

# A Comparison of RiverWare and StateMod as Water Allocation Model Platforms

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# Background

- **RiverWare:**

- Water rights model of the Colorado Rio Grande. CO Rio Grande Compact delivery logic with on-the-fly calculation of Curtailment (NRCS runoff forecast), Compact storage in reservoirs, irrigation district storage, municipal and ag pumping depletions, etc.
- Planning model for ECCV, ACWWA, and United on South Platte. Presented last year about pumping depletions, groundwater recharge, and river exchanges.

- **StateMod:**

- Worked as subcontractor on South Platte DSS. Focused on operating rules, plans, and reservoir operations for St. Vrain Creek, which includes Left Hand Creek, City of Longmont, and many irrigators and rural water districts.



# History and Use of StateMod

- Originally developed in 1986 (*2 years older than me*) – still maintained in Fortran
- State of Colorado: CWCB and DWR
- Support now from Open Water Foundation
- Users in Wyoming have adapted it
  
- The goal of the **Colorado Decision Support System (CDSS)** is to have a state-wide planning model that is integrated with a database of hydrologic data (**HydroBase**).



# Water Right Allocation in RiverWare

- First mention of water rights allocation using doctrine of Prior Appropriation is in v.5 (latest release is 6.9.4)
- Taught in “Water Accounting in RiverWare”

- CADSWES Training and support



- Perhaps not **RiverWare**'s primary focus – “Allocatable Flow” treated as an account, accounting methods allocate water within Computational Subbasin.

# Use as Water Allocation Platforms

- Prior Appropriation system
  - Reservoir operations
  - Accounting
1. **Agriculture:** Water Rights, IWR, CU, Return Flows
  2. **Municipal/Industrial (M&I):** Water Rights, Changed Water Rights/Decree Requirements, Reservoir operations, Trans-Basin Imports, Reusable Effluent
  3. **State/Federal:** ISF, Interstate Compact, Flood Control, Power Generation, Regional Supply



## RiverWare

- Demands are generated outside model platform
- Various methods determine efficiencies, return flow routing
- Multiple water rights require individual accounts

## StateMod

- StateCU generates demands
- StateMod input files specify efficiencies, return flow timing and location
- One water user may have several priorities



# Municipal / Industrial (M&I)

## RiverWare

- Water users have a demand for raw water
- Changed rights, return flow obligations, pumping depletions, recharge accretions, re-use, etc. require some **creativity** with objects, methods, and RPL

## StateMod

- In 2015-2016, large effort to incorporate municipal operations into operating rule suite
- Little flexibility to deviate from built-in operating rules



## RiverWare

- ISF reaches (Control points)
- Many built-in methods for flood control, hydroelectric, thermal, etc.
- RPL flexibility for Interstate Compact requirements

## StateMod

- ISF rights simulated
- Reservoir targets and specific Colorado Compacts (South Platte, Rio Grande, La Plata...)
- Little support for Federal-level operations

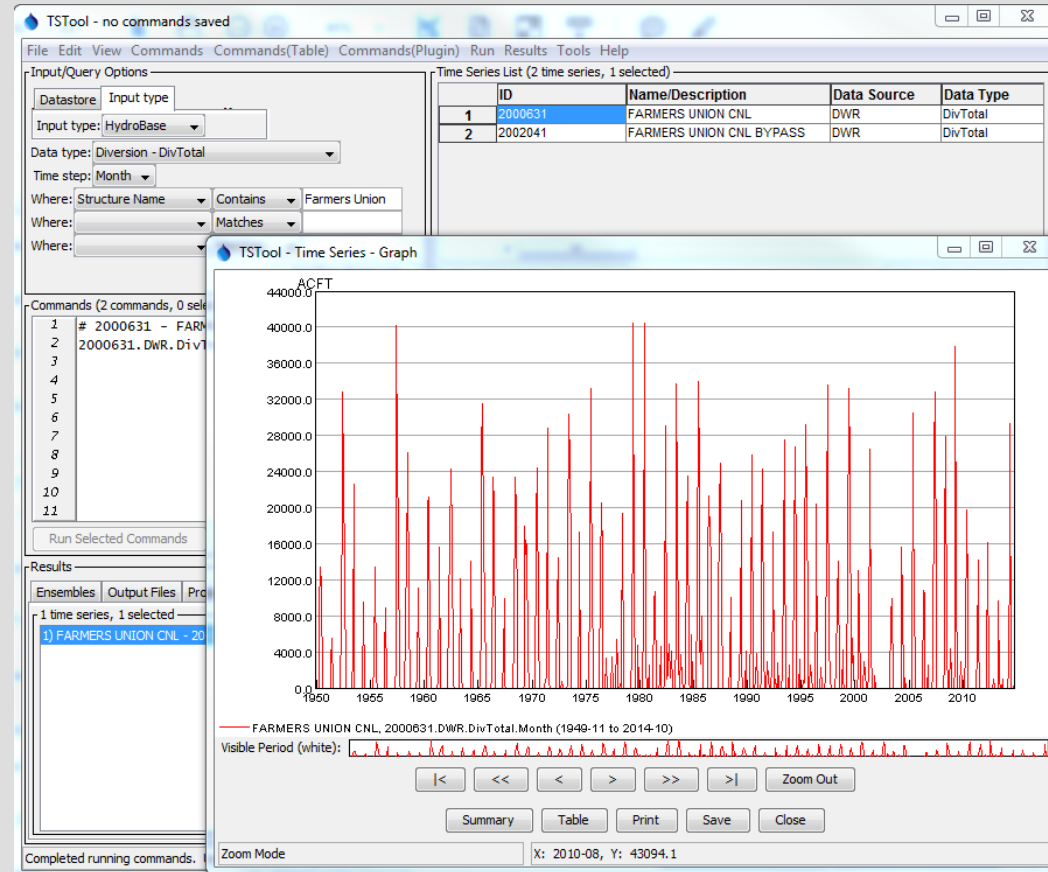




# Data Management - StateMod

- One of **StateMod's** greatest strengths is its integration with a database of hydrologic data, **HydroBase**

- Database updated by Colorado DWR several times annually
- Water rights, diversion records, reservoir volumes, climatic data, irrigation practice / coverage, streamflow, etc.
- Built-in methods for manipulation of data (fill, regression, etc.)



# Data Management - RiverWare

- DMI Manager, Snapshots, MRM
- For our purposes, water rights, hydrologic data, user demand, etc. is completely user supplied

Database DMI - Historical Inputs

Database DMI Name: Historical Inputs

Type:  Input  Output  Confirm Warnings  Record Invocations

DMI Configuration

Show:  Unused Slot Selections Column Widths:  Auto Fit  Manual

Dataset	On	Begin	End	Units
Slot Inflows Hist	1 ✓			
(30 Mile to Wagon Wheel Gain...	✓	Start Timestep	Finish Timestep	
30 Mile to Wagon Wh...		01-02-1980	12-31-2008	
Beaver Park Inflow.L...		01-02-1980	12-31-2008	
Conejos Inflow.Local...		01-02-1980	12-31-2008	
Los Pinos Inflows.Loc...		01-02-1980	12-31-2008	
North Clear Creek.Lo...		01-02-1980	12-31-2008	
Platoro to Mogote Ga...		01-02-1980	12-31-2008	
Rio Grande Reservoir...		01-02-1980	12-31-2008	
San Antonio Inflows....		01-02-1980	12-31-2008	
South Fork Gains.Loc...		01-02-1980	12-31-2008	
Wagon Wheel to Del ...		01-02-1980	12-31-2008	
Depletion Daily Hist	2 ✓			
(Anaconda Canal^1876_3.De...	✓	Start Timestep	Finish Timestep	
Anaconda Canal^18...		01-02-1980	12-31-2008	
Anaconda Canal^18...		01-02-1980	12-31-2008	
Anaconda Canal^18...		01-02-1980	12-31-2008	

Reset OK Cancel Apply

MRM Configuration - Climate Change Runs

Configuration

Name: ate Change Run] Policy:  Rules Input:  Input DMIs  None  Traces  Index Seq.

Mode: Concurrent

Run	Input DMI	Policy	Initial Date	Timesteps	Finish Date
1:	D 1	R 1	Jan 1, 1980	10592	Dec 31, 2008
2:	D 2	R 1	Jan 1, 1980	10592	Dec 31, 2008
3:	D 3	R 1	Jan 1, 1980	10592	Dec 31, 2008
4:	D 4	R 1	Jan 1, 1980	10592	Dec 31, 2008
5:	D 5	R 1	Jan 1, 1980	10592	Dec 31, 2008
6:	D 6	R 1	Jan 1, 1980	10592	Dec 31, 2008
7:	D 7	R 1	Jan 1, 1980	10592	Dec 31, 2008
8:	D 8	R 1	Jan 1, 1980	10592	Dec 31, 2008
9:	D 9	R 1	Jan 1, 1980	10592	Dec 31, 2008
10:	D 10	R 1	Jan 1, 1980	10592	Dec 31, 2008
11:	D 11	R 1	Jan 1, 1980	10592	Dec 31, 2008
12:	D 12	R 1	Jan 1, 1980	10592	Dec 31, 2008
13:	D 13	R 1	Jan 1, 1980	10592	Dec 31, 2008
14:	D 14	R 1	Jan 1, 1980	10592	Dec 31, 2008
15:	D 15	R 1	Jan 1, 1980	10592	Dec 31, 2008
16:	D 16	R 1	Jan 1, 1980	10592	Dec 31, 2008
17:	D 17	R 1	Jan 1, 1980	10592	Dec 31, 2008
18:	D 18	R 1	Jan 1, 1980	10592	Dec 31, 2008
19:	D 19	R 1	Jan 1, 1980	10592	Dec 31, 2008
20:	D 20	R 1	Jan 1, 1980	10592	Dec 31, 2008
21:	D 21	R 1	Jan 1, 1980	10592	Dec 31, 2008

OK Apply Reset Cancel



# Operational Flexibility

- **RiverWare** uses RPL – extremely flexible!
- **StateMod** uses modified priority system that intertwines water right administration number (Colorado) and operating rule order
  - Operating Rules and Plans are strictly controlled

Rule Editor - "RGBIP\_2016\_5\_23\_Trujillo\_and\_1\_year\_ops\_model.rls.gz : Reservoir Storage Acco..."

File Edit Rule View

SLVID Water Rio Grande Reservoir 1903 Release RPL Set Loaded

```
# Release water from SLVID 1903 account to maintain Farmers Union Canal at 400 cfs
Rio Grande Res Outflow Supply SLVID 1903 ( ) []
= IF ( Rio Grande_Farmers Union Diversion^Allocatable Flow.Diversion [@"t"] <= 300.00000000 "cfs" ) THEN
  AND Farmers Union Canal Sum of Shortages ( ) > 0.00000000 "cfs"
  Max ( 0.00000000 "cfs",
    MinItem (
      400.00000000 "cfs"
      - Rio Grande_Farmers Union Diversion^Allocatable Flow.Diversion [@"t"],
      VolumeToFlow ( Rio Grande Reservoir^SLVID 1903.Storage [@"t"],
        @"t"
      ),
      1,250.00000000 "cfs"
      - Rio Grande Reservoir Allocatable Flow to 30 Mile Gage Allocatable Flow.Supply [@"t"]
    )
  )
ELSE
  0.00000000 "cfs"
END IF
```

Show:  Execution Constraint  Description  Comments

Execute Rule Only When

```
NOT HasRuleFiredSuccessfully ( "ThisRule" ) AND @"t" >= @"24:00:00 May 1, Current Year"
```

C:\Users\Brian\Documents\SugarSync Shared Folders\SPDSS\SV2013\_FINAL2\StateMod\SV2013.opr - Notepad++

```
SV2013.opr SV2013.ddr CBT_Baseflows.stm STV_Long_CBT.stm LeftHand_BLDRES_CBT.stm SV2013.ddr SV2013_062316.rsp
```

```
508 #Changed Water Rights
509 #####
510 #Longmont Supply Ditch 1981 and 1987 changed rights
511 #####
512 ##Global monthly volumetric limit for 545 1981 changed DF rights type 47. Assuming average hydrology for
513 545_Pln1 LSupply81DFLim 0001.00000 0. 1 NA 1 545_
514 0.0 0.0 0.0 66.6 402.1 708.1 948.2 755.7 313.0 30.1 0.0 0.0 3223.9
515 ##Global monthly volumetric limit for 545 1987 changed DF rights type 47
516 545_Pln2 LSupply87DFLim 0001.00000 0. 1 NA 1 545_
517 0.0 0.0 0.0 13.7 82.4 144.6 193.7 154.3 64.3 6.1 0.0 0.0 659.1
518 ##Move 73.4% of ditch right to changed Longmont right. The 73.4% is a combination of 1981 and 1987 change
519 545_Pln3 LSupply_Full_Plan 5600.00000 0. 1 545_Pln 1 0500
520 0.0 0.0 0.0 80.3 484.5 852.7 1141.9 910.0 377.3 36.2 0.0 0.
521 ##Split the changed water right into the 1981 and 1987 portions since they each have different terms and
522 545_Pln4 LSupply_Split_Plan 5600.00001 0. 1 545_Pln81 83 545_
523 545_Pln87 17
524 ##Send water from the 81 change plan to LONG_IN demands through the Longmont N Pipeline.
525 545_Pln5 LSupply81_to_LONG_IN_N 21702.00001 1. 1 0SLONG_IN 1 545_
526 0500511 0 Carrier
527 545_Pln1
528 545_Pln3
529 0.0 0.0 0.0 58.0 63.2 65.1 65.9 64.9 60.7 0.0 0.0 0.0
530 ##Send water from the 87 change plan to LONG_IN demands through the Longmont N Pipeline.
531 545_Pln6 LSupply87_to_LONG_IN_N 21702.00001 1. 1 0SLONG_IN 1 545_
532 0500511 0 Carrier
533 545_Pln2
534 545_Pln3
535 0.0 0.0 0.0 56.2 63.6 64.7 66.4 65.0 61.1 0.0 0.0 0.0
536 ##Send water from the 81 change plan to LONG_IN demands through the Longmont S Pipeline.
537 545_Pln7 LSupply81_to_LONG_IN_S 18762.00001 1. 1 0SLONG_IN 1 545_
538 0500522 0 Carrier
539 545_Pln1
540 545_Pln3
541 0.0 0.0 0.0 58.0 63.2 65.1 65.9 64.9 60.7 0.0 0.0 0.0
542 ##Send water from the 87 change plan to LONG_IN demands through the Longmont S Pipeline.
543 545_Pln8 LSupply87_to_LONG_IN_S 18762.00001 1. 1 0SLONG_IN 1 545_
544 0500522 0 Carrier
545 545_Pln2
546 545_Pln3
```

Normal text file length:148176 lines:1460 Ln:38 Col:57 Sel:1|0 Dos/Windows UTF-8 INS

# GUI/Output and Visualization - StateMod

The image displays a multi-windowed software interface for StateMod. The background window shows a command prompt with the following text:

```
Datinp; Plan Station File (*.pln)  
Datinp; R  
Subroutine  
Riginp; I  
Riginp; R  
Riginp; D  
Oprinp; O  
Mdainp; fo  
Mdainp; I  
Subroutine  
Execut; Ye  
Execut; Ye  
Execut; Ye  
Execut; Ye  
Execut; Ye  
Execut; Ye  
Execut; Ye  
Execut; Ye  
Execut; Ye
```

The middle window, titled "StateDMI (StateCU)", shows a command list:

```
1 #  
2 # Command  
3 #  
4 #  
5 # Step 1  
6 ReadDivers  
7 #  
8 #  
9 # Step 2  
10 SetDivers  
11 #  
12 #  
13 # Step 3  
14 ReadDivers  
15 #  
16 #  
17 # Step 4  
18 #  
19 #  
20 # Step 5  
21 # SetDiver  
22 # SetDiver  
23 # SetDiver  
24 # SetDiver
```

The "TSTool" window shows a network diagram with nodes labeled "05\_SVCBT", "05\_SV3ST\_P", and "06724000".

The "TSTool - Time Series - Graph" window displays a line graph of river outflow in ACFT (Acre-Feet) from 1950 to 2012. The y-axis ranges from 0 to 14000.0. The x-axis shows years from 1950 to 2010. The graph shows a highly variable time series with a clear seasonal cycle. A legend at the bottom identifies the series as "MIDDLE SAINT VRAIN AT PE, MIDSTECO.StateMod.River\_Outflow.Month (1950-01 to 2012-12)".

At the bottom of the TSTool window, there are navigation buttons: Summary, Table, Print, Save, Close, and Zoom Out.

# GUI/Output and Visualization - RiverWare

The screenshot displays the RiverWare software interface with several windows open:

- Plot - Rio Grande near Lobatos Gage:** A window showing a plot of flow (cfs) over time, with a date of Jan 1, 1980. The y-axis ranges from 0.0000 to 7000.0000 cfs.
- Output Canvas Viewer - Reservoirs and Flows:** A window showing a legend for the plot, with a red box highlighting 'acre-ft'.
- Script Dashboard: EAU Model Script:** A window showing a list of model scripts with checkboxes, including 'Disable the RPL item Reservoir Storage 70 Ranch', 'Set 70 Ranch ECCV Storage', 'Set 70 Ranch ACW...', 'Disable the RPL ite...', 'Set Gilcrest ECCV S...', 'Set Gilcrest ACWW...', 'Disable the RPL ite...', 'Set United No 3 EC...', 'Set United No 3 AC...', 'Disable the RPL ite...', 'Set Barr ECCV Stor...', 'Set Barr ACWVA S...', 'Disable the RPL ite...', 'Set Binder Reserv...', 'Set Binder Reserv...', 'Disable the RPL ite...', and 'Set Brighton Latera...'. A date of Mar 9, 1982 is shown at the bottom.
- Scenario Explorer:** A complex flow diagram showing the flow of water through various reservoirs and gages. The diagram is organized into a hierarchical structure with nodes for 'Rio Grande Reservoir', '30 Mile Gage', 'Rio Grande Squaw Pass Confluence', 'Squaw Creek to Clear Creek', and 'Rio Grande Clear Creek Confluence'. Each node contains a list of flow components such as 'Allocable Flow', 'CPW Wrenuche', 'CPW Beaver', 'CPW Tabor', 'CPW Pedra', 'EMVD 1934 AED', 'EMVD 2503', 'SLWGD', 'SubDistrict 1', and 'Rio Grande Contact'. A text box overlaid on the diagram reads: 'Just heard about RiverWare Scenario Explorer – very excited for that'.

# Debugging – StateMod

```
C:\Users\Brian\Documents\SUGARSYNC SHARED FOLDERS\SPDSS\SV2013_FINAL2\StateMod\SV2013_062316...
File Edit Search View Encoding Language Settings Macro Run Plugins Window ?
LeftHand_BLDRES_CBT.stm SV2013.ddr SV2013_062316 SV2013_062316
2372321 GetFile; Opening River_Network
2372322 SV2013.rin
2372323
2372324 GetVer; File name = SV2013.rin
2372325 File version = 0
2372326
2372327 Datinp; Number of Network Station
2372328 Datinp; ioutN @ line 1053 0
2372329
2372330
2372331 Datinp; Reservoir Station File (
2372332
2372333 GetFile; Opening Reservoir_Station
2372334 SV2013.res
2372335
2372336 GetVer; File name = SV2013.res
2372337 File version = 0
2372338
2372339 GetRes; Reservoir Station File (
2372340 SV2013.res
2372341
2372342 GetRes; Warning See *.chk for det
2372343
2372344 GetRes; Number of Reservoirs =
2372345
2372346
2372347 Datinp; Diversion Station File (
2372348
2372349 GetFile; Opening Diversion_Station
2372350 SV2013.ddsf
2372351
2372352
2372353 GetFile; Problem reading file #
2372354 File name: SV2013.ddsf
2372355 Stopped in GetFile, see log file
2372356
length:99225815 lines:2372356 Ln:1 Col:1 Sel:0|0
```

“The Call” on the river (the most junior water right diverting) is a main feature of the output

```
C:\Users\Brian\Documents
File Edit Search View
SV2013_062316.xca
1 #
2 #
3 # *.xca Call Data File
4 #
5 # 1950 : iystr Starting year of simulation
6 # 2012 : iyend Ending year of simulation
7 #
8 # Statemod Version: 15.00.01 Date = 2015/10/28)
9 # Run date: 8/15/16 13: 2: 1
10 # Time Step: Monthly
11 #
12 #
13 #
14 Call Summary
15 Note: The calling right is estimated to be the most senior
16 water right at the calling location that is shorted.
17 If none is reported (NA) it typically occurs when a
18 structure is diverting at a carrier location, not its
19 physical location
20
21 OutCallR Year Mon Day Imcd Call Location Call Right Call Location Name
22
23 OutCallR 1950 JAN 1 107 0500547 171.2000 OLIGARCHY DITCH
24 OutCallR 1950 JAN 1 90 0500511 28.5000 LONGMONT NORTH PIPELINE
25 OutCallR 1950 JAN 1 120 05LONG_PUMP -1.0000
26 OutCallR 1950 FEB 1 120 05LONG_PUMP -1.0000
27 OutCallR 1950 FEB 1 75 0502115_Dwn -1.0000
28 OutCallR 1950 FEB 1 96 0500526 15.0000 HIGHLAND DITCH
29 OutCallR 1950 FEB 1 136 05_LHVRIN -1.0000 Left Hand Valley Reservo
30 OutCallR 1950 MAR 1 120 05LONG_PUMP -1.0000
31 OutCallR 1950 MAR 1 100 0500529 10.0000 SWEDE DITCH
32 OutCallR 1950 MAR 1 90 0500511 28.5000 LONGMONT NORTH PIPELINE
33 OutCallR 1950 MAR 1 145 05LONG_RFOs -1.0000
34 OutCallR 1950 APR 1 120 05LONG_PUMP -1.0000
35 OutCallR 1950 APR 1 143 0500575 999.0000 WILLIAMSON DITCH
36 OutCallR 1950 MAY 1 35 0500551 2.0200 PELLA DITCH
37 OutCallR 1950 MAY 1 120 05LONG_PUMP -1.0000
38 OutCallR 1950 JUN 1 35 0500551 2.0200 PELLA DITCH
39 OutCallR 1950 JUN 1 120 05LONG_PUMP -1.0000
40 OutCallR 1950 JUL 1 120 05LONG_PUMP -1.0000
Normal text length:129679 lines:1537 Ln:1 Col:1 Sel:0|0 Dos/Windows UTF-8 INS
```



# Debugging – RiverWare

The image shows a screenshot of the RiverWare RPL Debugger interface. The main window displays a list of diagnostic messages in the "Diagnostics Output Window - RiverWare 6.9.3 - EAU Model 8\_1\_16.mdl.gz". The messages are timestamped and include the rule name "Determine Beebe Draw Demands ECCV".

Overlaid on the debugger is a "Plots.Calling Right Rio Grande Priority" window. This window shows a plot of the rule's execution. The plot area displays the following code snippet:

```
FOR LIST ObjAcctList IN FOR ( OBJECT wu IN
  returnedList
  = FOR ( STRING acct IN AccountNamesByWaterType ( wu ,
    ( "HasWaterRightDemand" ) ) WITH LIST ObjAcct = returnedList DO
    objAcct
    = APPEND { wu , } ONTO returnedList
    { account }
  END FOR
END FOR

result
= WITH OBJECT wu = ObjAcctList <0> DO
  WITH STRING acct = ObjAcctList <1> DO
    IF ( wu ^ ( acct CONCAT ( "." CONCAT "Shortage" ) ) [] > 0.00000000 "cfs" AND wu ^ ( acct CONCAT ( "." CONCAT "Priority" ) ) [] < result ) THEN
      wu ^ ( acct CONCAT ( "." CONCAT "Priority" ) ) []
    ELSE
      result
    END IF
  END WITH
END WITH
END FOR
```

The plot shows the rule's execution time and range. The evaluation time is "End of timestep, current time" and the evaluation range is "Run start to run finish (Steps)". The plot area also shows a value of 198.

A text box overlaid on the plot area contains the following text:

“The Call” on the river (the most junior water right diverting) is not easily determined in RiverWare. More attention to this would be a very useful feature in RiverWare.



# RiverWare is Appropriate When...

- Operational **flexibility** (RPL) for complex accounting and administration
- **State** and **Federal**-level operations (large-scale)
- Small-scale M&I operations (decree terms, swaps, agreements), irrigation operations (SW/GW, reservoir supply, aug plans), or policy logic (Colorado Rio Grande Compact Curtailment)
- Multiple scenario
- **Visualization**





# StateMod is Appropriate When...

- Drawing heavily on **HydroBase** database of hydrologic data
- Focus on **agricultural** and **M&I** operations
- Generation of base flows
- Data manipulation (fill, regression, scaling, etc.)
- **Cooperative** modeling effort (CDSS)
  - Standardized techniques for ag/M&I operations
- Less wiggle room for scaling larger or smaller
  - State/Federal level not easy to incorporate, too large-scale
  - Municipal operations, decree terms, irrigation operations (SW, GW, aug plans, res supply) too small-scale

