UPPER RIO GRANDE WATER OPERATIONS PLANNING MODEL

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UPPER RIO GRANDE WATER OPERATIONS PLANNING MODEL

Base Run Start-up and Initial Conditions Assumptions

INTRODUCTION

The Upper Rio Grande Water Operations Model (URGWOM) planning model is similar to the URGWOM water operations model. The two models share rules and structure, with the principal difference being the temporal scale of the data used in the model analysis. The planning model evaluates multi-year hydrologic data and reservoir operations suitable for comparison of impacts of proposed changes to operating scenarios, while the water operations model is normally concerned with analysis of single year data required to make near-term operating decisions.

The planning model utilizes a generated sequence of hydrologic data based on the historic water supply period of 1975-2002. In order to initiate the operation of the hydrologic system simulated by the planning model certain assumptions are made about the conditions and data that are to exist upon initiation of the hydrologic sequence used in the planning model. Adjustments to the hydrologic "framework" of the water operations model were also incorporated into the planning model that allows the planning model to run under any hydrologic sequence and to allow the planning model to make certain projections necessary for long-term hydrologic analysis. The number of contractor accounts was also reduced to improve the efficiency of the model for long runs. The assumptions required to start up the planning model are described in this document. Hydrologic adjustments made to adapt the water operation model for planning purposes are also described.

HYDROLOGIC ADJUSTMENTS TO THE WATER OPERATIONS MODEL

HYDROLOGIC SEQUENCE

A function of the planning model is to simulate streamflow and reservoir operations over a long-term planning horizon of forty years, which coincides with the planning period used in the Water Operations Review and EIS. The sequence of streamflow data used in the planning model is based on the selected historic data from the Rio Grande for the years between 1975 and 2002 and is based on a hydrologic analysis prepared by S. S. Papadopulos & Associates, Inc. Table 1 shows the sequence of years of streamflow data used in the planning model. The planning years 2006-2015 simulate a sequence of drought years, when the annual natural flow of the Rio Grande at Otowi Bridge, as determined by the computed Otowi Index, is less than 710,000 acre-feet. The planning years 2016-2020 and 2023-2034 simulate sequences of wet year flows, when the annual natural flow of the Rio Grande at Otowi Bridge, as determined by the computed Otowi Index, is greater than 1.1 million acre-feet.

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Table 1. Forty-year flow sequence used in planning model.

Planning Year	Historic Year	Planning Year	Historic Year
2003	1982	2023	1978
2004	1988	2024	1998
2005	1992	2025	1999
2006	1976	2026	1986
2007	1989	2027	1999
2008	1996	2028	1991
2009	1977	2029	1980
2010	1989	2030	1992
2011	1989	2031	1985
2012	1981	2032	1998
2013	1996	2033	1978
2014	1996	2034	1998
2015	1977	2035	1976
2016	1988	2036	1991
2017	1987	2037	1989
2018	1975	2038	1984
2019	1998	2039	1992
2020	1976	2040	1988
2021	1975	2041	1982
2022	1978	2042	1991

RIVER CHANNEL SEEPAGE

River leakage in the Middle Rio Grande Valley of New Mexico (hereinafter called the Middle Valley) was initially computed outside of URGWOM using a FORTRAN program to compute daily gradients and flows between the river and riverside drains (Upper Rio Grande Water Operations Model physical Model Documentation: Third Technical Review Committee Draft pp 40-54). A version of the river leakage model is to be used for planning purposes. Historic daily river leakage would not be appropriate for estimating river leakage 40 years into the future. Step wise regression analysis between computed river leakage (dependent variable) and historic river flows at the upstream gage, riparian consumptive use, and riverside drain flow at an upstream gage (independent variables), where available, were used to develop relationships for each URGWOM river reach. A regression equation was developed for every month for each reach in the Middle Valley using S-PLUS (a statistical analysis software). CADWES modified the code to allow river leakage to be computed within the model. Table 2 shows the regression equations used in the planning model and statistics related to the regression. If one or more of the independent variables were not significant, it is not shown in the resulting equations.

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Table 2. River channel seepage equations.

Reach	Month	Regression equation. Leak is river leakage for the reach in cfs, flow is river flow at the upstream gage of the reach in cfs, boset is the bosque (riparian) consumptive use within the reach in acre-feet, BLFCC is flow in the low flow conveyance channel at Bernardo in cfs, SALFCC is flow in the low flow conveyance channel at San Acacia in cfs, SMLFCC is flow in the low flow conveyance channel at San Marcial in cfs.	R^2
Cochiti to San Felipe	January	Leak=11.823*log(flow)+0.00858*flow	0.996
	February	Leak=11.534*log(flow)+0.00916*flow	0.997
	March	Leak=11.522*log(flow)+0.00854*flow	0.997
	April	Leak=11.484*log(flow)+0.00853*flow-0.07445*boset	0.995
	May	Leak=9.359*log(flow)+0.00942*flow+0.01375*boset	0.995
	June	Leak=12.530*log(flow)+0.00816*flow-0.04441*boset	0.995
	July	Leak=12.174*log(flow)+0.00856*flow-0.02432*boset	0.997
	August	Leak=11.237*log(flow)+0.00864*flow+0.01286*boset	0.997
	September	Leak=12.309*log(flow)+0.00706*flow-0.02096*boset	0.997
	October	Leak=12.645*log(flow)+0.00605*flow-0.04813*boset	0.997
	November	Leak=12.029*log(flow)+0.00826*flow-0.04116*boset	0.998
	December	Leak=12.069*log(flow)+0.00783*flow	0.997
San Felipe to Central	January	Leak=41.851*log(flow)-0.00240*flow	0.998
	February	Leak=40.328*log(flow)+0.00190*flow	0.998
	March	Leak=38.408*log(flow)+0.00372*flow	0.998
	April	Leak=37.139*log(flow)+0.00609*flow	0.998
	May	Leak=33.904*log(flow)+0.00873*flow	0.998
	June	Leak=32.438*log(flow)+0.00867*flow+0.03249*boset	0.998
	July	Leak=34.873*log(flow)+0.00682*flow+0.01669*boset	0.998
	August	Leak=37.011*log(flow)+0.00418*flow	0.998
	September	Leak=37.239*log(flow)+.00480*flow-0.01823*boset	0.997
	October	Leak=38.138*log(flow)+.00175*flow-0.05818*boset	0.998
	November	Leak=40.921*log(flow)+0.00033*flow-0.14444*boset	0.998
	December	Leak=42.283*log(flow)-0.00420*flow	0.998
Central to Bernardo	January	Leak=86.953*log(flow)-0.00235*flow	0.993
	February	Leak=83.783*log(flow)+0.00786*flow	0.993
	March	Leak=80.767*log(flow)+0.01125*flow	0.993
	April	Leak=78.004*log(flow)+0.01630*flow	0.992
	May	Leak=69.773*log(flow)+0.0196*flow+0.03796*boset	0.994
	June	Leak=71.043*log(flow)+0.02121*flow	0.993
	July	Leak=75.301*log(flow)+0.01953*flow-0.022301*boset	0.990
	August	Leak=75.455*log(flow)+0.01215*flow	0.988
	September	Leak=64.424*log(flow)+0.02110*flow+0.16454*boset	0.981
	October	Leak=75.268*log(flow)-0.00276*flow+0.17929*boset	0.983
	November	Leak=80.753*log(flow)+0.00861*flow+0.23846*boset	0.992
	December	Leak=81.873*log(flow)+0.00876*flow	0.992
Bernardo to San Acacia	January	Leak=56.339*log(flow)-0.00500*flow-6.152*BLFCC	0.890
	February	Leak=47.950*log(flow)+0.01126*flow-4.723*BLFCC	0.903
	March	Leak=41.573*log(flow)+0.00885*flow-1.088*BLFCC	0.881
	April	Leak=35.172*log(flow)+0.01669*flow-0.94079*BLFCC+.29757*boset	0.905
	May	Leak=24.061*log(flow)+0.01170*flow-1.557*BLFCC+.31356*boset	0.886

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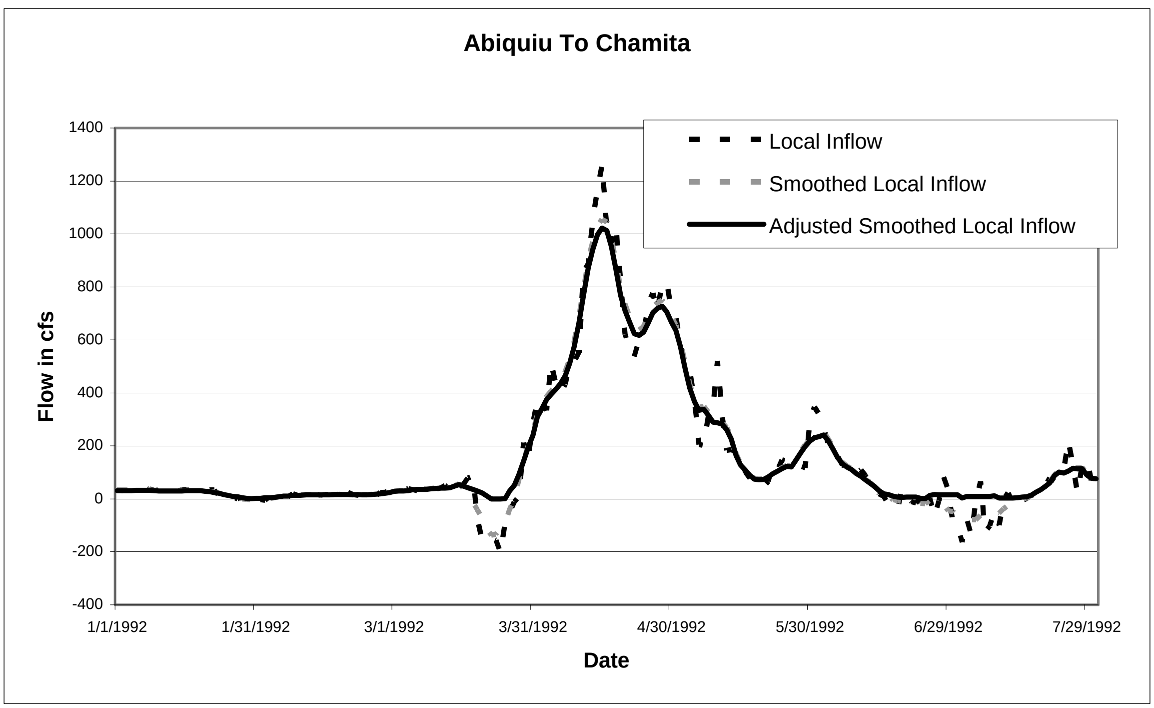
	June	Leak=7.691*log(flow)+0.01936*flow-2.296*BLFCC+.45309*boset	0.883
	July	Leak=4.512*log(flow)+0.02530*flow-1.625*BLFCC+.50435*boset	0.897
	August	Leak=5.584*log(flow)+0.03305*flow-1.442*BLFCC+.67401*boset	0.867
	September	Leak=8.794*log(flow)+0.04074*flow-1.046*BLFCC+.80125*boset	0.818
	October	Leak=39.503*log(flow)+0.00616*flow-0.817*BLFCC+.21641*boset	0.786
	November	Leak=50.417*log(flow)+0.00775*flow-2.935*BLFCC-.73414*boset	0.902
	December	Leak=51.115*log(flow)+0.00915*flow-4.752*BLFCC	0.892
San Acacia to San Marcial (ET is for the reach San Acacia to San Marcial)	January	Leak=135.77*log(flow)-.089257*flow-.313441*SALFCC+72.422*boset	0.911
	February	Leak=113.83*log(flow)-0.00623*flow-0.31177*SALFCC+44.708*boset	0.924
	March	Leak=109.47*log(flow)+0.00997*flow-0.30171*SALFCC	0.899
	April	Leak=95.224*log(flow)+.035428*flow-.323148*SALFCC-.599559*boset	0.899
	May	Leak=133.15*log(flow)+.020116*flow-.395948*SALFCC-1.4758*boset	0.916
	June	Leak=37.579*log(flow)+.068440*flow-.392025*SALFCC+.526582boset	0.898
	July	Leak=17.281*log(flow)+.07581*flow-0.49101*SALFCC+0.94878*boset	0.887
	August	Leak=91.033*log(flow)+.06276*flow-0.45024*SALFCC-0.64984*boset	0.849
	September	Leak=61.172*log(flow)+.08385*flow-0.67960*SALFCC	0.786
	October	Leak=66.810*log(flow)+0.09616*flow-0.44664*SALFCC-0.60462*boset	0.744
	November	Leak=86.509*log(flow)+0.09095*flow*-0.31180*SALFCC-4.344boset	0.920
	December	Leak=75.311*log(flow)+0.13091*flow-1.30789*SALFCC	0.923
San Marcial to Elephant Butte (boset is for the reach San Acacia to San Marcial)	January	Leak=34.197*log(flow)-0.04690*flow-0.01404*SMLFCC+12.144*boset	0.768
	February	Leak=27.696*log(flow)-0.01107*flow-0.03425*SMLFCC+12.266*boset	0.791
	March	Leak=25.719*log(flow)-0.01079*flow-0.01371*SMLFCC	0.710
	April	Leak=19.275*log(flow)-0.00618*flow+0.38782*boset	0.701
	May	Leak=30.091*log(flow)-0.00415*flow-0.10275*SMLFCC+0.53218*boset	0.791
	June	Leak=18.158*log(flow)+0.00170*flow-0.08833*SMLFCC+0.54549*boset	0.775
	July	Leak=11.734*log(flow)-0.00030*flow-0.02370*SMLFCC+0.36991*boset	0.644
	August	Leak=8.912*log(flow)+0.01151*flow+0.02043*SMLFCC+0.15159*boset	0.600
	September	Leak=3.663*log(flow)+0.00951*flow+0.13764*SMLFCC-0.15548*boset	0.475
	October	Leak=9.696*log(flow)+0.01299*flow+0.04559*SMLFCC-0.47199*boset	0.352
	November	Leak=17.212*log(flow)+0.01618*flow-1.447*boset	0.684
	December	Leak=28.062*log(flow)-0.00905*flow-19.070*boset	0.728

LOCAL INFLOWS ABOVE COCHITI DAM

Local inflow is an important factor for reaches above Cochiti Dam where snowmelt-runoff is a significant component of the flow. Therefore, local inflows need to be developed as part of the input for the planning model for reaches above Cochiti Dam. As discussed in the Physical Model Documentation – Physical Model Validation (December 2002), the smoothed local inflow method (using a 7-day centered moving average) is suitable local inflow for use in the Planning Model.

One drawback to the smoothed local inflow method is that negative results may occur, which is not desirable for input into the model. An adjustment to the smoothed local inflows was performed to eliminate this problem. For the period of historical data used in the model (1975-1999), the volume of negative flows was proportioned to reduce the positive flows, and the negative flows were set to zero. Reducing the positive flows by the same volume of the negative flows preserves the total volume of the local inflow hydrograph. Since the negative flows were a fairly small percentage of the total volume of the hydrograph, the positive flows were reduced only a slight amount, preserving the daily variability and peaks of the smoothed hydrographs. This adjustment was made for each reach above Cochiti Dam. Figure 1 provides an example of the adjustment made to a local inflow hydrograph for the Abiquiu to Chamita reach.

Figure 1. Example of smoothed local inflow hydrograph adjustment



DATA SMOOTHING

When the hydrologic input data was assembled for the 40-year planning sequence, it was discovered that discontinuities may arise between December 31st and January 1st of each year. These discontinuities may be caused by cases where a year's worth of data is repeated each year or with the reorganized data sequence. In some cases, these discontinuities may cause strange results when run through the model. To reduce this problem, centered moving averages were computed around these dates. On selected data types and for each year where data records were concatenated, the data from December 28th to January 4th were used to compute 3- to 7-day centered moving averages depending on the number of values available in this time window. Data types include evapo-transpiration, temperature, surface ice coverage, local inflows, and return flows.

INTRODUCTION AND DEVELOPMENT OF HISTORIC FORECAST ERROR

Reservoir operators in the Rio Grande Basin have historically relied upon forecasts of inflow developed by such agencies as the National Resource Conservation Service (NRCS). These forecasts are generally developed by rivershed runoff models and by regression techniques, and are supplied to the reservoir operator as a volume of water over a specified time range. In the Rio Grande Basin, the time period is usually March through July, as this is the period of time when about 70 percent of the flow volume occurs. The reservoir operator then takes this forecast and distributes it to a smaller time scale such as a daily time step. Operators in the Rio Grande Basin have historically used what is termed a similar year distribution. This distribution is determined by searching the historical records of flow at the forecast point and finding a year with volume of runoff during the March through July period similar to the current forecast of flow. The daily percent of flow is then computed by dividing the actual historical daily volume of flow by the actual historical March through July volume of flow, thus creating unit hydrograph. The volume of forecast flow is then multiplied by the unit hydrograph to distribute the forecasted flow on a daily basis. Operators then use this "forecasted inflow" to help them determine the basic decision of how much water to release.

In order for a planning model using historical data to accurately portray operation decisions, the basic technique of using forecasts of inflow whenever release decisions require looking ahead must be incorporated into the model. This way, modeling results will as accurately as possible reflect the information available to the operator when operation decisions are made. If the model is run over a historical time frame, the flow into a reservoir is already known, so either historical forecasts must be used or a method to incorporate historical forecast error must be incorporated into the model. Using historical forecasts would be fine for modeling during the period when they are available, but usually the period of historical forecasts is short and would not be available for model runs that need to project far into the future. Therefore we are proposing to use an algorithm that builds historical forecast errors into it.

The basic premise of the historic forecast error algorithm is that forecast error can be predicted from the actual (March-July) runoff, and the previous months forecast error. In the Rio Grande River Basin, runoff forecasts have been historically given as a volume of unregulated flow from March through July. Unregulated flow at any point in the river is defined as the amount of water that would flow at the forecast point if there were no reservoirs located upstream of the forecast point. The historic forecast error for a given forecast point such as the flow of the Rio Chama at La Puente was developed by an analysis of historical forecasts and the actual unregulated flow of the Rio Chama near La Puente. Forecast error is defined by the following equation:

$$FE = RO - HF$$

where FE = Forecast error
RO = Actual unregulated runoff for the March - July period
HF = Historic forecast

The calculation was done each month for the entire historical forecast period of 1965 through 1997. From this equation it is obvious that the forecast error can be both positive and negative.

A multiple regression was then performed for each month with the Y term being the current month forecast error, the X_1 term being actual March-July runoff, and the X_2 term being the previous months forecast error. Of course in January there is no previous months forecast error, so it was

assumed to be zero. This regression technique produced very good results. The R squared values ranged from .87 to .70. The analysis points out two very important things about historical forecast error in the Rio Grande River Basin. First, there is a tendency to over forecast runoff in dry years and under forecast runoff in wet years. The second thing is that there is a strong relationship between the current months forecast error and the previous months forecast error. This analysis was performed in an Excel spreadsheet named RioGrandeUnreg.xls.
Based upon this regression analysis, the following algorithm was used to produce forecast errors similar to those that have occurred historically:

$$\text{Forecast Error} = (C_1 * I) + (C_2 * E) + C_3 + (R * S)$$

Where:

- C_1 = The X_1 multiple regression coefficient that relates the current months forecast error to the actual March-July unregulated flow near La Puente.
- C_2 = The X_2 multiple regression coefficient relating the current months forecast error to the previous months forecast error.
- C_3 = The intercept of the multiple regression.
- I = The actual March-July unregulated flow at a forecast point.
- E = Previous months forecast error. For example if the current month was April this would be the forecast error computed for March.
- R = A random number between 1 and -1. The same seed is used for this random number so that a comparison of models can be made.
- S = The standard error of the multiple regression.

Because of the random component in this algorithm, the computed forecast error may, on occasion, exceed the actual range of the historical forecast error. Therefore each months forecast error is bounded by ± 3 times the standard error of the multiple regression. This keeps the estimate of error within a 99.5 percent confidence interval. The forecast error for July is computed as 1/4 of the computed June forecast error. For the August-December period forecast error would be computed as the minimum of the July forecast error or 10 percent.

The forecast error volume is determined by the above algorithm on the first day of each month during the run. The estimated forecast error is then converted into a percent of forecast error. It is assumed that the forecast error will be evenly distributed across the remaining March – July period and therefore the forecasted inflow during each day of the month is assumed to be the actual inflow times the percent forecast error for the current month.

RIO GRANDE COMPACT ACCOUNTING

STORAGE ACCOUNTS IN ELEPHANT BUTTE RESERVOIR

Four storage accounts have been set up for accounting of water in Elephant Butte Reservoir. These include an account for Albuquerque's San Juan-Chama Project water (authorized by P. L. 97-140), and Rio Grande storage accounts for Credit/Debit Water (Colorado and New Mexico) and Usable Water in Project Storage. The Rio Grande Compact defines Usable Water as "all water, exclusive of credit water, which is in Project Storage and which is available for release in accordance with irrigation demands, including deliveries to Mexico." The total storage of water in Elephant Butte Reservoir is the sum of water in the four accounts.

ELEPHANT BUTTE RESERVOIR STORAGE INITIAL CONDITIONS

The initial conditions in storage in Elephant Butte Reservoir used in the planning model are the storage amounts that existed in the accounts in Elephant Butte Reservoir as of December 31,

2002. Table 4 is a tabulation of the of the initial storage account values used in the planning model.

Table 3. Elephant Butte Reservoir storage account initial conditions.

Storage Account	Initial condition (acre-feet, rounded)
Albuquerque San Juan-Chama Project Water	8,200
Colorado Credit Water	42,800
New Mexico Credit Water	265,000
Usable Water	34,100
Total:	350,100

In the computation of the states' future years' credit and debit status, the planning model assumes that the Colorado annual actual delivery will equal its annual scheduled delivery as measured by the flow of the Conejos River at Mouths and the Rio Grande at Lobatos less Conejos River at Mouths. The New Mexico accrued credit/debit status will be based on the accrued difference between the annual scheduled delivery and the annual actual delivery. The scheduled delivery is based on application of the modeled flow at Otowi (adjusted for the operation of reservoirs constructed after 1929 and for transmountain diversions) to the Compact delivery schedules and the actual delivery is the modeled inflows to Elephant Butte Reservoir and modeled releases from Elephant Butte Reservoir.

POSSIBLE CREDIT WATER RELINQUISHMENT

Article VII of the Rio Grande Compact provides, in part, that Colorado and New Mexico shall not increase the amount of water in storage in reservoirs constructed after 1929 whenever there is less than 400,000 acre-feet of Usable Water in Project Storage, provided that Colorado or New Mexico, or both, may relinquish accrued credits at any time, and Texas may accept such relinquished water, and in such event the state, or states, so relinquishing shall be entitled to store water in the amount of the water so relinquished. Because the occurrence or the amount of credit water relinquishment is a matter decided by the states depending upon the existent conditions, the planning model does not determine the occurrence of credit water relinquishment.

FORECASTING USABLE WATER IN PROJECT STORAGE

Planning model rules for the operation of Project Storage (Elephant Butte and Caballo Reservoirs) contain a schedule for the normal release of 790,000 acre-feet from Project Storage. In the event that the total of the projected inflow and the amount of Usable Water in storage is inadequate to provide for a release of 790,000 acre-feet, the daily releases are reduced proportionally to take into account the available supply.

In order to estimate the projected inflow to Elephant Butte Reservoir to determine the releases from Project Storage, the planning model will use 65% of the March-June forecasted flow of the Rio Grande at the Otowi gage as the estimated runoff into Elephant Butte Reservoir for the same period. This value may be adjusted if determined to be necessary.

INITIAL RESERVOIR STORAGE CONTENT

The initial reservoir storage contents used in the planning model are those contents that existed in reservoirs modeled in the planning model as of midnight, December 31, 2002. Table 3 summarizes the storage amount of each account in reservoirs modeled in the planning model.

Table 4. Planning model initial storage contents.

Reservoir *Account*	Initial Storage (acre-feet)
Heron	
San Juan-Chama Project water (SJ-C)	*161,141*
Rio Grande water (native)	*-382*
Total	160,759
El Vado	
Albuquerque (SJ-C)	*0*
Combined San Juan-Chama Project Contractors	*6,069*
MRGCD (SJ-C)	*2*
Reclamation (ESA/drought reserve)	*0*
Rio Grande (native)	*5,124*
Total	11,195
Abiquiu	
Albuquerque (SJ-C)	*31,375*
Combined San Juan-Chama Project Contractors	*11,591*
MRGCD (SJ-C)	*0*
Reclamation (native)	*0*
Rio Grande	*1*
Accumulated sediment deposited since previous survey	*782*
Total	43,749
Cochiti	
Cochiti Recreation Pool	*47,710*
Rio Grande	*-142*
Accumulated sediment deposited since previous survey	*1237*
Total	48,805
Jemez	
Sediment Pool (SJ-C)	*0*
Rio Grande (native)	*0*
Accumulated Sediment deposited since previous survey	*0*
Total	0
Elephant Butte (rounded)	
Albuquerque (SJ-C)	*8,200*
CO accrued credit	*42,800*
NM accrued credit	*265,000*
Rio Grande (Rio Grande Project Usable Water)	*34,100*
Total	350,100
Caballo	
Total *(Rio Grande Project Usable Water)*	37,300

MINIMUM AND TARGET RESERVOIR STORAGE LEVELS

Nominal minimum storage levels are maintained in some of the reservoirs modeled in the planning model. The model rules require that a minimum storage level of between zero and 1,000 acre-feet be maintained in Heron, El Vado, Abiquiu and Cochiti Reservoirs. Table 5 lists the minimum pools used in the planning model.

Table 5. Tabulation of minimum reservoir levels used in planning model.

Reservoir	Minimum Storage Level (acre-feet)
Heron	< 1,000
El Vado	< 1,000
Abiquiu	< 1,000
Cochiti Lake	< 1,000
Jemez Canyon	0
Elephant Butte	2,000
Caballo	2,000

PROPOSED CITY OF ALBUQUERQUE DRINKING WATER PROJECT

Albuquerque is planning the development of a surface water diversion project intended to utilize and deplete their San Juan-Chama Project water. The URGWOM planning model will simulate some aspects of Albuquerque’s project beginning in 2006. The planning model was modified to break the San Felipe to Central reach into two reaches at the Paseo del Norte Bridge. Unrelated to Albuquerque’s project, the Central to Bernardo reach was broken into two reaches at Isleta Dam.

Albuquerque has utilized the URGWOM hydrologic sequence of years to estimate the schedule of San Juan-Chama Project releases to be made to meet the project demand. This demand includes the required releases from Abiquiu Reservoir to meet current diversion demand, as well as Albuquerque’s estimate of the amount of San Juan-Chama Project water required to be released from Abiquiu Reservoir to offset the impacts of Albuquerque’s current and historic (residual) groundwater pumping on the flow of the Rio Grande.

The URGWOM planning model is not capable of simulating the change in river channel seepage due to the change in Albuquerque’s groundwater pumping. Over the forty-year planning period, Albuquerque estimates that the impacts of groundwater pumping on the flow of the Rio Grande will decline from about 75,000 acre-feet in 2003 to about 31,000 in 2019, and then increase to about 41,000 acre-feet at the end of the planning period in 2042. This analysis assumes a 40% reduction in per capita water use from 250 gpcd to 150 gpcd by 2015. Since other wastewater returns were not adjusted over time and depletions are not increased over time (which may offset the effects of increased return flows), the URGWOM planning model assumes an estimated steady state return flow from the Albuquerque Southside Wastewater Reclamation Plant, based on the 2001 discharge data.

CURTAILMENT STRATEGY

The City of Albuquerque’s proposed Drinking Water Project Plan calls for a constant release of about 66 cfs of Albuquerque’s San Juan-Chama Project water from Abiquiu Reservoir beginning in 2006 and extending through the planning period (2042). After incurring conveyance losses between Abiquiu Dam and Albuquerque, approximately 65 cfs of San Juan-Chama Project water would reach the proposed diversion facility near the Paseo del Notre Bridge. There, a constant diversion of 130 cfs would occur throughout the year provided flows are more than or equal to a specified 'threshold flow' of 260 cfs just above the diversion point. The 130-cfs Drinking Water Project diversion would include 65 cfs of Albuquerque's San Juan-Chama Project water and 65 cfs of Rio Grande water. The 65 cfs of San Juan-Chama Project water would be consumptively used within the City's Water Service Area. The 65 cfs of Rio Grande water would, in effect, be returned to the river at the City's Southside Wastewater Reclamation Plant outfall below Rio Bravo. Under this plan there would be a reach of the Rio Grande between the point of diversion and point of return flow (about 14 miles) that would be depleted relative to native flows by 65 cfs on average.

Albuquerque intends to ensure that the proposed Drinking Water Project diversions do not dry up or otherwise adversely affect the riverine ecology between the diversion and return flow points by implementing the curtailment strategy described below. For the full operation of the Drinking Water Project under a constant release-diversion scenario, the flow at the Paseo del Norte diversion point must be at least 260 cfs based on the following:

- A diversion rate of 130 cfs comprised of 65 cfs of San Juan-Chama Project water and 65 cfs of native water
- A fishway bypass flow on the west side of the river and flow at the outlet of the sluiceway on the east side of the river that would provide for downstream movement of sediment and fish past the intake screens, which when combined equals 130 cfs.

Thus, the total flow required for full operation of the Drinking Water Project at a diversion rate of 130 cfs would be 260 cfs. If the river flow above the diversion point is less than 260 cfs, the flow to the intake would be curtailed to ensure proper operation of the sluiceway and fishway facilities, and to minimize depletion effects in the 14-mile reach between the diversion and the Southside Wastewater Reclamation Plant discharge point. In order for the Drinking Water Project to operate fully, the amount of Rio Grande water in the river at the diversion point must be a minimum of 195 cfs.

When native flows at the diversion point fall below 195 cfs (total flow of 260 cfs with 65 cfs of San Juan-Chama Project in the river), the City would begin curtailing the quantity of the diversion by 1 cfs for each drop of 1 cfs native flow. However, the City would continue to release from upstream and divert at Albuquerque the full 65 cfs of San Juan-Chama Project water. As native flow continues to drop, Drinking Water Project diversions would be reduced accordingly. When native flow drops to 130 cfs above the Drinking Water Project diversions, San Juan-Chama Project releases would be cut off entirely.

RELEASE OF ALBUQUERQUE SAN JUAN-CHAMA PROJECT WATER FROM ABIQUIU RESERVOIR DURING FLOOD CONTROL OPERATIONS

Albuquerque's proposed Drinking Water Project calls for a constant, year-round release of Albuquerque's San Juan-Chama Project water from Abiquiu Reservoir, after it is delivered from Heron Reservoir. During periods of time when Abiquiu Reservoir is in flood control operation, this planned operation would be in conflict with the provisions of P.L. 86-645, which requires that Abiquiu Reservoir is to be operated so that accumulated flood control storage is evacuated at the maximum rate practicable under conditions at the time. Due to the limited channel capacity of the Rio Chama below Abiquiu Dam, the release of native water retained in the reservoir during flood control operations is the first priority water released, and releases of San Juan-Chama Project water would be deferred until after cessation of flood control operations.

During periods of time when Abiquiu Reservoir is in flood control operations and the channel capacity below Abiquiu Dam is restricted to releases of natural flow only, the planning model will transfer Albuquerque's San Juan-Chama Project release into the Rio Grande account in order that the water may be released to meet the City's Drinking Water Project demand. This accounting is done only for the purposes of running the planning model. The Albuquerque Drinking Water Project could evaluate the planning model runs to determine the extent of the impact of the operation of Abiquiu Reservoir for flood control purposes would have on the release of San Juan-Chama Project water for use by the Drinking Water Project.

FUTURE ALBUQUERQUE LEASES AND EXCHANGES OF SAN JUAN-CHAMA PROJECT WATER

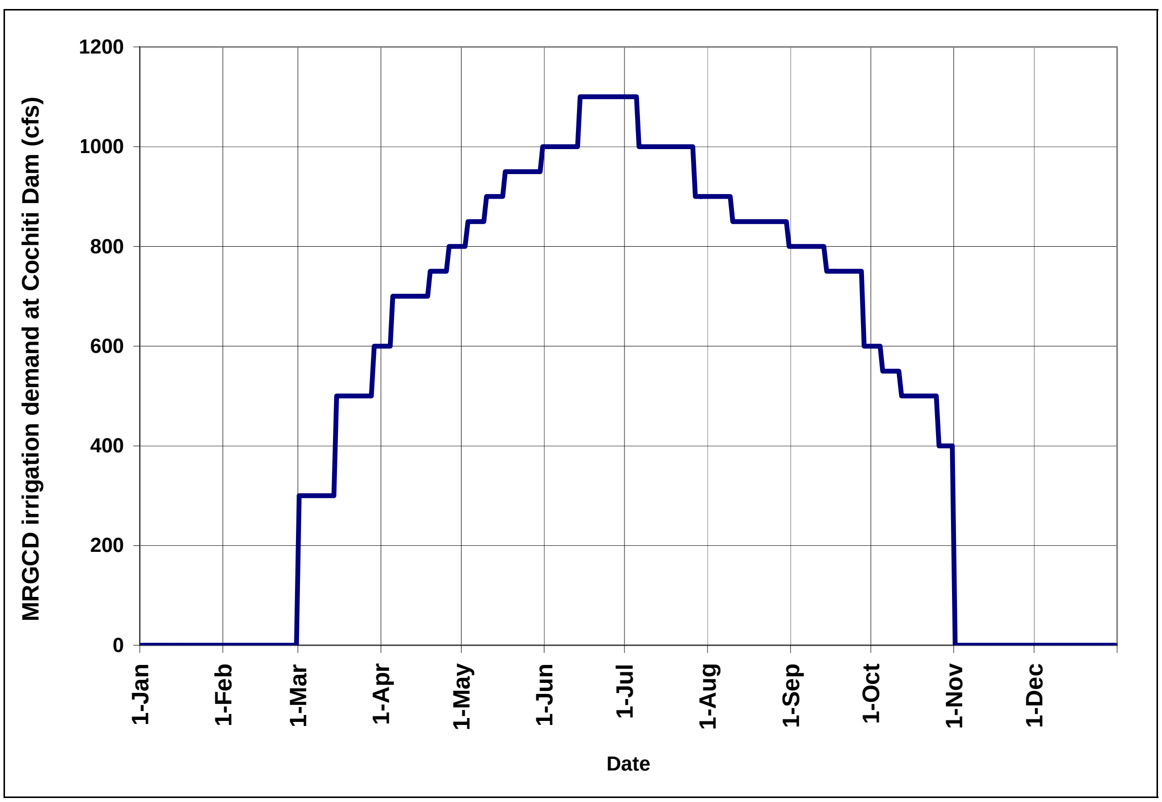
In past years, Albuquerque has entered into leases and exchanges of San Juan-Chama Project water in excess of its current demand for Project water. The planning model runs do not include any leases or exchanges of San Juan-Chama Project water, as the entire supply of Albuquerque's San Juan-Chama Project water will be required to meet the demand of Albuquerque's proposed Drinking Water Project.

MIDDLE RIO GRANDE CONSERVANCY DISTRICT (MRGCD)

IRRIGATION DEMAND SCHEDULE

The planning model will use the 2001 total release from Cochiti Dam as the Middle Rio Grande Conservancy District (MRGCD) irrigation demand. The 2001 cropping pattern is also used in the planning model. The same values (2001) will be used each year of the planning model run. The MRGCD irrigation demand schedule totals 377,700 acre-feet each year. Figure 2 is a hydrograph showing the daily flow values used in the planning model for the MRGCD irrigation demand.

Figure 2. MRGCD demand schedule at Cochiti Dam



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ADJUSTMENT OF DOWNSTREAM CANAL/DRAIN FLOW TO ACCOUNT FOR SHORTAGES TO DIVERSION DEMAND

The development of the URGWOM model relies upon the measured flow in the canals and drains at each URGWOM river cross-section to ensure that the water budget balances in each URGWOM reach. These historic measured values reflect the actual measured diversion of water into the MRGCD canals and the water supply available in those years. Because the planning model uses a fixed diversion demand but with a variable water supply, the amount of flow leaving the reach in the canals and drains must be adjusted to reflect shortages to the fixed demand. Without making these adjustments, the use of the historic flow in the canal/drain gage below the bifurcations along with the 2001 MRGCD diversion data would add water to the river system that would not otherwise be there if the water supply was less than the 2001 water supply. To solve this problem a relation between the amount of water diverted and the gaged flow below the bifurcations was developed for each bifurcation in the planning model. Even though the irrigation demand schedule is for average to wet period demands, the model still reflects the quantity of shortages during drought periods.

The data used for the development of the relations came from the physical calibration of the water operations model. The non-irrigation months were removed from the data set since there were no diversions. The March data was also removed from the data set because many of the diversions did not have any flow for most of the month and it was decided that the no flow data would skew the results. The mean daily flow for the time period from May through October was determined for years 1985 to 1997. This set of years was used so that recent changes in the operation of the river and canals could be analyzed. The plot of the annual mean flows and results of the regression analysis are shown in Figures 2 through 6. In all but one of the relations offset was not significant. The only relation where the offset was significant was for the diversions below Isleta and Bernardo drains and canals, shown in Figure 5.

Figure 3. Relation of annual mean flows between combined diversions below Cochiti Dam and Cochiti East Side Main Canal at San Felipe.

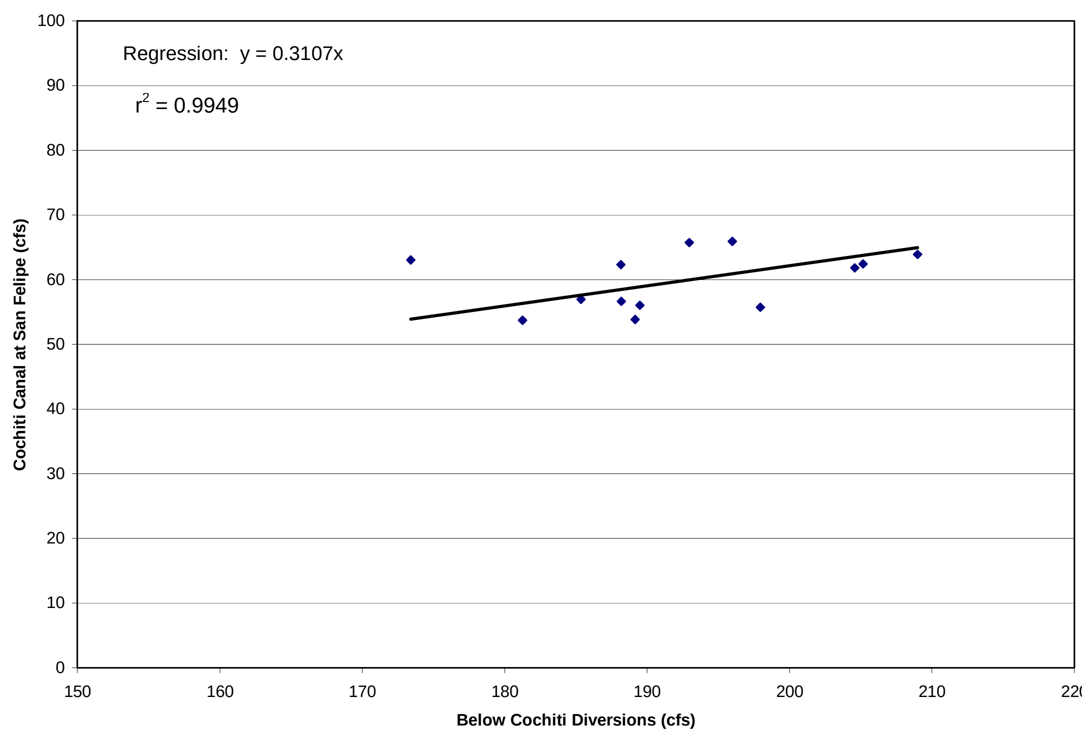

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Figure 4. Relation of annual mean flows between combined diversions below San Felipe and Central combined drains and canals.

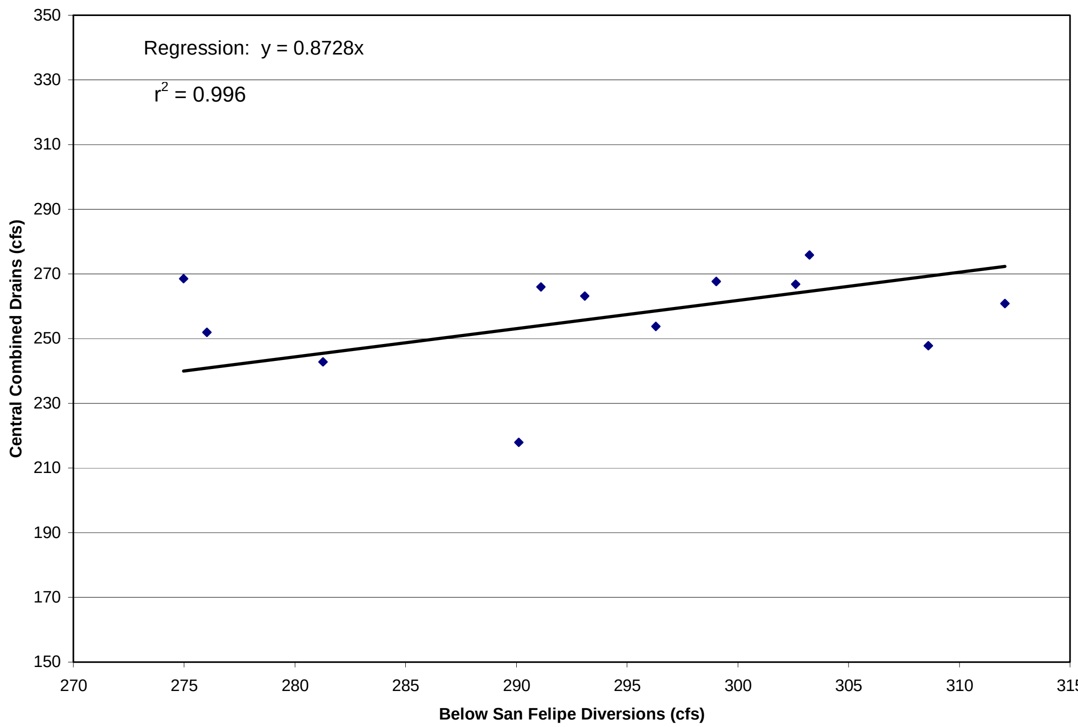


Figure 5. Relation of annual mean flows between diversions below Isleta and Bernardo drains and canals.

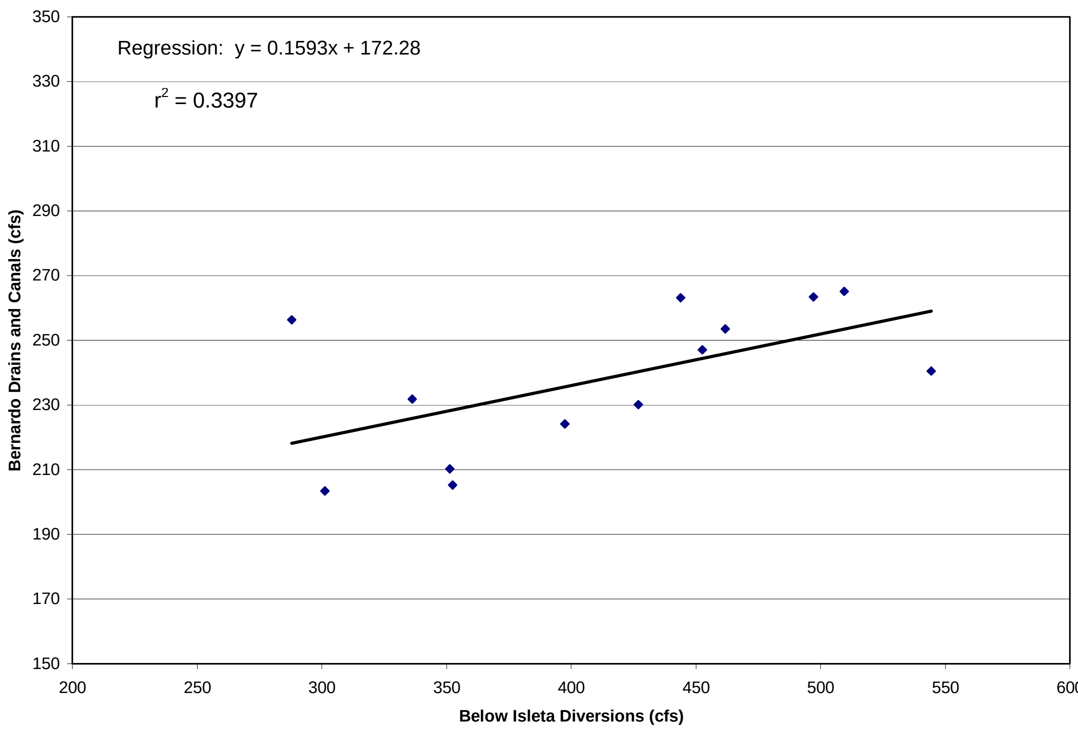


Figure 6. Relation of annual mean flows between combined Bernardo drains and canals and Unit 7 flow through.

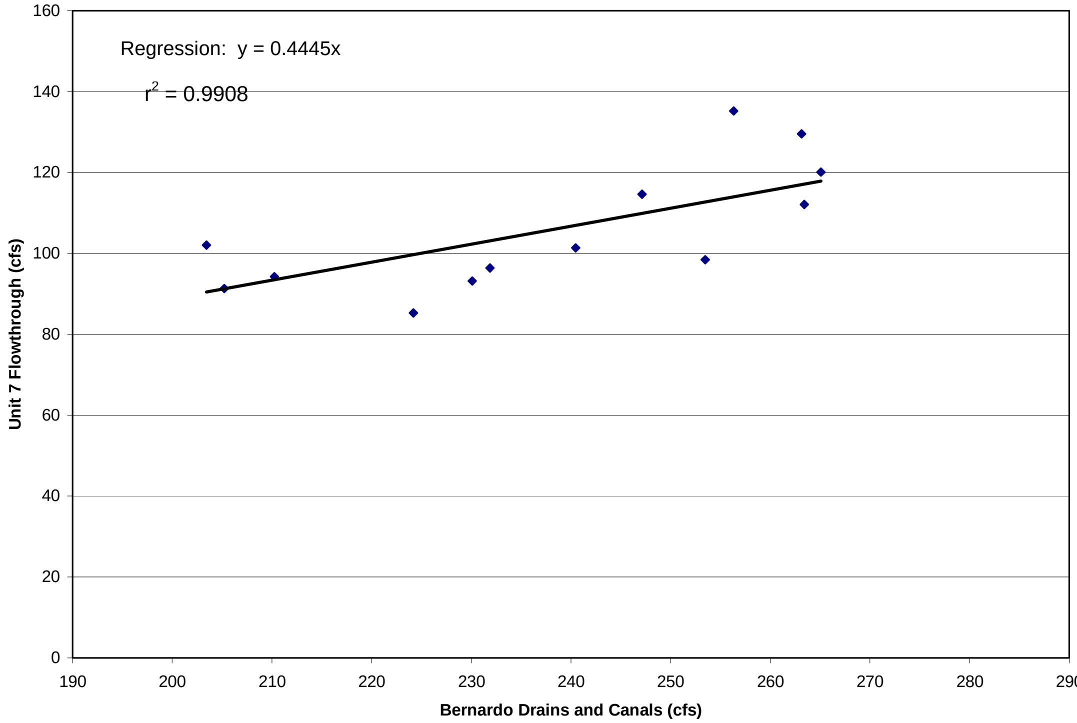
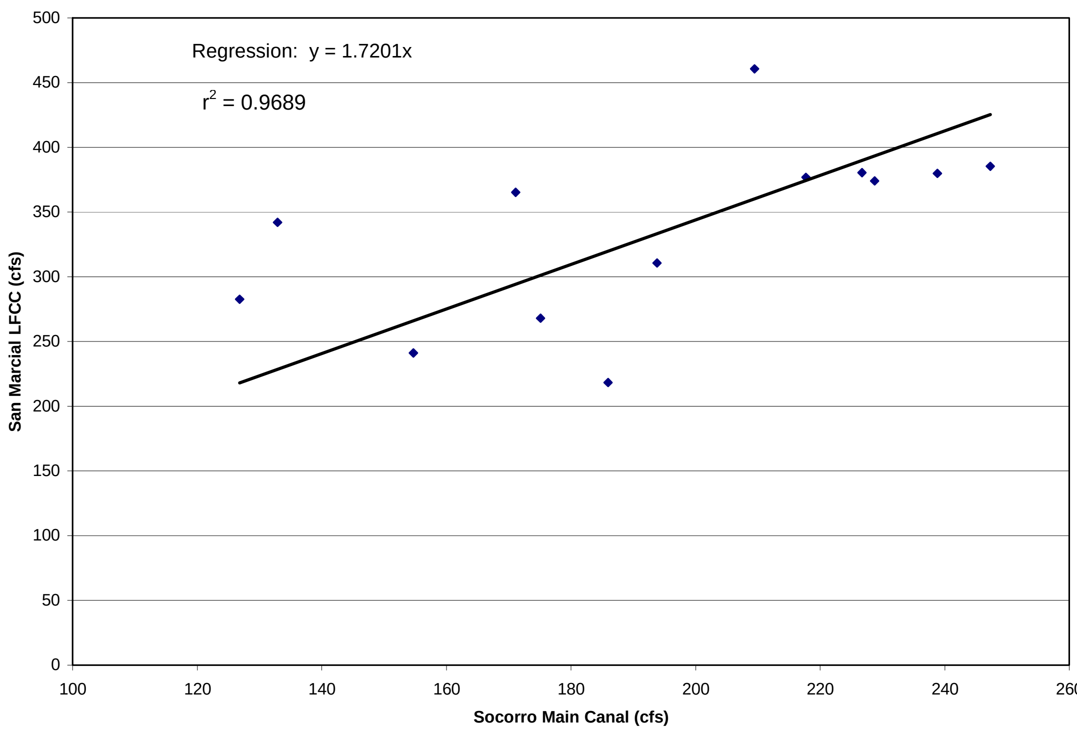


Figure 7. Relation of annual mean flows between Socorro Main Canal and San Marcial Low Flow Conveyance Channel.

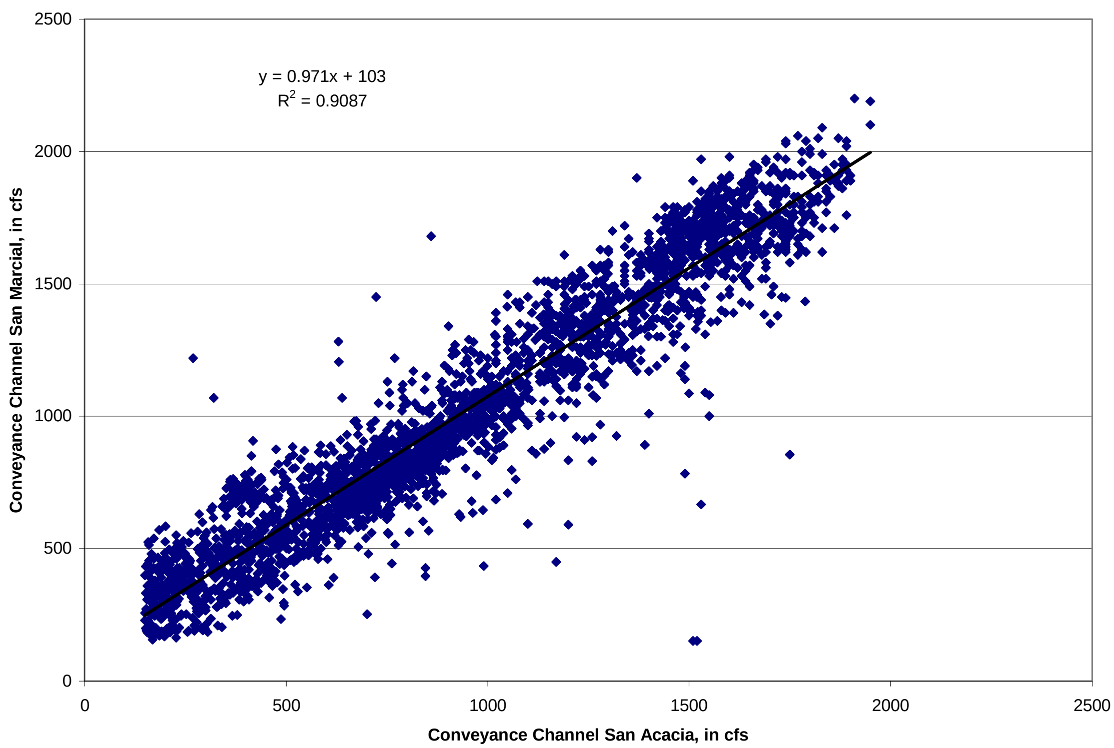


METHOD TO ESTIMATE FLOW IN RIO GRANDE CONVEYANCE CHANNEL AT SAN MARCIAL

The relationship of the diversion at Socorro Main Canal and the flow at the gage at the Conveyance Channel at San Marcial can be used for most cases except when there is a diversion into the Conveyance Channel at San Acacia. A separate analysis was completed for the periods when water was diverted into the Conveyance Channel at San Acacia that demonstrated a different relation.

Statistical analysis was completed to determine a relation between gages upstream and the gage on the Conveyance Channel at San Marcial when water was diverted into the Conveyance Channel at San Acacia. Analysis of the diversion to Socorro Main Canal was shown not to be significant compared to the diversion into the Conveyance Channel. So the determination of the relation between the gages on the two conveyance channels was started. Flow data from the USGS for the two gages on the conveyance channel for the period 1964-85 was used for the analysis. Graphical review of the data from two conveyance channels indicated a strong relationship above 120 cfs and much scatter below. When running a least squares regression the scatter below 120 cfs skewed the relationship over the entire range of data. The regression analysis was again run without the data below 120 cfs and the relationship over the range above 120 cfs was determined to be good, which was used for the model. For flows below 120 cfs, the relation is a good approximation. Figure 8 shows the relationship between the flow of the Rio Grande Conveyance Channel at San Acacia versus the flow of the Rio Grande conveyance Channel at San Marcial for flows in excess of 120 cfs.

Figure 8. Flow of the Rio Grande Conveyance Channel at San Acacia versus the flow of the Rio Grande Conveyance Channel at San Marcial.



SAN JUAN-CHAMA PROJECT

REDUCTION OF ANNUAL ALLOCATION ON ACCOUNT OF WATER SUPPLY SHORTAGES

On January 1 of each year, the planning model makes an initial allocation of San Juan-Chama Project water to the Project contractors. The allocation is based on the amount of water in storage in Heron Reservoir on January 1st. In the event that the storage of San Juan-Chama Project water in Heron Reservoir is inadequate to provide a full supply of water to the Project contractors, the annual allocations are reduced proportionally in accordance with the amount of water in storage. (See Section 11.(a) of Public Law 87-483, June 13, 1962)

In years when the annual allocations are reduced due to a shortage in supply of water in Heron Reservoir, the planning model makes a second apportionment on July 1st. San Juan-Chama Project water is apportioned a second time to the contractors up to the full allocation of each contractor based on the amount of water in storage in Heron Reservoir on July 1st.

COMBINED CONTRACTORS ACCOUNTS

The URGWOM Accounting and Water Operations Models utilize a total of thirteen San Juan-Chama Project Contractors accounts, plus an additional account for Bureau of Reclamation conservation storage purposes. This number of accounts is cumbersome and not necessary for the purposes of the planning model. In order to simplify the running of the planning model, only five San Juan-Chama Project accounts are used: Albuquerque, the Middle Rio Grande Conservancy District, the Bureau of Reclamation conservation storage account and the Cochiti Reservoir Recreation Pool; all remaining San Juan-Chama Project contractors accounts are combined into a single account.

The remaining or combined San Juan-Chama Project accounts include San Juan Pueblo, Jicarilla Apache, Belen, Bernalillo, Española, Taos, Red River, Twining, Los Lunas, Los Alamos, Santa Fe, and the Pojoaque Valley Irrigation District. The planning model makes releases of the combined San Juan-Chama Project accounts on a fixed schedule that is repeated in each year of the planning model run.

CONTRACTOR RELEASE PRIORITY

Releases of San Juan-Chama Project water are made in accordance with the demands of the contracting entity. The planning model releases water in the following order of priority: 1) City of Albuquerque water, which is released in the beginning of the year, 2) Middle Rio Grande Conservancy District water, which is released to meet demands during the irrigation season, 3) the combined accounts of the remaining San Juan-Chama Project contractors; and 4) releases to offset evaporation losses in Cochiti Reservoir.

RESERVOIR OPERATIONS

BIOLOGICAL OPINION – MIDDLE RIO GRANDE

At this time, the planning model *does not* simulate the operation of Abiquiu Reservoir, Cochiti Lake and Jemez Canyon Reservoir in order to evaluate compliance with the provisions of the *Final Biological and Conference Opinions on Effects of Actions Associated with Programmatic Biological Assessment of Bureau of Reclamation's Water & River Maintenance Operations, Army Corps of Engineers Flood Control Operation, and Related Non-Federal Actions on the Middle Rio Grande* dated March 17, 2003. Among other items, these Opinions, which are to be in effect through February 28, 2013, set target flow levels at locations in the middle Rio Grande as measured at Albuquerque, San Acacia, and San Marcial. Variable target flow levels are designed specifically for dry, average, or wet runoff conditions. The dry, average, and wet runoff conditions are based on the Natural Resources Conservation Service's April 1 "Most Probable" Streamflow Forecast.

RELEASES FROM ELEPHANT BUTTE DAM FOR HYDROELECTRIC POWER

The planning model simulates hydroelectric power generation releases from Elephant Butte Dam. During the non-irrigation season, these releases are stored in Caballo Reservoir for release during the following irrigation season. The historic average mean daily flow of the Rio Grande below Elephant Butte Dam for the 1975-2000 period was used as the basis for the Elephant Butte Reservoir releases for hydroelectric power generation, and were adjusted to provide for a normal release from Project Storage of 790,000 acre-feet per annum. If Rio Grande Project Storage and the forecasted inflow are inadequate to meet the normal release of 790,000 acre-feet, the daily releases are reduced in proportion to the amount that each day's flow bears to the total annual flow. Not all of the flow of the Rio Grande below Elephant Butte Dam is available for hydroelectric power generation. Some of the water released from the reservoir is released through the Elephant Butte Dam outlet works and bypasses the turbines. The amount of water released for hydroelectric power generation is based on the capacity of the penstock. All other releases are assumed to bypass the penstock through the outlet works.

CHANGES TO THE URGWOM RULESET

There have been substantial changes made to the URGWOM ruleset over the past twelve months. A list of these changes is shown below:

1. Implementation of RiverWare pre-defined functions that allow the association of supplies to reservoirs and accounts
2. Implementation of pre-defined supply functions in URGWOM ruleset
3. Substantial work on the Indian Storage Requirements Operations at El Vado Reservoir
4. Change in the execution order of the ruleset from top down to bottom up
5. Cleaned up the ruleset
6. Added rules to compute Rio Grande Compact details including credit relinquishment
7. Added greater control on overfilling accounts in reservoirs downstream of Heron
8. Implemented the new RiverWare periodic table slots in the model and ruleset
9. Performance enhancement of ruleset
10. Reconciliation problems fixed

Implementation of RiverWare pre-defined supply functions that allow the association of supplies to reservoirs and accounts – The theory behind associating supplies to reservoirs and accounts was developed and delivered to CADSWES for implementation. Included in this was the implementation of ReleaseType, and DestinationType to be added to supplies. Additionally, 13 pre-defined functions were prototyped for inclusion into RiverWare's pre-defined functions. The pre-defined functions include: AccountNamesByAccountType, AccountNamesByWaterOwner, AccountNamesByWaterType, AccountNamesFromObjReleaseDestination, DestinationsFromObjectReleaseType, SupplyNamesFrom, SupplyNamesFrom1To1, SupplyNamesFromIntra, SupplyNamesFromIntra1To1, SupplyNamesTo, SupplyNamesTo1To1, SupplyNamesToIntra, SupplyNamesToIntra1To1.

Implementation of pre-defined functions in URGWOM ruleset – Using the pre-defined functions listed above a set of URGWOM specific functions were developed to take advantage of this new functionality. The use of these functions made it possible to get rid of at least 100 functions that were "Hard Wired" for a particular model. Use of these functions also made it possible to use the same ruleset for both the water operations and planning models (even with different accounts). This will make the long-term maintenance of the ruleset(s) much easier.

Substantial work on the Indian Storage Requirements Operations at El Vado Reservoir – It was discovered that the Indian Storage Requirements as initially implemented was not adequate for current operations especially when Article VII of the Rio Grande Compact is in effect. The Indian Storage Requirement calculations were changed and changes were made to the operation of El Vado Reservoir when Article VII is in effect.

Change in the execution order of the ruleset from top down to bottom up - The URGWOM ruleset was initially designed to execute with the highest priority rule firing first through the last priority rule (top down - descending). Because of this type of execution, constraints had been implemented in order to get the rules to execute in the correct sequence. This caused some confusion on how the rules fired and resulted in reduced model performance. During this last year, a scheme to fire rules from the bottom up (ascending) in RiverWare was developed. This scheme allows the lowest priority rule to fire first, then the next lowest, until finally the highest priority rules fires. This implementation made for a straight-forward firing order of the rules as well as providing performance improvements.

Cleaned up the ruleset – Through the development of the operations ruleset, numerous changes and enhancements have been made in RiverWare. Because of this, some parts of the ruleset had become antiquated. Therefore, an effort was made to go through the entire ruleset to update functions and entirely eliminate some, or replace with pre-defined functions. This helped make the ruleset easier to maintain as well as improve performance.

Added rules to compute Rio Grande Compact details, including credit relinquishment – Much of the detailed accounting had been completed previously in testing; however, it had not been completely implemented in the URGWOM models. These compact calculations, as well as their effect on operation, were implemented in URGWOM, including the effect of credit relinquishment.

Added greater control on overfilling and over releasing storage accounts – In the previous URGWOM ruleset, there were several situations that occurred that caused downstream accounts to be overfilled and/or upstream accounts to over release (causing negative account storages). With the ability to tie supplies with accounts, it became easier to write rules and functions to control overfilling and overdraft of accounts. One of the main features of this was to separate the rules that compute San Juan account releases into release types and destination types, instead of in one rule.

Implemented the new RiverWare periodic table slots in the model and ruleset – This implementation provided for much cleaner access to repeating numbers and a lot less confusion to the user on how to change values in tables with dates.

Performance enhancement of ruleset – In addition to the performance enhancements made above, the new functionality of RiverWare allowing the user to analyze the performance of rules and functions was used to determine bottlenecks in the execution of the ruleset. These bottlenecks were identified and fixed to improve the execution performance by about 50 percent.

Reconciliation problems fixed – Fixed bugs in logic that were previously causing reconciliation problems (account releases not adding up to total releases).