RECLAMATION

Managing Water in the West

WRIMS – Water Resources Integrated Modeling System

Nancy Parker

U.S. Bureau of Reclamation

February 21-22, 2012

U.S. Department of the Interior
Bureau of Reclamation

WRIMS Overview

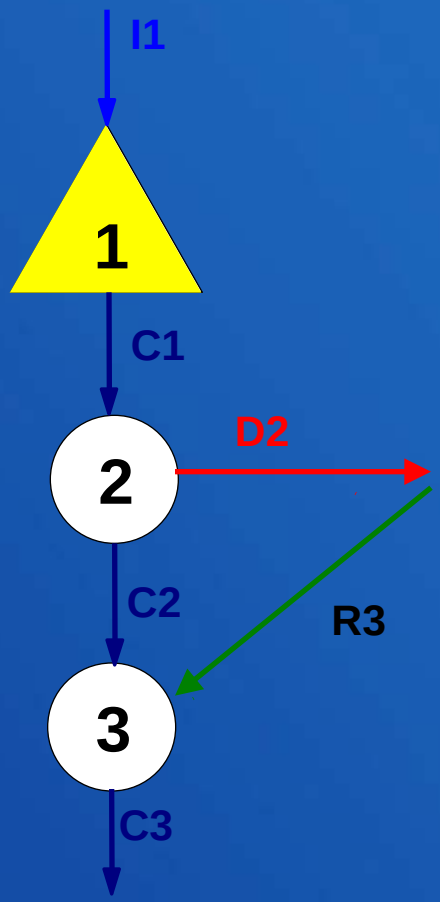
- WRIMS is a general purpose water resources management tool for modeling surface water and/or groundwater allocations
- Water Resources Integrated Modeling System
- Developed and maintained by the California Department of Water Resources
- CVP/SWP Planning Modeling
- Klamath Project Planning Modeling

RECLAMATION

WRIMS Basics

- Physical river system represented as a network of nodes (reservoirs, diversion points) and arcs (river channels, canals)

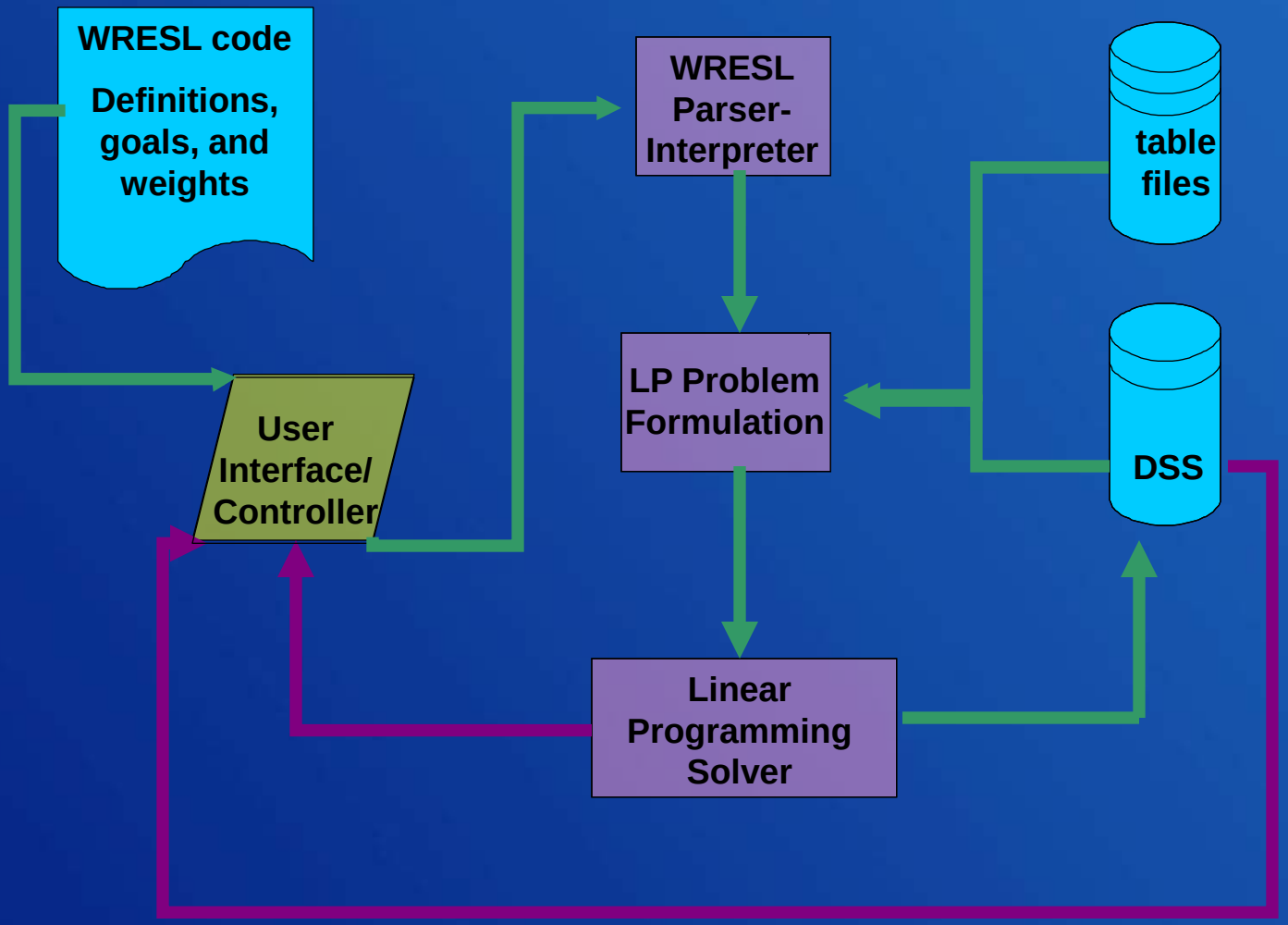
- Describe what the problem is, not how to solve it



WRIMS Basics

- Water Resources Engineering Simulation Language (wresl) Code
  - Define variables, Write goals/constraints
  - "English-like" syntax
- Input
  - Time series inputs – HEC-DSS (monthly, daily)
  - Parameter/Function inputs – ascii tables
- Output
  - HEC-DSS

WRIMS Components and Structure

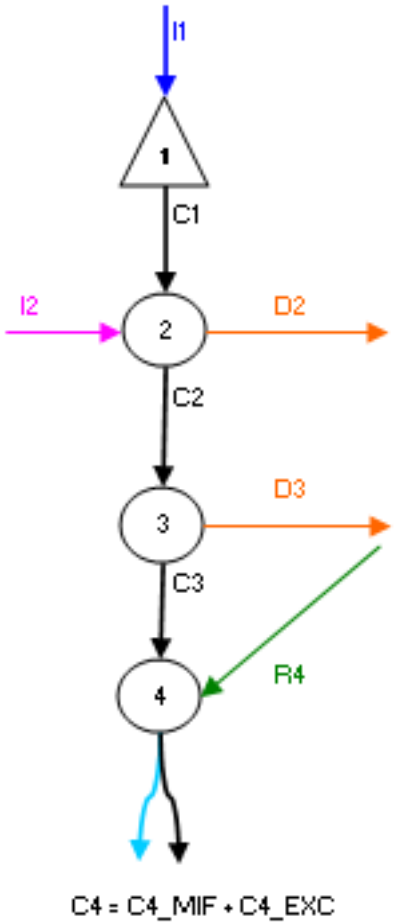


RECLAMATION

WRESL Basics – Three Elements

- **Definitions**
  - **State Variables** – Input data (time series or lookup) or values calculated from input data
  - **Decision Variables** – Storage, Flows, Diversions, or other values calculated at run time
- **Goals / Constraints** – describe physical and institutional limits on operations; **hard or soft**, **constant or conditional**
- **Weights** – prioritize flows, deliveries, storage

Optimization Problem



C4 = C4_MIF + C4_EXC

Connectivity

I1 + S1(-1) = S1_1 + S1_2 + S1_3 + E1 + C1

C1 + I2 = D2 + C2

C2 = D3+ C3

C3 + R4 = C4

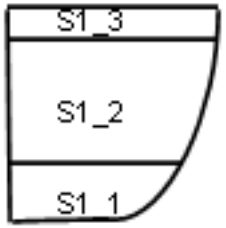
Storage Zones

S1 = S1_1 + S1_2 + S1_3

S1_1 < 150

S1_2 < 300

S1_3 < 50



50 taf Flood Space

300 taf Conservation Pool

150 taf Minimum Storage

Operation Constraints

C1 < release capacity

D2 < constant demand

R3 = factor * D2

D3 < time series demand

C4_MIF < minimum flow

Weights	
S1_1	2000
S1_2	1000
S1_3	-10000
D2	1100
D3	1050
C4_MIF	1200

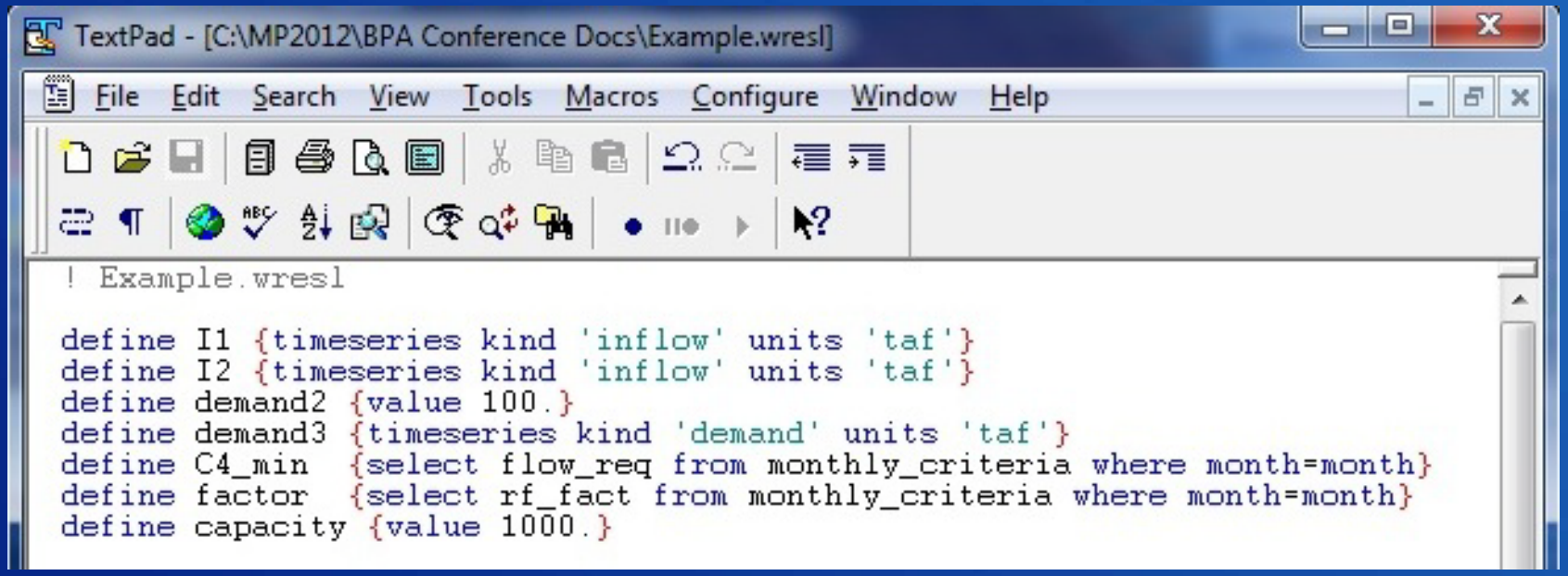
Sorted Weights	
S1_1	2000
C4_MIF	1200
D2	1100
D3	1050
S1_2	1000
S1_3	-10000

Objective Function:

Max Z = 2000*S1_1 + 1000*S1_2 -10000*S1_3 + 1100*D2 + 1050*D3 + 1200*C4_MIF

WRIMS Example

- **Define Inputs**



WRIMS Example

- **Define Decision Variables**

```
define S1 {std kind 'storage' units 'taf'}
define S1_1 {std kind 'storage-level' units 'taf'}
define S1_2 {std kind 'storage-level' units 'taf'}
define S1_3 {std kind 'storage-level' units 'taf'}
goal totS4 {S4 = S4_1 + S4_2 + S4_3}
define C1 {std kind 'channel' units 'cfs'}
define C2 {std kind 'channel' units 'cfs'}
define C3 {std kind 'channel' units 'cfs'}
define C4 {std kind 'channel' units 'cfs'}
define C4_MIF {std kind 'flow-minimum' units 'cfs'}
define C4_EXC {std kind 'flow-excess' units 'cfs'}
goal totC4 {C4 = C4_MIF + C4_EXC}

define D1 {std kind 'diversion' units 'cfs'}
define D2 {std kind 'diversion' units 'cfs'}
define R4 {std kind 'return' units 'cfs'}
```

WRIMS Example

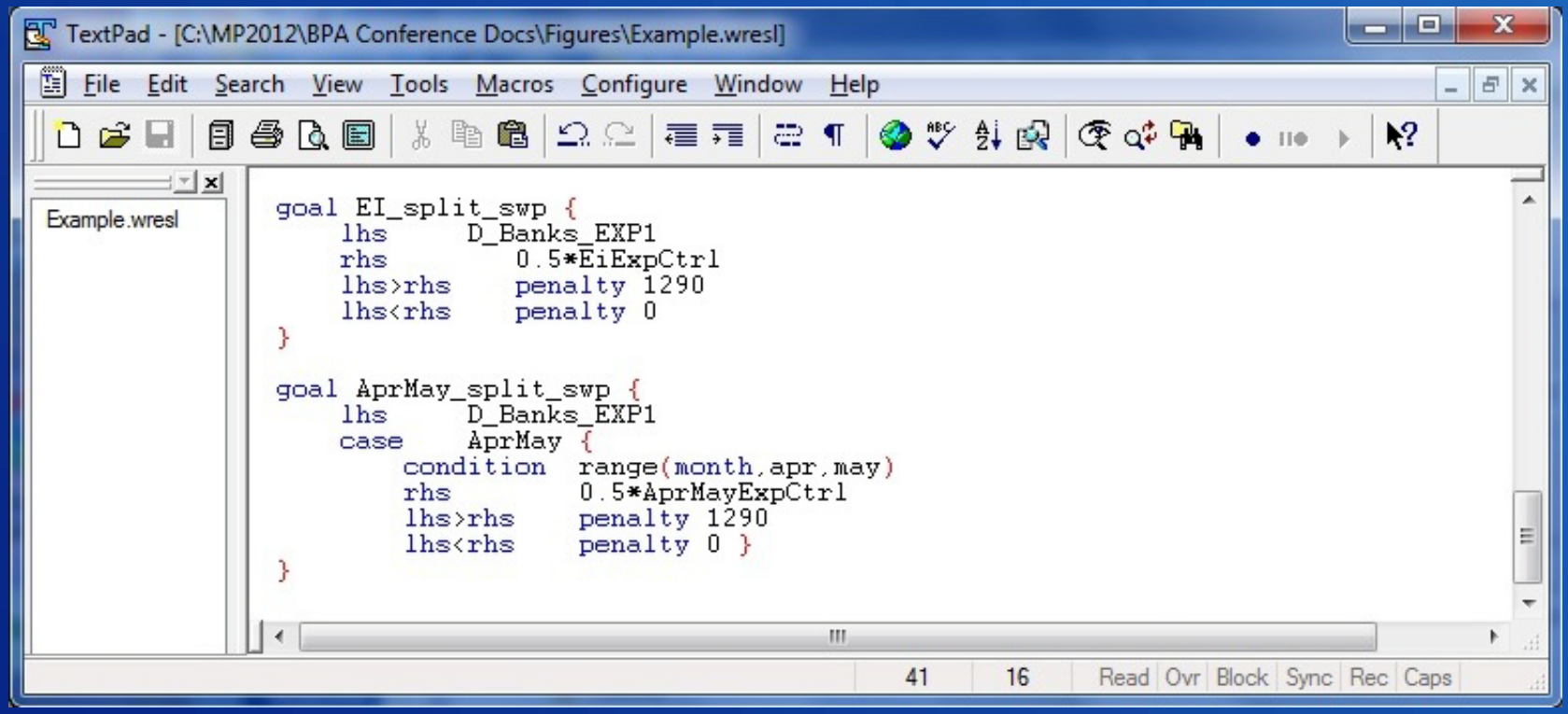
- **Write Constraints and Goals**
- **Weight Decision Variables**

```
goal continuity1 {I1 - C1 - E1 = S1*taf_cfs - S1(-1)*taf_cfs}
goal continuity2 {C1 + I2 - D2 - C2 = 0.}

goal LimitRelease {C1 < capacity}
goal meetD2       {D2 < demand2}
goal meetD3       {D3 < demand3}
goal setD3Return  {R4 = D3 * factor}
goal MeetMinFlow  {C4_MIF < C4_min}

Objective obj = {
[S1_1,    2000*taf_cfs],
[C4_MIF,  1200],
[D2,      1100],
[D3,      1050],
[S1_2,    1000*taf_cfs],
[C4_EXC,  -100],
[S1_3,   -1000*taf_cfs]
}
```

RECLAMATION

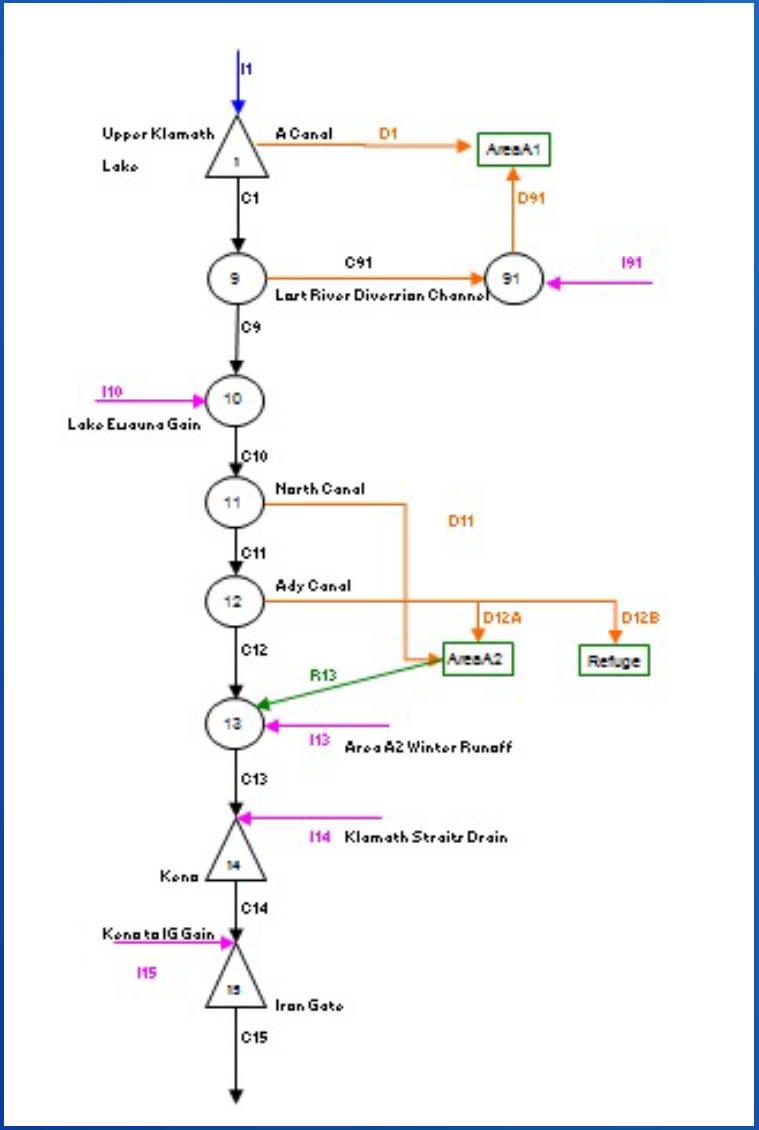
WRIMS Example

- **Soft Constraints – slack and surplus penalties**



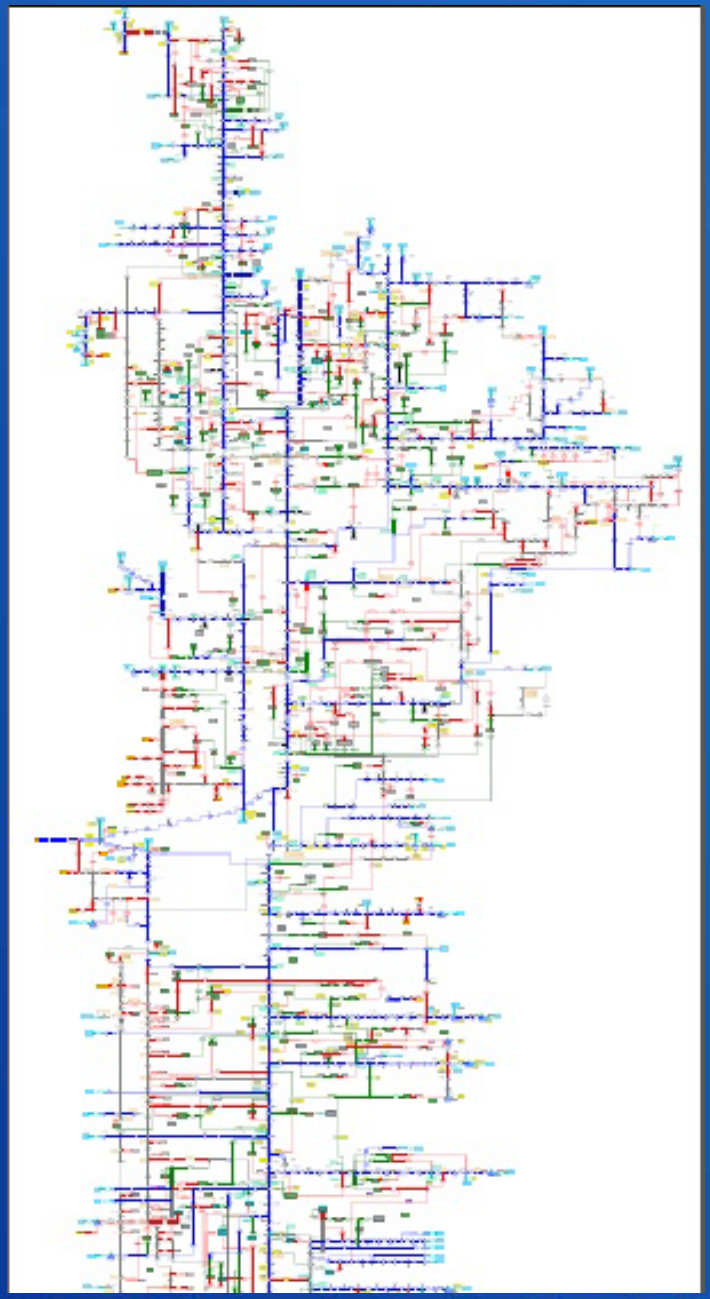
RECLAMATION

WRIMS Example



RECLAMATION

WRIMS Example



RECLAMATION

WRIMS Solution

- XA LP/MILP Solver – Sunset Software
  - $1250
  - Hardware license
- Maximize objective function value while meeting user specified constraints
- Integer variables allow dynamic switches
- Solution vs. optimization
- Debugging is an acquired skill

RECLAMATION

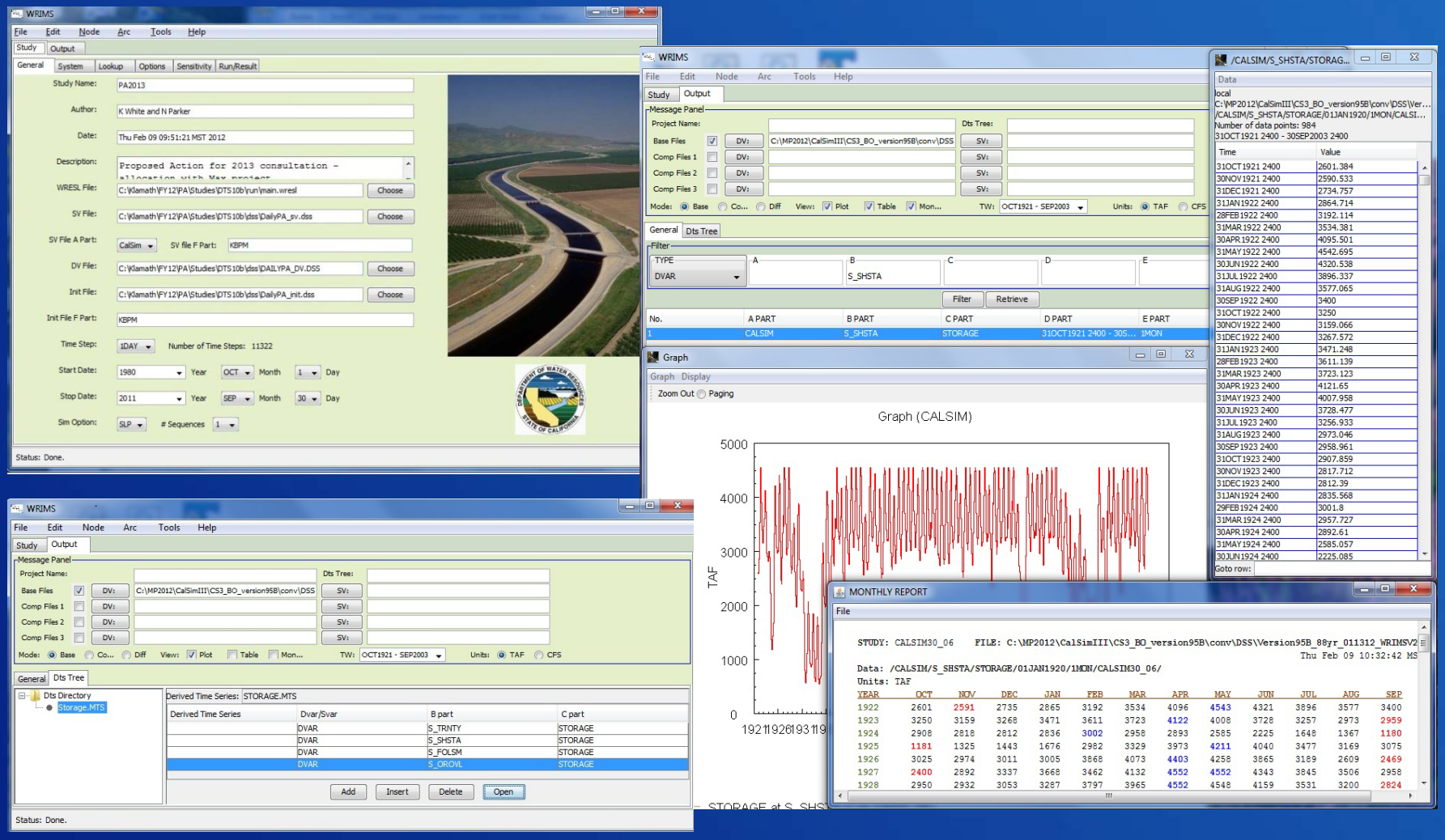
WRIMS Software

- Conditional or multiple solutions within each time step allow for layering of constraints
- Can incorporate external functions or dll's
- Position analysis capabilities enable use of ensemble input data sets
- Flow routing using arc "storage"
- Mixed timestep simulations – look-ahead forecasting and routing applications

WRIMS User Experience

- **Problems are hard; models should help**
- **WRIMS development done in text files**
  - **custom, readable, searchable, “story-line”, text highlights**
- **GUI facilitates running the model**
- **GUI enables basic results processing – variable lists, time series, plots, tables**

WRIMS Look and Feel



RECLAMATION