APPENDIX C

Mammoth Community Water District
Water Balance Operations Model
Technical Appendix

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APPENDIX C
MCWD WATER BALANCE OPERATIONS MODEL
TECHNICAL APPENDIX

1.0 PURPOSE OF THE MODEL

As a result of CEQA requirements necessitated by Mammoth Community Water District's (MCWD's) Notice of Preparation for a Draft Environmental Impact Report (EIR) for Changes in Mammoth Creek Bypass Flow Requirements, Point of Measurement, Water Operation Constraints, and Place of Use, a model capable of characterizing flows in Mammoth Creek associated with existing conditions, as well as flows associated with alternative water operations, is necessary.

The Water Balance Operations Model (MCWD Model) simulates operations in Mammoth Creek from Lake Mary downstream to the Old Highway 395 Gage located near US Highway 395. Simulated flows in Mammoth Creek also serve as input to estimate flows in Hot Creek at the United States Geological Survey (USGS) Hot Creek Flume Gage. Within this large section of Mammoth Creek, MCWD diverts water for municipal uses directly from Lake Mary inflow and/or from water stored in the lake. The MCWD Model can simulate existing conditions and alternative operations over the expected range of hydrologic conditions; allowing evaluation of system responses for Mammoth Creek flows at multiple locations, as well as Lake Mary water surface elevation and storage.

2.0 MODEL DESCRIPTION

The MCWD Model is an application of conservation of mass to the analysis of physical systems. By accounting for material entering and leaving a system (in this case water), mass flows can be identified which might have been unknown, or difficult to measure without this technique. The conservation of mass law revolves around mass conservation (i.e., water cannot disappear or be created spontaneously). The general form for a water balance is the water that enters a system must, by conservation of mass, either leave the system or accumulate within the system (i.e., go into lake storage).

Mathematically, the mass balance for a water system is as follows:

Input = Output + Accumulation

In the absence of any accumulation (change in lake storage), water flowing in and out will be the same. However, if this is not the case then the mass balance equation must be amended to allow for the accretion or depletion of water.

Input + Accretion = Output + Accumulation

Note that the one term (Accretion) is used in the equation, which will be negative for depletion flows (water lost from the creek) and positive for accretion flows (gains). Also, because there is no storage at a streamflow gage, the Accumulation term is zero resulting in the following equation for flow nodes.

Input + Accretion = Output

Figure C-1 is a schematic representation of the MCWD Model. Model input (hydrology) was developed using data obtained from MCWD, Los Angeles Department of Water and Power (LADWP), USGS, and California Department of Fish and Game (CDFG).

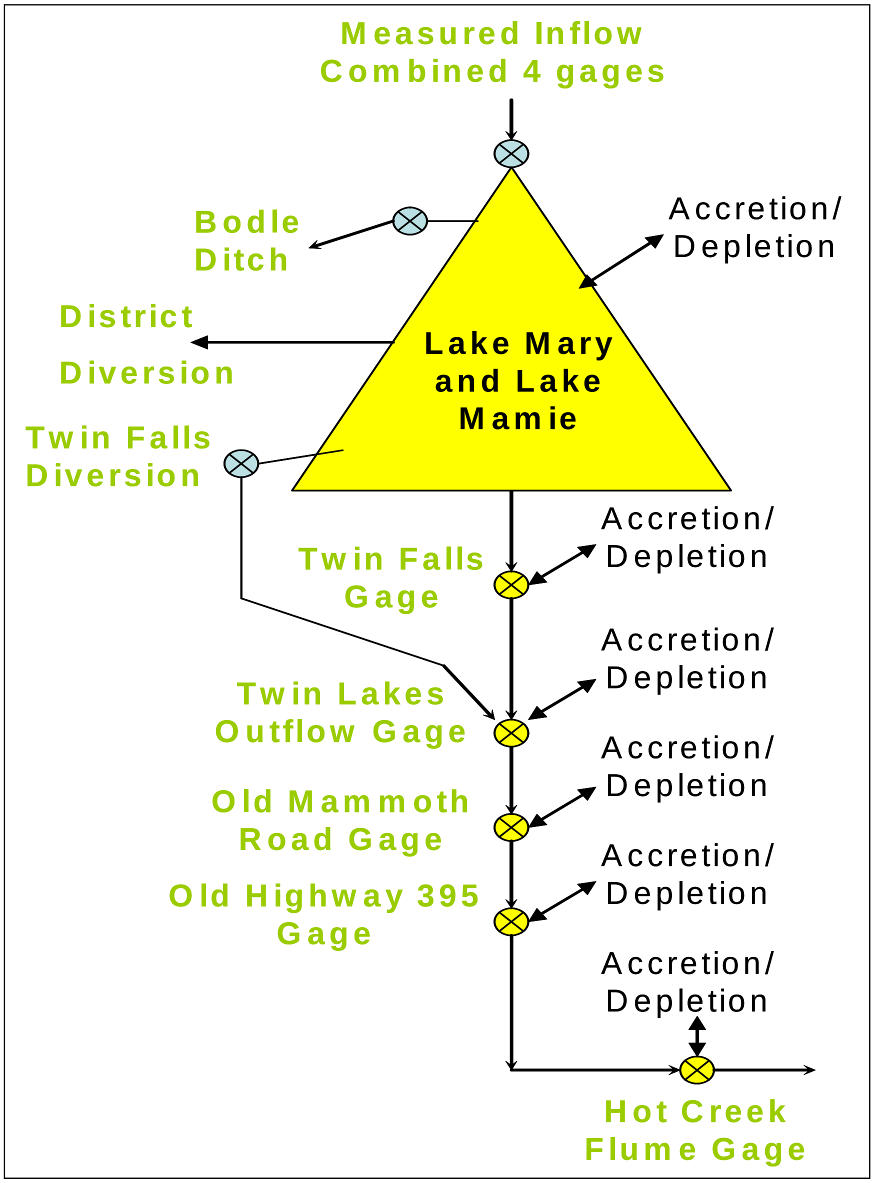


Figure C-1. Schematic Representation of the Water Balance Model Used for the Mammoth Creek Draft EIR

The model hydrology was constructed using daily historical Lake Mary inflow, Bodle Ditch diversion, MCWD diversion, Twin Falls diversion, Twin Lakes outflow, OMR Gage flow, OLD395 Gage flow, and Hot Creek Flume Gage flow. Daily accretions and depletions between measured flow points were estimated, using the amended equation described above, given the known flows at each of these locations.

For the intended purposes of comparative alternatives analysis, the model incorporates the above described operating rules and will produce required outputs for each alternative. The following describes the model features and output nodes, hydrology requirements, and accretion and depletion terms:

Model Features (Nodes)

- Lake Mary – Reservoir Storage Node
- Twin Lakes Outflow – Flow Node
- OMR Gage – Flow Node
- OLD395 Gage – Flow Node
- Hot Creek Flume Gage – Flow Node

Hydrology Requirements (Daily)

- Lake Mary Inflow
- Bodle Ditch Diversion
- Lake Mary Accretion/Depletion[1]
- Lake Mary to Twin Lakes Outflow Accretion/Depletion
- Twin Lakes Outflow to OMR Gage Accretion/Depletion
- OMR Gage to OLD395 Gage Accretion/Depletion
- OLD395 Gage to Hot Creek Flume Accretion/Depletion

The water balance operations model was developed in Microsoft Excel in order to provide MCWD and stakeholders the opportunity to examine all aspects of the model, as well as facilitate the desire to provide the model to stakeholders. The MCWD Model operates on a daily time-step. As such, it will compute the system status at the end of each day.

The MCWD Model does not account for hydraulic travel time in the flow routing. Specifically, changes in the outflow from Lake Mary are evident at all nodes on the same day as they are made. Because the modeling results are being used as a comparative tool to evaluate alternatives, potential errors associated with excluding hydraulic routing are identical for each alternative and, therefore, will not affect the comparative analyses.

The MCWD Model makes no attempt to quantify the ground water/surface water interaction in the system. Because the MCWD Model used the mass balance procedure, the ground water/surface water interaction is implicitly included in the accretion/depletion values along with all other possible sources such as unmeasured inflow or diversions, evaporation, data errors, etc. Information was not available to quantify the ground water interaction, so it could not be separated from the other unknown quantities.

3.0 DATA

The MCWD Model required various series of daily records within the period of modeled hydrology (see Section 3.2, below) to comprehensively evaluate the potential effects of alternatives. The required data are listed below.

[1] The Accretion/Depletion term at each node includes changes in streamflow upstream of the node due to all factors including local stream inflow, overland, non-point inflow, diversions, precipitation, evaporation, and surface water/ground water interaction.

Major Gage Records

The major gage records included:

- Daily Mammoth Creek flow at the MCWD Gage near Old Mammoth Road (OMR Gage)
- Daily Mammoth Creek flow at the LADWP Gage near Highway 395 (OLD395 Gage)
- Daily Hot Creek flow at the USGS Hot Creek Flume Gage

MCWD Operation Sheets

The system operations data included:

- Daily Lake Mary storage, inflow, outflow, and diversions
- Bodle Ditch diversions
- Daily Lake Mamie inflow and outflow
- Daily Twin Lakes inflow and outflow
- Twin Falls diversions

Snowpack Water Content at Mammoth Pass

The Mammoth Pass snowpack water content data was used to determine runoff year types (see Section 3.3, below).

3.1 DATA COLLECTION

Required MCWD Model data were solicited from multiple sources. Obtained data was compiled to build the daily series listed in Section 3.0, and the resulting series were scrutinized for missing values and potential erroneous recordings (see Section 3.4, below).

Mammoth Pass snowpack water content data measured by LADWP for the modeled hydrological period was downloaded from the California Data Exchange Center (CDEC) for station “MAM”.

3.2 MODELED HYDROLOGICAL PERIOD

The hydrological period modeled by the MCWD Model extends from April 1988 through March 2008, because:

- April 1988 through March 2008 represents the existing condition for CEQA purposes because it generally corresponds to the duration of existing fish population monitoring and analyses.
- April 1988 through March 2008 represents recent operations and current demands.
- The period extending from April 1988 through March 2008 is of sufficient duration to capture the range of climatologic and hydrologic variability present in the historical period of record.
- April 1988 through March 2008 reflects flow gains/losses that occurred during the period representing the Existing Condition.

- ❑ The period extending from April 1988 through March 2008 provides consistency of database applications (e.g., existing condition, fish population analyses, water availability, demands, flows, runoff year (snowpack water content)) for EIR analyses.

3.3 RUNOFF YEAR TYPE DETERMINATION

The April 1988 through March 2008 hydrological period was classified into runoff year types to facilitate resolution of data issues, to provide flexibility in developing alternative Mammoth Creek operations, and to refine the operations/flow analyses according to water availability. The runoff year was defined as beginning on April 1 and extending through March 31 of the following calendar year. Runoff year types are identified as Wet, Normal, or Dry.

April 1 snowpack water content (SWC) data for the Mammoth Pass station was used to delineate the runoff year types for the modeled hydrological period. LADWP measures the SWC at this station on or about April 1 of each year, and reports both the "raw" measurement and a "revised" measurement. The "revised" records consist of the SWC adjusted to the first of the month based on estimated precipitation between the actual measurement date and April 1. The "revised" records are available only until April 1, 2000. Therefore, the "revised" April 1 snowpack water contents for 1988 through 2000 and the "raw" SWC since 2001 were used for the runoff year type characterization.

The runoff year type definitions were based on a 20/80 frequency demarcation which is consistent with CDFG's recommendation and the State Water Resources Control Board's (SWRCB) adoption for the Mono Basin Decision D-1631 (pages 18-19). Consequently, the upper Dry year boundary was calculated as the 20 percentile of the LADWP April 1 snowpack water content data for the years 1988 through 2007, and the upper Normal year boundary was calculated as the 80 percentile of the same data series. These calculations lead to the following runoff year type classification:

- ❑ ***Wet Year***: April 1 snowpack water content **>** 60.2 inches
- ❑ ***Normal Year:*** April 1 snowpack water content ≥ 25.6 inches but ≤ 60.2 inches
- ❑ ***Dry Year:*** April 1 snowpack water content **<** 25.6 inches

Figure C-2 displays the categorization of the 1988 through 2007 runoff years resulting from the above classification.

It has been suggested that SWC on May 1 may provide a more reliable indicator of water availability. Examination of available data indicated that there are some differences between April 1 and May 1 SWC records, but using a May 1 SWC as the basis for runoff year type categorization was rejected because Mammoth Pass May 1 SWC has not been recorded since May 1, 1986.

Section 5.2 (below) contains additional discussion regarding utilization of the April 1 SWC to categorize runoff year type.

3.4 DATA QUALITY ASSURANCE/QUALITY CONTROL

After compiling the available daily data for the April 1988 through March 2008 period, the resulting series were scrutinized for completeness (i.e., presence and extent of missing data) and quality (i.e., detection of potential erroneous recordings). Inspection of the daily records identified missing data for short periods extending from one to a few days, and longer periods extending for one or more weeks. Annotations in some of the records also identified suspect readings caused by external forces (e.g., frozen gages, debris obstructing measurements, power or mechanical failures of the installed equipment). **Table C-1** displays the range of available daily data, by month, for various locations over the 20 years included in the hydrologic model.

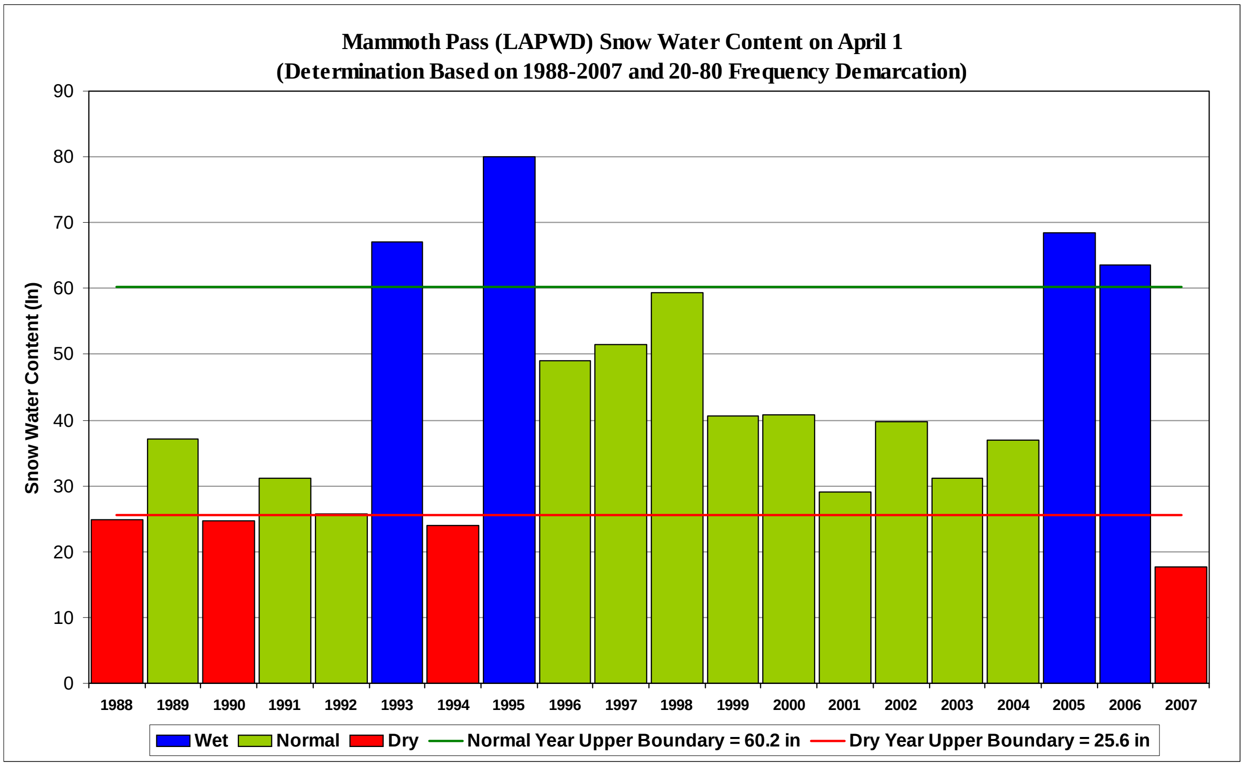


Figure C-2. Classification of Runoff Years during the Modeled Hydrologic Period

Table C-1. Minimum and Maximum Number of Days per Month with Useable Data (April 1988 through March 2008)

Location	April			May			June			July			August			September		
	Min Days		Max Days	Min Days		Max Days	Min Days		Max Days	Min Days		Max Days	Min Days		Max Days	Min Days		Max Days
Lake Mary Inflow	0	-	5	0	-	29	0	-	30	4	-	31	7	-	31	3	-	30
Lake Mary Storage Change	1	-	20	8	-	31	21	-	30	16	-	31	13	-	31	11	-	30
Bodle Ditch Diversion	0	-	30	0	-	31	0	-	30	8	-	31	1	-	31	1	-	30
OMR	26	-	30	28	-	31	28	-	30	23	-	31	22	-	31	29	-	30
OLD395	29	-	30	27	-	31	27	-	30	25	-	31	20	-	31	26	-	30

Location	October			November			December			January			February			March		
	Min Days		Max Days	Min Days		Max Days	Min Days		Max Days	Min Days		Max Days	Min Days		Max Days	Min Days		Max Days
Lake Mary Inflow	2	-	31	0	-	30	0	-	11	0	-	4	0	-	4	0	-	5
Lake Mary Storage Change	17	-	31	2	-	30	0	-	21	0	-	15	0	-	15	0	-	22
Bodle Ditch Diversion	0	-	31	0	-	30	0	-	31	0	-	31	0	-	29	0	-	31
OMR	29	-	31	21	-	30	14	-	31	6	-	31	20	-	29	22	-	31
OLD395	30	-	31	11	-	30	3	-	31	27	-	31	17	-	29	4	-	31

3.4.1 INITIAL DATA SCREENING

Initial inspections of the daily data series identified periods of consecutive days with identical readings at a gage, while the data series for the closest gage upstream or downstream exhibited daily variation. These periods of constant readings were particularly evident during winter months and were attributed to frozen or stuck gages. Additionally, days with aberrant, often extremely high flow readings at one gage without comparably high readings in the closest gages upstream or downstream to the site of the aberrant observation, and with no clear relation to precipitation data recorded at the USBR Mammoth Pass (MHP) meteorological station, also were identified. Both the constant and the aberrantly high records were eliminated from the calculation of daily accretions and depletions.

Additionally, potential erroneous recordings at the OMR and OLD395 flow gages were identified by the examination of the residual distributions obtained by performing simple linear regressions between both flow variables sorted by month and runoff year types (see Section 3.3, above). For each monthly and runoff year type regression line, the Studentized residuals[2] with absolute value greater than 2 were identified, and the pattern of the series of consecutive OMR and OLD395 flow records surrounding the pair that produced the large residual were examined. The pairs of records with identified large residuals were eliminated from the model calculation of daily accretions and depletions, particularly when the daily distributional patterns of OMR and OLD395 flow records surrounding the pair were not parsimonious.

3.4.2 TREATMENT OF MISSING DATA

Because the MCWD Model operates on a daily time-step calculating daily accretions and depletions between consecutive flow gages, daily flow values at all the gage locations indicated in Figure C-1 must be included over the entire modeled hydrologic period. Consequently, missing data were estimated by one of two methods. For periods of missing data extending from one to several days, values were estimated based on the flow values of the previous and subsequent daily data points, often using simple averaging or linear interpolation. The longer gaps in the data sets, extending for one or more weeks, were typically estimated using linear regression equations, developed by runoff year type and month, for the particular flow locations.

For example, if a two-week gap in the data for the OMR Gage occurred during April of a dry runoff year, the daily flows obtained from the OLD395 Gage were input into the regression equation describing the relationship of natural logarithm of OMR flow as function of the natural logarithm of OLD395 flow for April of dry years. After applying the antilogarithm to the predicted values, the results would be utilized as the estimated flows for the OMR Gage during the period when daily flows were missing. An analogous process was used to estimate daily flows at the OLD395 Gage when data gaps occurred at that gage, but daily flow data were available at the OMR Gage.

The intercept and slope parameters of the monthly linear regressions relating OMR and OLD395 flows are presented in **Table C-2** and **Table C-3**. Scatter plots, intercept and slope parameters, coefficients of determination (r^2), and levels of significance (P) of the linear regressions used to reconstruct OMR Gage daily flows from OLD395 Gage daily flows by month and runoff year type are presented in **Figures C-3 through C-14**. Scatter plots and

[2] The Studentized residuals are defined as the common residuals (i.e., the observed value minus the value predicted by the regression) divided by their standard error.

parameters of the linear regressions used to reconstruct OLD395 Gage daily flows from OMR Gage daily flows by month and runoff year type are presented in **Figures C-15 through C-26**.

For those occasions when daily flow data where not available at either the OMR or OLD395 gages, linear interpolation was performed between the last known and the next known data point at the OMR Gage, and the appropriate month/runoff year type regression equation was used to estimate the data at the OLD395 Gage.

Table C-2. Intercept and Slope Parameters of the Monthly Linear Regressions Used to Reconstruct OMR Gage Flows from OLD395 Gage Flows in Dry, Normal and Wet Runoff Years

Ln (OMR Flow +1) = *Intercept* + *Slope* x Ln (OLD395 Flow + 1)						
Month	**DRY**		**NORMAL**		**WET**	
	Intercept	*Slope*	*Intercept*	*Slope*	*Intercept*	*Slope*
April	0.846681	0.708622	0.647730	0.794712	0.612831	0.784223
May	0.135409	1.011033	0.351797	0.918989	-0.020151	0.996564
June	-0.049899	1.049083	0.112763	0.960964	0.320468	0.919299
July	0.195296	0.925839	0.244389	0.891901	-0.465094	1.055652
August	0.876204	0.613433	0.550178	0.742856	-0.582984	1.041894
September	0.886592	0.591959	0.760136	0.633092	0.000663	0.848854
October	0.760416	0.671043	1.029204	0.493257	1.289882	0.412206
November	0.858254	0.672672	0.757506	0.676857	1.681853	0.244525
December	1.239445	0.456363	1.066281	0.560518	0.928145	0.634842
January	1.174003	0.536299	0.948461	0.623924	0.752727	0.702962
February	1.062034	0.537888	0.910539	0.627930	0.308571	0.893905
March	0.763647	0.768827	0.846198	0.681784	1.033426	0.601548

Table C-3. Intercept and Slope Parameters of the Monthly Linear Regressions Used to Reconstruct OLD395 Gage Flows from OMR Gage Flows in Dry, Normal and Wet Runoff Years

Ln (OLD395 Flow +1) = *Intercept* + *Slope* x Ln (OMR Flow + 1)						
Month	**DRY**		**NORMAL**		**WET**	
	Intercept	*Slope*	*Intercept*	*Slope*	*Intercept*	*Slope*
April	-0.646121	1.181467	-0.668625	1.202298	-0.463102	1.155212
May	0.063651	0.926125	-0.294308	1.063133	0.107068	0.981568
June	0.668002	0.763321	0.012485	1.007483	0.369855	0.936930
July	0.150039	0.930639	-0.126159	1.073754	0.593157	0.912568
August	0.540029	0.654427	-0.426699	1.219880	0.768067	0.895776
September	-0.561450	1.178757	-0.670503	1.337564	0.198838	1.099236
October	-0.952650	1.391030	-0.989522	1.497528	-0.353188	1.247851
November	-0.194777	0.931719	-0.326669	1.123168	0.867223	0.673389
December	-0.925910	1.279423	-0.390730	1.089031	0.404886	0.809799
January	-0.883876	1.232945	-0.683711	1.228653	0.790049	0.622652
February	-1.435002	1.583146	-0.615097	1.210304	0.155340	0.903578
March	-0.638834	1.142117	-0.810760	1.276398	-0.720573	1.244373

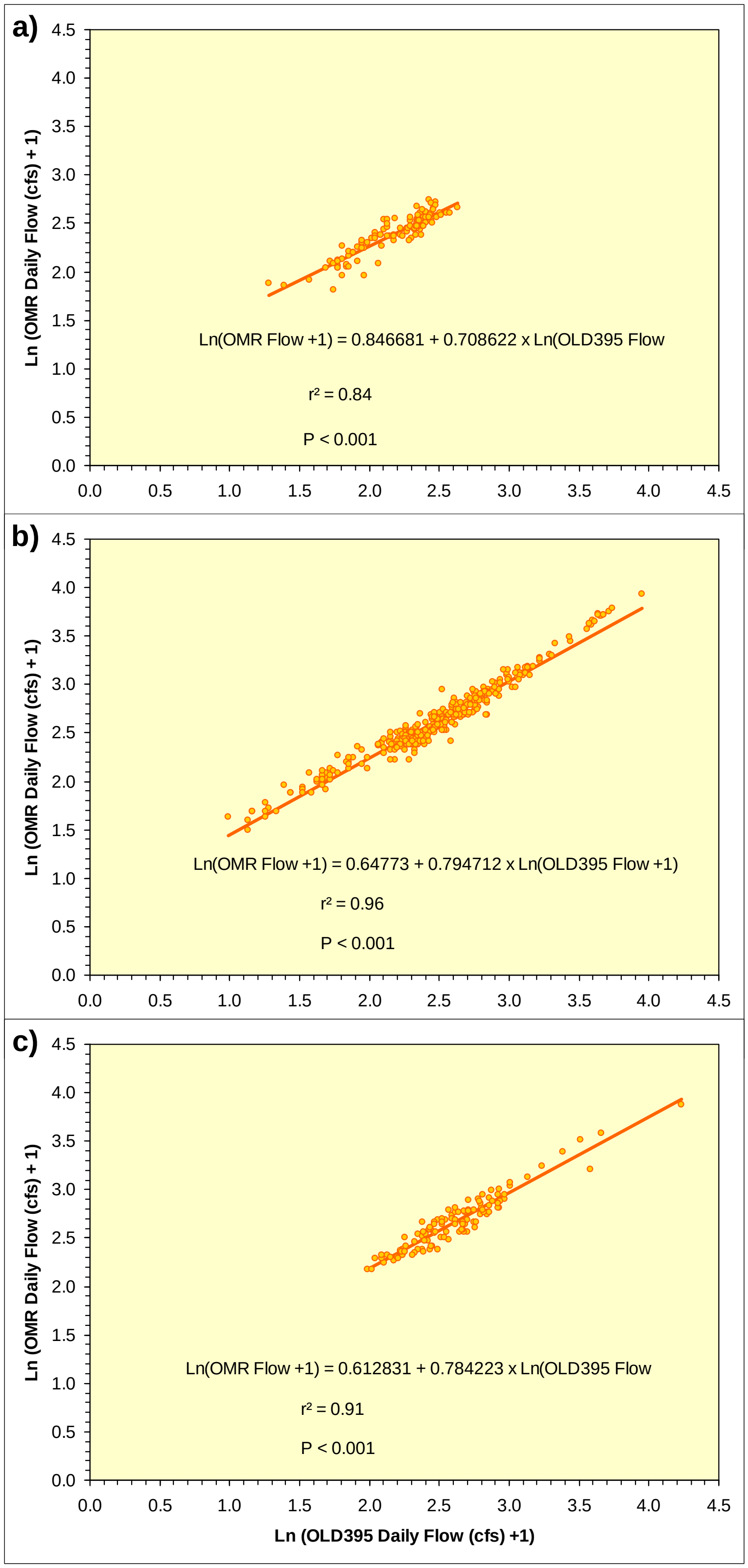


Figure C-3. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OMR Gage Daily Flows from OLD395 Gage Daily Flows during April for (a) Dry, (b) Normal, and (c) Wet Runoff Years

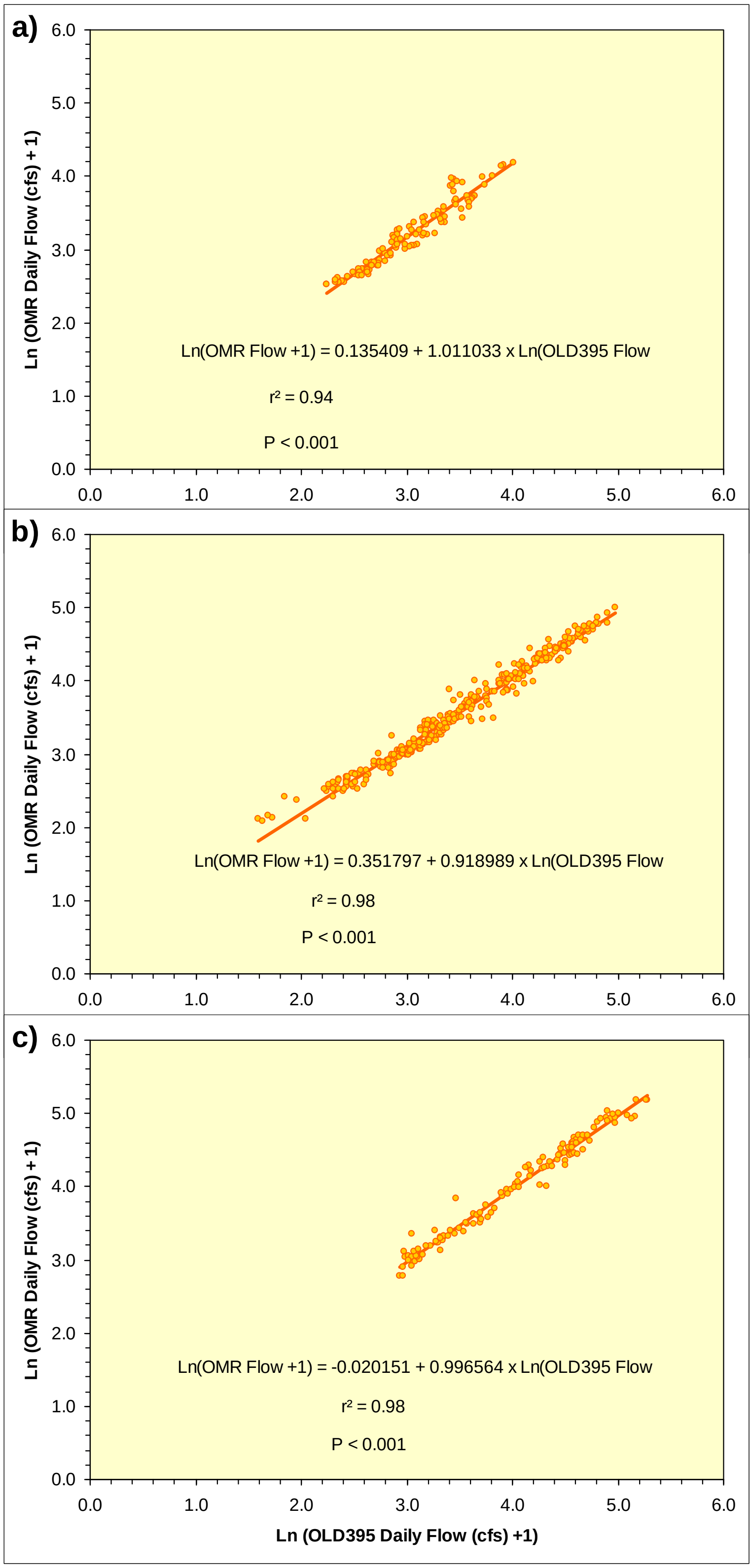


Figure C-4. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OMR Gage Daily Flows from OLD395 Gage Daily Flows during May for (a) Dry, (b) Normal, and (c) Wet Runoff Years

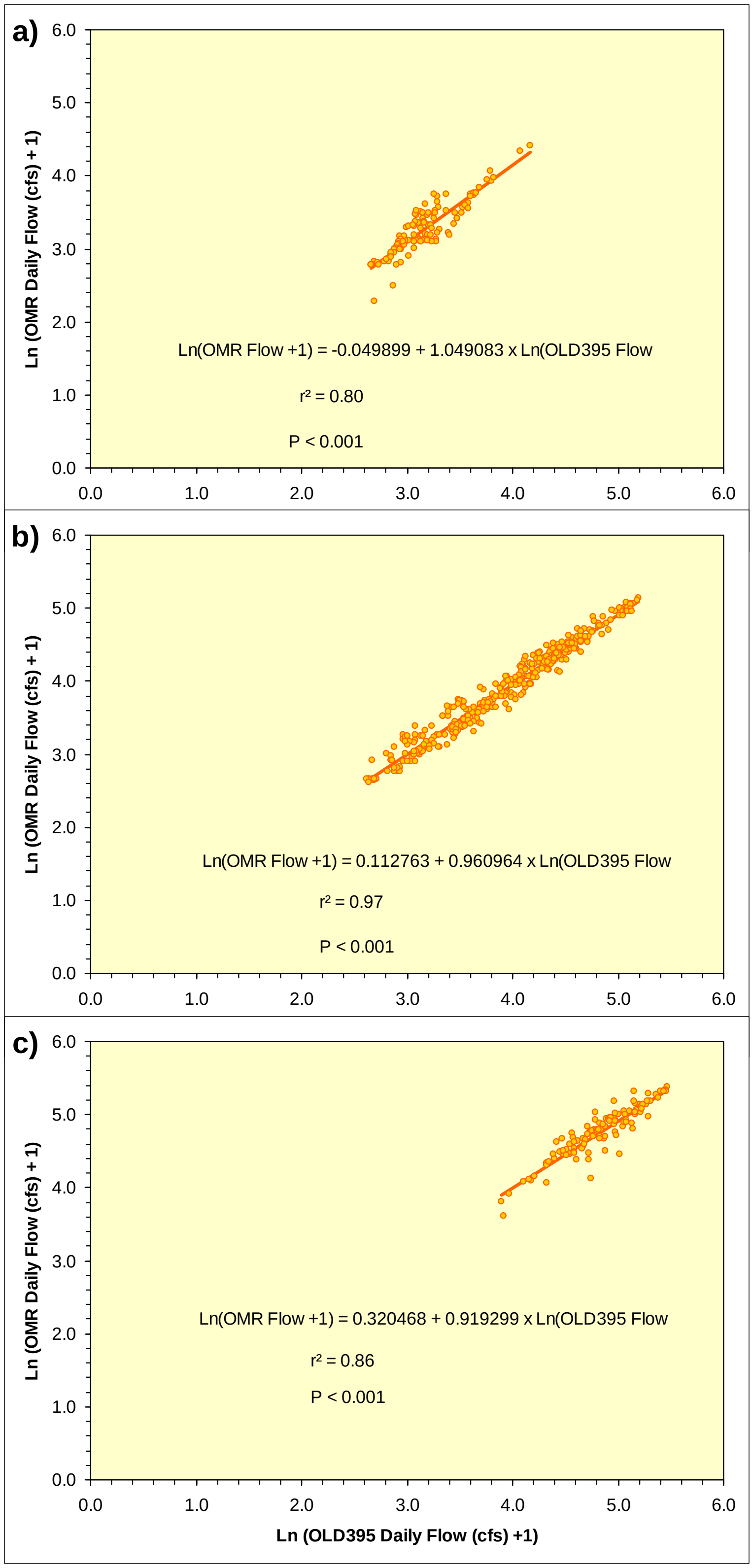


Figure C-5. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OMR Gage Daily Flows from OLD395 Gage Daily Flows during June for (a) Dry, (b) Normal, and (c) Wet Runoff Years

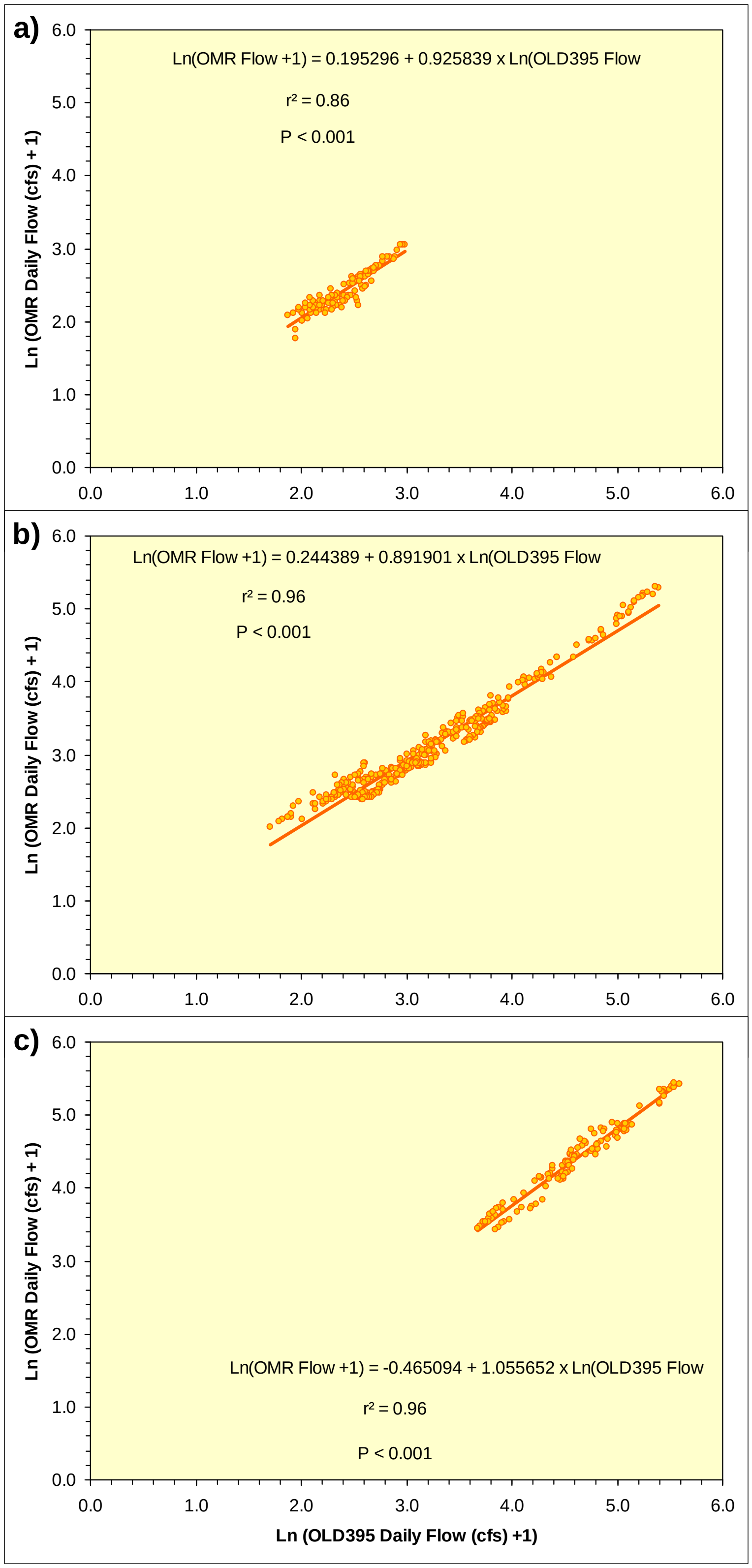


Figure C-6. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OMR Gage Daily Flows from OLD395 Gage Daily Flows during July for (a) Dry, (b) Normal, and (c) Wet Runoff Years

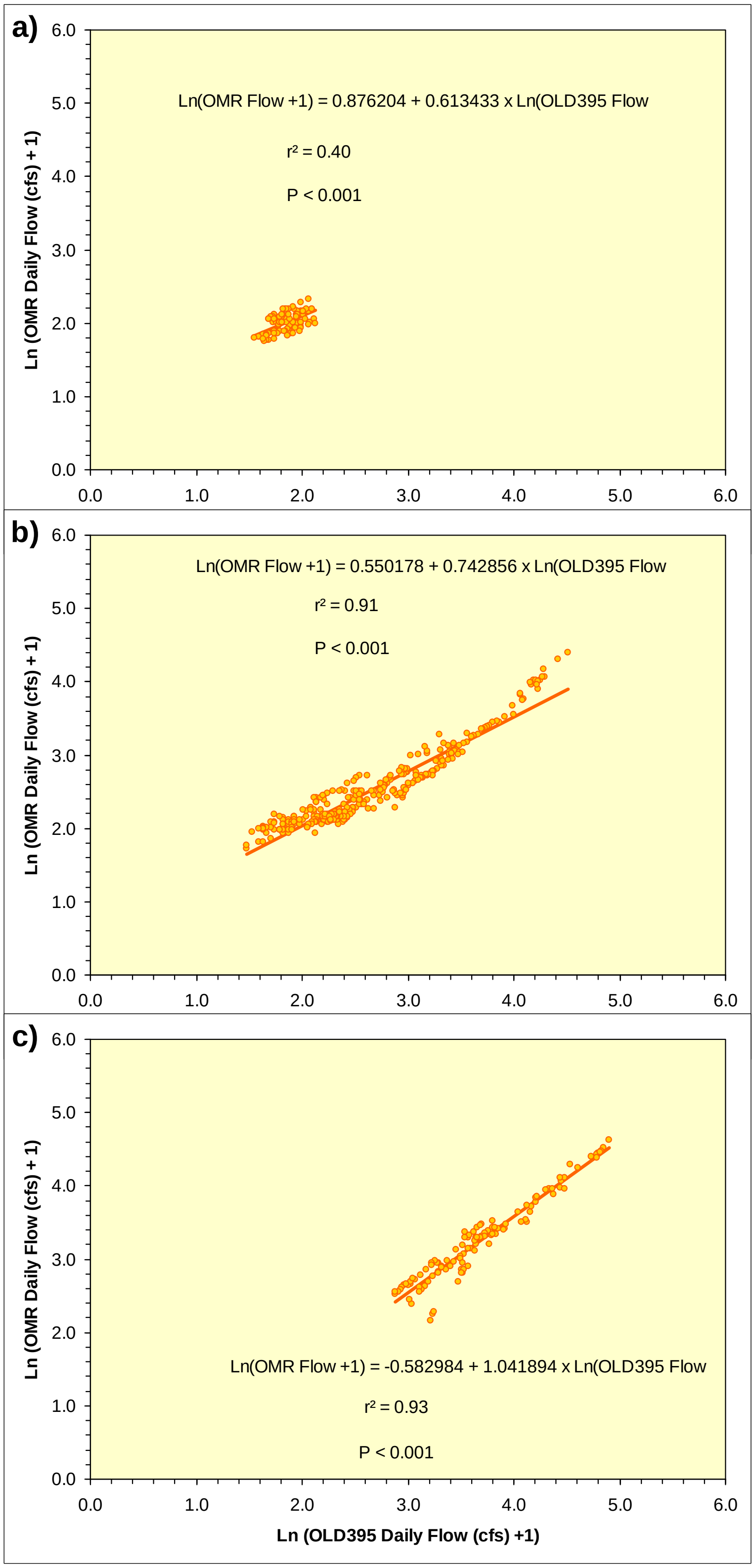


Figure C-7. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OMR Gage Daily Flows from OLD395 Gage Daily Flows during August for (a) Dry, (b) Normal, and (c) Wet Runoff Years

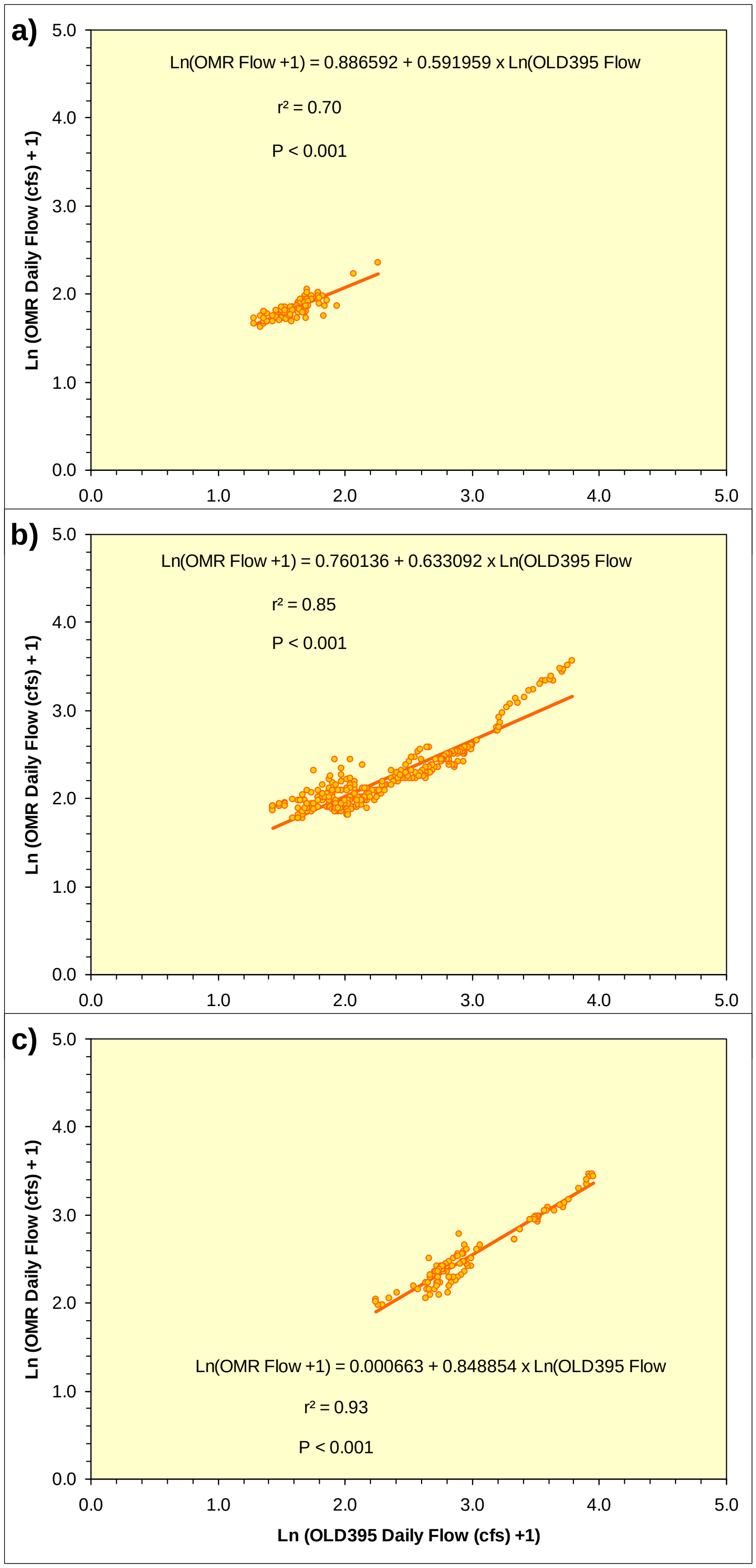


Figure C-8. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OMR Gage Daily Flows from OLD395 Gage Daily Flows during September for (a) Dry, (b) Normal, and (c) Wet Runoff Years

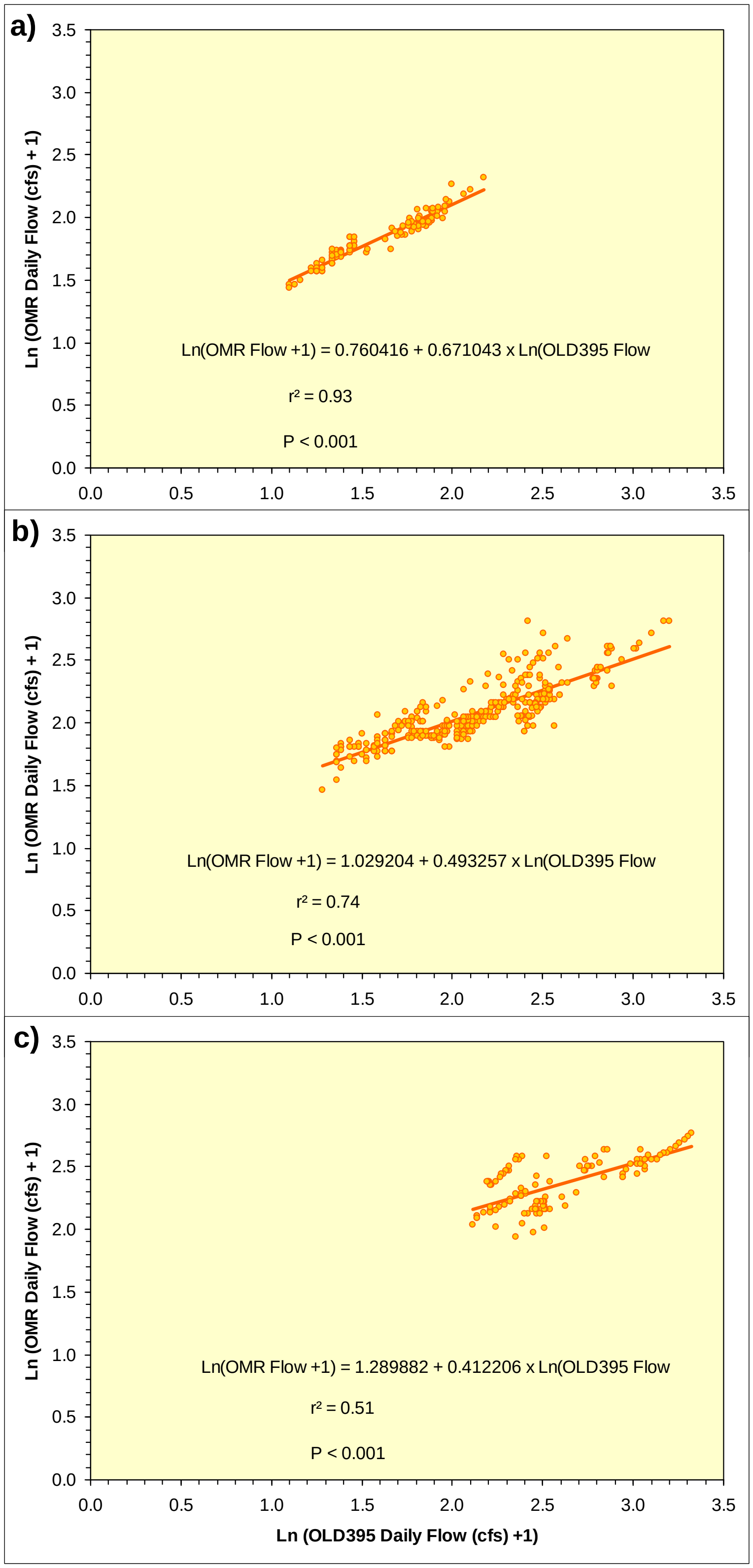


Figure C-9. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OMR Gage Daily Flows from OLD395 Gage Daily Flows during October for (a) Dry, (b) Normal, and (c) Wet Runoff Years

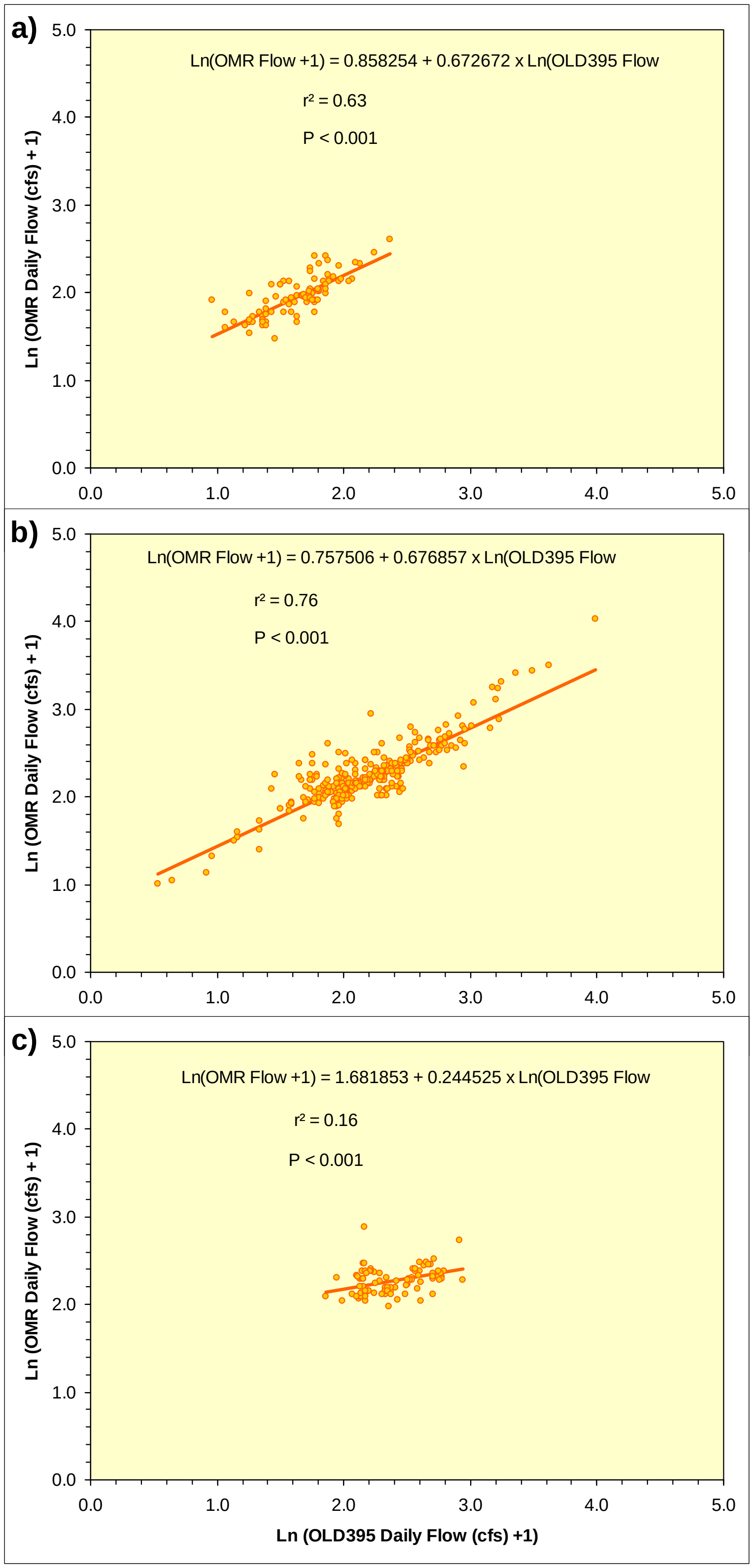


Figure C-10. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OMR Gage Daily Flows from OLD395 Gage Daily Flows during November for (a) Dry, (b) Normal, and (c) Wet Runoff Years

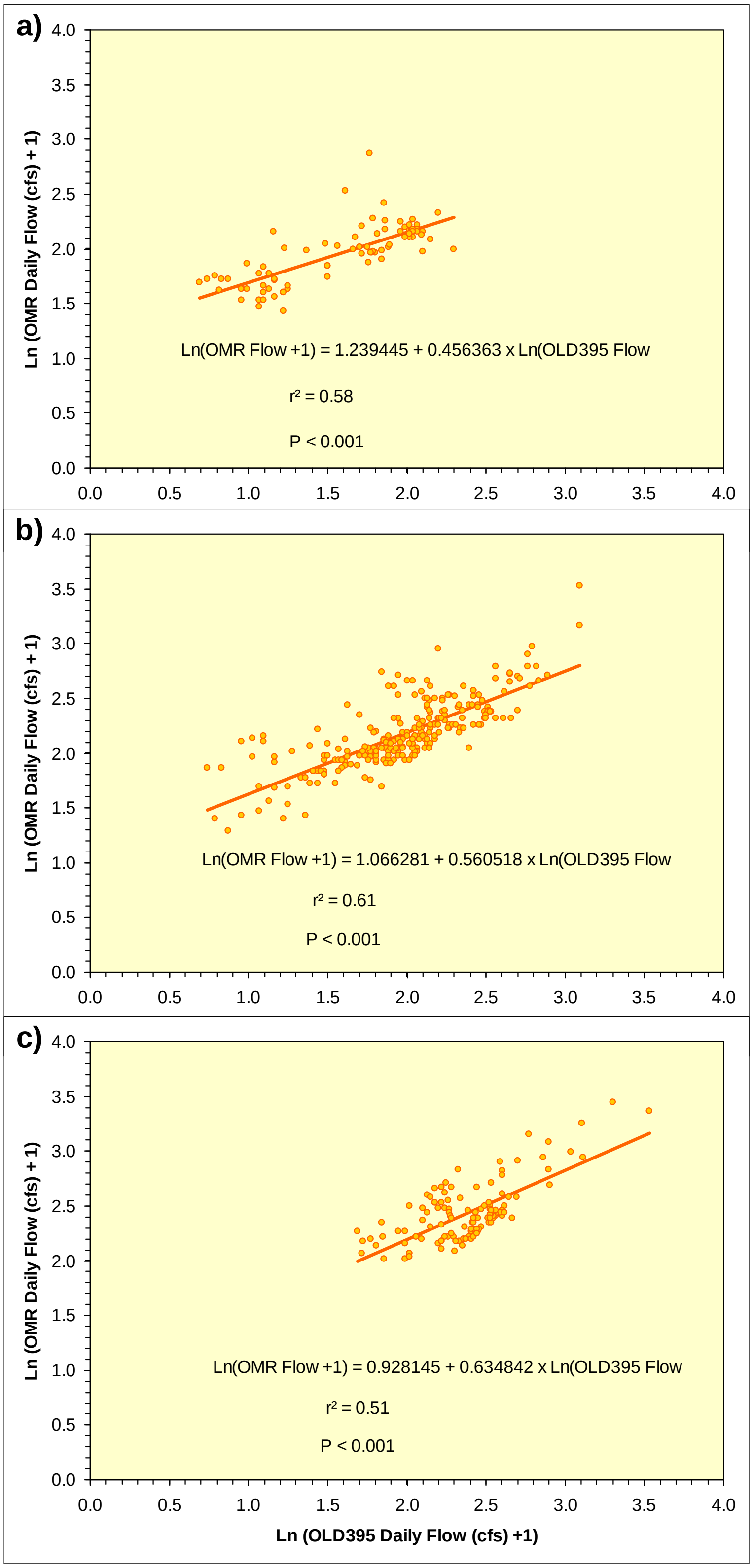


Figure C-11. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OMR Gage Daily Flows from OLD395 Gage Daily Flows during December for (a) Dry, (b) Normal, and (c) Wet Runoff Years

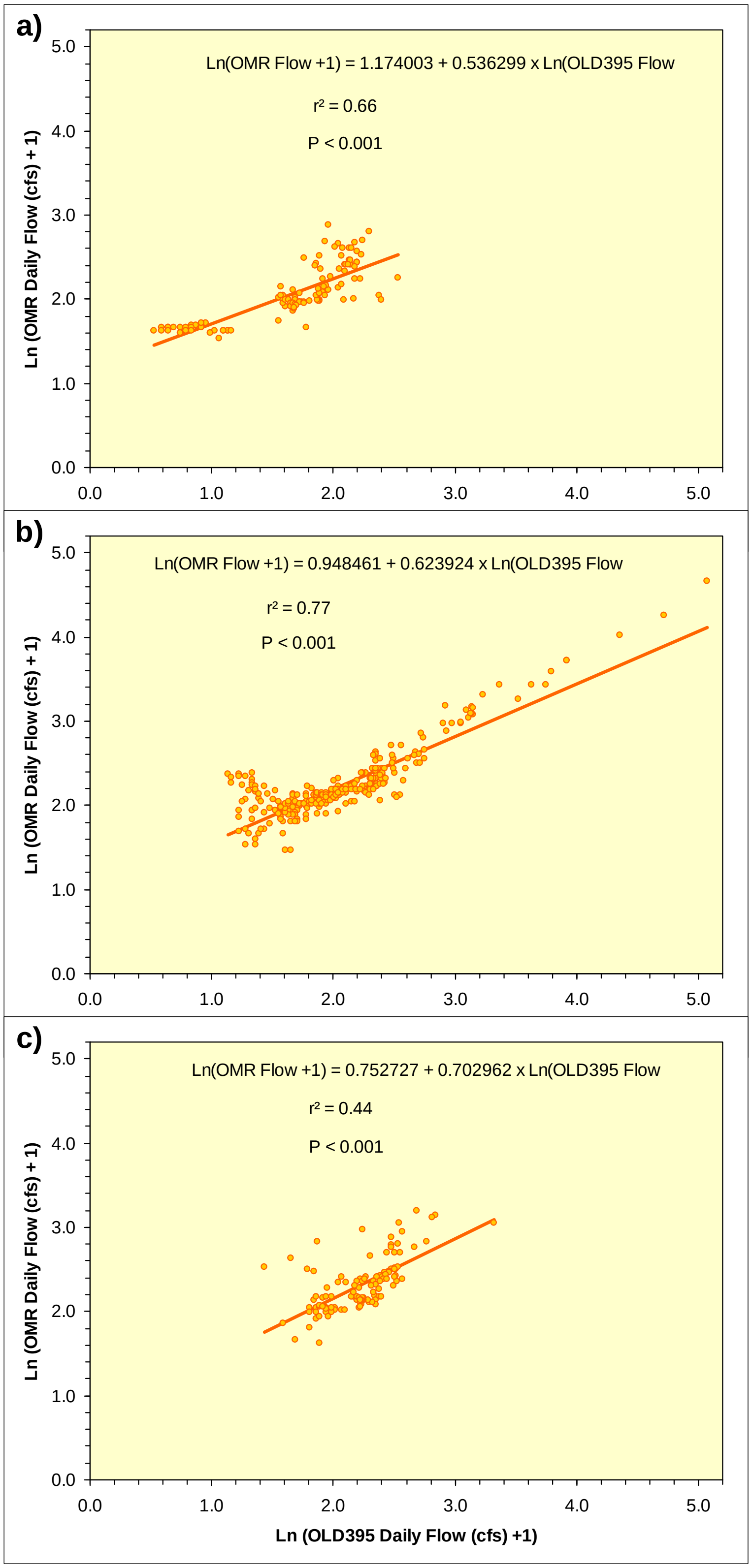


Figure C-12. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OMR Gage Daily Flows from OLD395 Gage Daily Flows during January for (a) Dry, (b) Normal, and (c) Wet Runoff Years

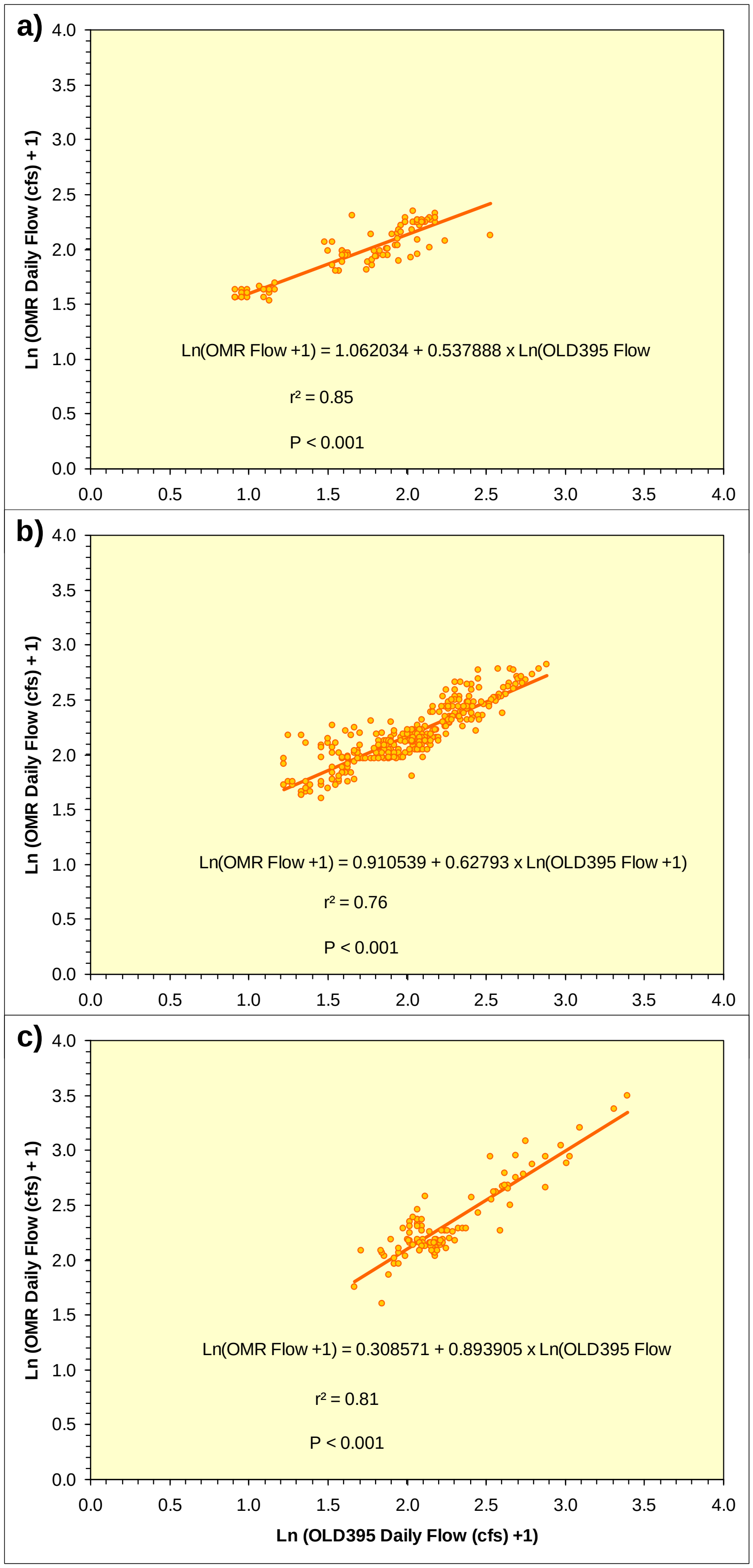


Figure C-13. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OMR Gage Daily Flows from OLD395 Gage Daily Flows during February for (a) Dry, (b) Normal, and (c) Wet Runoff Years

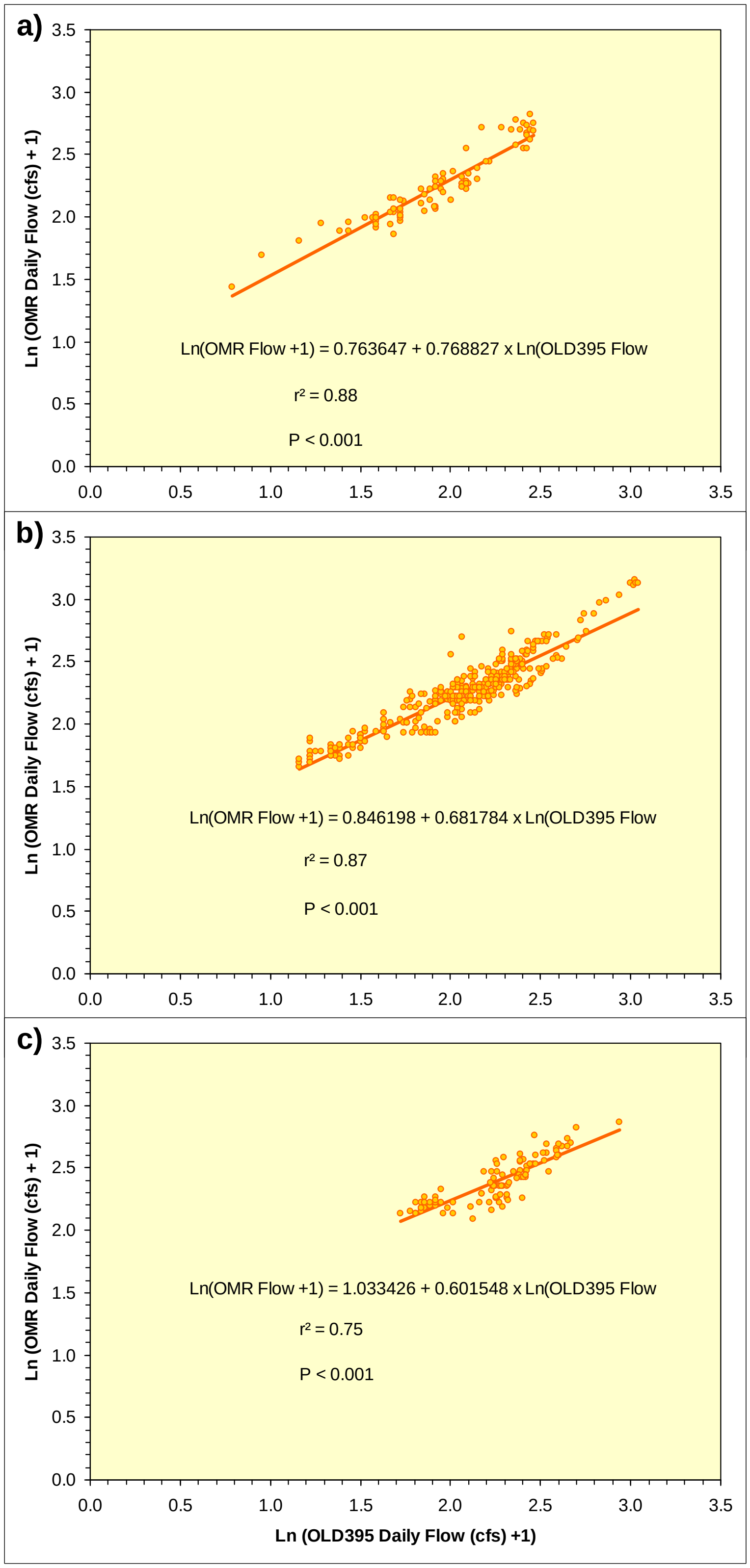


Figure C-14. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OMR Gage Daily Flows from OLD395 Gage Daily Flows during March for (a) Dry, (b) Normal, and (c) Wet Runoff Years

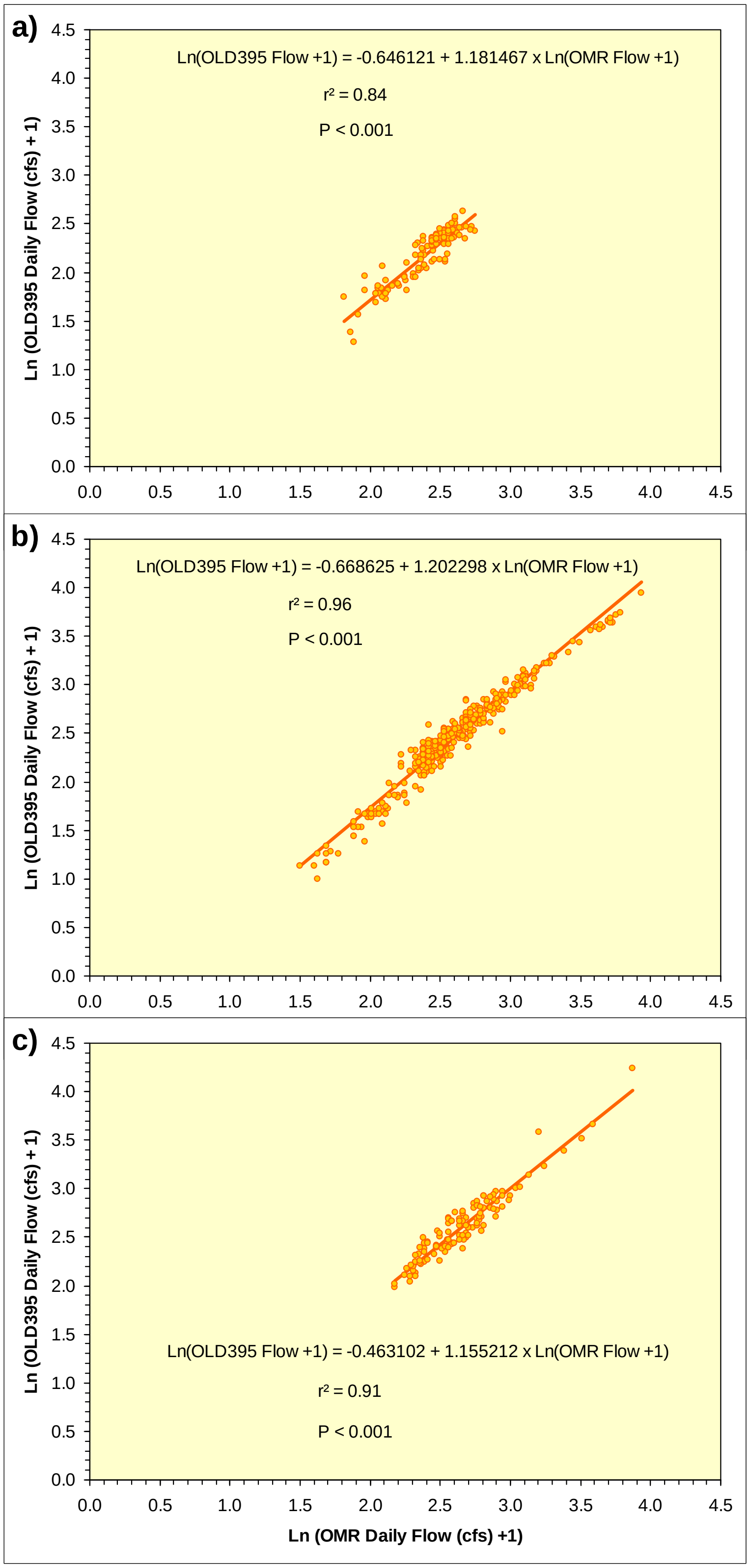


Figure C-15. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OLD395 Gage Daily Flows from OMR Gage Daily Flows during April for (a) Dry, (b) Normal, and (c) Wet Runoff Years

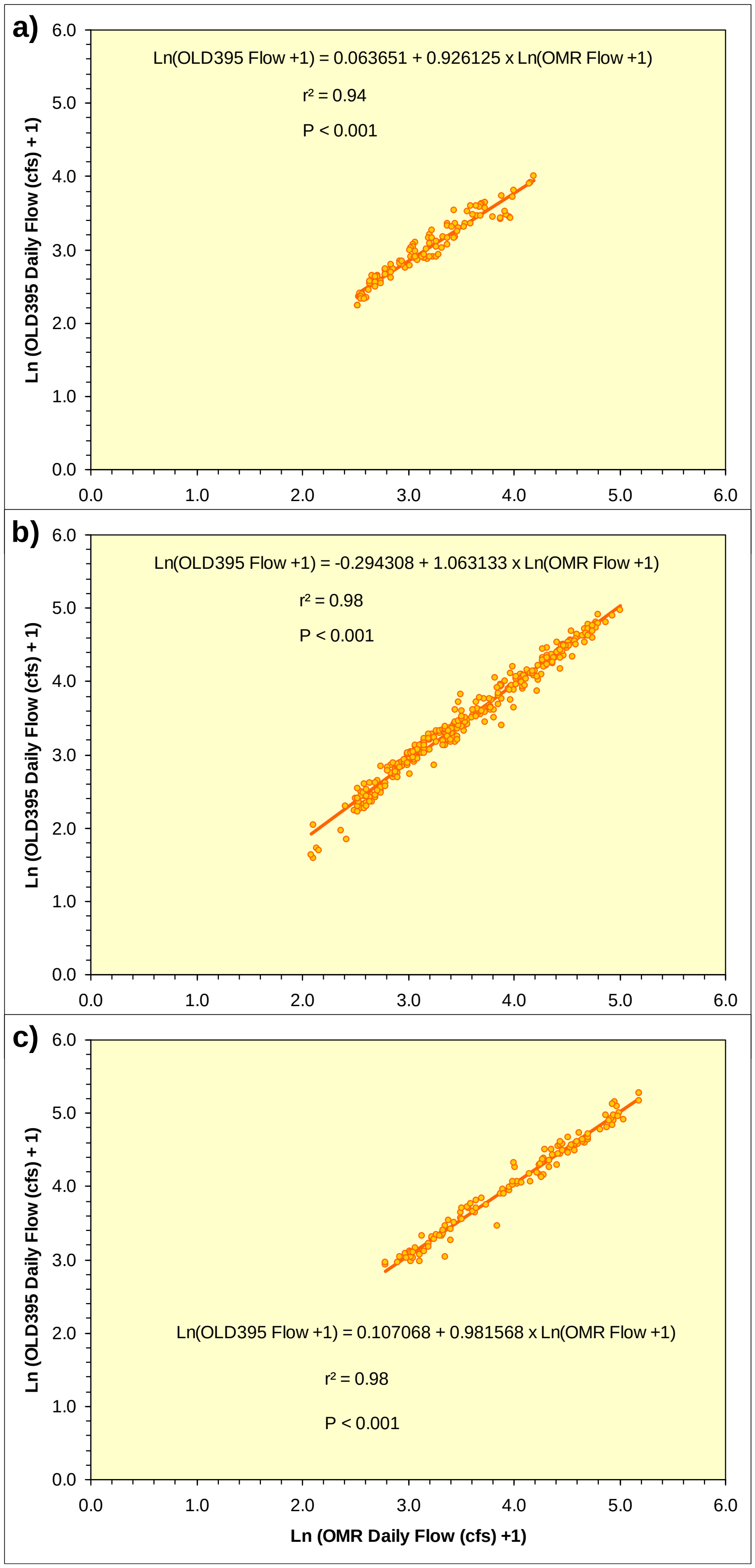


Figure C-16. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OLD395 Gage Daily Flows from OMR Gage Daily Flows during May for (a) Dry, (b) Normal, and (c) Wet Runoff Years

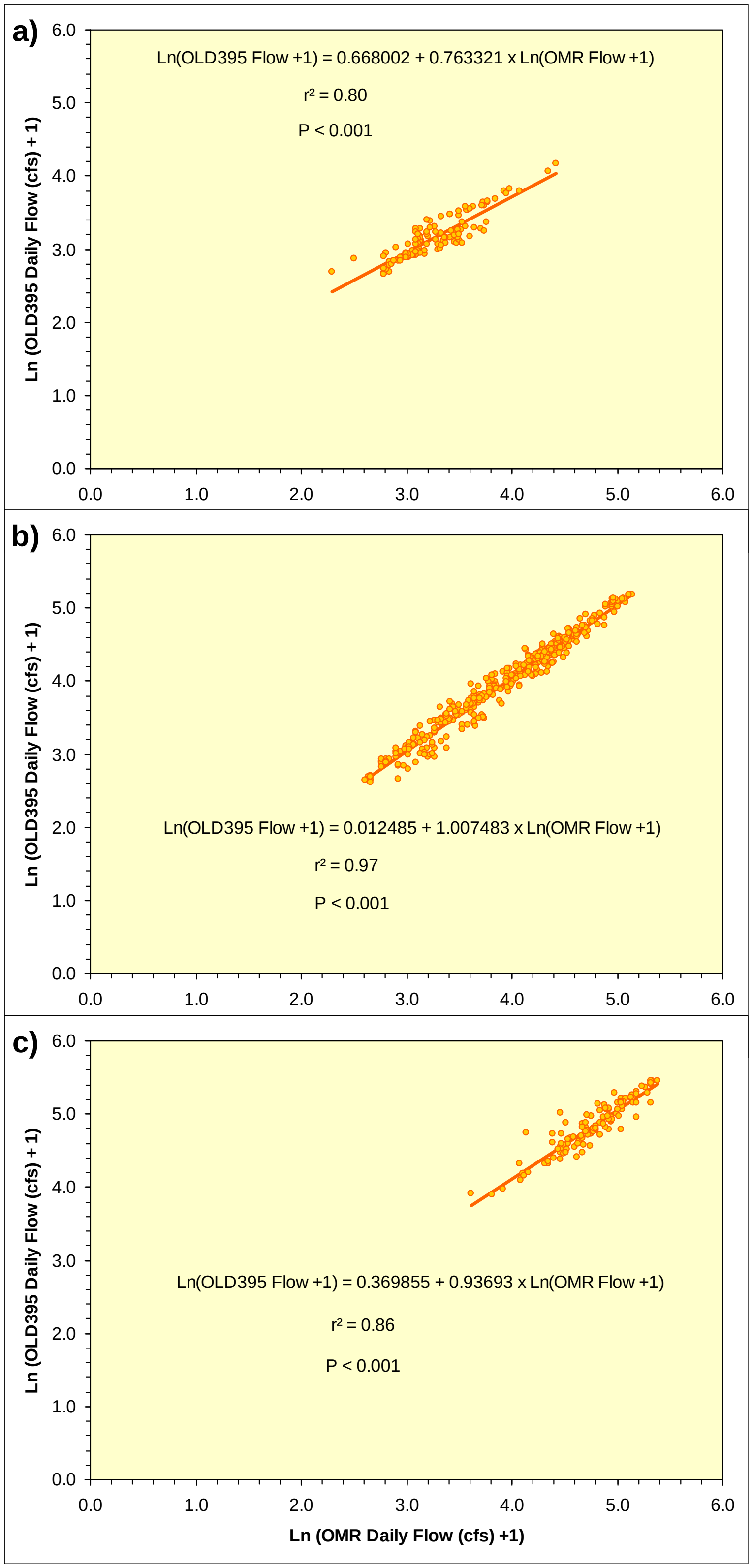


Figure C-17. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OLD395 Gage Daily Flows from OMR Gage Daily Flows during June for (a) dry, (b) Normal, and (c) Wet Runoff Years

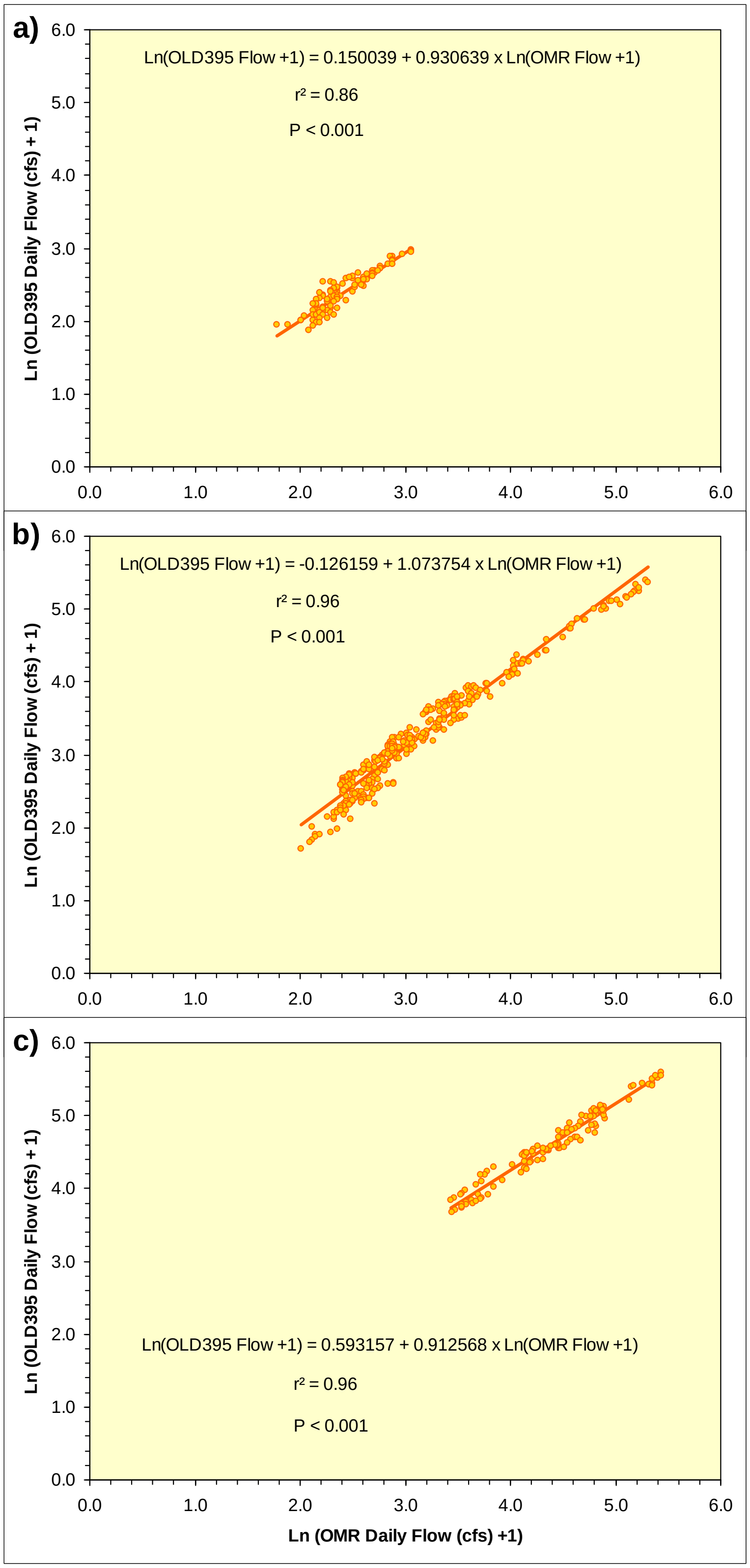


Figure C-18. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OLD395 Gage Daily Flows from OMR Gage Daily Flows during July for (a) Dry, (b) Normal, and (c) Wet Runoff Years

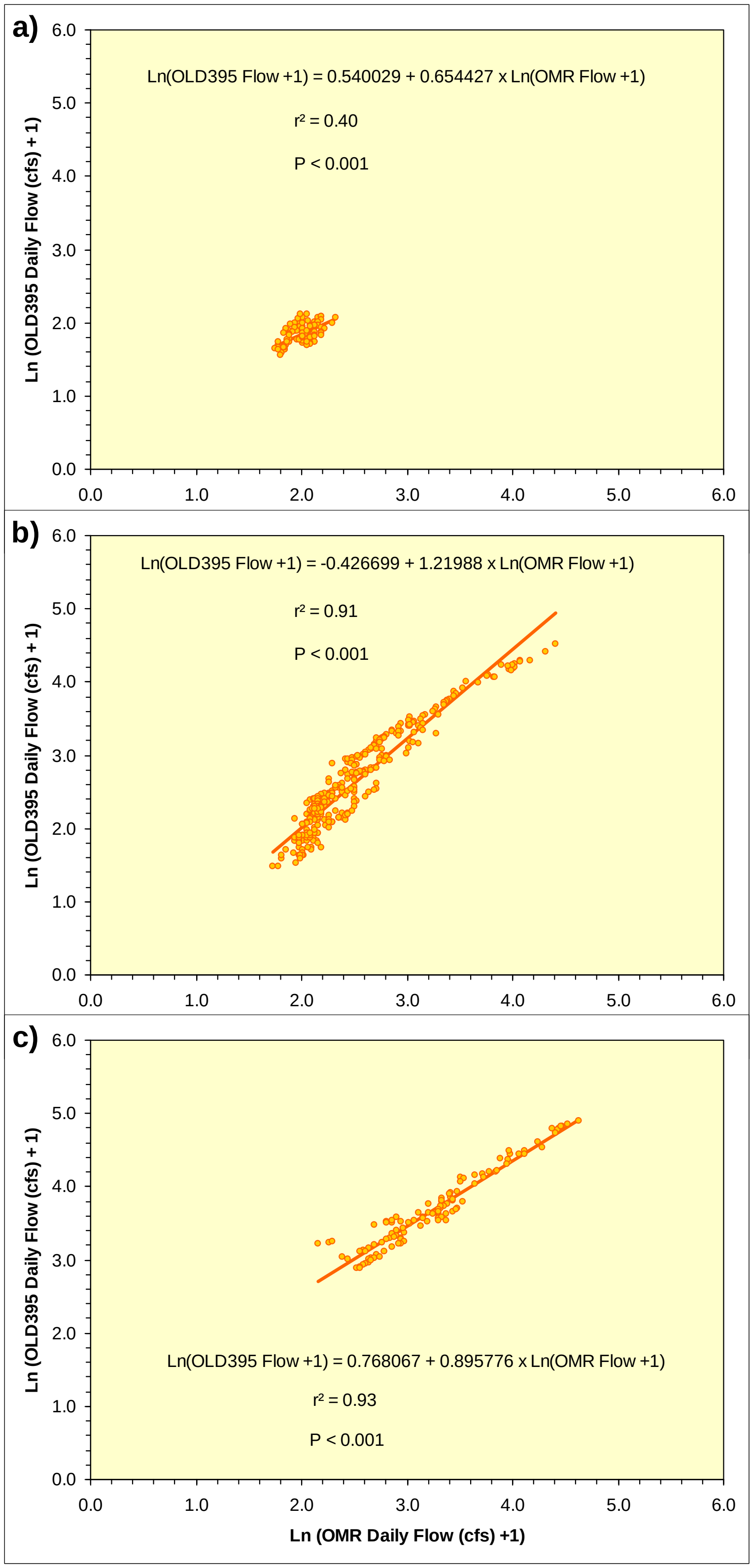


Figure C-19. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OLD395 Gage Daily Flows from OMR Gage Daily Flows during August for (a) Dry, (b) Normal, and (c) Wet Runoff Years

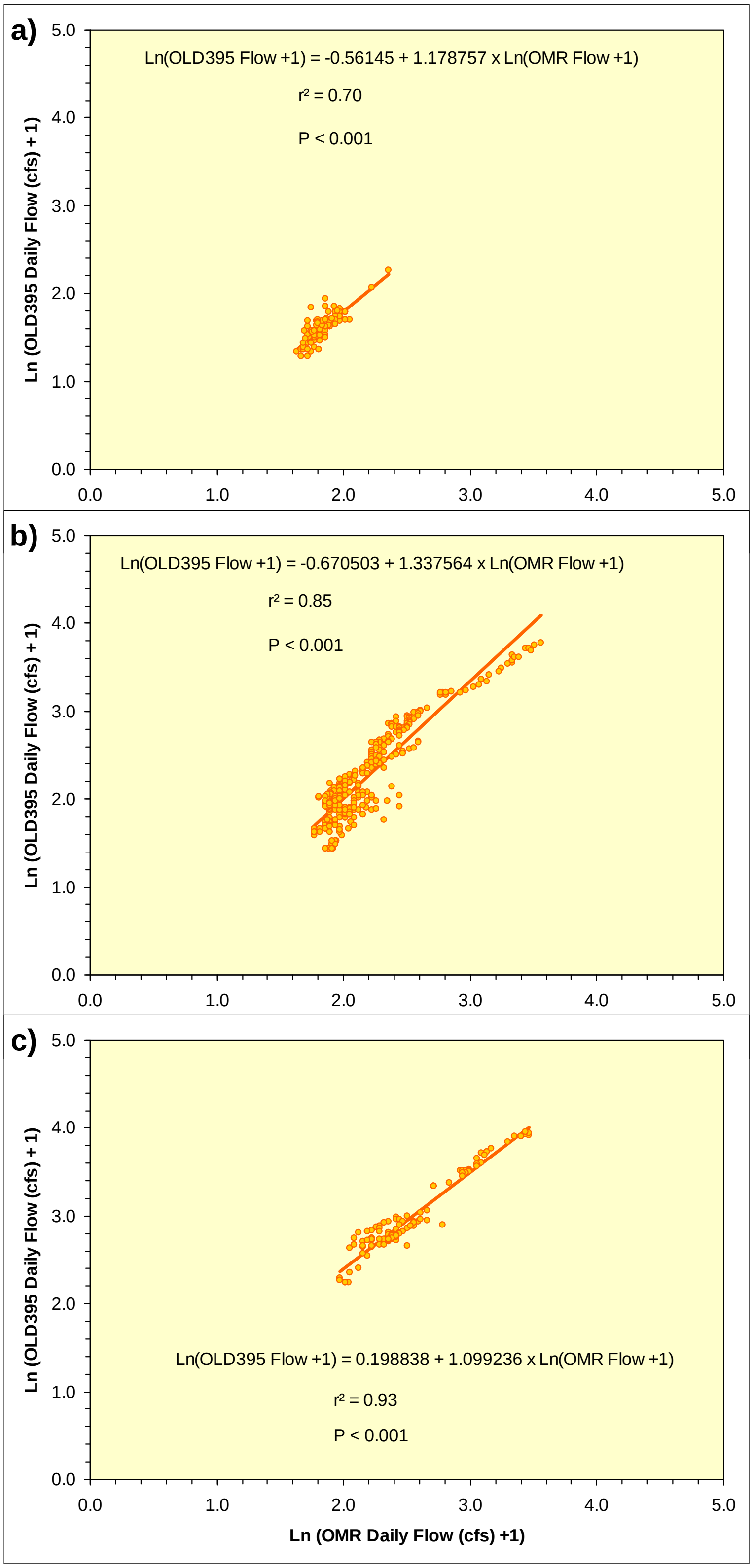


Figure C-20. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OLD395 Gage Daily Flows from OMR Gage Daily Flows during September for (a) Dry, (b) Normal, and (c) Wet Runoff Years

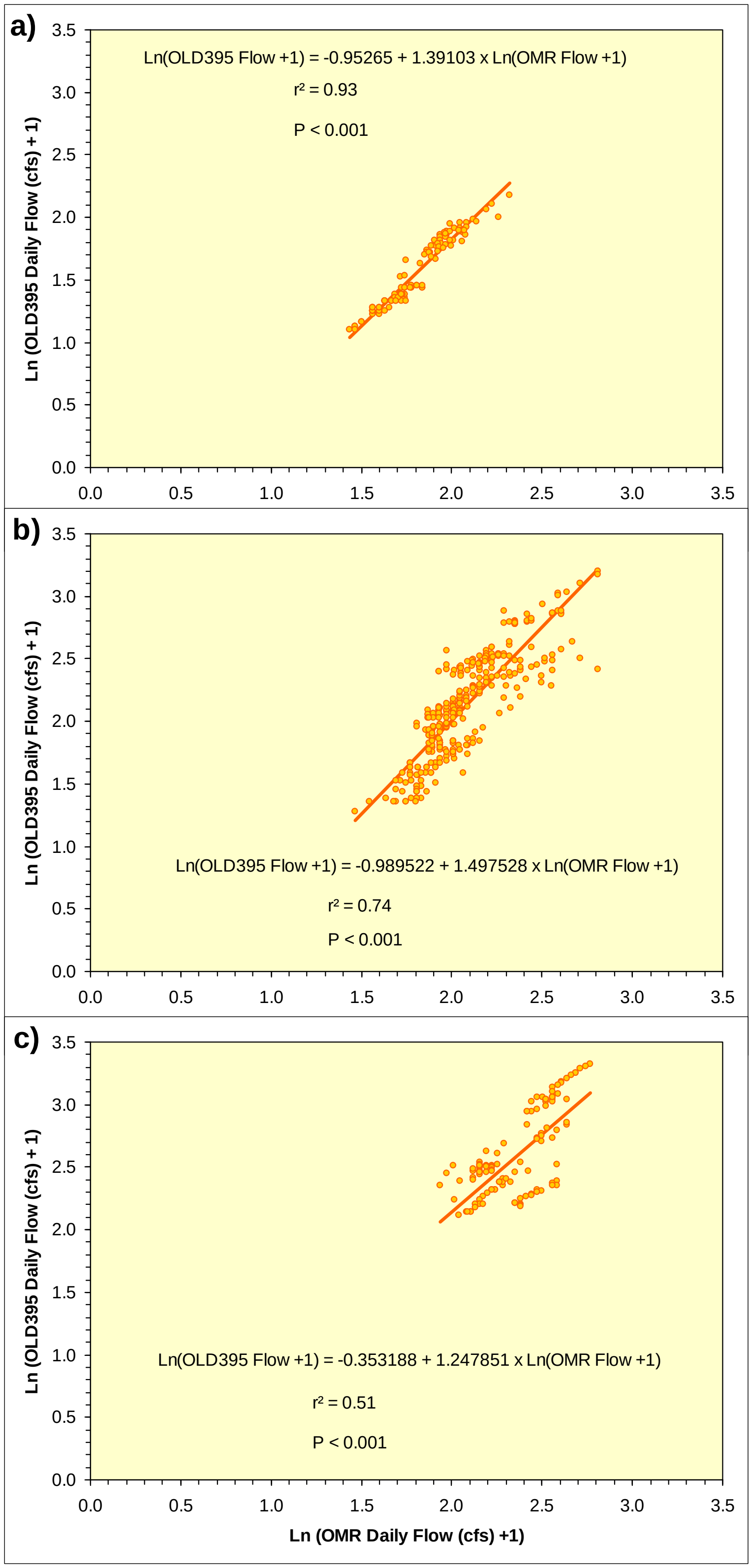


Figure C-21. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OLD395 Gage Daily Flows from OMR Gage Daily Flows during October for (a) Dry, (b) Normal, and (c) Wet Runoff Years

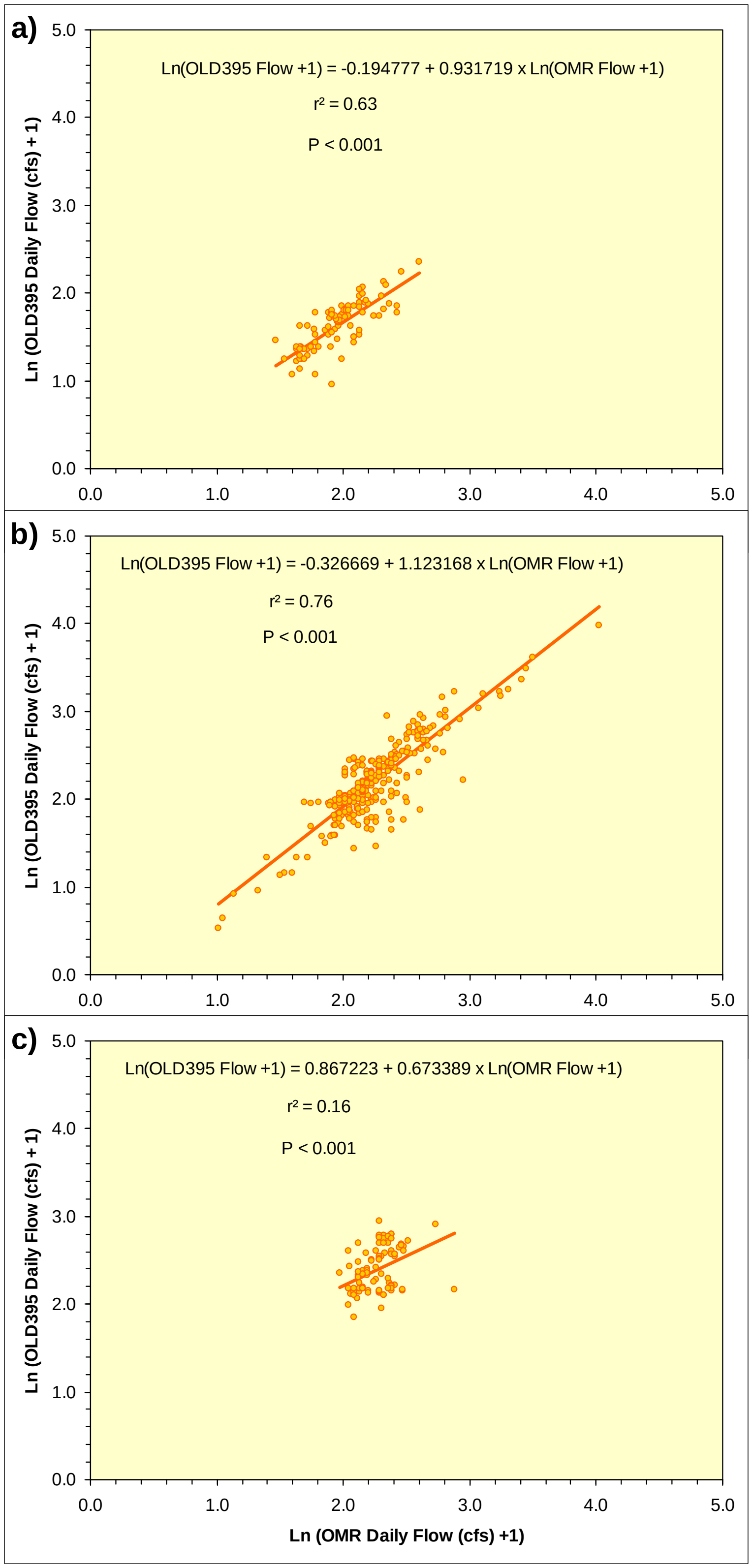


Figure C-22. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OLD395 Gage Daily Flows from OMR Gage Daily Flows during November for (a) Dry, (b) Normal, and (c) Wet Runoff Years

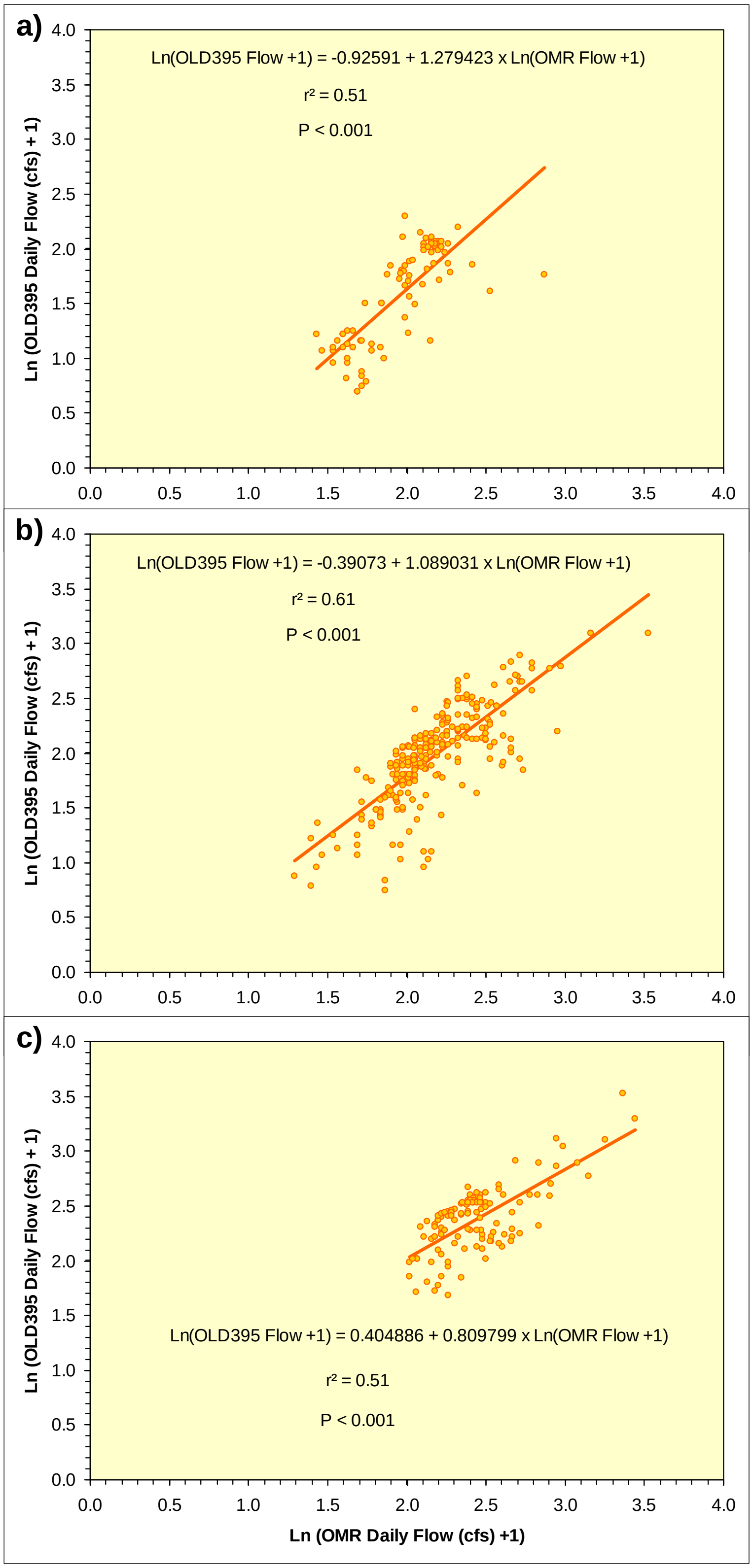


Figure C-23. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OLD395 Gage Daily Flows from OMR Gage Daily Flows during December for (a) Dry, (b) Normal, and (c) Wet Runoff Years

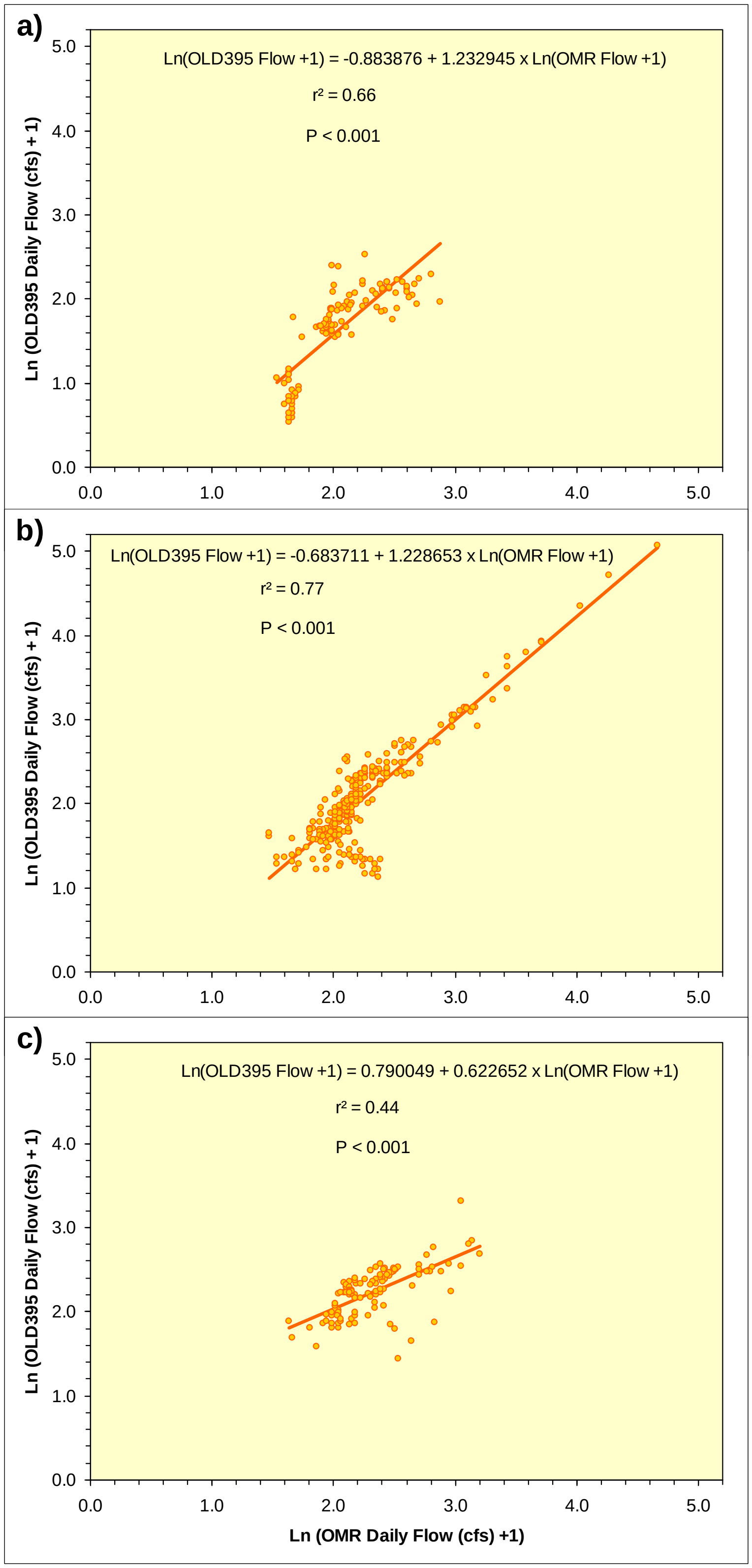


Figure C-24. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OLD395 Gage Daily Flows from OMR Gage Daily Flows during January for (a) Dry, (b) Normal, and (c) Wet Runoff Years

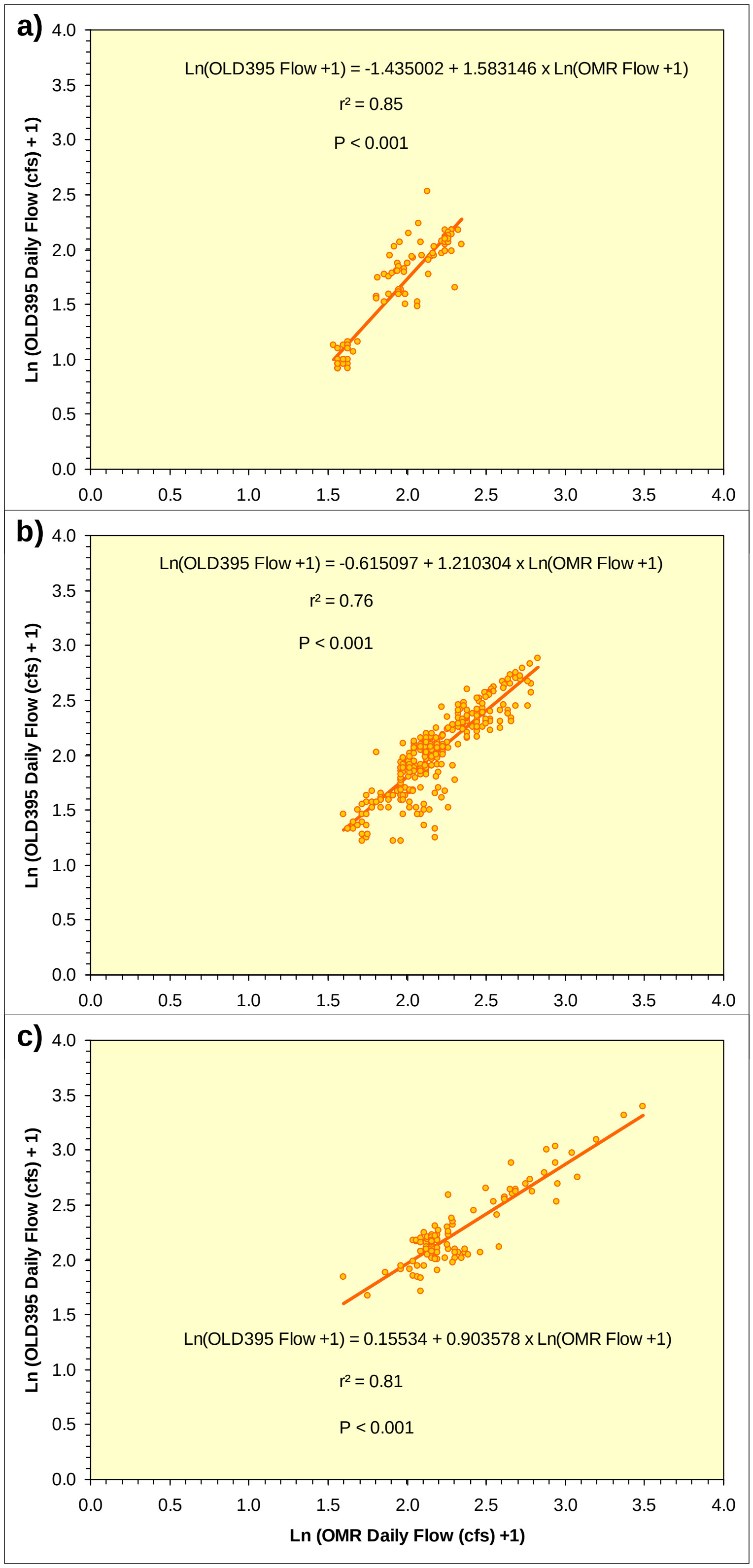


Figure C-25. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OLD395 Gage Daily Flows from OMR Gage Daily Flows during February for (a) Dry, (b) Normal, and (c) Wet Runoff Years

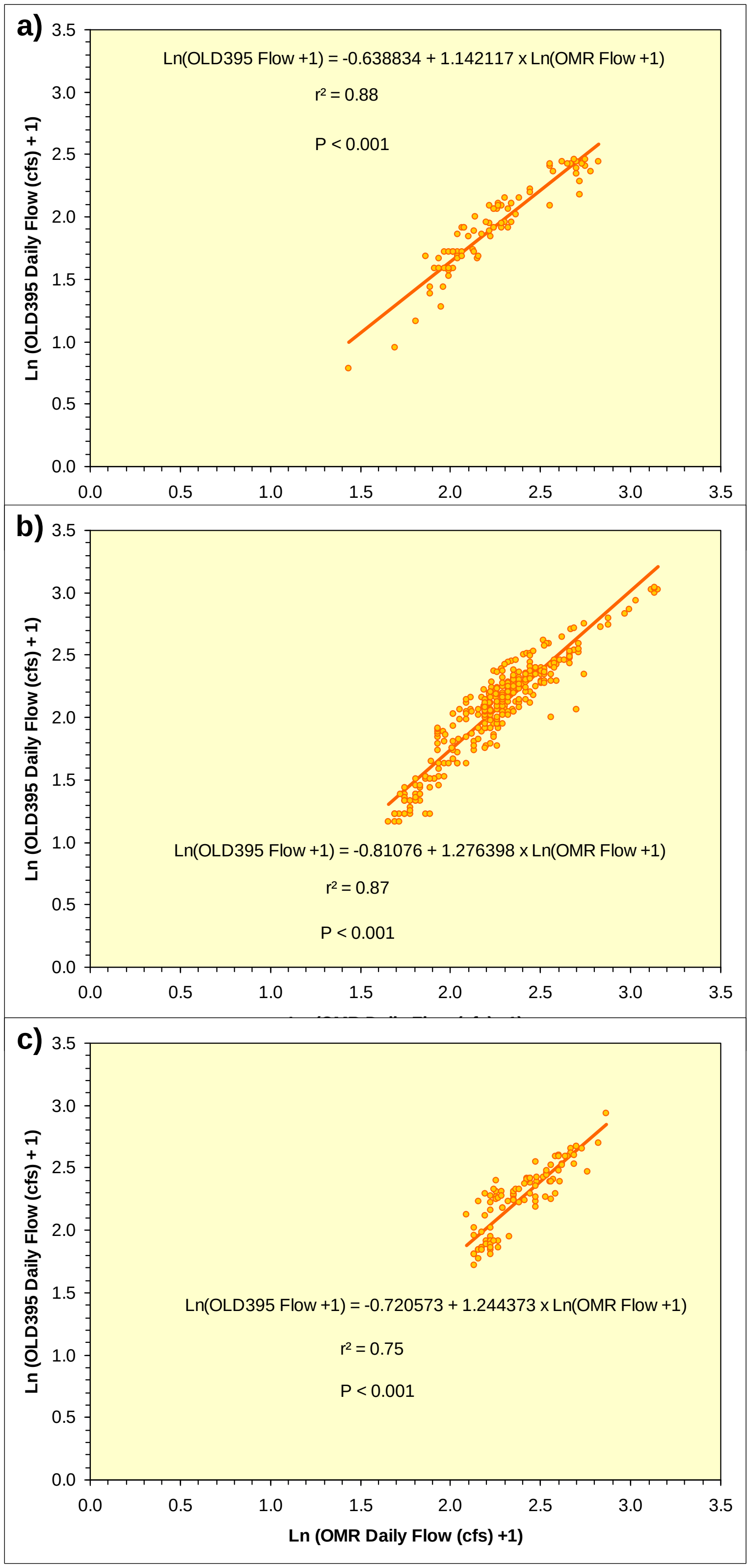


Figure C-26. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Used to Reconstruct OLD395 Gage Daily Flows from OMR Gage Daily Flows during March for (a) Dry, (b) Normal, and (c) Wet Runoff Years

3.5 MODEL TREATMENT OF ACCRETIONS AND DEPLETIONS

Accretions and depletions between the various nodes, and the manner in which accretions and depletions were addressed in the MCWD Model are as follows.

- ❑ Accretions and depletions between the various nodes are not calculated by the MCWD Model.
- ❑ Accretions and depletions are calculated externally and input to the MCWD Model.
- ❑ Accretions and depletions between two adjacent locations (i.e., nodes) are calculated from known points of measurement in Mammoth Creek and reservoirs (see Figure C-1).
- ❑ For each day in the simulated period when there is a reliable data record (see data QA/QC procedure described above) at two adjacent nodes, the accretion or depletion is the resultant difference between the data records at the two nodes.
- ❑ For periods of missing data extending from one to several days, values were estimated based on the data values of the previous and subsequent daily data points, often using simple averaging or linear interpolation.
- ❑ The longer gaps in the data sets, extending for one or more weeks, were typically estimated using linear regression equations, developed by runoff year type and month, for the particular flow locations.
- ❑ After the missing data value is generated, the accretion or depletion is calculated as the difference between the data values at the two nodes.

Because the MCWD Model operates on a daily time-step calculating daily accretions and depletions between consecutive flow gages, daily flow values at the gage locations must be included over the entire modeled hydrologic period. Thus, input to the MCWD Model includes estimates of accretions and depletions derived from both reliable recorded data, as well as reconstructed data to fill in missing data gaps.

4.0 OPERATING RULES

The various operating rules that were applied in the water balance operations model to characterize the MCWD Diversion-Lake Mary-Mammoth Creek system Existing Condition are listed below.

- ❑ MCWD Diversion Rights
  - Direct diversion of up to 5.039 cfs from May 1 through November 1, and 5.0 cfs for the remainder of the year up to the annual (April though March) total of 2,760 AF (Permit 17332, Licenses 5715 and 12593)
  - Diversion to storage of up to 606 AF between April 1 and June 30 each year (Permit 17332)
  - Diversion to storage of up to 54 AF between September 1 and September 30 each year (Permit 17332)

- Lakes' Operation Rules
  - No flood control operation at Lake Mary
  - Lake Mary storage is not used to meet downstream flow requirements
  - No maximum allowable refill rate for Lake Mary
  - Up to 606 AF between April 1 and June 30 each year can be stored in Lake Mary
  - Lake Mary maximum drawdown is 3 ft (325 AF) by September 15
  - Lake Mary total maximum drawdown is 5.7 ft (606 AF)
  - No storage operations at Lake Mamie and Twin Lakes (Forest Service Letter dated 12/14/2005)
- Mammoth Creek Flow Requirements
  - Lake Mary outflow from June 1 through October 31 = 1.5 cfs
  - Twin Lakes outflow from January 1 through December 31 = 3.0 cfs
  - Twin Falls diversion year-round = 0.5 cfs
- MCWD Lake Mary Operation priority for use of inflow (based on the above operation limits and MCWD diversion goals)

  1/1 – 3/31

  - Meet downstream flow requirements
  - Divert up to MCWD demand
  - Divert from Lake Mary storage up to MCWD demand
  - Release remaining inflow

  4/1 – 6/30

  - Meet downstream flow requirements
  - Divert up to MCWD demands
  - Fill Lake Mary (up to 606 AF of fill)
  - Release remaining inflow

  7/1 – 8/31

  - Meet downstream flow requirements
  - Divert up to MCWD demands
  - Divert from Lake Mary storage up to MCWD demand
  - Release remaining inflow

9/1 – 9/30

- Meet downstream flow requirements
- Divert up to MCWD demands
- Fill Lake Mary (up to 54 AF of fill)
- Release remaining inflow

10/1 – 12/31

- Meet downstream flow requirements
- Divert up to MCWD demands
- Divert from Lake Mary storage up to MCWD demand
- Release remaining inflow

4.1 MCWD DEMAND

Mammoth Creek flows are affected by MCWD diversions. Because MCWD is required to operate in compliance with bypass flow requirements, the MCWD Model applies specified operation priorities to meet the flow requirements while attempting to meet MCWD's demand for water diverted at Lake Mary. For the existing condition, actual MCWD Lake Mary diversions are used in the MCWD Model. Alternative modeling scenarios may identify different demands.

4.2 SYSTEM SIMULATION AND INITIAL CONDITIONS

The MCWD Model simulates storage and flows on a serial basis beginning April 1988 through March 2008. Using the "Serial" simulation, the initial model condition (Lake Mary storage) is set to that which historically existed on March 31, 1987 and differences between modeled and historical Lake Mary storage values accrue sequentially throughout the entire period, ending on March 31, 2008.

4.3 ADDITIONAL INPUT PARAMETERS

The MCWD Model also recognizes other input parameters which affect system operations. These parameters are generally associated with facility or Permit/License terms. Although the model operator may alter these values, it is unlikely that they would or should be modified. A list of parameters and their present values follows.

- ❑ Lake Mary starting storage = 2,692 AF (midnight 3/31/1988)
- ❑ Lake Mary maximum storage = 3,200 AF
- ❑ Lake Mary minimum storage, January 1 through June 30 and September 16 through December 31 = 2,595 AF
- ❑ Lake Mary minimum storage, July 1 through September 15 = 2,875 AF
- ❑ Lake Mary daily refill criteria, April 1 through June 30 = approximation of historic operations

5.0 MODEL PERFORMANCE

The MCWD Model has been developed to simulate existing flow conditions and alternative operation scenarios – specifically, alternative bypass flow requirements and MCWD levels of demand. As previously discussed, the MCWD Model incorporates input parameters and applies operational rules and priorities to simulate outputs (e.g., streamflows, diversions and lake storages). In effect, if the MCWD Model rules are identical to those which were observed during the hydrologic period of record, then modeled and existing condition (i.e., historical) streamflows, diversions and lake storages would be identical. In reality, there are several reasons why the results will not be identical.

As previously mentioned, the MCWD Model does not take travel time into account when performing the system mass balance. Consequently, model output shows that water released into Mammoth Creek from Lake Mary on a given day will arrive at every downstream flow node on that same day. In reality, the release could take one or more days to transit the creek.

The MCWD Model also is more efficient than human operators. The MCWD Model will store water in Lake Mary whenever conditions and operating constraints allow, and will make instantaneous release changes with perfect foresight for meeting bypass flow requirements. Again, in reality, operators are not equipped to make instantaneous changes to releases, nor can they identify the precise release necessary to meet a bypass flow requirement one or more days in the future.

As a result of the travel time limitation and the lack of information describing the exact historical actions taken by system operators to set releases or store water in Lake Mary, the MCWD Model cannot perfectly reproduce historical operations. The inability of the MCWD Model to perfectly reproduce historical conditions does not obviate the utility of the model for alternative operational scenario comparisons, as long as the model output reasonably approximate expected conditions. Model performance can be evaluated by comparing model simulations of existing condition (i.e., historical) flows at the OMR gage to flows that actually occurred at that gage over the simulation period (runoff years 1988-2007).

5.1 COMPARISON OF ANNUALLY OBSERVED AND MODELED OMR FLOWS

Measured (i.e., historical) OMR daily flows were compared to the modeled historical OMR daily flows for each of the 20 runoff years of the modeled hydrological period. For these comparisons, the observed OMR flows were the daily measured flows at the OMR gage that remained following the data QA/QC procedure described in Section 3.4. The modeled OMR flows were those obtained by applying the MCWD Model to simulate flows at the OMR gage flow node.

For each runoff year, the comparison of historical and modeled OMR flows included the following graphs and calculations:

- ❑ Scatter plot of the modeled flows as a function of the historical flows to visualize the distribution of the data points with respect to the identity line (i.e., the line of perfect agreement between historical and modeled flows)
- ❑ Calculation of the difference of modeled minus historical flows
- ❑ Histogram of the flow differences with a fitted normal distribution overlaid to visually inspect departures from normality

- Calculation of the correlation coefficient (*r*) to evaluate the presence and strength of any linear relationship existing between the modeled and historical flows
- Calculation of the general bias of the modeled flows with respect to the historical flows (*B*) and its statistical significance (*p*).

Additionally, the results for each runoff year include the correlation coefficient (i.e., r) for the corresponding historical flows at OMR (HF_{OMR}) and modeled flows at OMR (MF_{OMR}) series, its standard error (i.e., SE_r), t statistic (i.e., t_r) and p-value p that gives the probability of rejecting the null hypothesis that the correlation is equal to zero, when it is in fact true. The formulae used to calculate r, SE_r and t_r were:

$$r = \frac{\sum_n \left(HF_{OMR} - \overline{HF}_{OMR}\right) \times \left(MF_{OMR} - \overline{MF}_{OMR}\right)}{\sqrt{\sum_n \left(HF_{OMR} - \overline{HF}_{OMR}\right)^2 \times \sum_n \left(MF_{OMR} - \overline{MF}_{OMR}\right)^2}}; \qquad SE_r = \sqrt{\frac{1-r^2}{n-2}}; \qquad \text{and}$$

$t_r = \dfrac{r}{SE_r}$, where n is the sample size, and $\overline{HF}_{OMR}$ and $\overline{MF}_{OMR}$ are the averages for the two flow series.

Finally, the bias of the modeled flows with respect to the historical flows, its standard error, t statistic and probability of rejecting the null hypothesis that the bias is equal to zero, when it is in fact true were also calculated using the following formulae:

$$Bias = \sum_n d \Big/ n; \qquad SE_{Bias} = \sqrt{\frac{\sum_n \left(d - Bias\right)^2}{n \times \left(n-1\right)}} \text{;and} \qquad t_{Bias} = \frac{Bias}{SE_{Bias}}.$$

The results of these comparisons are summarized in **Table C-4**. Results for each individual runoff year are presented in **Figures C-27** through **C-46**.

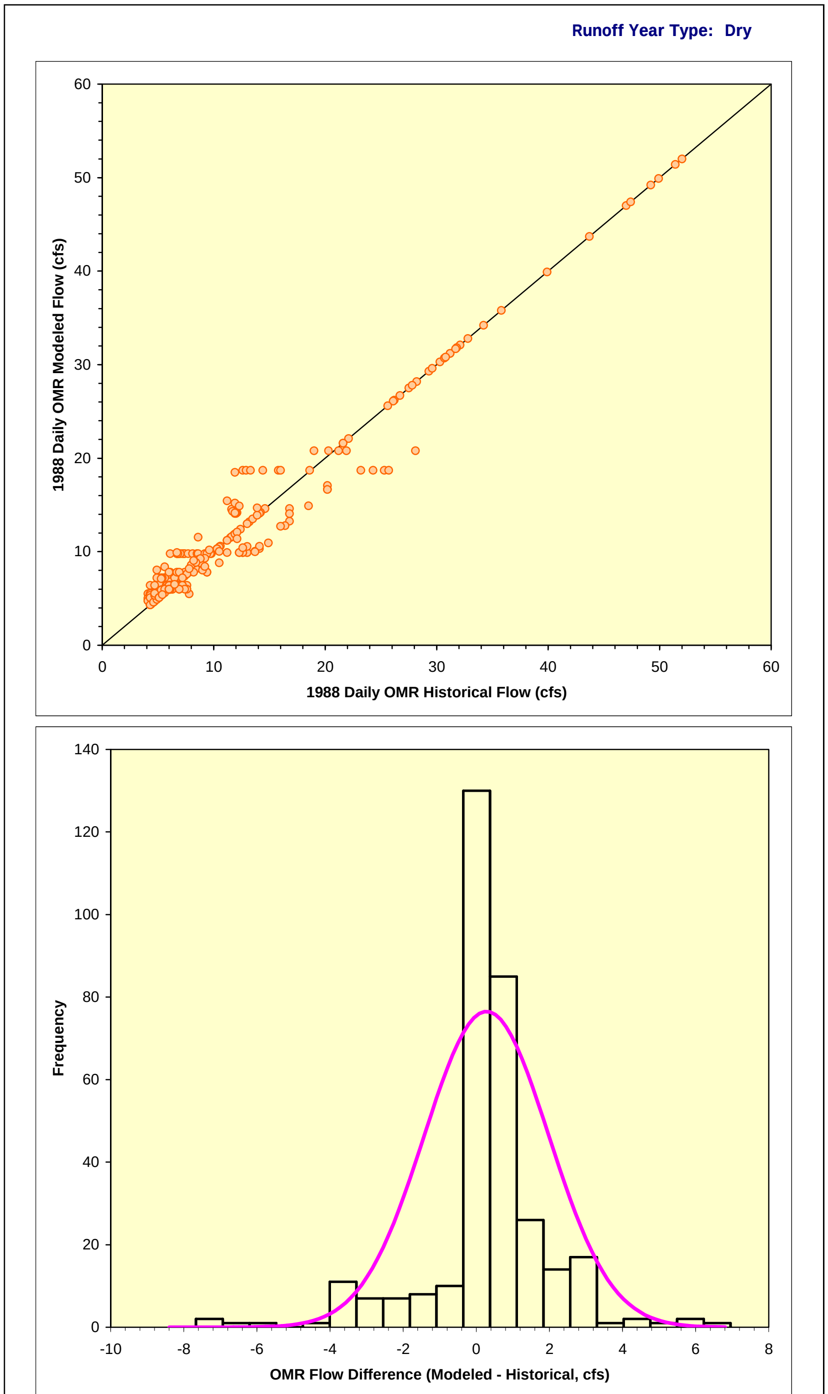
All of the scatter plots in Figures C-27 through C-46 indicate the presence of strong linear relationships of modeled flows as a function of historical OMR flows. In fact, the correlation coefficients were always greater than 0.97 and highly significant for the 20 modeled runoff years (Table C-4). A closer inspection of these plots indicates that the data points did not always distribute randomly about the identity lines. Instead, data points frequently were distributed either below or above the identity lines.

The histograms of the daily difference of modeled minus historical flows indicate that the distributions of flow differences generally did not conform to normal distributions. Instead, the histograms generally suggest leptokurtic distributions (i.e., distributions that have more concentration of values around the mean), that were often skewed (i.e., not symmetric). The means or averages of the daily flow differences of each runoff year are the measure of the overall bias (*B*) of the modeled flows relative to the historical flows. Examination of Table C-4 and Figures C-27 through C-46 indicate that eight of the 20 years exhibited no significant bias, four of the 20 years exhibited a significant negative bias, and the remaining eight years exhibited a significant positive bias.

One potential contribution to the bias observed between modeled and historic flows at the OMR gage may be attributable to the greater uncertainty of measured and unmeasured hydrologic influences during periods of higher precipitation. Real-time Lake Mary operations will be different than the modeled instantaneous operation for reasons associated with the infrastructure configuration and personnel safety concerns. These operational differences coupled with other factors like stream bank overflow or local precipitation events all contribute to differences. It is also important to recognize that the availability of measured data is reduced during the wettest months of the year (see Table C-1). The absence of complete data during the wet months creates a situation where estimates of flow at one or more locations are necessary to construct the model input.

Table C-4. Correlation Coefficients (r) and Bias (B) of the Modeled OMR Flows with Respect to the Historical Flows, and Their Respective Statistical Significance (p) for Each Runoff Year of the Modeled Hydrological period (April 1988 through March 2008)

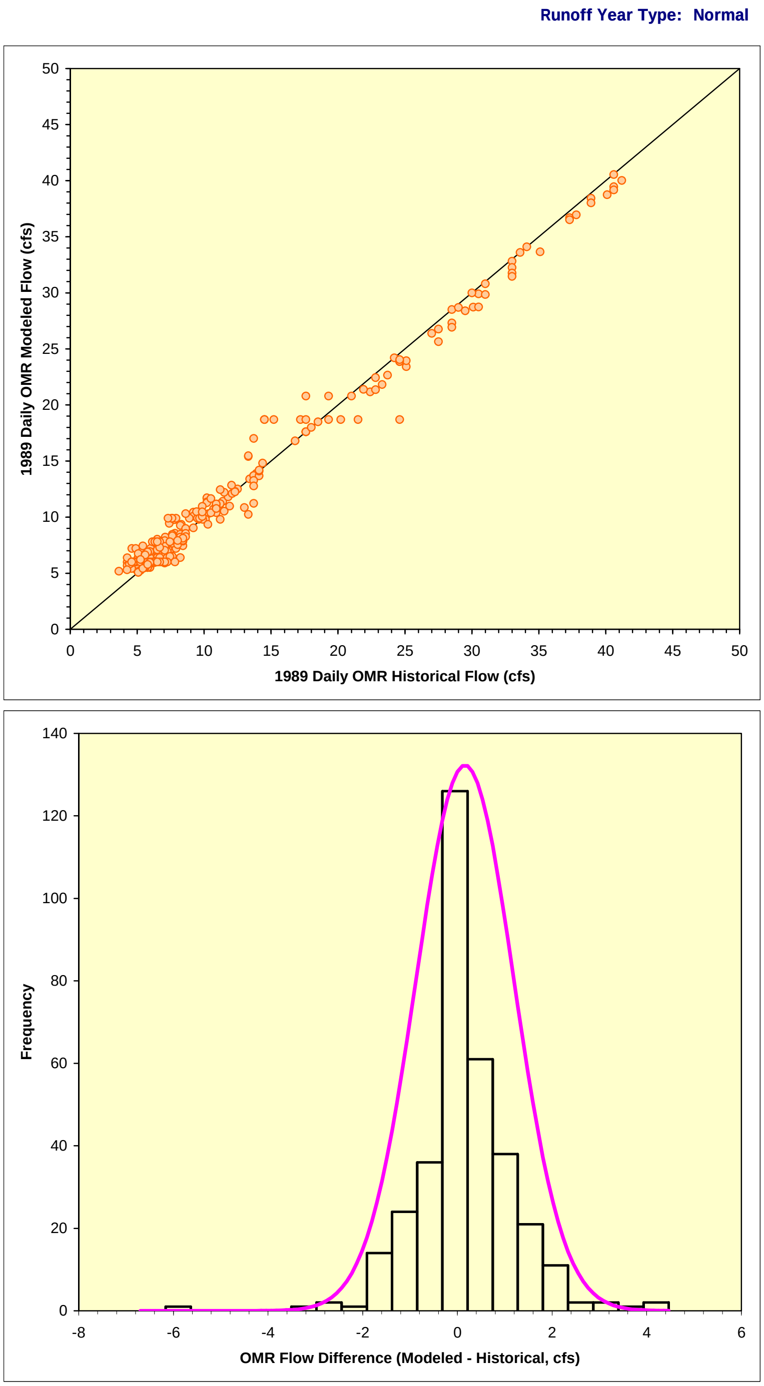
Runoff Year	Type	Correlation		Bias	
		r	***p***	***B***	***p***
1988	D	0.982	< 0.001	0.280	0.003
1989	N	0.993	< 0.001	0.160	0.004
1990	D	0.978	< 0.001	1.152	< 0.001
1991	N	0.995	< 0.001	0.406	< 0.001
1992	N	0.981	< 0.001	0.166	0.024
1993	W	0.999	< 0.001	-0.639	< 0.001
1994	D	0.991	< 0.001	0.191	0.029
1995	W	0.999	< 0.001	-0.255	0.006
1996	N	0.996	< 0.001	-0.098	0.549
1997	N	0.998	< 0.001	-0.149	0.072
1998	N	0.999	< 0.001	-0.208	0.007
1999	N	0.996	< 0.001	0.278	0.029
2000	N	0.999	< 0.001	-0.010	0.869
2001	N	0.998	< 0.001	0.091	0.190
2002	N	0.995	< 0.001	-0.191	0.028
2003	N	0.992	< 0.001	-0.324	0.079
2004	N	0.988	< 0.001	0.211	0.071
2005	W	1.000	< 0.001	-0.011	0.869
2006	W	0.996	< 0.001	0.475	0.051
2007	D	0.988	< 0.001	0.347	< 0.001



Sample size = 327

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	0.98	0.01	94.18	< 0.001
Bias	0.28	0.09	2.97	0.003

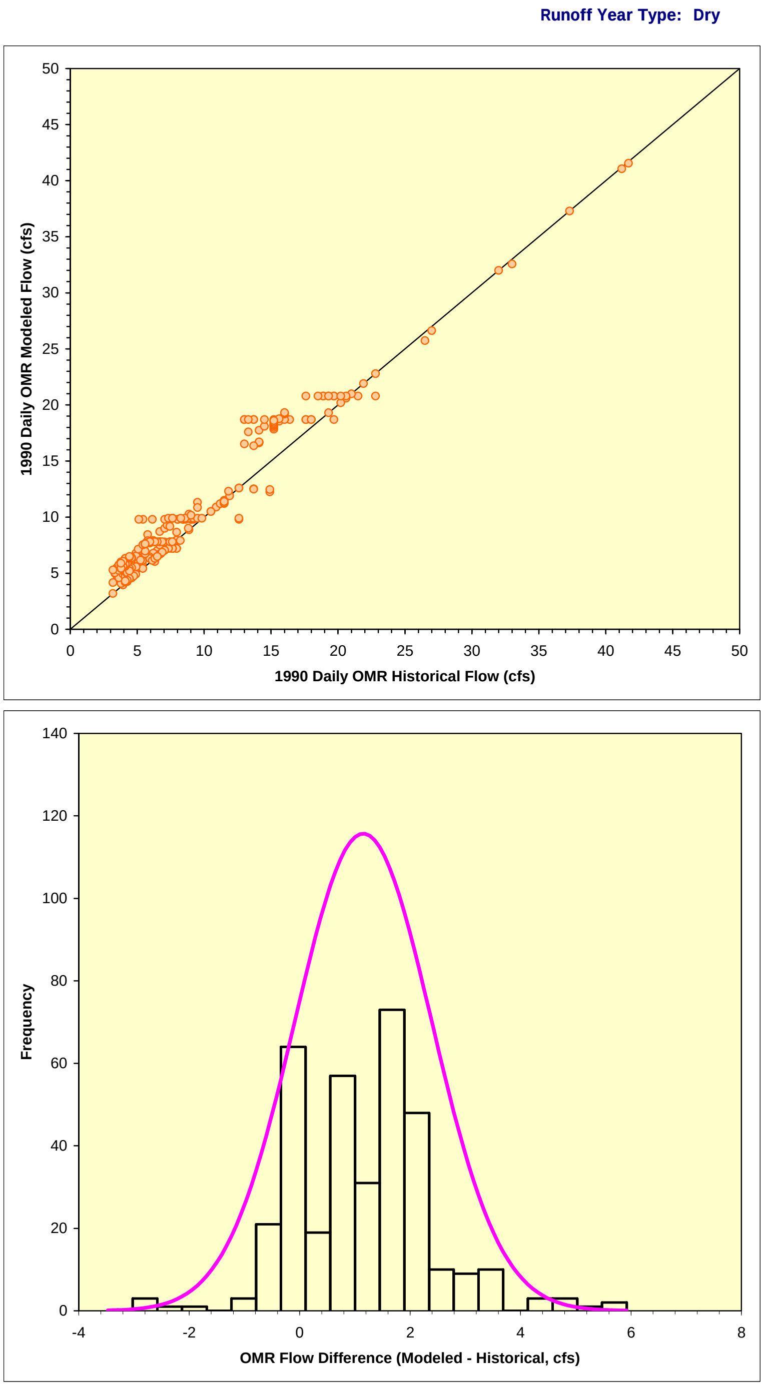
Figure C-27. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 1988 (April 1, 1988 through March 31, 1989)



Sample size = 343

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	0.99	0.01	157.34	< 0.001
Bias	0.16	0.06	2.87	0.004

Figure C-28. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 1989 (April 1, 1989 through March 31, 1990)

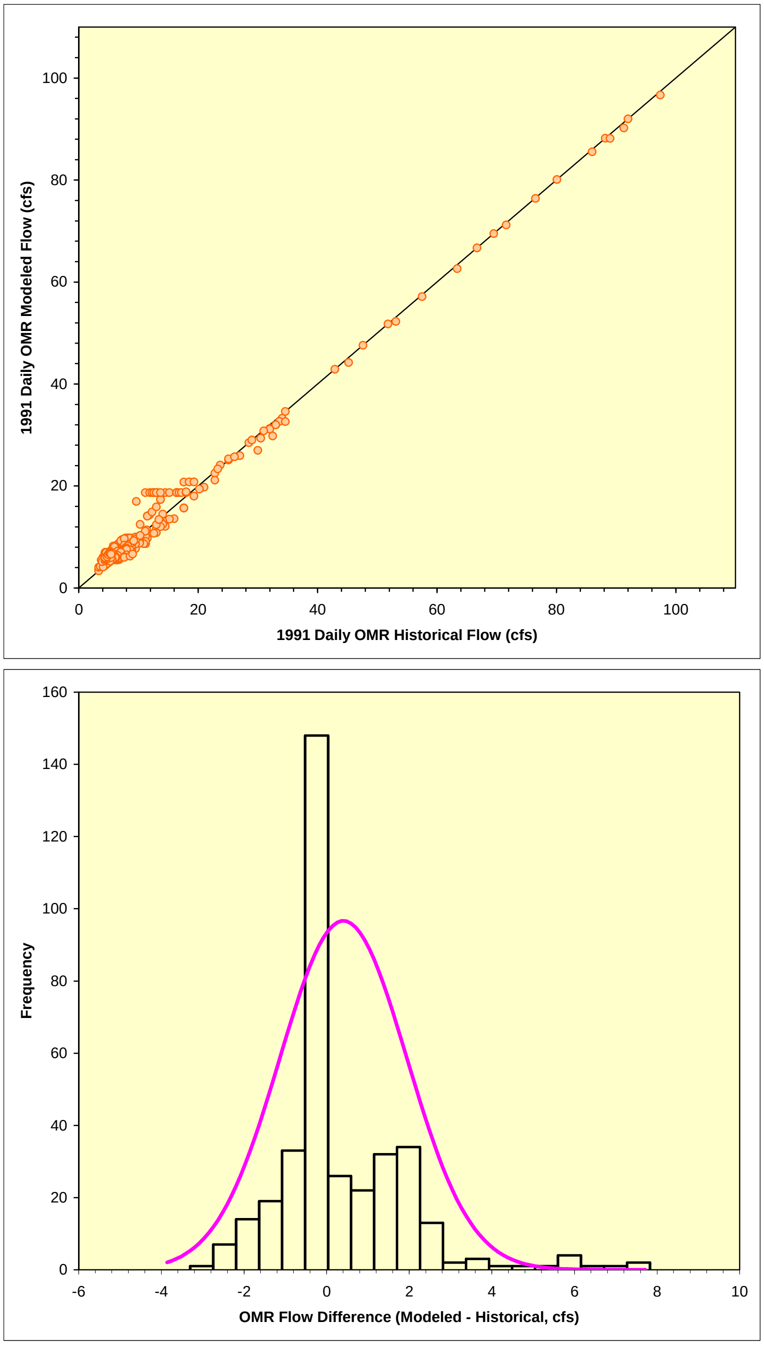


Sample size = 359

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	0.98	0.01	88.88	< 0.001
Bias	1.15	0.07	17.61	< 0.001

Figure C-29. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 1990 (April 1, 1990 through March 31, 1991)

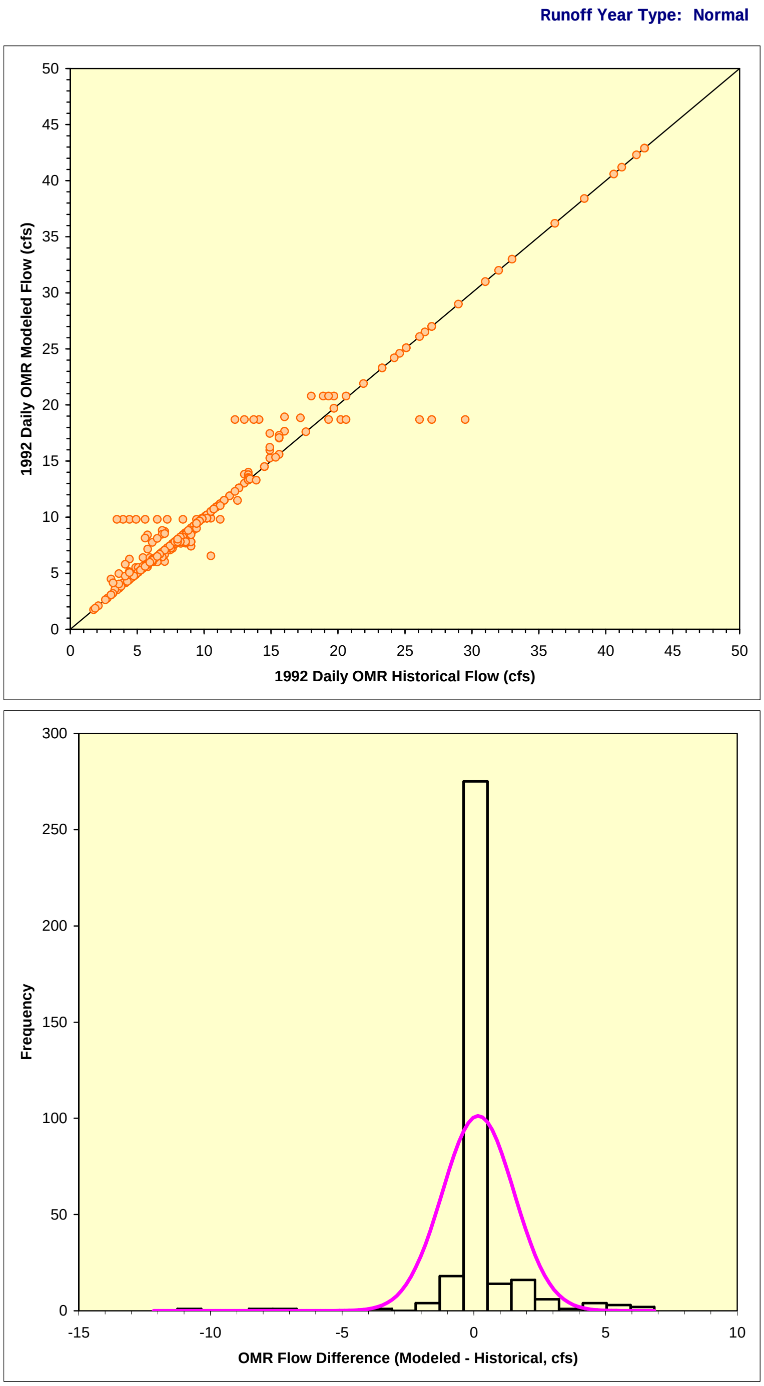
Runoff Year Type: Normal



Sample size = 365

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	0.99	0.01	187.76	< 0.001
Bias	0.41	0.08	5.04	< 0.001

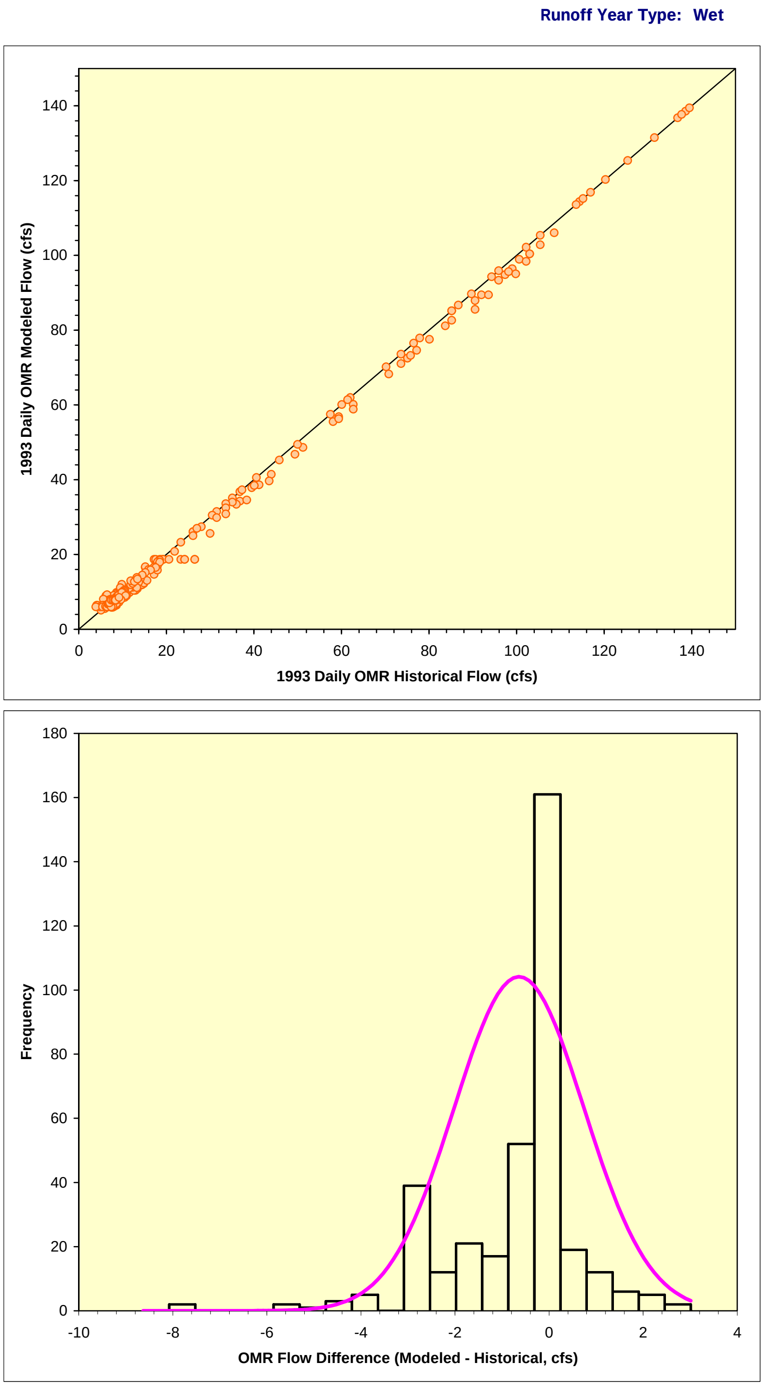
Figure C-30. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 1991 (April 1, 1991 through March 31, 1992)



Sample size = 347

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	0.98	0.01	94.12	< 0.001
Bias	0.17	0.07	2.26	0.024

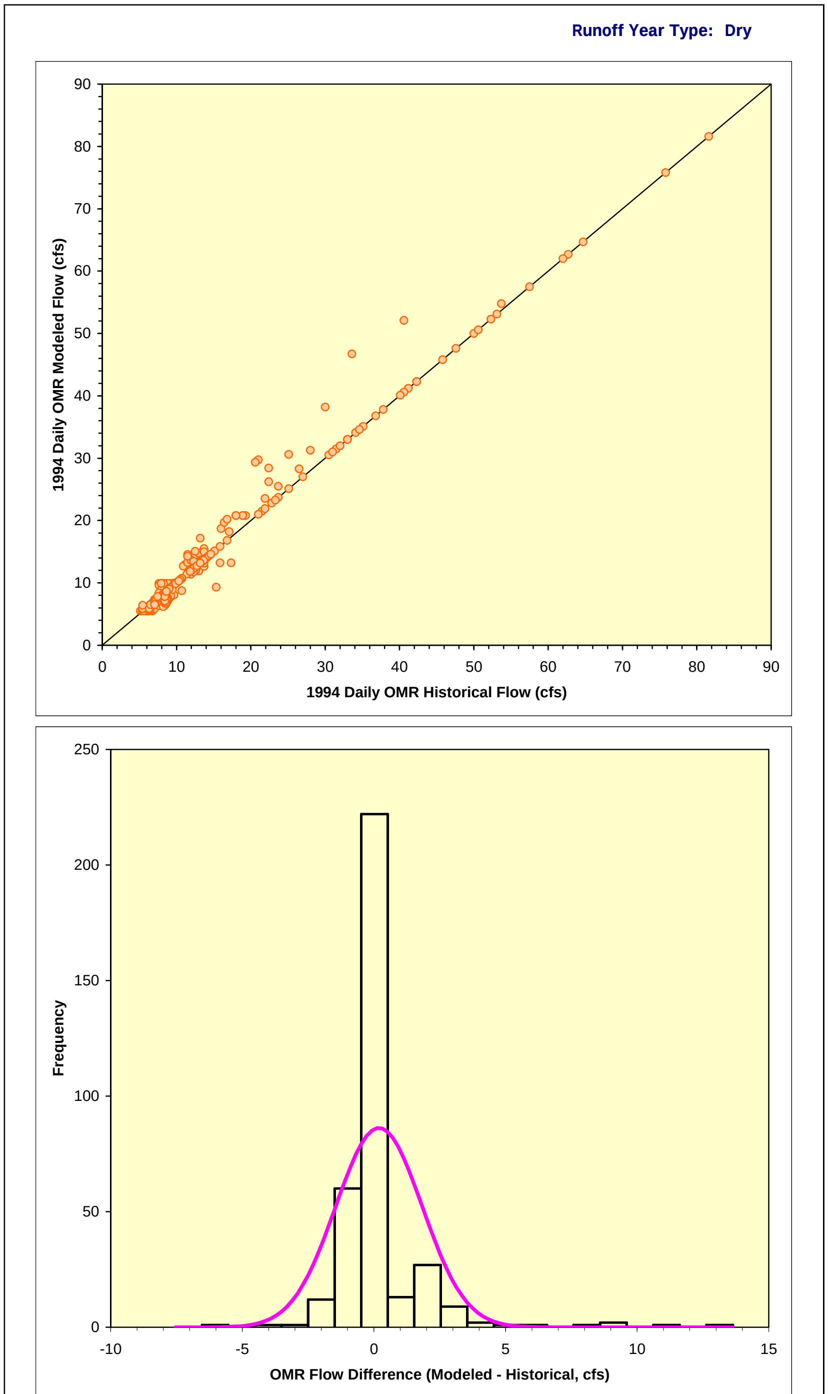
Figure C-31. Comparison of Measured Daily (i.e., historical) Flows and Modeled Flows at OMR Gage for Runoff Year 1992 (April 1, 1992 through March 31, 1993)



Sample size = 359

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	1.00	0.00	445.31	< 0.001
Bias	-0.64	0.07	-8.76	< 0.001

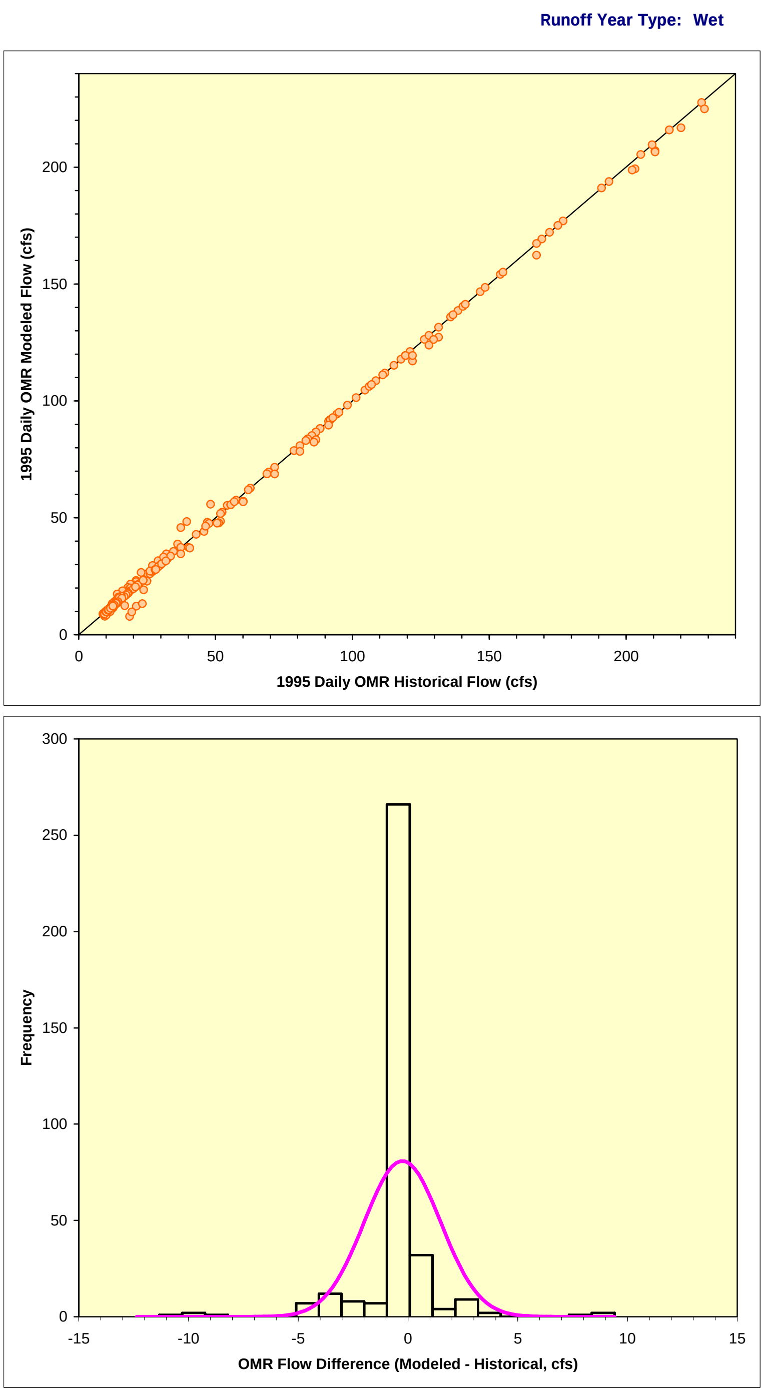
Figure C-32. Comparison of Measured Daily (i.e., historical) Flows and Modeled Flows at OMR Gage for Runoff Year 1993 (April 1, 1993 through March 31, 1994)



Sample size = 355

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	0.99	0.01	139.85	< 0.001
Bias	0.19	0.09	2.19	0.029

Figure C-33. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 1994 (April 1, 1994 through March 31, 1995)

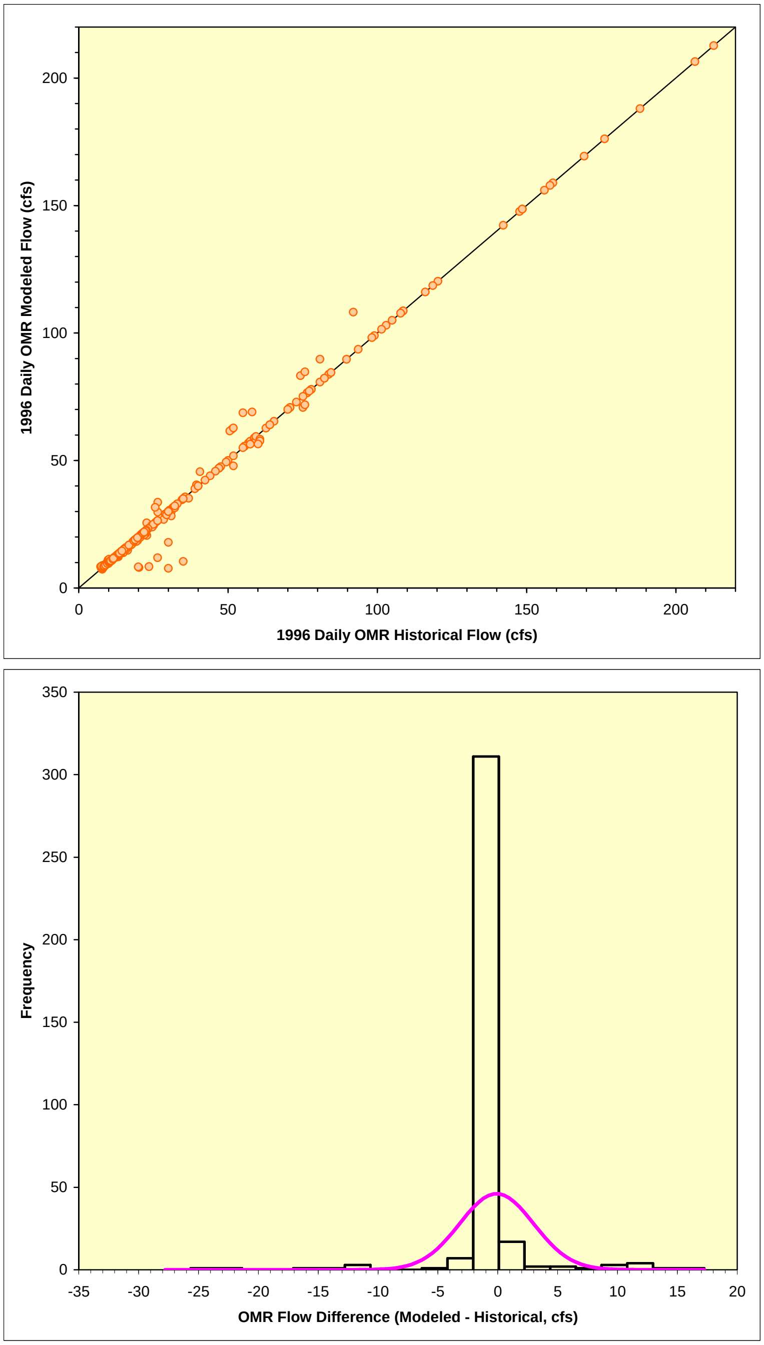


Sample size = 354

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	1.00	0.00	555.46	< 0.001
Bias	-0.25	0.09	-2.75	0.006

Figure C-34. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 1995 (April 1, 1995 through March 31, 1996)

Runoff Year Type: Normal

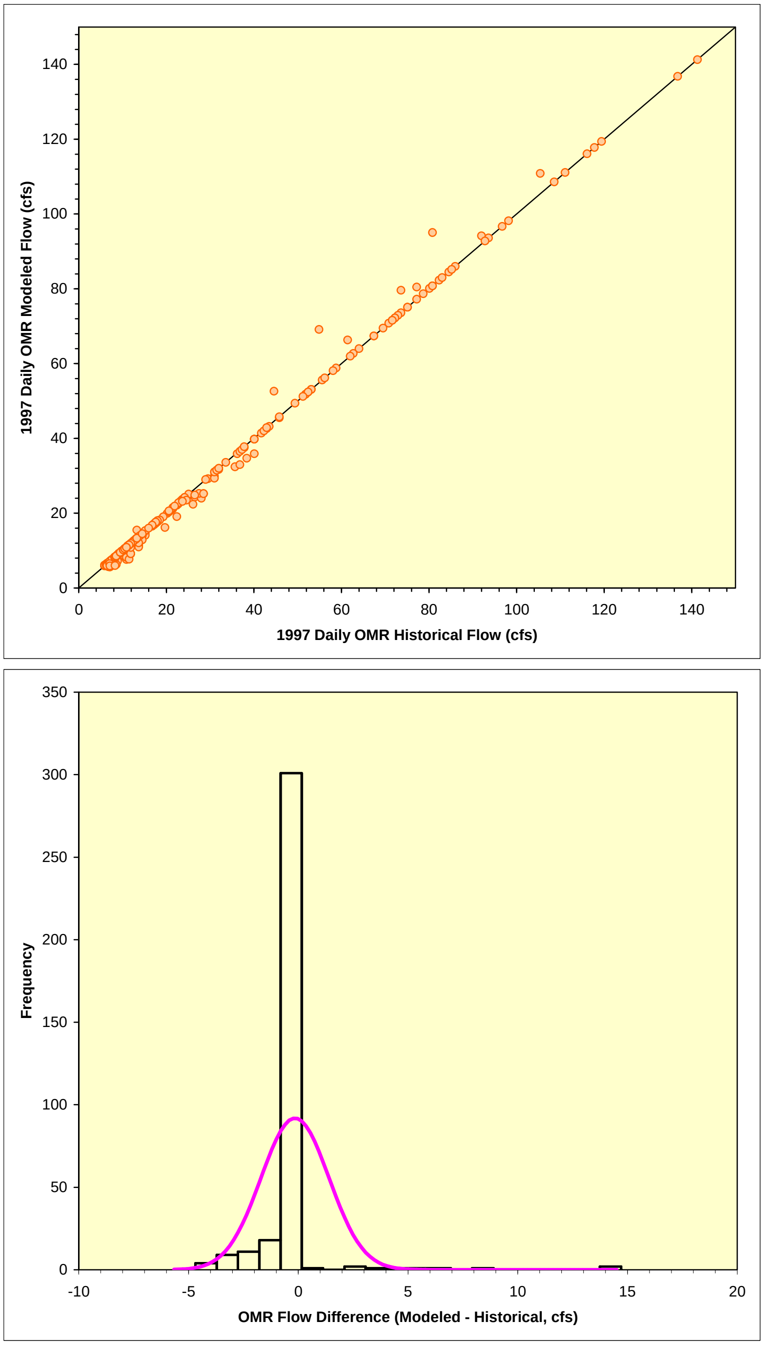


Sample size = 357

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	1.00	0.00	218.68	< 0.001
Bias	-0.10	0.16	-0.60	0.549

Figure C-35. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 1996 (April 1, 1996 through March 31, 1997)

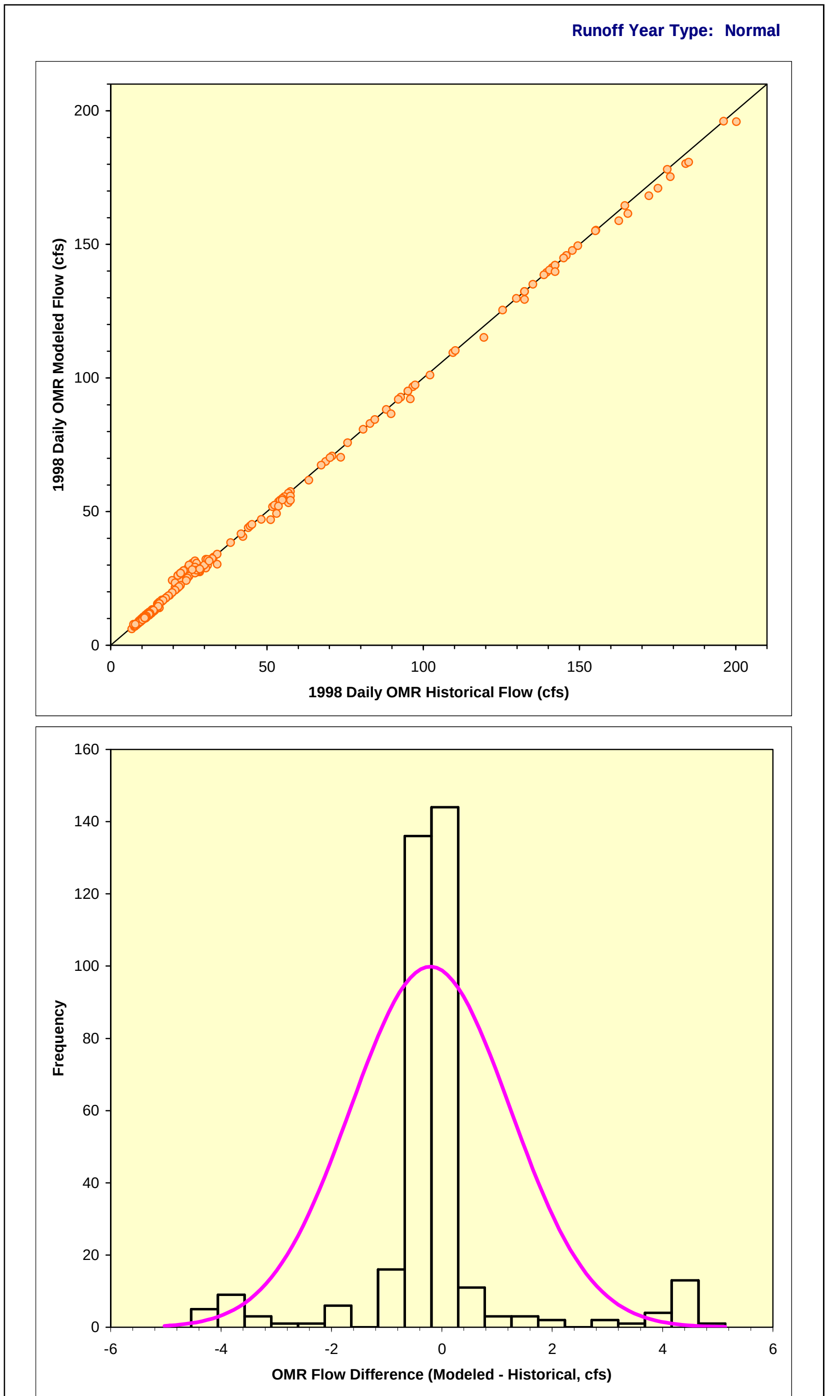
Runoff Year Type: Normal



Sample size = 353

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	1.00	0.00	325.58	< 0.001
Bias	-0.15	0.08	-1.80	0.072

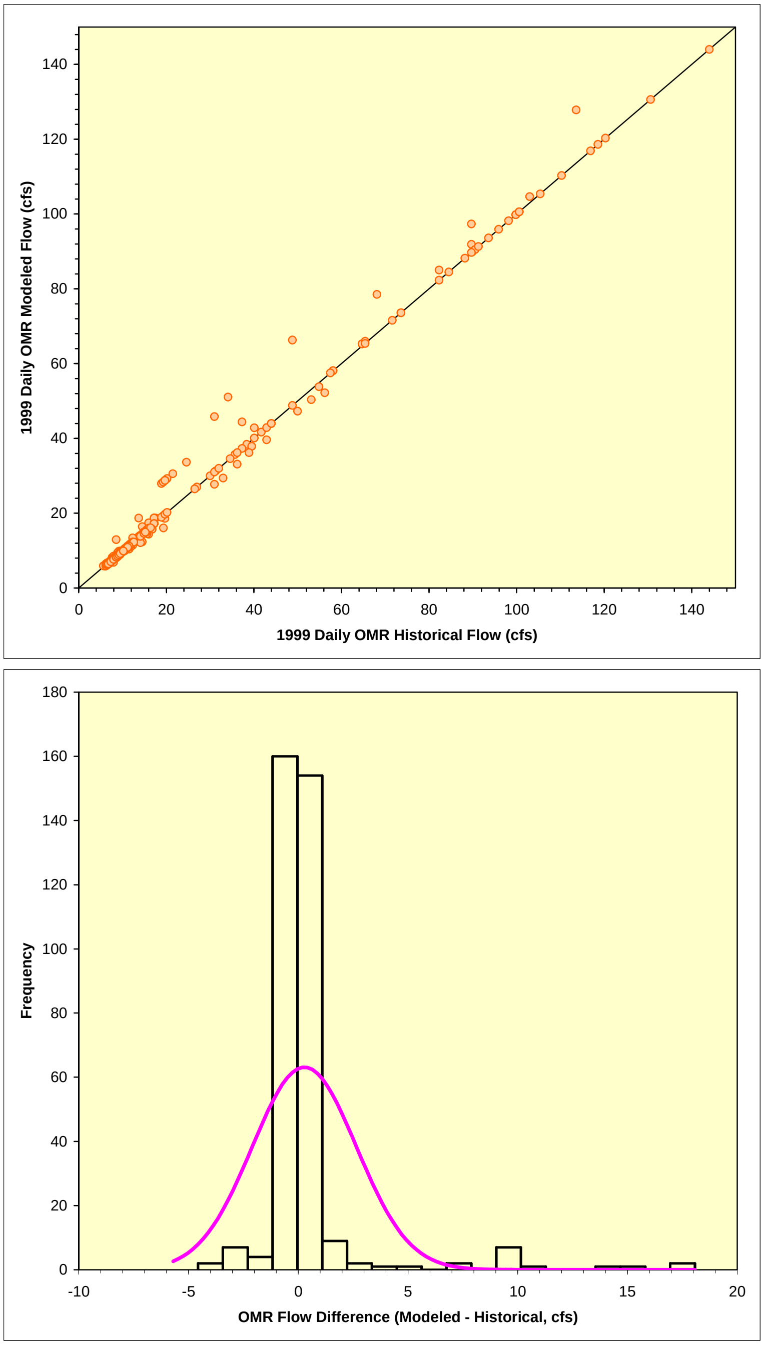
Figure C-36. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 1997 (April 1, 1997 through March 31, 1998)



Sample size = 361

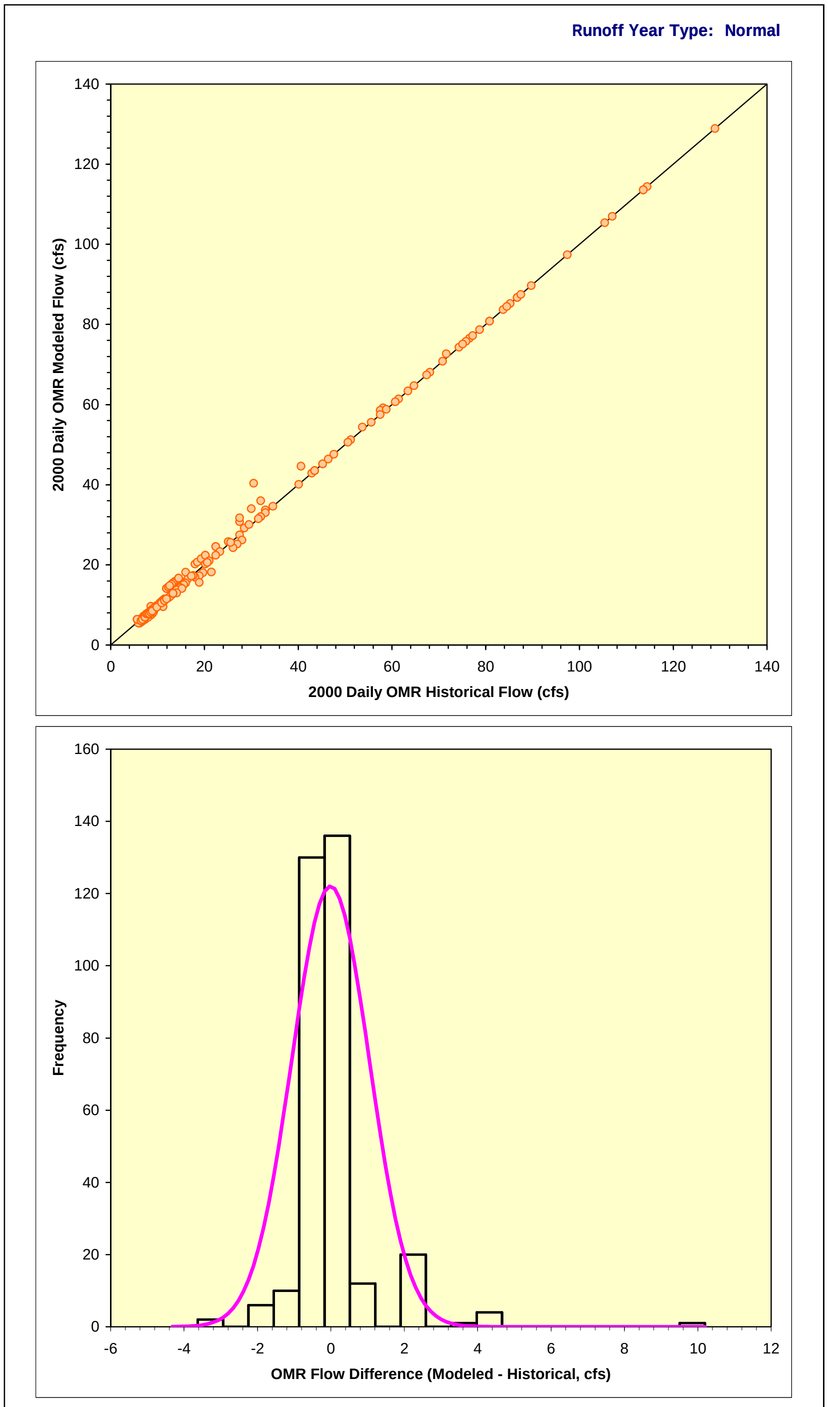
Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	1.00	0.00	577.06	< 0.001
Bias	-0.21	0.08	-2.73	0.007

Figure C-37. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 1998 (April 1, 1998 through March 31, 1999)



Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	1.00	0.00	212.39	< 0.001
Bias	0.28	0.13	2.20	0.029

Figure C-38. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 1999 (April 1, 1999 through March 31, 2000)

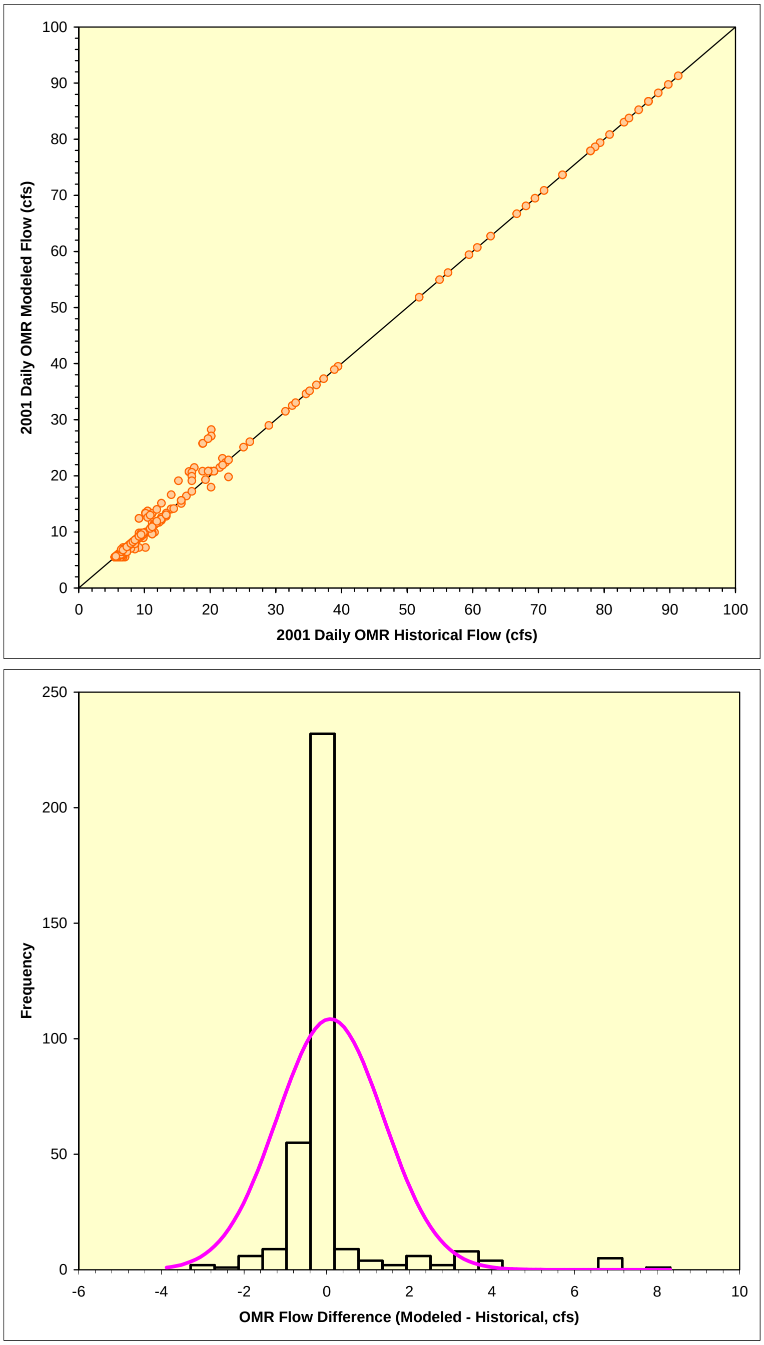


Sample size = 322

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	1.00	0.00	408.52	< 0.001
Bias	-0.01	0.06	-0.17	0.869

Figure C-39. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 2000 (April 1, 2000 through March 31, 2001)

Runoff Year Type: Normal

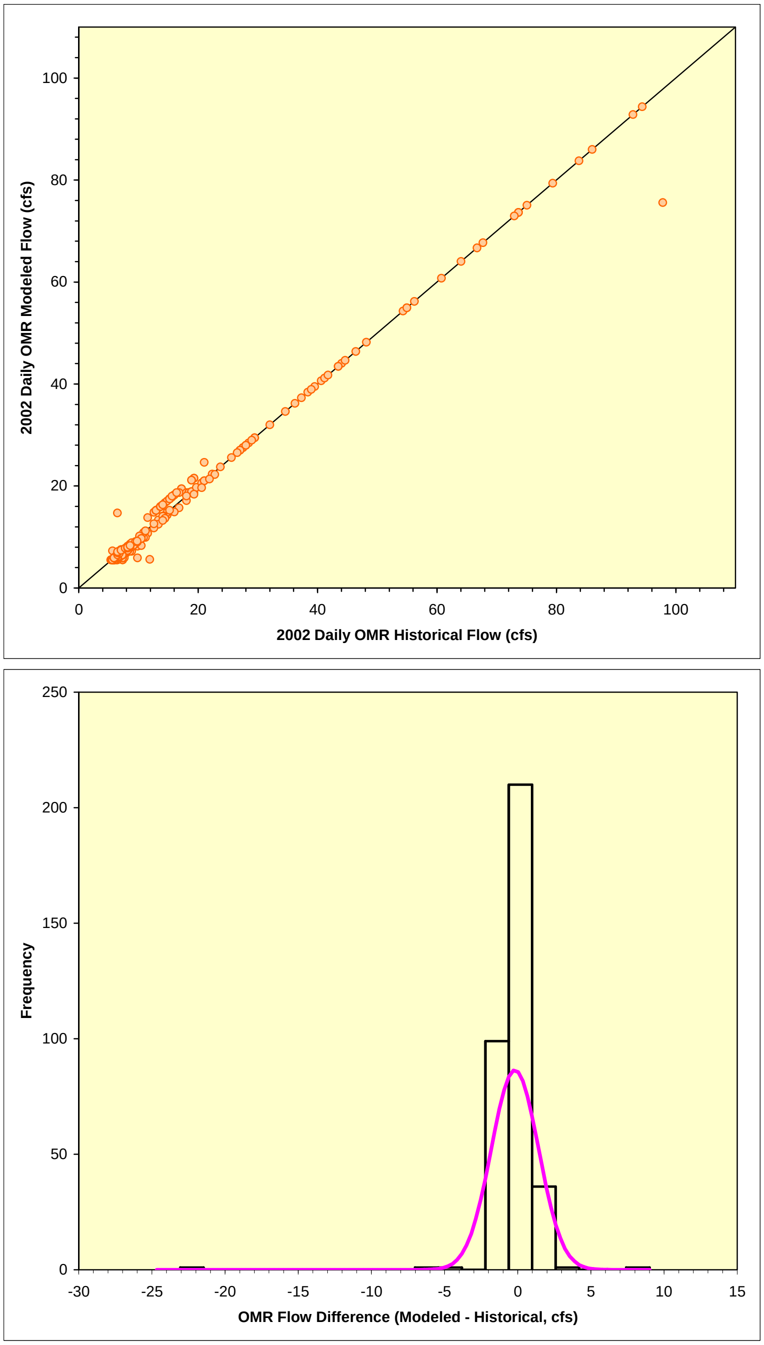


Sample size = 346

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	1.00	0.00	269.55	< 0.001
Bias	0.09	0.07	1.31	0.190

Figure C-40. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 2001 (April 1, 2001 through March 31, 2002)

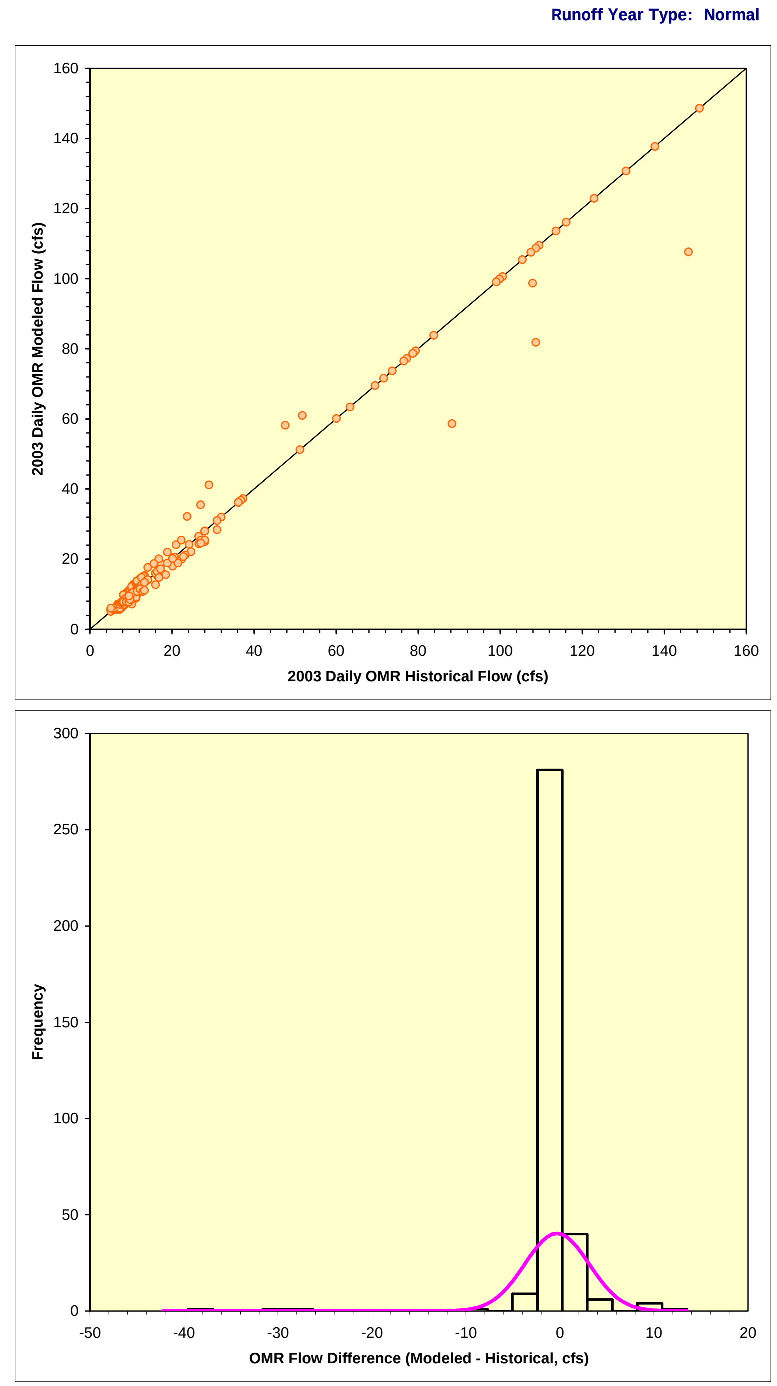
Runoff Year Type: Normal



Sample size = 350

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	0.99	0.01	185.67	< 0.001
Bias	-0.19	0.09	-2.21	0.028

Figure C-41. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 2002 (April 1, 2002 through March 31, 2003)

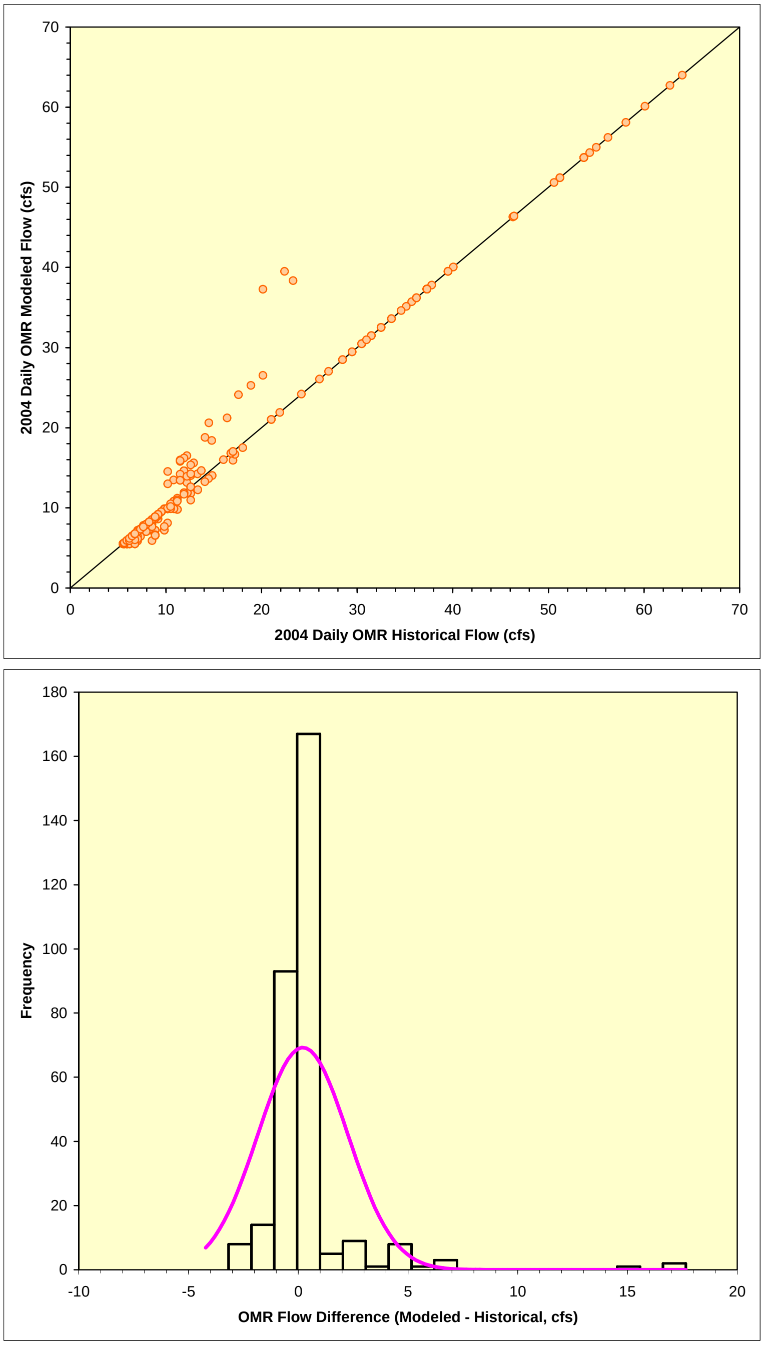


Sample size = 345

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	0.99	0.01	143.84	< 0.001
Bias	-0.32	0.18	-1.76	0.079

Figure C-42. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 2003 (April 1, 2003 through March 31, 2004)

Runoff Year Type: Normal

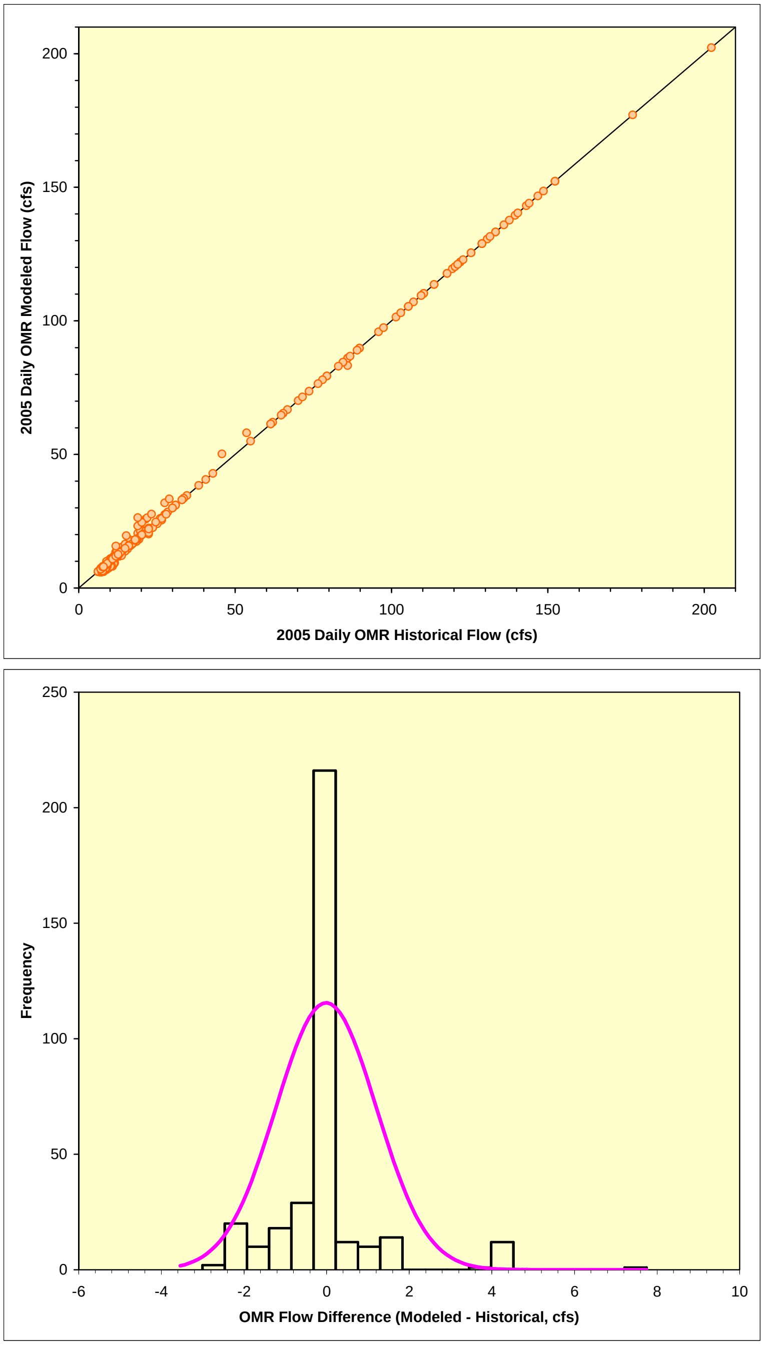


Sample size = 312

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	0.99	0.01	111.06	< 0.001
Bias	0.21	0.12	1.81	0.071

Figure C-43. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 2004 (April 1, 2004 through March 31, 2005)

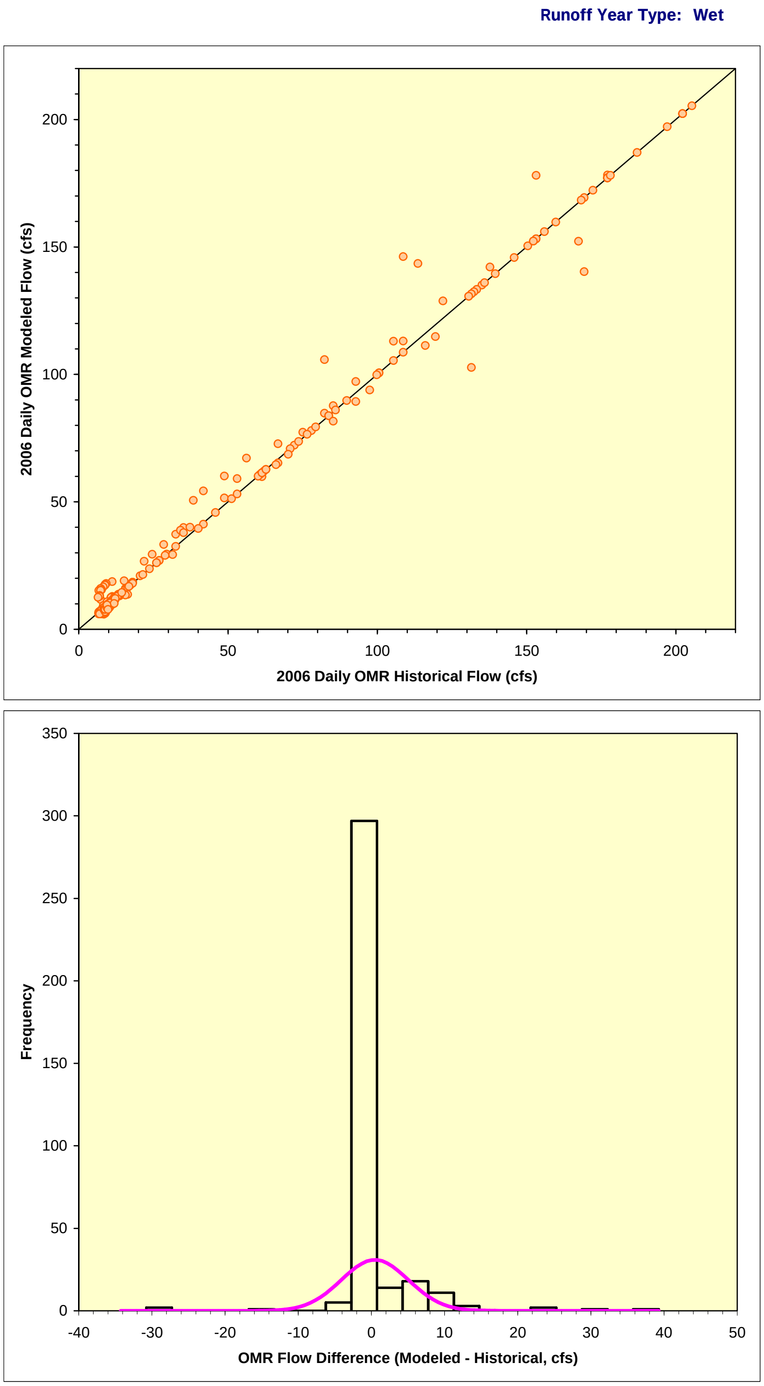
Runoff Year Type: Wet



Sample size = 345

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	1.00	0.00	623.51	< 0.001
Bias	-0.01	0.07	-0.16	0.869

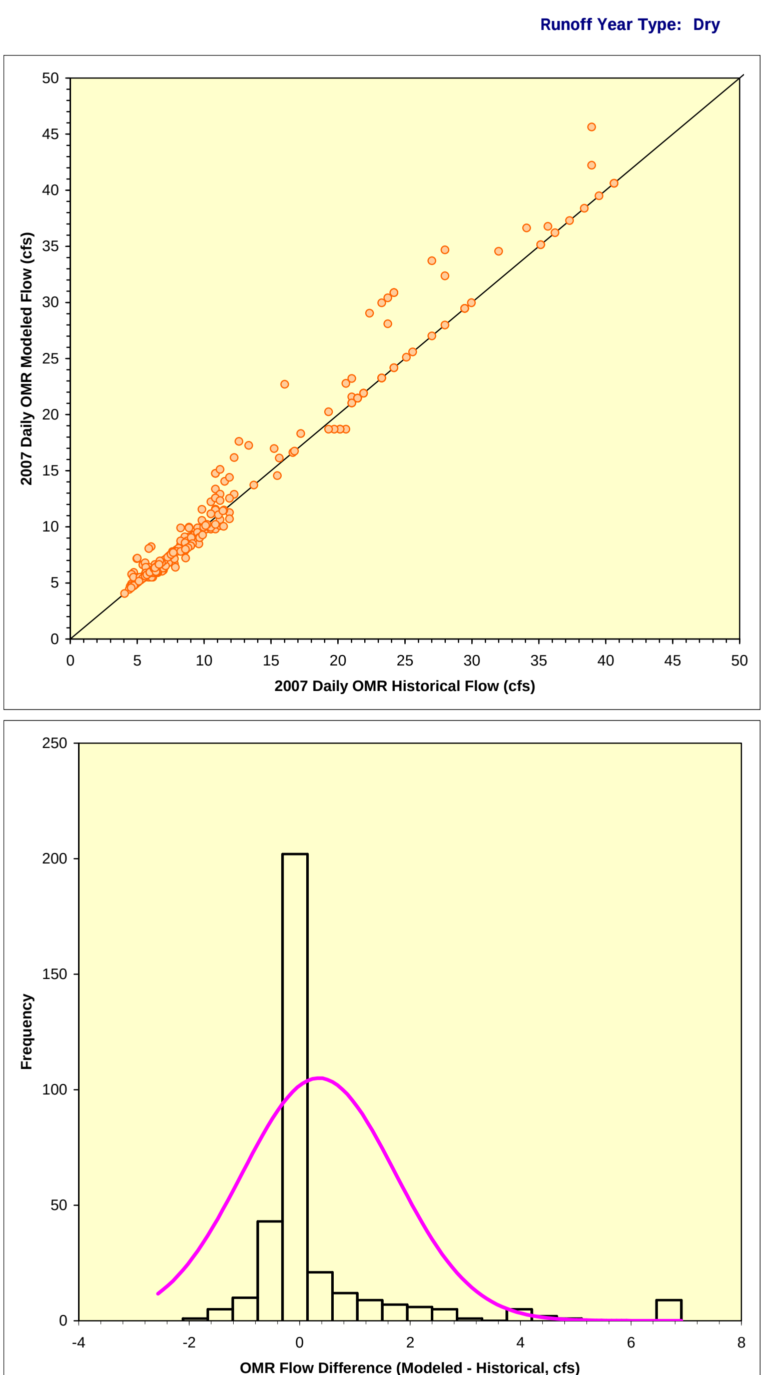
Figure C-44. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 2005 (April 1, 2005 through March 31, 2006)



Sample size = 355

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	1.00	0.00	204.36	< 0.001
Bias	0.48	0.24	1.96	0.051

Figure C-45. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 2006 (April 1, 2006 through March 31, 2007)



Sample size = 339

Statistic	Value	*SE*	*t* Statistic	*p*
Correlation *r*	0.99	0.01	117.12	< 0.001
Bias	0.35	0.08	4.60	< 0.001

Figure C-46. Comparison of Measured Daily (i.e., Historical) Flows and Modeled Flows at OMR Gage for Runoff Year 2007 (April 1, 2007 through March 31, 2008)

5.2 COMPARISON OF MONTHLY OBSERVED AND MODELED OMR FLOWS

Modeled historical OMR daily flows were compared to the measured historical OMR daily flows for each month of the 20 runoff years included in the modeled hydrologic period. For these comparisons, the measured OMR flows were the daily measured flows at the OMR gage that remained following the data QA/QC procedure described in section 3.4. The modeled OMR daily flows were those obtained by applying the MCWD Model to simulate daily flows at the OMR gage. The intercept and slope parameters, coefficients of determination (r^2), and levels of significance (P) of the linear regressions between monthly historical simulated daily flows at the OMR gage and measured historical daily flows at the OMR gage are presented in **Figures C-47** through **C-58**.

Examination of the scatter plots in Figures C-47 through C-58 indicated a consistent trend for each of the 12 months included in the evaluation. This trend is characterized by a number of data points where the modeled OMR daily flow is equal to the minimum bypass requirement for that month, whereas the corresponding measured daily flow is persistently variable (represented by the area included within the outlined demarcation in Figures C-47 through C-58).

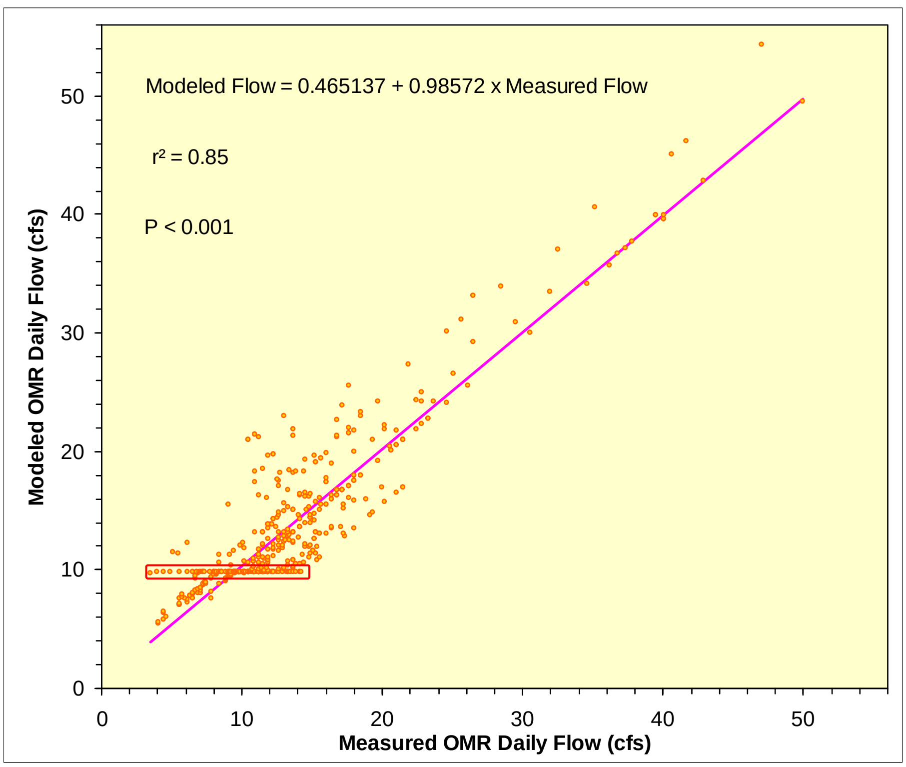


Figure C-47. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during April of 1988-2007 Runoff Years

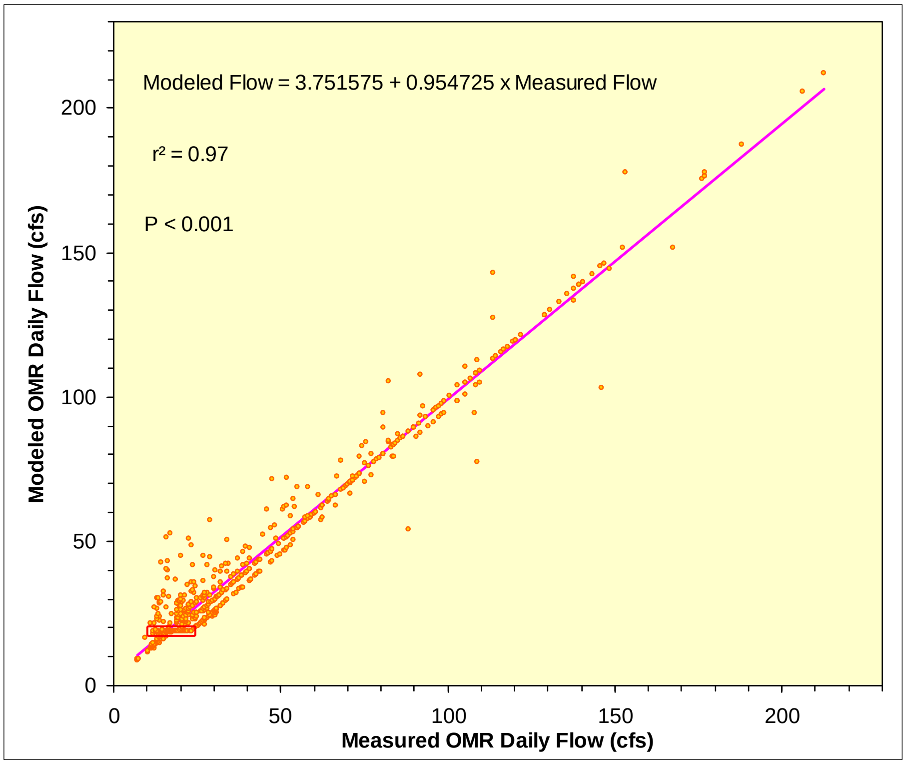


Figure C-48. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during May of 1988-2007 Runoff Years

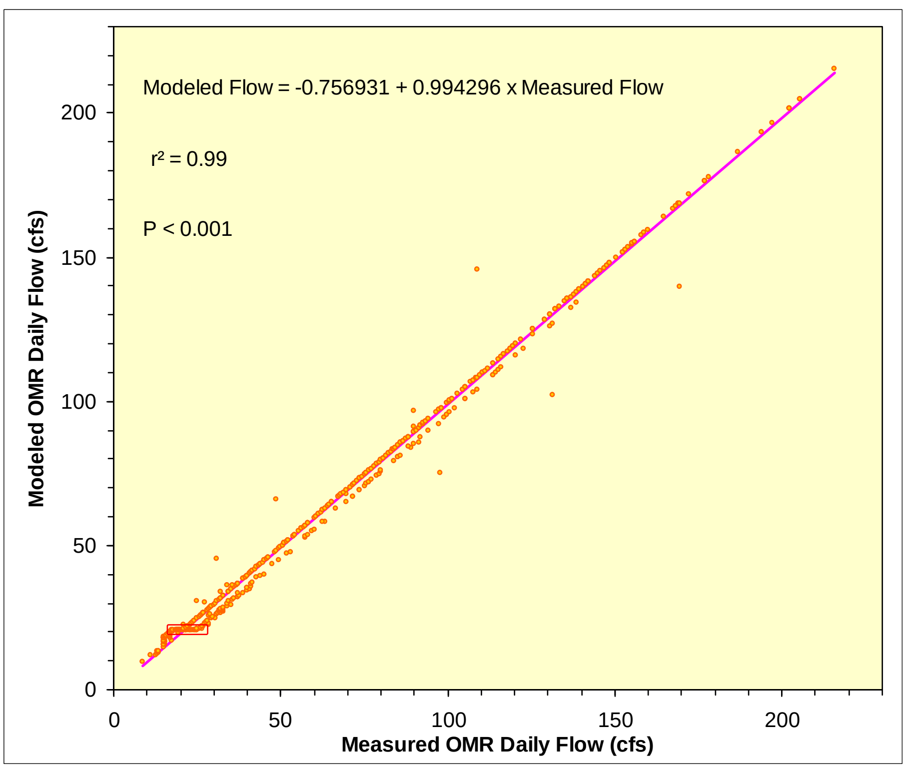


Figure C-49. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during June of 1988-2007 Runoff Years

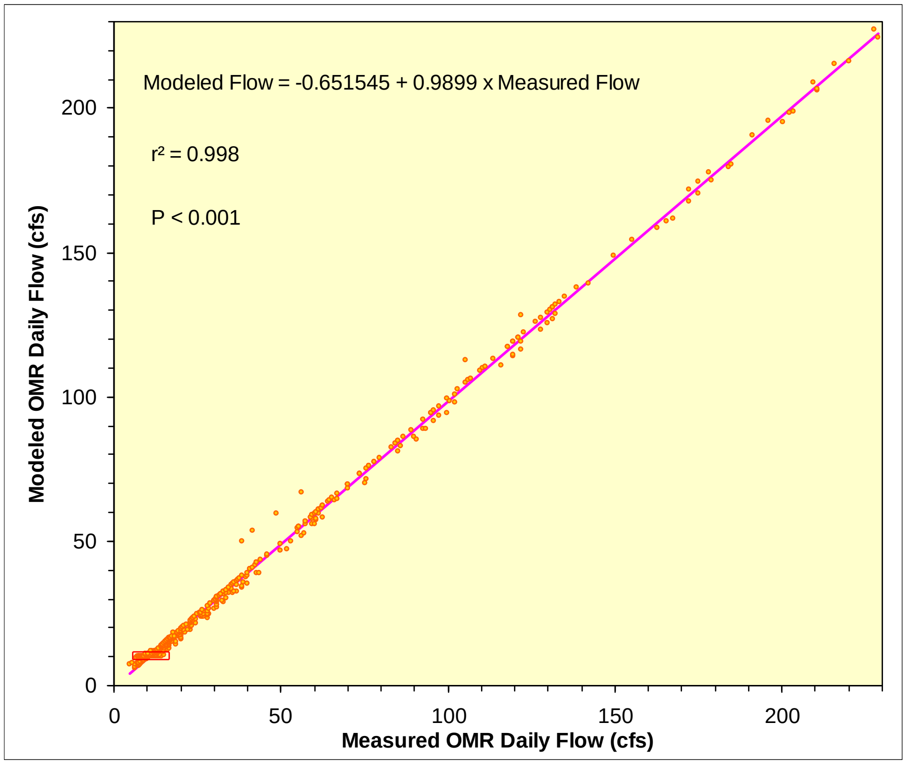


Figure C-50. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during July of 1988-2007 Runoff Years

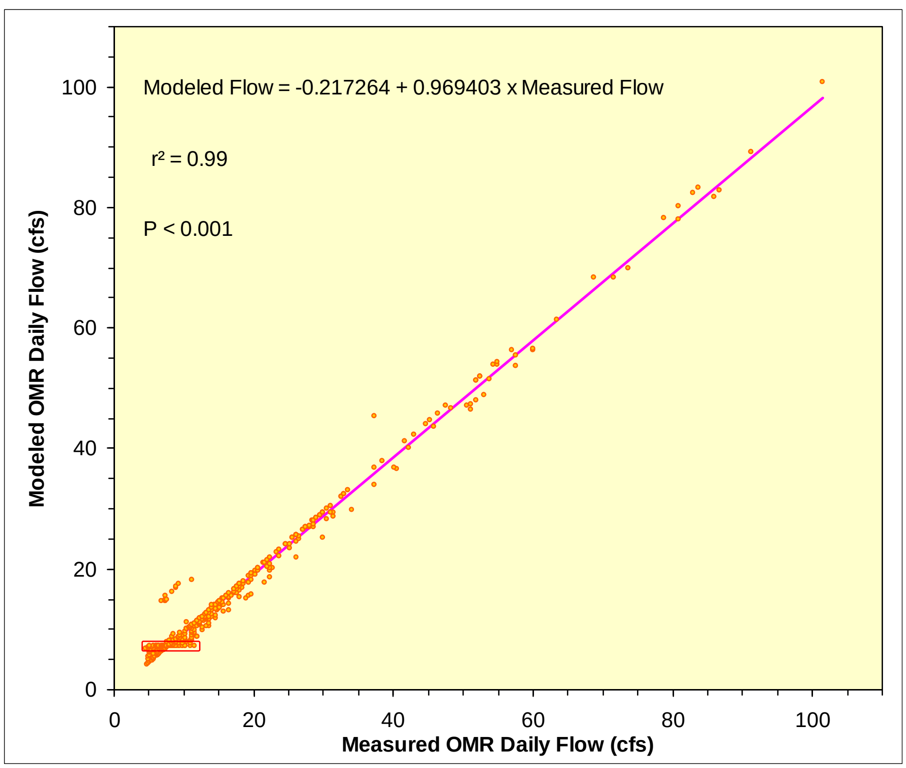


Figure C-51. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during August of 1988-2007 Runoff Years

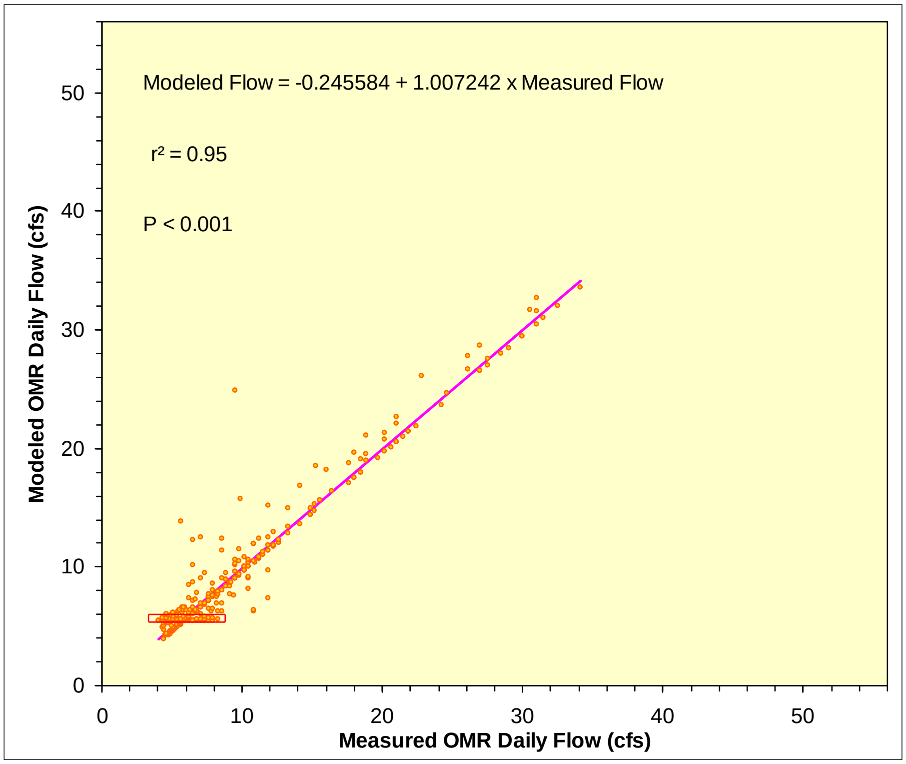


Figure C-52. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during September of 1988-2007 Runoff Years

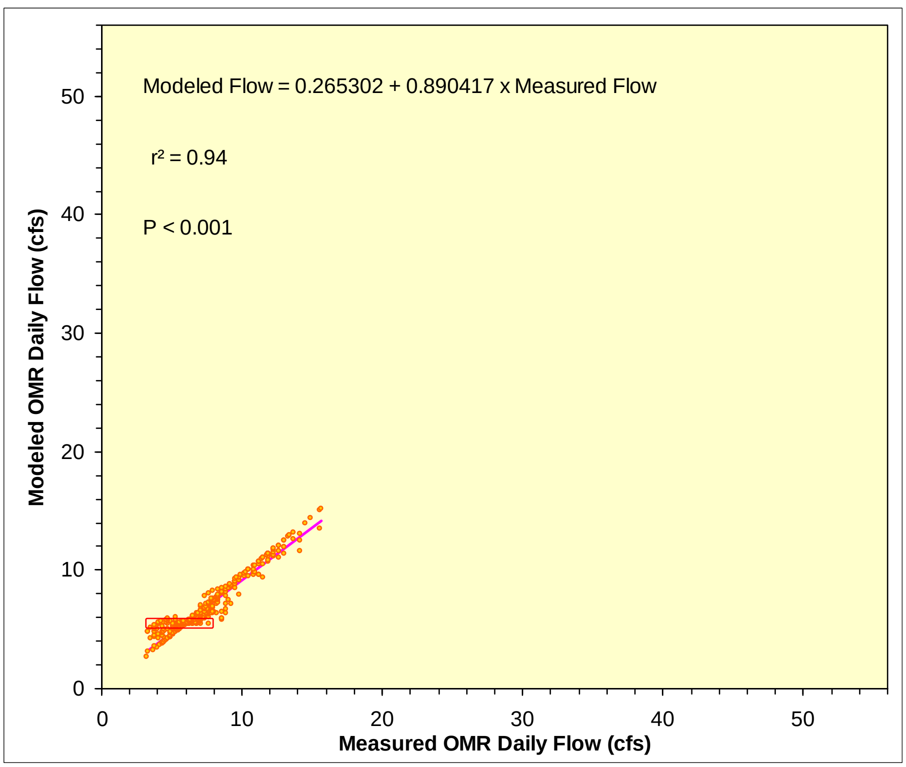


Figure C-53. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during October of 1988-2007 Runoff Years

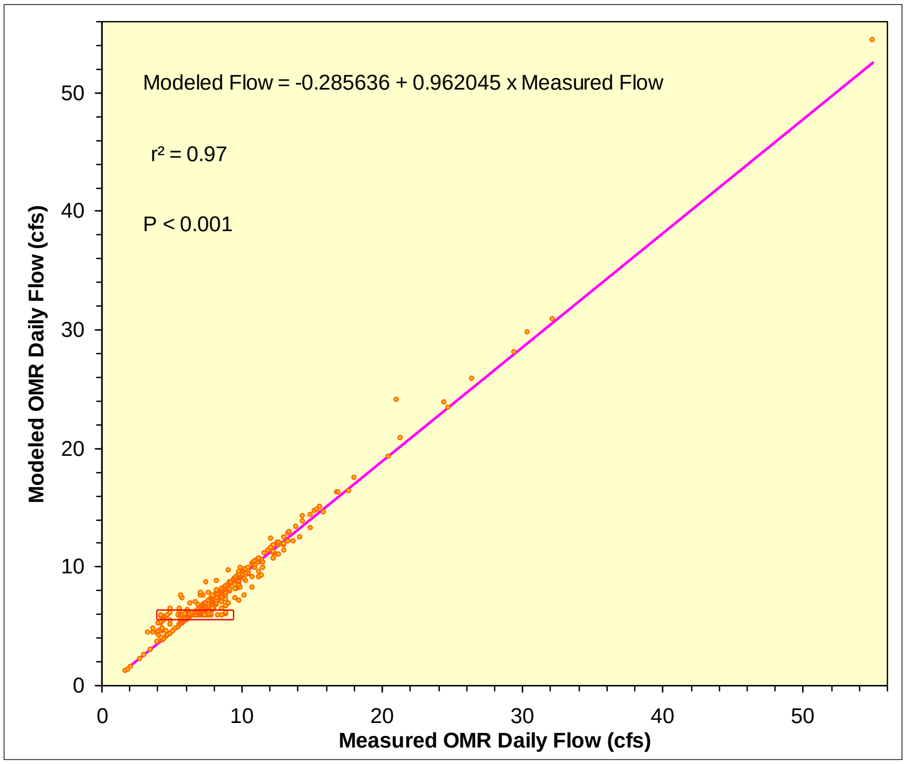


Figure C-54. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during November of 1988-2007 Runoff Years

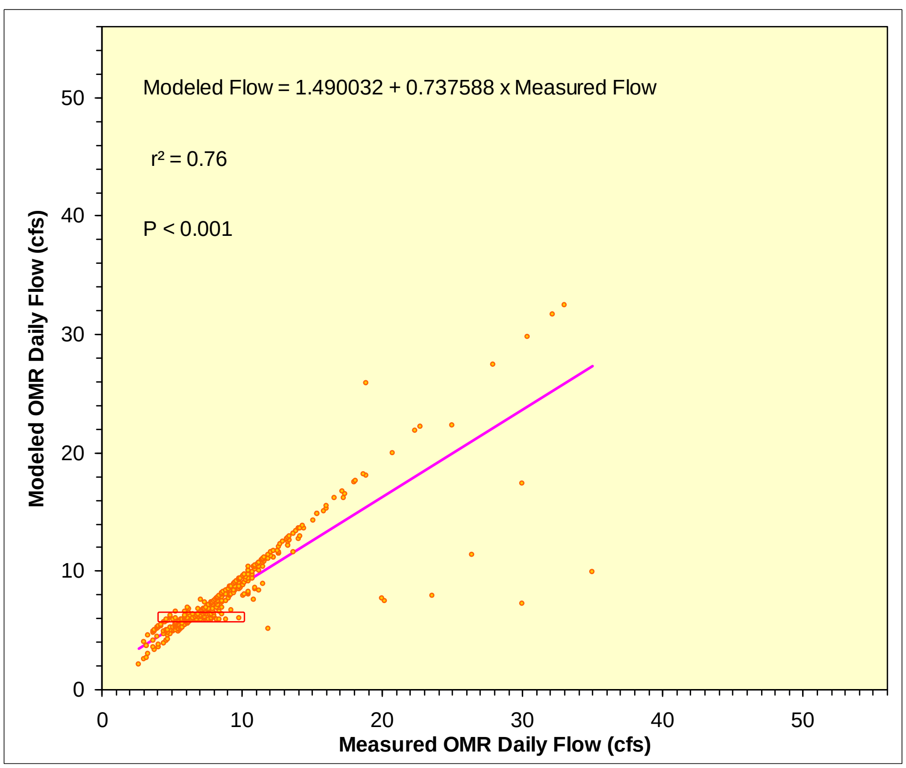


Figure C-55. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during December of 1988-2007 Runoff Years

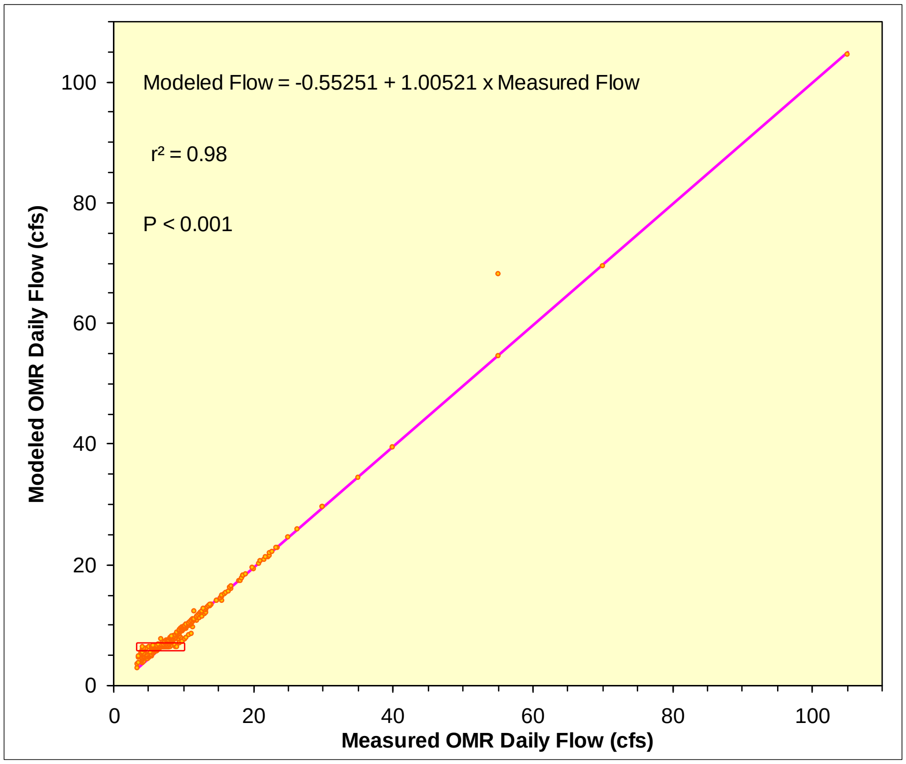


Figure C-56. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during January of 1988-2007 Runoff Years

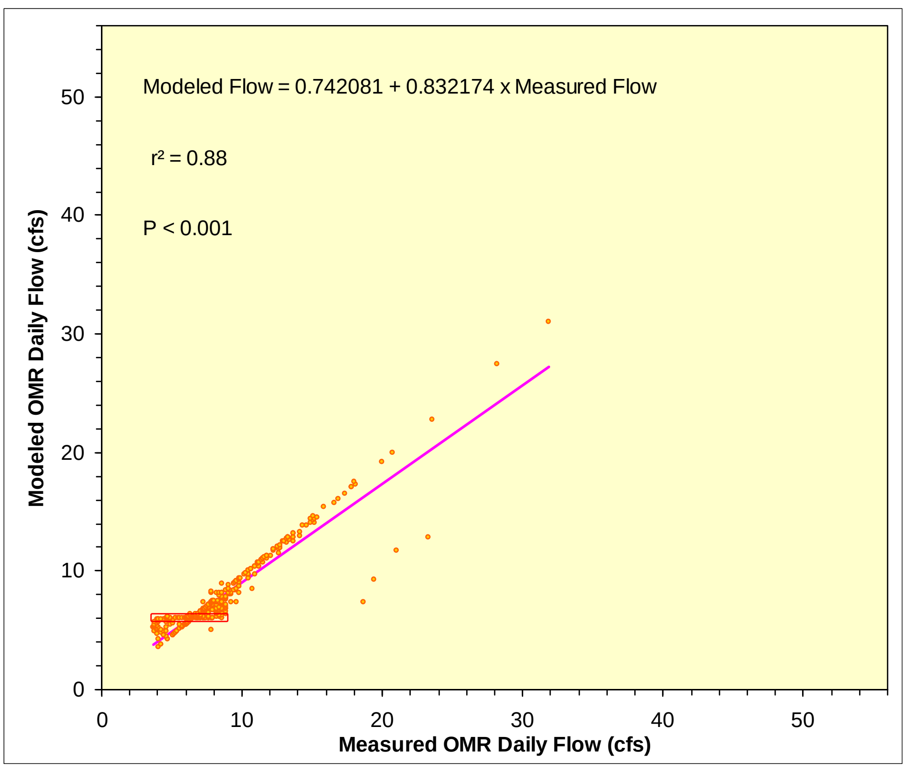


Figure C-57. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during February of 1988-2007 Runoff Years

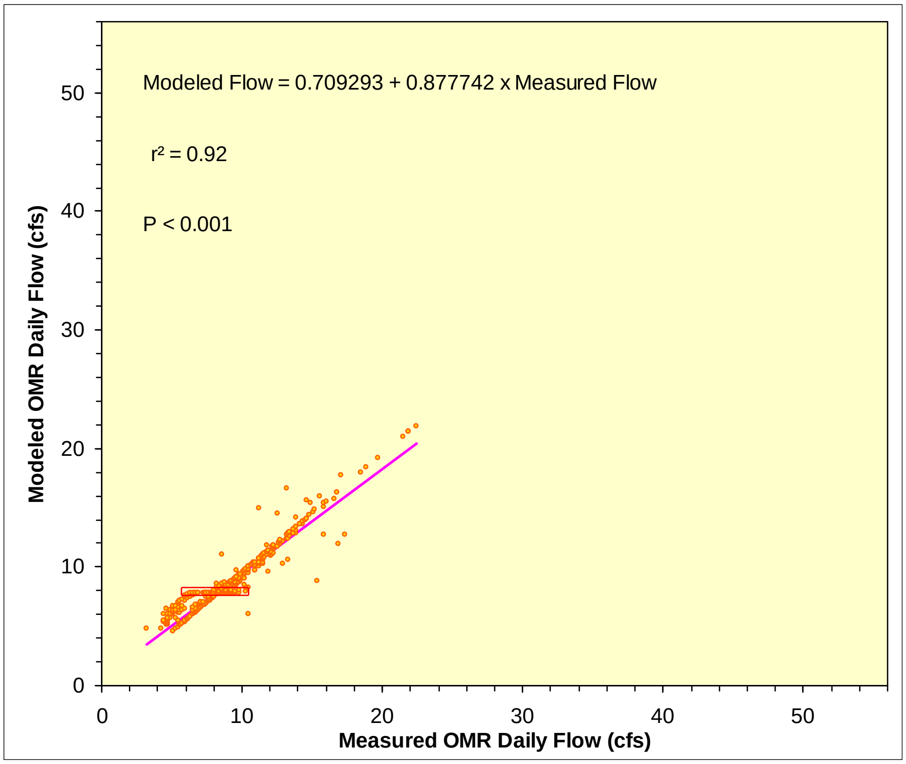


Figure C-58. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during March of 1988-2007 Runoff Years

Further examination of the data included in the monthly regressions revealed that on a number of occasions, measured historical OMR daily flows were less than 90% of the monthly minimum bypass flow requirement, when modeled historical daily flows were equal to the minimum bypass requirement, indicating that there was sufficient unimpaired flow to meet the OMR bypass requirement. Month-by-month descriptions of these occurrences follow.

- ❑ April
  - 29 occasions when measured historical daily flows are less than 90% of the minimum bypass flow requirement and modeled historical daily flows are equal to the minimum bypass flow requirement
  - 27 of the 29 occasions occurred during 1988-1992
- ❑ May
  - 13 occasions when measured historical daily flows are less than 90% of the minimum bypass flow requirement and modeled historical daily flows are equal to the minimum bypass flow requirement
  - 9 of the 13 occasions occurred during 1988-1992
- ❑ June
  - 4 occasions when measured historical daily flows are less than 90% of the minimum bypass flow requirement and modeled historical daily flows are equal to the minimum bypass flow requirement
  - 3 of the 4 occasions occurred during 1988-1992

- July
  - 21 occasions when measured historical daily flows are less than 90% of the minimum bypass flow requirement and modeled historical daily flows are equal to the minimum bypass flow requirement
  - 15 of the 21 occasions occurred during 1988-1992
- August
  - 10 occasions when measured historical daily flows are less than 90% of the minimum bypass flow requirement and modeled historical daily flows are equal to the minimum bypass flow requirement
  - The 10 occasions occurred during 1988-1992
- September
  - 21 occasions when measured historical daily flows are less than 90% of the minimum bypass flow requirement and modeled historical daily flows are equal to the minimum bypass flow requirement
  - The 21 occasions occurred during 1988-1992
- October
  - 2 occasions when measured historical daily flows are less than 90% of the minimum bypass flow requirement and modeled historical daily flows are equal to the minimum bypass flow requirement
  - The 2 occasions occurred during 1988-1992
- November
  - 2 occasions when measured historical daily flows are less than 90% of the minimum bypass flow requirement and modeled historical daily flows are equal to the minimum bypass flow requirement
  - The 2 occasions occurred during 1988-1992
- December
  - 3 occasions when measured historical daily flows are less than 90% of the minimum bypass flow requirement and modeled historical daily flows are equal to the minimum bypass flow requirement
  - The 3 occasions occurred during 1988-1992
- January
  - 13 occasions when measured historical daily flows are less than 90% of the minimum bypass flow requirement and modeled historical daily flows are equal to the minimum bypass flow requirement
  - 7 of the 13 occasions occurred during 1988-1992

- February
  - 8 occasions when measured historical daily flows are less than 90% of the minimum bypass flow requirement and modeled historical daily flows are equal to the minimum bypass flow requirement
  - 7 of the 8 occasions occurred during 1988-1992
- March
  - 7 occasions when measured historical daily flows are less than 90% of the minimum bypass flow requirement and modeled historical daily flows are equal to the minimum bypass flow requirement
  - The 7 occasions occurred during 1988-1992

Overall, there were 133 occasions when measured historical OMR daily flows were less than 90% of the monthly minimum bypass flow requirement, when modeled historical daily flows were equal to the minimum bypass flow requirement, indicating that there was sufficient unimpaired flow to meet the OMR bypass requirement. Of these 133 occasions, 113 occasions (85%) occurred from runoff year 1988 through runoff year 1992.

In September 1991, MCWD submitted to the SWRCB the Beak (1991) Instream Flow Report, which presented minimum bypass flow recommendations for Mammoth Creek. In December 1991, MCWD filed a petition with the SWRCB requesting that it amend permit 17322 to include the Beak (1991) recommendations for minimum bypass flow requirements in Mammoth Creek. A sequence of events ensued, including a public hearing, issuance of a revised C&D order (No. 9P2), a petition to the SWRCB for reconsideration, and an appearance before the Mono County Superior Court. During this sequence of events, MCWD generally began voluntarily operating in accordance with the Beak (1991) minimum bypass flow requirements since the early 1990s until August 1996, when the Mono County Superior Court issued a ruling requiring implementation of the proposed minimum bypass flow requirements.

The above examination of the data suggests that MCWD has operated in accordance with the Beak (1991) minimum bypass flow requirements since runoff year 1993 to the present.

Additional evaluation of model performance was conducted by comparing modeled daily historical OMR flows with the measured daily historical OMR flows for each month of the runoff years included in the modeled hydrologic period, excluding runoff years 1988 through 1992. For these comparisons, the measured OMR flows were the measured daily flows at the OMR gage that remained following the data QA/QC procedure as described above. The intercept and slope parameters, coefficients of determination (r^2), and levels of significance (P) of the linear regressions between monthly historical simulated daily flows at the OMR gage and measured historical daily flows at the OMR gage for runoff years 1993 through 2007 are presented in **Figures C-59** through **C-70**.

All of the monthly linear regressions in Figures C-59 through C-70 were highly significant ($P < 0.001$), and with the exception of December, their coefficients of determination (r^2) ranged from 0.89 to 0.99, indicating strong monthly linear relationships between modeled and measured historical OMR daily flows for runoff years 1993 through 2007. The coefficient of determination for the December regression ($r^2 = 0.72$), although highly significant ($P < 0.001$), suggests a more moderate linear relationship between modeled and measured daily historical OMR flows.

Further examination of the December regression (Figure C-67) indicates that a group of data points (indicated by the area included within the outlined demarcation in Figure C-67) represented outliers which influenced the strength of the linear relationship between modeled and measured historical daily OMR flows. These 7 data points, representing days when measured historical OMR daily flows were much higher than modeled historical OMR daily flows occurred during December 1996. A NOAA Western Region Technical Attachment (No. 97-13) prepared by the Nexrad Weather Service Forecast Office in Reno, Nevada, documented that during the period extending from December 1996 through early January 1997 an extremely wet weather pattern developed over the eastern Pacific Ocean and western United States, and the eastern Sierra Nevada Mountains were hit with copious amounts of precipitation. Precipitation included heavy rainfall onto the snowpack. Examination of data recorded at the USBR Mammoth Pass (MHP) meteorological station (elevation 9,300 ft) confirmed these precipitation events, and demonstrated that daily air temperatures rose well above freezing throughout much of December 1996. The MCWD Model did not well account for the extreme episodic events, represented by the 7 data point outliers.

Upon removal of these 7 data points, the linear regression between modeled and measured historical OMR daily flows during December for runoff years 1993 through 2007 was highly significant ($P < 0.001$), with a coefficient of determination (r^2) of 0.96.

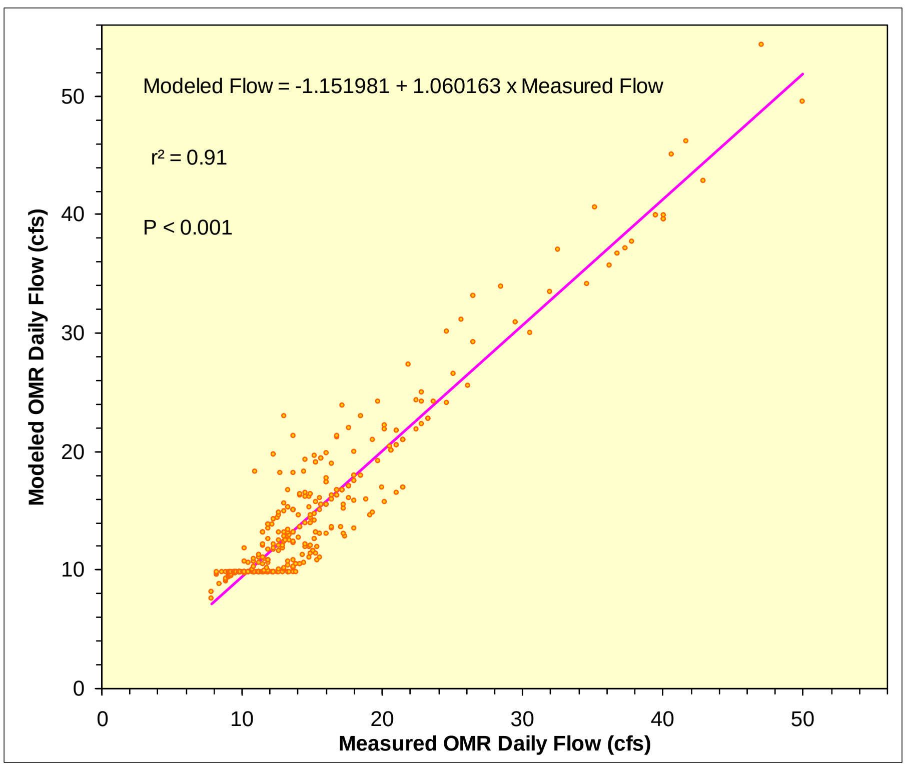


Figure C-59. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during April of 1993-2007 Runoff Years

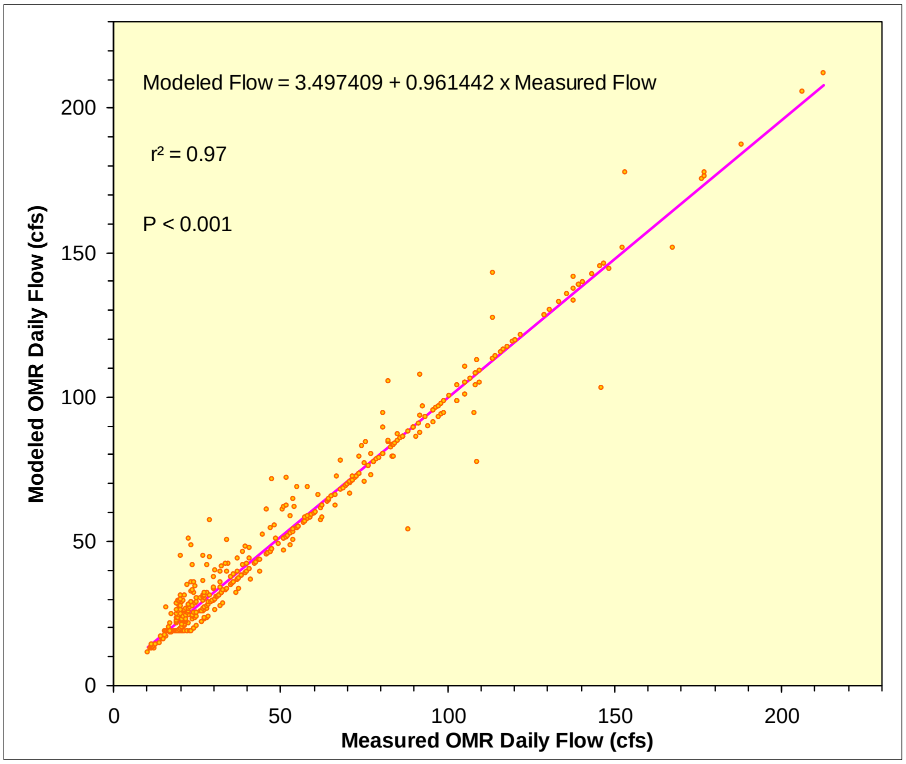


Figure C-60. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during May of 1993-2007 Runoff Years

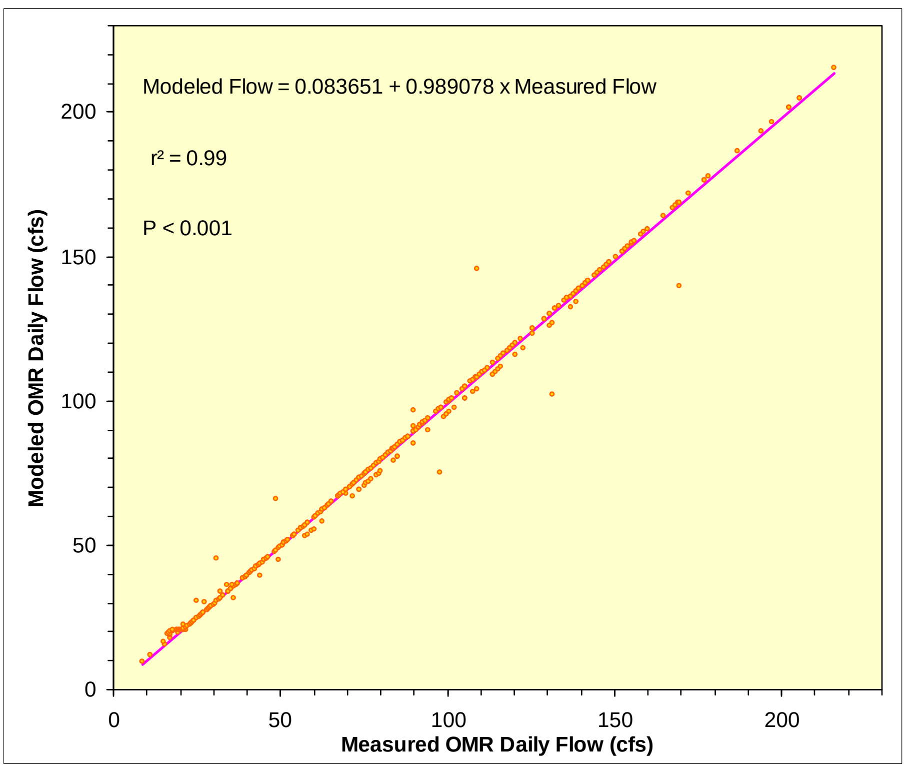


Figure C-61. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during June of 1993-2007 Runoff Years

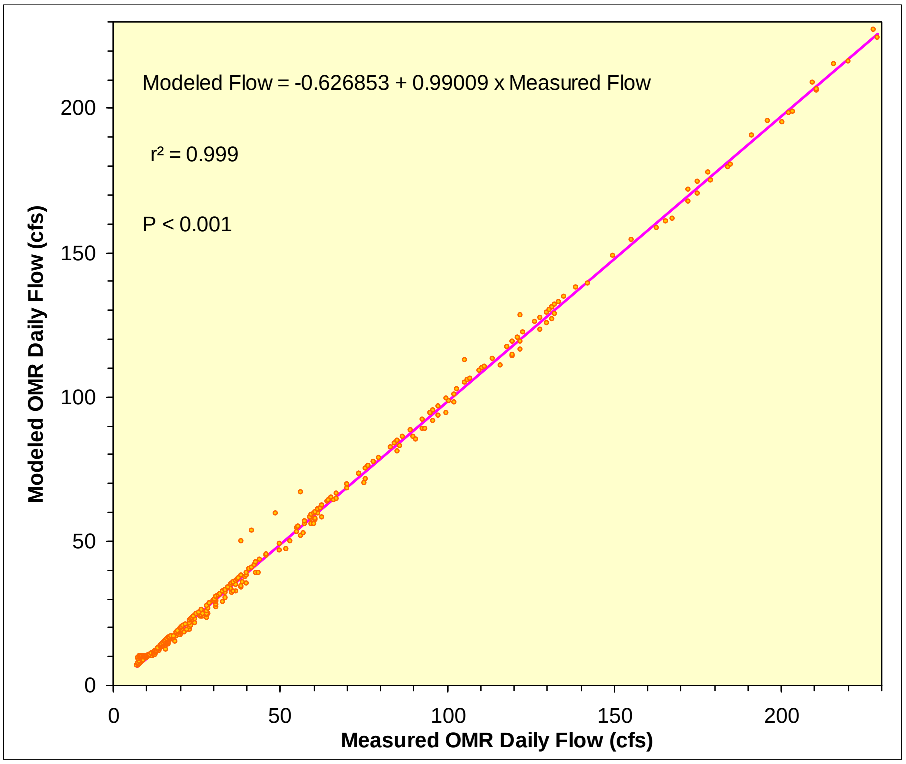


Figure C-62. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows During July of 1993-2007 Runoff Years

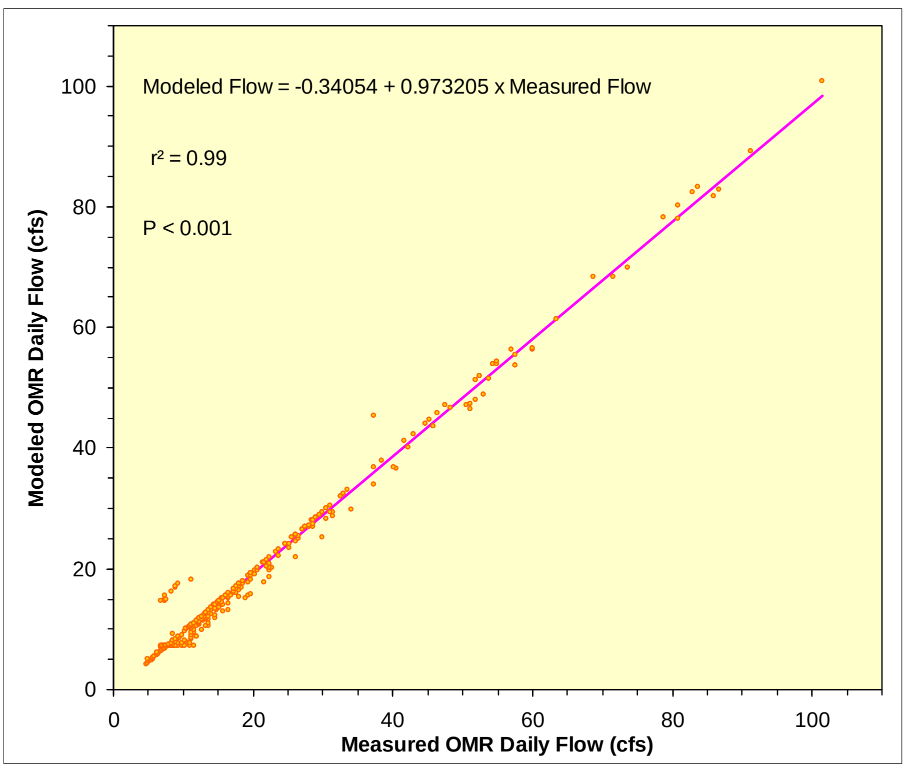


Figure C-63. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during August of 1993-2007 Runoff Years

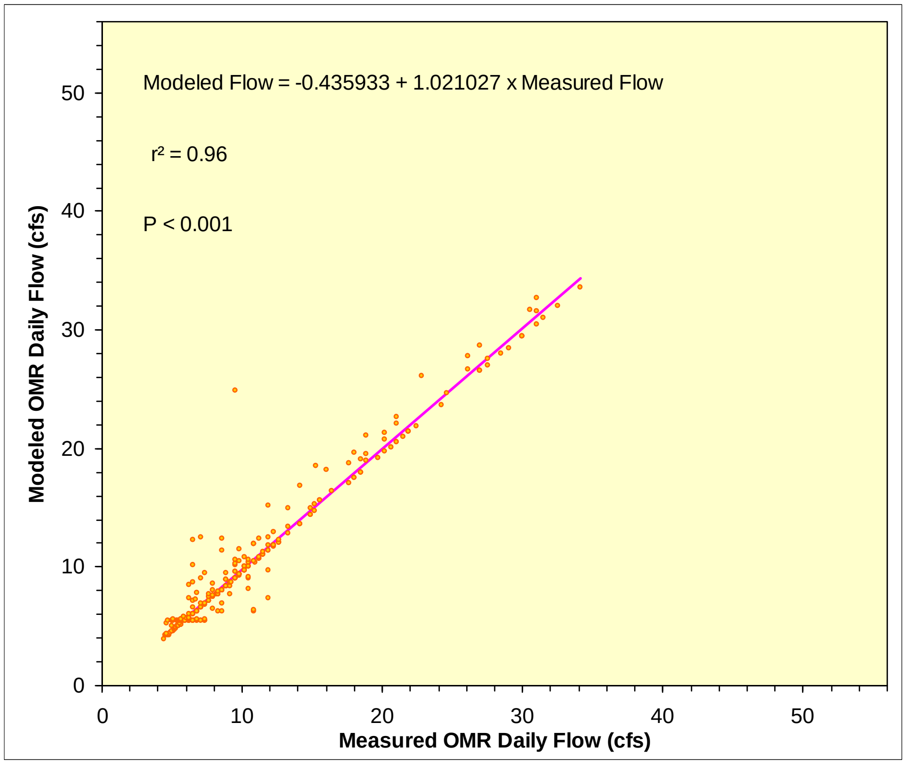


Figure C-64. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during September of 1993-2007 Runoff Years

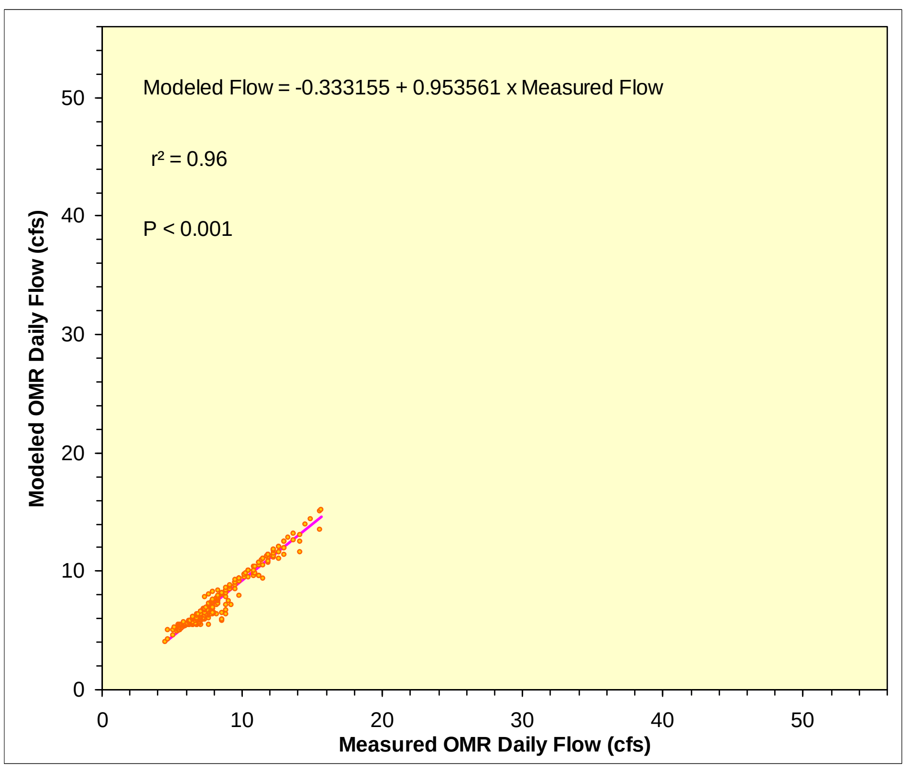


Figure C-65. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during October of 1993-2007 Runoff Years

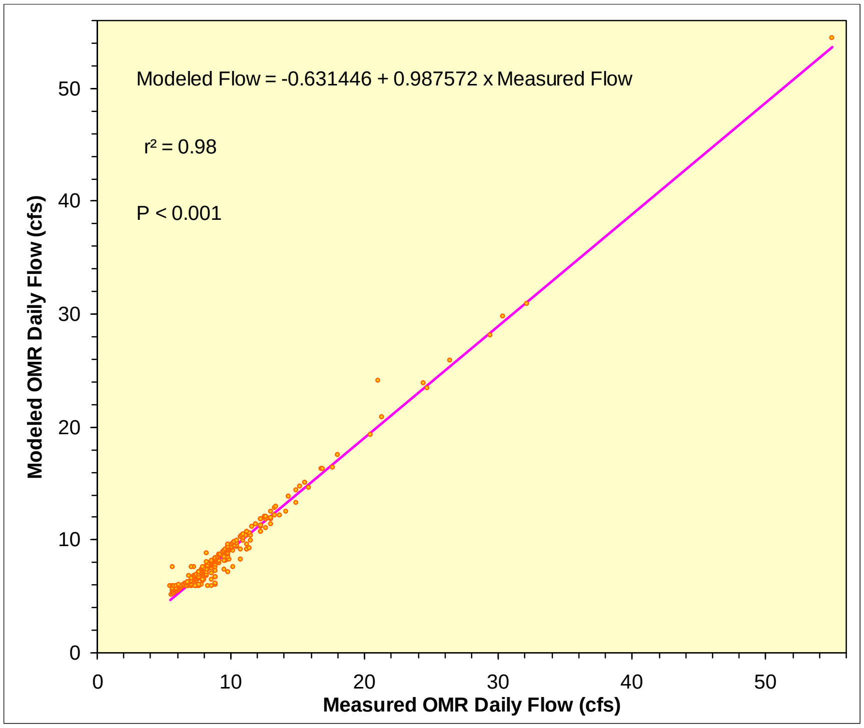


Figure C-66. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during November of 1993-2007 Runoff Years

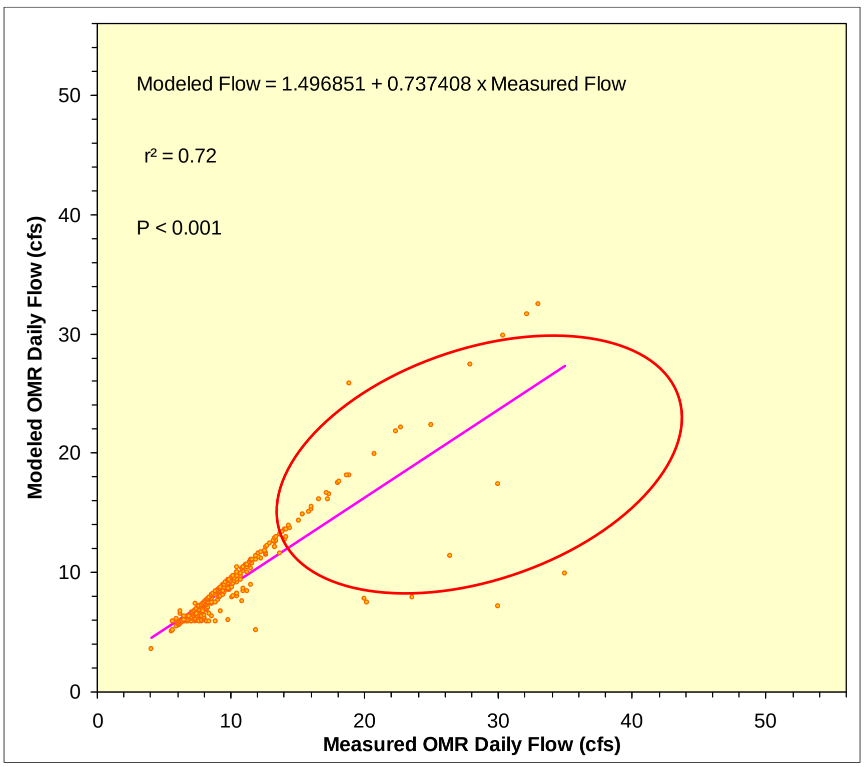


Figure C-67. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during December of 1993-2007 Runoff Years

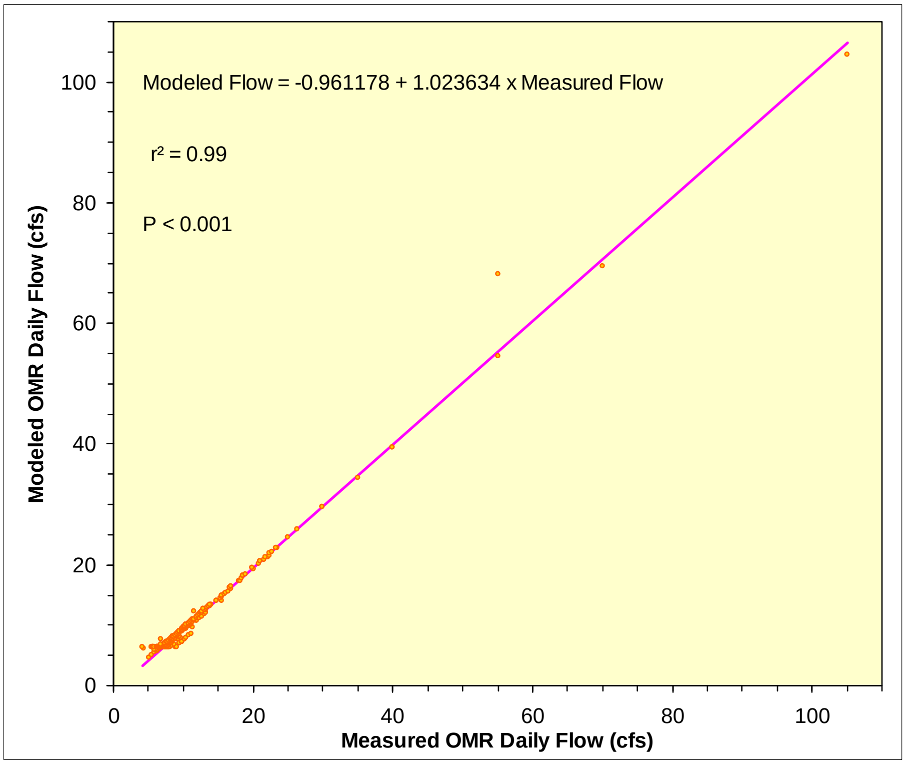


Figure C-68. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during January of 1993-2007 Runoff Years

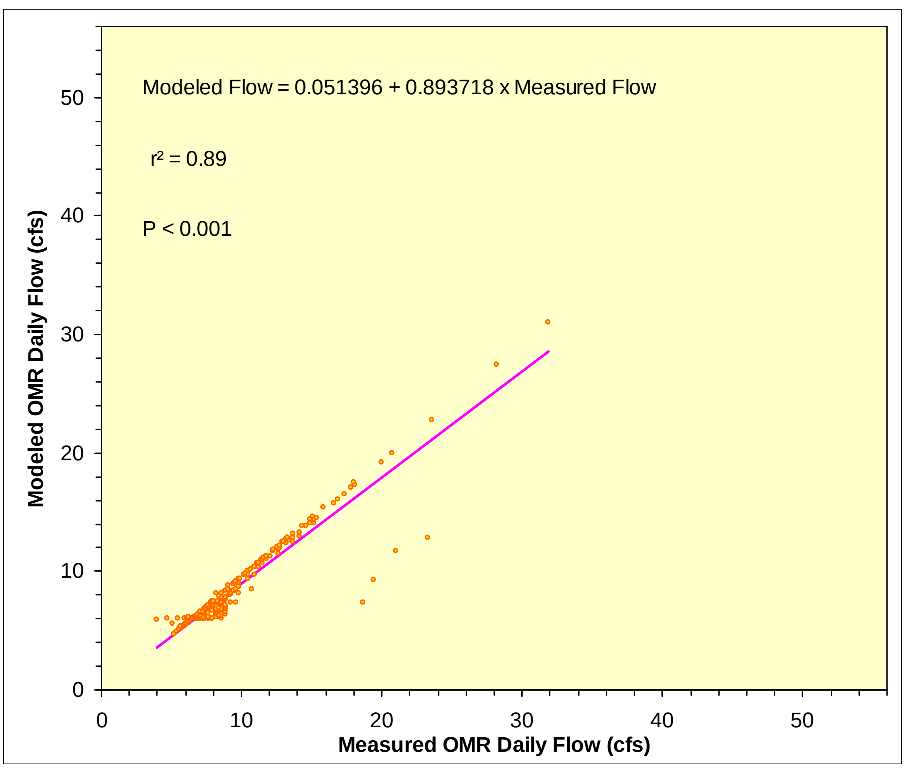


Figure C-69. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during February of 1993-2007 Runoff Years

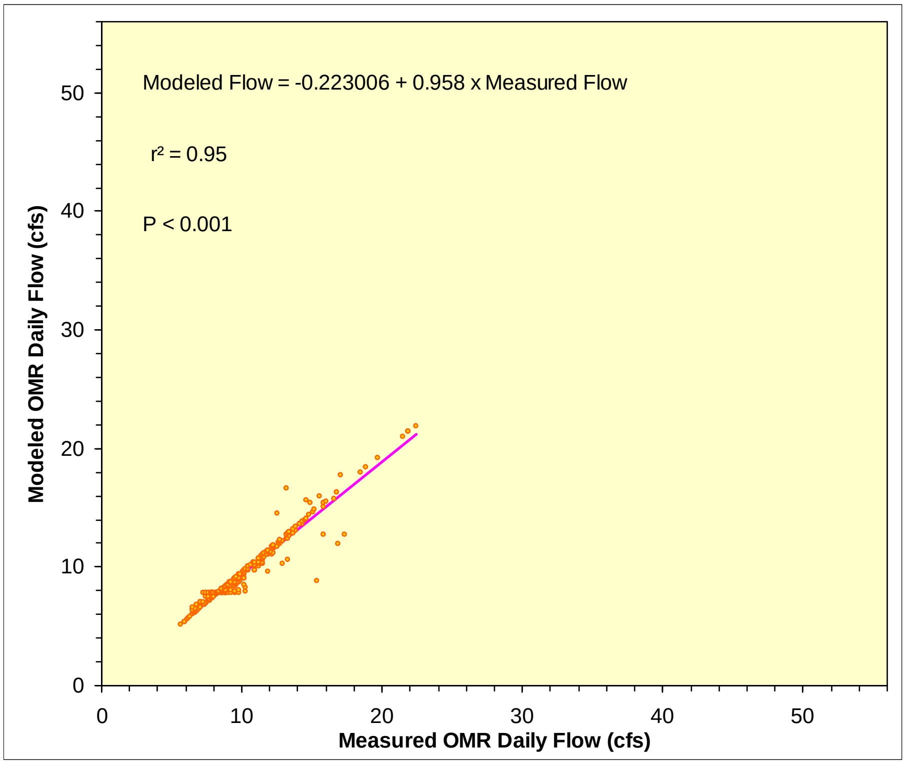


Figure C-70. Intercept and Slope Parameters, Coefficient of Determination (r^2), and Level of Significance (P) of the Linear Regression Comparing Modeled OMR Gage Daily Flows to Measured OMR Gage Daily Flows during March of 1993-2007 Runoff Years

5.3 Characterization of Unimpaired Flows

Throughout the modeled period of record, MCWD has operated its storage and diversion infrastructure. Thus, an "unimpaired" flow condition was not observed in the Mammoth Creek. The MCWD Model can be configured to approximate unimpaired conditions by removing the effects of the existing infrastructure. This is accomplished by setting all of the Lake Mary storage parameters to zero, and eliminating all MCWD diversions. While the resultant streamflows are not truly unimpaired values, they do approximate conditions without MCWD operations.

One use of the unimpaired flow construct is to verify that the runoff year type designations are appropriate. To evaluate whether the April 1 SWC at Mammoth Pass is a reliable indicator of runoff year type, the correlation between SWC (explanatory variable) and cumulative April 1 through March 31 daily OMR "unimpaired" flows (in AF) was examined using linear regression. A large and statistically significant positive correlation coefficient was considered a good indication that April 1 SWC at Mammoth Pass is a reliable indicator of runoff year type. **Figure C-71** displays the unimpaired flow obtained from the model relative to the April 1 SWC at Mammoth Pass for each of the 20 runoff years (circles) of the modeled hydrological period, and the regression line relating both variables. The correlation between modeled unimpaired flow and April 1 SWC at Mammoth Pass is strong and highly significant ($r = 0.92$, $P < 0.0001$).

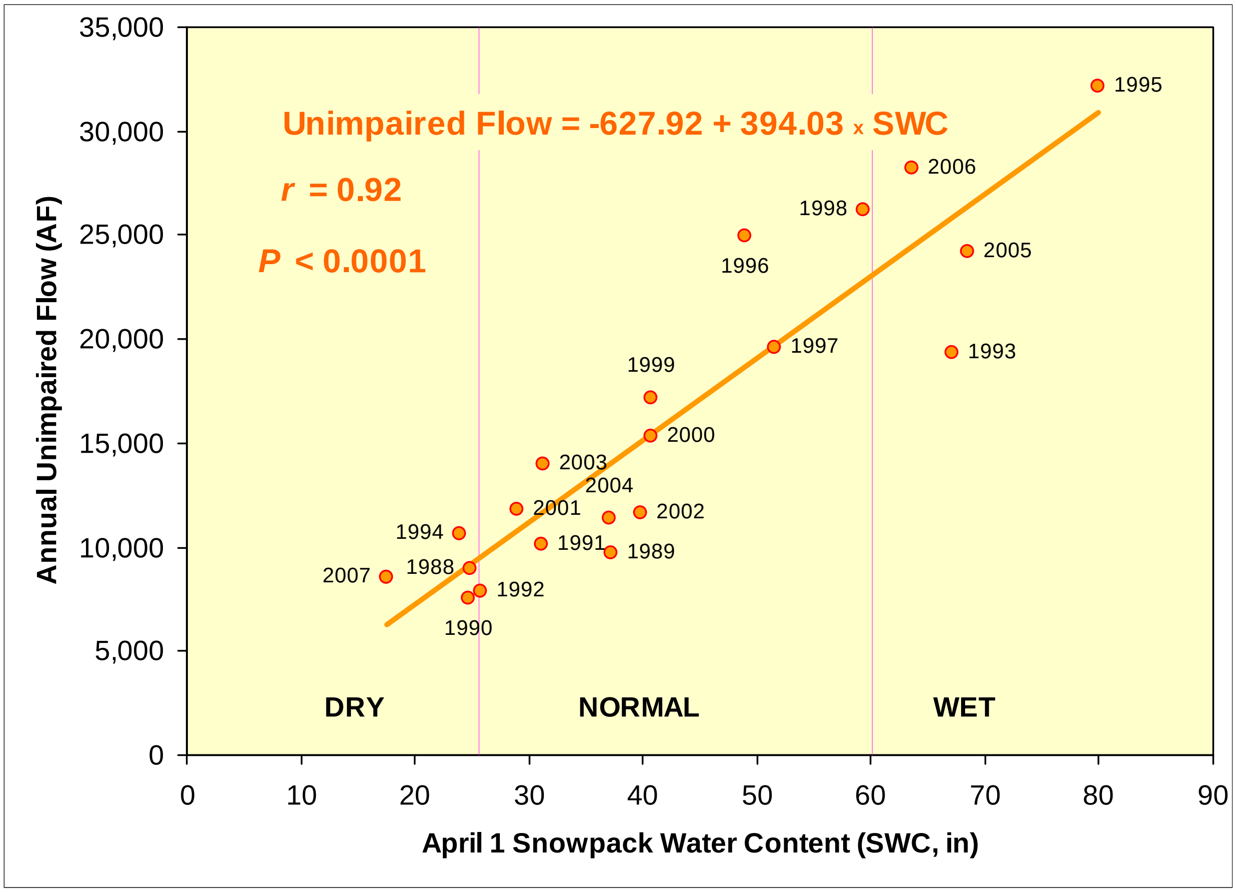


Figure C-71. Unimpaired Flow Relative to April 1 Snowpack Water Content at Mammoth Pass

6.0 REFERENCES

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