998 and 1971-2014 sequences as well as the resulting 2006-2120 sequence. Note that the artificial drought resulted in a dryer overall 71-98 period than the historical period suggested. Whereas, the updated sequence results in a significantly dryer overall model sequence (2006-2120).

Table C1. Historical and updated Annual Rio Grande Flows (cfs)

	Original WRMS		Updated	
	Average	**Median**	**Average**	**Median**
1971-1998	1,326	810	1,390	847
1971-2014	N/A	N/A	1,187	740
2006-2060	1,362	816	1,167	725
2006-2120	N/A	N/A	1,237	763

Figure C1. Raw and Adjusted Monthly Flow at Albuquerque

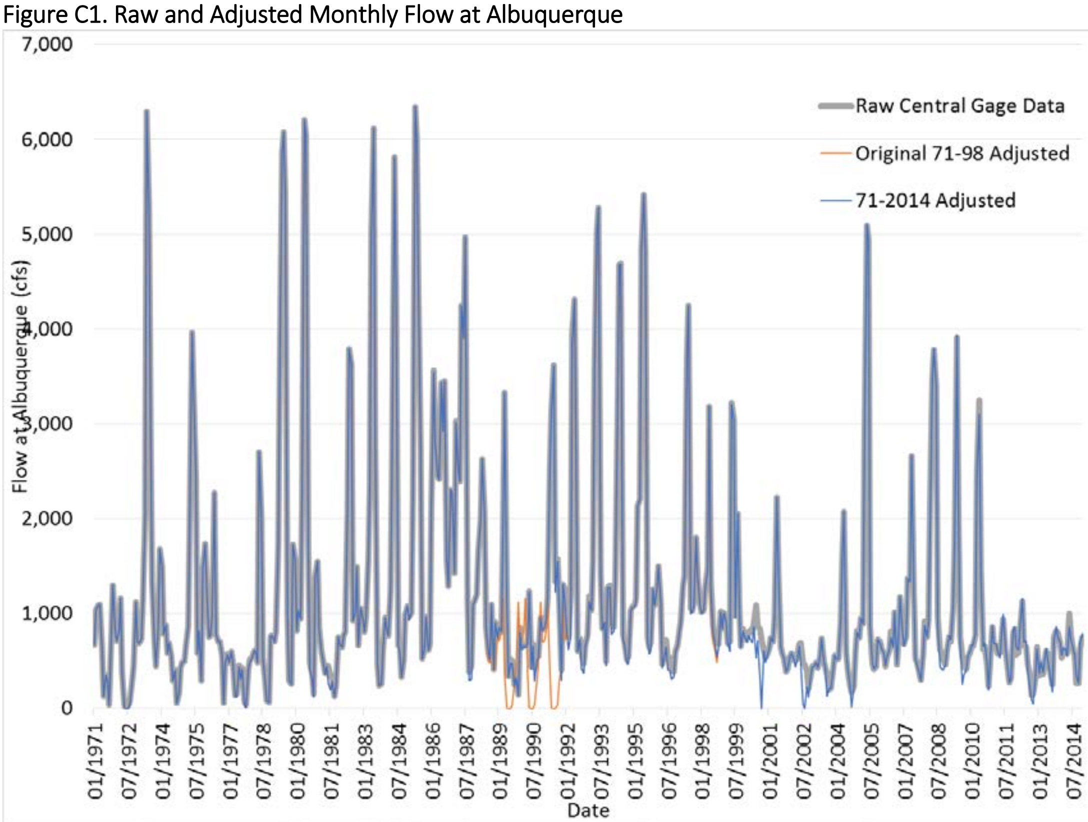
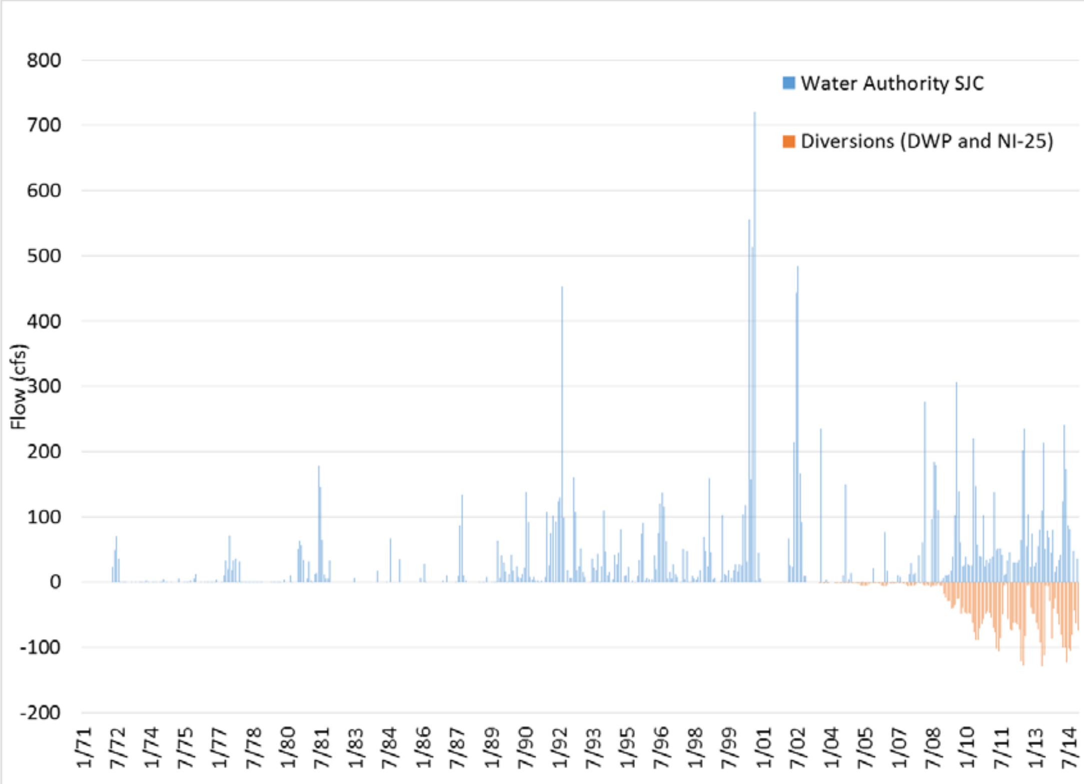


Figure C2. Central Gage Adjustments



Appendix D

Historical Variability and Drought Compared to Recent Projections

Historical Variability and Drought Compared to Recent Projections

Introduction

Water-supply hydrologies were developed as part of the Water Authority 2017 WRMS update. These hydrologies reflect potential future water availability from the San Juan-Chama Project and flow of the Rio Grande. The hydrologies are coupled with different demand projections and will ultimately be used to asses supply gaps. These hydrologies consist of observed Rio Grande flows at the Central Avenue gauge in Albuquerque and climate-change impacted flows developed for the Water Authority by the West Wide Climate Risk Assessment Team, part of the Basin Study Program under the SECURE water act. This Appendix examines recent work on potential drought conditions under climate change, compares the WRMS water-supply hydrologies to historical hydrology reconstructed from tree-ring data, and examines historical and recent climate change datasets.

Development of WRMS Water Supply Hydrologies with Climate Change

The climate-change impacted flows were based on 112 bias-corrected and statistically downscaled projections of temperature and precipitation from 16 Global Climate Models (GCM) run for three different emission scenarios and a variety of boundary conditions, as part of the Phase 3 of the Coupled Model Intercomparison Project (CMIP3). For the purpose of regional-planning, the West Wide Climate Risk Assessment Team used a Hybrid-Delta Ensemble (HDe) method (Brekke, 2010; Reclamation, 2015) to create five hydrologic projections that captured both the temperature and precipitation trends of the GCMs as well as historical variability of the Rio Grande. The five projections were completed by first grouping the 112 temperature and precipitation sequences based on percentiles of change in average (over a representative area for the Upper Rio Grande basin) temperature and precipitation for 3 different periods - 2030s, 2050s, and 2080s. The percentiles of change in average temperature and precipitation were classified into five categories:

- 'Warm Dry' (WD) – below the 50th percentile for temperature increase and below the 50th percentile for precipitation.
- 'Warm Wet' (WW) - below the 50th percentile for temperature increase and above the 50th percentile for precipitation.
- 'Hot Dry' (HD) – above the 50th percentile for temperature increase and below the 50th percentile for precipitation.
- 'Hot Wet' (HW) - above the 50th percentile of temperature increase and above the 50th percentile of precipitation.
- 'Central' (C) – between the 25th and 75th percentile for both temperature increase and precipitation.

The distribution of changes in monthly precipitation and temperature in each of the above 5 categories were used to alter historical temperature and precipitation data for 1951-1998. The modified temperature and precipitation time-series were then used as input to a VIC (Variable Infiltration Capacity) model (a macro-scale hydrologic model) to derive hydrologic sequences. The hydrologic and climate sequences were, in turn, input into URGSiM - a monthly mass balance model - to simulate movement of surface and ground water through the Upper Rio Grande basin under current management practices and demands.

The HDe data assembled (as described above) by the West Wide Climate Risk Assessment Team consisted of Azotea flows (as part of the Drinking Water Project); storage, outflows, evaporation rate, and precipitation rate at Heron; storage, outflows, evaporation rate, and precipitation rate at Abiquiu; flows at the Central Avenue gauge; storage, outflows, evaporation rate, and precipitation rate at Elephant Butte; and reference ET for the Albuquerque region. Of the five climate change categories, three were chosen for this analysis to represent the range of climate change impacts – warm wet (WW), central (C), hot dry (HD) – for the three periods (2030s, 2050s, and 2080s). The underlying assumption for the HDe analysis is that the GCMs are consistent and reliable indicators of average changes in temperature and precipitation, while being less consistent and reliable in the prediction of inter-annual variability. To account for inter-annual variability in the climate projections, historical hydrology (1951-1998) is used as a basis for the climate sequences.

Climate Change driven Droughts

From a planning perspective, the important consideration is whether the hydrologic sequences chosen adequately represent potential hydrologic variability and potential future drought conditions. A recent paper (Cook et al., 2015) compared drought metrics under future climate change to historic droughts. The study is based on the recent CMIP5 GCM ensemble and focuses on representative concentration pathway (RCP) 8.5 “business-as-usual” high emissions scenario and the RCP 4.5, a more moderate emissions scenario. In addition to measured historical data, the study includes tree-ring based hydro-climate reconstructions to represent droughts over the last millennium (1000-2005). Millennial-length hydro-climate reconstructions feature notable periods of extensive and persistent Medieval-era droughts, which exceed the duration of any drought observed during the historical record (1850 – 2010 CE). The authors use a modified (incorporating the Penman Monteith equation for estimating evapo-transpiration demands) Palmer Drought Severity Index (PDSI); summer (June-July) integrated soil moisture for shallow (< 30 cm) soils (soil moisture [SM]-30cm); and summer (June-July) integrated soil moisture for deeper (2 – 3 m) soils (SM-2m). The study suggests that based on all three metrics the southwest is expected to show markedly consistent drying over the latter half of the 21st century (2050–2099). Projected changes in the Southwest (2050–2099 CE) for all three moisture balance metrics are significantly drier compared to both the modern interval (1850–2005 CE) and reconstructed 1100–1300 CE records. The distribution of the three metrics for the two emission scenarios are compared to historical and reconstructed North American Drought Atlas (NADA) records in the figure below:

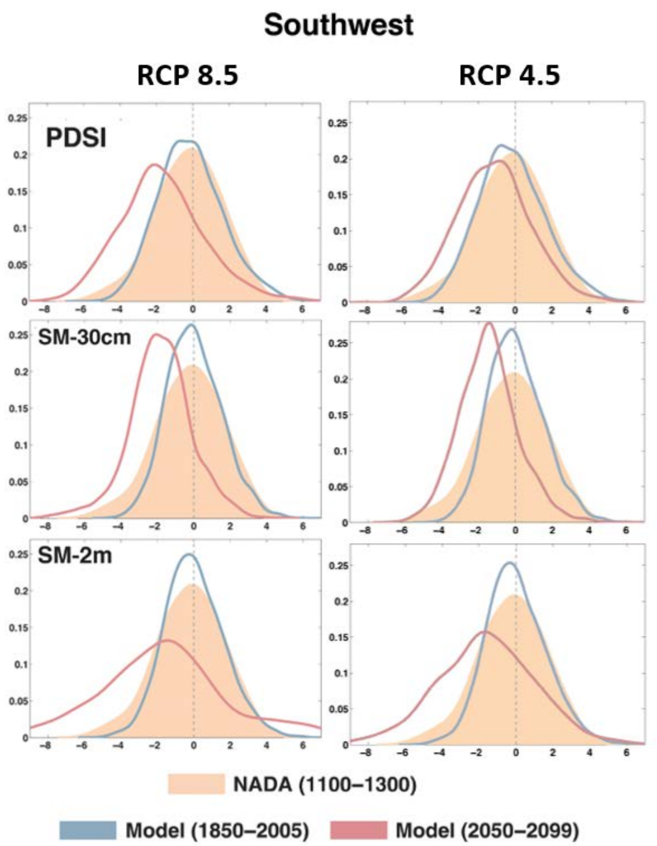


Figure 1: Comparison of three drought metrics (PDSI, SM-30cm, and SM-2m) over three different periods (1100-1300, 1850-2005, and 2050-2099) for the Southwest for two different emission scenarios (RCP 8.5 and RCP 4.5). Drought metrics for 2050-2099 are seen to be worse than those for the two historical periods. (Cook et al., 2015)

These results are consistent with another study by (Gutzler and Robbins, 2011) that looked at regional drought statistics under climate change (based on the CMIP3 GCM ensemble) for the western United States. The study also points to a persistent and consistent (across different GCMs) drying in New Mexico. The figure below compares average (over 25 years) changes in precipitation and evapotranspiration and PDSI for New Mexico for the 20th and 21st century:

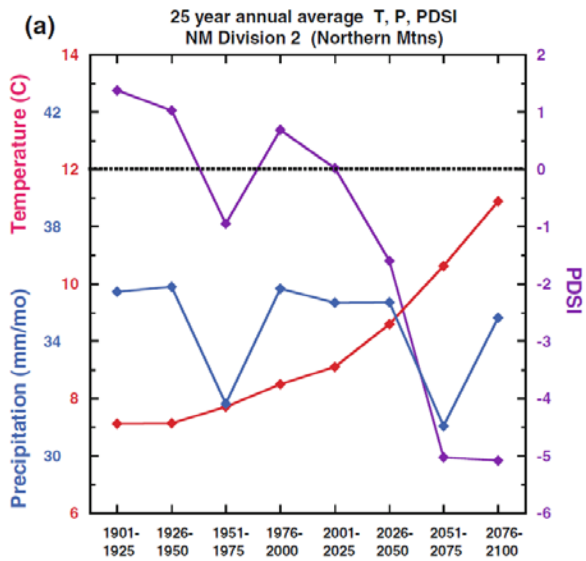


Figure 2: Average change in temperature, precipitation and PDSI for New Mexico from 1900 to 2100. (Gutzler and Robbins, 2011)

Comparison of Water Supply Hydrologies to Historical Tree-Ring/Flow Reconstructions

Tree-ring based climate reconstructions allow us to look at multi-decadal droughts over the millennium. Cook et al. compared drought indices from reconstructed climate records with predictions from GCMs (Cook et al, 2014). Results indicated that future conditions can be expected to be warmer and (in general) drier than conditions observed over the historic period. While, GCMs give us an indicator of the severity of future drought (mostly driven by warmer conditions) they do not provide consistent trends on the frequency and duration of such droughts. Most climate change impact analyses are conducted by downscaling and transforming historical hydrologic sequences with respect to ‘average’ future climate conditions. As such, if the historical sequence has a wet period (e.g. 1975 – 2000), the relatively wet period will be part of the climate-impacted time-series. However, historical data is still our most reliable source of information for the duration and frequency of future droughts. Streamflow reconstructions from tree rings have been made available (http://treeflow.info/rio-grande-basin#field-other-hydroclimatic-recons) for various gauges in the Rio Grande Basin as part of a NOAA funded project to expand and improve the usability of tree-ring reconstructions for drought planning and water management in the Rio Grande basin. The reconstructions are based on linear regressions between tree-ring thickness and observed flow records. The Figure below shows streamflows (annual and 10-year average) at Otowi from the reconstructed records compared with flows at Otowi from the West Wide Climate Risk Assessment HDe dataset for different future climate scenarios.

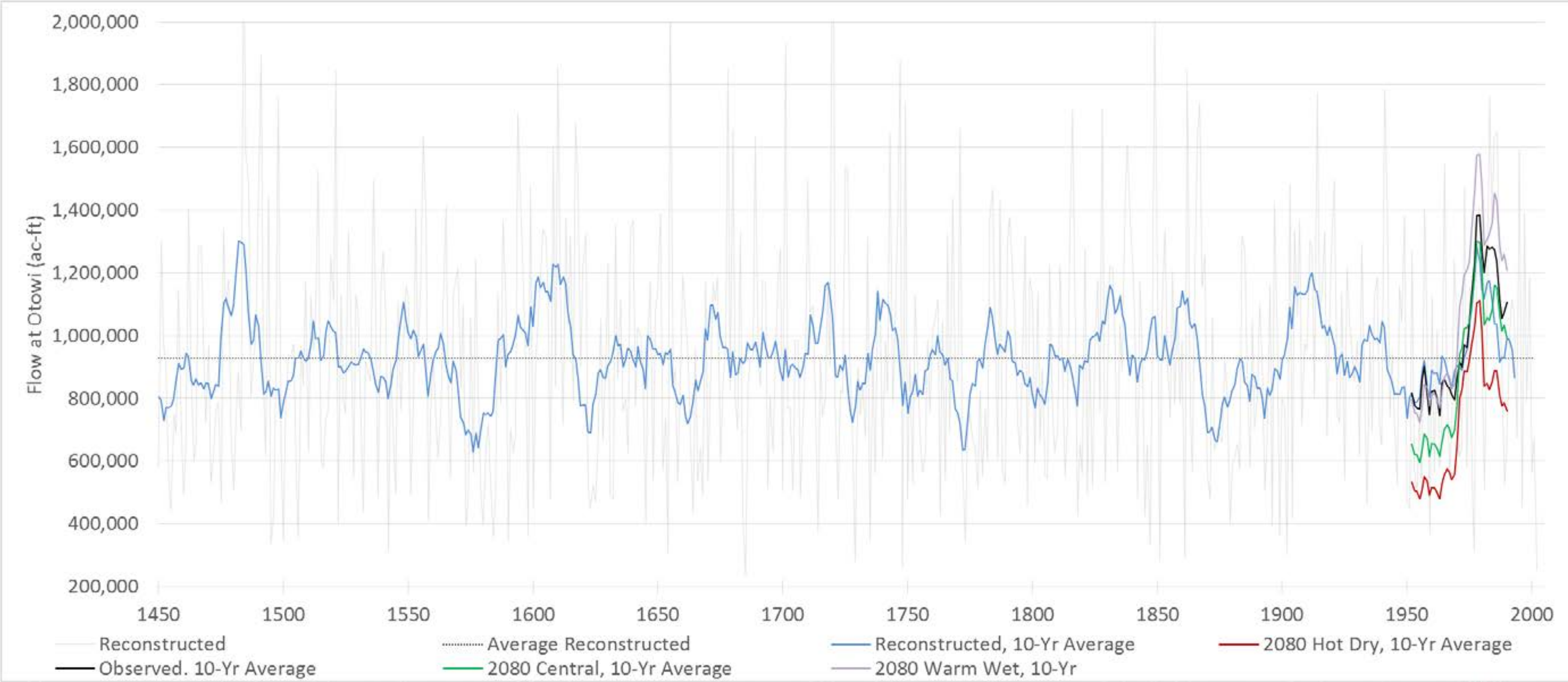


Figure 4: Annual and 10-year average streamflows at Otowi from the reconstructed records compared with observed and 10-year average simulated flows from the West Wide Climate Risk Assessment HDe dataset (2080-HD, 2080 WW, 2080 C).

As can be seen from the figure, flows under hot-dry conditions for 2080 (red line), are generally lower than those seen in the reconstructed or historical record. For the sake of this assessment, we assume that persistent below average flows at Otowi are indicative of drought conditions. As such, the two longest droughts from the reconstructed periods correspond to a 34-year span from 1877 to 1909 and a 21-year span from 1574 to 1594. The drought of the 50s is also of note. Based on the Otowi flows, this 16–year drought period starts in 1945 and ends in 1966. Since the West Wide Climate Risk Assessment HDe time-series are based on the 1951-1998 sequence, they too show the same low flow conditions for the 50s. As such, the drought of the 50s is exacerbated in the 2080-HD scenario and shows up as a multi-decadal drought more severe (in terms of magnitude) than the multi-decadal droughts of the 1800s and 1500s.

The overall average flow over the reconstructed period of 926,000 ac-ft/yr is about 7 percent less than the average flow in the observed time period from 1958 to 2000 (note though that the simulated historical period is 3 percent lower than observed). However, the 2080 Hot-Dry and 2080 Central sequences are both lower than the paleo-reinstructed sequence with the Hot Dry flow reduced by more than 20 percent. Further, both climate change sequences are less than the minimum flow in any 100-year sequence from the paleo record.

Based on this assessment, it can be concluded that the drought of the 1950s as simulated in the West Wide Climate Risk Assessment HDe hydrologic sequences is comparable to historic droughts in the paleo-reconstructed records. Likewise, it appears that the 1950s drought under a Hot-Dry climate is of greater magnitude than any droughts from the tree-ring record and that the average flow for the Hot-Dry sequence is less than paleo-reconstructed records over comparable periods.

Comparison of Climate Change Projections – CMIP3 and CMIP5

Recently, the IPCC published the CMIP5 dataset, representing the latest in ongoing study and refinement of climate science. However, at the time development of this update to the WRMS, CMIP5 data have not been downscaled and bias-corrected by Reclamation for use in western water planning. A study conducted by a research group (Seager et al., 2012) from the Lamont Doherty Earth Observatory of Columbia University compared predictions from CMIP3 and CMIP5 for precipitation – evaporation anomalies (used as a surrogate indicator for drought) in the Southwest. The figure below shows trends from the model for the calibration (1900 - 2000) and prediction (2000 - 2099) periods.

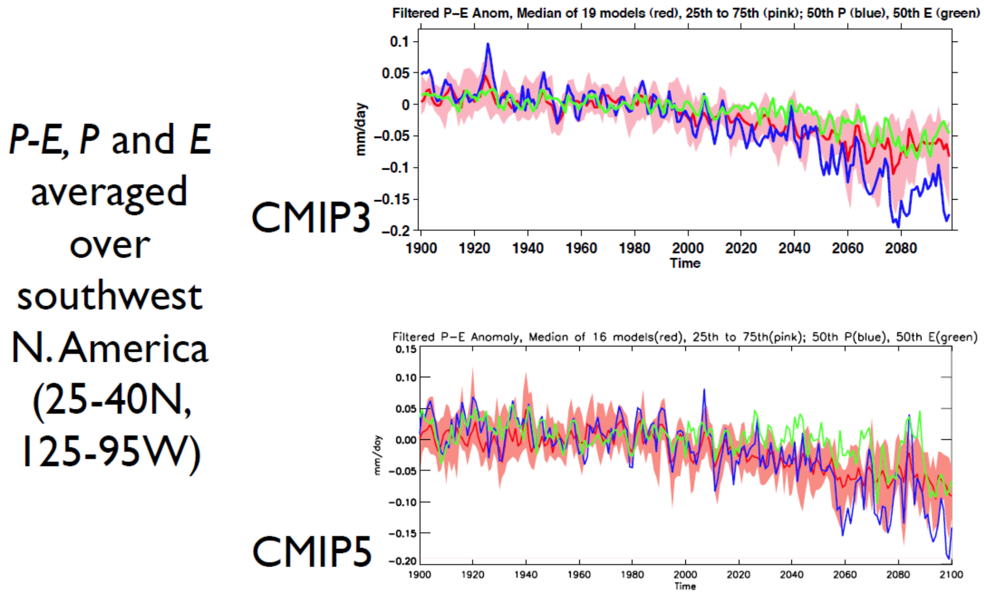


Figure 3: Comparison of trends in precipitation and temperature anomalies for CMIP3 and CMIP5. (Seager et al., 2012)

Seager et al. point out that while overall trends and range of results are consistent between CMIP3 and CMIP5, there are differences in the inter-annual variability (Seager et al., 2012). The CMIP5 ensemble predicts slightly wetter conditions for New Mexico, but overall the P-E anomaly grows over time indicating progressively dryer conditions, for both CMIP3 and CMIP5.

Based on this literature survey, it is indicative that average multi-decadal change in precipitation and temperature are consistent across CMIP3 and CMIP5. These findings are consistent with recommendations from the recent US Bureau of Reclamation (Reclamation, 2015) study that released downscaled hydrologic projections for CMIP3 and CMIP5. The report states that '*while future downscaled climate and hydrology projections based on CMIP5 may inform future analyses, many completed and ongoing studies have been informed by CMIP3 projections that were selected as best information available at the time of study. Even though CMIP5 is newer, it has not been determined to be a better or more reliable source of climate projections compared to existing CMIP3 climate projections. As such, CMIP5 projections may be considered an addition to (not a replacement of) the existing CMIP3 projections until a final decision that CMIP5 is superior is issued by the climate modeling community.*'

References

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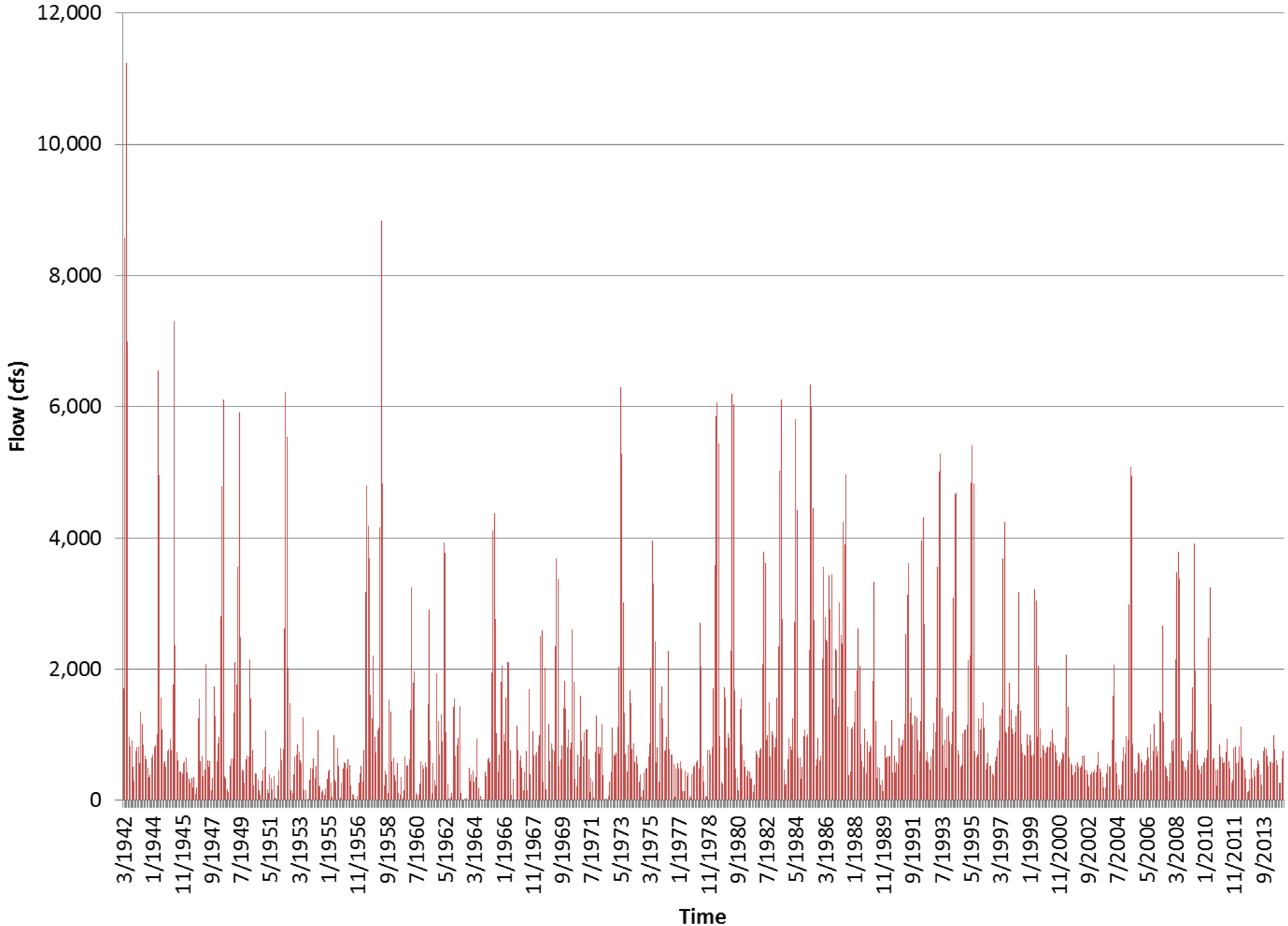
Seager, R., M. Ting, C. Li, B. Cook, N. Naik, J. Nakamura, and H. Liu, "Anthropogenic southwest drying CMIP5 style", Presentation made at the Lamont-Doherty Earth Observatory of Columbia University, available at http://www.ldeo.columbia.edu/res/div/ocp/glodech/PDFS/SeagerSW_CMIP5.pdf.

Appendix E

Select Larger Size Figures


12,000
10,000
8,000
6,000
4,000
2,000
0
Flow (cfs)
3/1942
1/1944
11/1945
9/1947
7/1949
5/1951
3/1953
1/1955
11/1956
9/1958
7/1960
5/1962
3/1964
1/1966
11/1967
9/1969
7/1971
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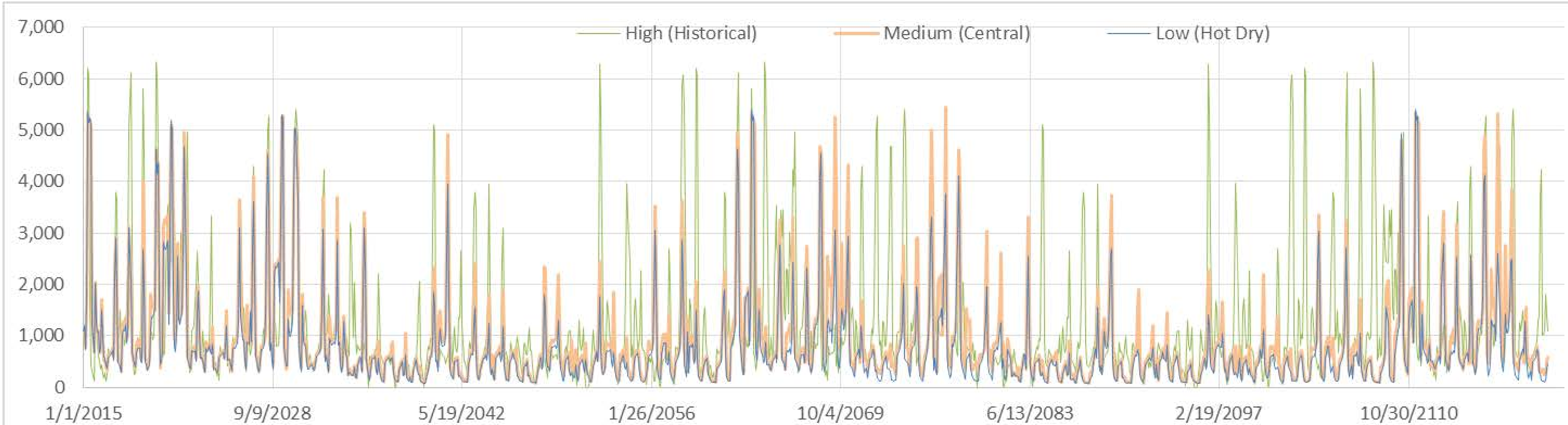
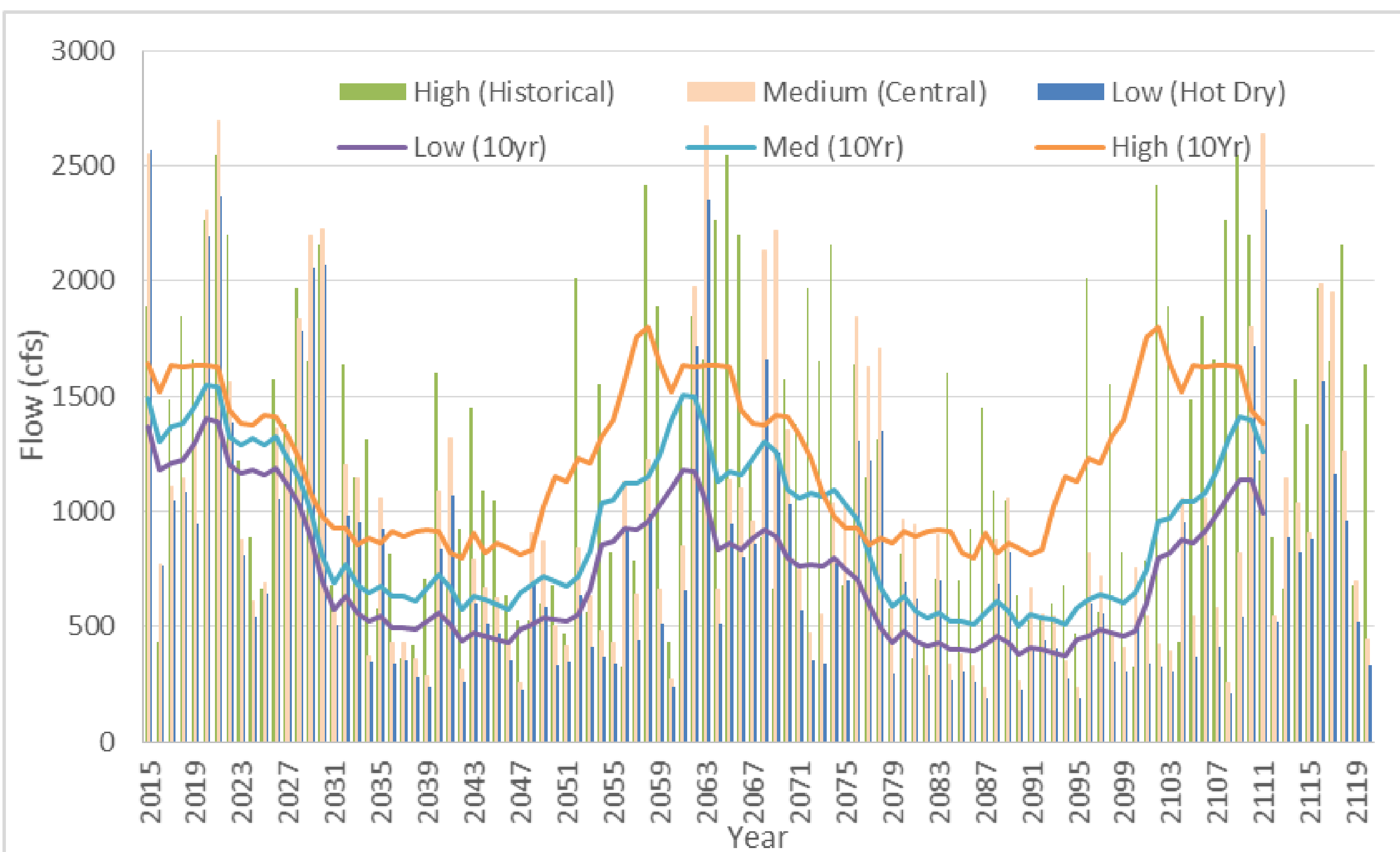
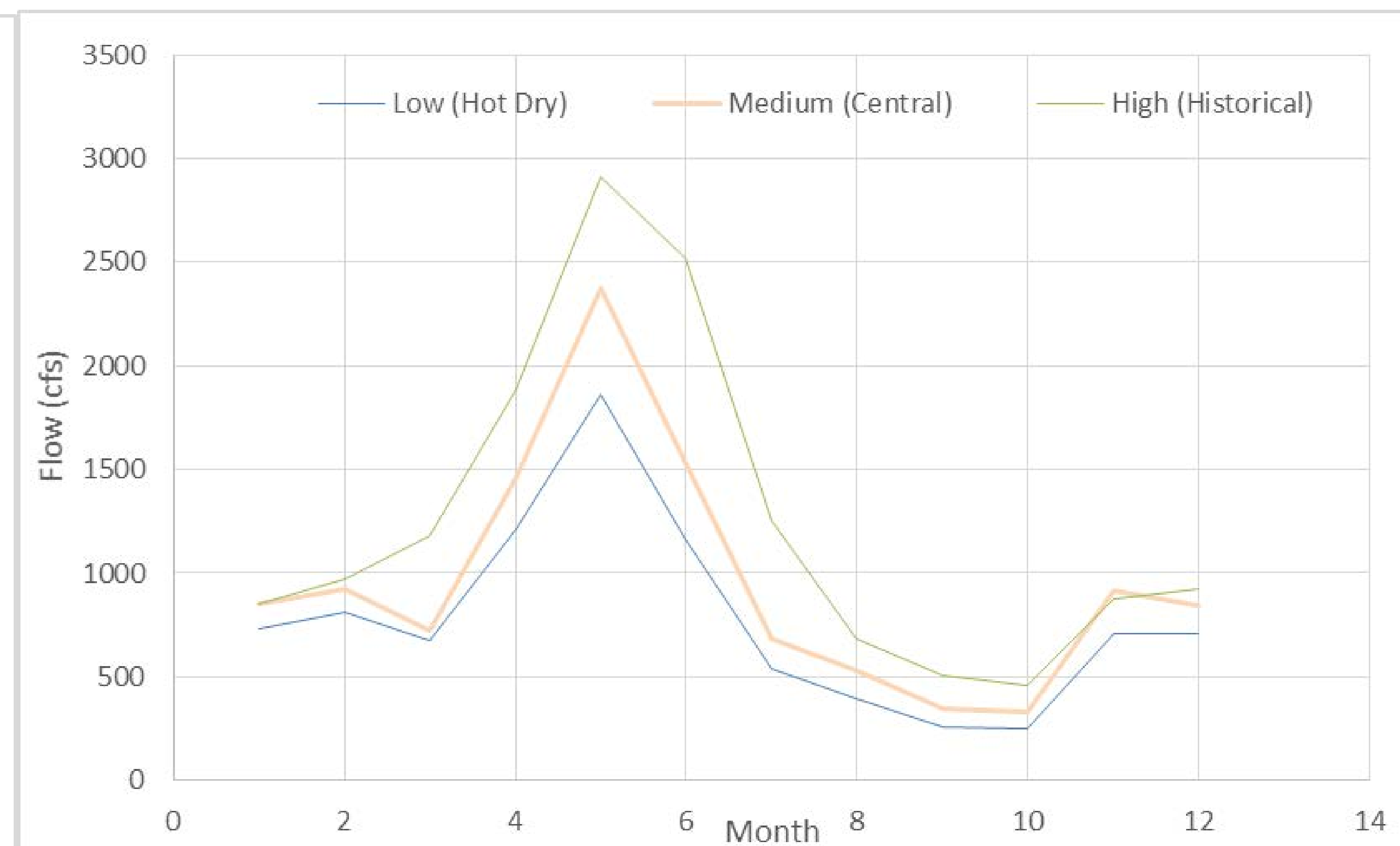
11/2011
9/2013
Time


High (Historical)
Medium (Central)
Low (Hot Dry)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1/1/2015
9/9/2028
5/19/2042
1/26/2056
10/4/2069
6/13/2083
2/19/2097
10/30/2110


High (Historical)
Medium (Central)
Low (Hot Dry)
Low (10yr)
Med (10Yr)
High (10Yr)
Flow (cfs)
Year


Low (Hot Dry)
Medium (Central)
High (Historical)
Flow (cfs)
Month