UPPER RIO GRANDE WATER OPERATIONS MODEL

Middle Rio Grande Valley Model Calibration and Validation

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INTRODUCTION

The calibration and validation procedures described here are for the URGWOM model version 2.0, the Middle Rio Grande Valley, Cochiti Reservoir to Elephant Butte Reservoir section. The Middle Rio Grande Valley includes the six reaches: Cochiti to San Felipe, San Felipe to Albuquerque, Albuquerque to Bernardo, Bernardo to San Acacia, San Acacia to San Marcial, and San Marcial to Elephant Butte.

CALIBRATION

Calibration often helps to refine the conceptual model. Earlier calibrations of the URGWOM Middle Rio Grande Valley model resulted in changes to the conceptual model. Future changes to the conceptual model will require recalibration.

The flow of the Rio Grande between Cochiti Dam and Elephant Butte Reservoir is complex and affected by riverside drains, canals, acequias, laterals, turnouts, and return-flow wasteways on both the east and west side of the river. The model simplifies this flow system to the Rio Grande and one parallel channel representing combined riverside drain and canal flow from Cochiti to San Acacia. From San Acacia to San Marcial the model has a river channel and two parallel channels. The innermost channel represents the Low-Flow Conveyance Channel. The outermost channel represents the Socorro Main Canal.

Calibration generally refers to the adjustment of model parameters to achieve an unbiased simulation model with small differences between the modeled parameter and a measured, check parameter. Differences between the modeled parameter (streamflow) and the measured, check parameter (historical, measured streamflow) are called residuals and are examined to understand model fit.

Modeled parameters included independent data inputs for river-channel evaporation loss; river-channel leakage; river routing; Middle Rio Grande Conservancy District (MRGCD) diversions; canal and riverside drain flows; municipal, wastewater return flows; MRGCD agricultural evapotranspiration loss (consumptive use); bosque or riparian evapotranspiration loss; tributary inflow; canal seepage; irrigated-acreage deep percolation; and crop, riparian and other land-use acreages. These independent data inputs were the best available estimates or measured data as described earlier in this document. If the data inputs, model conceptualization, and the RiverWare methods were able to perfectly describe the river system, running the model would result in a match between modeled and historical, measured flows. This ideal situation did not occur, and therefore, assuming that the current model conceptualization and RiverWare methods are a good approximation of the river system, model calibration was necessary.

CALIBRATION METHODS

The objective of model calibration was to provide an unbiased model, that is, a model that neither over predicts nor under predicts average or total streamflow for the calibration period. It was recognized that the calibrated model might under predict or over predict streamflow on any given day.

The calibration period was selected to include periods of record when there was no precipitation and no recession from a precipitation event. These days were called dry days. The reasons for picking dry days were: precipitation could cause ungaged tributary and overland flow within reaches, rapid changes in flow, bank storage and drainage from bank storage. Tributaries that are gaged and included in the model are Galisteo River, Jemez River, North Floodway Channel, Tijeras Arroyo, South Diversion Channel, and Rio Puerco. There are numerous other channels that flow in response to precipitation, but are ungaged. The periods of record selected for model calibration were the fourth or successive days (for example: fourth, or fourth and fifth, or fourth, fifth, and sixth, and so on days) with no measurable precipitation at the Albuquerque WSFO Airport, Bernardo, Bosque del Apache, Corrales, Los Lunas 3 SSW, or Socorro stations between January 1, 1985 and December 31, 1997. Measurable precipitation was 0.01 inch or greater. The criterion was applied, so that, if any one or more of the 6 stations had measurable precipitation, that date and the following 3 days were eliminated from the period of record selected for model calibration. The model was run for all days from January 1, 1985 through December 31, 1997, but only the dry days were selected for calibrating.

The dry days were subdivided into two groups: irrigation-season dry days, and non-irrigation-season dry days. Modelers chose two seasons for calibration, because it was noted that a one-season procedure seemed to be biased during part of the year. The irrigation-season and non-irrigation season divisions were natural subdivisions based on river operation. Irrigation season was defined as March 16 through October 31; non-irrigation season was defined as November 16 through February 28. March 1 through March 15 and November 1 through November 15 were considered transition periods and were not included in either season. A total of 1,726 dry days were used to calibrate the model for the irrigation and non-irrigation seasons. The stated criteria resulted in a total of 1,061 irrigation-season dry days, and 665 non-irrigation-season dry days.

CALIBRATION CRITERION AND PARAMETERS

The calibration criterion was that the sum of the differences, between daily-modeled and historical, daily-measured streamflow, for the selected calibration days equal zero. In other words, the sum of the positive differences and the negative differences should offset each other. The difference between the daily-modeled flow and the historical, daily-measured flow is called the residual. The summation of the residuals was minimized to less than 0.1 cubic foot per second (cfs), but was not exactly zero.

A model parameter needed to be selected that could be varied in a reasonable way and that would significantly affect the modeled streamflow. The amount of river leakage passed between the river and the riverside drains was selected to vary. Varying the amount of river leakage intercepted by the riverside drains, affected the amount of return flow to the river. Figure 1 is an example reach from the RiverWare workspace with the names of model objects used to make calibration adjustments highlighted in black rectangles.

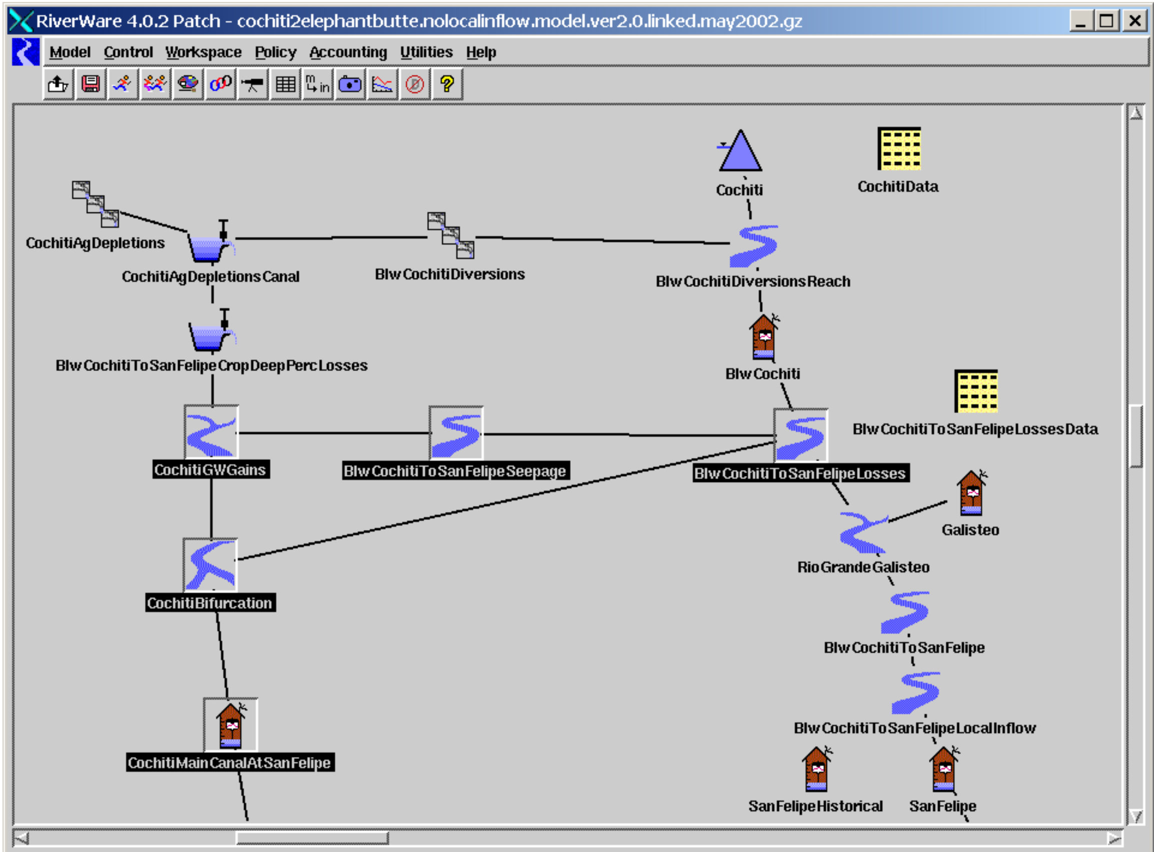


Figure 1. Example segment from the Cochiti to San Felipe reach with RiverWare workspace objects used to make calibration adjustments highlighted in black rectangles.

Using the Cochiti to San Felipe reach as an example, the calibration procedure consisted of changing the value of the “Variable GainLoss Coeff Table” slot of the “BlwCochitiToSanFelipeSeepage” reach object. The value in the “Variable GainLoss Coeff Table” slot affects the quantity, river leakage less riparian consumptive use that is passed from the “BlwCochitiToSanFelipeLosses” reach object to the “CochitiGWGains” reach object. Outflow from the “CochitiGWGains” reach object is passed to the “CochitiBifurcation” bifurcation object. Outflow from the bifurcation object to the “CochitiMainCanalAtSanFelipe” streamgage object is equal to the historical, measured flow for this streamgage. The difference of outflow from the “CochitiGWGains” reach object and the historical, measured flow for the “CochitiMainCanalAtSanFelipe” streamgage object is computed by the bifurcation object and passed from the bifurcation object to the “BlwCochitiToSanFelipeLosses” reach object in the return flow slot. The quantity passed in the return flow slot of the “BlwCochitiToSanFelipeLosses” reach object can be either positive or negative and represents the model computed return flow for the reach, plus any errors. Modelers changed the value in the “Variable GainLoss Coeff Table” slot of the “BlwCochitiToSanFelipeSeepage” reach object until the modeled flow volume, for dry days, at the “SanFelipe” streamgage object matched the historical flow volume, for dry days, at the “SanFelipeHistorical” streamgage object. In other words, modelers adjusted the value of the “Variable GainLoss Coeff Table” slot until the sum of the differences between historical, measured flow and modeled flow, for dry days, was about zero (fig. 2).

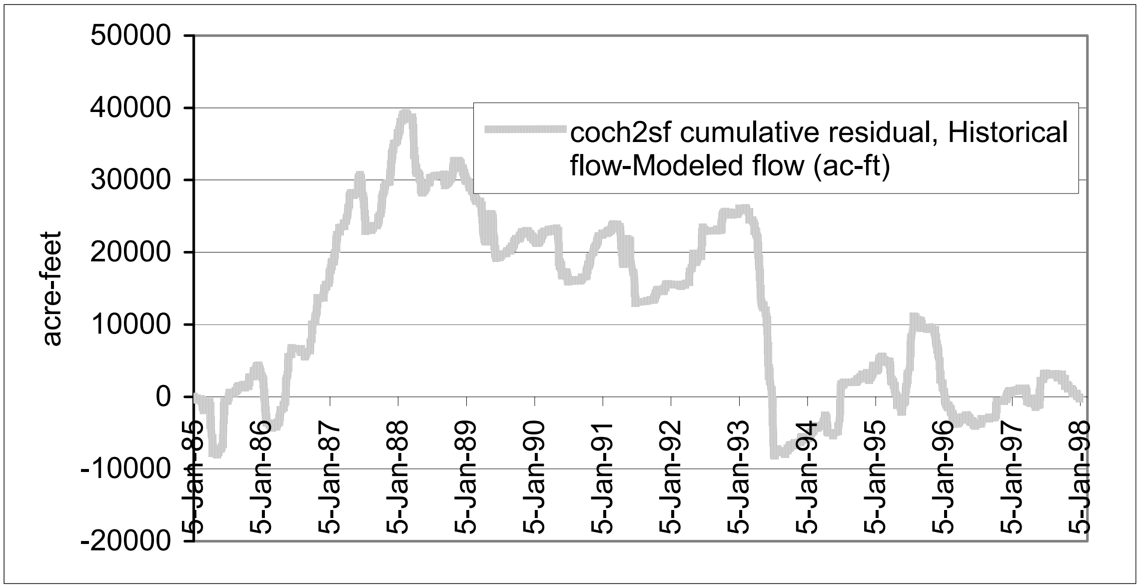


Figure 2. Dry-days, cumulative residual for the reach, Cochiti to San Felipe, 1985-1997.

Modelers used travel times rounded to the nearest 1day for movement of the quantity, river leakage minus riparian consumptive use (CU), between the river and the riverside drains. Travel-time lags were based on correlation coefficient analysis of flow in drains and flow in the river. Modelers used a two-day lag for the reach, Bernardo to San Acacia and a one-day lag for the San Acacia to San Marcial reach. No time lag was used in the other reaches.

CALIBRATION RESULTS

The middle valley model was calibrated for two different types of runs. One type of run was an independent simulation of flow, for any one of the 6 middle-valley reaches. The second type of run assumed a release from Cochiti Reservoir to the downstream end of any reach in the middle valley. In the first type of run, the historical, measured streamflow was used as an input to the gages at the upstream end of the Rio Grande and parallel channel, and at the downstream parallel channel gage, while the model solved for the downstream flow in the Rio Grande. In the second type of run, labeled as a linked-reach model, the historical, measured release from Cochiti Reservoir was used as a flow input at the upstream end of the model and the historical, measured streamflow was used as an input at the downstream parallel channel gage, while the model solved for the downstream flow in the Rio Grande. In the second type of run, the routed flow was passed through the model at each of the intervening streamflow gage cross-sections. It was assumed that the second type of run is of most interest because of reservoir operations in the Rio Grande Middle Valley. For reader clarification purposes, the reach terminology that refers to the second type of run always begins with “Cochiti” for the beginning of the reach. The first reach, Cochiti to San Felipe, was the same for both types of runs.

Calibration results for an independent run of any of the 6 middle valley reaches are given in the table below. The optimized value for the “Variable GainLoss Coeff Table” slot is shown for each reach.

Table 1. Independent run optimized value for the "Variable GainLoss Coeff Table" slot.

	Optimized value for "Variable GainLoss Coeff Table" slot of reach object	
Reach	**Non-irrigation season**[1]	**Irrigation season**[1]
Cochiti to San Felipe	1.189	-0.048
San Felipe to Albuquerque	0.144	0.265
Albuquerque to Bernardo	0.286	0.133
Bernardo to San Acacia	0.073	0.639
San Acacia to San Marcial	-0.292	-0.459
San Marcial to Elephant Butte	-1.066	1.55

1. Positive values mean calibration increased amount seepage discharge to the drain, negative values means that the amount of channel seepage was reduced before intercepted by drain.

The following table gives further clarification of the optimized riverside-drain interception value used above:

Table 2. Clarification of the optimized riverside-drain interception value for independent run.

	Optimized drain interception (expressed as % of (river leakage – riparian CU))	
Reach	**Non-irrigation season**	**Irrigation season**
Cochiti to San Felipe	218.9% of (river leakage – riparian CU loss) value is intercepted by drain	95.2% of (river leakage – riparian CU loss) value is intercepted by drain
San Felipe to Albuquerque	114.4% of (river leakage – riparian CU loss) value is intercepted by drain	126.5% of (river leakage – riparian CU loss) value is intercepted by drain
Albuquerque to Bernardo	128.6% of (river leakage – riparian CU loss) value is intercepted by drain	113.3% of (river leakage – riparian CU loss) value is intercepted by drain
Bernardo to San Acacia	107.3% of (river leakage – riparian CU loss) value is intercepted by drain	163.9% of (river leakage – riparian CU loss) value is intercepted by drain
San Acacia to San Marcial	70.8% of (river leakage – riparian CU loss) value is intercepted by drain	54.1% of (river leakage – riparian CU loss) value is intercepted by drain
San Marcial to Elephant Butte	No river leakage is intercepted; and 6.6% of (river leakage – riparian CU loss) value is subtracted from drain flow.	255% of (river leakage – riparian CU loss) value is intercepted by drain

The optimized riverside-drain interception may be greater than 100 percent of the quantity, river leakage minus riparian consumptive use for several reasons. It could be because the conceptual model does not include any modeling objects that allow groundwater-table flow to the riverside drains from the outer or canal-and-upland side, but only from the inner or Rio Grande side. The riverside drains may be intercepting the groundwater table on both sides and therefore the model has to compensate by requiring an increase in the percentage of the quantity, river leakage minus riparian consumptive use. Or, the river leakage may be too small. Or, the riparian consumptive use may be too large. Or, a combination of these factors could be occurring simultaneously.

Calibration results for a linked-reach model run of the 6 middle valley reaches are given in the table below. The optimized value for the “Variable GainLoss Coeff Table” slot is shown for each reach.

Table 3. Linked-reach optimized value for the "Variable GainLoss Coeff Table" slot.

	Optimized value for "Variable GainLoss Coeff Table" slot of reach object	
Reach	**Non-irrigation season**	**Irrigation season**
Cochiti to San Felipe	1.189	-0.048
Cochiti to Albuquerque	0.145	0.272
Cochiti to Bernardo	0.289	0.119
Cochiti to San Acacia	0.085	0.622
Cochiti to San Marcial	-0.293	-0.482
Cochiti to Elephant Butte	-1.21	1.607

The following table gives further clarification of the optimized riverside-drain interception value used above:

Table 4. Clarification of the optimized riverside-drain interception values for linked-reach model.

	Optimized drain interception (expressed as % of (river leakage – riparian CU))	
Reach	**Non-irrigation season**	**Irrigation season**
Cochiti to San Felipe	218.9% of (river leakage – riparian CU loss) value is intercepted by drain	95.2% of (river leakage – riparian CU loss) value is intercepted by drain
Cochiti to Albuquerque	114.5% of (river leakage – riparian CU loss) value is intercepted by drain	127.2% of (river leakage – riparian CU loss) value is intercepted by drain
Cochiti to Bernardo	128.9% of (river leakage – riparian CU loss) value is intercepted by drain	111.9% of (river leakage – riparian CU loss) value is intercepted by drain
Cochiti to San Acacia	108.5% of (river leakage – riparian CU loss) value is intercepted by drain	162.2% of (river leakage – riparian CU loss) value is intercepted by drain
Cochiti to San Marcial	70.7% of (river leakage – riparian CU loss) value is intercepted by drain	51.8% of (river leakage – riparian CU loss) value is intercepted by drain
Cochiti to Elephant Butte	No river leakage is intercepted; and 21% of (river leakage – riparian CU loss) value is subtracted from drain flow.	260.7% of (river leakage – riparian CU loss) value is intercepted by drain

Again, the optimized riverside-drain interception may be greater than 100 percent of the quantity, river leakage minus riparian consumptive use for the reasons discussed previously.

Daily-mean-modeled flow and historical, daily-mean-measured flow, for a linked-reach model run, for each of the 6 middle valley reaches is shown (figs. 3-8). Plots include all days for the time period January 1, 1985 through December 31, 1997 with the exception that the reach from San Marcial to Elephant Butte is through December 31, 1996. For the San Marcial to Elephant Butte reach the calculated inflow to Elephant Butte is incomplete after December 31, 1996. Daily-mean-modeled flow and historical, daily-mean-measured flow for all days are shown to allow comparisons on days when there is precipitation, as well as, on dry days.

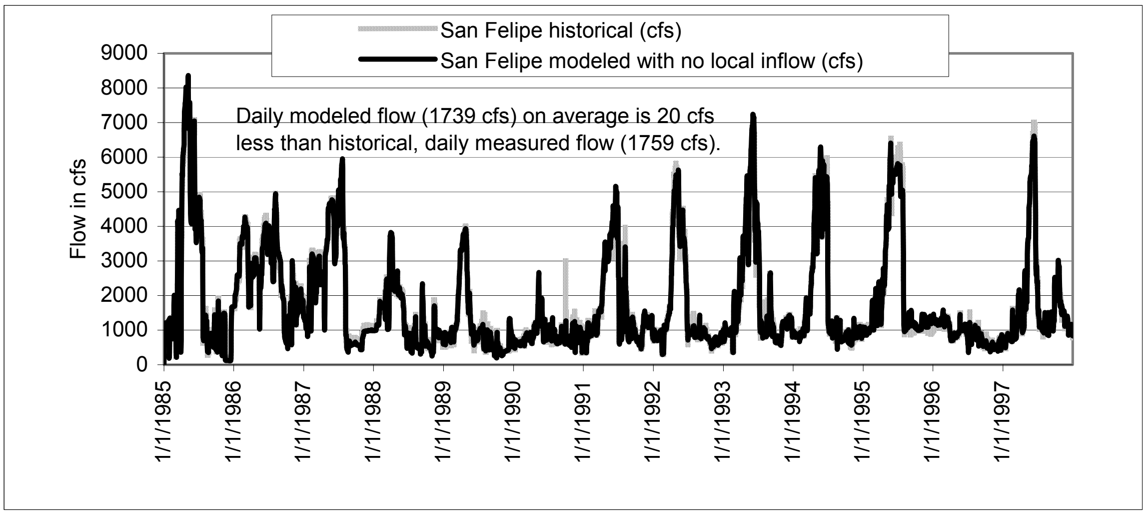


Figure 3. Daily-mean-modeled flow and historical, daily-mean-measured flow, from below Cochiti Reservoir to San Felipe for the period of record, January 1, 1985 through December 31, 1997.

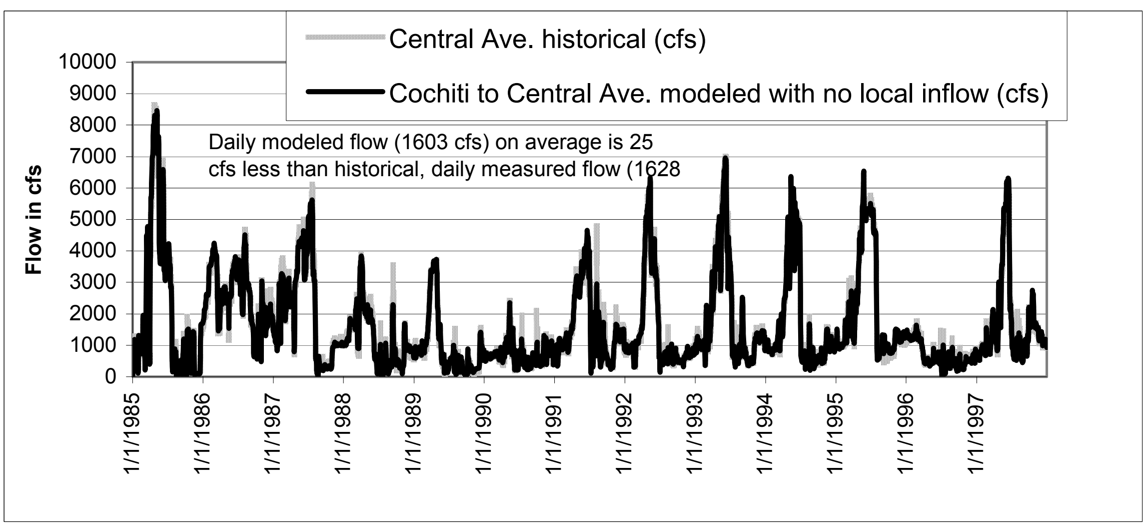


Figure 4. Daily-mean-modeled flow and historical, daily-mean-measured flow, from Cochiti Reservoir to Central Avenue, Albuquerque for the period of record, January 1, 1985 through December 31, 1997.

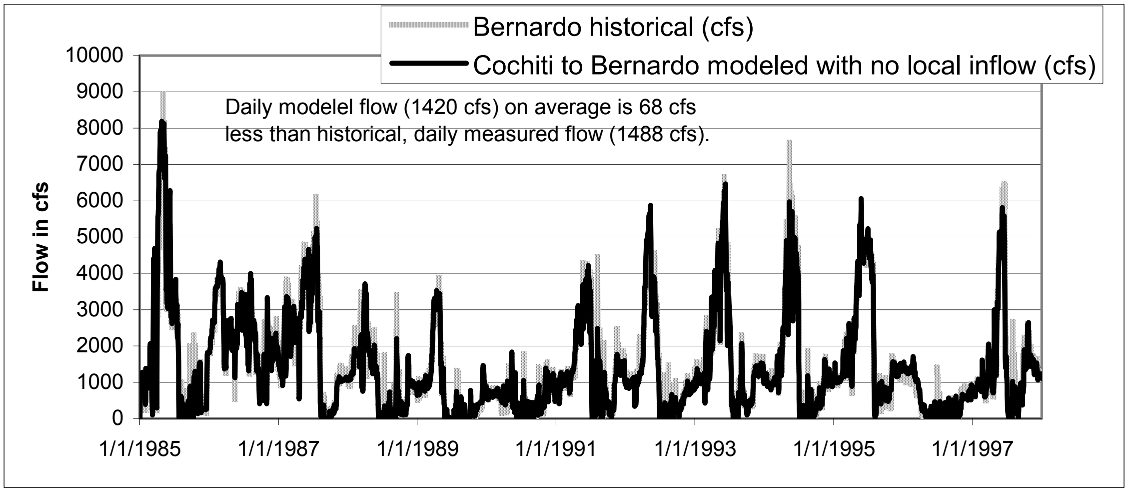


Figure 5. Daily-mean-modeled flow and historical, daily-mean-measured flow, from Cochiti Reservoir to Bernardo for the period of record, January 1, 1985 through December 31, 1997.

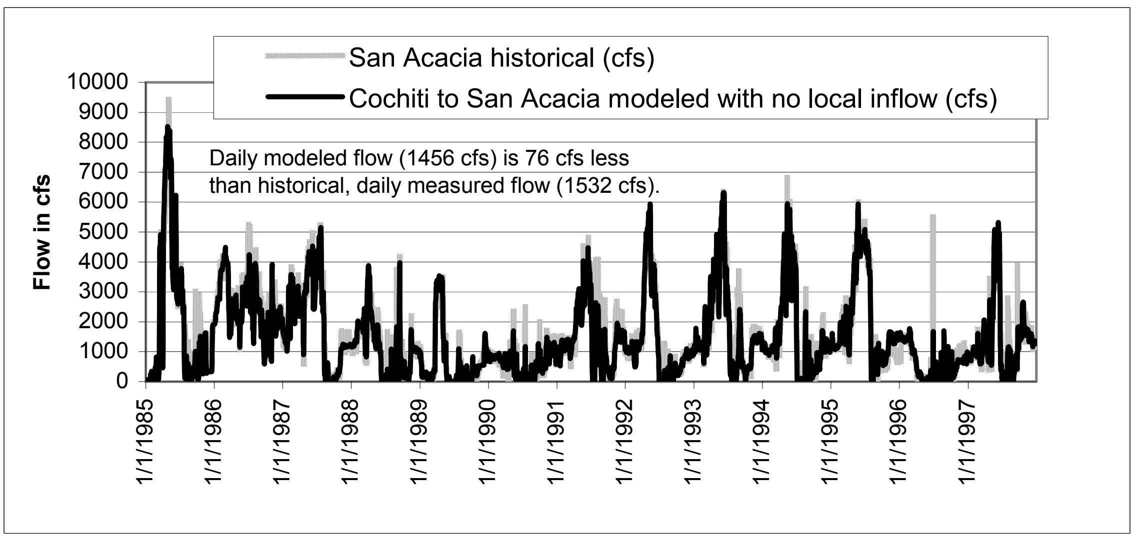


Figure 6. Daily-mean-modeled flow and historical, daily-mean-measured flow, from Cochiti Reservoir to San Acacia for the period of record, January 1, 1985 through December 31, 1997.

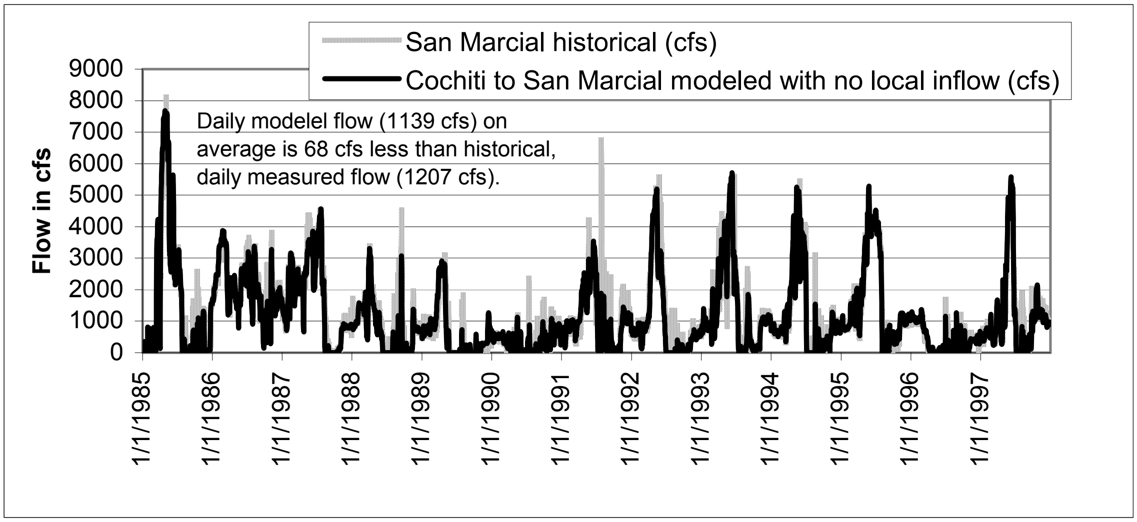


Figure 7. Daily-mean-modeled flow and historical, daily-mean-measured flow, from Cochiti Reservoir to San Marcial for the period of record, January 1, 1985 through December 31, 1997.

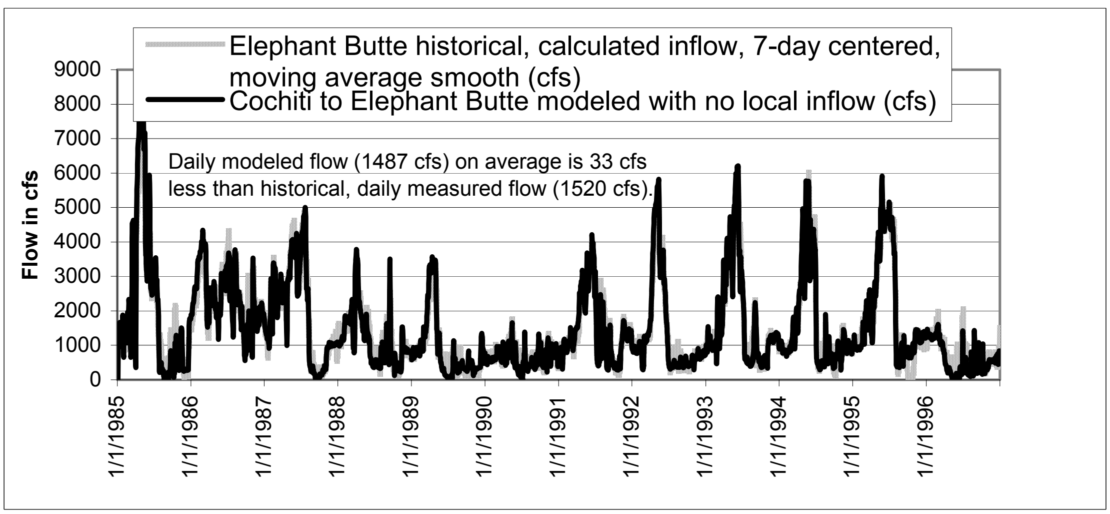


Figure 8. Daily-mean-modeled flow and historical, daily-mean-measured flow, from Cochiti Reservoir to Elephant Butte for the period of record, January 1, 1985 through December 31, 1997.

Daily-mean-modeled flow and historical, daily-mean-measured flow plots, for the independent reach model run, for each of the six middle valley reaches are not shown. This is in the interest of avoiding repetition and because they are quite similar to the linked reach plots.

On average, when all days are considered, the daily-modeled streamflow for the 5 reaches from Cochiti to San Marcial is less than the historical, daily-measured streamflow. This is the result of including days with precipitation. The runoff from ungaged tributaries and small drainage channels on precipitation days increases the historical, daily-measured streamflow average. The model does not include any ungaged inflow (often called local inflow or side inflow).

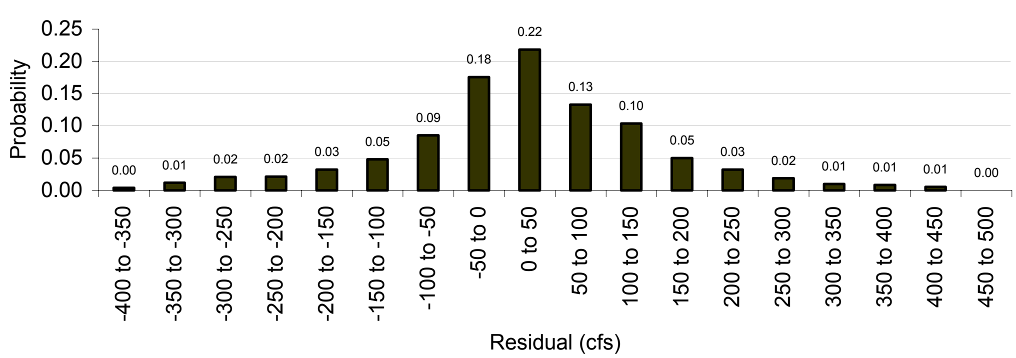
URGWOM indirectly estimates ungaged inflow. URGWOM does not directly compute ungaged inflow, which could be done utilizing a rainfall-runoff model, such as the U.S. Geological Survey's

Modular Modeling System or the U.S. Army Corps of Engineers' Hydrologic Engineering Center Hydrological Modeling System. Use of these models is one way to directly calculate inflows and would be input to the URGWOM model, but is not included as part of the process.

CALIBRATION MODEL FIT

A commonly used measure of model fit is the residual or difference between the historical, measured flow and the modeled flow. Errors in the model input data, inadequacies in the model's attempt to simulate the hydrologic system, and error introduced by precipitation and flow in ungaged channels cause differences between historical, measured flow and modeled flow.

The probability of occurrence associated with the residuals and the absolute values of the residuals gives the expected percent of the time that modeled flows will be within certain limits of historical, measured flows. Graphs of the probability density function of residuals and the cumulative probability of absolute residuals are shown for each of the calibrated reaches, Cochiti to San Felipe, Cochiti to Albuquerque, Cochiti to Bernardo, Cochiti to San Acacia, Cochiti to San Marcial, and Cochiti to Elephant Butte (figs. 9-14). The graphs include the 4,742 days between January 7, 1985 and December 31, 1997, rather than just the 1,726 dry days that were used for calibration. This gives a better idea of the model fit even for days that may have precipitation.



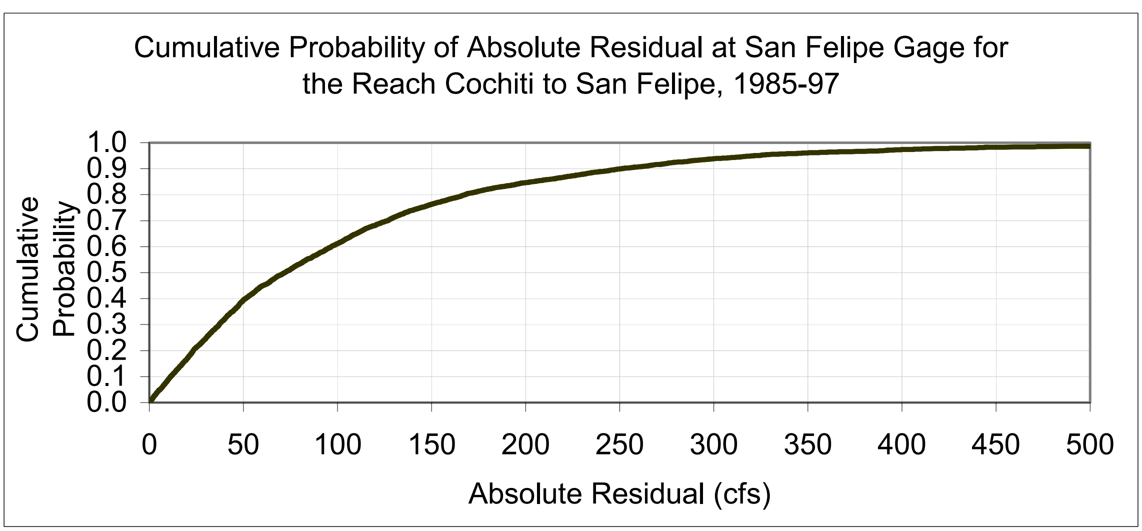
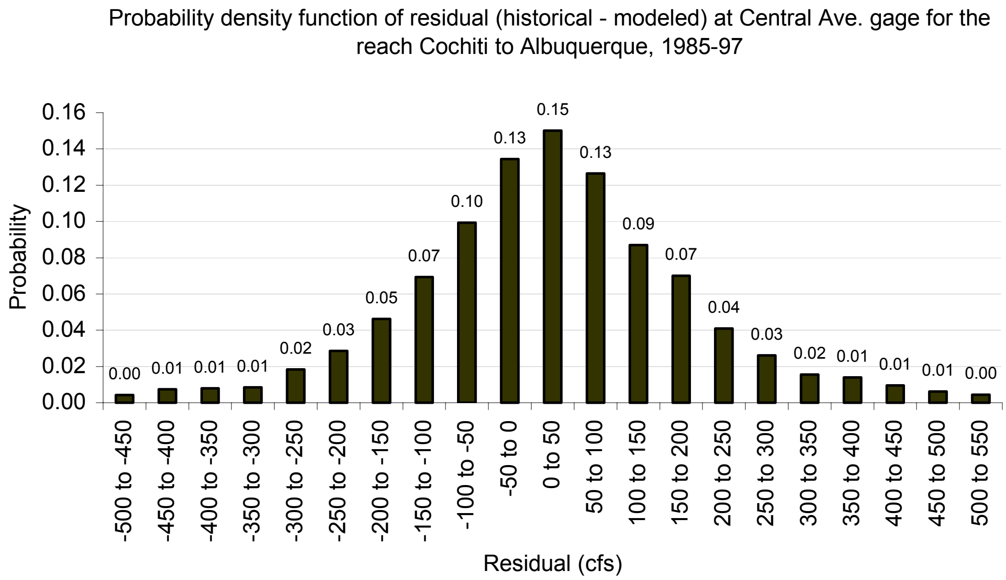


Figure 9. Probability plots at San Felipe gage for the reach, Cochiti to San Felipe, 1985-97



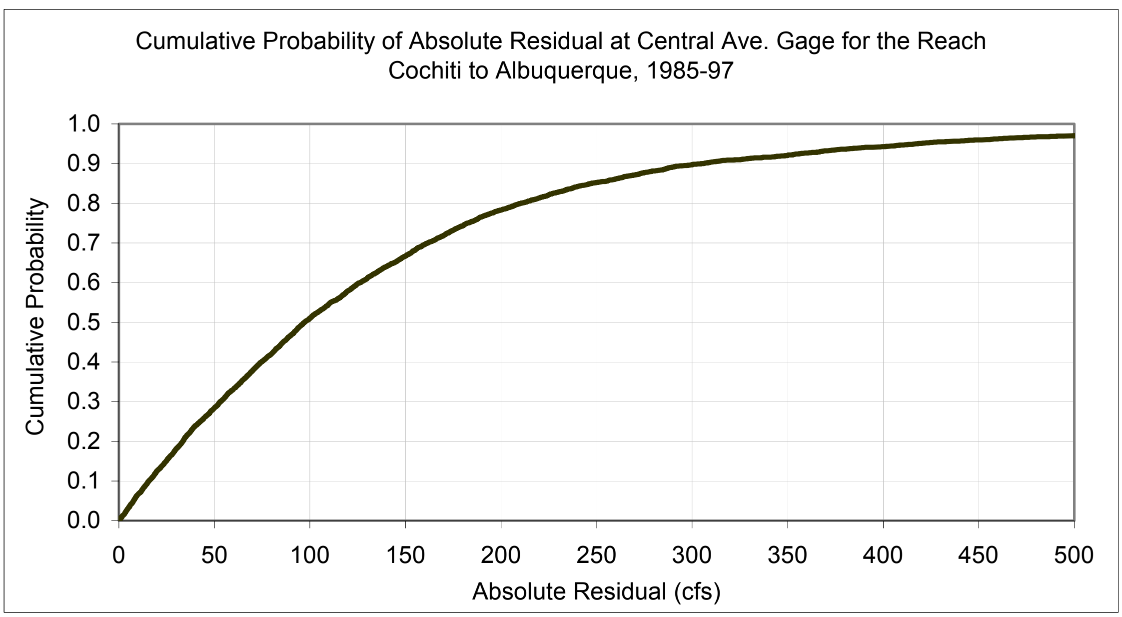
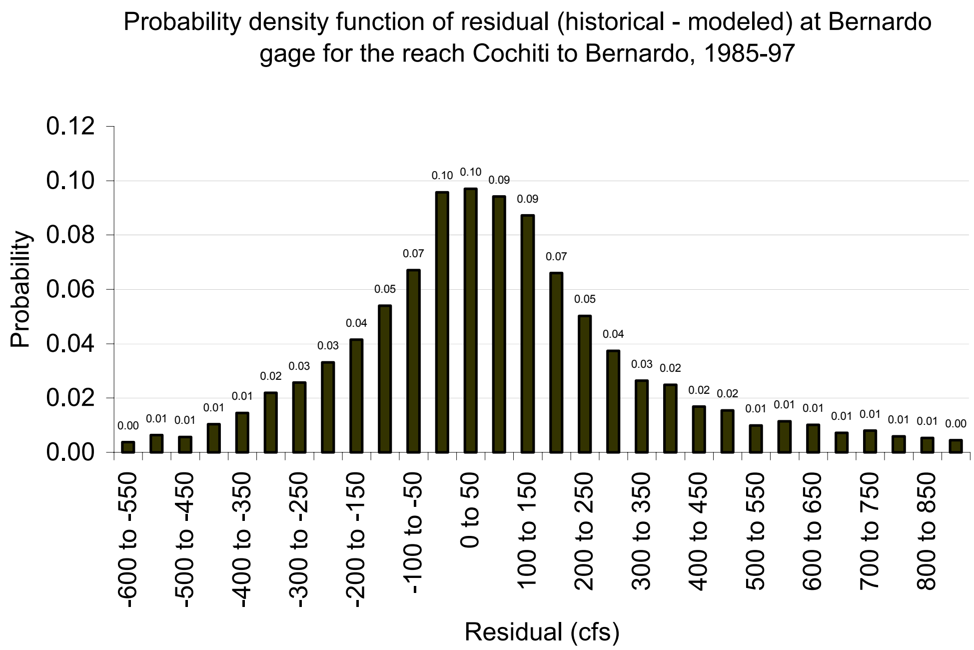


Figure 10. Probability plots at San Felipe gage for the reach, Cochiti to Albuquerque, 1985-97



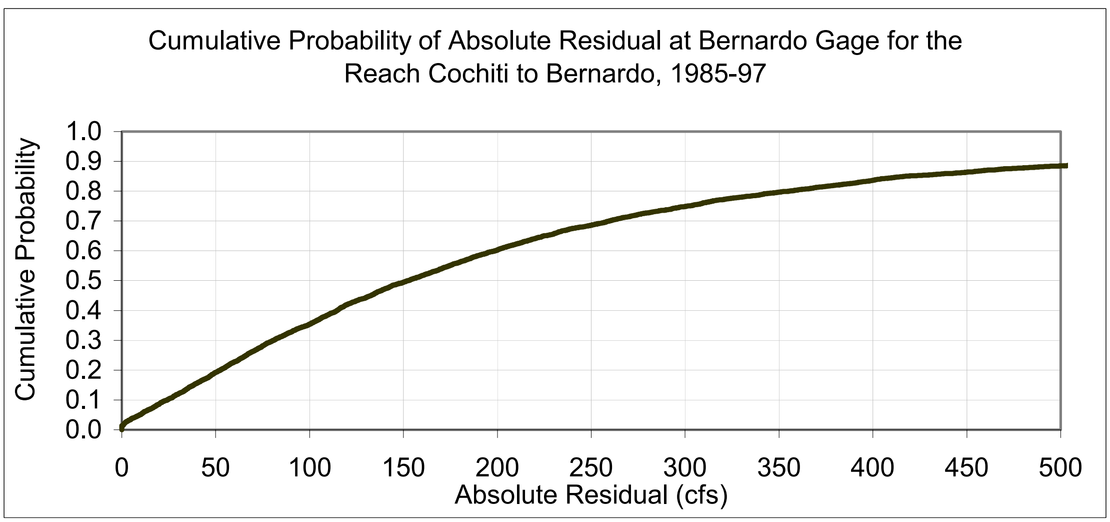
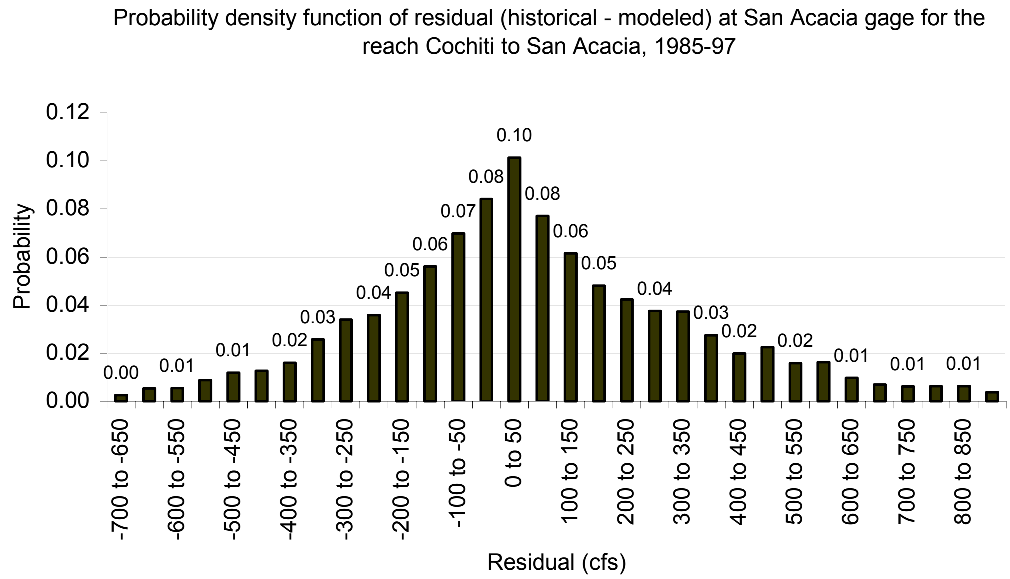


Figure 11. Probability plots at Bernardo gage for the reach, Cochiti to Bernardo, 1985-97.



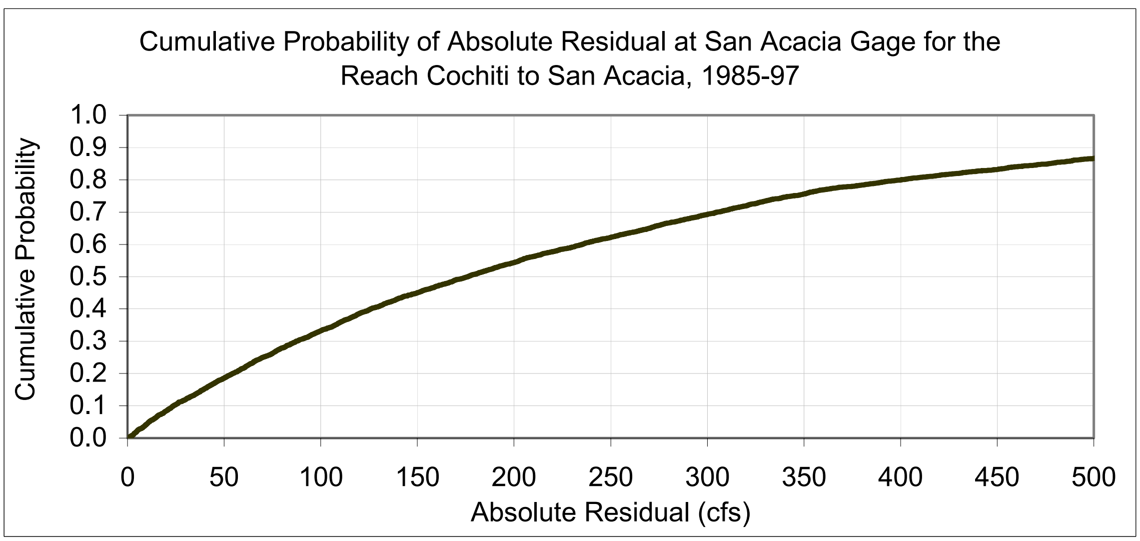
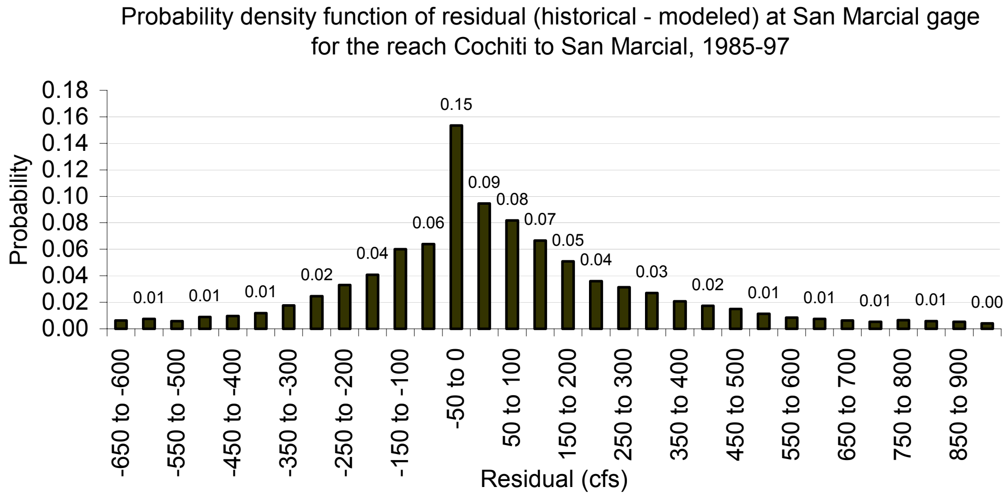


Figure 12. Probability plots at San Acacia gage for the reach Cochiti to San Acacia, 1985-97



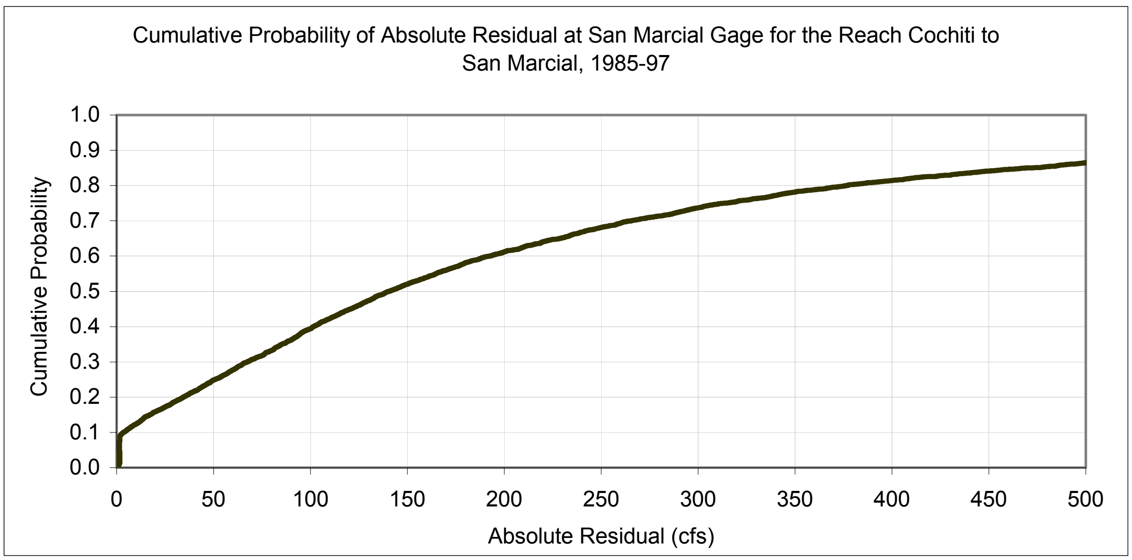
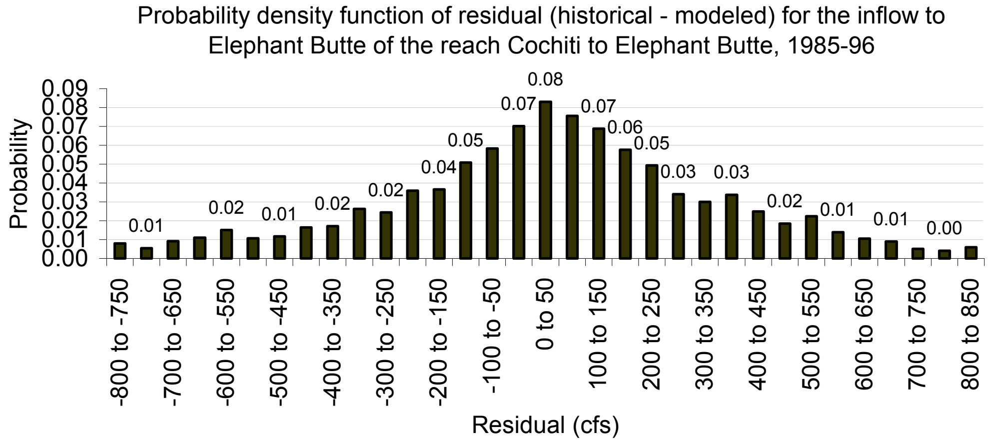


Figure 13. Probability plots at San Marcial gage for the reach, Cochiti to San Marcial, 1985-97.



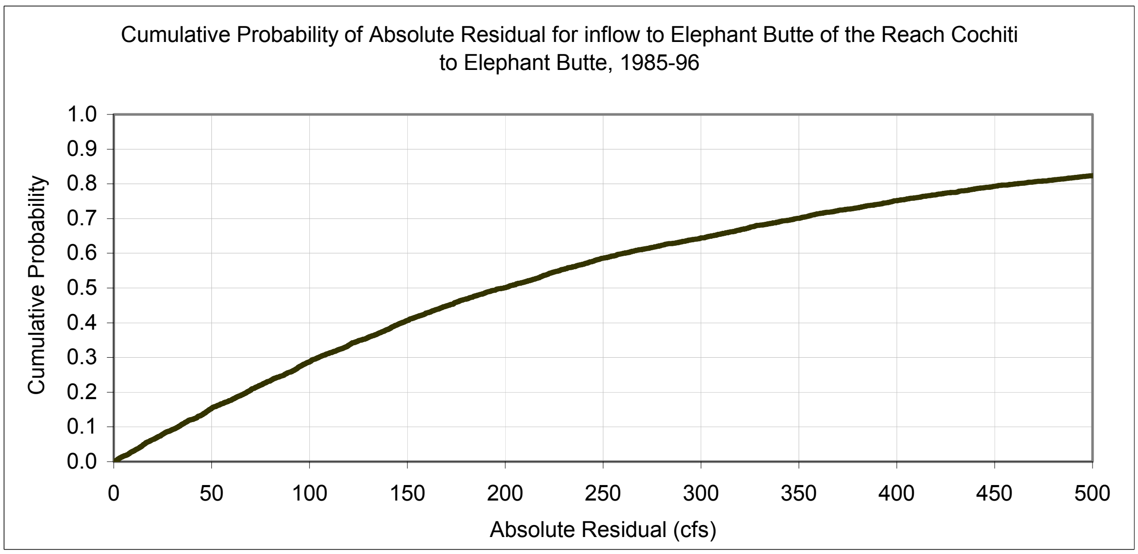


Figure 14. Probability plots at Elephant Butte inflow for the reach, Cochiti to Elephant Butte, 1985-96.

The cumulative probability plots of the absolute residual show that the reach from Cochiti to San Felipe will have the smallest difference between modeled and historical, measured flow most of the time, while the reach from Cochiti to Elephant Butte will have the greatest difference. This is in part because the error accumulates as the reach length increases. Based on this calibration, the expectation that the model will predict flow within plus or minus 50 cfs, or plus or minus 100 cfs, of the historical, measured flow is given for each reach in the table below. Data in the table applies for any day (or any flow rate) during the 1985-1997 period. During this period of time, flows ranged from 0 to about 8,000 cfs, but varied between reaches and years.

Table 5. Expectation that the model will predict flow within plus or monus 50 cfs, or plus or minus 100 cfs, of the historical, measrued flow, for the 1985-1997 period.

Reach	Expectation that the difference between modeled and historical, measured flow is within + or – 50 cfs	Expectation that the difference between modeled and historical, measured flow is within + or – 100 cfs
Cochiti to San Felipe	40%	62%
Cochiti to Albuquerque	28%	51%
Cochiti to Bernardo	20%	36%
Cochiti to San Acacia	18%	33%
Cochiti to San Marcial	24%	38%
Cochiti to Elephant Butte	15%	29%

VALIDATION

The objective of the validation procedure was to test the expectations established using this calibration of the URGWOM middle valley model. A test that is independent of the calibration data requires a data set that is different than the 1985-97-time period used for calibration. The validation procedure consisted of running the model for all 730 days in the 2-year time period, January 1, 1998 through December 31, 1999.

The following tables summarize the expectation that the model will predict flow within plus or minus 50 cfs, or plus or minus 100 cfs, of the historical, measured flow. Measured, historical flow ranged from 0 to about 4,500 cfs during 1998-99. The table below is for each independent reach through San Marcial. In this analysis the model is run independently for each reach using known historical inflow at the upstream end of the reach, and allowing the model to predict flow at the downstream end of the reach.

Table 6. Expectation that the independent-reach model will predict flow within plus or minus 50 cfs, or plus or minus 100 cfs, of the historical measured flow, for the 1998-1999 period.

Reach	Expectation that the difference between modeled and historical, measured flow is within + or – 50 cfs	Expectation that the difference between modeled and historical, measured flow is within + or – 100 cfs
Cochiti to San Felipe	42%	73%
San Felipe to Albuquerque	36%	64%
Albuquerque to Bernardo	27%	50%
Bernardo to San Acacia	38%	65%
San Acacia to San Marcial	31%	51%

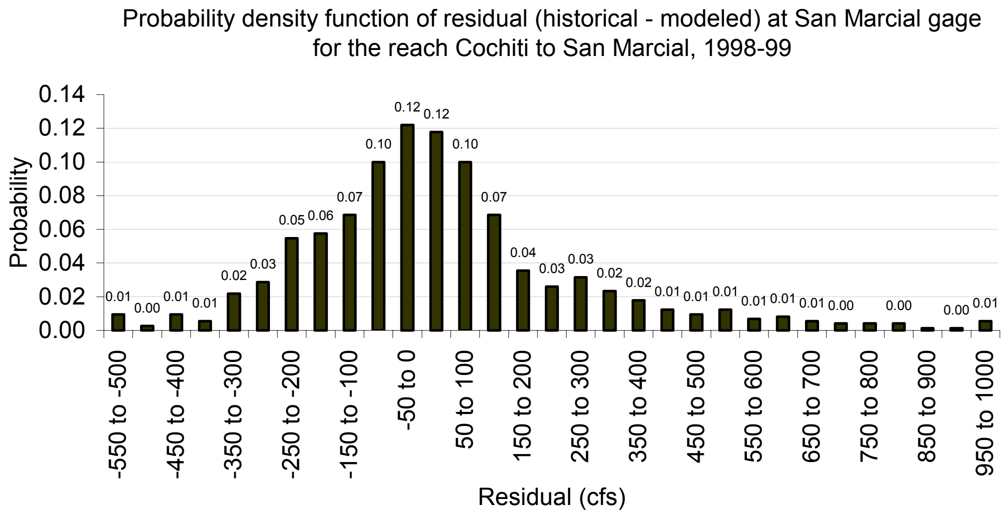
The expectation that the model will predict flow within + or – 100 cfs is better for the independent reach and for the time period 1998-99. That is, the percentage of time that the model predicts flow within + or – 100 cfs is greater for the 1998-99 period than for the 1985-97 period. This may be due to fewer precipitation events during 1998-99, or more accurate streamflow measurements during recent years.

An alternate analysis is the linked-reach model run. In this case the model is run using historical outflow from Cochiti Reservoir at the upstream end of the reach, and allowed to predict flow at each downstream gage, San Felipe, Central Avenue, Bernardo, San Acacia and San Marcial. Modeled flow at gages is not allowed to go below zero, although there are days when predicted losses in the model would drive the flow below zero. The table below summarizes the expectation that the model will predict flow within plus or minus 50 cfs, or plus or minus 100 cfs, of the historical, measured flow for each downstream gaging station using the historical outflow from Cochiti Reservoir as input for each cumulative reach. The data is for a model run using the 1998-99 period of record.

Table 7. Expectation that the linked-reach model will predict flow within plus or minus 50 cfs, or plus or minus 100 cfs of the historical, measured flow.

Reach	Expectation that the difference between modeled and historical, measured flow is within + or – 50 cfs	Expectation that the difference between modeled and historical, measured flow is within + or – 100 cfs
Cochiti to San Felipe	42%	73%
Cochiti to Albuquerque	41%	72%
Cochiti to Bernardo	26%	46%
Cochiti to San Acacia	20%	40%
Cochiti to San Marcial	23%	44%

The expectation that the model will predict flow within + or –50 cfs or + or –100 cfs is better for the 1998-99 period of record, when compared to the 1985-97 period of record. Again the model predicts best for the reach Cochiti to San Felipe and least well for the last two reaches, Cochiti to San Acacia and Cochiti to San Marcial. For the reach Cochiti to San Felipe the expectation that the daily-mean flow predicted by the model will be within 100 cfs of the historical, measured flow is 73 percent. For the reach Cochiti to San Marcial, the expectation that the daily-mean flow predicted by the model will be within 100 cfs of the historical, daily-mean-measured flow is 44 percent. Detailed information is given in the two graphs below for the reach from Cochiti to San Marcial. Graphs are shown for just the one reach to avoid repetition.



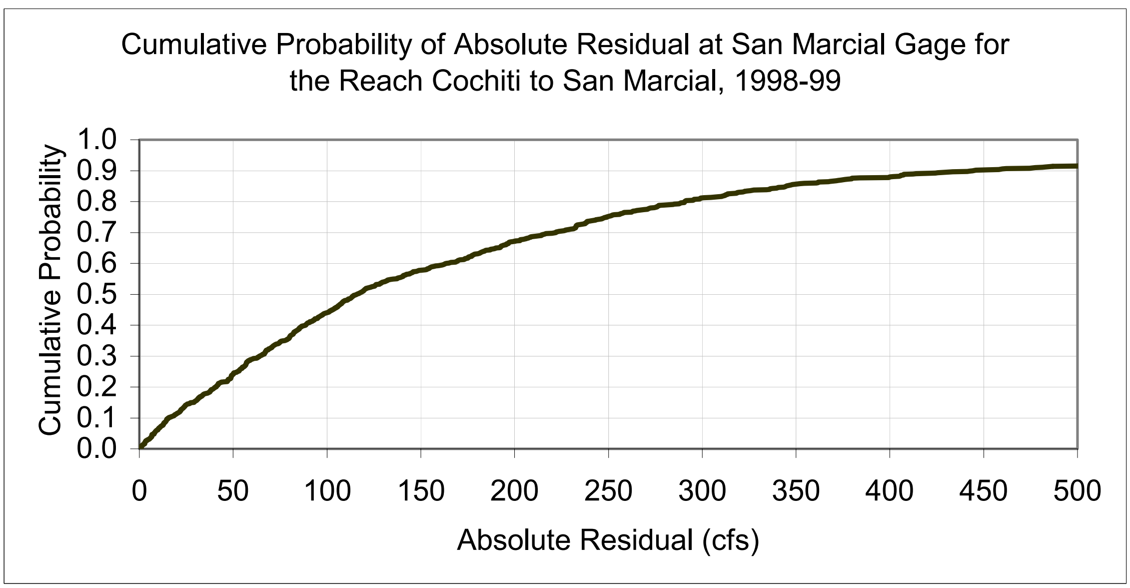


Figure 15. Probability plots at San Marcial gage for the reach, Cochiti to San Marcial, 1998-1999.

SELECTED RESIDUAL ANALYSIS

Analyses of residuals for specific flow volumes, seasons, and time periods may also be prepared for this version of the model. One example is for the reach from Cochiti to Central Avenue, Albuquerque, with outflow from Cochiti Reservoir equal to or less than 1200 cfs, and the 4th or more day of no precipitation for the irrigation season, March through October 1985-99. This type of residual analysis is of interest when it is assumed that the water supply in the reservoir is critical and water managers are operating under drought conditions. A plot of the cumulative probabilities of the absolute residuals for these data is shown below.

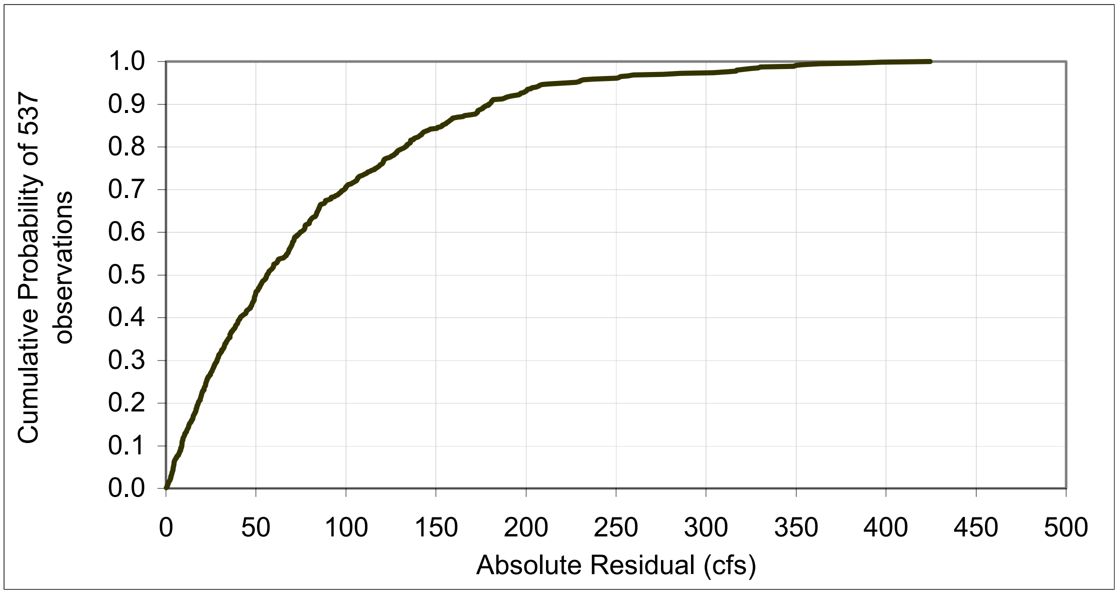


Figure 16. Cumulative probability of absolute residual at Central Ave. gage for the reach Cochiti to Albuquerque, filtered for outflow from Cochiti Reservoir equal to or less than 1200 cfs and fourth or more day of no precipitation, March through October, 1985-1999

For example, assume that the model predicts that a release of 900 cfs is needed to achieve a flow of 500 cfs at Central Avenue. The cumulative probability chart shows that about 25 percent of the time the flow at Central Avenue will be between about + or – 20 cfs (480 – 520 cfs); 50 percent of the time the flow at Central Avenue will be between about + or – 60 cfs (440 – 560 cfs); 90 percent of the time the flow at Central Avenue will be between about + or – 175 cfs (325 – 675 cfs). The chart is useful to determine expected error.

COMPARISON BETWEEN RESIDUALS AND STREAMFLOW GAGE ERRORS

The difference between measured historical and modeled flow is often within the estimated percentage of streamflow gage measurement error. This indicates that some of the differences between historical and modeled flow can often be accounted for by streamflow gage measurement error. The U.S. Geological Survey, W.R.D., reports that 95 percent of daily streamflow measurements for the gages, Rio Grande at San Felipe, Rio Grande at Central Avenue, Rio Grande at Bernardo, and Rio Grande at San Marcial are within plus or minus 10 percent of the true value; while 95 percent of daily streamflow measurements for the gage, Rio Grande at San Acacia are within plus or minus 15 percent of the true value. Using the plus or minus 10 percent and plus or minus 15 percent values for 100 percent of daily streamflow measurements results in the following percentage of days that streamflow measurement error can explain all of the difference between measured historical and modeled streamflow.

Table 8. Percentage of days that streamflow measurement error can explain all of the difference between measured historical and modeled streamflow.

Reach	1985-99, non-zero, flow days that modeled flow was within 10% (or 15%) of the measured flow	1998-99, non-zero, flow days that modeled flow was within 10% (or 15%) of the measured flow
Cochiti to San Felipe	76%	85%
San Felipe to Albuquerque	62%	68%
Albuquerque to Bernardo	39%	45%
Bernardo to San Acacia	55%	67%
San Acacia to San Marcial	36%	29%
Cochiti to Albuquerque	61%	74%
Cochiti to Bernardo	37%	41%
Cochiti to San Acacia	45%	49%
Cochiti to San Marcial	31%	31%

On the other days a varying percentage of the difference can be explained by streamflow measurement error, but the remainder is attributable to other factors. Possible other factors, excluding any local inflow, include errors in river-channel evaporation loss rates, river-channel leakage rates, river routing, Middle Rio Grande Conservancy District (MRGCD) diversion volumes, MRGCD agricultural depletions, bosque or riparian depletions, tributary inflow rates, canal seepage rates, irrigated-acreage deep percolation rates, and estimated crop, riparian and other land-use acreages. These other factors do not have error estimates associated with them.