Review of DSM2 Hydro

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Outline

- Overview of DSM2
- Governing equations and numerical method
- Computational grid
- Gates, reservoirs and water transfers
- Input and output
- Calibration and validation
- Applications
- Technical Support

DSM2 Simulation Domain

-- From DSM2 Workshop, 2009

Bay-Delta detail image from CALFED

DSM2 Models

HYDRO

Hydrodynamics

QUAL

Water Quality

PTM

Particle Tracking

Under development

GTM

Water Quality
(including sediment)

Under development

-- From DSM2 Workshop, 2009

History of Hydro

- Originated from USGS FourPt model (Delong et al., 1997)
- Adapted for the Delta, calibrated and validated
- CalFed Bay-Delta Program – first major application

Hydro Governing Equations

$Equations\ of\ mass\ and\ momentum\ conservation\ for\ \ unsteady\ \ channel\ fow:$

$$\frac{\partial(\rho M_a A)}{\partial t} + \frac{\partial(\rho Q)}{\partial x} - \rho_l q = 0$$

$$\frac{\partial(\rho M_q Q)}{\partial t} + \frac{\partial\left(\beta\rho\frac{Q^2}{A} + \rho g I_1\right)}{\partial x} + \rho g A(S_0 + S_f) - \rho g I_2 = 0$$

$$I_1 = \int_0^h (h-\eta)\sigma d\eta$$

$$I_1 = \int_0^h (h-\eta)\frac{\partial\sigma}{\partial x} d\eta$$

$M_a: area - weighted\ sinuosity\ coefficient;\ M_q: flow\ weighted\ sinuosity\ coefficient;$

$S_0: channel - bottom\ slope;\ S_f: flow\ weighted\ sinuosity\ coefficient;$

$\beta: momentum\ coefficient;\ \sigma: width\ of\ channel; h: depth\ of\ flow;$

$A: cross - sectional\ area; q: lateral\ inflow; \rho_l: density\ of\ lateral\ inflow$

$--from\ Detlong\ et\ al., 1997$

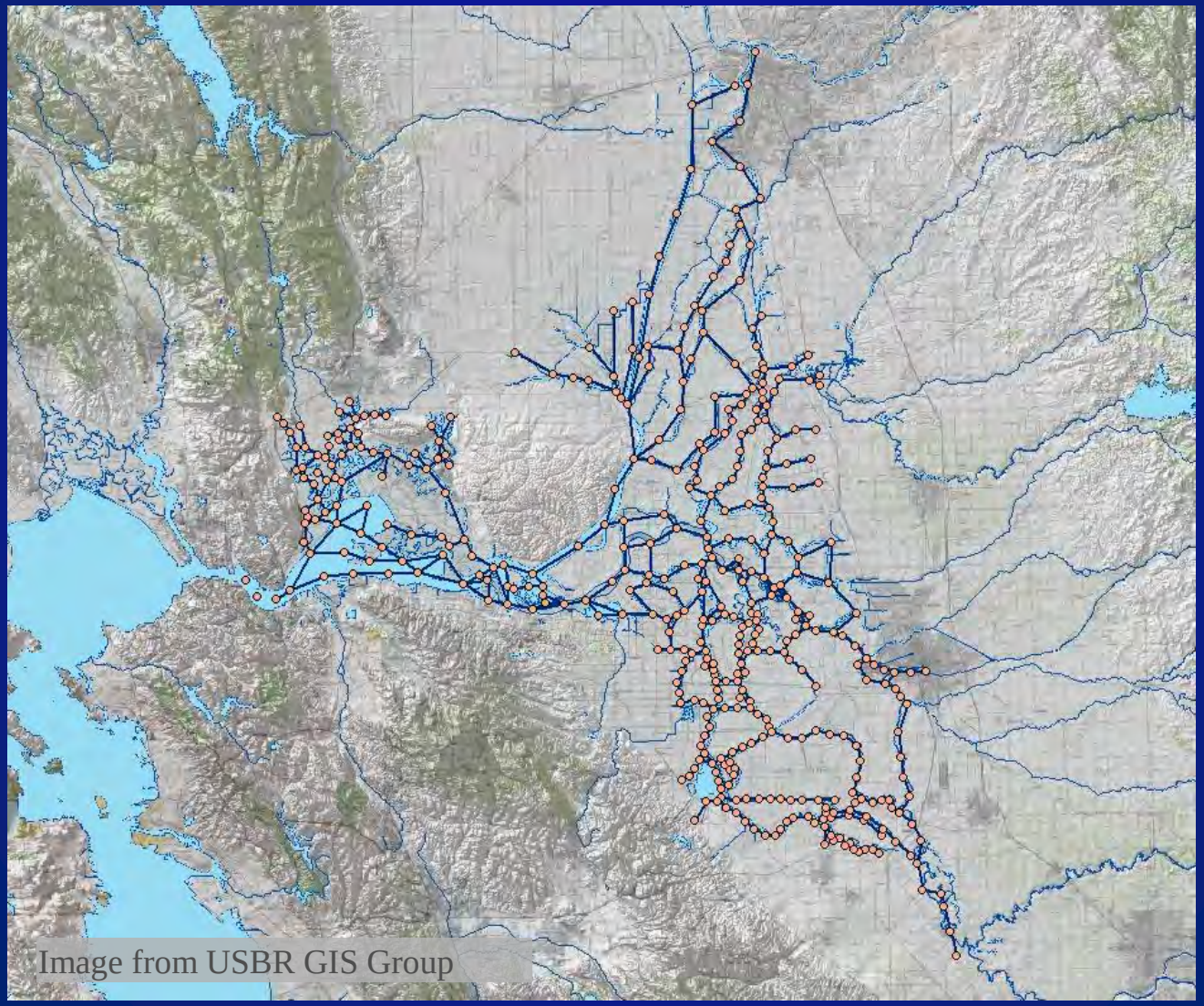
Numerical Method

- Numerical integration of governing equations in time and space
- Discretization using Four-Point-Implicit numerical scheme
- Iterative solution of system equations
- Unconditionally stable

Hydro Assumptions at Junctions

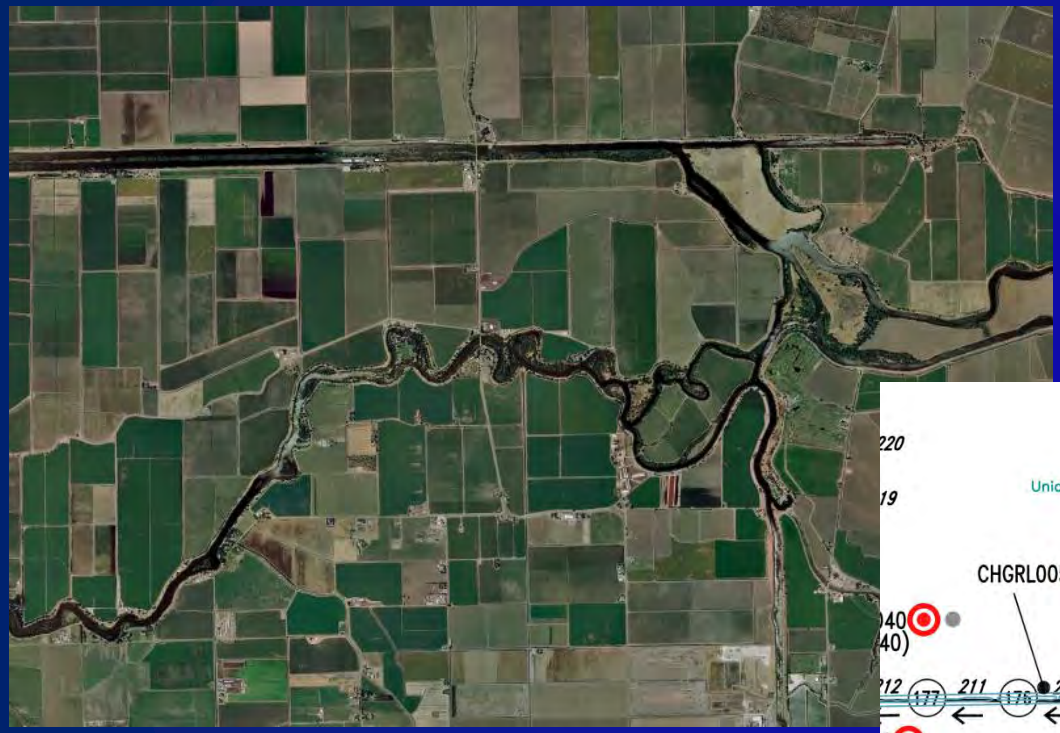
- Continuity $\sum Q_{in} = \sum Q_{out}$
- Equal stage $Z_{in} = Z_{out}$

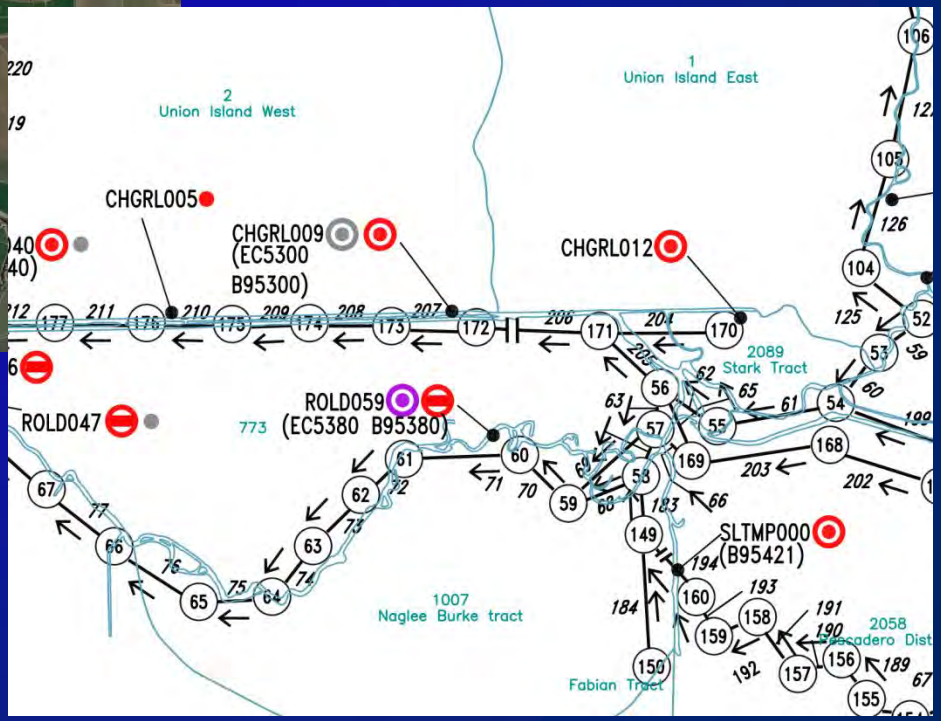
Computational Grid



-- From DSM2 Workshop, 2009

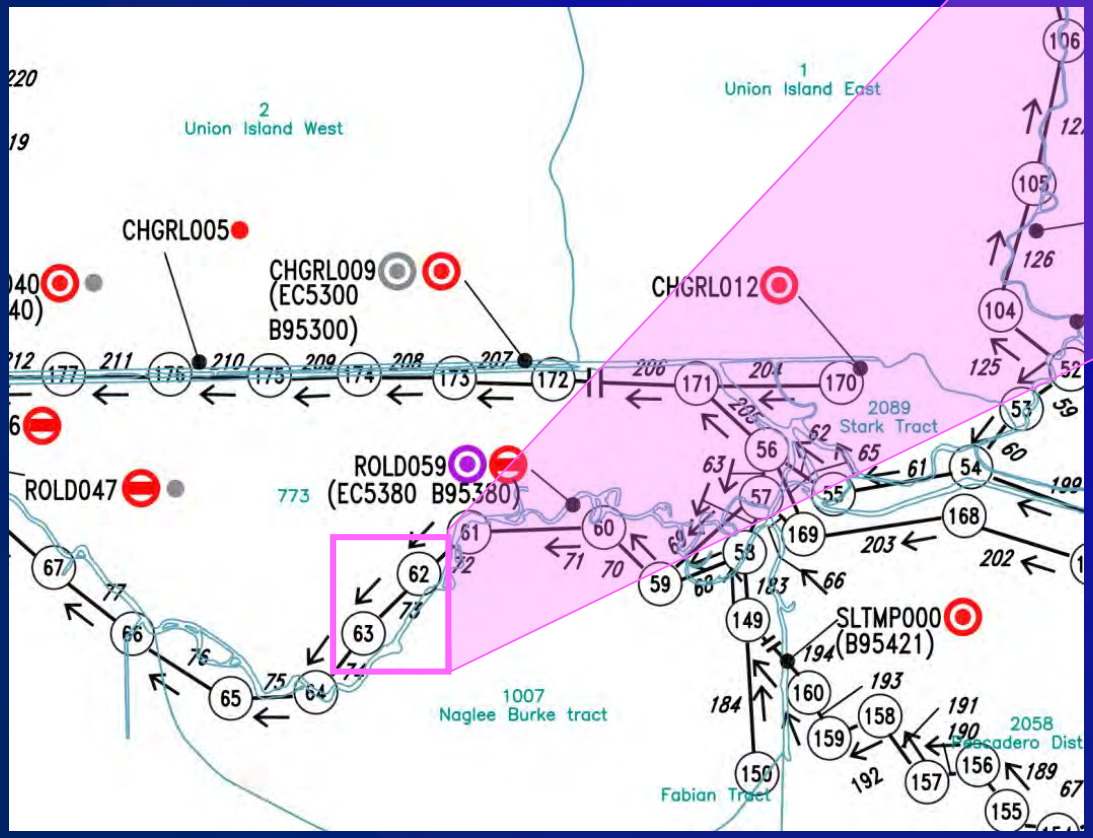
Grid: Channels and Nodes

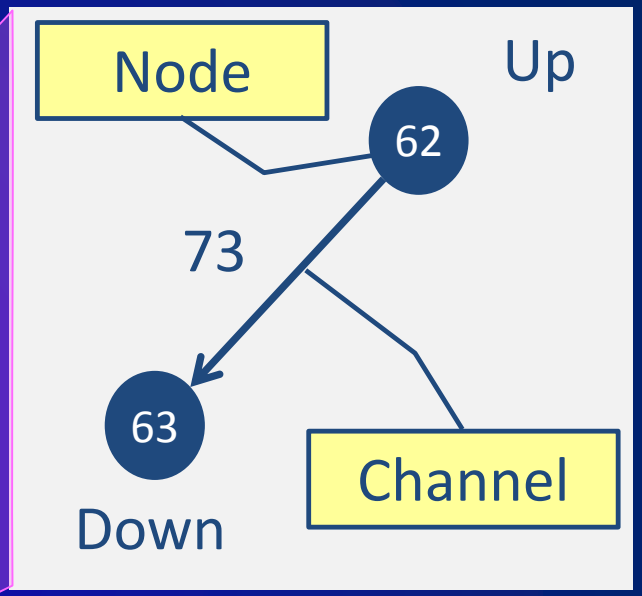




-- From DSM2 Workshop, 2009

Grid: Channels and Nodes





Direction "mostly" seaward/downstream

-- From DSM2 Workshop, 2009

Grid: Channel Table

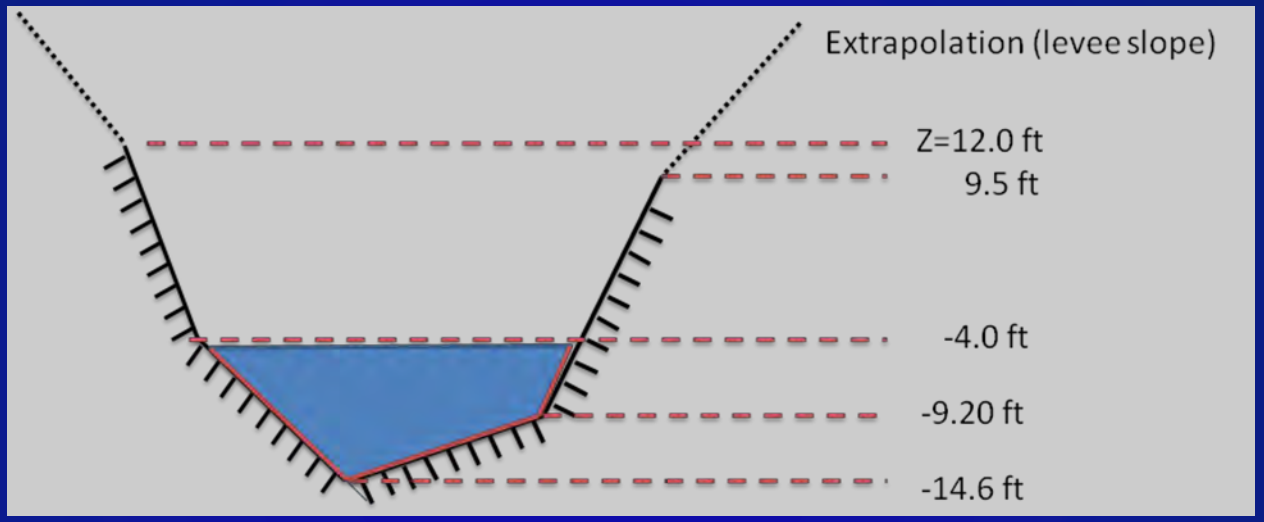
- Connectivity
- Manning and Dispersion coefficients

```
CHANNEL
CHAN_NO LENGTH   MANNING DISPERSION  UPNODE  DOWNNODE
1        15000     0.035        0.3       1         2
2        15000     0.035        0.3       2         3
3        15000     0.035        0.3       3         4
4        15000     0.035        0.3       4         5
5        18000     0.035        0.3       5         6
6        12000     0.035        0.3       6         7
END
```

-- From DSM2 Workshop, 2009

--Non-prismatic channels
--Irregular cross sections

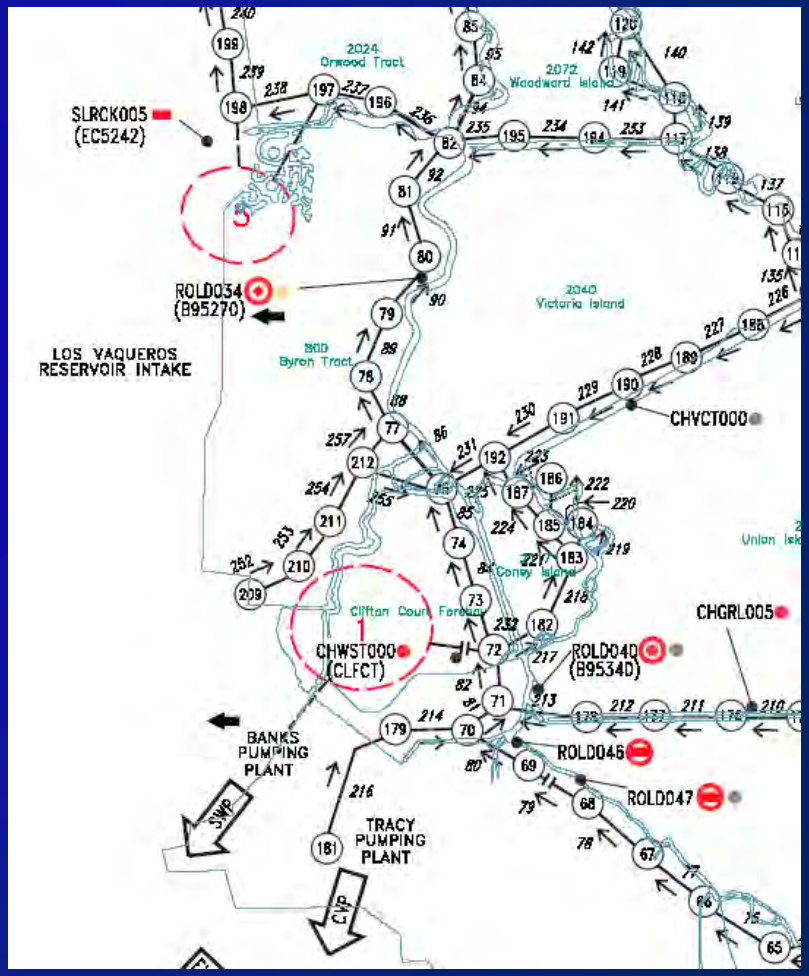
Grid: Channel Geometry




```
XSECT_LAYER
CHAN_NO   DIST    ELEV     AREA   WIDTH WET_PERIM
123        0.5   -14.6      0.0     0.0       0.0
123        0.5    -9.2    216.0    80.0     102.5
123        0.5    -4.0    736.0   120.0     141.0
123        0.5     9.5   2410.0   160.0     182.3
123        0.5    12.0   3028.5   162.0     198.0
END
```

-- From DSM2 Workshop, 2009

Reservoirs in Hydro



- Open water bodies
- Connect to nodes or gates

Reservoirs in Hydro

- Instantly well-mixed
- Geometry represented by table of stage vs. area
- In/out flows calculated according to the equation of conservation of energy

-- From DSM2 Workshop, 2009

Reservoirs in Hydro

1. Clifton Court Forebay
2. Mildred Island
3. Bethel Island
4. Frank's Tract
5. Discovery Bay
6. Liberty Island

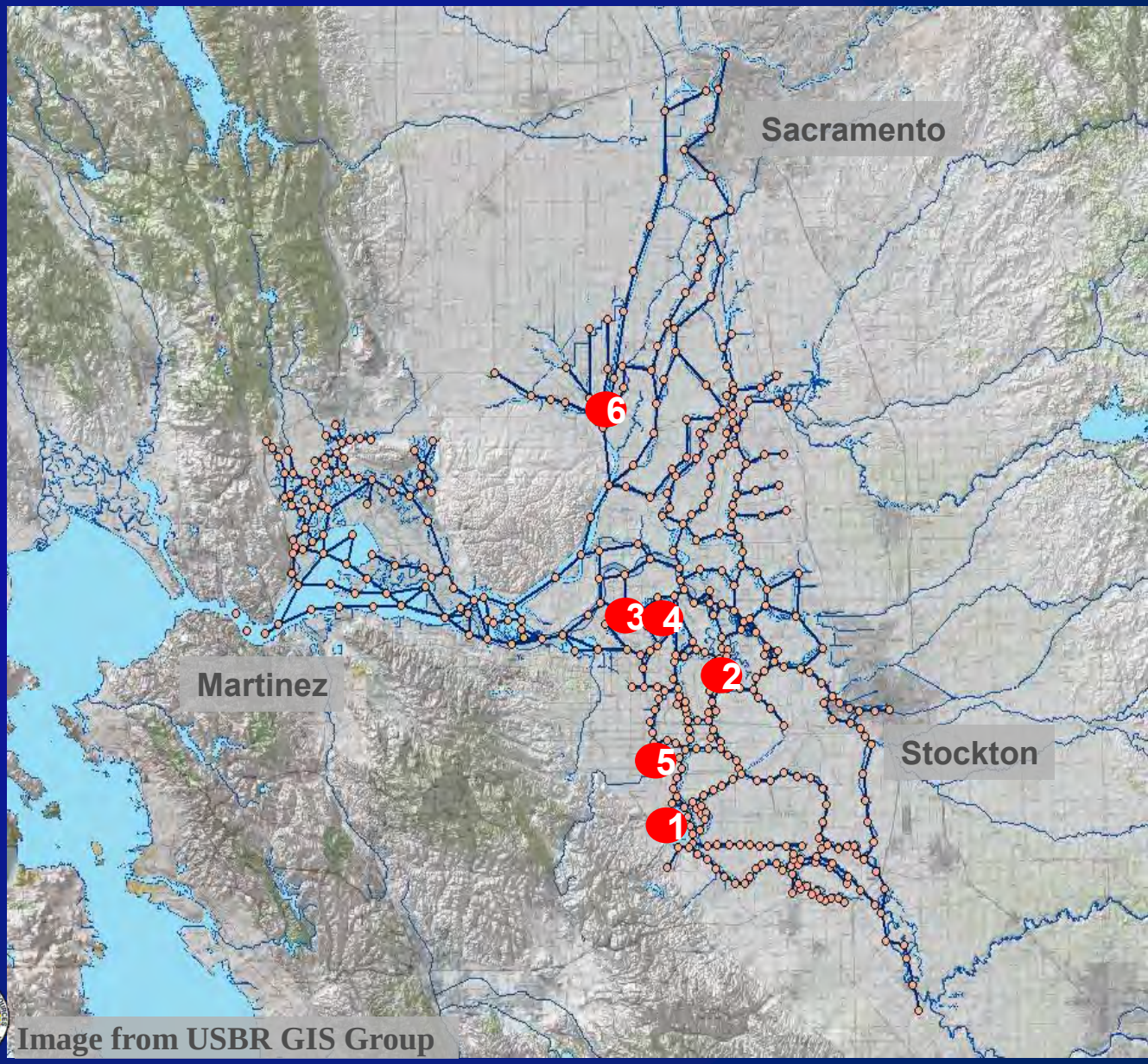
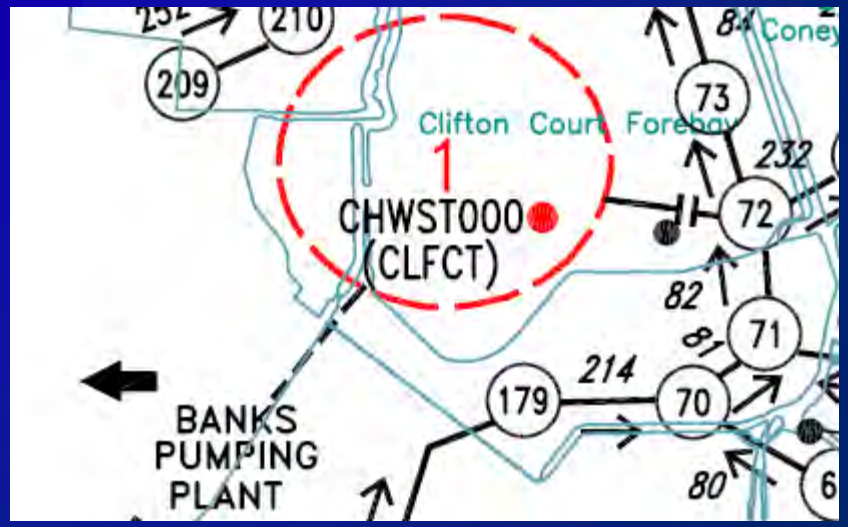


Image from USBR GIS Group

Gates in Hydro



- Any flow control structures
- Connect to a channel or a reservoir

Gates in Hydro

- In/out flow calculated by gate equations
- A gate associated a number of hydraulic devices:
  - Pipes and weirs
  - Each of device can be operated independently to control flow
  - Operation can be controlled by time series or operation rules

-- From DSM2 Workshop, 2009

Gates in Hydro

1. Delta Cross Channel

2. Goodyear Slough
3. Morrow Island Intake
4. Morrow Is. C-line outfall
5. Morrow Is. M-line outfall
6. Roaring River Sl. Intake
7. Montezuma Slough salinity control gate

8. 7-Mile Sl. @ 3-Mile Sl.
9. 7-Mile Sl. @ SJR
10. Sandmound Slough

Temporary Barriers
11. Middle River
12. Grant Line Canal
13. Old River at Tracy.
14. Head of Old River

15. Tom Paine Slough
16. Paradise Cut Weir

17. Clifton Court Forebay

-- From DSM2 Workshop, 2009

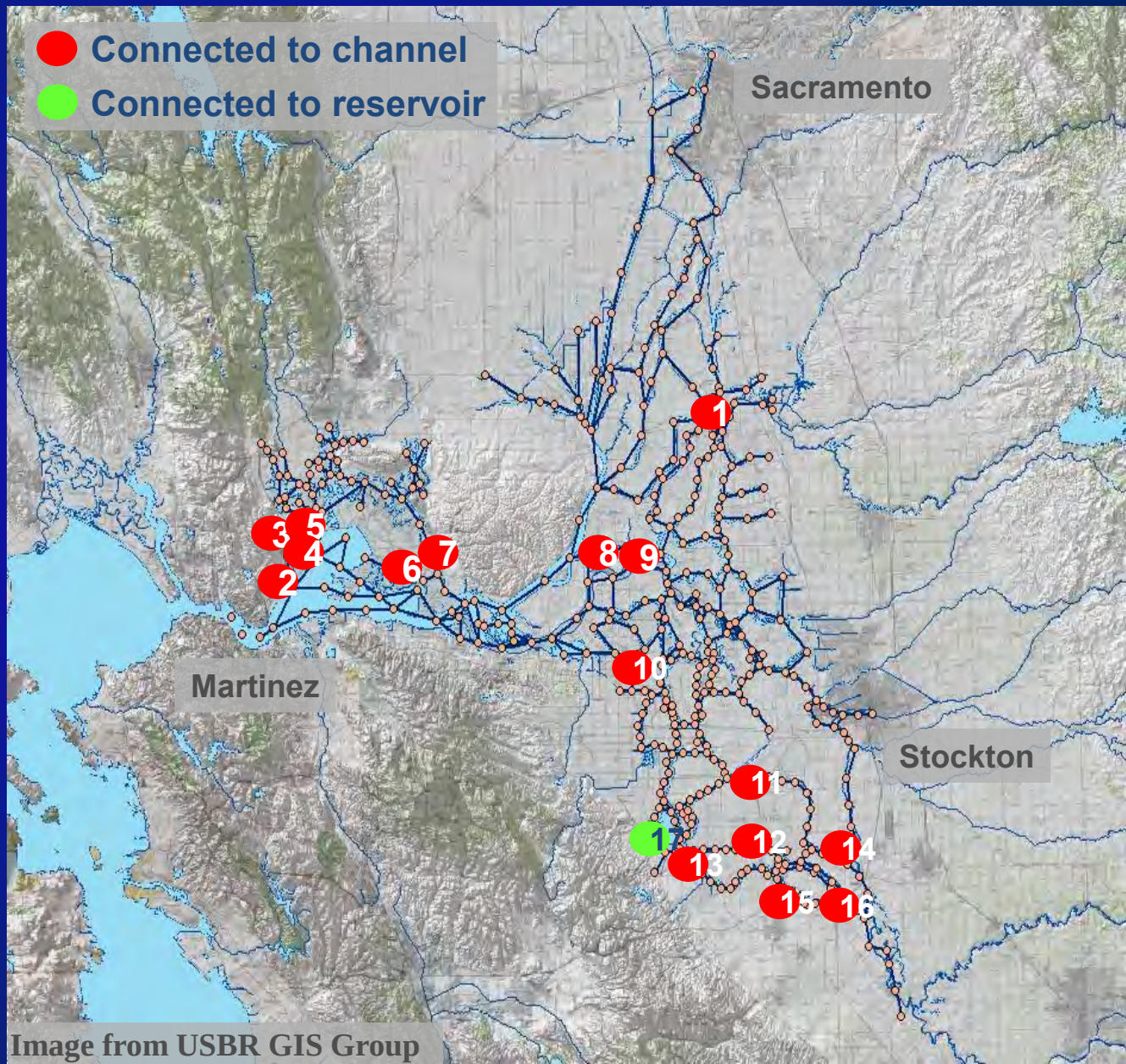


Image from USBR GIS Group

Water Transfer DSM2 Hydro

- Direct water connections from a reservoir or node to another reservoir or node
- Instantaneous movements of water without any detailed description of physics or storage
- Transferred flow can be
  - Constant
  - Based on a time series

-- From DSM2 Workshop, 2009

DSM2 Hydro Input

- Model configuration parameters
- Channel Geometry, barriers, gate configurations and operations
- Initial conditions
- Boundary conditions

DSM2 Boundary Conditions

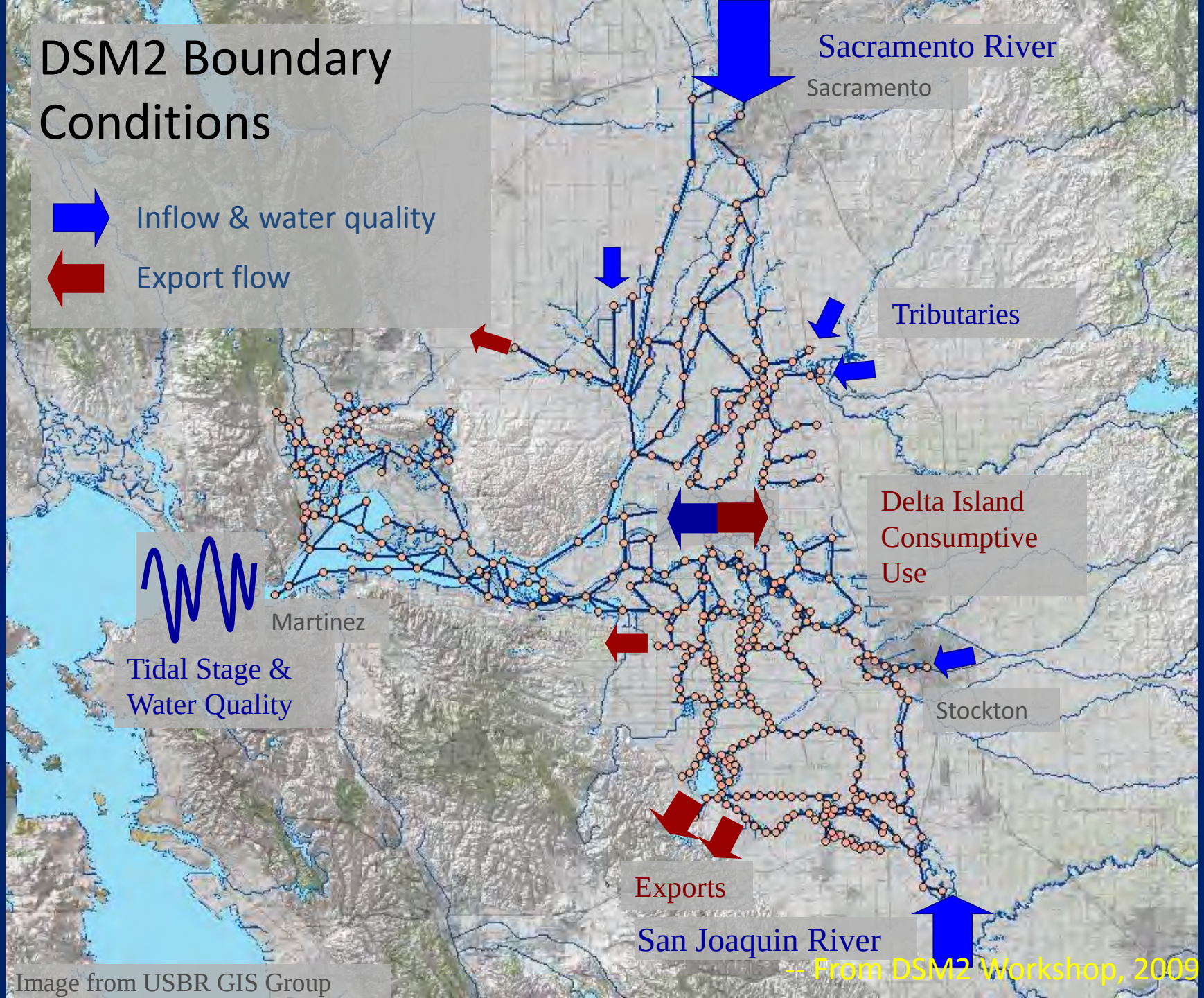


Image from USBR GIS Group

-- From DSM2 Workshop, 2009

DSM2 Hydro Output

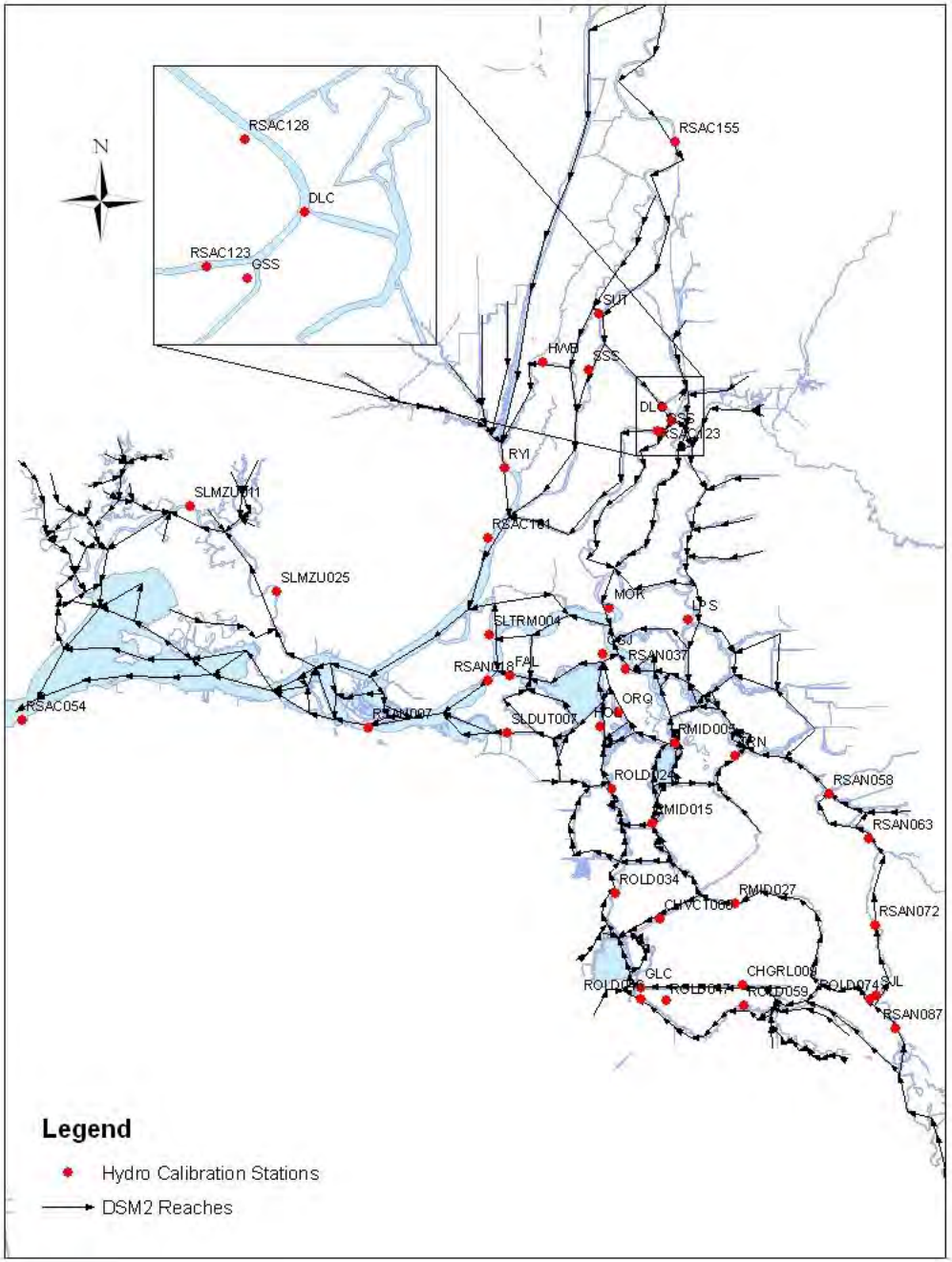
- Tide file in HDF5 format for PTM, QUAL and GTM
  - Flow and stage at every node
  - Input data
- Output in DSS format
  - Flow, stage, velocity at user defined locations

DSM2 Hydro Calibration Validation

Calibration performed periodically for

- Changes in geometry
- Better boundary data
- New model features

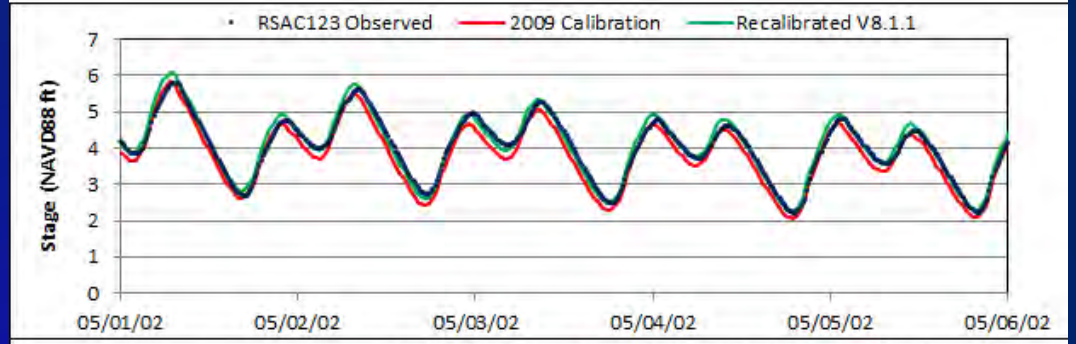
DSM2 Hydro Calibration Stations

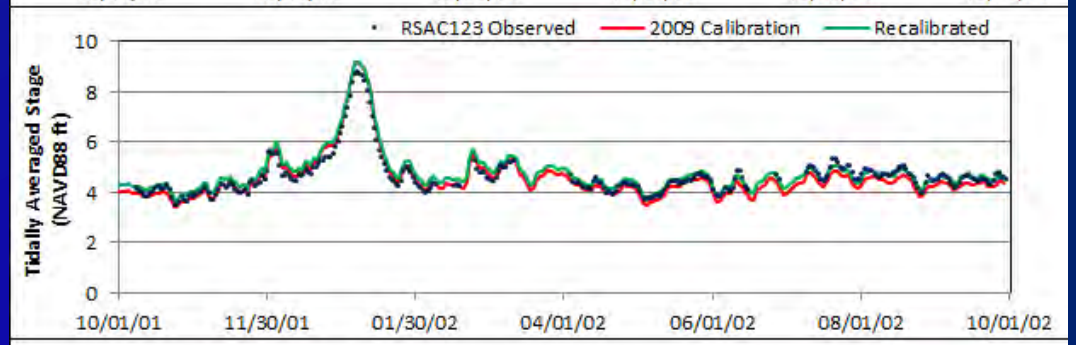


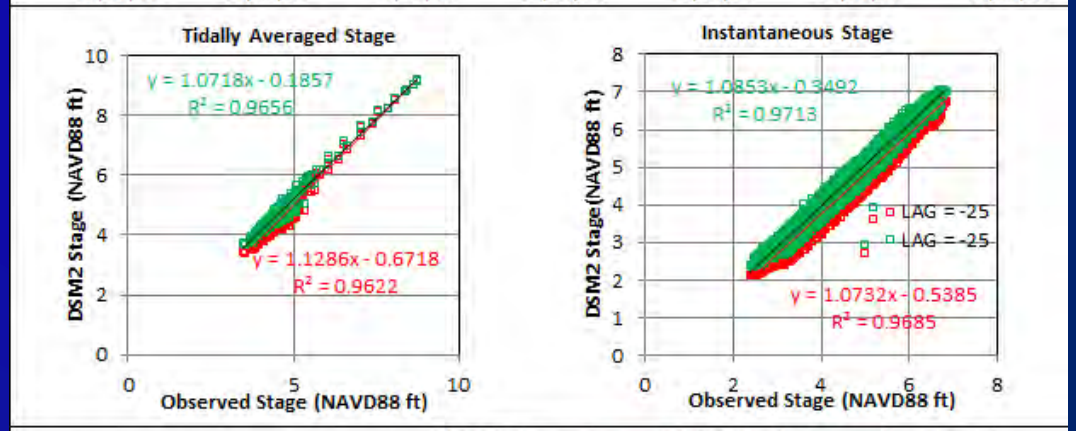
--From Liu et al., 2010

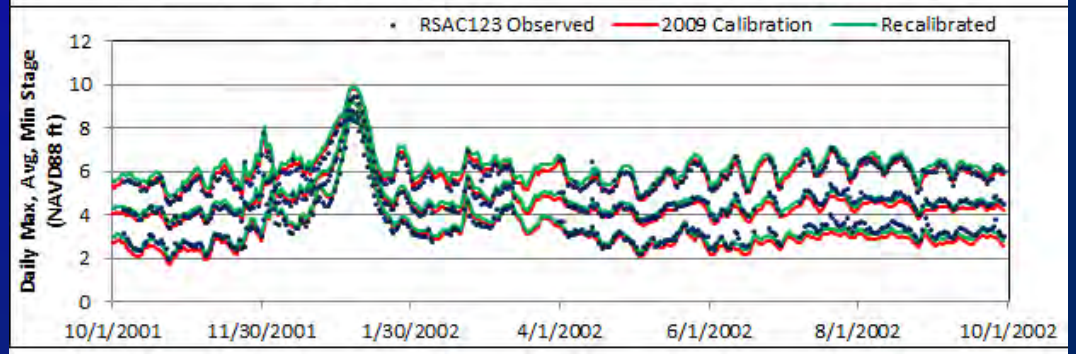
Hydro Calibration

Stage at RSAC123 (in Sac River near Georgiana slough)





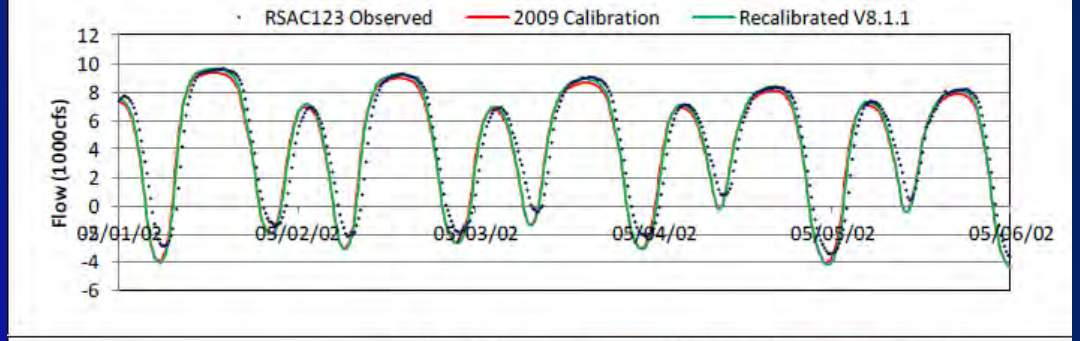


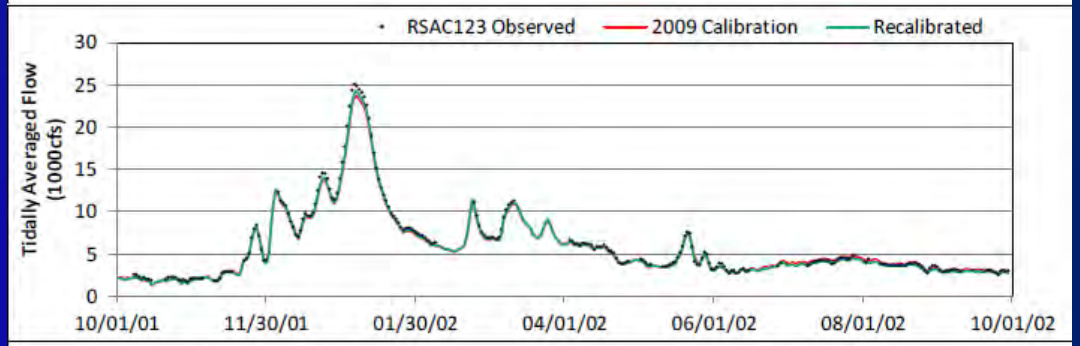


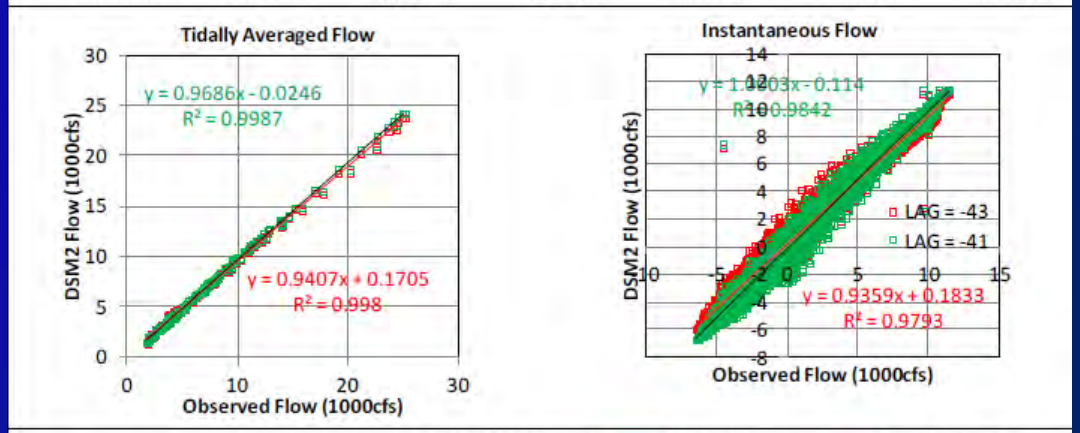
--From Liu et al., 2010

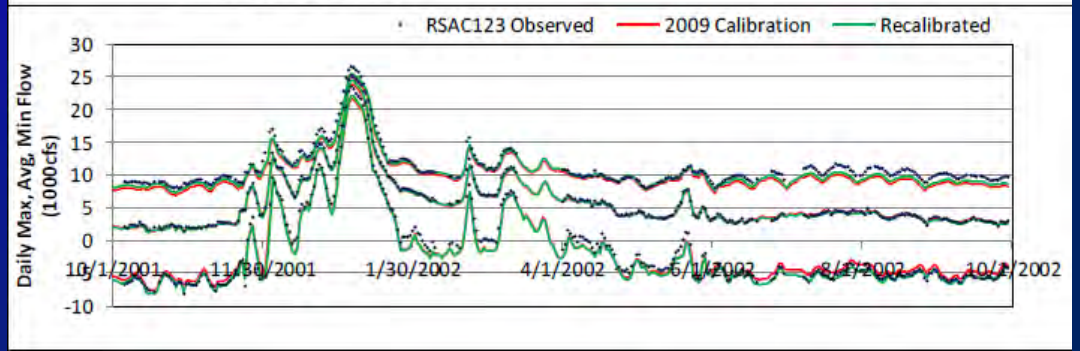
Hydro Calibration

Flow at RSAC123 (in Sac River near Georgiana slough)





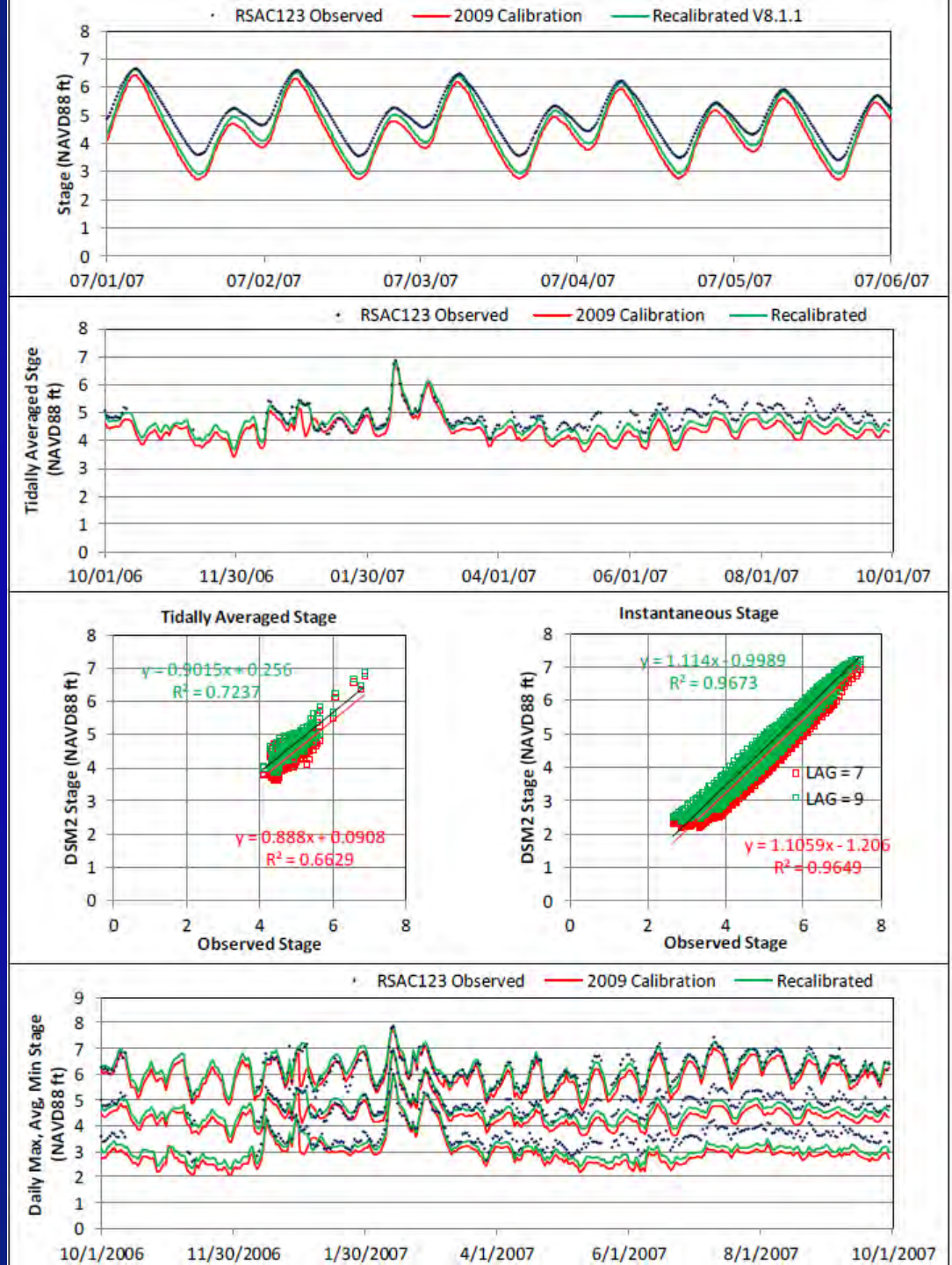




--From Liu et al., 2010

Hydro Validation

Stage at RSAC123 (in Sac River near Georgiana slough)



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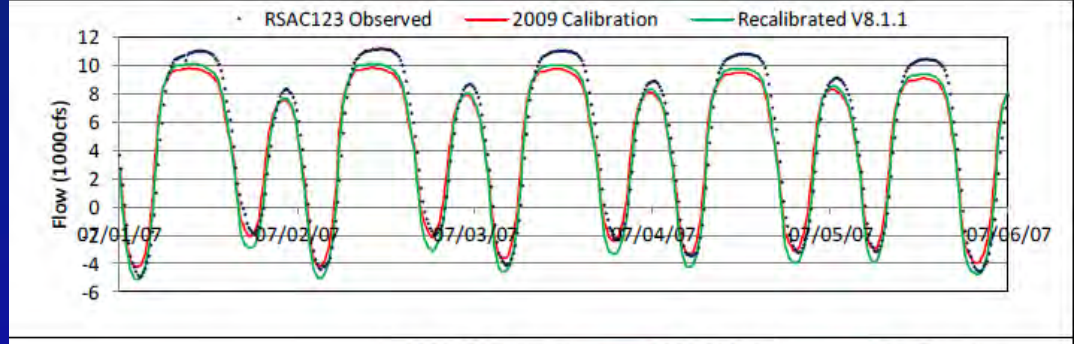
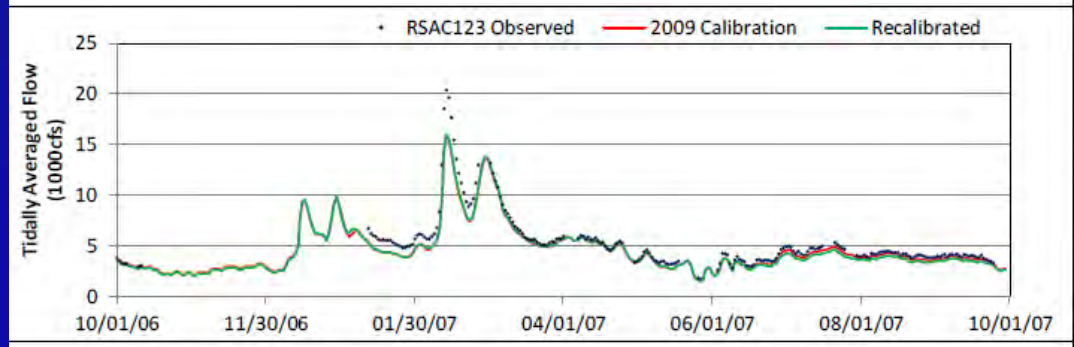
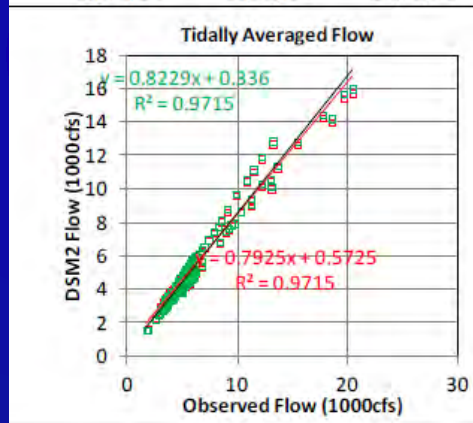
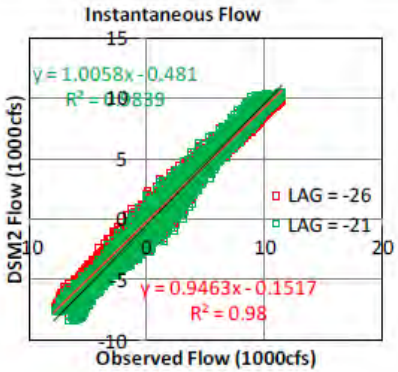
Hydro Validation

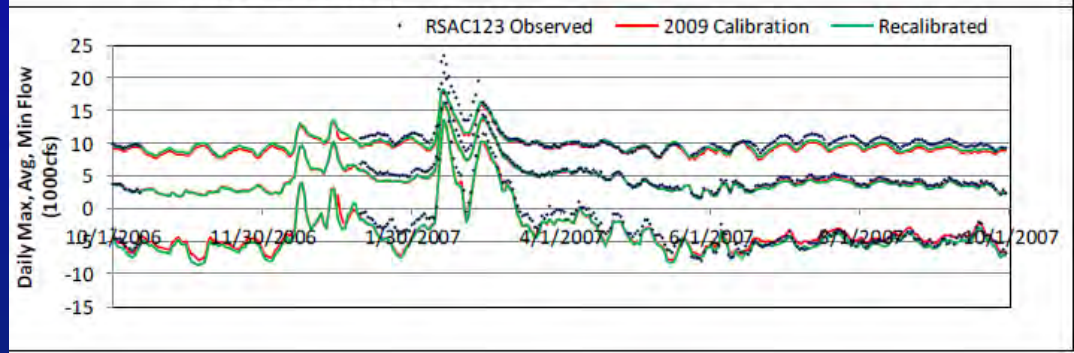
Flow at RSAC123 (in Sac River near Georgiana slough)











--From Liu et al., 2010

Release

- Nov 2016 release – most recent
- Early 2018 – next release
  - GTM
  - ePTM (DWR version)
  - DETAW/Channel Depletion Model

DSM2 Applications

Used by most Delta studies including

- CalFed Bay-Delta Program (e.g., Surface Storage Investigation)
- South Delta Improvement Program
- Bay Delta Conservation Plan (California WaterFix)
- Operations Criteria and Plan (OCAP)

……

DSM2 Applications

DSM2
Applications

Historical

Replicate historical conditions

Forecasting
(Real-Time)

Project conditions for the near future

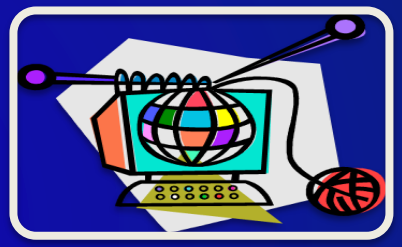
Planning

Hypothetical Delta changes

Technical Support: DSM2UG

Three meetings a year

One summer newsletter



Website & DSM2-User mailing list

-- From DSM2 Workshop, 2009

Review of DSM2 PTM

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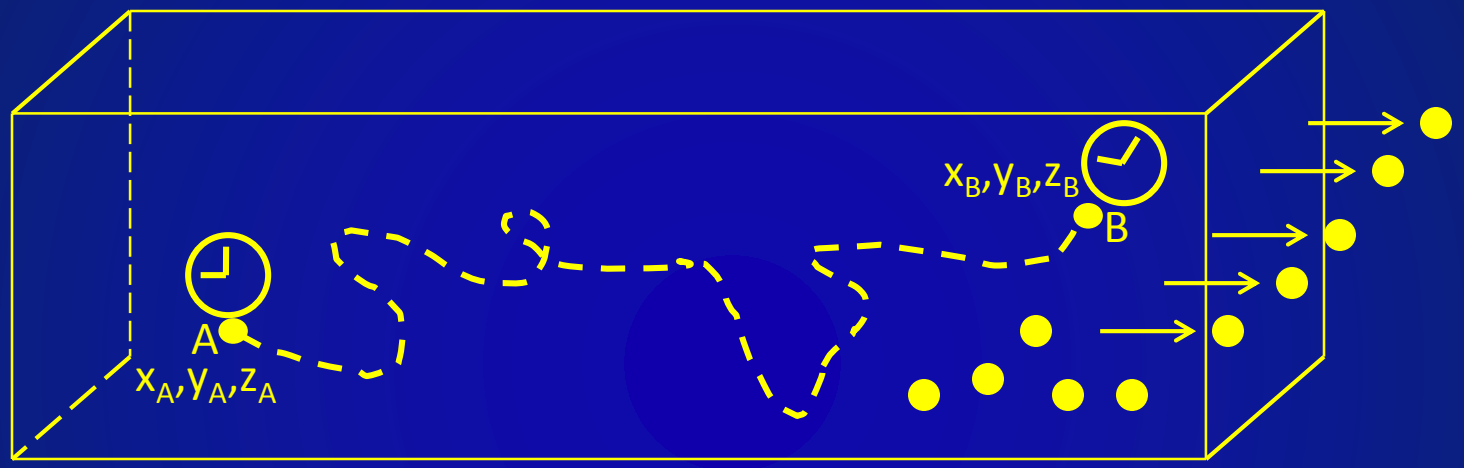
Modeling Support Branch
California Department of Water Resources

History of PTM Development

- Original algorithm developed by Gilbert Bogle
- Implemented in FORTRAN by Tara Smith
- Implemented in Java by Nicky Sandhu

PTM Overview



- Tracking neutrally-buoyant particle positions in 3D space
- Individual particle travel time from A to B
- Particle flux: # of particles passing specified location
- Particle concentration: # of particles in specified area

Governing Equations

Random Work Model /RDM (Rodean,1996):

$$dx_i = \left(u_i + \frac{\partial \varepsilon_i}{\partial x_i}\right) dt + R\sqrt{2\varepsilon_i dt}$$

$i = x, y, z;$

R: random number;

u_i: velocity

ε_i: eddy diffusivity

Governing Equations

$$dx_i = \left(u_i + \frac{\partial \varepsilon_i}{\partial x_i}\right) dt + R\sqrt{2\varepsilon_i dt}$$

x: diffusion << advection

$$dx = u_x dt \qquad u_x = \bar{u}F(y)F(z)$$

y, z: diffusion >> advection

$$dy = R\sqrt{2\varepsilon_y dt}$$

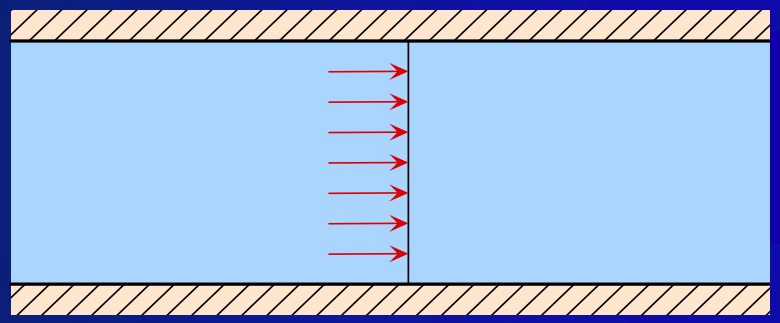
$$dz = R\sqrt{2\varepsilon_z dt}$$

ε_y, ε_z calculated using shear velocity and water depth

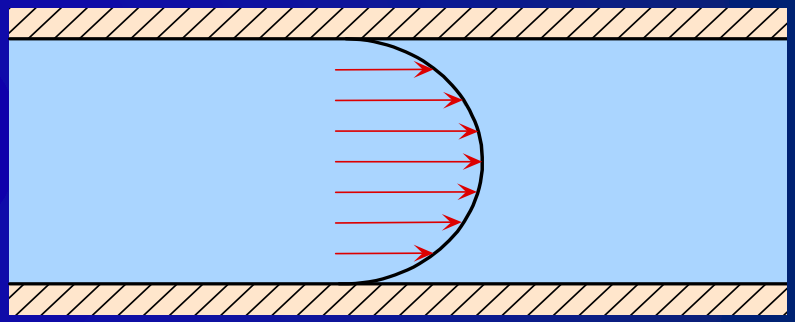
Quasi-3D Velocity Profile

Hydrodynamic Information from DSM2-Hydro

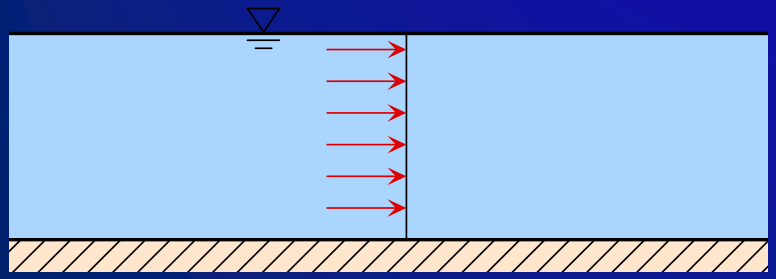
Quasi Velocity profile inside of DSM2-PTM



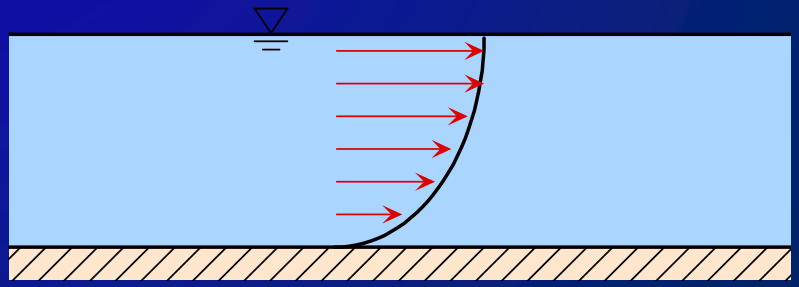
Lateral



$F(y)$: Quadratic polynomial



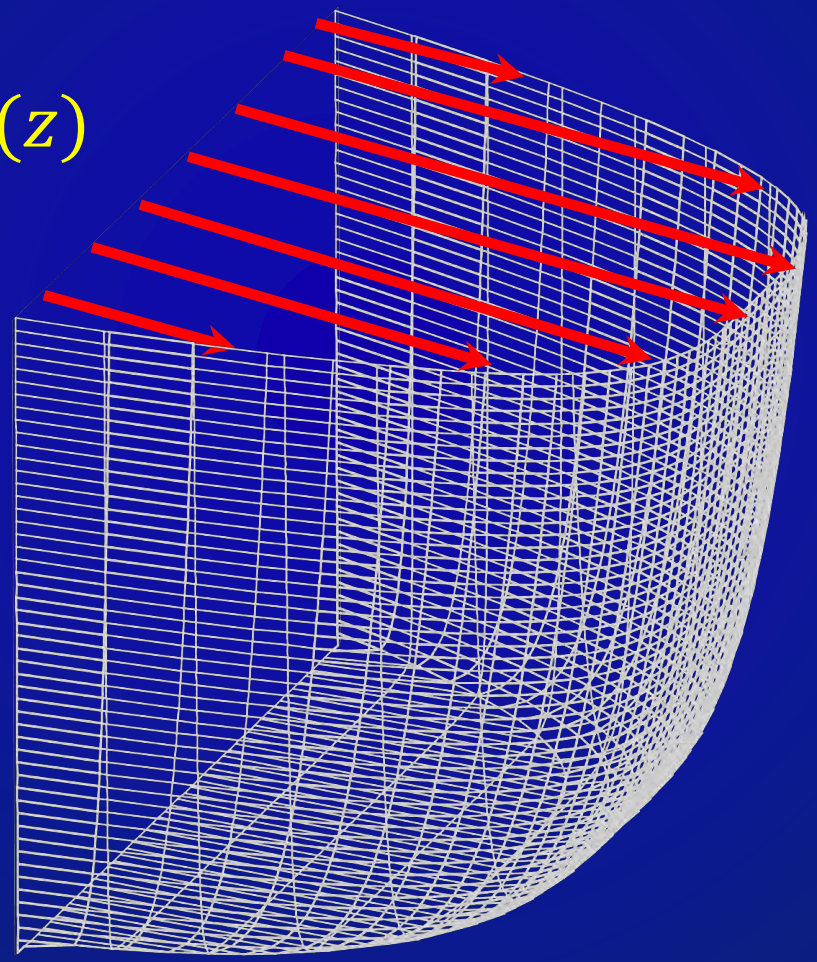
Vertical



$F(z)$: Von Karman Logarithmic

Quasi-3D Velocity Field

$$u_x = \bar{u}F(y)F(z)$$



Cross Sectional Velocity Profiles

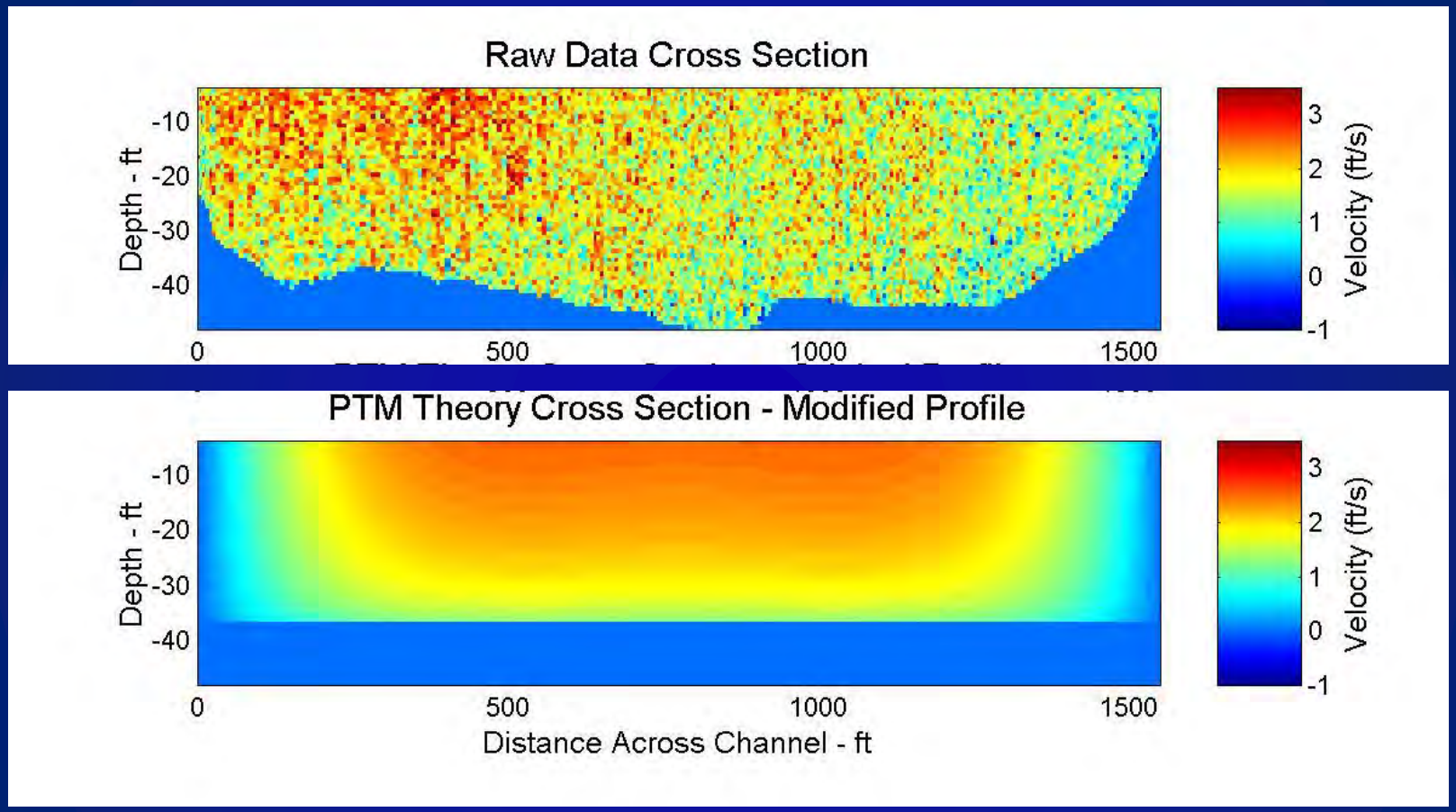


Image from Aaron Miller, 2002

Channel Geometry Representation

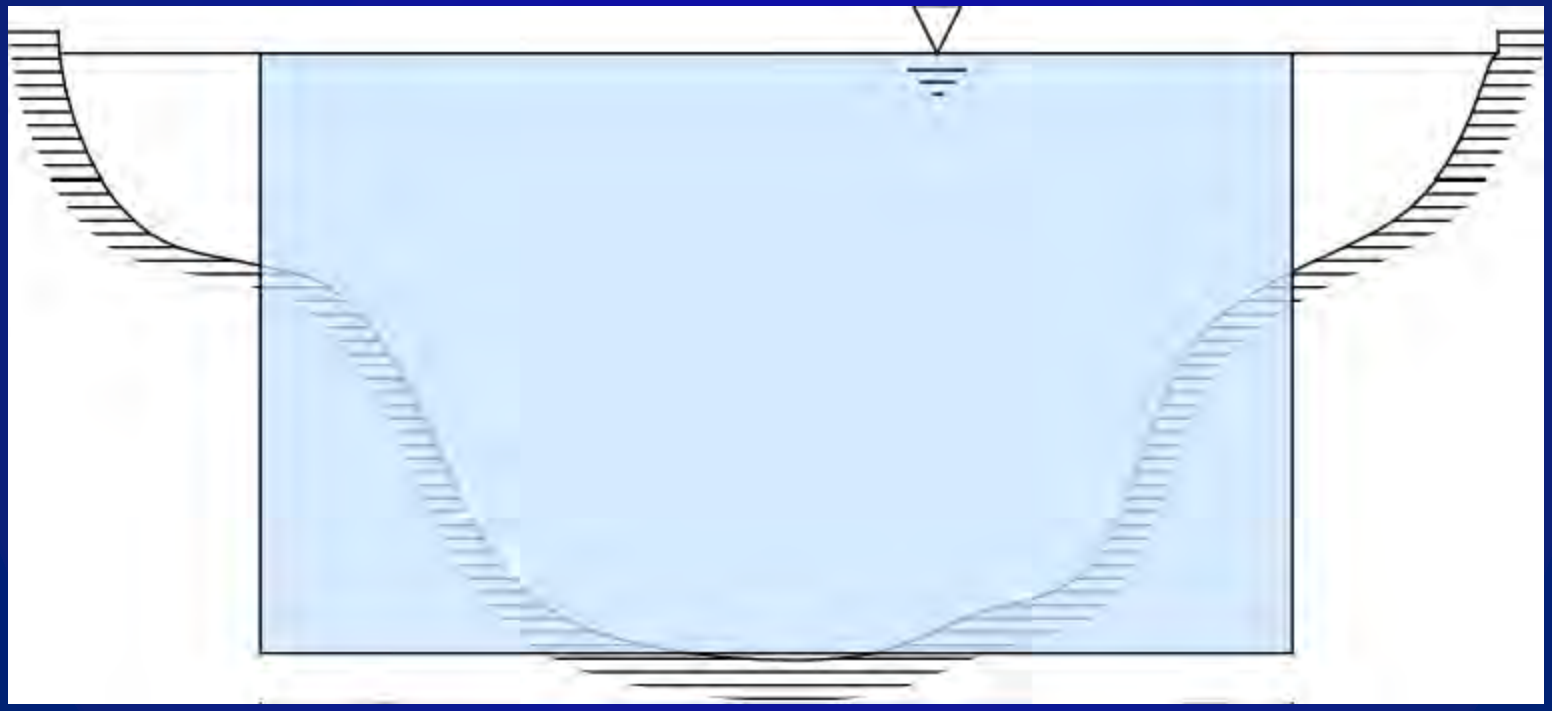


Image from Aaron Miller, 2002

Path Decided by Flow Split

$At\ junctions$:

$$probability\ of\ entering\ a\ channel = \frac{Flow\ entering\ the\ channel}{total\ flow\ @\ junction}$$

$In\ reservoirs$:

- $instantly\ well\ mixed$
- $probability\ of\ entering\ a\ connecting\ channel = \frac{out\ Flow\ to\ the\ channel * time\ step}{reservoir\ total\ volume}$

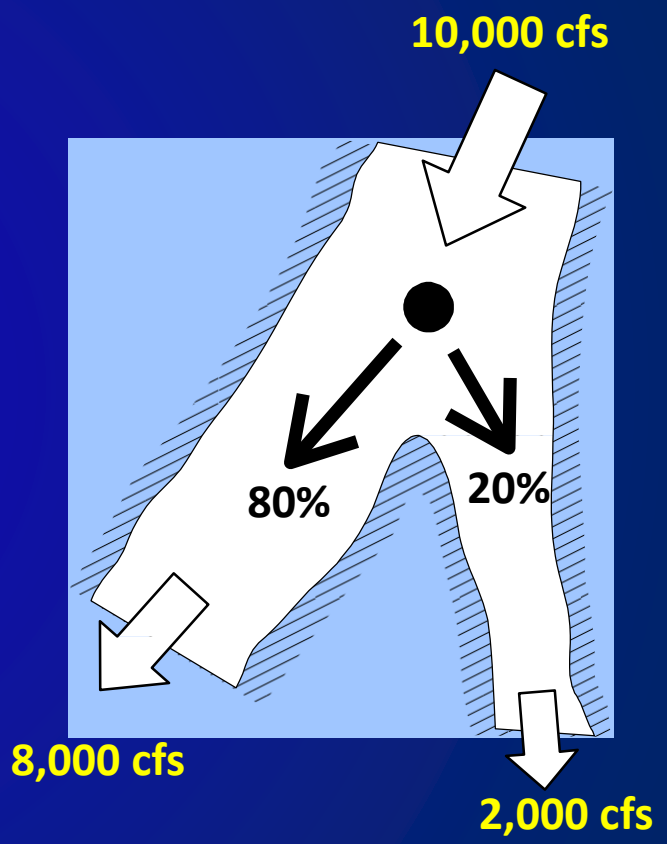


Image from Aaron Miller, 2002

Collision Algorithm

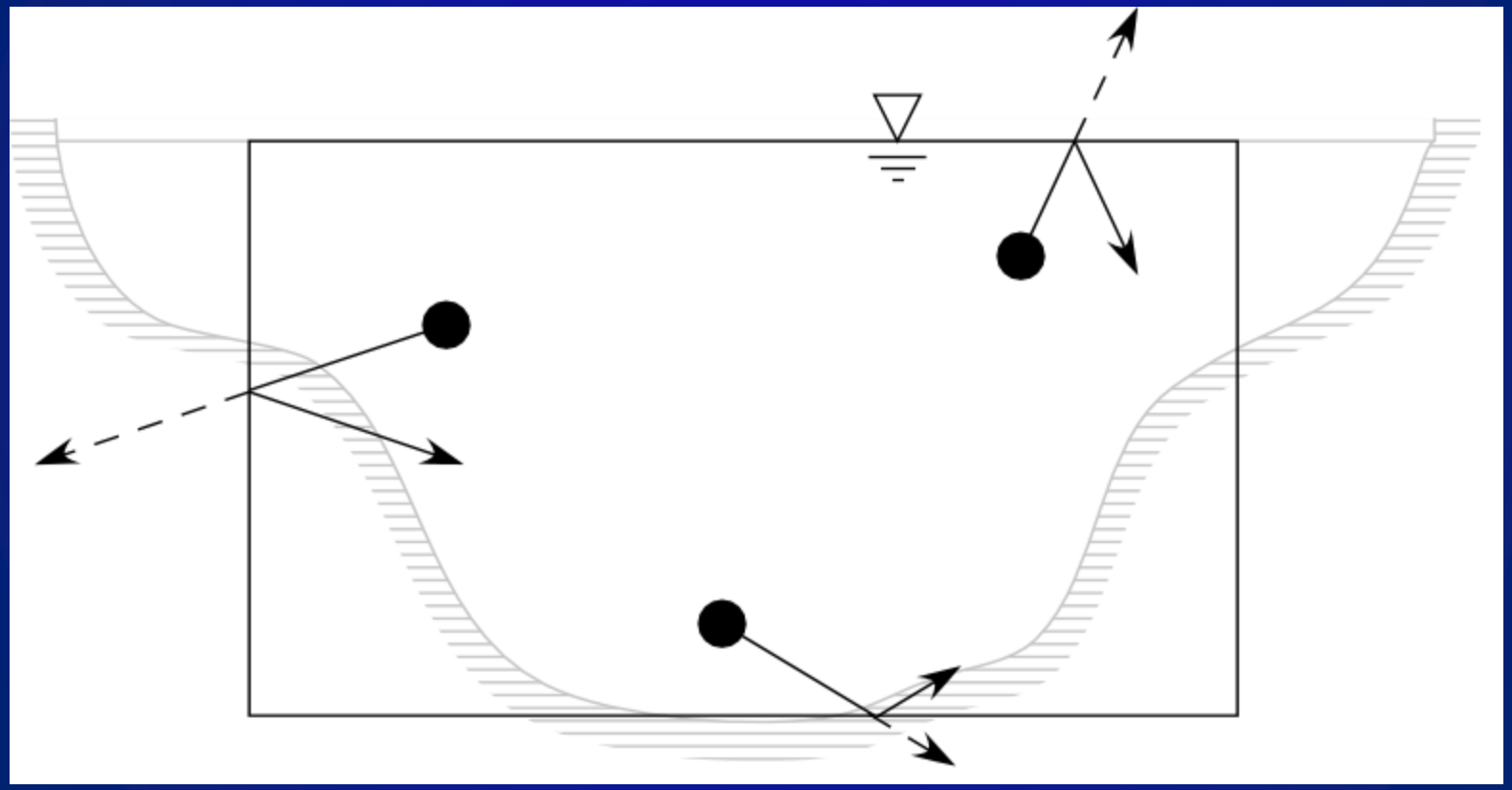


Image from Aaron Miller, 2002

PTM Input

- Model parameters (diffusion coefficients, etc.)
- Hydro output file (Tide File)
- Particle release info (where, when, how many)

PTM Output

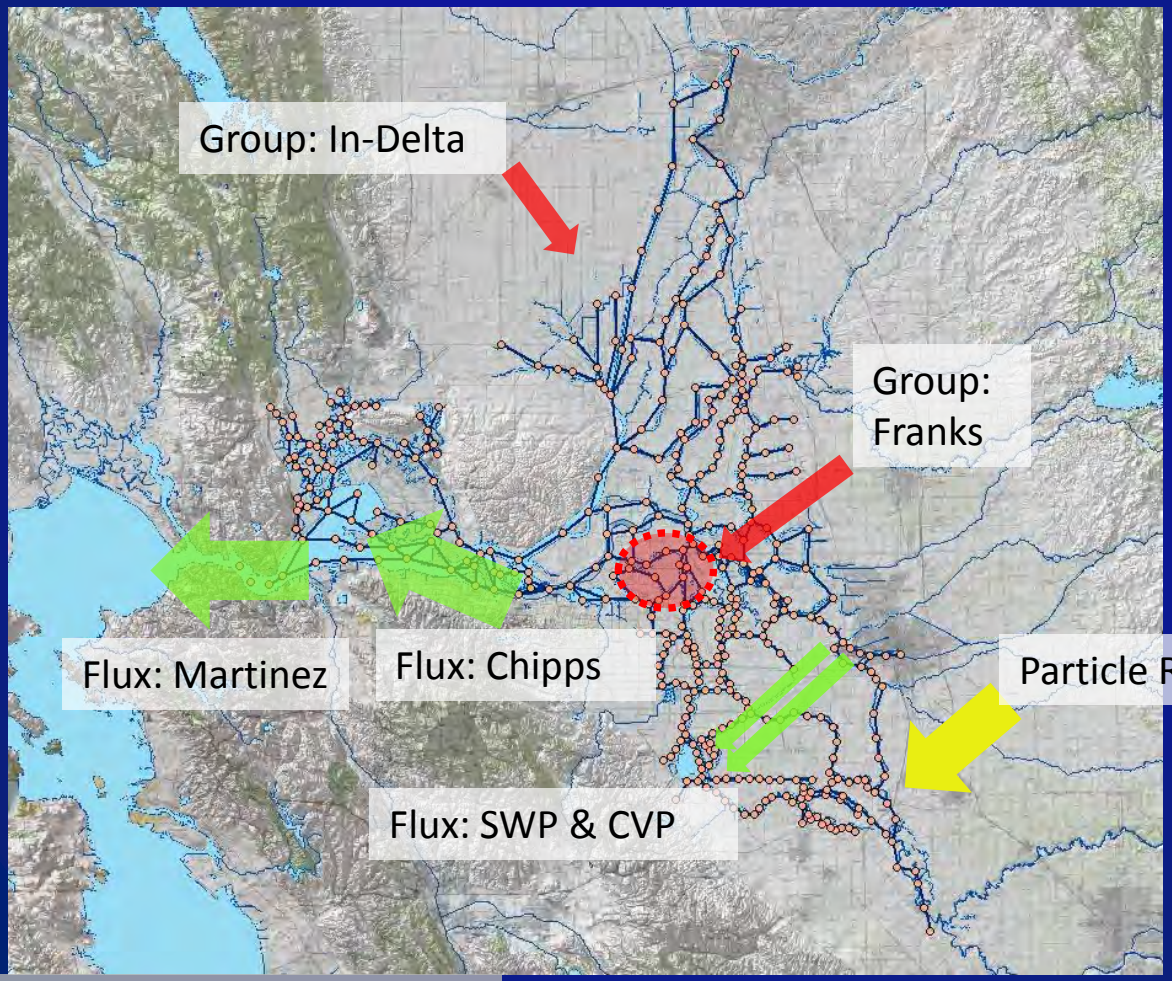
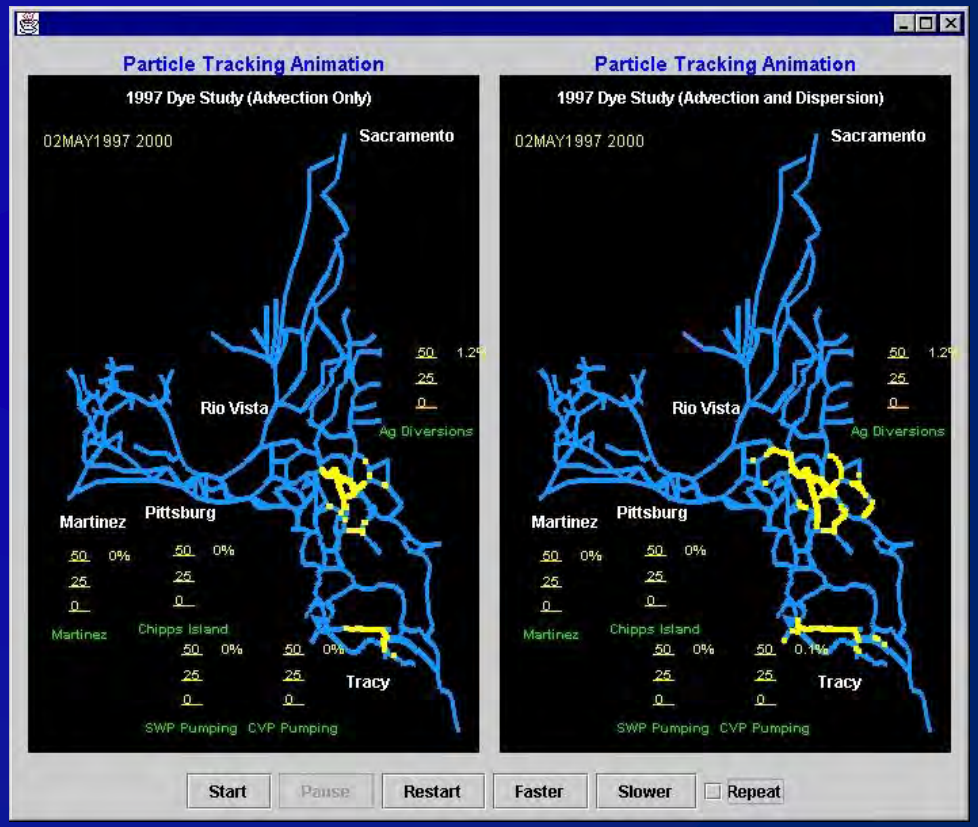


Image from USBR GIS Group

-- From DSM2 Workshop, 2009

Animation of DSM2-PTM

- DSM2-PTM provides an animation tool.
  - Two side-by-side panes
- Use text output and animation output.



-- From DSM2 Workshop, 2009

Limitations

- Quasi 3-D based on 1-D Model
- Many assumptions
  - Rectangular channels
  - Instantly mixing in reservoirs
  - Flow split (Junctions) ratio for path
- Neutrally buoyant particles
  - No active behavior
  - Always alive

-- From DSM2 Workshop, 2009

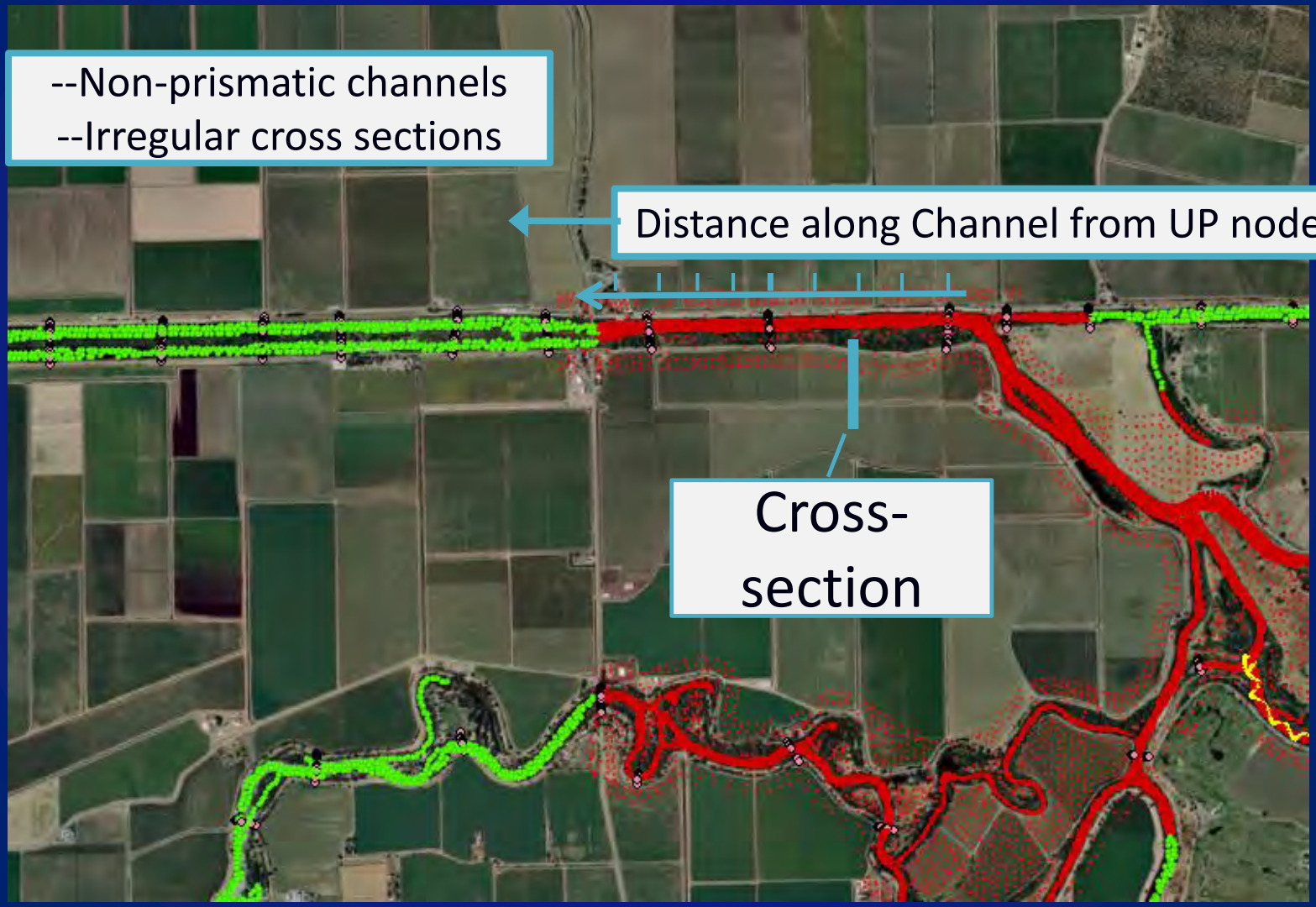
Thanks!

and

Questions?

Supplementary

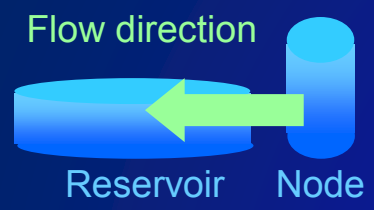
Grid: Channel Geometry



-- From DSM2 Workshop, 2009

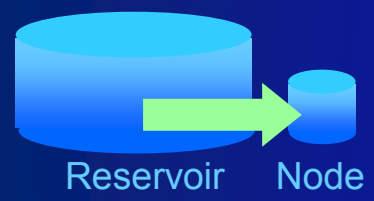
Reservoir Equations

When $Z_{res} < Z_{node}$



$$Q = C_{to}\sqrt{2g\left(z_{node} - z_{res}\right)}$$

When $Z_{res} > Z_{node}$



$$Q = C_{from}\sqrt{2g\left(z_{res} - z_{node}\right)}$$

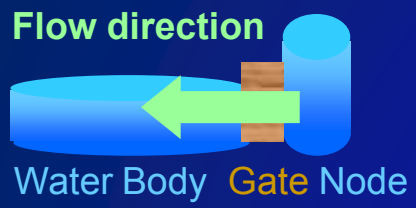
Where:

- C_{to} and C_{from} = coefficients representing the hydraulic efficiency of the reservoir connection and the nominal area perpendicular to flow
- g = gravity
- z_{res} and z_{node} = water surface elevations at the reservoir and node (node surface is assessed by means of a reference channel that has no reservoirs attached to it)

-- From DSM2 Workshop, 2009

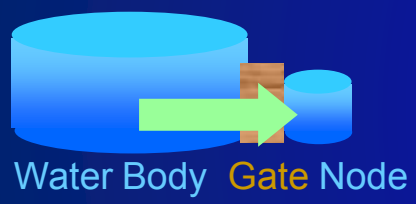
Gate Equations

When $Z_{wb} < Z_{node}$



$$Q = nC_{op_from}C_{from}A(z_{node}, p)\sqrt{2g(z_{node} - z_{wb})}$$

When $Z_{wb} > Z_{node}$



$$Q = nC_{op_to}C_{to}A(z_{wb}, p)\sqrt{2g(z_{wb} - z_{node})}$$

Where:

- n = number of duplicate devices, g=gravity,
- C_{op_to} and C_{op_from} = operating coefficient for controls, e.g. flap valves
- C_{to} and C_{from} = coefficients representing gate's hydraulic efficiency
- A = area of flow depending on higher water surface and position p
- z_{res} and z_{node} = water surface elevations at the reservoir and node

-- From DSM2 Workshop, 2009

Hydro Data Requirements

- hydro data
  - Fixed data
    - Scalars
    - Geometry data
    - Permanent gates and reservoirs
  - Time-variable data, update needed
    - Boundaries
      - Inflows: SAC, SJR, YOLO, Eastside
      - Exports: SWP, CVP, CCC, and NB
      - Stage: Martinez
    - Inland sources ← DICU generates
    - Gate timing

-- From DSM2 Workshop, 2009