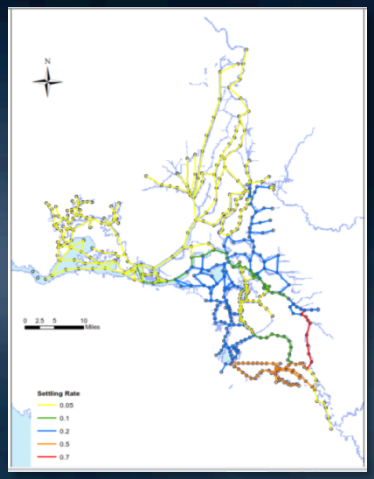
Forecasting Delta Turbidity Conditions
with Artificial Neural Networks



7th Biennial Bay-Delta Science Conference

October 18, 2012

Paul Hutton, Ph.D., P.E.

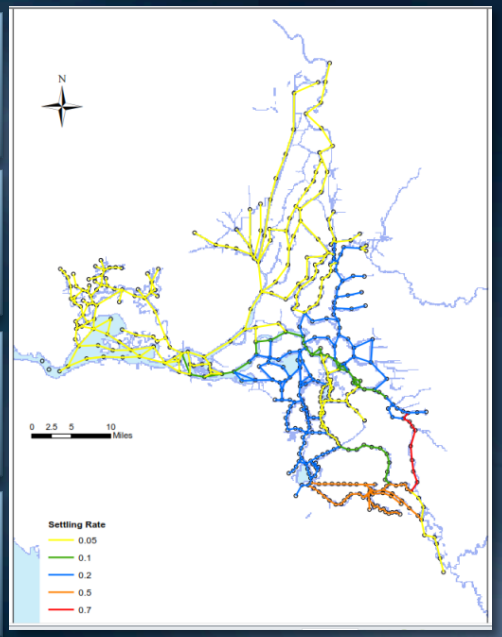
Forecasting Delta Turbidity Conditions
with Artificial Neural Networks

Background

Model Description

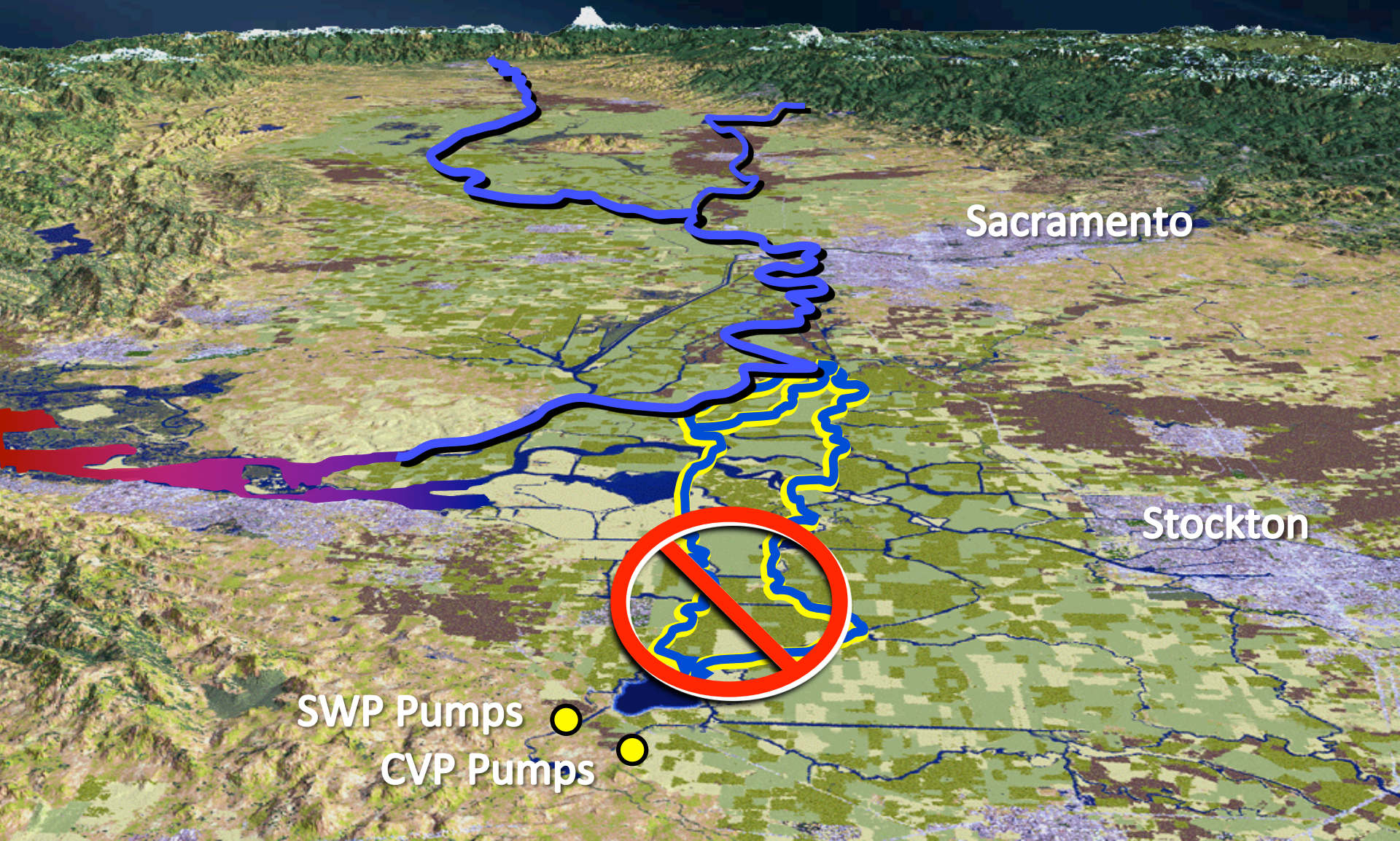
Sample Results

Next Steps

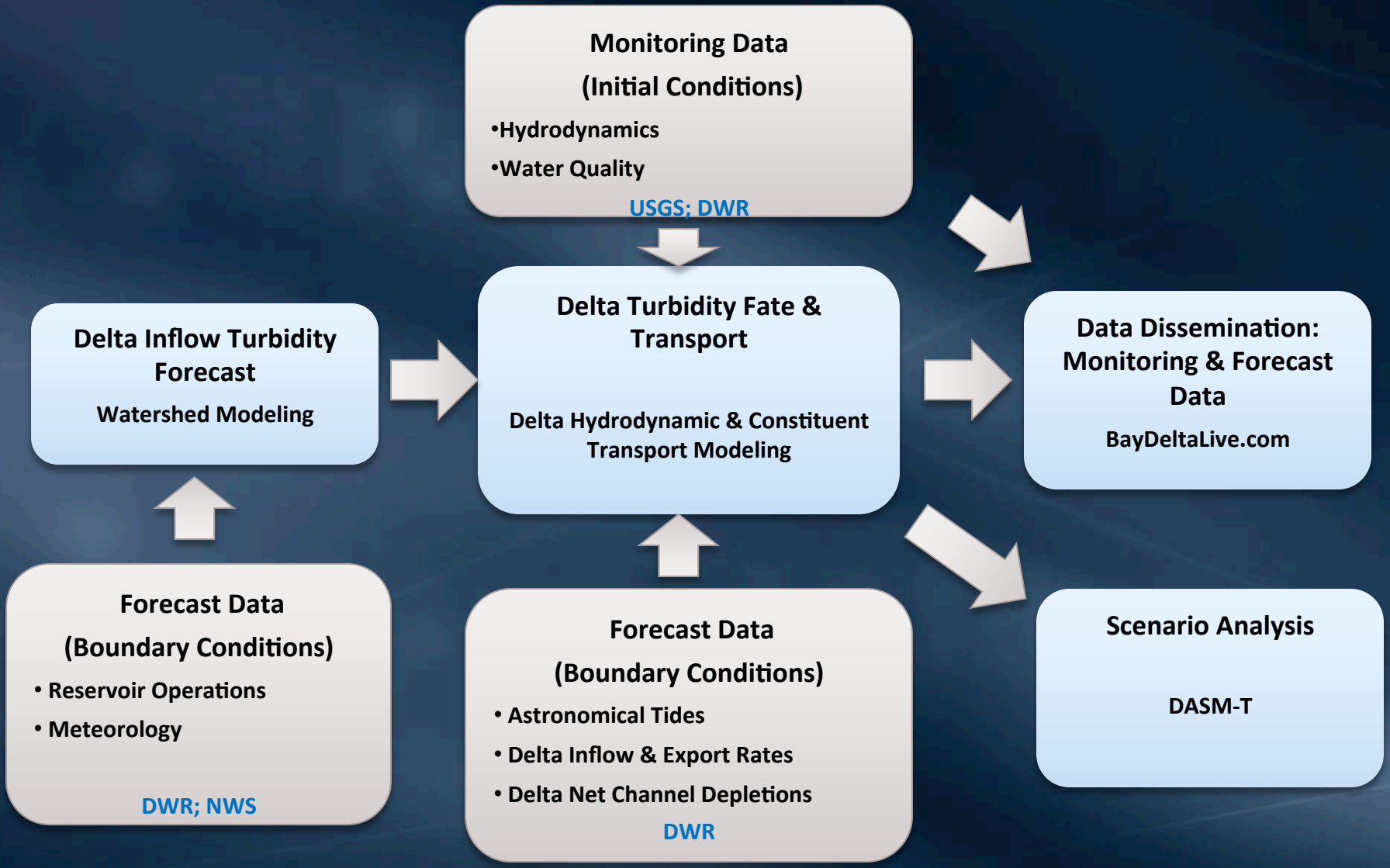


Biological Opinion "First Flush" Action

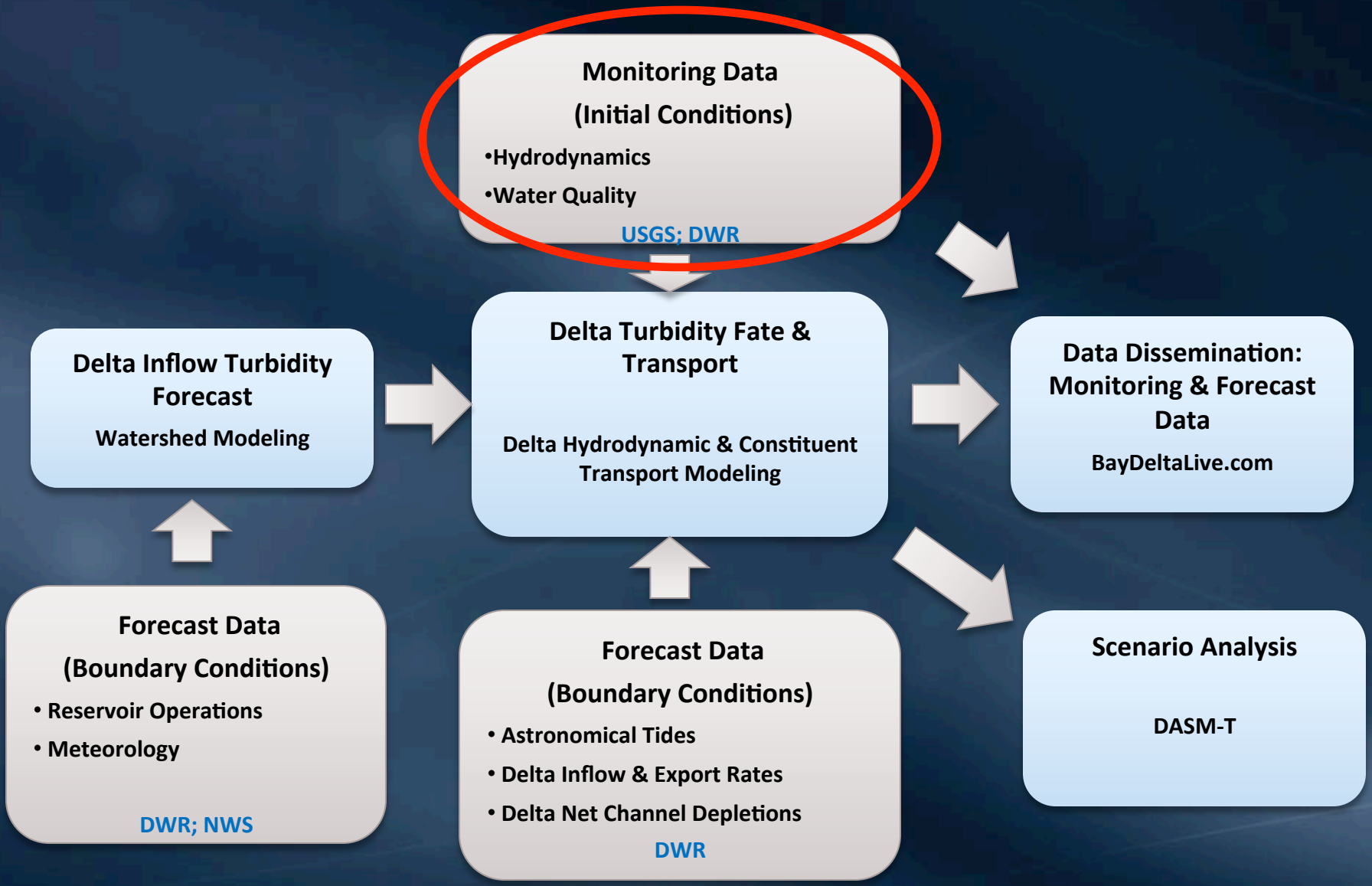
Restricts Pumping Operations



Forecasting Process

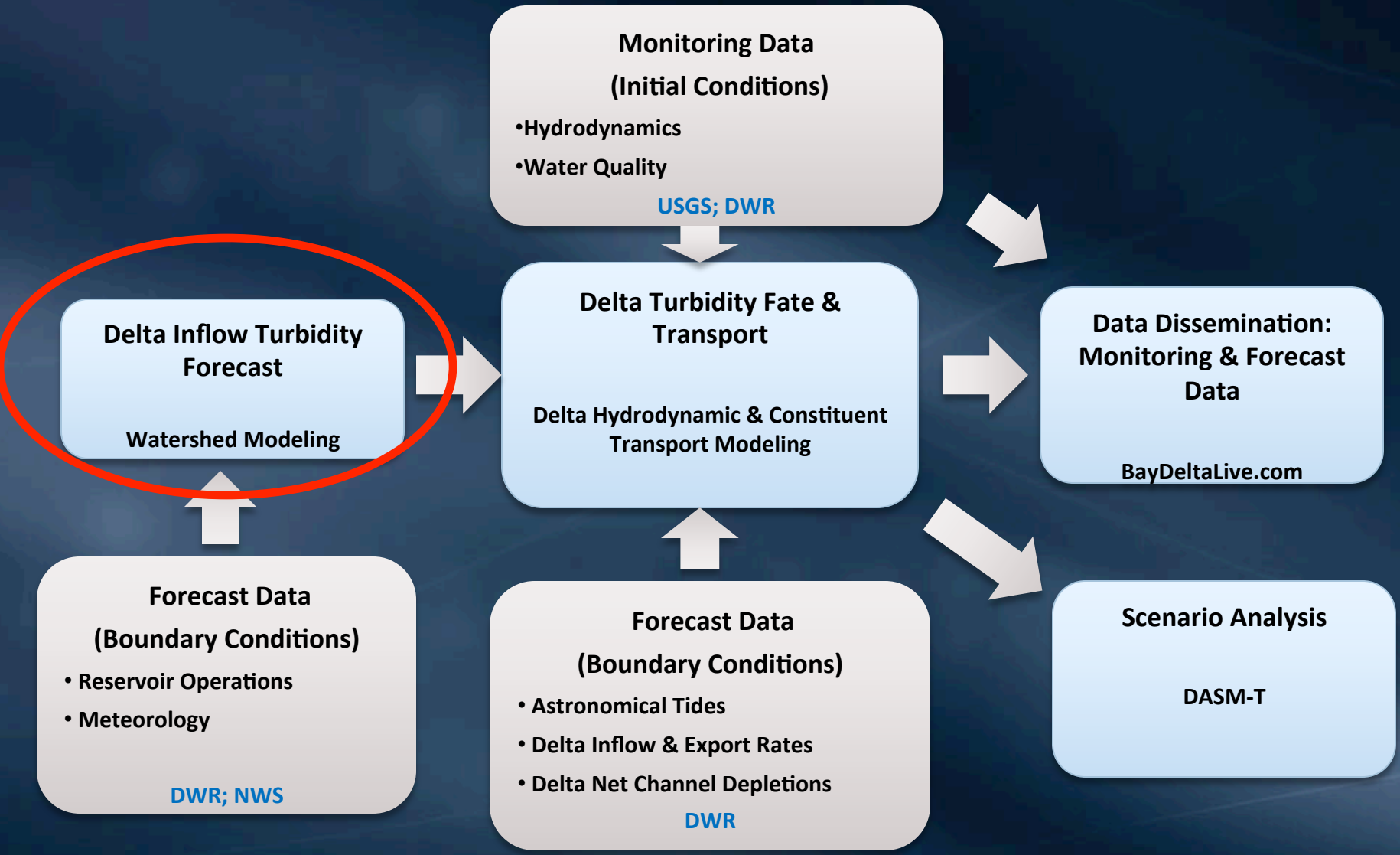


Forecasting Process



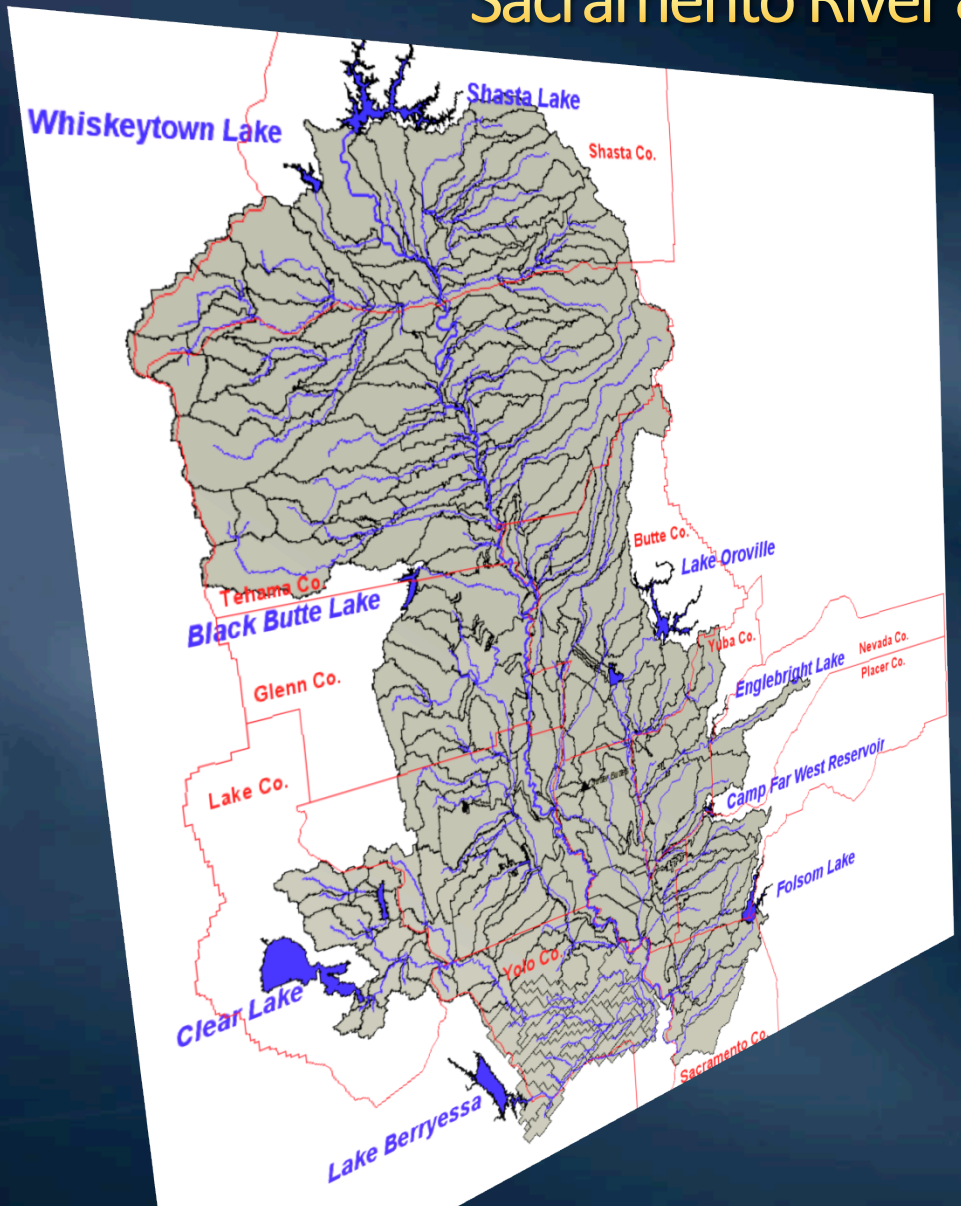
Turbidity Monitoring Sites

Forecasting Process



Delta Inflow Turbidity Forecast

Sacramento River & Yolo Bypass



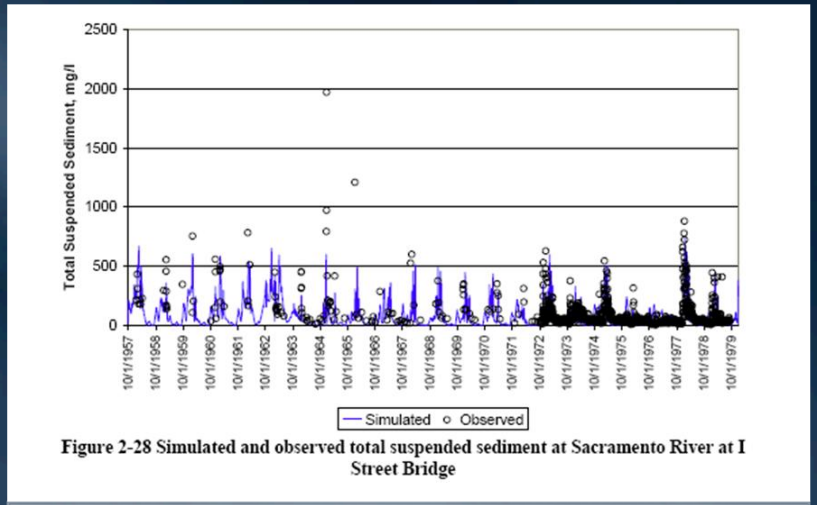
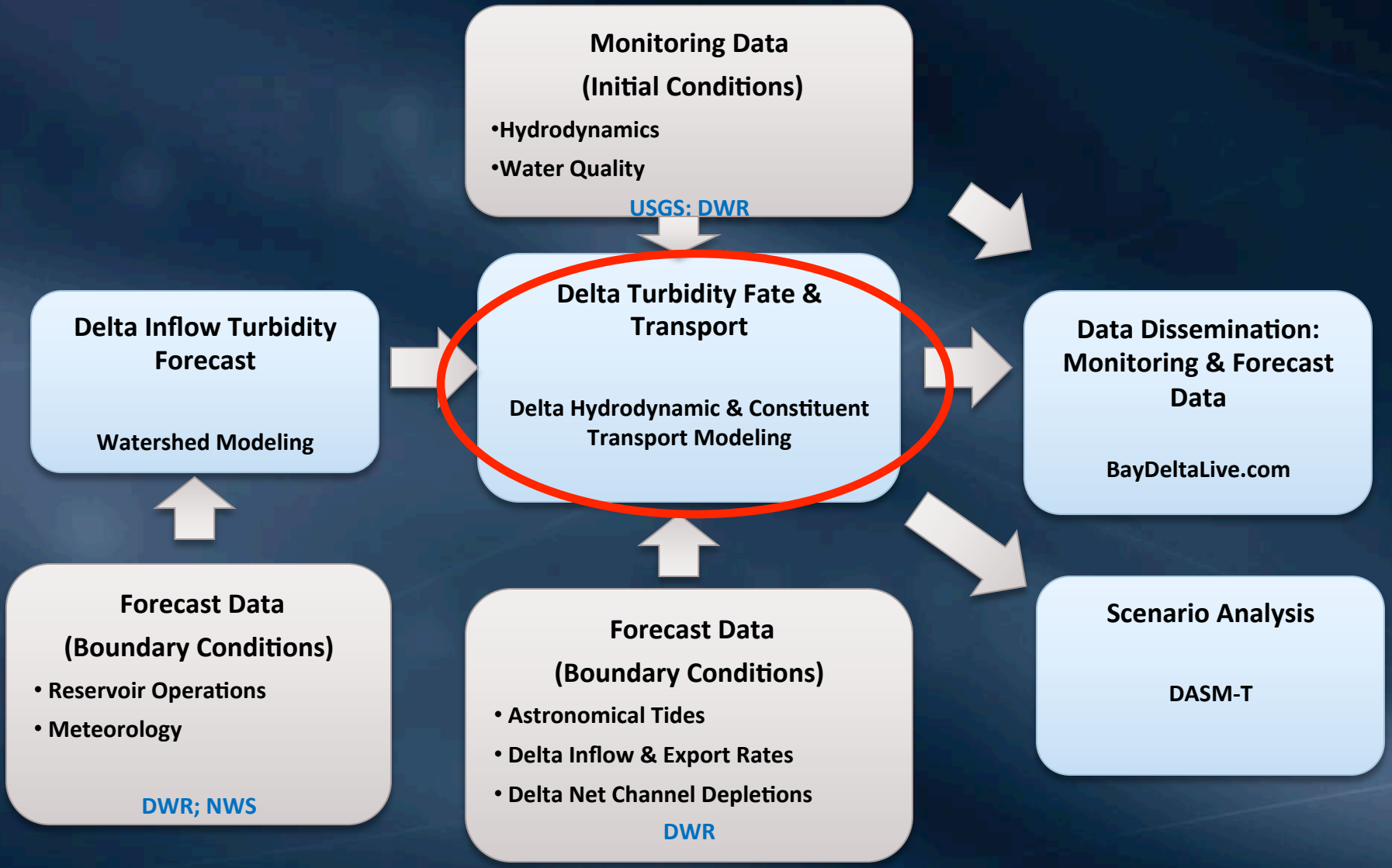
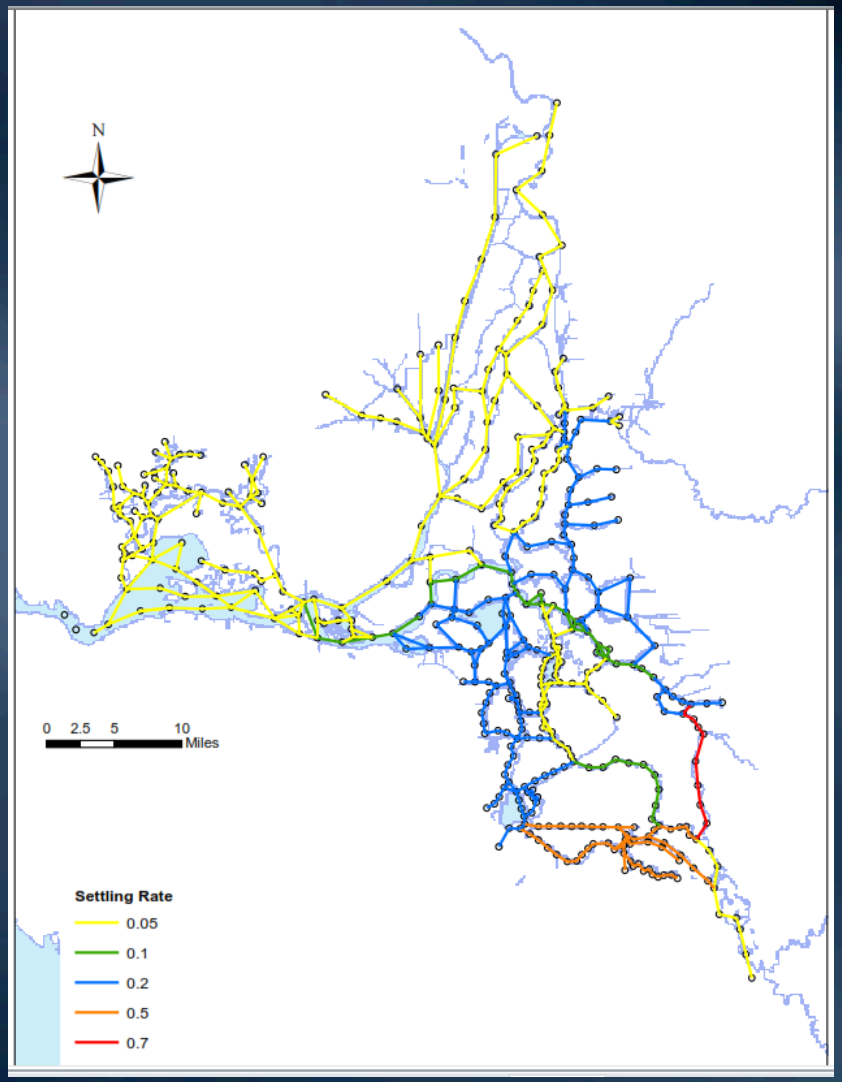


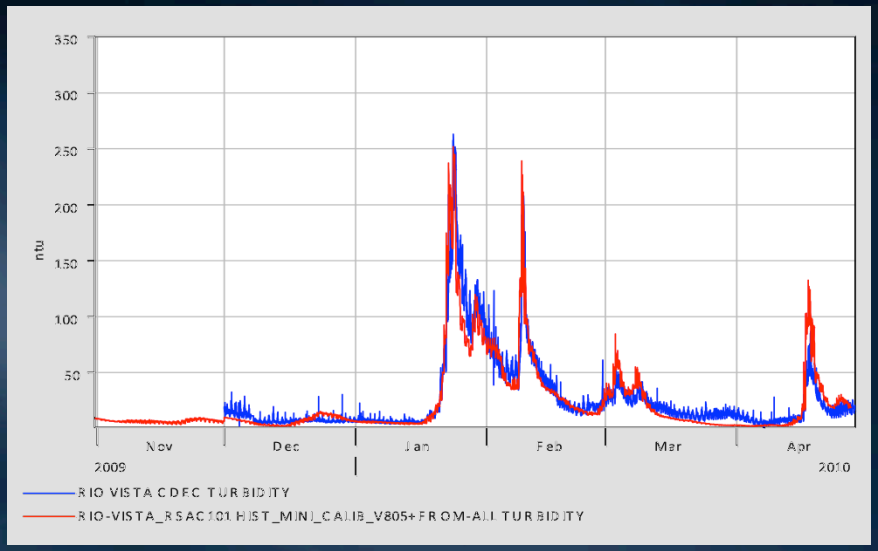
Figure 2-28 Simulated and observed total suspended sediment at Sacramento River at I Street Bridge

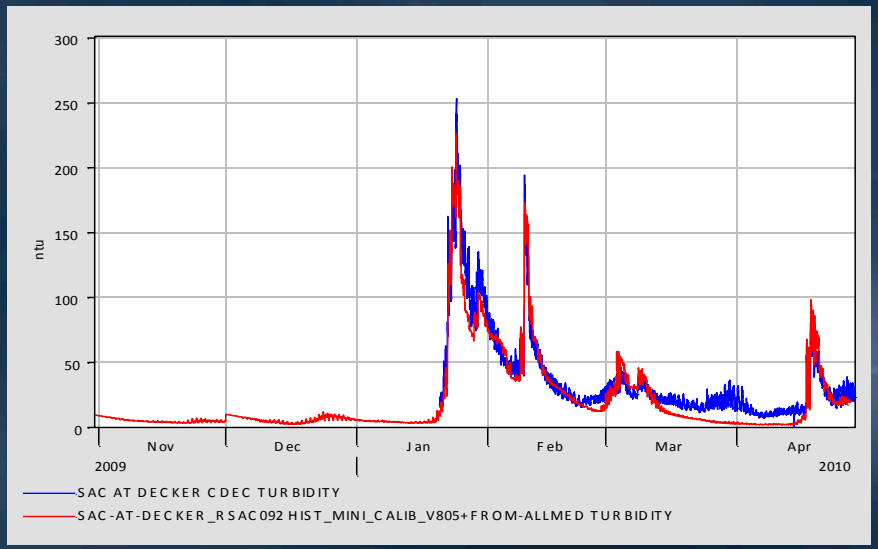
Forecasting Process



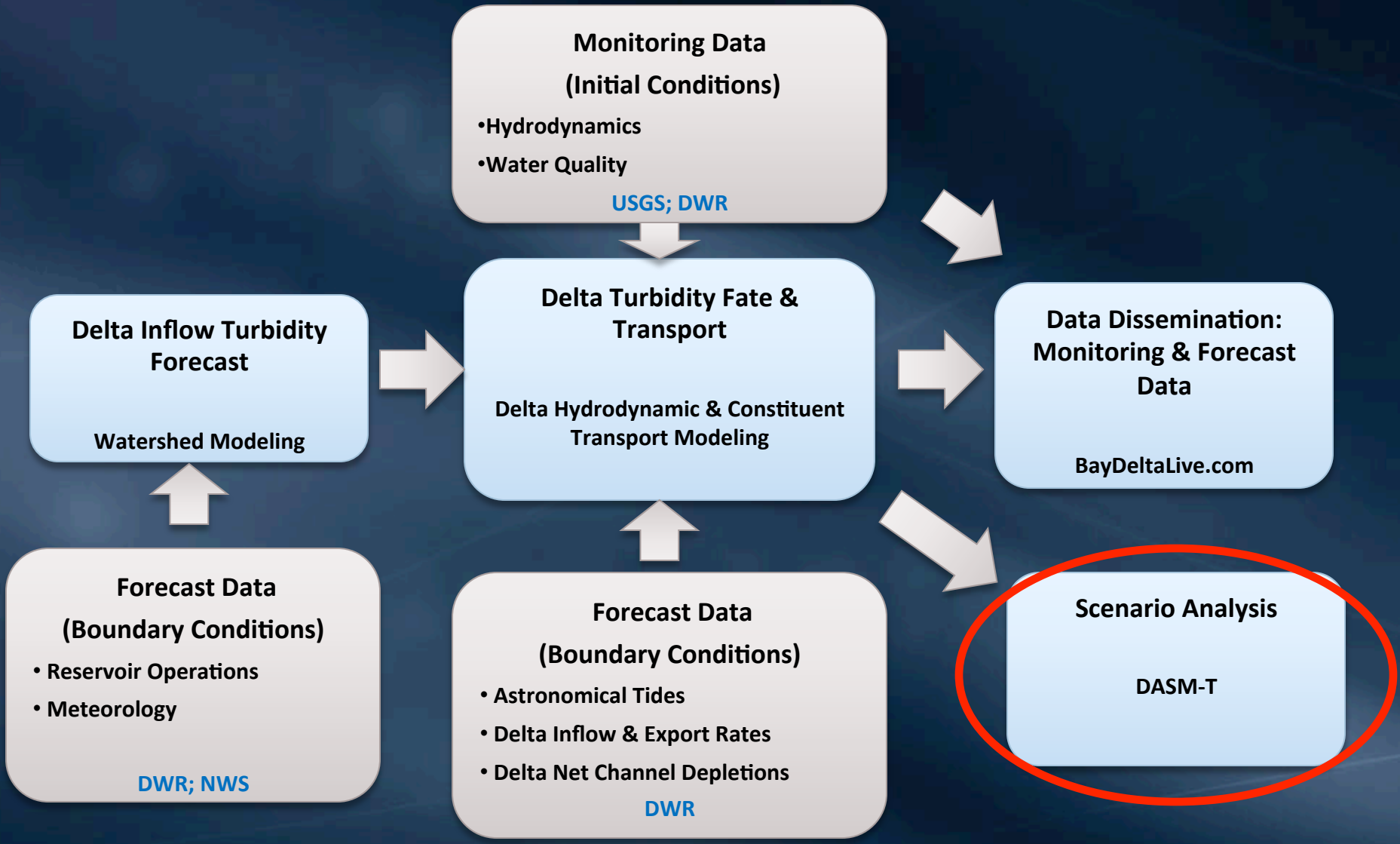
Delta Turbidity Fate & Transport





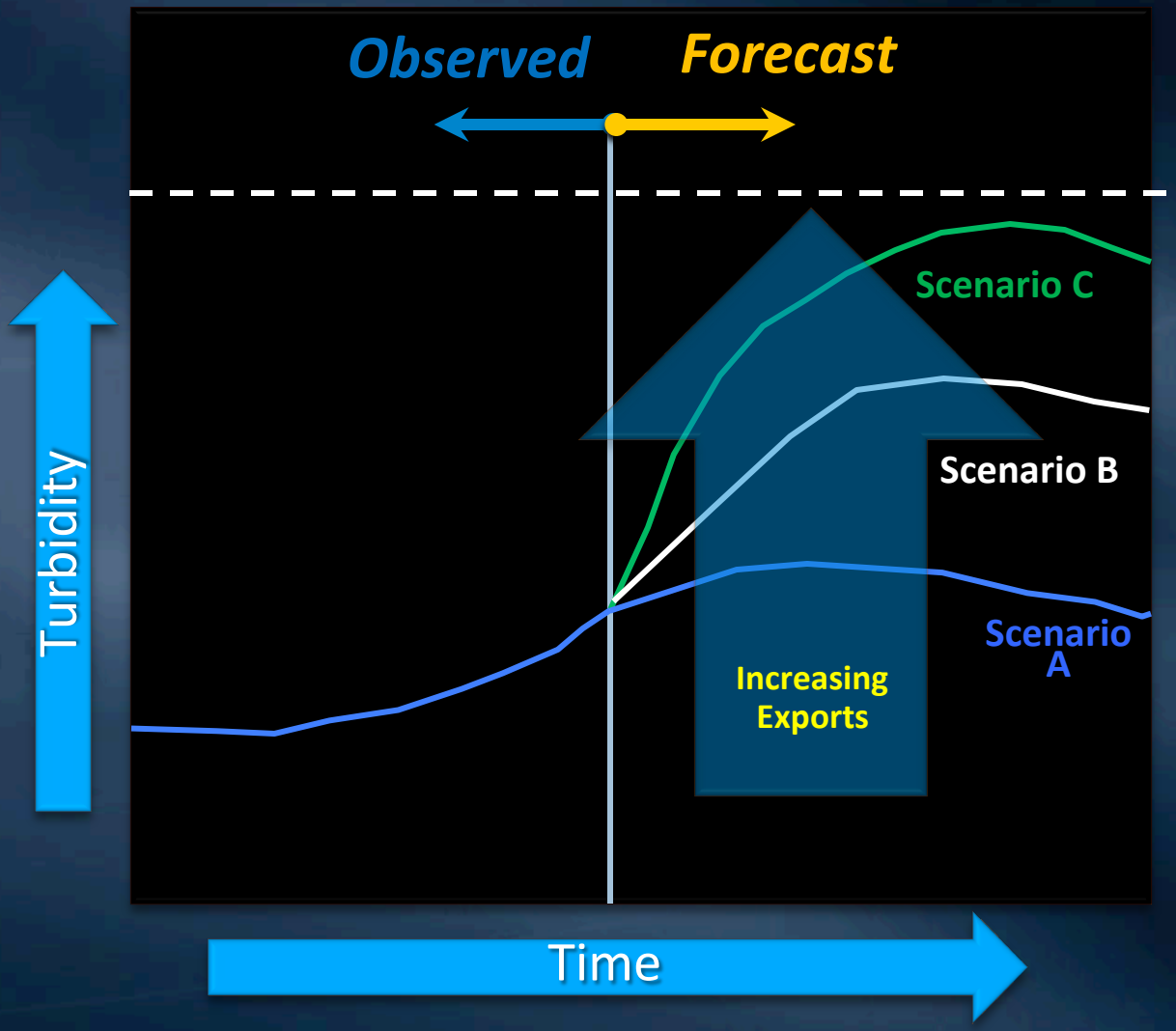


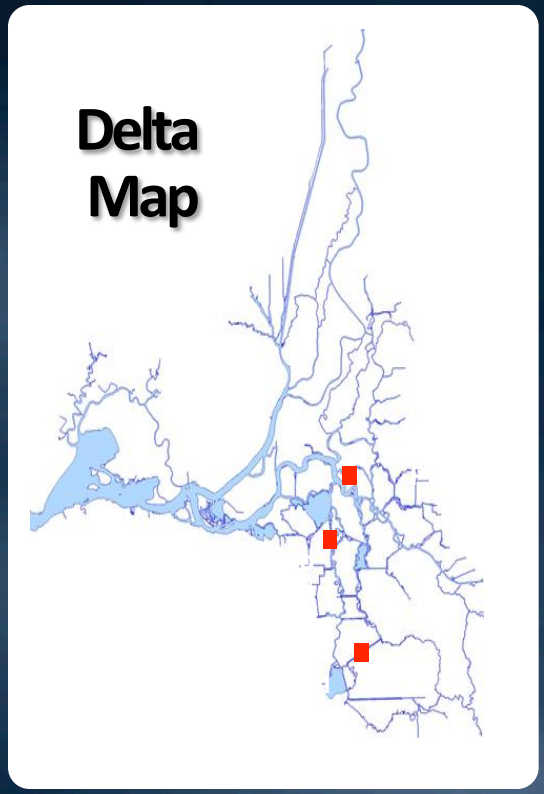
Forecasting Process



Delta Turbidity Forecasting

Scenario Analysis





Forecasting Delta Turbidity Conditions
with Artificial Neural Networks

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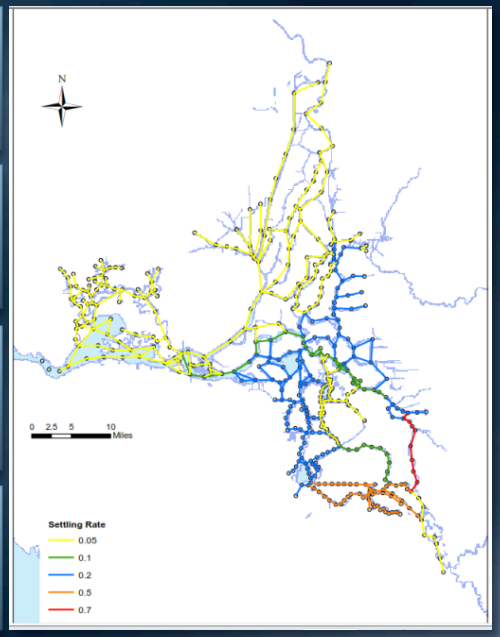
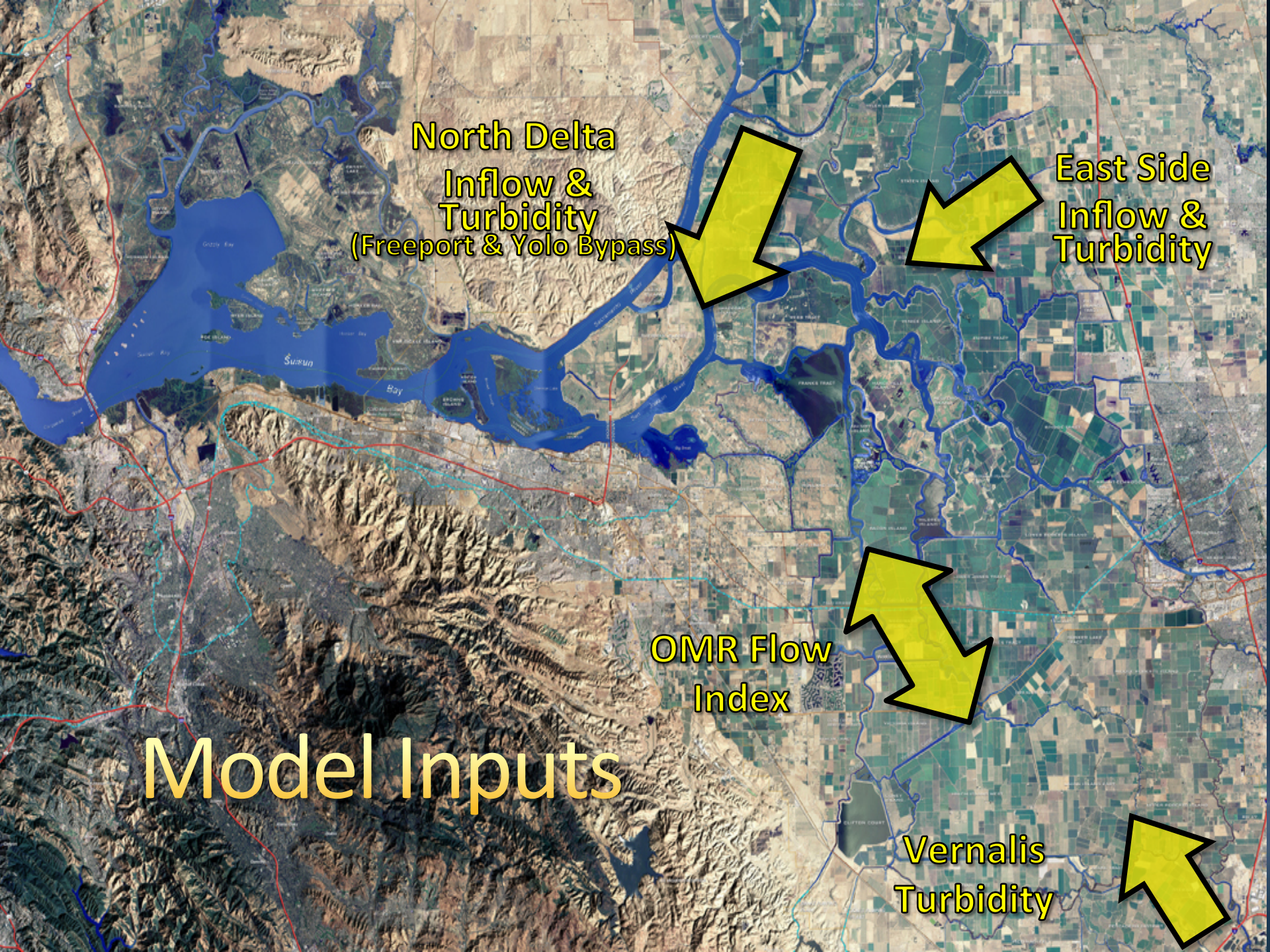
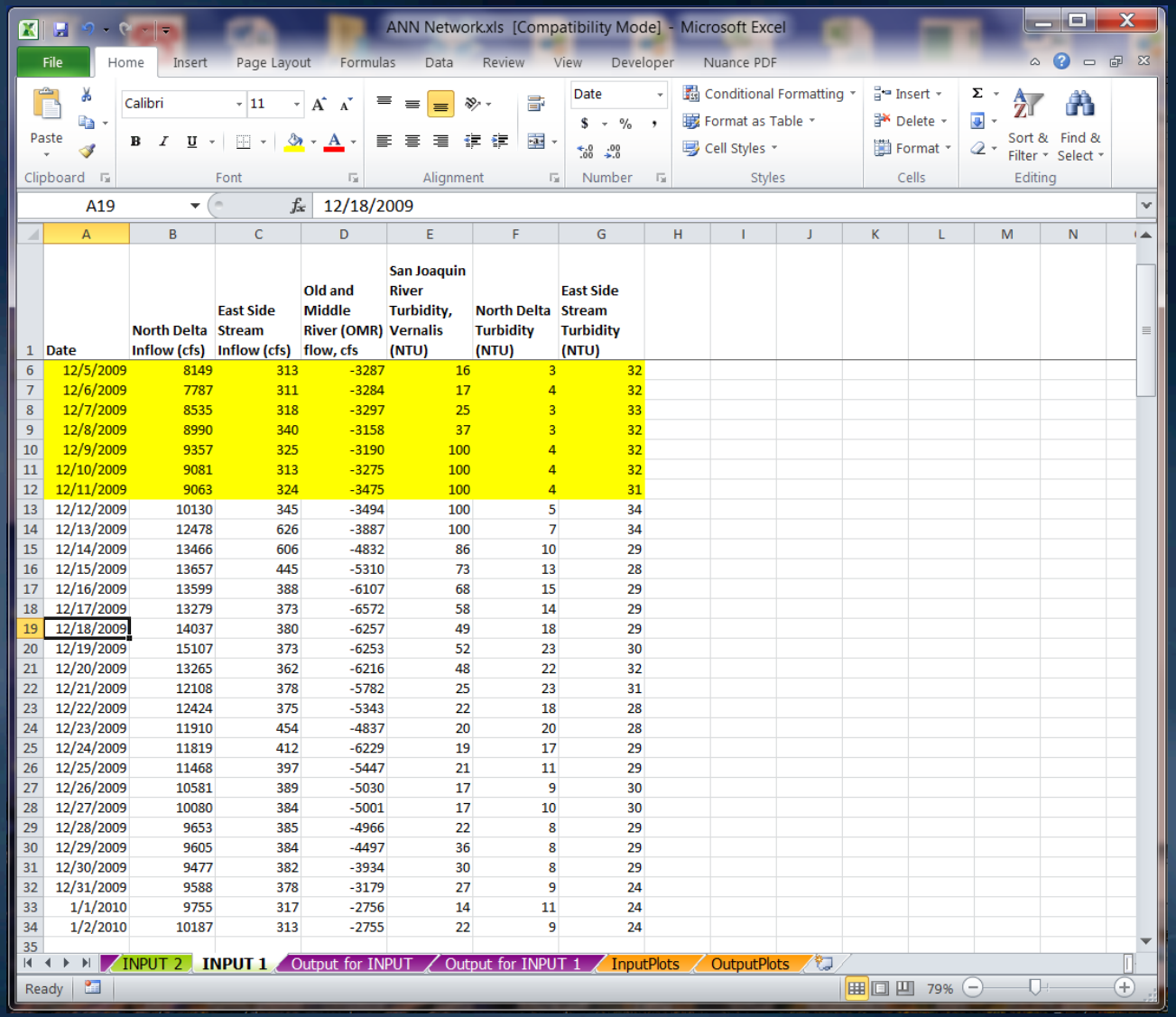
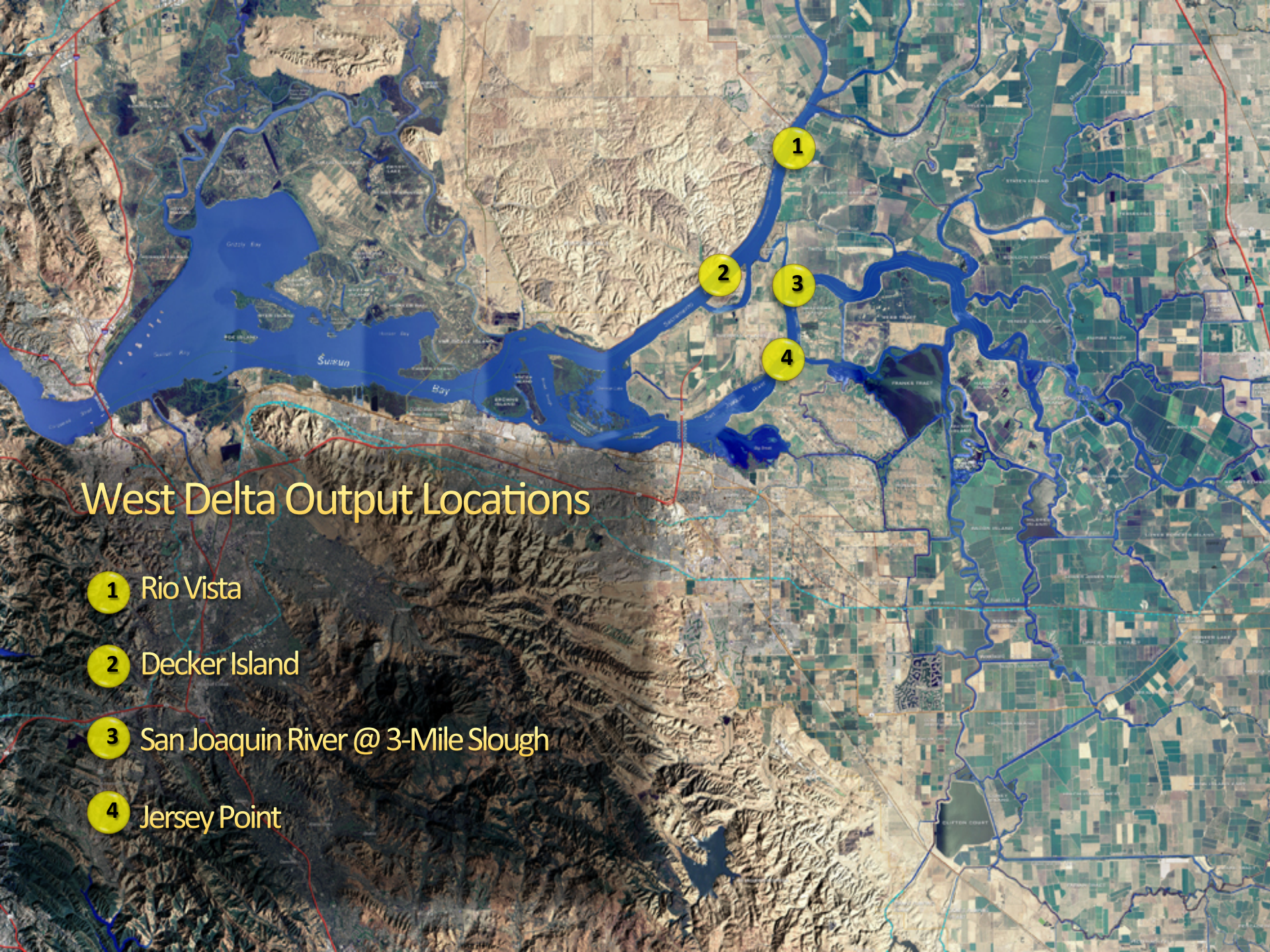


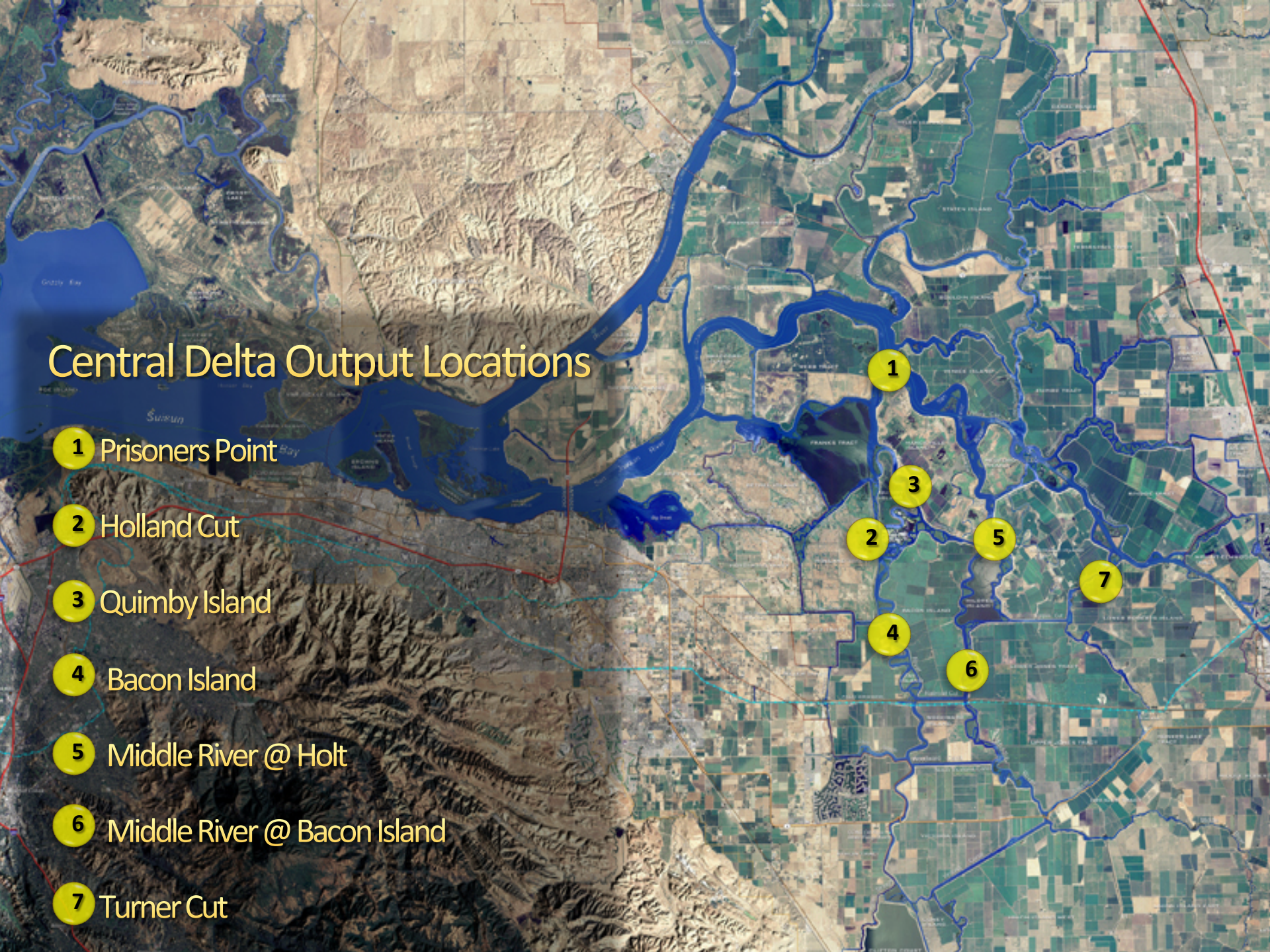

North Delta
Inflow &
Turbidity
(Freeport & Yolo Bypass)
East Side
Inflow &
Turbidity
OMR Flow
Index
Vernalis
Turbidity
Model Inputs

DASM-T Sample Input File



	A	B	C	D	E	F	G
1	Date	North Delta Inflow (cfs)	East Side Stream Inflow (cfs)	Old and Middle River (OMR) flow, cfs	San Joaquin River Turbidity, Vernalis (NTU)	North Delta Turbidity (NTU)	East Side Stream Turbidity (NTU)
6	12/5/2009	8149	313	-3287	16	3	32
7	12/6/2009	7787	311	-3284	17	4	32
8	12/7/2009	8535	318	-3297	25	3	33
9	12/8/2009	8990	340	-3158	37	3	32
10	12/9/2009	9357	325	-3190	100	4	32
11	12/10/2009	9081	313	-3275	100	4	32
12	12/11/2009	9063	324	-3475	100	4	31
13	12/12/2009	10130	345	-3494	100	5	34
14	12/13/2009	12478	626	-3887	100	7	34
15	12/14/2009	13466	606	-4832	86	10	29
16	12/15/2009	13657	445	-5310	73	13	28
17	12/16/2009	13599	388	-6107	68	15	29
18	12/17/2009	13279	373	-6572	58	14	29
19	12/18/2009	14037	380	-6257	49	18	29
20	12/19/2009	15107	373	-6253	52	23	30
21	12/20/2009	13265	362	-6216	48	22	32
22	12/21/2009	12108	378	-5782	25	23	31
23	12/22/2009	12424	375	-5343	22	18	28
24	12/23/2009	11910	454	-4837	20	20	28
25	12/24/2009	11819	412	-6229	19	17	29
26	12/25/2009	11468	397	-5447	21	11	29
27	12/26/2009	10581	389	-5030	17	9	30
28	12/27/2009	10080	384	-5001	17	10	30
29	12/28/2009	9653	385	-4966	22	8	29
30	12/29/2009	9605	384	-4497	36	8	29
31	12/30/2009	9477	382	-3934	30	8	29
32	12/31/2009	9588	378	-3179	27	9	24
33	1/1/2010	9755	317	-2756	14	11	24
34	1/2/2010	10187	313	-2755	22	9	24
35							


West Delta Output Locations
1 Rio Vista
2 Decker Island
3 San Joaquin River @ 3-Mile Slough
4 Jersey Point


Central Delta Output Locations
1 Prisoners Point
2 Holland Cut
3 Quimby Island
4 Bacon Island
5 Middle River @ Holt
6 Middle River @ Bacon Island
7 Turner Cut
1
3
2
5
7
4
6


South Delta Output
Locations
1
2 Old River @ Highway 4
3 Clifton Court Forebay Intake
4 Victoria Canal
5 Middle River @ Union Island
6 Grant Line Canal @ Tracy
San Joaquin River @ Garwood
1
3
2
5
4
6

DASM-T Model Description

- Neural network trained to emulate DSM2 turbidity fate and transport
- Training data developed from 12 DSM2 simulations – 36 years (water years 1976-2011)
- Applicable for adult smelt pre-spawning period (December-February). Assumes DCC gates are closed and south Delta barriers not installed.
- Training process: 60% calibration; 20% validation; 20% testing

Forecasting Delta Turbidity Conditions

with Artificial Neural Networks

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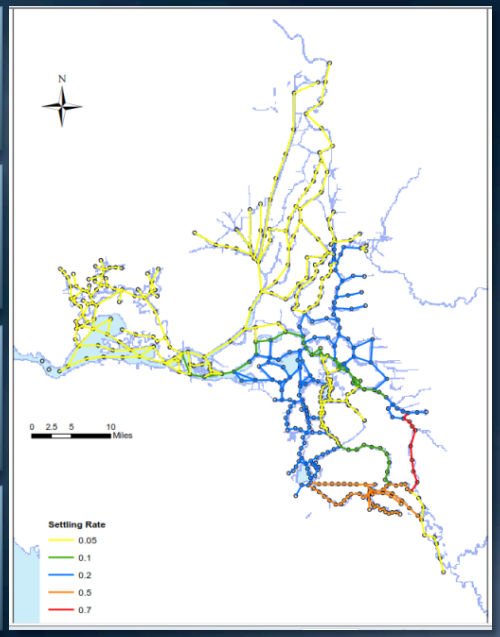
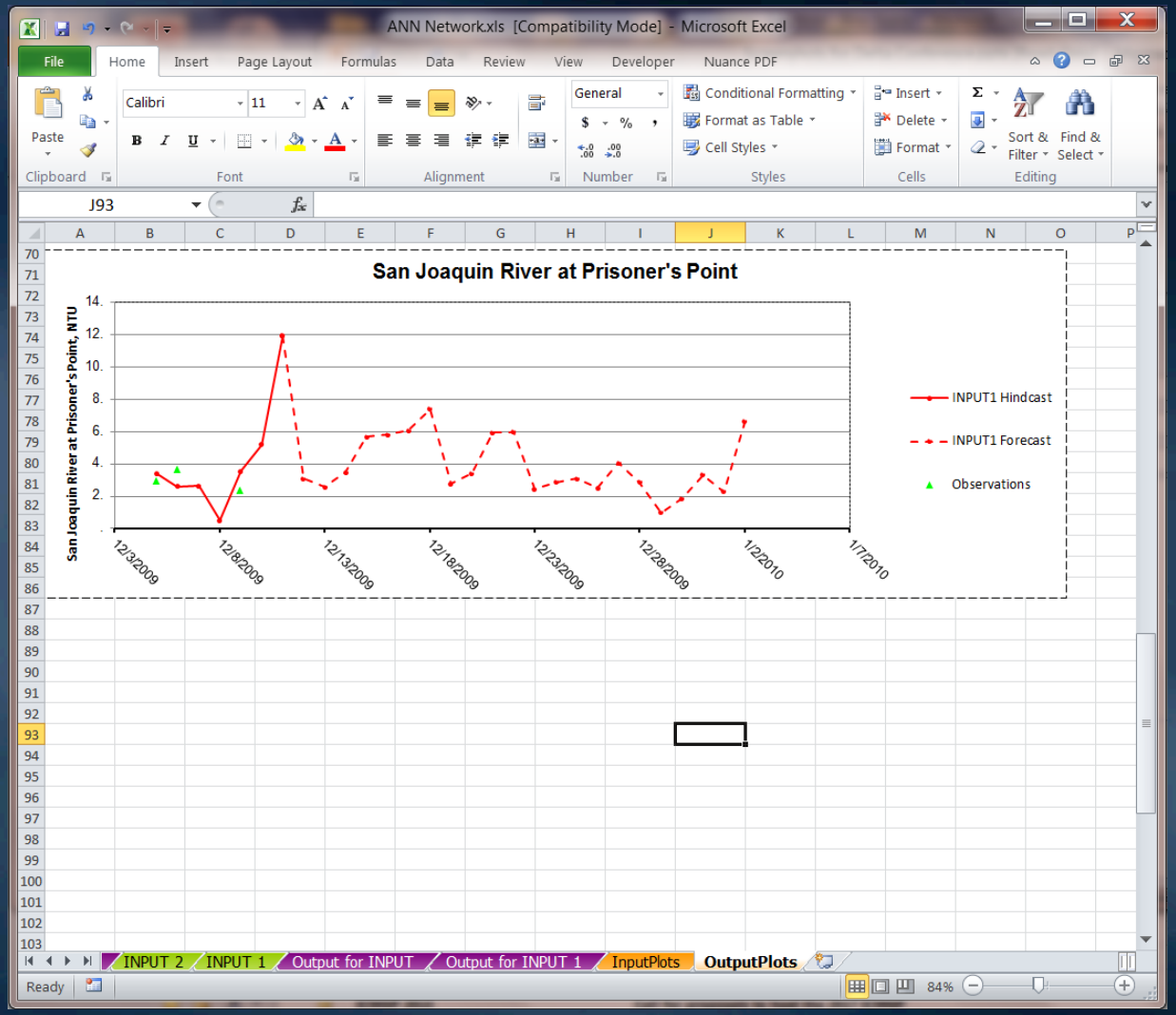
Next Steps

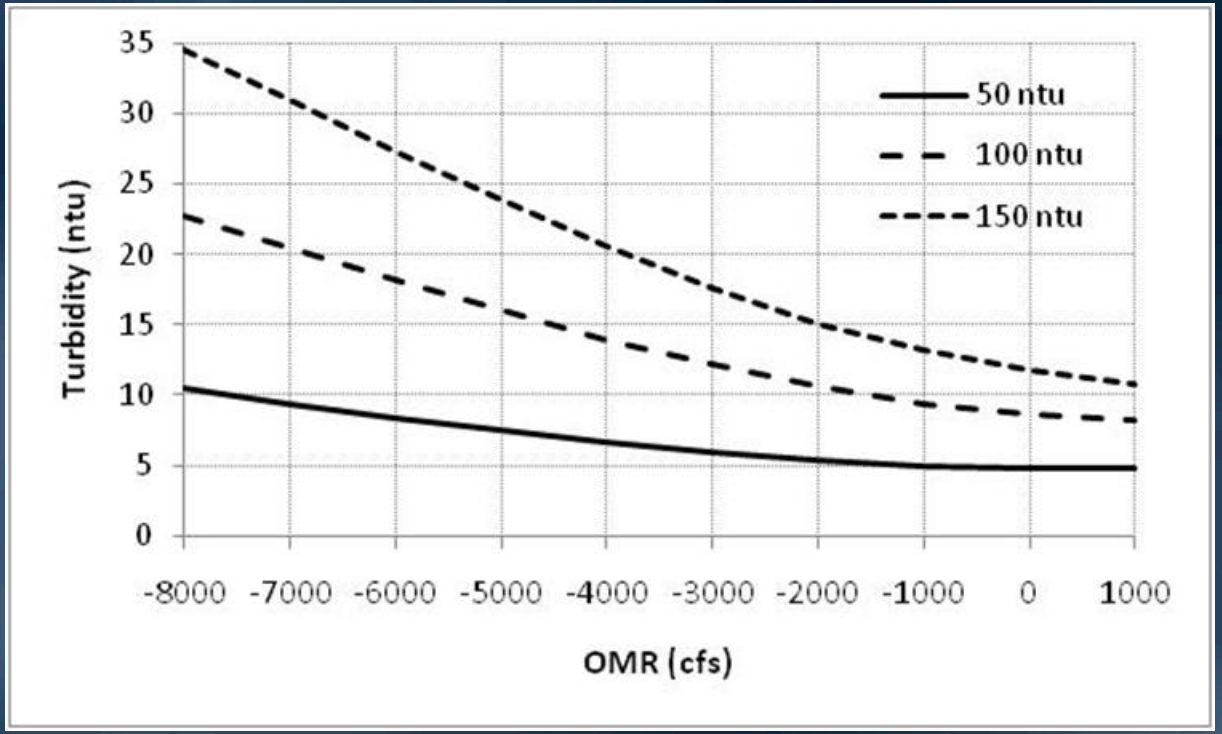


DASM-T Sample Output File



Steady State Flow-Turbidity Relationship as a Function of North Delta Turbidity

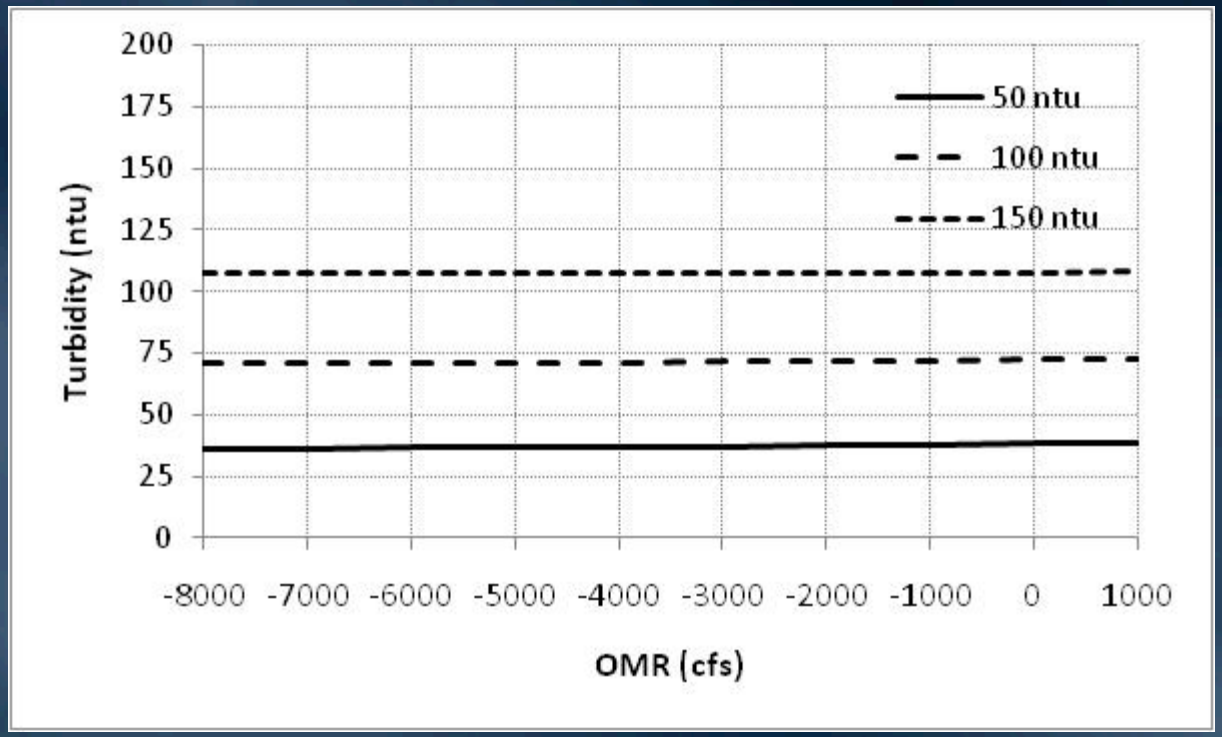
San Joaquin River @ Prisoner's Point



Steady State Assumptions
North Delta Flow = 30,000 cfs
East Side Flow = 1500 cfs
Vernalis Turbidity = 30 ntu
East Side Turbidity = 30 ntu

Steady State Flow-Turbidity Relationship as a Function of North Delta Turbidity

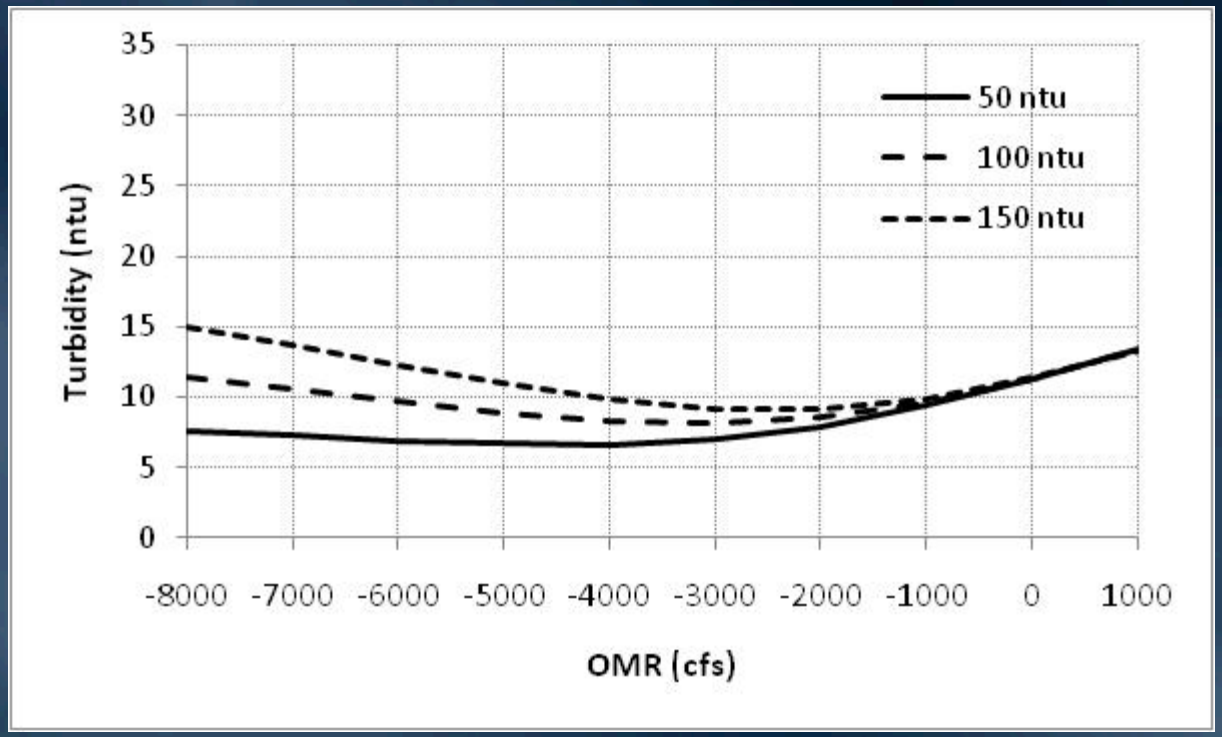
Sacramento River @ Rio Vista



Steady State Assumptions
North Delta Flow = 30,000 cfs
East Side Flow = 1500 cfs
Vernalis Turbidity = 30 ntu
East Side Turbidity = 30 ntu

Steady State Flow-Turbidity Relationship as a Function of North Delta Turbidity

Clifton Court Forebay Entrance



Steady State Assumptions
North Delta Flow = 30,000 cfs
East Side Flow = 1500 cfs
Vernalis Turbidity = 30 ntu
East Side Turbidity = 30 ntu

Forecasting Delta Turbidity Conditions

with Artificial Neural Networks

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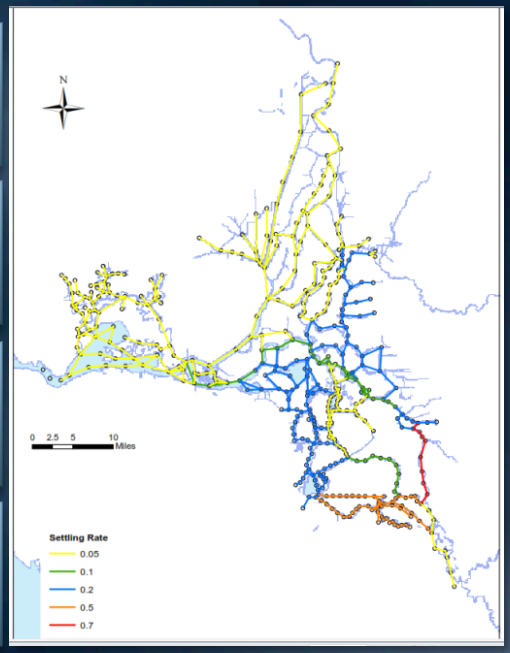


Next Steps

- DASM-T will be integrated into tools suite during the pilot forecasts beginning this winter.
- DASM-T will be publically available.
- DWR has tentatively agreed to pilot the forecasting procedure this winter.
- We encourage USFWS staff, as well as the DSWG, to pilot DASM-T.

Acknowledgements

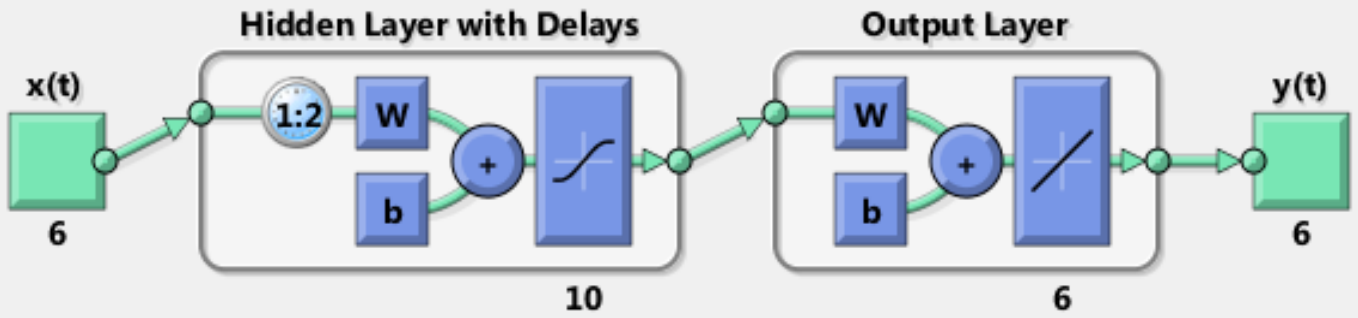
Dr. Sujoy Roy, Tetra Tech, Inc.
Dr. Limin Chen, Tetra Tech, Inc.

Paul Hutton, Ph.D., P.E.
phutton@mwdh2o.com

EXTRA SLIDES

ANN Model Structure

Matlab Feed Forward



$y(t) = f(x(t-1), ..., x(t-d))$

Inputs = 6 boundaries (3 flow & 3 turbidity)
Hidden Neurons = 10
Time delay = 1-2 days
Outputs: turbidity at 6 locations

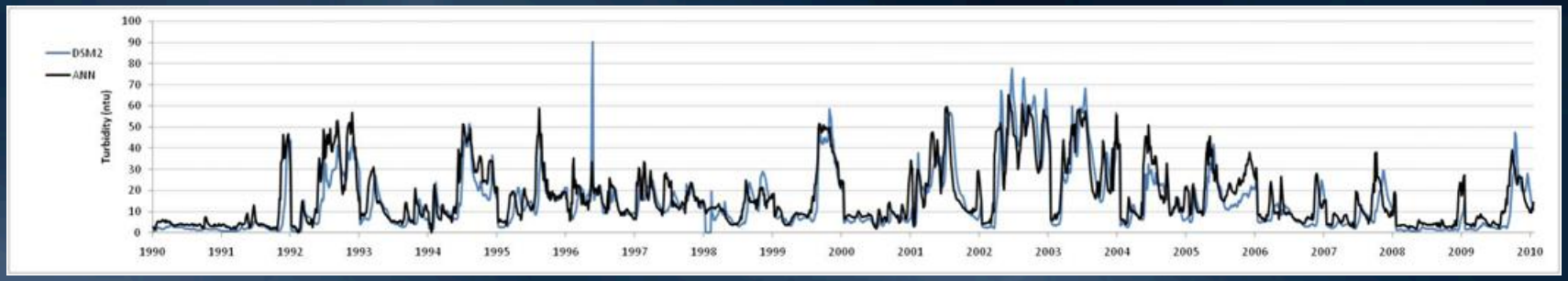
ANN Model Structure

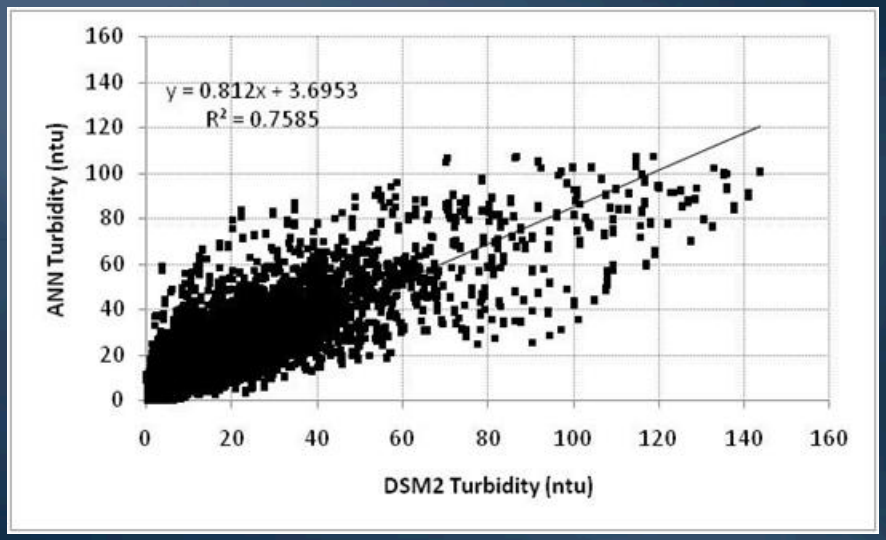
Training Process

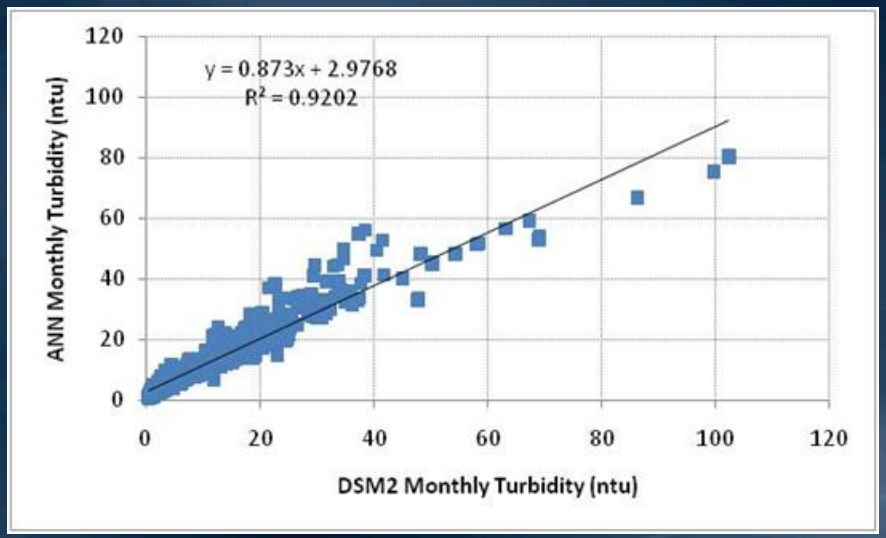
- DSM2 data points are randomly assigned:
  - Training 60%
  - Validation 20%
  - Testing 20%
- Training data are used to compute network parameters. Intermediate results are iteratively compared with validation data until residual error is minimized.
- Testing data are independent of training and validation data and are used to evaluate network predictive power.

Model Results

San Joaquin River @ Prisoner's Point (Dec-Feb)







Model Results: Summary Statistics

ANN Turbidity (ntu) = Φ1 + Φ2 * DSM2 Turbidity (ntu)

Location	Daily			Monthly		
	Φ_1	Φ_2	R^2	Φ_1	Φ_2	R^2
Sacramento River @ Rio Vista	3.5	0.97	0.94	1.1	1.01	0.99
Old River @ Quimby Island	2.0	0.89	0.83	1.7	0.91	0.96
Old River @ Bacon Island	1.8	0.82	0.78	1.5	0.85	0.93
San Joaquin River @ Prisoner's Point	3.7	0.81	0.76	3.0	0.87	0.92
Middle River @ Holt	2.0	0.76	0.69	1.7	0.82	0.89
Clifton Court Forebay Entrance	3.1	0.75	0.73	1.3	0.90	0.91