Coordinated Water Resources Database & Model Development

Phase III Completion Report

Sponsored by U.S. Army Corps of Engineers

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URGWOM Steering Committee Meeting

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US Army Corps of Engineers ®

Outline

- Project Overview
- SOW for Phase III
- Deliverables
- Plan for Future Phases
- Lower Rio Grande Flood Control Model: RiverWare Model Development (Tillery)

Project Overview

- Develop coordinated water resources database for easy access and sharing as well as model development
- Develop a RiverWare model of the Rio Grande flow between Elephant Butte Dam, New Mexico and Fort Quitman, Texas for flood control planning

Phase III Scope of Work

- Compile and verify the water quality data
- Assess the data availability for expansion of the URGWOM model
- Develop the RiverWare model for the Rio Grande flow for the selected reaches between Elephant Butte Reservoir and El Paso

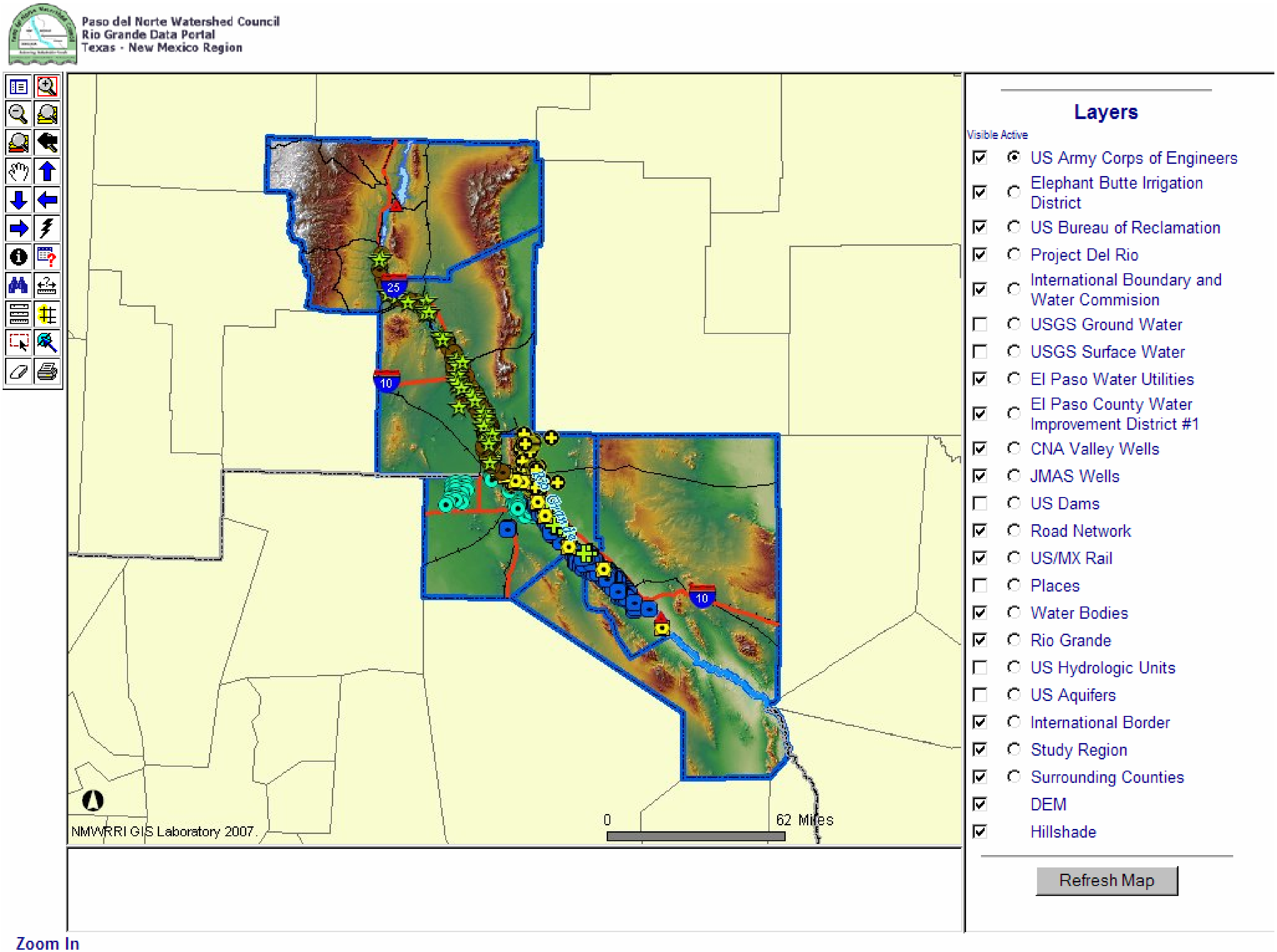
Phase III Scope of Work

- Organize a RiverWare training workshop on rule-based simulations
- Provide technical assistance in development of the FLO-2D model
- Implement data transfer interface between the coordinated database and hydrologic models

Deliverables

- Coordinated database and numerical model

  http://www.pdnwc.org/
- Project reports published as Technical Reports: one published and three in review.
- Organized two RiverWare training workshops for regional stakeholders
- Provided comments for development of the FLO-2D model


Paso del Norte Watershed Council
Rio Grande Data Portal
Texas - New Mexico Region
25
10
10
NMWRRI GIS Laboratory 2007.
0
62 Miles
Layers
Visible Active
US Army Corps of Engineers
Elephant Butte Irrigation District
US Bureau of Reclamation
Project Del Rio
International Boundary and Water Commision
USGS Ground Water
USGS Surface Water
El Paso Water Utilities
El Paso County Water Improvement District #1
CNA Valley Wells
JMAS Wells
US Dams
Road Network
US/MX Rail
Places
Water Bodies
Rio Grande
US Hydrologic Units
US Aquifers
International Border
Study Region
Surrounding Counties
DEM
Hillshade
Refresh Map
Zoom In

Plan for future phases

- Enhance the RiverWare model for the Rio Grande reaches in the Mesilla Basin by emphasizing SW/GW interactions;
- Expand the RiverWare model for the reaches between El Paso to Fort Quitman for flood control planning;

Plan for future phases (cont.)

- Assess management scenarios with containment of storm water to reduce run-off discharge into the river and irrigation system and recharge aquifers during the flood; and
- Assess 2006 flood events using the enhanced RiverWare model.


STOP

LOWER RIO GRANDE FLOOD CONTROL MODEL: RiverWare Model Development

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Overview

- Objectives
- Lower Rio Grande Reaches
- Surface Water/Groundwater Interactions
- ARIMA Transfer Functions
- RiverWare Model Development
- RiverWare Model Results
- Conclusions

Phase III, Task 7 - Objectives

- Subtask c
  - Develop conceptual model for surface/ground water interaction
  - Develop RiverWare model for Lower Rio Grande (LRG)
  - Use RiverWare DMI to link data to the model

Lower Rio Grande Reaches

- Reach definitions were based on:
  - Physiography of study area
  - Locations of major diversion dams
    - Rincon Reach – Below Caballo to Leasburg Div. Dam
    - Leasburg Reach – Leasburg to Mesilla Div. Dam
    - Mesilla Reach – Mesilla Div. Dam to RG at El Paso
- Reaches were intended to:
  - Resemble actual geometry of the system
  - Fit the available data

Lower Rio Grande Reaches (con't)

- Lower Rio Grande flows across
  - Rincon Valley Basin
  - Selden Canyon (high bedrock zone)
  - Mesilla Bolson
  - El Paso Narrows (high bedrock zone)

- High bedrock zones create separate groundwater systems
  - River below Caballo to Selden Canyon (Rincon Reach)
  - River below Selden Canyon to El Paso Narrows (Leasburg and Mesilla Reaches)

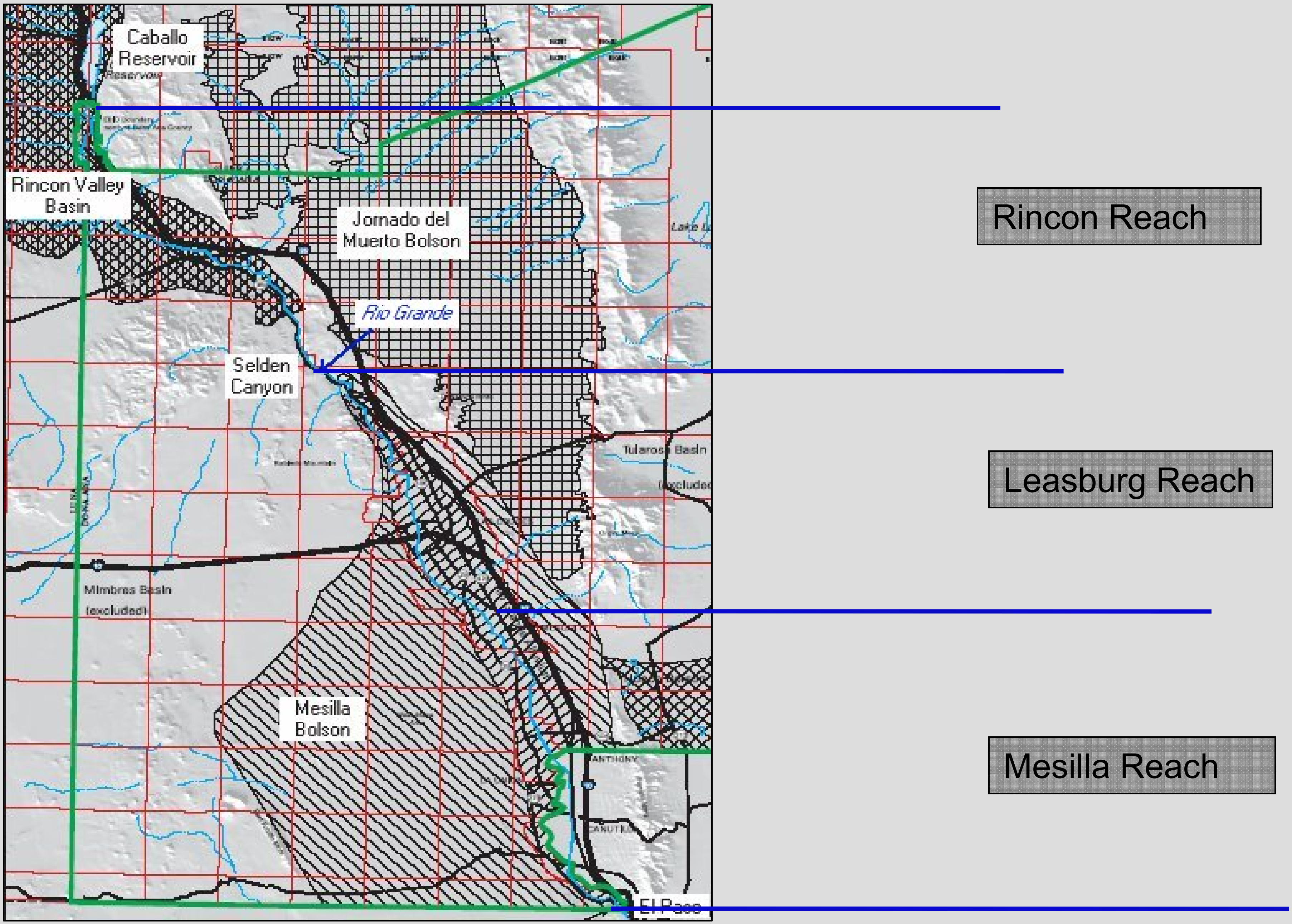


Figure 1. Lower Rio Grande Basins (Terracon et al., 2004)

Mesilla Reach:

- Between Mesilla Div. Dam and RG at El Paso
- Water is diverted at Mesilla Div. Dam to:
  - Westside Canal
  - Eastside Canal
  - Del Rio Lateral
- Return flows are from Westside and Eastside Canal diversions

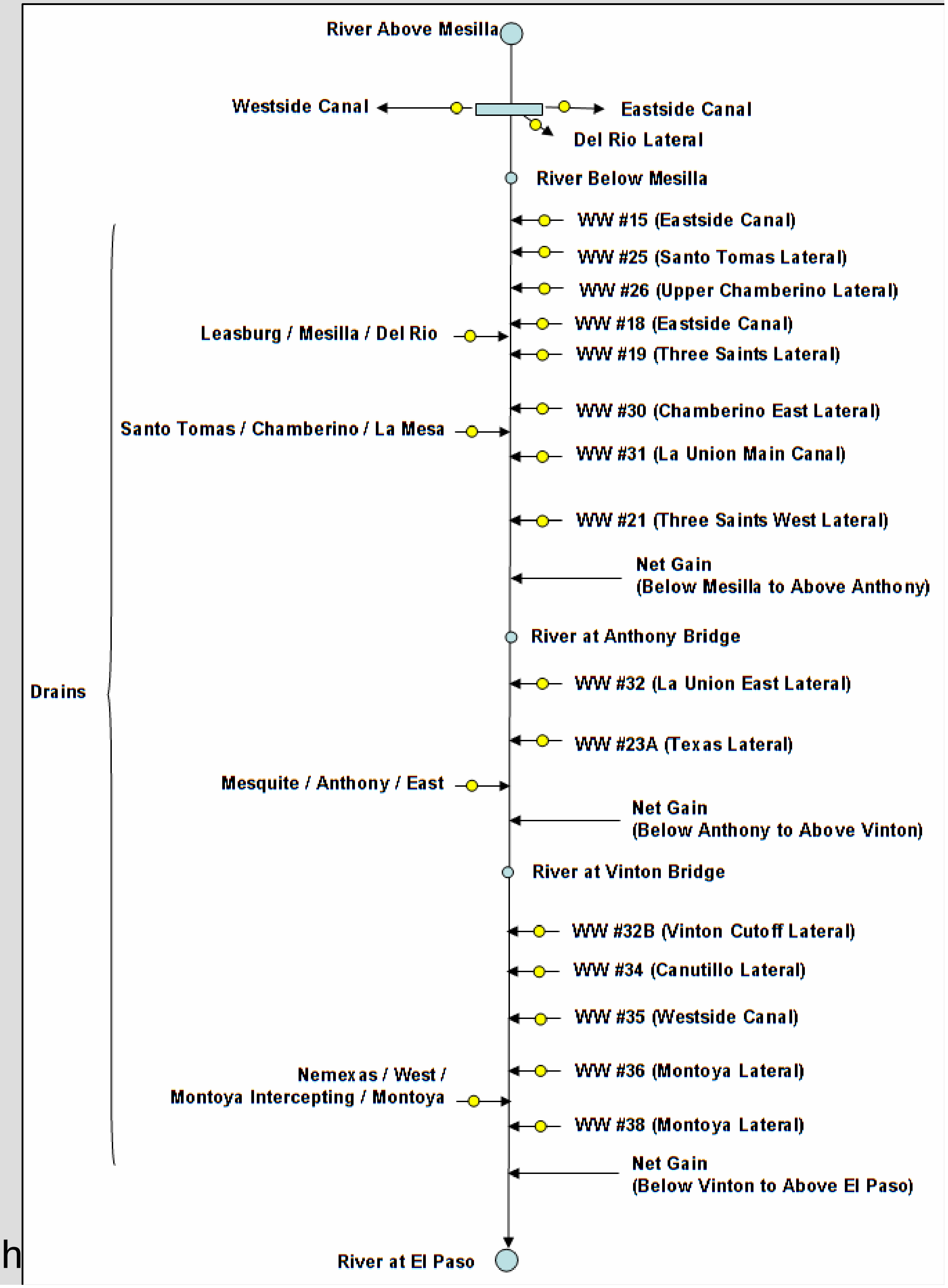


Figure 5. Schematic of the Mesilla Reach

Surface / Groundwater Interactions

- Conceptual Model
  - The main variables of interest for forecasting flows
    - Diversions
    - Conveyance infiltration
    - Deep percolation from irrigation
    - Groundwater withdrawal
    - Precipitation
  - The variable with largest effect on interactions = DIVERSION

Surface/Groundwater Interactions

- Conceptual Model (con't)
  - Use diversions as input time-series to an ARIMA *Transfer Function* model to predict return flow
  - Even though ground-water withdrawals can be significant
    - Ground-water pumping is strongly correlated to diversions
    - So using diversion data indirectly accounts for ground-water pumping

ARIMA *Transfer Function* Analysis

AutoRegressive Integrated Moving Average

Commonly called Box-Jenkins Approach

- Use ARIMA *Transfer Function* model to
  - Simulate relationships between diversions and drain return flows
- Return flow predictions are made from a linear combination of
  - Past values of the return flow
  - Current and past values of the diversion
  - Past errors (or residuals)
- Residuals are represented by ARMA model

ARIMA *Transfer Function* Analysis

- Advantages of *Transfer Function* Model
  - Accounts for current and past values in predicting future values
  - Represents physical process while maintaining statistical cohesion
  - Doesn’t assume residuals are independent

- Disadvantages of *Transfer Function* Model
  - More difficult and time consuming to derive and implement
  - Must re-evaluate whenever system changes

Transfer Function Model Form

$$\left(1-B^{12}\right)Z_t = \omega_o\left(1-B^{12}\right)X_t + \frac{\left(1-\theta_1 B^{12}\right)}{\left(1-\phi_1 B\right)\left(1-\phi_2 B^{11}\right)}a_t$$

Z_t = Drain flow (LN) at time period t (AF)
X_t = Diversion at time period t (AF)
a_t = Residuals = Y_t (actual) – Y_t (predicted)
B = Back-shift operator, used to take differences over time of a value
t = Time period
ω_o= Regression coefficient for diversion
ϕ_1, ϕ_2 = Autoregressive parameters for the residuals ARMA model
θ_1= Moving-average parameter for the residuals ARMA model

SAS System for Windows, V9.1 used for Time Series Analysis

Forecast Equation Form

$$\hat{Z}_n = Z_{n-12} + \phi_1\left(Z_{n-1} - Z_{n-13}\right) - \phi_1\phi_2\left(Z_{n-12} - Z_{n-24}\right) + \phi_2\left(Z_{n-11} - Z_{n-23}\right) + \omega_o\left[X_n - X_{n-12} - \phi_1(X_{n-1} - X_{n-13}) + \phi_1\phi_2\left(X_{n-12} - X_{n-24}\right) - \phi_2\left(X_{n-11} - X_{n-23}\right)\right] - \theta_1\left(Z_{n-12} - \hat{Z}_{n-12}\right)$$

Z_{n-i} = Drain flow for first month after observed data (AF)
X_{n-i} = Diversion (AF) at month n-i
n = number of observations
i = number of months of lag
$\phi_1 = 0.54189$
$\phi_2 = 0.22134$
$\theta_1 = 0.72055$
$\omega_o = 0.00005324$

Transfer Functions Implemented

- Rincon Reach
  - Garfield Drain from Arrey Canal Diversion
  - Hatch Drain from Arrey Canal Diversion
  - Rincon Drain from Arrey Canal Diversion

- Mesilla Reach
  - Del Rio Drain from Eastside Canal Diversion
  - La Mesa Drain from Westside Canal Diversion
  - East Drain from Eastside Canal Diversion
  - Montoya Drain from Westside Canal Diversion

RiverWare Model Development

- Time period simulated in model
  - Jan 1985 through Dec 1999
- Using observed data
  - Jan 1985 through Dec 1998
- Flow data units
  - Acre-feet/month
- Monthly time steps

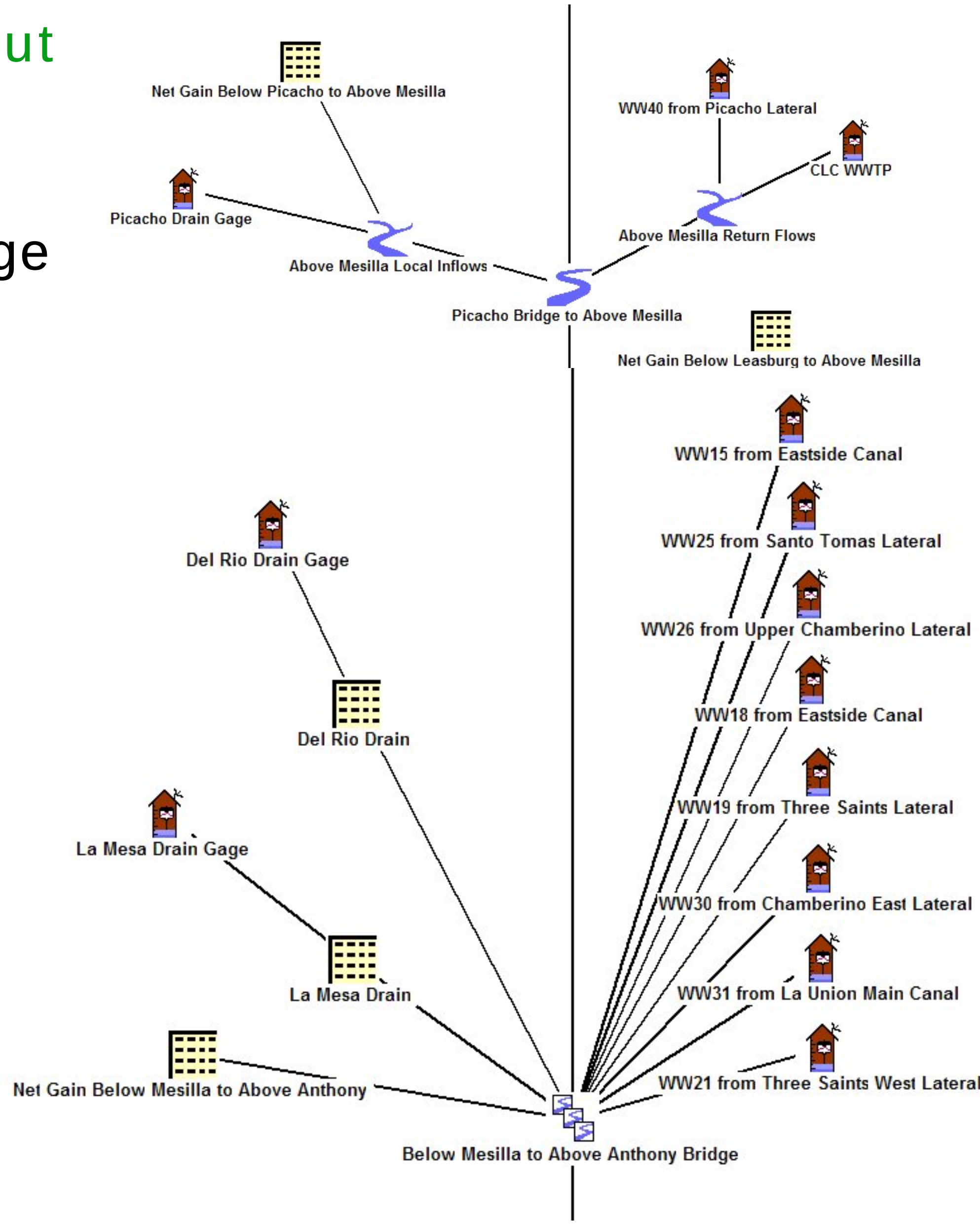
Model Development (con't)

- Rules were used to calculate transfer function expressions
  - To make sure equations were executed in proper order
  - To make sure there are valid values for all time steps

- Dimensionless data were used in transfer function calculations
  - To circumvent RiverWare's automatic conversions on monthly data based on number of days in the month
  - Exponential function does not work with units of AF/mo on value to be exponeniated

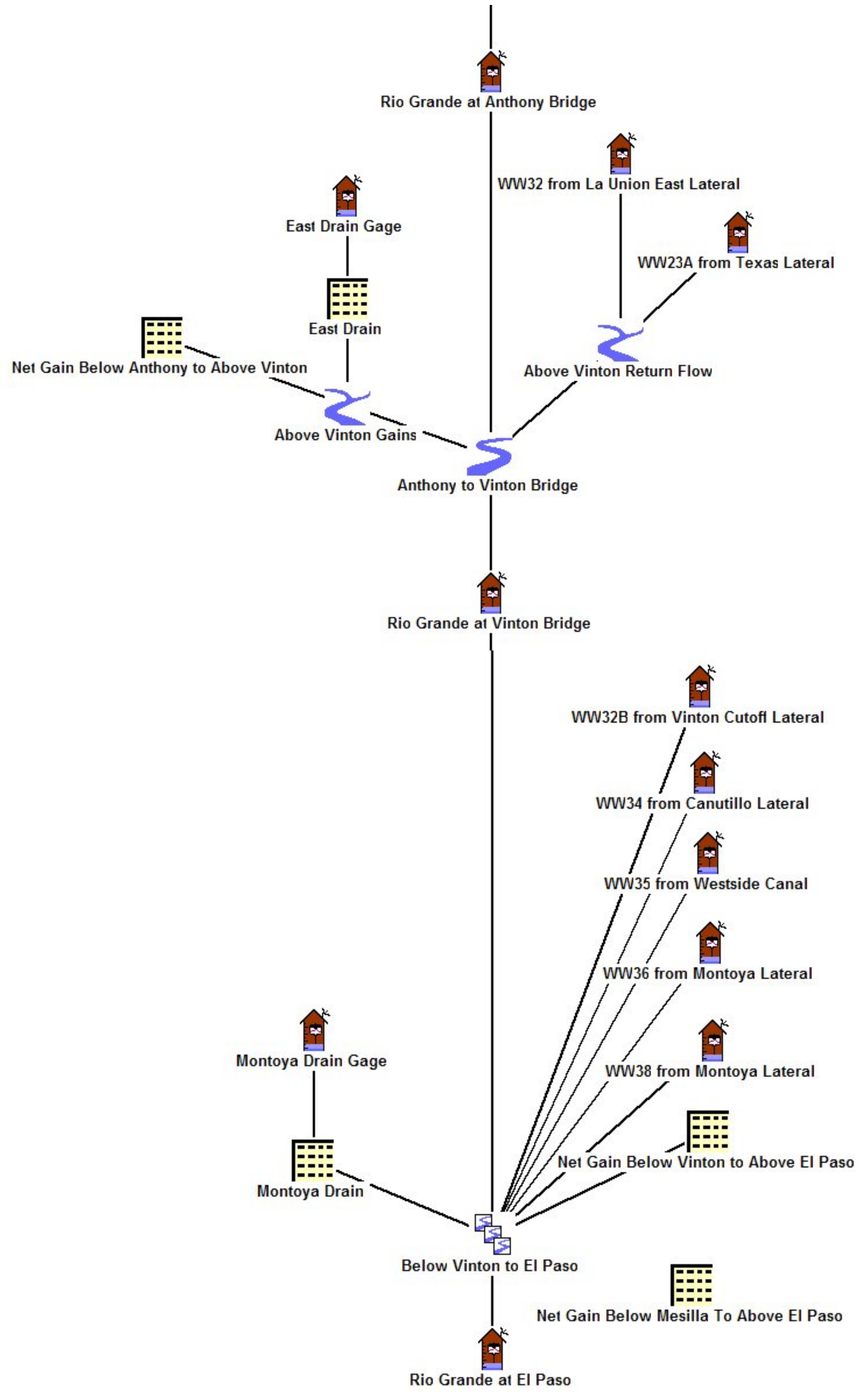
❑RiverWare Model Layout

- ➢Mesilla Reach to Above Anthony Bridge



❑RiverWare Model Layout

➢Mesilla Reach
Below Anthony Bridge



Input Data

- Input data sites require monthly historic data for 1985 through 1999
  - Sites that are not calculated require historic data for entire simulation time period

- Forecast data sites require monthly historic data for 1985 through 1987
  - Forecast equations may use data from up to 24-months ago, so 2 years of historic data must be available

Input Data (con't)

- Forecast data sites require previous forecast results for 1986
  - Forecast data in model starts in 1987
  - Forecast equations require previous forecast data for up to 12-months ago
  - Results from SAS simulation are used for previous forecast data

Input Data Sites

Rincon Reach	Leasburg Reach	Mesilla Reach
River below Caballo	Leasburg Canal	Westside Canal
Arrey Canal	City of LC WWTP	Eastside Canal
Percha Lateral	Picacho Drain	Del Rio Lateral
All Wasteways	Net Gain	Net Gain
	All Wasteways	All Wasteways

Forecast Data Sites

Rincon Reach	Leasburg Reach	Mesilla Reach
Garfield Drain	none	Del Rio Drain
Hatch Drain		La Mesa Drain
Rincon Drain		East Drain
Net Gain		Montoya Drain

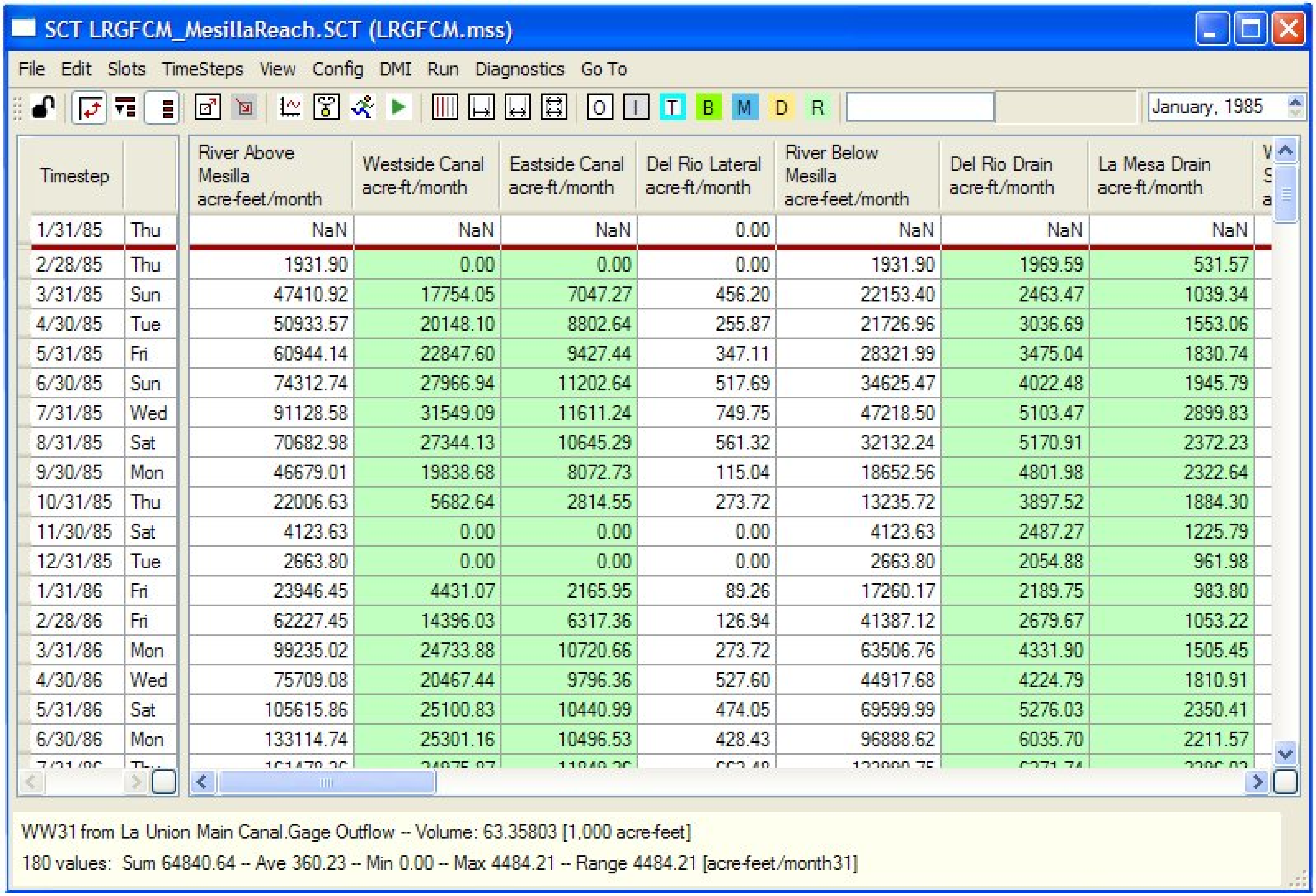
Output Data Sites

Rincon Reach	Leasburg Reach	Mesilla Reach
Garfield Drain	Gain Below Leasburg to Picacho Bridge	Del Rio Drain
Hatch Drain	River at Picacho Bridge	La Mesa Drain
Rincon Drain	Gain Below Picacho Bridge to Above Mesilla	East Drain
Gain Below Caballo to Haynor Brdg	Gain Below Leasburg to Above Mesilla	Montoya Drain
River at Haynor Bridge	River Above Mesilla	Gain Below Mesilla to Above Anthony
Gain Below Haynor Bridge to Above Leasburg		River at Anthony Bridge
Gain Below Caballo to Above Leasburg		Gain Below Anthony to Above Vinton
River Above Leasburg		River at Vinton Bridge
		Gain Below Vinton to Above El Paso
		Gain Below Mesilla to Above El Paso
		River at El Paso

RiverWare System Control Tables

SCTs were developed for each Reach.

Sample SCT for Mesilla Reach.



SCT LRGFCM_MesillaReach.SCT (LRGFCM.mss)

File Edit Slots TimeSteps View Config DMI Run Diagnostics Go To

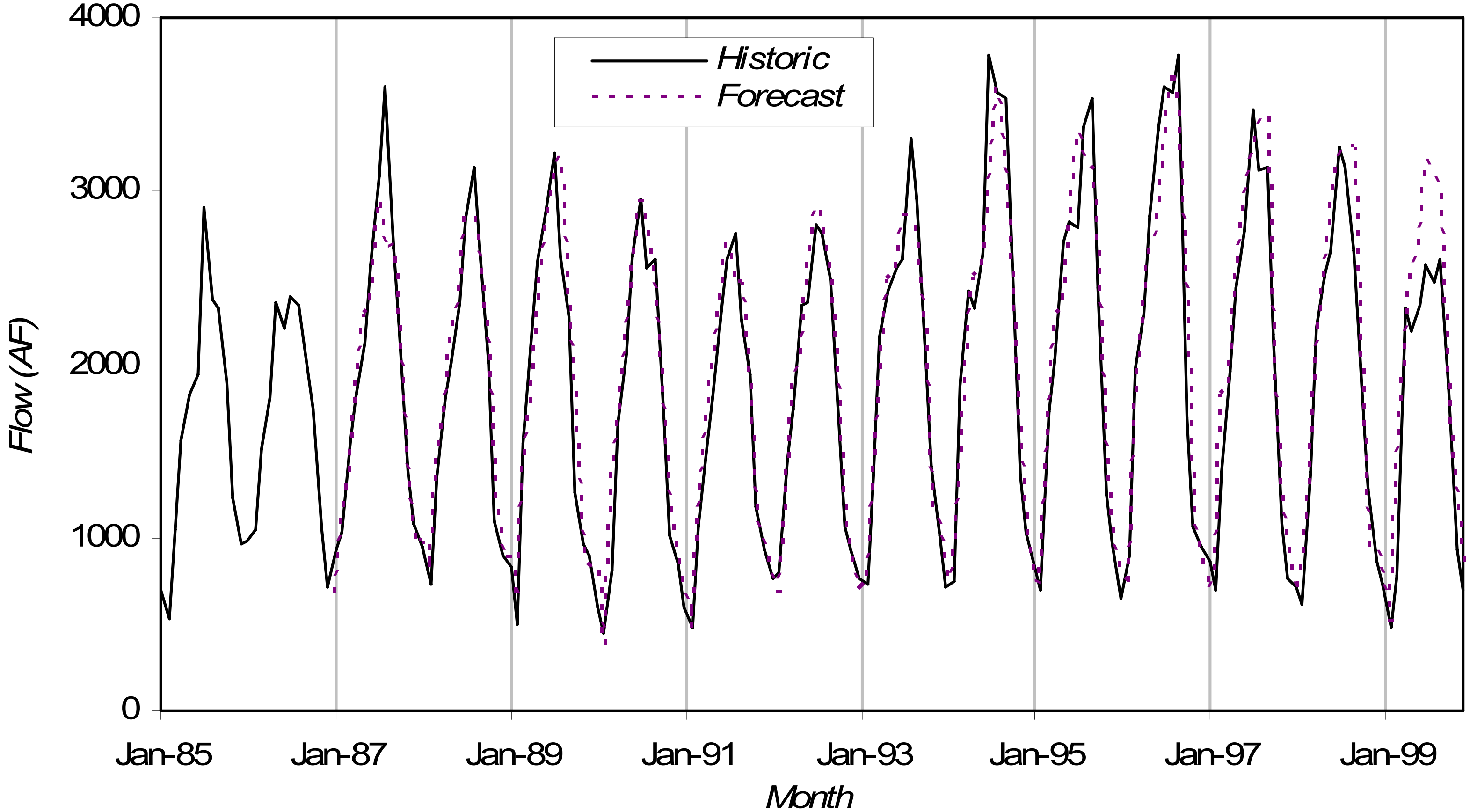
January, 1985

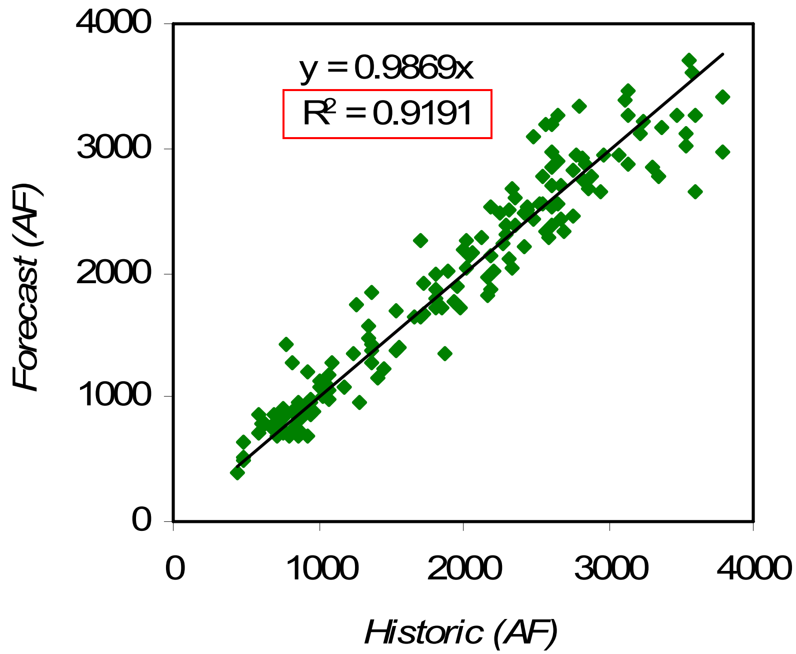
Timestep		River Above Mesilla acre-feet/month	Westside Canal acre-ft/month	Eastside Canal acre-ft/month	Del Rio Lateral acre-ft/month	River Below Mesilla acre-feet/month	Del Rio Drain acre-ft/month	La Mesa Drain acre-ft/month
1/31/85	Thu	NaN	NaN	NaN	0.00	NaN	NaN	NaN
2/28/85	Thu	1931.90	0.00	0.00	0.00	1931.90	1969.59	531.57
3/31/85	Sun	47410.92	17754.05	7047.27	456.20	22153.40	2463.47	1039.34
4/30/85	Tue	50933.57	20148.10	8802.64	255.87	21726.96	3036.69	1553.06
5/31/85	Fri	60944.14	22847.60	9427.44	347.11	28321.99	3475.04	1830.74
6/30/85	Sun	74312.74	27966.94	11202.64	517.69	34625.47	4022.48	1945.79
7/31/85	Wed	91128.58	31549.09	11611.24	749.75	47218.50	5103.47	2899.83
8/31/85	Sat	70682.98	27344.13	10645.29	561.32	32132.24	5170.91	2372.23
9/30/85	Mon	46679.01	19838.68	8072.73	115.04	18652.56	4801.98	2322.64
10/31/85	Thu	22006.63	5682.64	2814.55	273.72	13235.72	3897.52	1884.30
11/30/85	Sat	4123.63	0.00	0.00	0.00	4123.63	2487.27	1225.79
12/31/85	Tue	2663.80	0.00	0.00	0.00	2663.80	2054.88	961.98
1/31/86	Fri	23946.45	4431.07	2165.95	89.26	17260.17	2189.75	983.80
2/28/86	Fri	62227.45	14396.03	6317.36	126.94	41387.12	2679.67	1053.22
3/31/86	Mon	99235.02	24733.88	10720.66	273.72	63506.76	4331.90	1505.45
4/30/86	Wed	75709.08	20467.44	9796.36	527.60	44917.68	4224.79	1810.91
5/31/86	Sat	105615.86	25100.83	10440.99	474.05	69599.99	5276.03	2350.41
6/30/86	Mon	133114.74	25301.16	10496.53	428.43	96888.62	6035.70	2211.57

WW31 from La Union Main Canal.Gage Outflow -- Volume: 63.35803 [1,000 acre-feet]

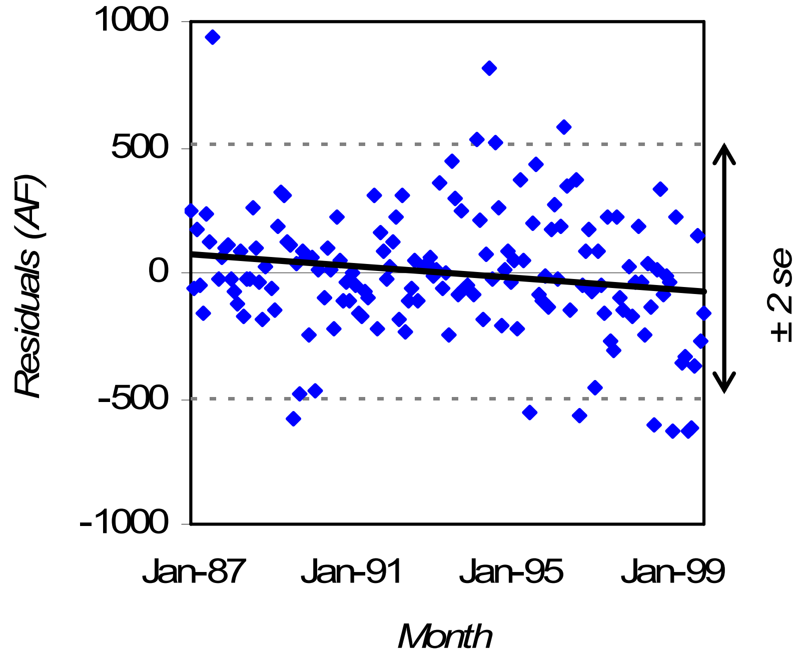
180 values: Sum 64840.64 -- Ave 360.23 -- Min 0.00 -- Max 4484.21 -- Range 4484.21 [acre-feet/month31]

Results for La Mesa Drain



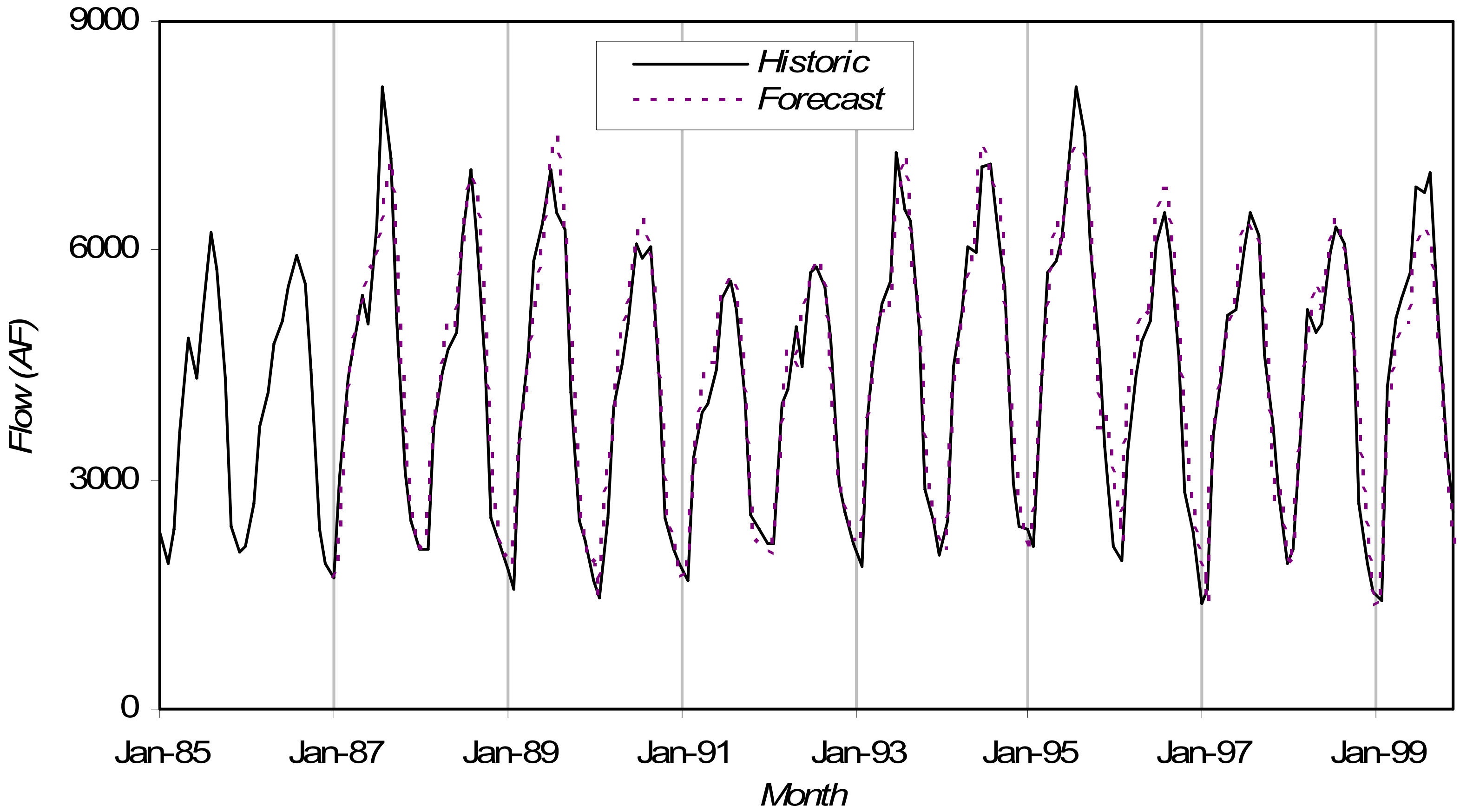


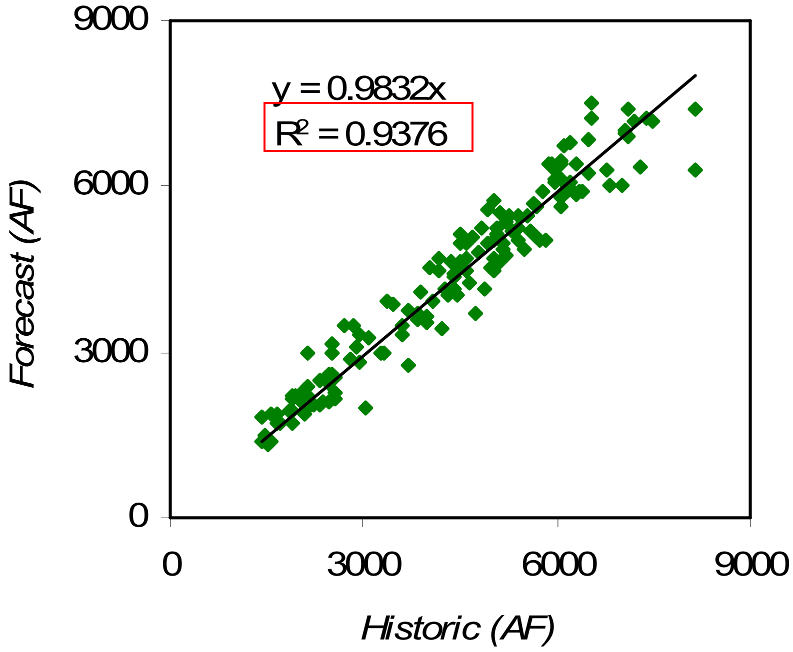
Residuals



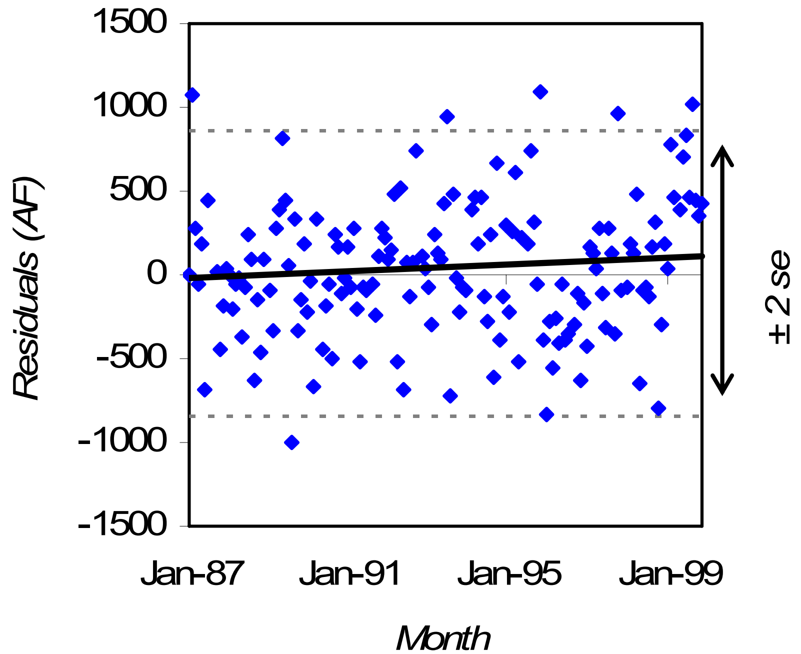
Correlation for La Mesa Drain forecast data vs. actual data

Results for Montoya Drain



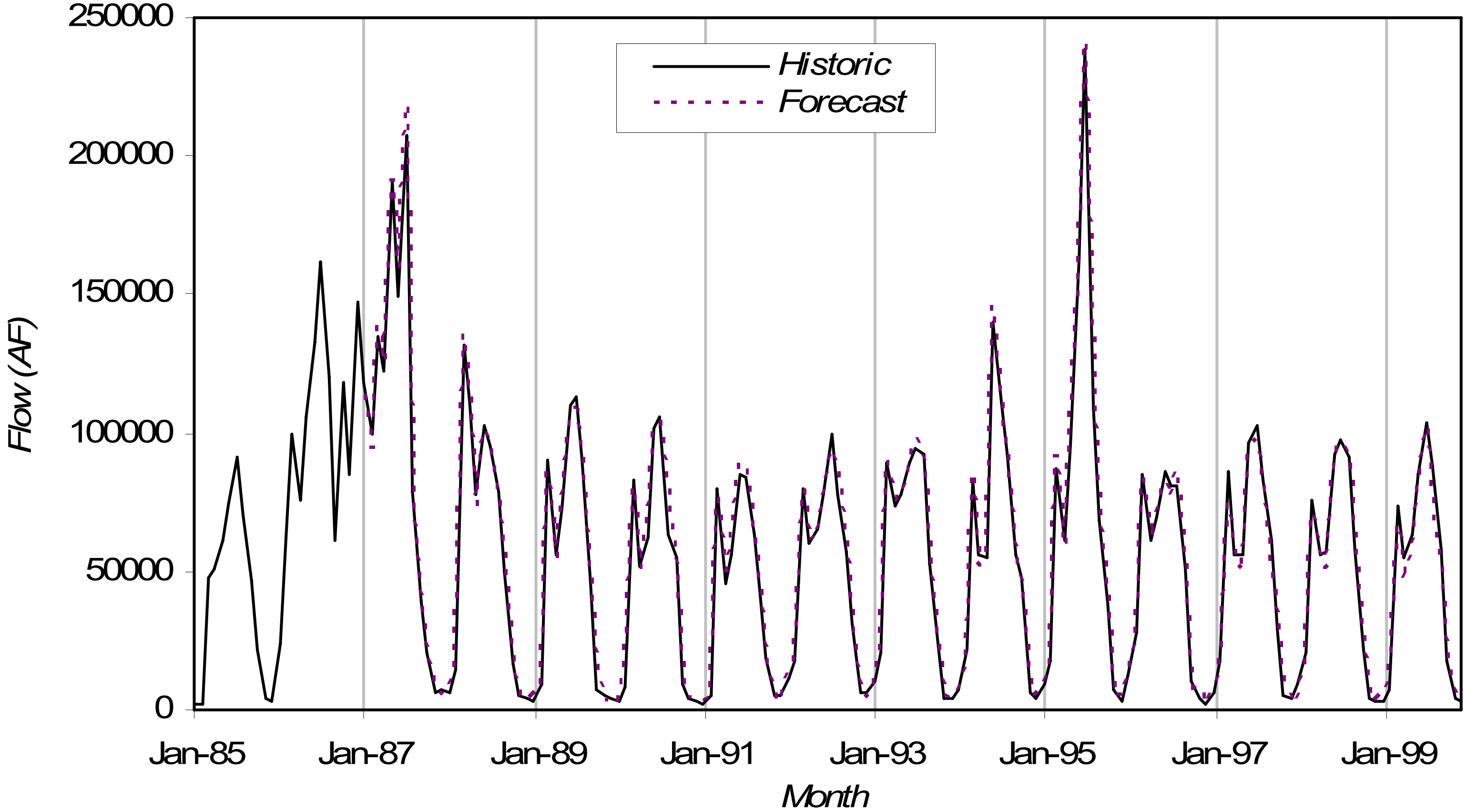


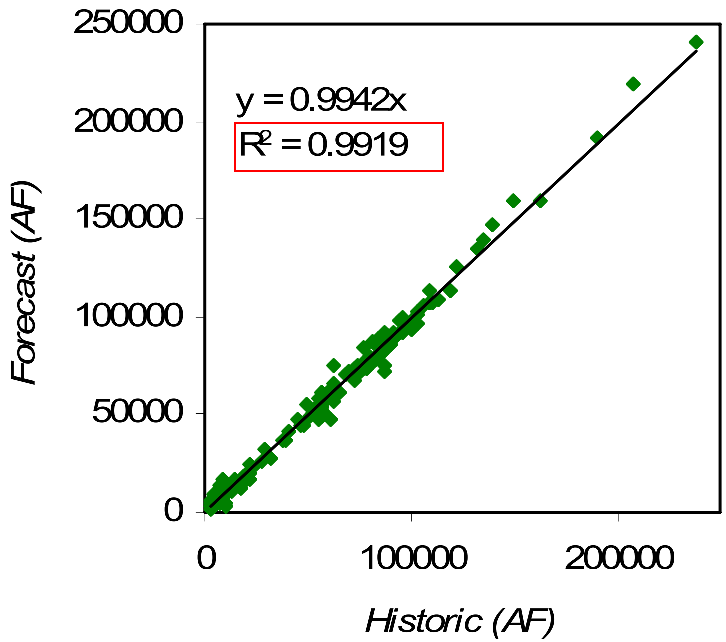
Residuals



Correlation for Montoya Drain forecast data vs. actual data

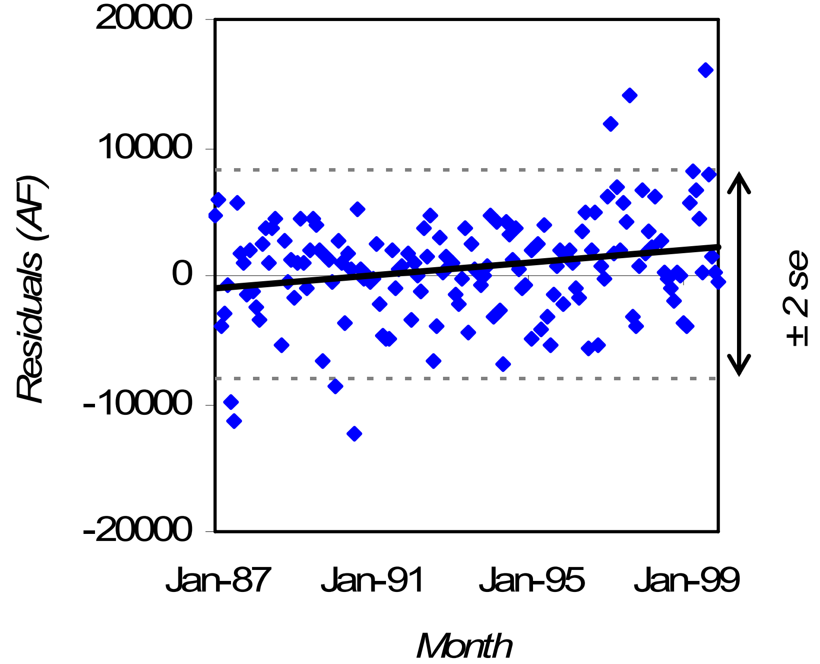
Results for River Above Mesilla



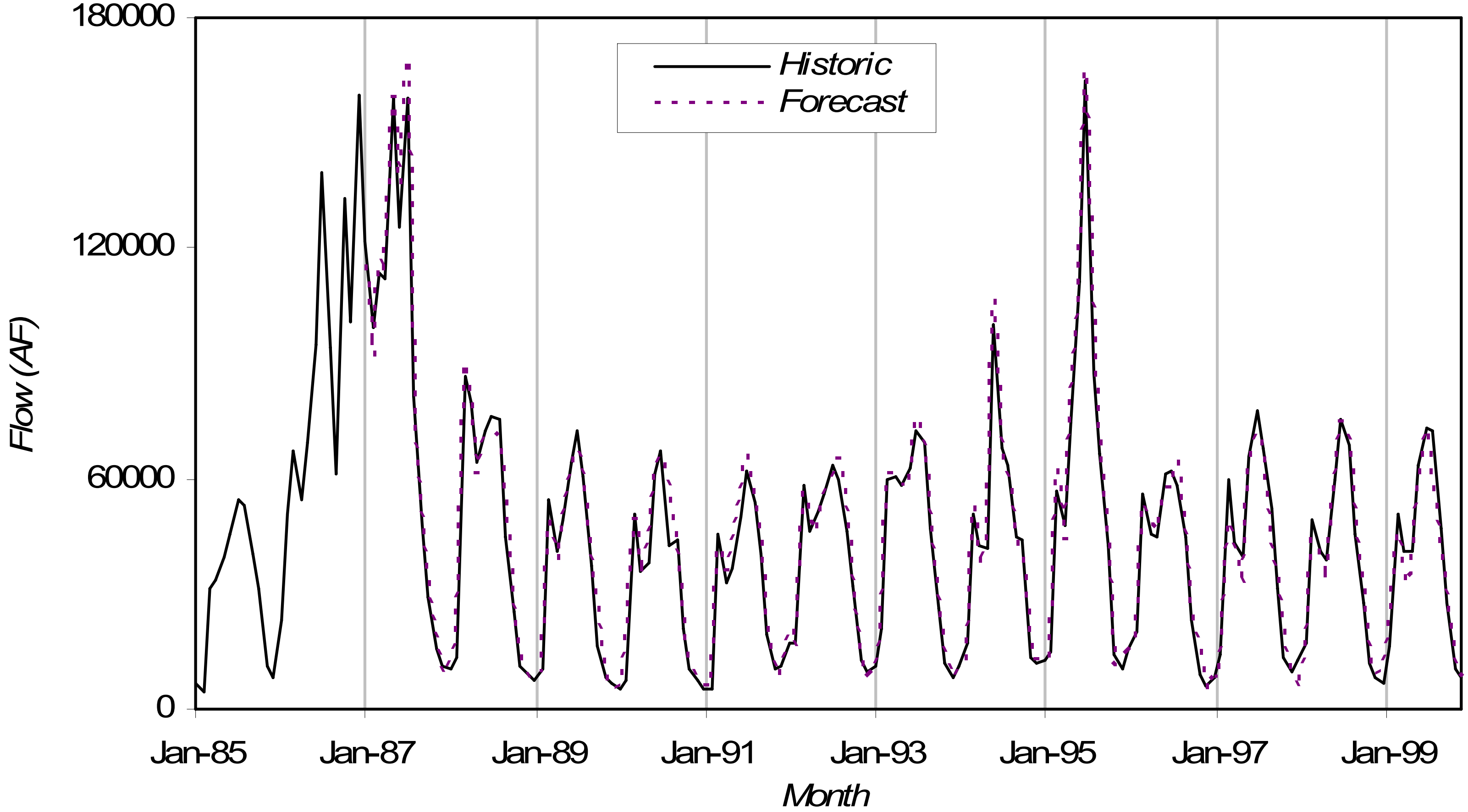


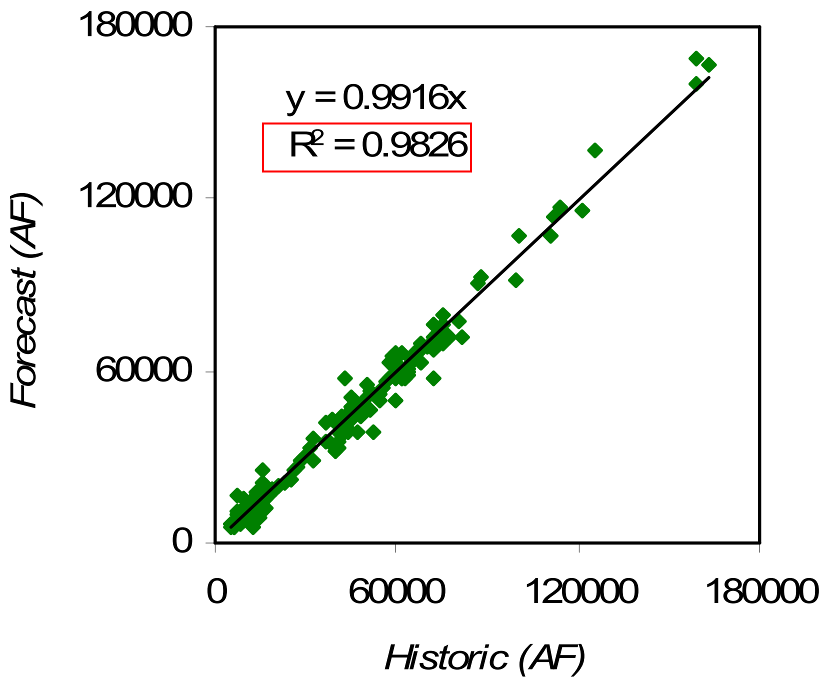
Correlation for River Above Mesilla forecast data vs. actual data

Residuals



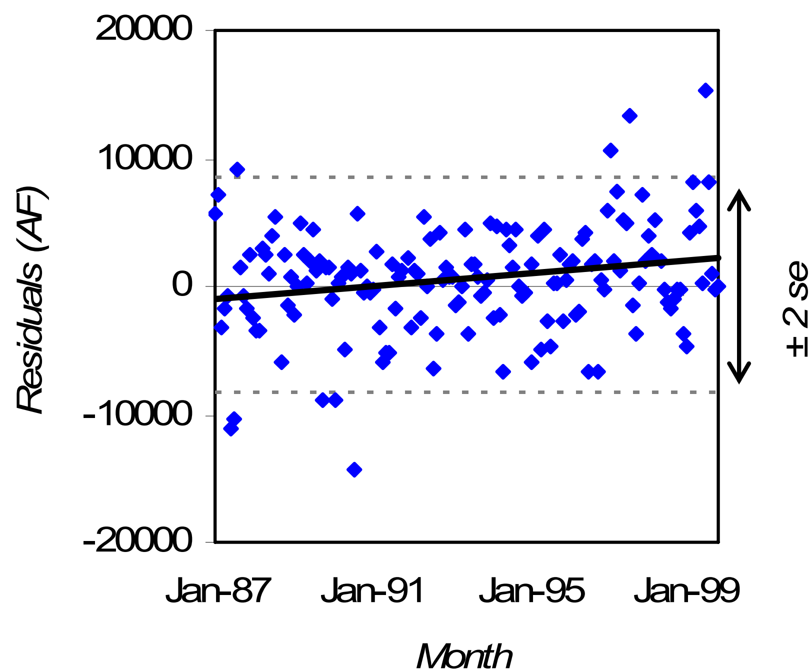
Results for River At El Paso





Correlation for River At El Paso forecast data vs. actual data

Residuals



CONCLUSIONS

- ARIMA *Transfer Functions* are adequate for estimating drain return flows from diversions
- Results are highly correlated with historic values
- Equations provide more accurate results than simple linear relationships
- However, deriving and implementing the *Transfer Function* equations can be difficult and time consuming

Questions?