WESTSIM / SHEDTOOL : Toolbox for simulating groundwater conjunctive use, agricultural drainage and wetland return flows on the west-side of the San Joaquin Basin

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U. S. Bureau of Reclamation, Sacramento, CA

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MWH Americas Inc., Sacramento, CA

CWEMF Central Valley Groundwater Workshop
July 11, 2008

Outline

- Model support 2002-2005
- IWFM overview
- WESTSIM description
- Calibration tools
- Other related work/Status

Model Support (2002-2005)

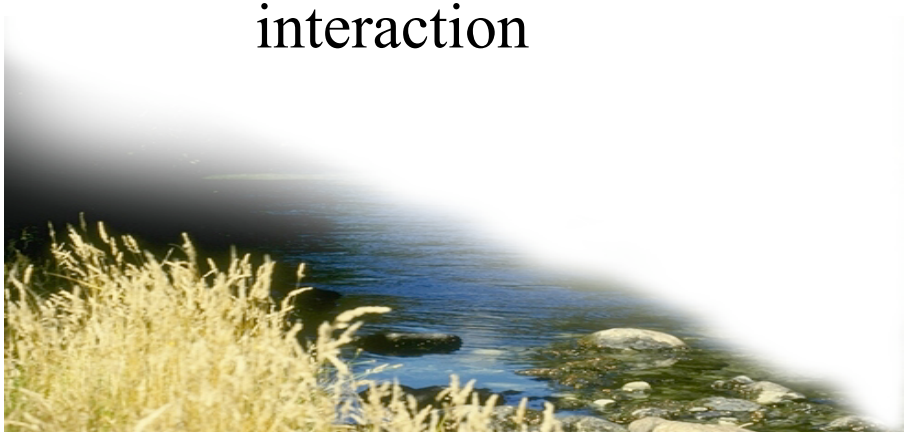
- Model development
- Data collection
- Conversion of input files from IGSM to IWFM
- Extending simulation period and input data from 1970-1993 to 1970-2000
- Development of calibration tools

MODELING TOOL: IWFM

- Integrated Water Flow Model (IWFM), formerly known as IGSM2, developed by the Modeling Support Branch of the Bay-Delta Office of DWR
- Simulates GW, SW, stream-groundwater interaction, and other components of the hydrologic system
- Models GW flow as a quasi 3-D system and solves the governing flow equation using the Galerkin finite element method
- Land use based approach of calculating water demand
- Z-budget post-processor for subsurface flow computations

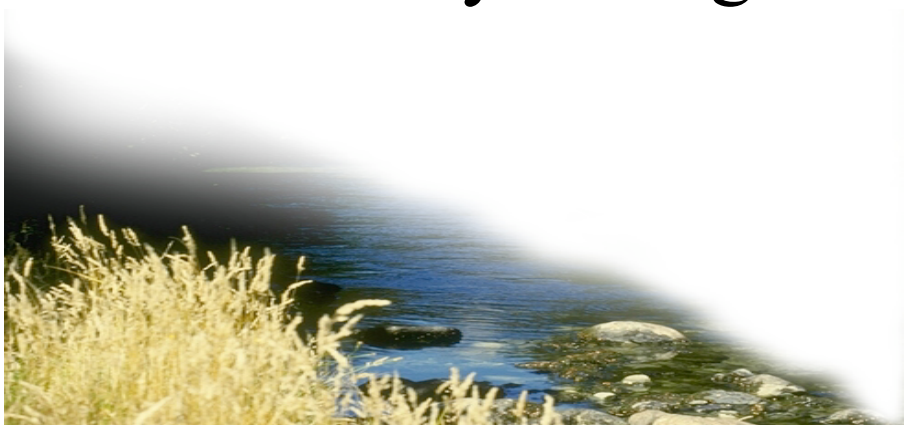
WESTSIM MODEL

- West-side of San Joaquin River Basin
- Monthly time step
- Contains 63 subregions, which are defined by collections of finite elements, to represent individual water districts, refuges, or cities
- Contains detailed inputs of surface water use, land use, evapotranspiration, streamflow, return flows, and aquifer characteristics for the period of 1970-2000
- Would simulate agricultural water demand, groundwater pumping, groundwater recharge, and stream-aquifer interaction



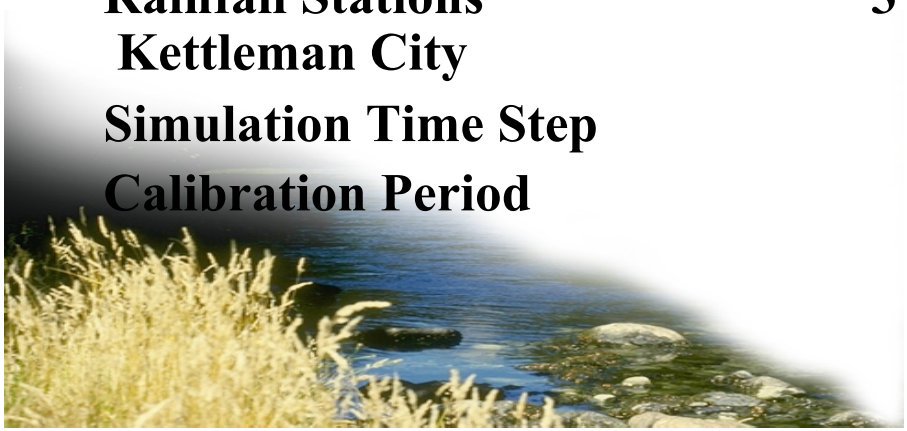
Possible Applications

- Groundwater impact analysis
- Land retirement
- Conjunctive use planning
- Safe yield analysis
- Salinity management



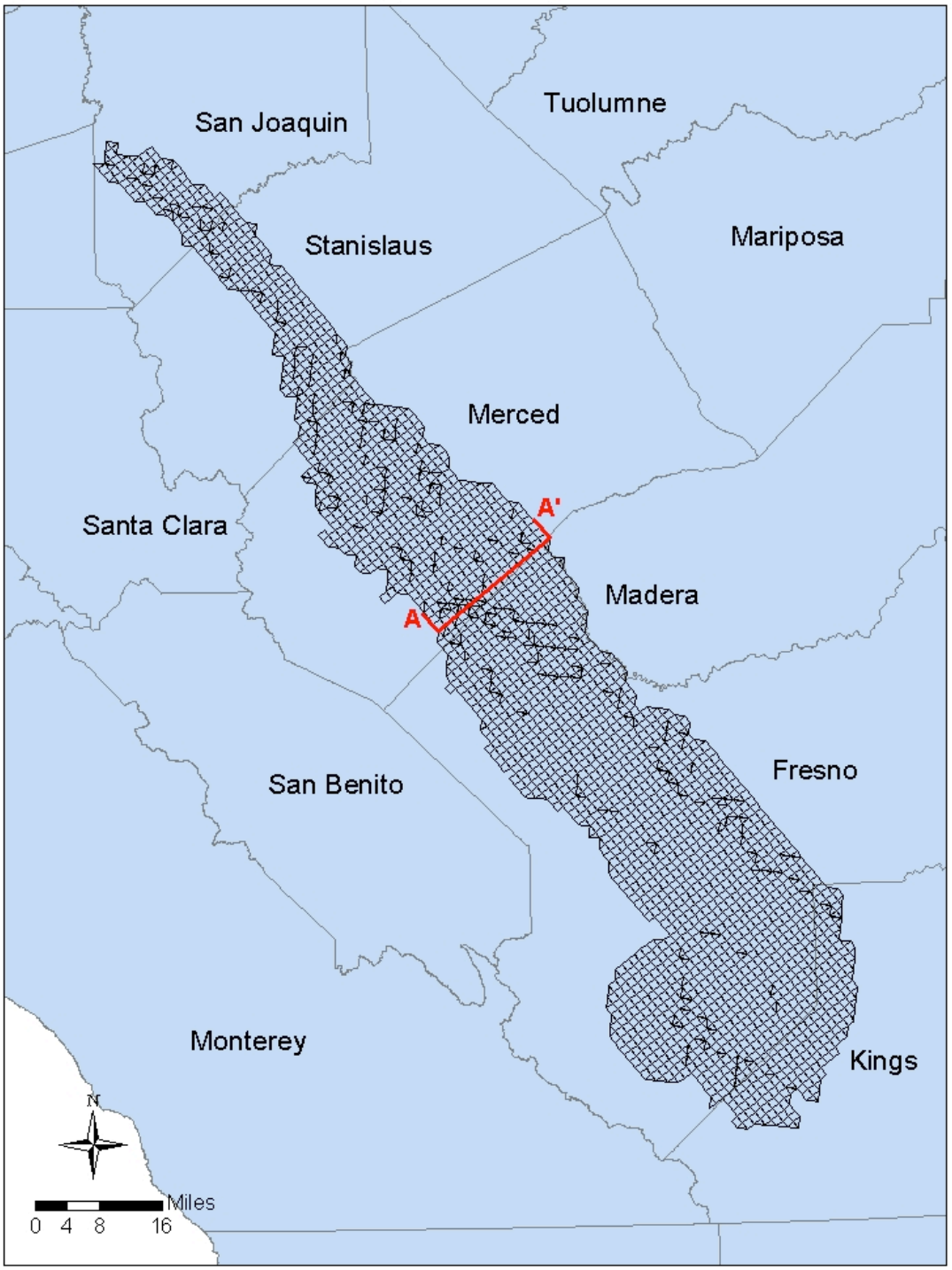
WESTSIM MODEL FEATURES

Model region	**1,550,874**	**acres**
Subregions	**63**	**WDs/IDs, Cities, Refuges**
Elements	**2,602**	
Groundwater Nodes	**2,716**	
Crop types	**16**	
Aquifer layers	**7**	**5 above Corcoran Clay**
Land use types	**4**	**Agricultural, urban, native vegetation, riparian**
Streams Modeled	**11**	
Stream Nodes	**351**	
Small Watersheds	**6**	
Rainfall Stations	**3**	**Tracy, Los Banos, Kettleman City**
Simulation Time Step		**Monthly**
Calibration Period		**1970-2000**

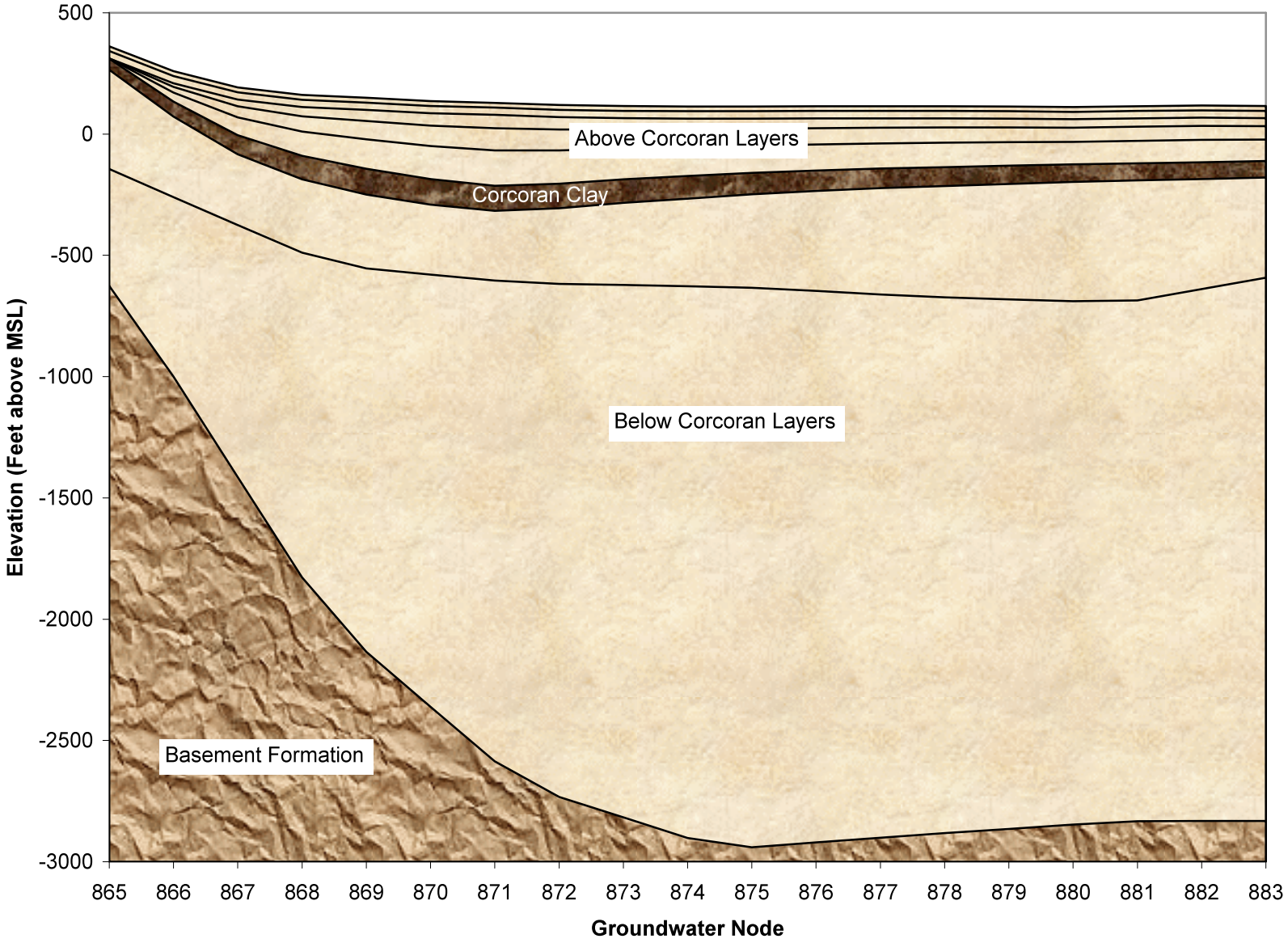


West-side of San Joaquin Basin

Sample Cross-Section A-A’

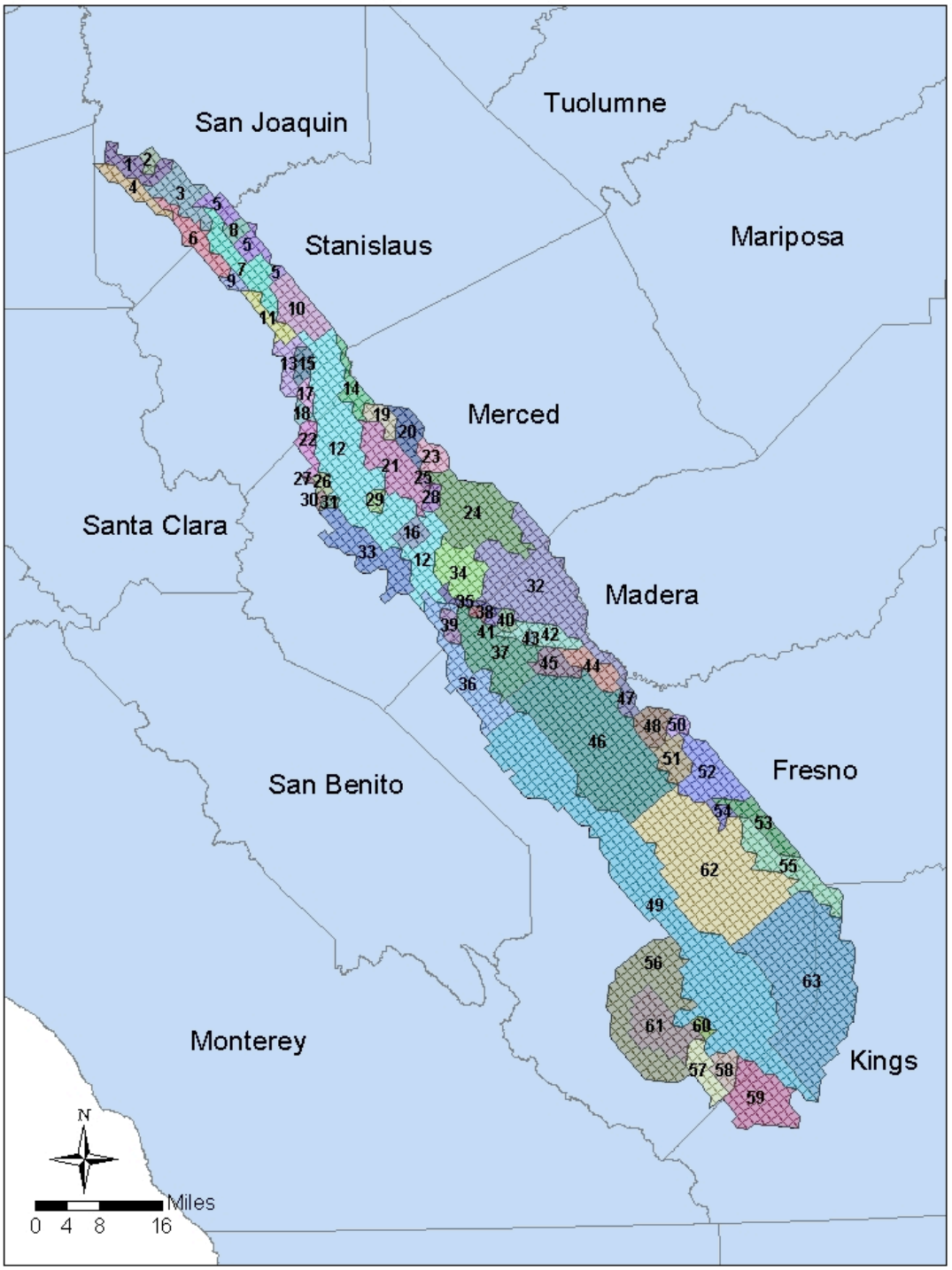


Sample Cross-Section A-A’



63 Subregions:

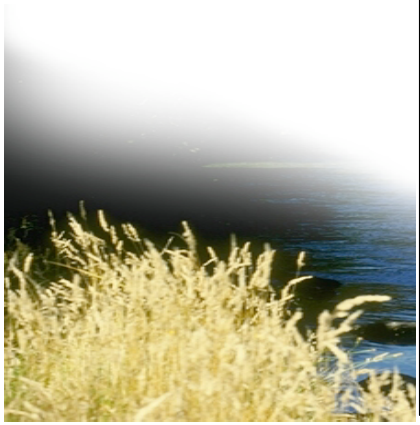
Cities, Irrigation Districts, and Refuges

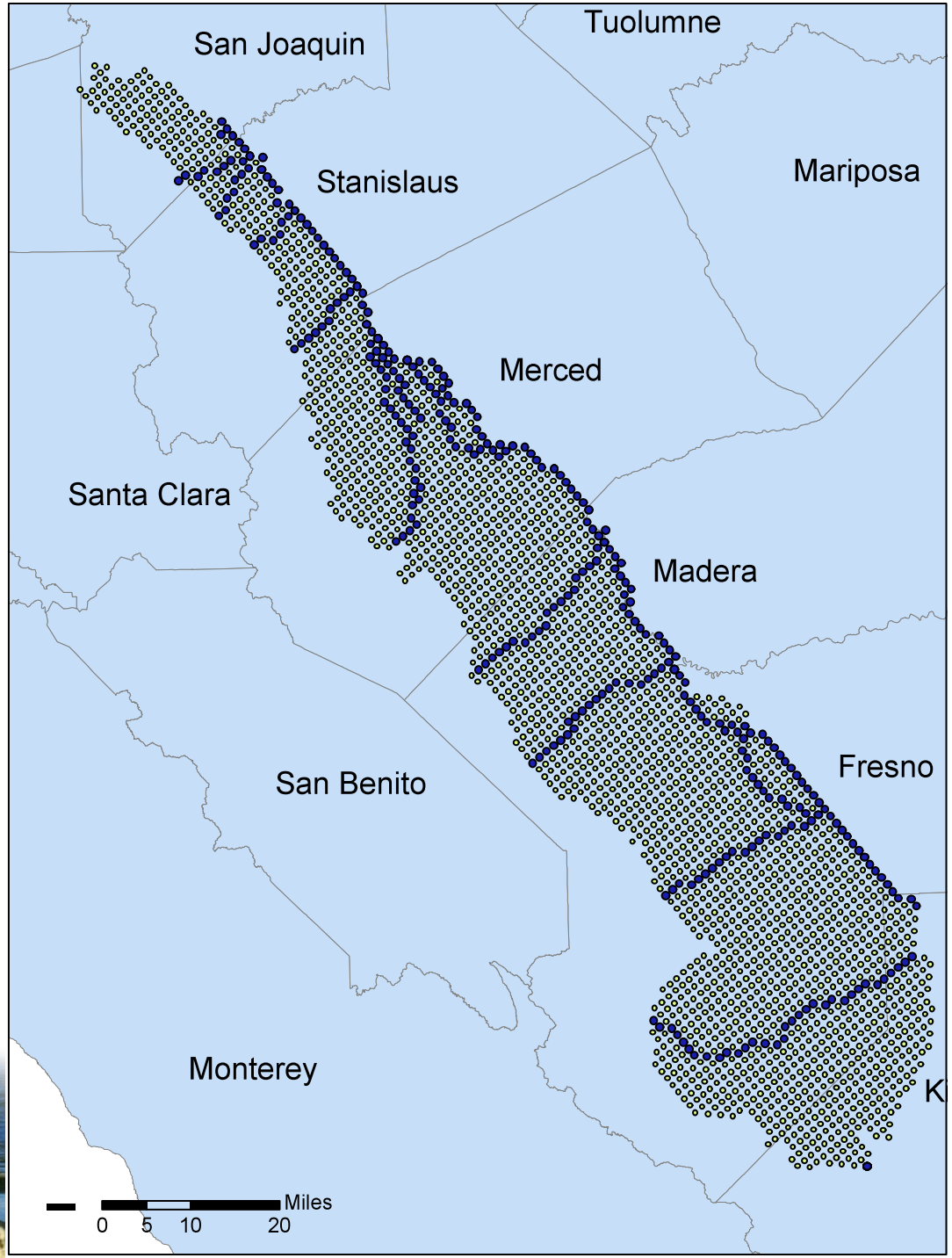


SUBREGION LIST

1 - Westside Water District	22 - Mustang Water District	43 - Widren Water District
2 - City of Tracy	23 - San Luis/Kesterson (South)	44 - Firebaugh Canal Co (South)
3 - Banta Carbona Irrigation District	24 - San Luis Canal Company	45 - Broadview Water District
4 - Plainview Water District	25 - Salt Slough	46 - Westlands Water District (Northeast)
5 - San Joaquin\Stanislaus Unincorporated	26 - Quinto Water District	47 - Mendota Water Management Agency
6 - Hospital Water District	27 - Lansdale Water District	48 - Fresno Slough Water District
7 - West Stanislaus Irrigation District	28 - Los Banos Water Management Agency	49 - Westlands Water District (West)
8 - El Solyo Water District	29 - Volta Water Management Agency	50 - Traction Ranch
9 - Kern Canyon Water District	30 - Centinella Water District	51 - Tranquility Irrigation District
10 - Patterson Water District	31 - Romero Water District	52 - James Irrigation District
11 - Del Puerto Water District	32 - Central California Irrigation District (South)	53 - Stinson Water District
12 - Central California Irrigation District (Central)	33 - San Luis Water District (DMC)	54 - Mid Valley Water Authority (North)
13 - Sunflower Water District	34 - Grasslands Water District (South)	55 - Mid Valley Water Authority (South)
14 - Stanislaus\Merced Unicorporated	35 - Eagle Field/CCID Contractors	56 - City of Coalinga (West)
15 - Orestimba Water District	36 - San Luis Water District (SLC)	57 - Pleasant Valley Water District (South)
16 - City of Los Banos	37 - Panoche Water District (DMC/SLC)	58 - Fresno County Unincorporated
17 - Foothill Water District	38 - Eagle Field Water District (South)	59 - City of Avenal
18 - Davis Water District	39 - Pacheco Water District	60 - City of Coalinga (East)
19 - San Luis/Kesterson (North)	40 - Mercy Springs Water District	61 - Pleasant Valley Water District (North)
20 - West Gallo	41 - Oro Loma Water District	62 - Westlands Water District (East)
21 - Grasslands Water District (North)	42 - Firebaugh Canal Co (North)	63 - Westlands Water District (Southeast)

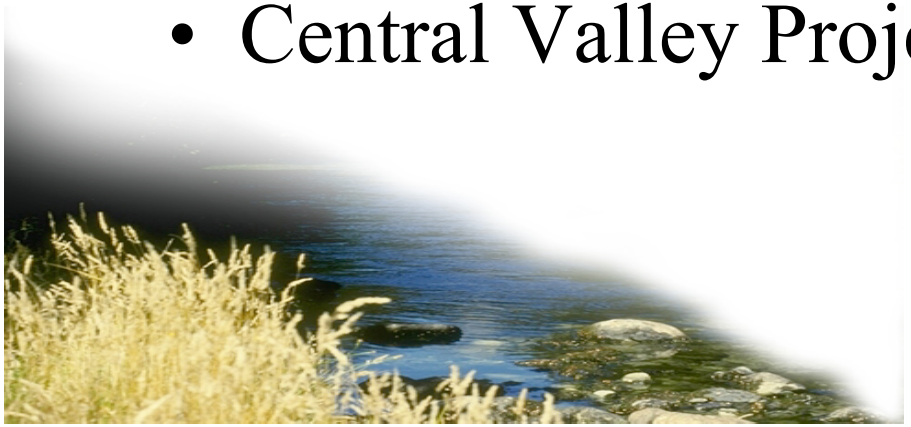
351 Stream Nodes

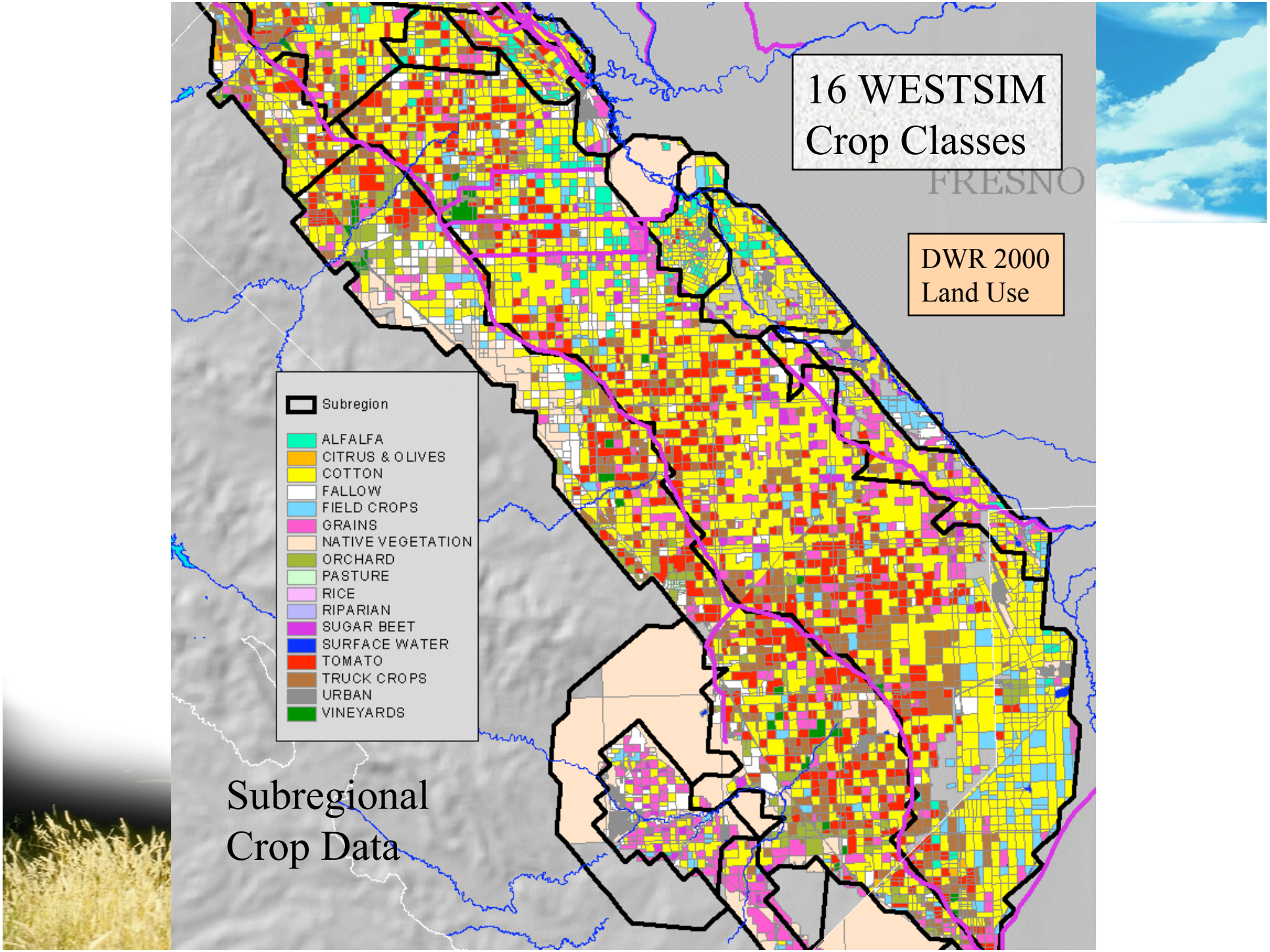




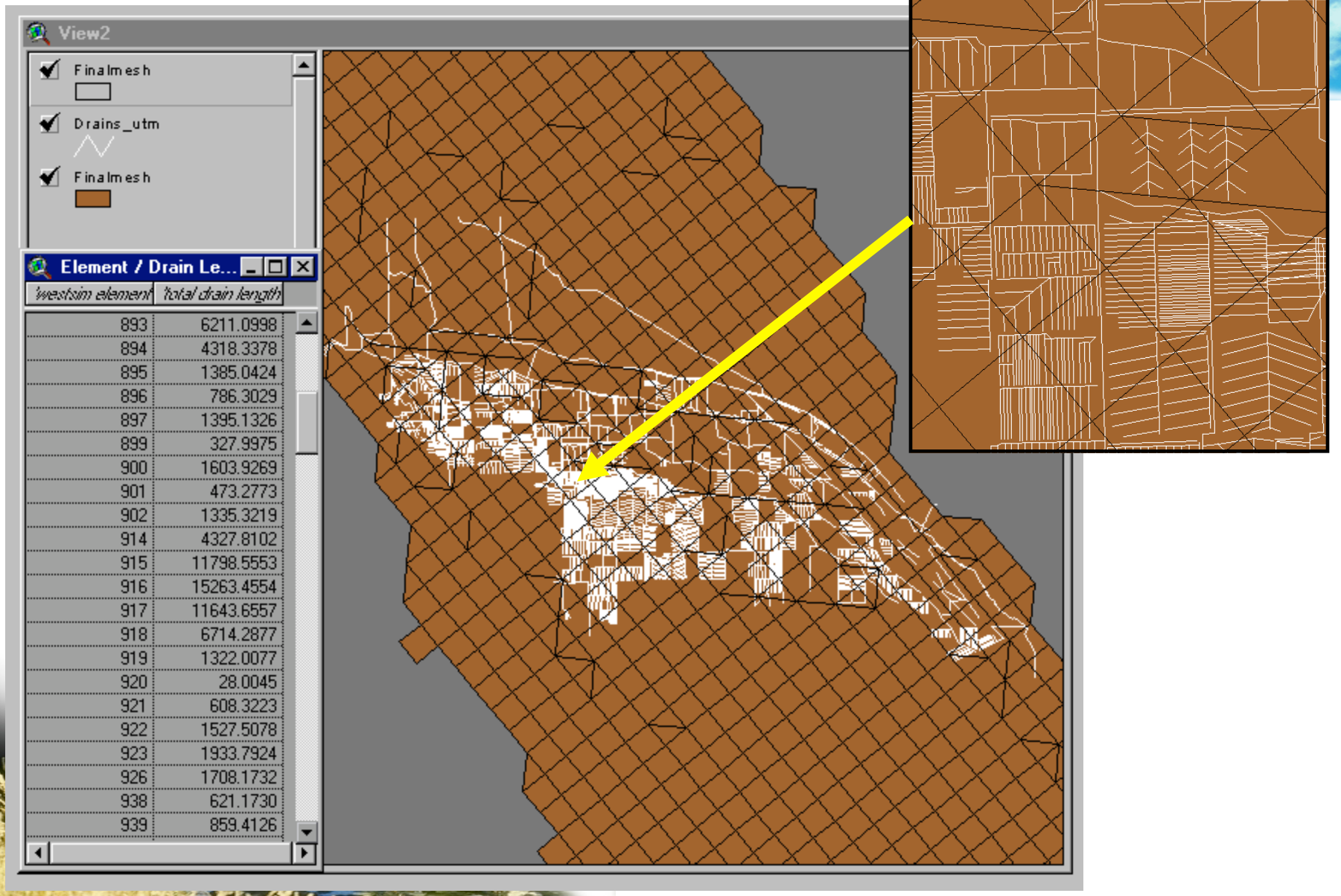
WESTSIM INPUT DATA

- Landuse/cropping (DWR Surveys, USBR)
- Precipitation (NCDC)
- Evapotranspiration (USGS, CIMIS)
- Streamflow (USGS, DWR)
- River Diversions (SJRIO2)
- Central Valley Project deliveries (USBR)




16 WESTSIM
Crop Classes
FRESNO
DWR 2000
Land Use
Subregion
ALFALFA
CITRUS & OLIVES
COTTON
FALLOW
FIELD CROPS
GRAINS
NATIVE VEGETATION
ORCHARD
PASTURE
RICE
RIPARIAN
SUGAR BEET
SURFACE WATER
TOMATO
TRUCK CROPS
URBAN
VINEYARDS
Subregional
Crop Data

Total Drain Length per Element



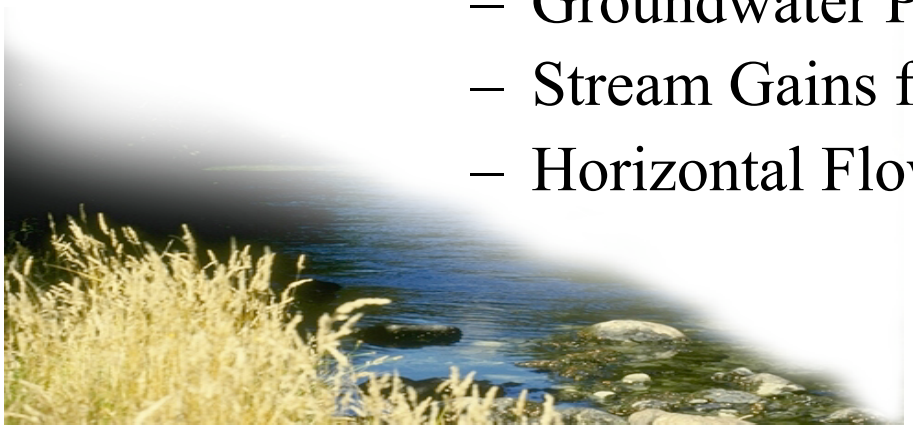
WESTSIM SIMULATION OUTPUT

- Water Budgets
  - Land and Water Use
  - Groundwater
  - Root Zone Moisture
  - Stream
- Groundwater Surface Elevations
- Stream Flows

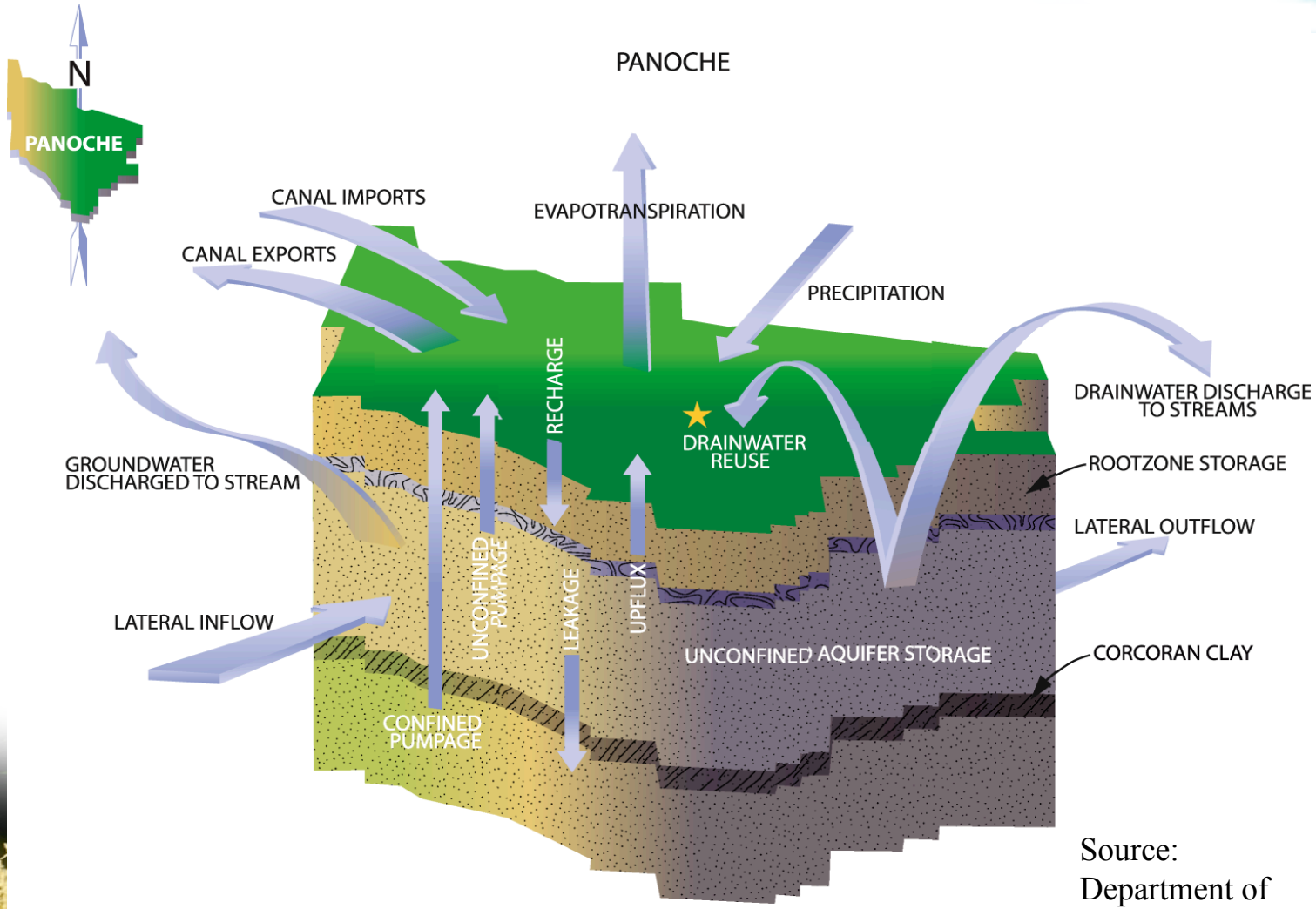
GROUNDWATER BUDGET

(In - Out = Δ Storage)

- Inflows:
  - Deep Percolation
  - Stream Losses to GW
  - Horizontal Flows In
  - Artificial Recharge
- Outflows:
  - Tile Drainage
  - Groundwater Pumping
  - Stream Gains from GW
  - Horizontal Flows Out



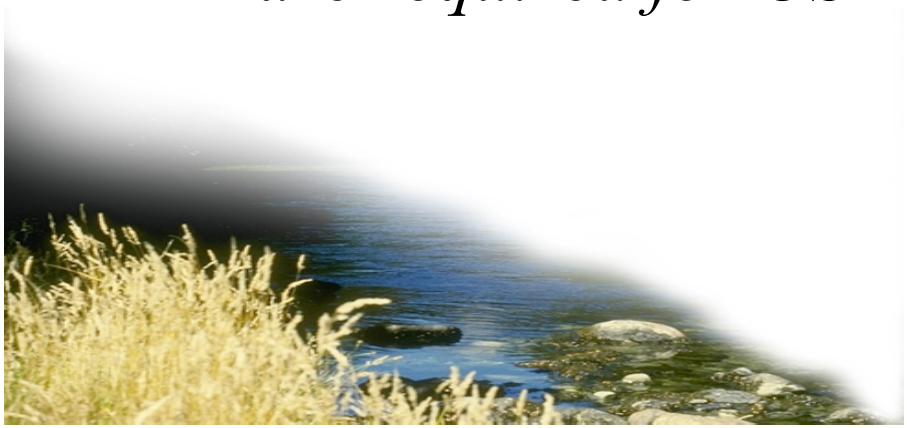
GROUNDWATER BUDGET SCHEMATIC



Source:
Department of
Water Resources

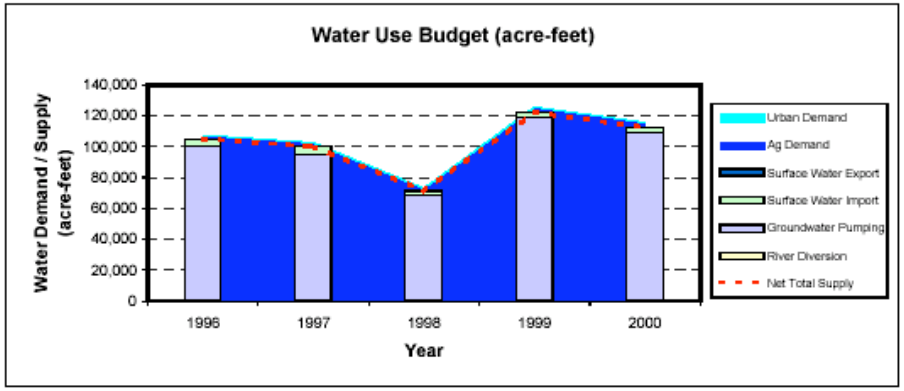
SURFACE AND GROUNDWATER BUDGETS

- Water use and groundwater budgets in tabular and graphical format.
- Wanted to develop a water balance on a subregion basis to aid in calibration and to encourage interaction with water districts. *(Water Budgets are required for USBR Contract Renewal)*



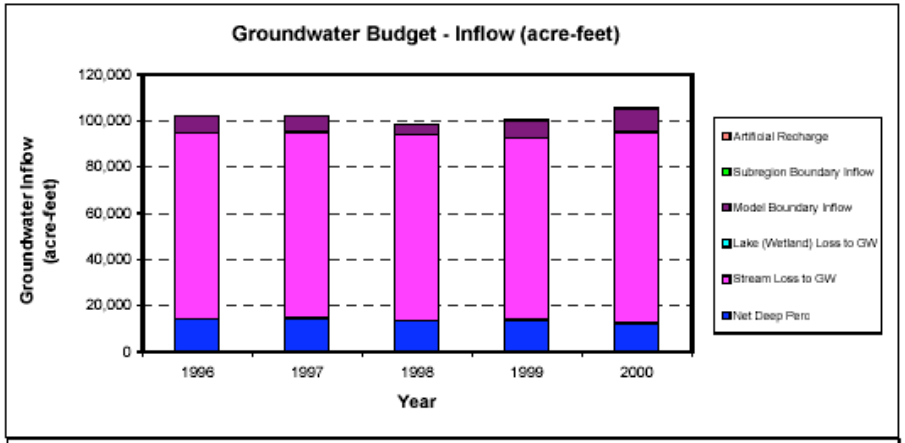
Water Use Budget (acre-feet)
Fresno Slough Water District

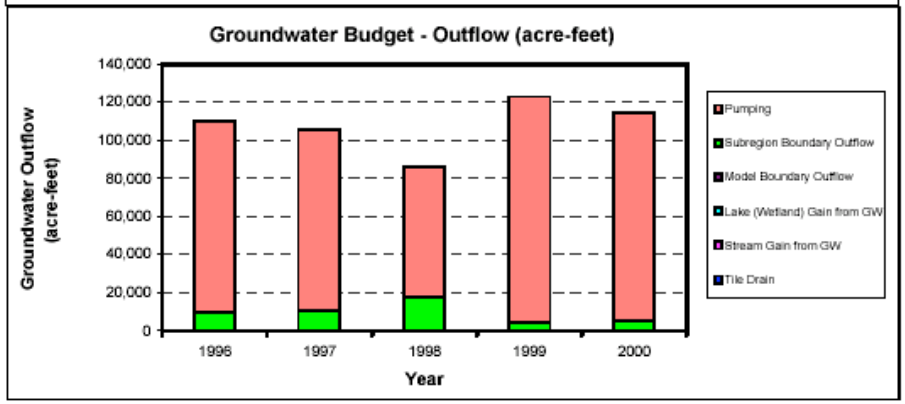
Water Use Budget	1996	1997	1998	1999	2000	5-Year Average
DEMAND						
Ag Demand	107,386	102,525	72,908	125,548	115,651	104,803
Urban Demand	0	0	0	0	0	0
Total Demand	107,386	102,525	72,908	125,548	115,651	104,803
SUPPLY						
River Diversion	0	0	0	0	0	0
Groundwater Pumping	100,170	94,736	68,496	118,719	109,157	98,255
Surface Water Import	4,781	5,292	2,663	3,552	3,258	3,909
Total Supply	104,951	100,028	71,159	122,270	112,415	102,165
Surface Water Export	0	0	0	0	0	0
Non-recoverable Loss						
Net Total Supply	104,951	100,028	71,159	122,270	112,415	102,165
Shortage (Surplus)	2,435	2,497	1,749	3,278	3,236	2,639



Groundwater Budget (acre-feet)
Fresno Slough Water District

Groundwater Budget	1996	1997	1998	1999	2000	5-Year Average
INFLOW						
Net Deep Perc	13,952	14,658	13,234	13,836	12,243	13,584
Stream Loss to GW	80,616	80,542	80,871	78,616	82,868	80,703
Lake (Wetland) Loss to GW	0	0	0	0	0	0
Model Boundary Inflow	7,537	7,130	4,185	7,809	10,278	7,388
Subregion Boundary Inflow	0	0	0	0	0	0
Artificial Recharge	0	0	0	0	0	0
Total Inflow	102,104	102,330	98,290	100,261	105,389	101,675
OUTFLOW						
Tile Drain	0	0	0	0	0	0
Pumping	100,170	94,736	68,496	118,719	109,157	98,255
Stream Gain from GW	0	0	0	0	0	0
Lake (Wetland) Gain from GW	0	0	0	0	0	0
Model Boundary Outflow	0	0	0	0	0	0
Subregion Boundary Outflow	9,434	10,537	17,555	4,222	5,404	9,431
Total Outflow	109,604	105,273	86,051	122,941	114,561	107,686
Change in Storage	-7,499	-2,943	12,239	-22,680	-9,172	-6,011
Change in Storage (AF/acre)	-0.65	-0.26	1.06	-1.97	-0.80	-0.52





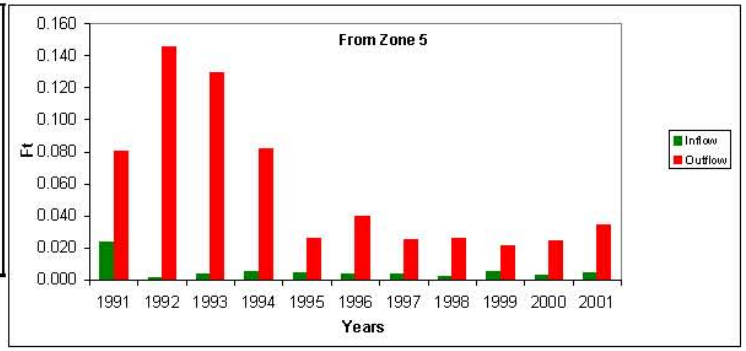
Water use and groundwater budgets

Select Zone Number **10**

Notes
Zone 73 is Below Corcoran Clay
Zone 10 Area = 20802 ACRES
Number of Zones = 126

Select Result Units

- Volume (Acre-Feet)
- Water Depth (ft) — **"Volume divided by the Total Zone Area"**
- Water Depth (ft) — **"Volume divided by the Irrigated Area ONLY"**



IGSM2 ZONE BUDGET IN Ft FOR ZONE 10

Inflow	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	AnnuAvera
Streams Loss to GW	1.43	0.79	0.51	0.49	0.14	0.43	0.17	0.19	0.16	0.26	0.18	0.43
Tile Drains	-	-	-	-	-	-	-	-	-	-	-	-
Subsidence	-	-	-	-	-	-	-	-	-	-	-	-
Net Deep Percolation	6.27	3.07	3.32	3.78	0.75	2.13	1.48	1.37	1.77	1.22	1.37	2.41
General Head BC	0.03	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01
Small Watershed Baseflow	-	-	-	-	-	-	-	-	-	-	-	-
Diversion Recoverable Loss	-	-	-	-	-	-	-	-	-	-	-	-
Bypass Recoverable Loss	-	-	-	-	-	-	-	-	-	-	-	-
Lakes(Wetland)Loss to GW	-	-	-	-	-	-	-	-	-	-	-	-
Pumping by Element	-	-	-	-	-	-	-	-	-	-	-	-
From Zone 5	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
From Zone 7	1.14	0.30	0.25	0.20	0.08	0.13	0.11	0.12	0.13	0.14	0.15	0.25
From Zone 11	0.69	0.33	0.31	0.19	0.07	0.17	0.18	0.20	0.19	0.22	0.22	0.25
From Zone 12	0.51	0.35	0.31	0.19	0.06	0.09	0.05	0.05	0.07	0.06	0.05	0.16
From Zone 73	0.13	0.23	0.16	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.06
Total	10.23	5.09	4.89	4.93	1.13	2.98	2.01	1.95	2.34	1.91	1.99	3.59

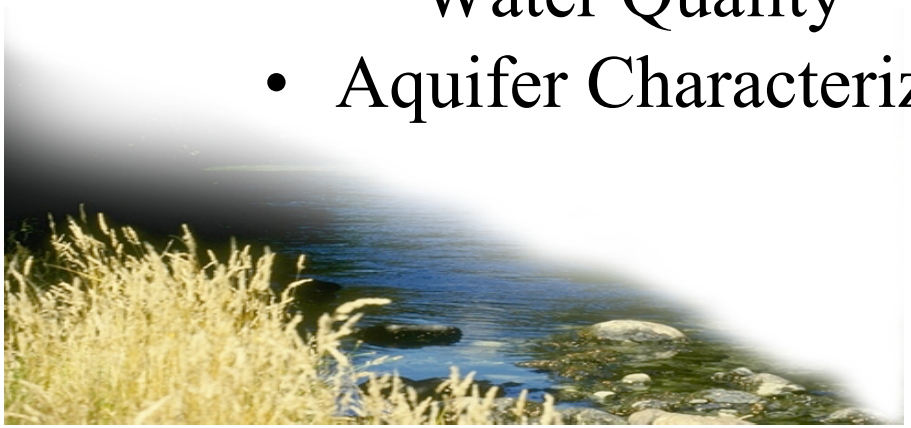
Outflow	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	AnnuAvera
Streams Gain From GW	1.51	1.60	1.38	0.75	0.46	0.73	0.58	0.59	0.69	0.74	0.67	0.88
Tile Drains	-	-	-	-	-	-	-	-	-	-	-	-
Subsidence	-	-	-	-	-	-	-	-	-	-	-	-
Net Deep Percolation	-	-	-	-	-	-	-	-	-	-	-	-
General Head BC	2.12	2.43	2.10	1.38	0.58	0.80	0.63	0.66	0.66	0.68	0.69	1.16
Small Watershed Baseflow	-	-	-	-	-	-	-	-	-	-	-	-
Diversion Recoverable Loss	-	-	-	-	-	-	-	-	-	-	-	-
Bypass Recoverable Loss	-	-	-	-	-	-	-	-	-	-	-	-
Lakes(Wetland) Gain From GW	-	-	-	-	-	-	-	-	-	-	-	-
Pumping by Element	-	-	-	-	-	-	-	-	0.02	-	0.02	0.00
To Zone 5	0.08	0.15	0.13	0.08	0.03	0.04	0.03	0.03	0.02	0.02	0.03	0.06
To Zone 7	0.08	0.19	0.14	0.10	0.03	0.05	0.03	0.03	0.02	0.02	0.03	0.07
To Zone 11	0.01	0.03	0.02	0.02	0.01	0.01	0.00	0.00	0.00	-	0.00	0.01
To Zone 12	0.05	0.05	0.05	0.06	0.03	0.05	0.05	0.07	0.06	0.07	0.10	0.06
To Zone 73	0.27	0.03	0.04	0.04	0.02	0.04	0.04	0.05	0.06	0.07	0.07	0.07
Total	4.13	4.48	3.86	2.44	1.15	1.71	1.36	1.43	1.53	1.61	1.62	2.30

Storage	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	AnnuAvera
IN	1.34	1.32	0.93	0.25	0.46	0.42	0.38	0.41	0.43	0.43	0.44	0.62
OUT	7.44	1.93	1.97	2.73	0.45	1.68	1.03	0.93	1.25	0.73	0.82	1.91
Change	6.10	0.61	1.03	2.49	(0.01)	1.26	0.65	0.52	0.81	0.30	0.38	1.29

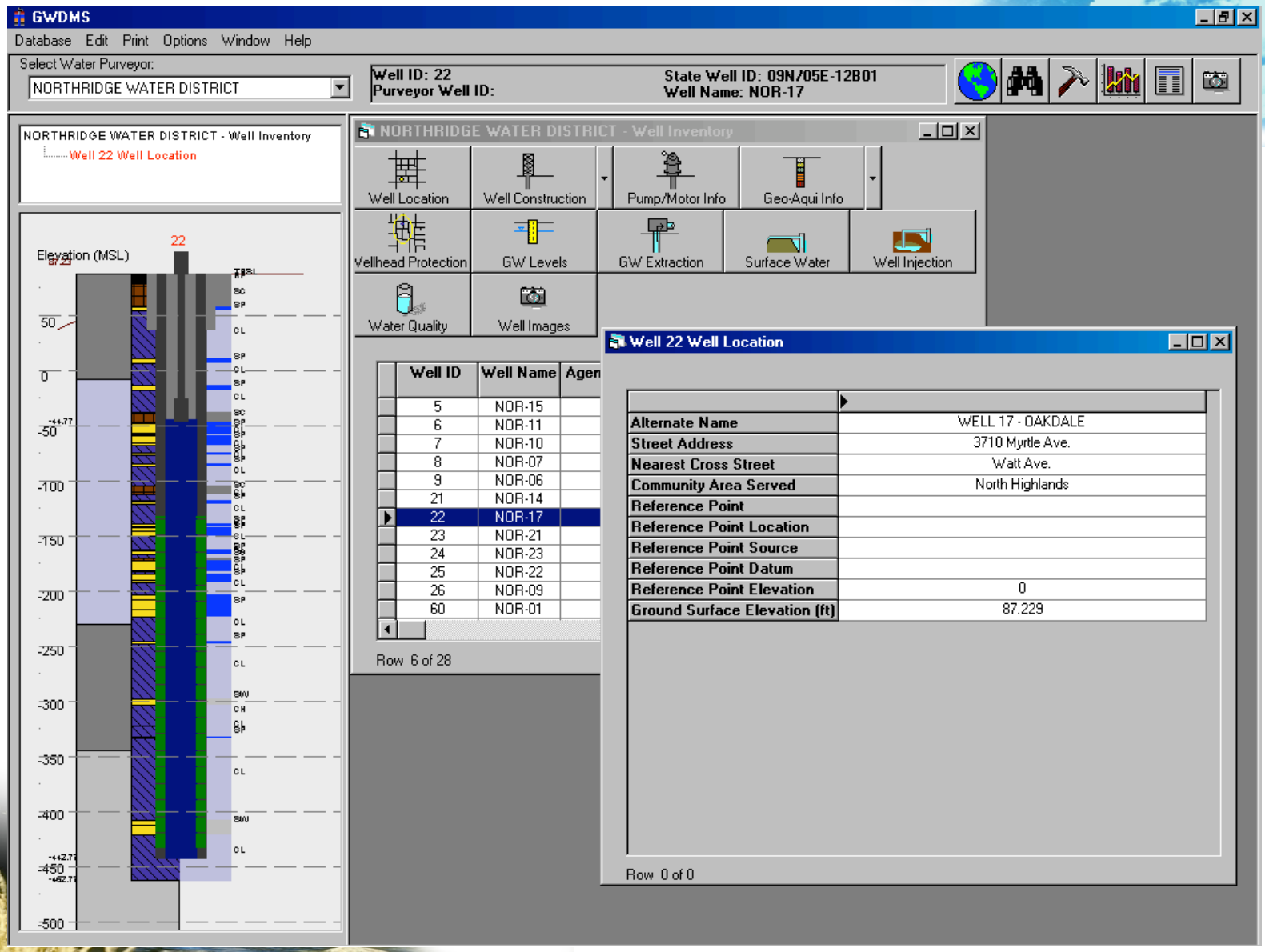
Soil Budget	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	AnnuAvera
Agricultural Area (1000 Acres)	4.1	3.1	3.6	5.9	14.2	10.6	14.3	14.4	14.7	14.7	14.7	10.39
Precipitation	0.61	0.58	0.82	1.51	0.80	1.02	1.11	0.94	1.68	0.86	0.80	0.98
Runoff	0.23	0.16	0.25	0.44	0.10	0.19	0.15	0.16	0.45	0.07	0.12	0.21
Prime Applied Water	12.46	17.11	14.37	9.98	3.69	5.06	3.79	3.45	3.38	3.23	3.42	7.27
Reused Water	6.81	10.56	8.52	5.41	0.31	1.42	0.34	0.24	0.43	0.24	0.20	3.14
Return Flow	5.80	10.21	7.81	4.15	0.08	0.38	0.08	0.06	0.11	0.06	0.05	2.62
Actual ET	4.10	4.42	4.30	4.12	3.21	3.69	3.18	3.03	2.80	2.82	2.84	3.50

SHEDTOOL

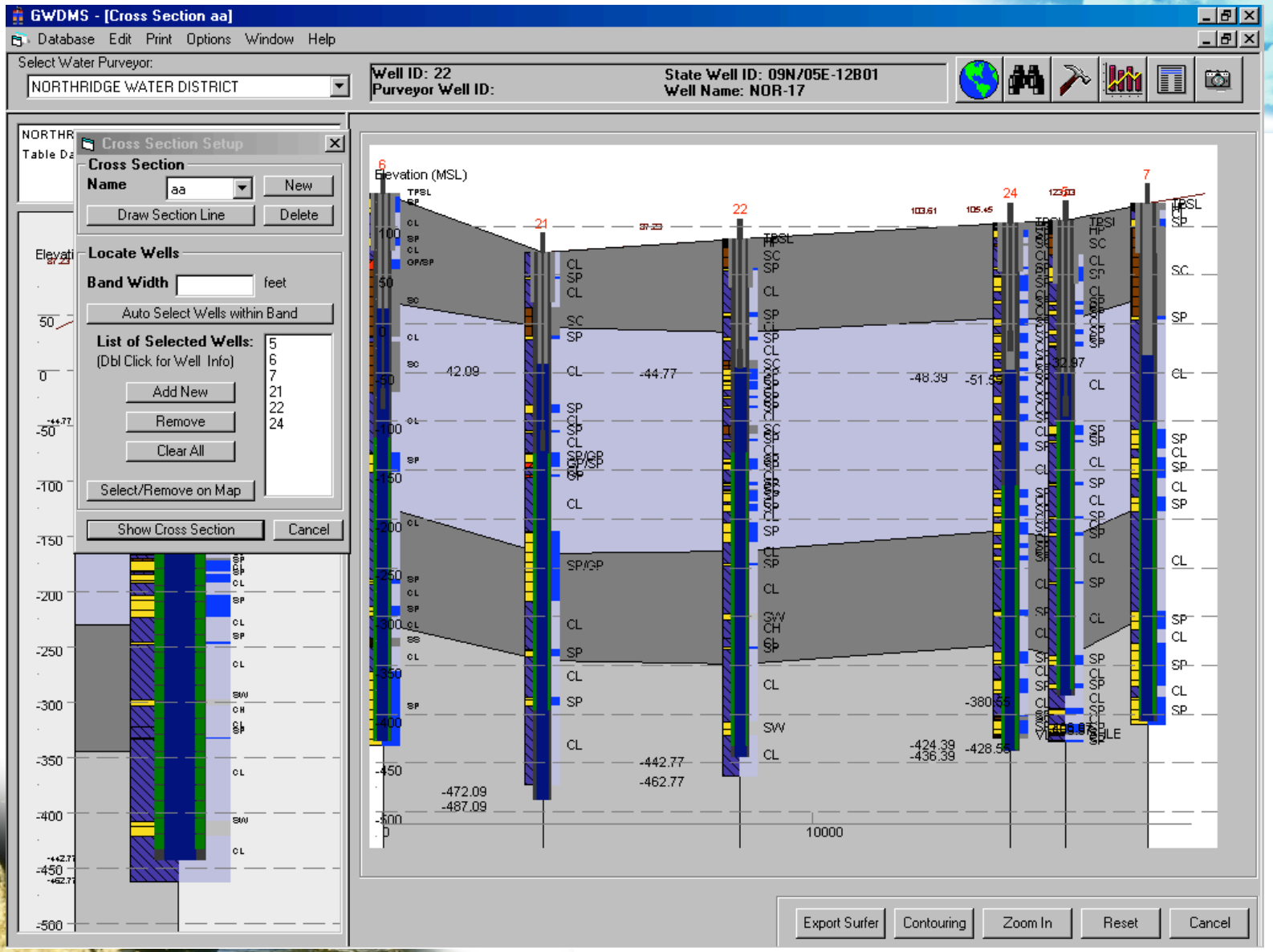
- Graphical User Interface
- Data Storage and Security
- Well Construction Data
- Well Location and Siting Constraints
- Long-term Monitoring
  - Extraction Volumes
  - Water Elevations
  - Water Quality
- Aquifer Characterization



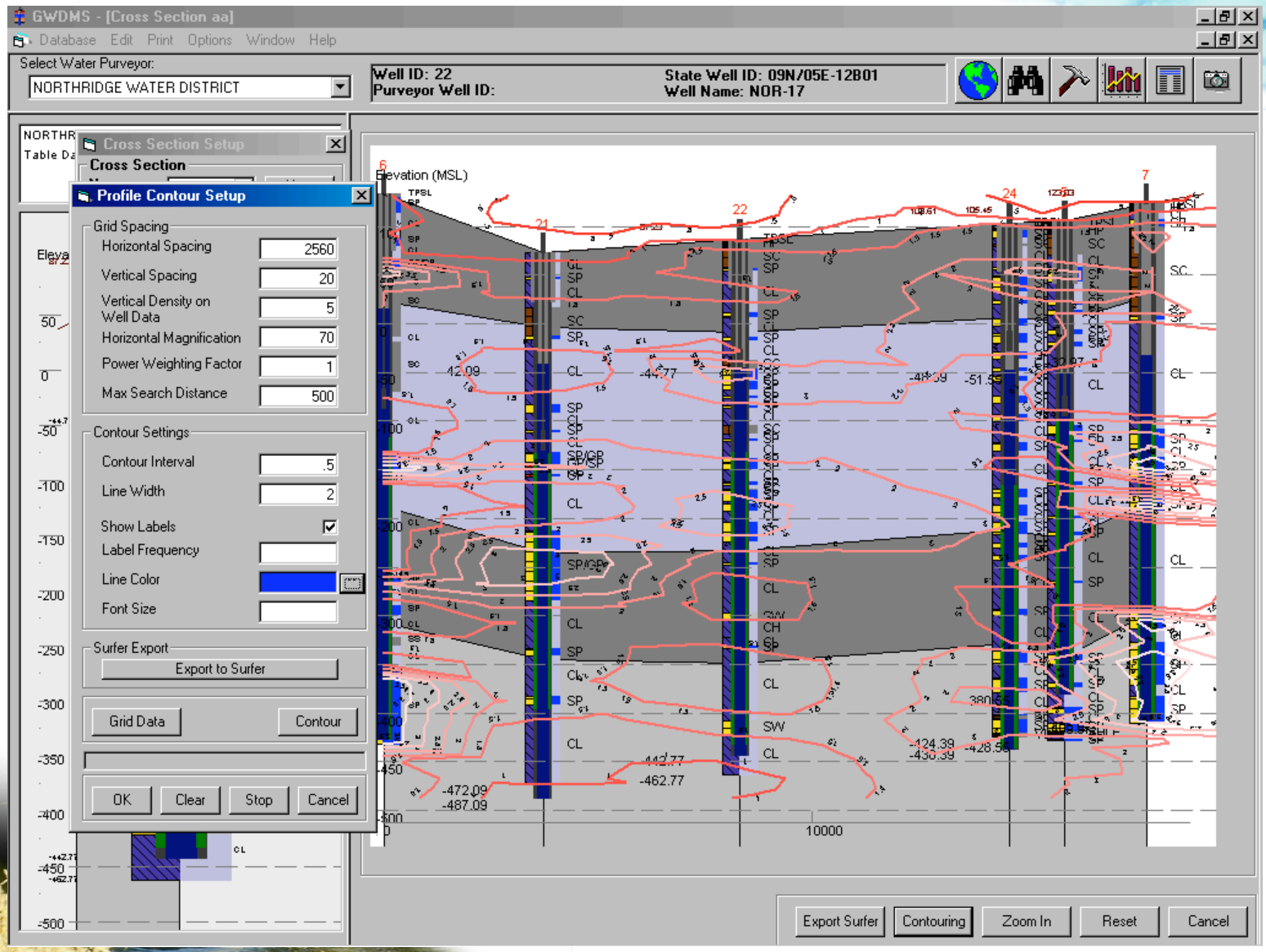
Well Data

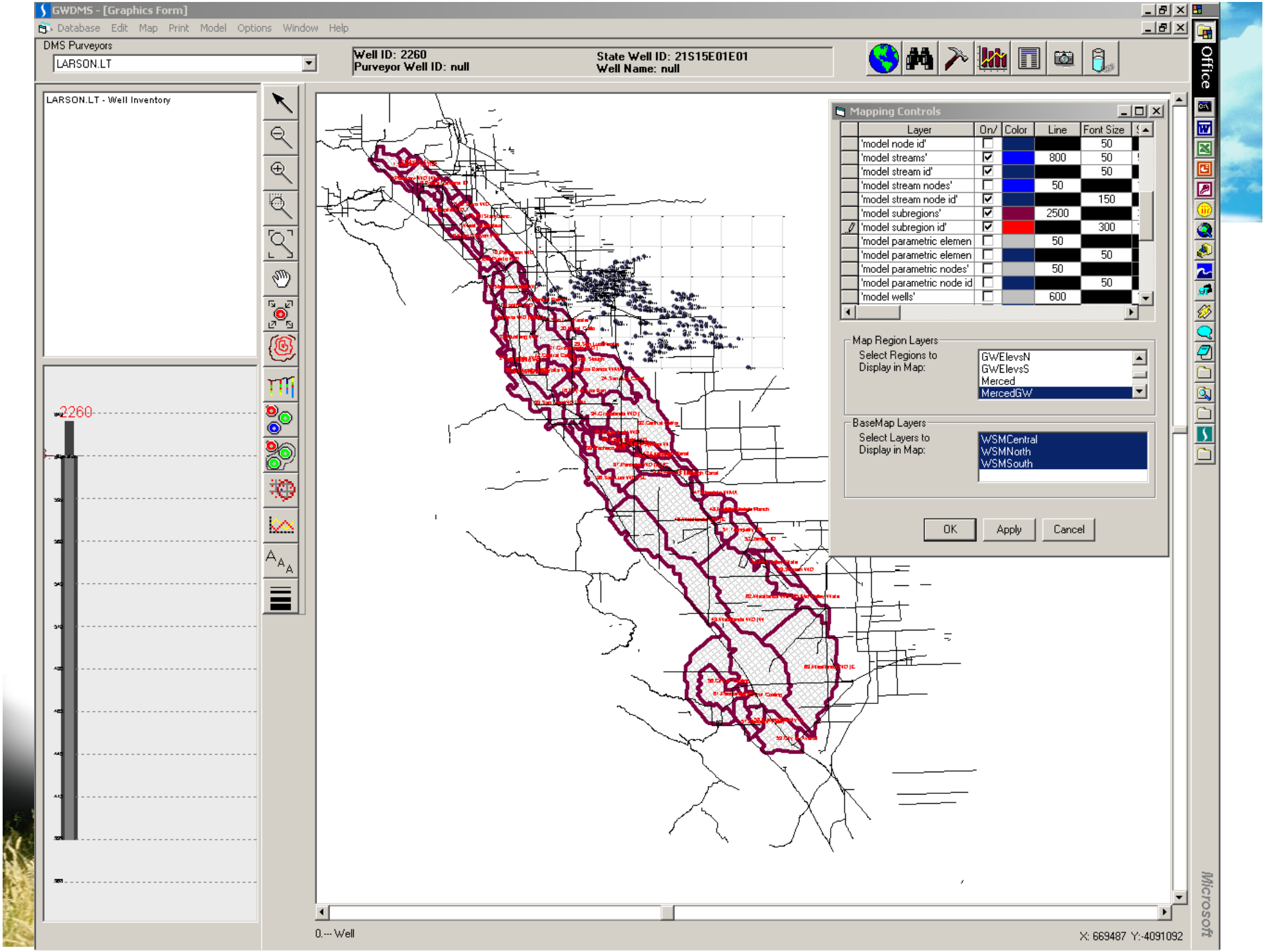

GWDMS
Database Edit Print Options Window Help
Select Water Purveyor:
NORTHRIDGE WATER DISTRICT
Well ID: 22
Purveyor Well ID:
State Well ID: 09N/05E-12B01
Well Name: NOR-17
NORTHRIDGE WATER DISTRICT - Well Inventory
Well 22 Well Location
Elevation (MSL)
22
Well Location
Well Construction
Pump/Motor Info
Geo-Aqui Info
Vellhead Protection
GW Levels
GW Extraction
Surface Water
Well Injection
Water Quality
Well Images
Well ID
Well Name
5 NOR-15
6 NOR-11
7 NOR-10
8 NOR-07
9 NOR-06
21 NOR-14
22 NOR-17
23 NOR-21
24 NOR-23
25 NOR-22
26 NOR-09
60 NOR-01
Row 6 of 28
Well 22 Well Location
Alternate Name WELL 17 - OAKDALE
Street Address 3710 Myrtle Ave.
Nearest Cross Street Watt Ave.
Community Area Served North Highlands
Reference Point
Reference Point Location
Reference Point Source
Reference Point Datum
Reference Point Elevation 0
Ground Surface Elevation (ft) 87.229
Row 0 of 0

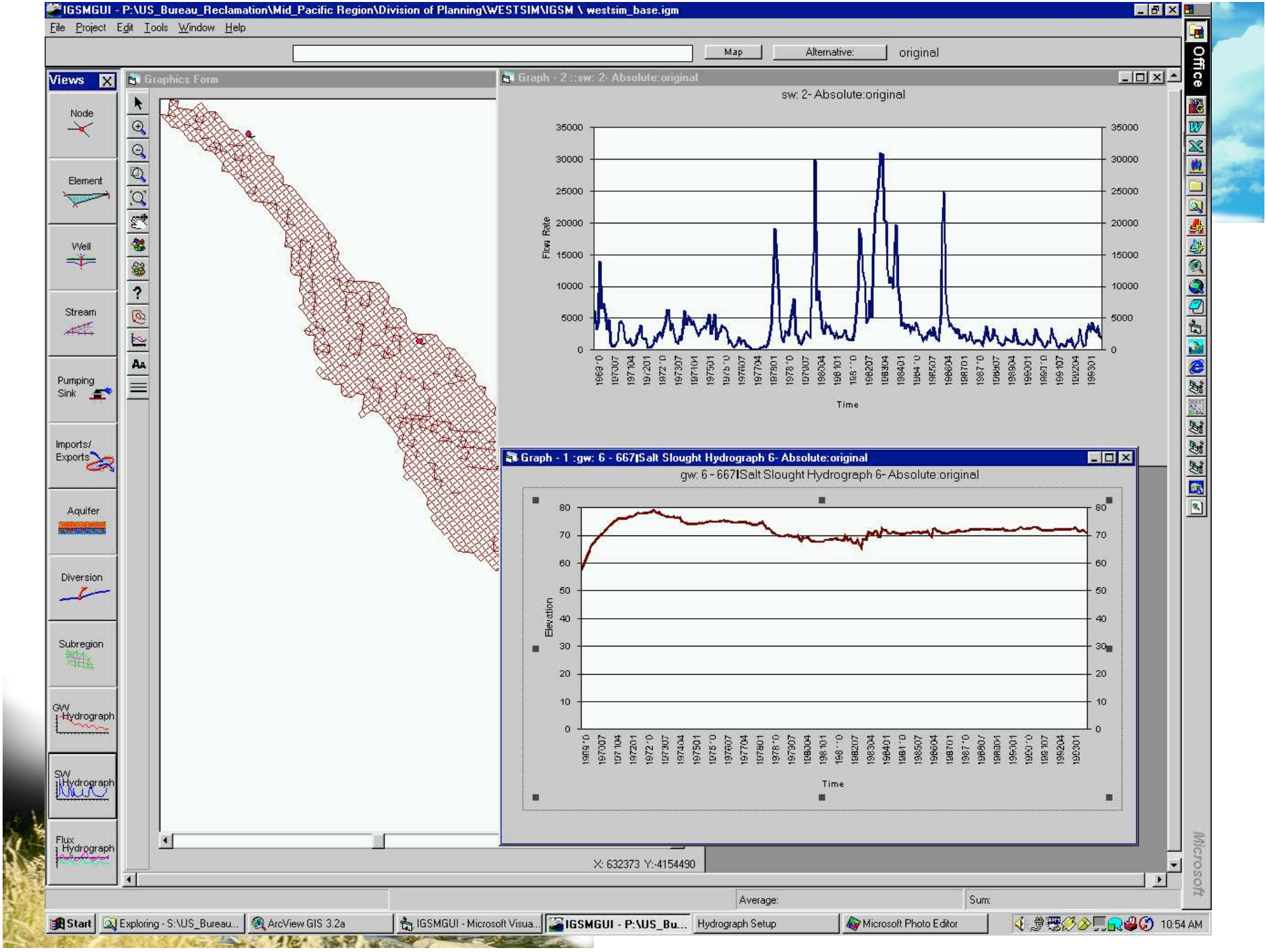
LITHOLOGY PROFILES



CONTOURING AQUIFER CHARACTERISTICS




GWDMS - [Graphics Form]
Database Edit Map Print Model Options Window Help
DMS Purveyors
LARSON.LT
Well ID: 2260
Purveyor Well ID: null
State Well ID: 21S15E01E01
Well Name: null
LARSON.LT - Well Inventory
2260
Mapping Controls
Layer
On/
Color
Line
Font Size
'model node id'
'model streams'
'model stream id'
'model stream nodes'
'model stream node id'
'model subregions'
'model subregion id'
'model parametric elemen
'model parametric elemen
'model parametric nodes'
'model parametric node id
'model wells'
Map Region Layers
Select Regions to Display in Map:
GWElevsN
GWElevsS
Merced
MercedGW
BaseMap Layers
Select Layers to Display in Map:
WSMCentral
WSMNorth
WSMSouth
OK
Apply
Cancel
0.--- Well
X: 669487 Y:-4091092
Office
Microsoft


IGSMGUI - P:\US_Bureau_Reclamation\Mid_Pacific Region\Division of Planning\WESTSIM\IGSM \ westsim_base.igm
File Project Edit Tools Window Help
Map
Alternative:
original
Views
Node
Element
Well
Stream
Pumping Sink
Imports/ Exports
Aquifer
Diversion
Subregion
GW Hydrograph
SW Hydrograph
Flux Hydrograph
Graphics Form
Graph - 2 ::sw: 2- Absolute:original
sw: 2- Absolute:original
Flow Rate
Time
Graph - 1 :gw: 6 - 667ISalt Slought Hydrograph 6- Absolute:original
gw: 6 - 667ISalt Slought Hydrograph 6- Absolute:original
Elevation
Time
X: 632373 Y:-4154490
Average:
Sum:
Start
Exploring - S:\US_Bureau...
ArcView GIS 3.2a
IGSMGUI - Microsoft Visua...
IGSMGUI - P:\US_Bu...
Hydrograph Setup
Microsoft Photo Editor
10:54 AM
Office
Microsoft

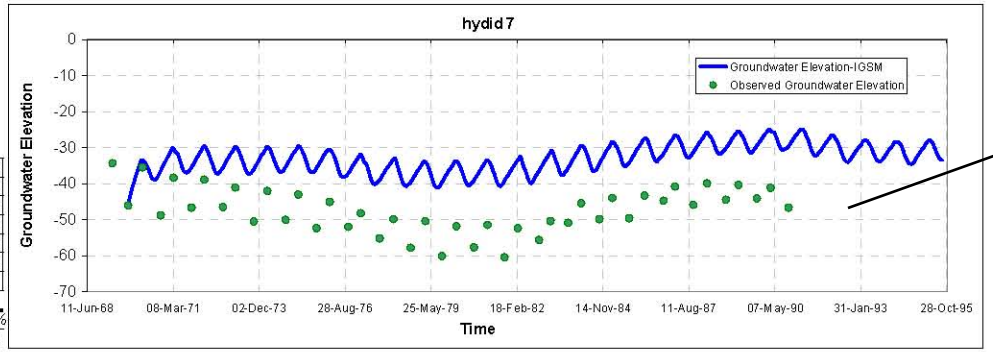
Refresh Data

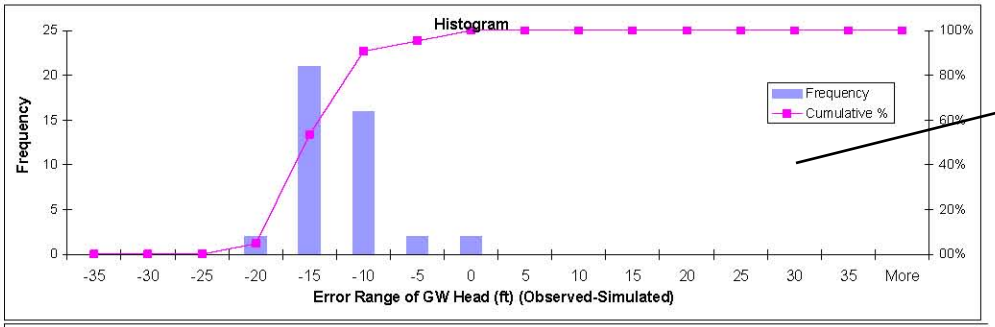
Single Hydrograph Analysis

hydid 7

Model Number of Data Points	312
Observed Number of Data Points	44
Average of Model Data	-33.14
Average of Observed Data	-47.77
Mean Absolute Error	14.63
Correlation (R2)	0.73
Error Autocorrelation	0.81

Bin	Frequency	Cumulative %
-35	0	.00%
-30	0	.00%
-25	0	.00%
-20	2	4.65%
-15	21	53.49%
-10	16	90.70%
-5	2	95.35%
0	2	100.00%
5	0	100.00%
10	0	100.00%
15	0	100.00%
20	0	100.00%
25	0	100.00%
30	0	100.00%
35	0	100.00%
More	0	100.00%





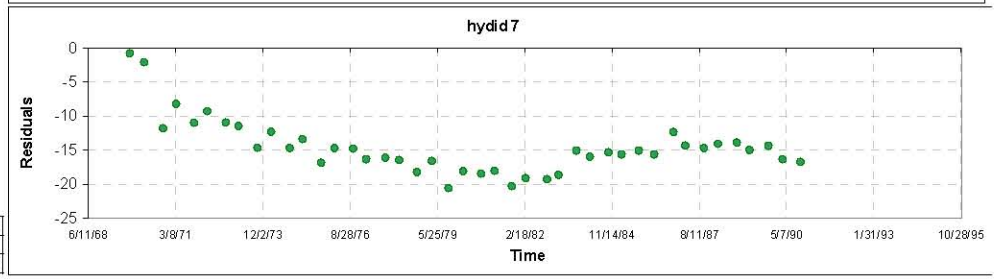
Multi Hydrograph Analysis

Plot Error Histogram

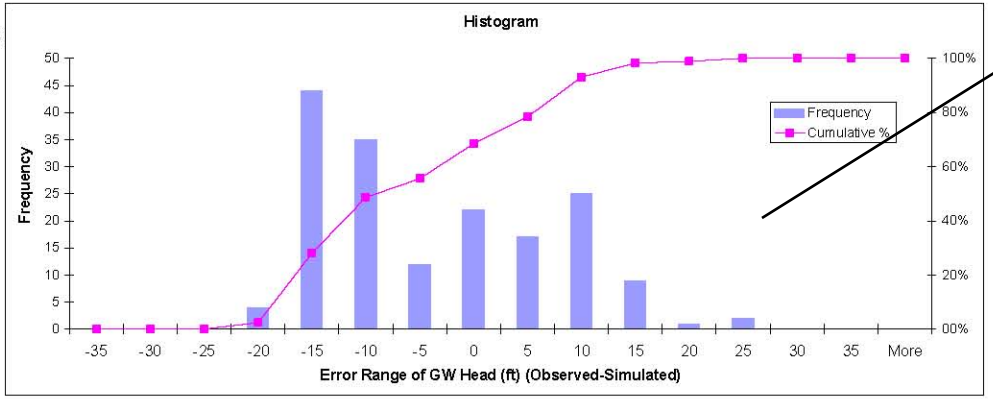
List of Selected Hydrographs

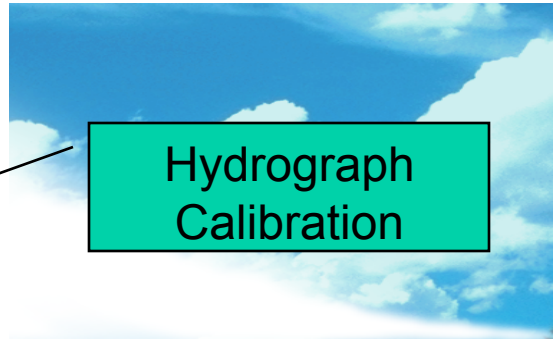
hydid 2 sethydrograph
hydid 4
hydid 6
hydid 9

Number of Data Points	171
Mean Absolute Error	10.70
Error Autocorrelation	0.91



Bin	Frequency	Cumulative %
-35	0	.00%
-30	0	.00%
-25	0	.00%
-20	4	2.34%
-15	44	28.07%
-10	35	48.54%
-5	12	55.56%
0	22	68.42%
5	17	78.36%
10	25	92.98%
15	9	98.25%
20	1	98.83%
25	2	100.00%
30	0	100.00%
35	0	100.00%
More	0	100.00%





Hydrograph Calibration

Difference (model vs. actual) Histogram

Difference Histogram for all Hydrographs

Related Efforts

- SJR Water Quality Module (Reclamation, 2004)
- CALSIM III (Reclamation/DWR, 2008)
- SJR Restoration Program (Reclamation, 2008)
- MERCEDSIM (LBNL)

Status

- The calibration of the water balance and groundwater system was not completed when work was suspended in December 2005
- Initial calibration parameters were defined and well and stream hydrograph locations were preliminarily identified
- Still a source of data for related analysis and modeling efforts

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