DSM2 Nutrient Model Update: SFEI/USGS/RMA Project

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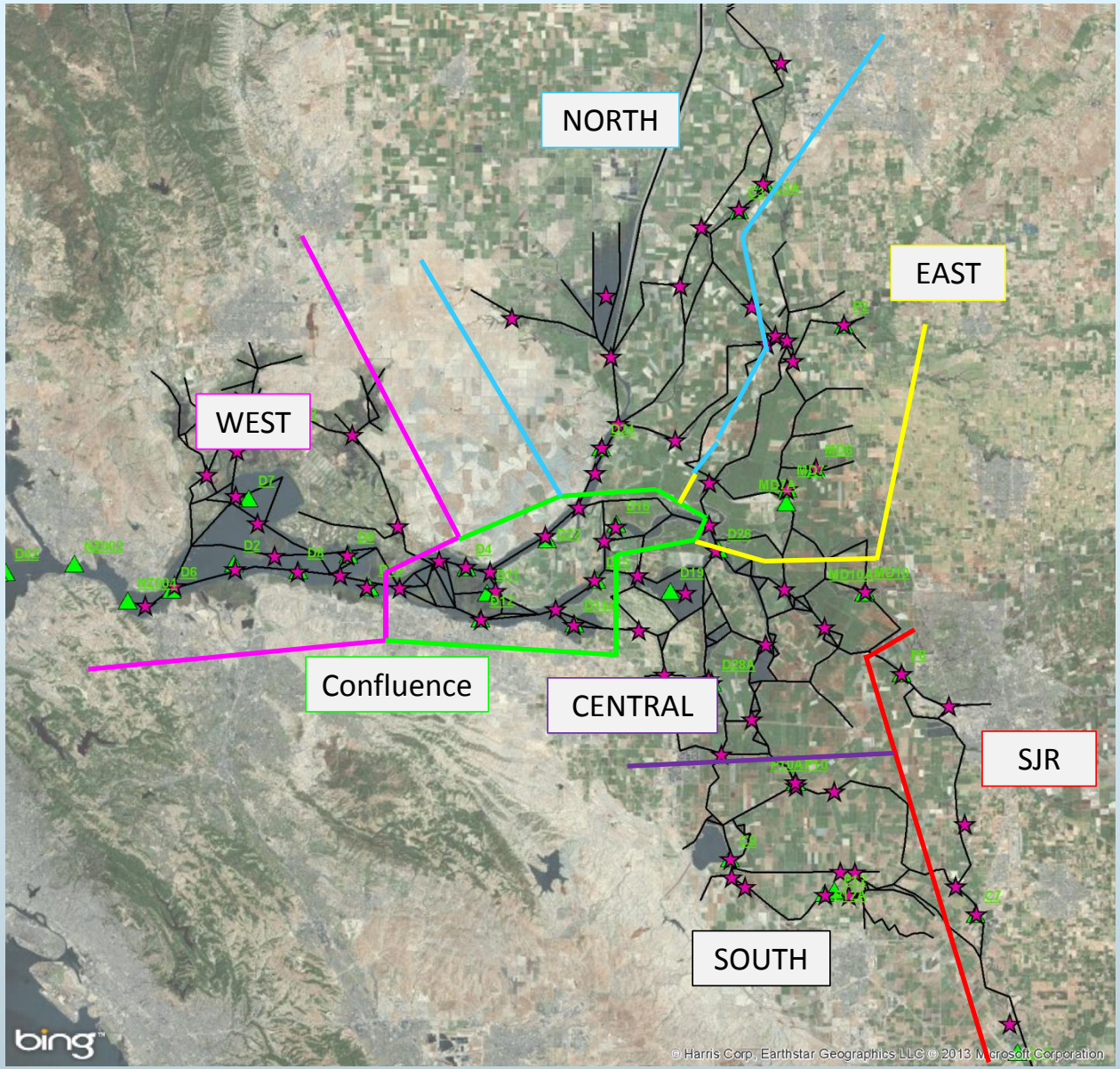
RMA RESOURCE MANAGEMENT ASSOCIATES
WATER RESOURCES ENGINEERING

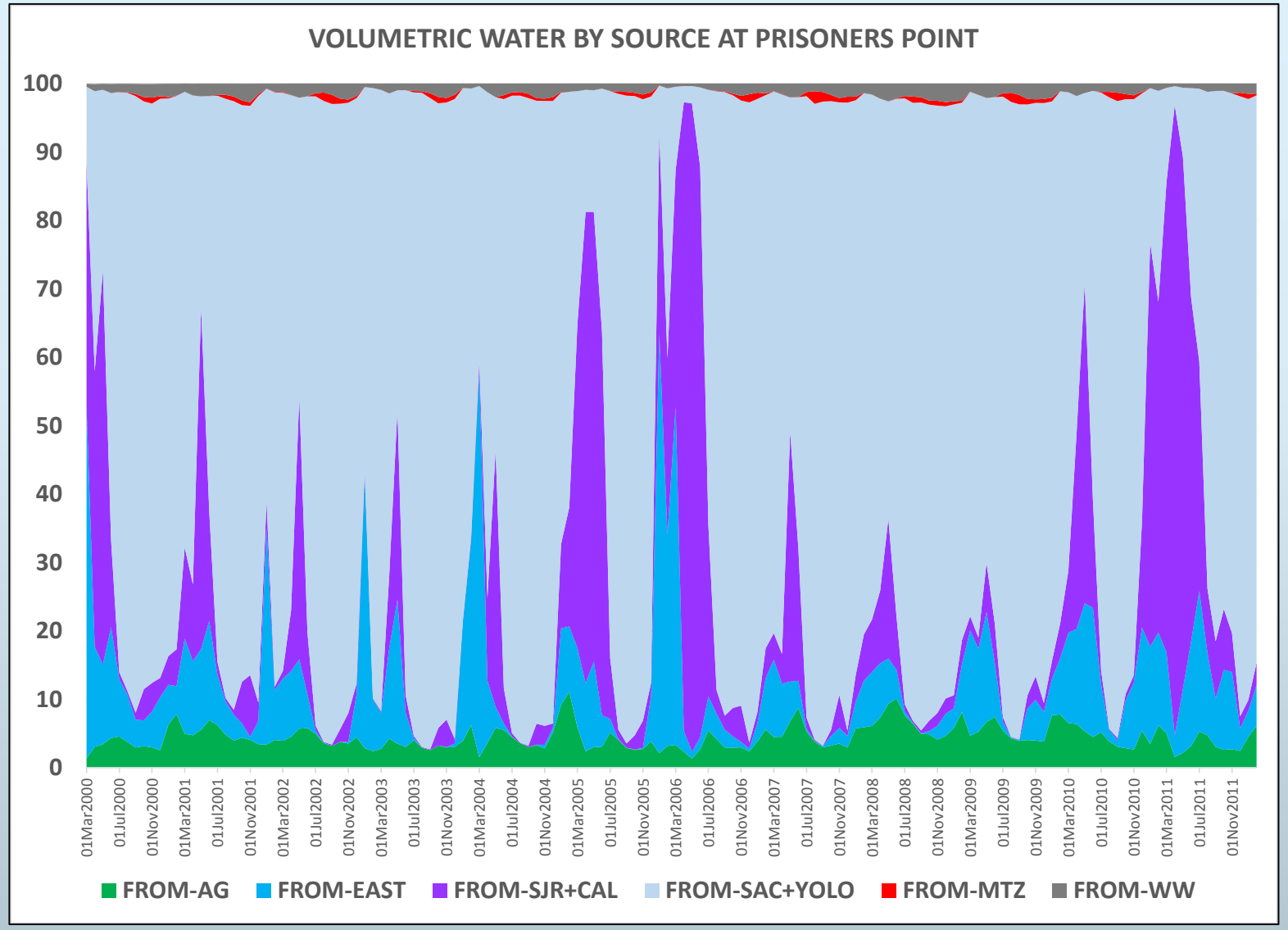
Project Summary

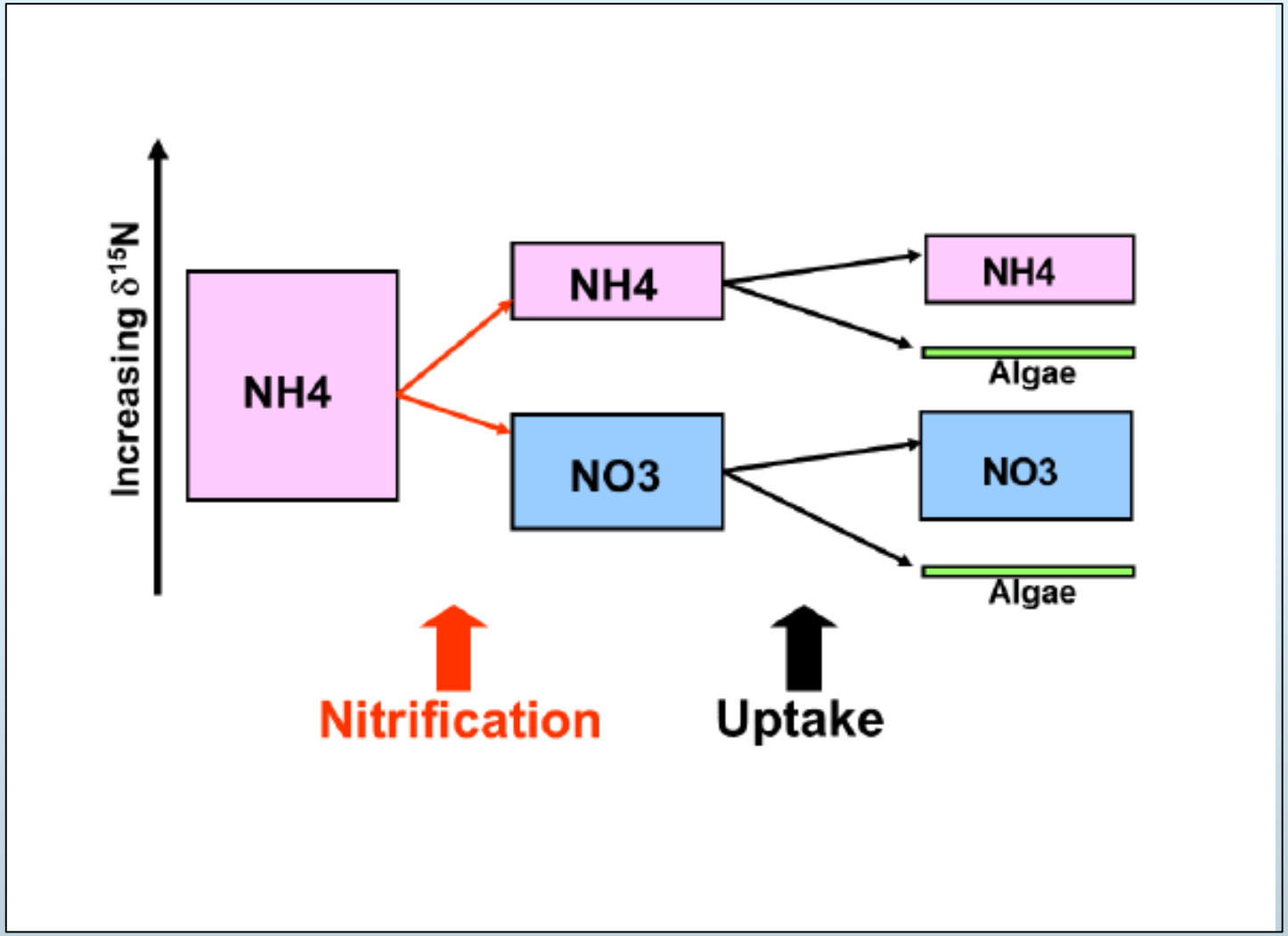
- SFEI-led project to: identify long-term and seasonal trends in nutrient form (e.g., NH_4 vs. NO_3), concentrations and ratios, and explore the factors contributing to spatial, seasonal and temporal variability
- Objectives:
  - Synthesize: EMP data through 03/2012, “recent” USGS isotope data, nutrient model output
  - Quantify nutrient loads to the Delta and loads from the Delta to Suisun Bay
  - Update DSM2 nutrient model using:
    - HYDRO V-8.1.2
    - QUAL V-8.1.3 – used additional data in calibration not used in project analyses
      - Lehman data from Liberty island sampling
      - “Receiving water” data from effluent source monitoring locations



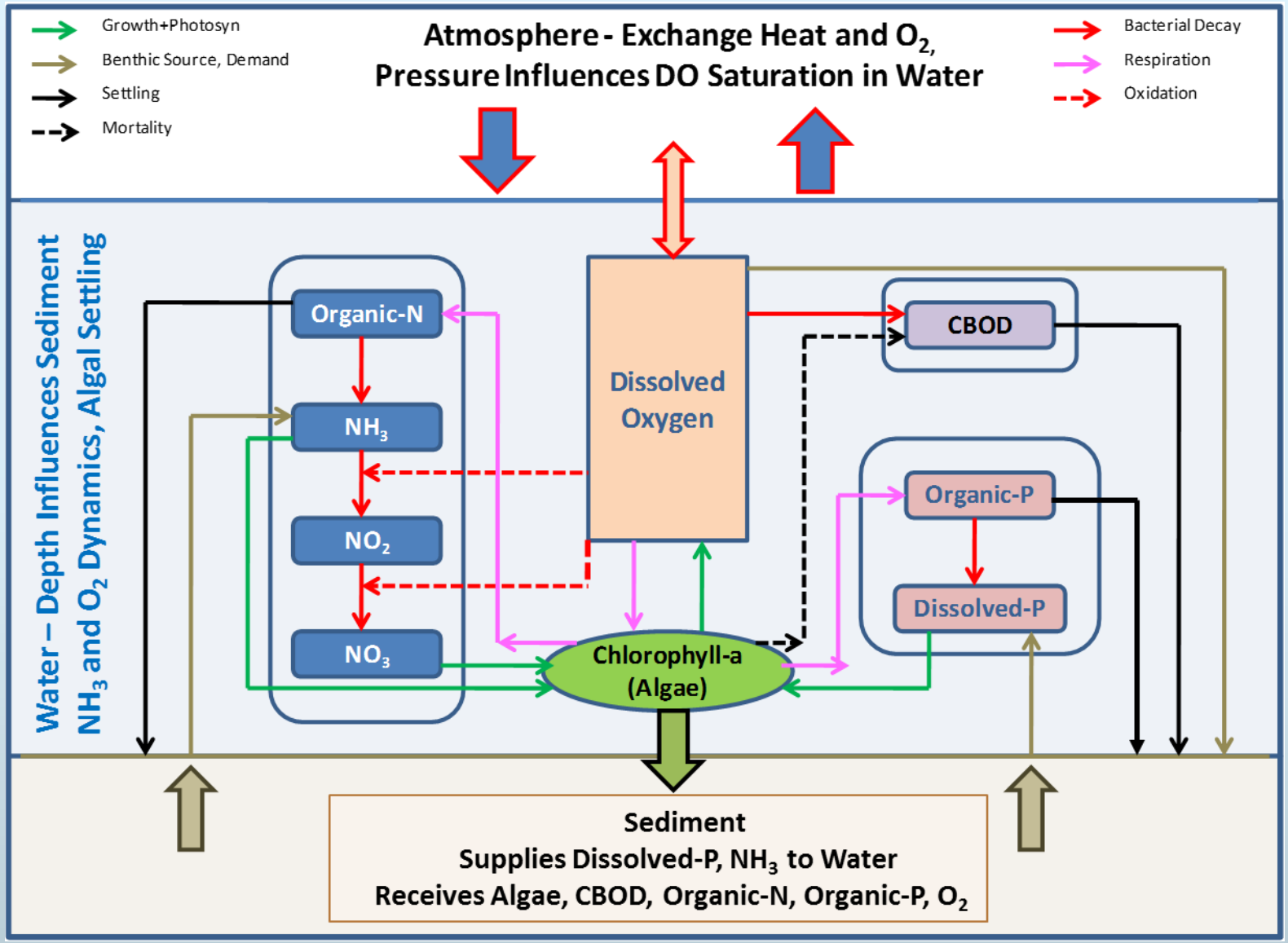
Project: Seven regions defined to understand mass balances within the DSM2 model domain –
Using net monthly-average flows to/from each region, monthly nutrient loads calculated for several constituents

Volumetric calculations were used to interpret isotope data





“Cartoon” from Carol Kendall, USGS – Box sizes not to scale – generally algae utilize NH4 over NO3


Growth+Photosyn
Benthic Source, Demand
Settling
Mortality
Atmosphere - Exchange Heat and O_2,
Pressure Influences DO Saturation in Water
Bacterial Decay
Respiration
Oxidation
Water – Depth Influences Sediment
NH_3 and O_2 Dynamics, Algal Settling
Organic-N
NH_3
NO_2
NO_3
Dissolved Oxygen
CBOD
Organic-P
Dissolved-P
Chlorophyll-a (Algae)
Sediment
Supplies Dissolved-P, NH_3 to Water
Receives Algae, CBOD, Organic-N, Organic-P, O_2

Current Status of QUAL Nutrient Model:

- Hydrodynamics:
  - Inflow/outflow/ops boundary conditions (BCs) updated through 03/2012
  - Effluent flows through 03/2012; many sites have a data gap 2009 - 2010
- DICU:
  - Updated through 03/2012
  - Major update in DICU nutrient and water temperature BCs
- Water Quality/Water Temperature
  - Major reworking of meteorological BCs; recalibrated water temperature sub-model
  - Model time span extended to 03/2012 - recalibrated nutrient model 01/2000 to 03/2012

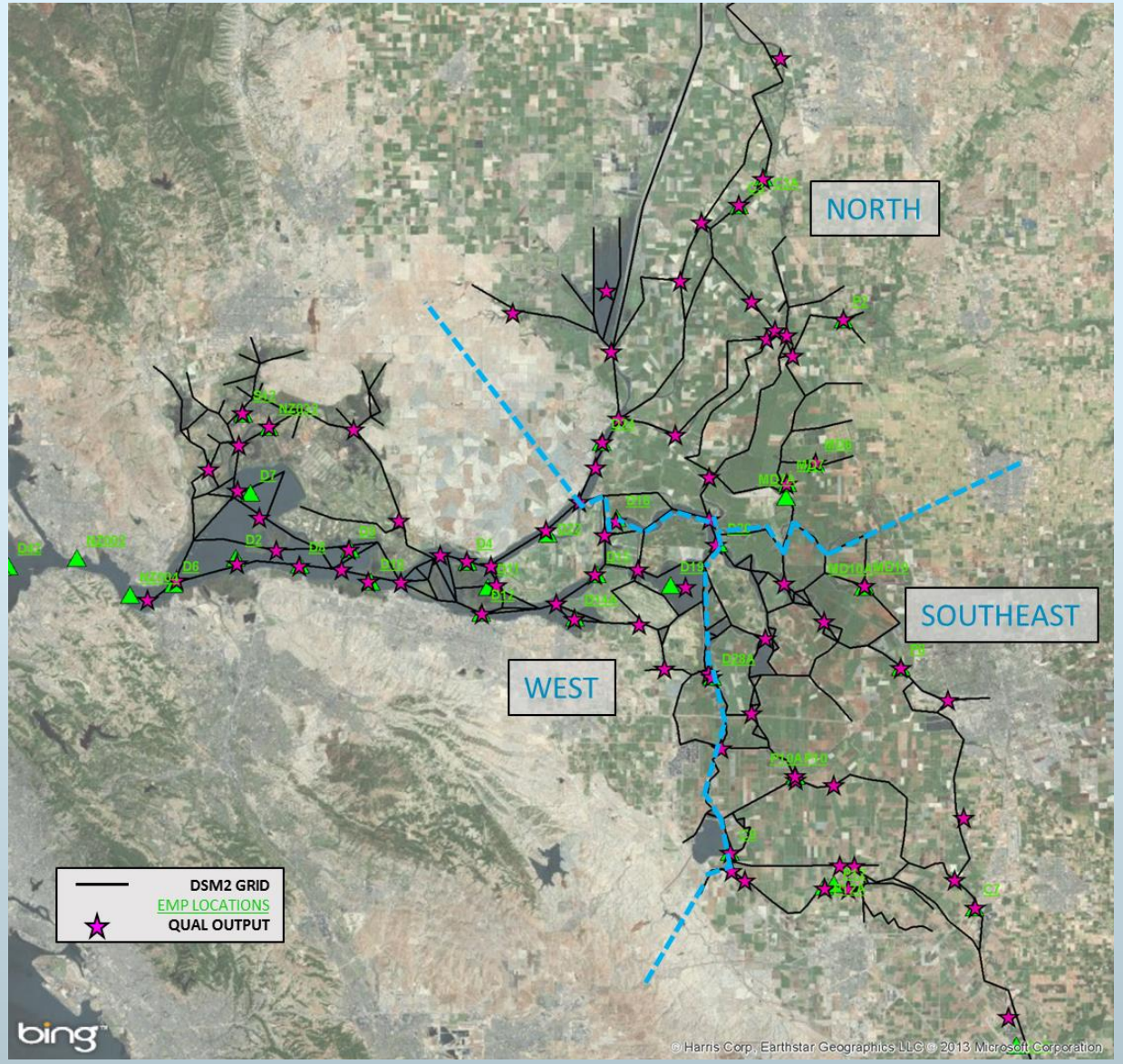
Current Status (cont.)

- There are 11 equations in the nutrient model – so for every inflow location 11 concentrations were specified:
  - 7 major inflow locations
  - 11 effluent locations
  - 257 DICU locations, split into 3 regions
  - So, 231 (=11*21) boundary condition time series developed, 2000 – 03/2012
  - Plus: time series for wind, dry bulb, wet bulb, cloud cover, atm. pressure
- SFEI project is complete:
  - DSM2 nutrient model file structure delivered to DWR and SFEI
  - Documentation delivered to DWR and IEP project sponsors by SFEI
  - See Hari or Min YU for DSM2 model set-up and/or documentation

New Effluent Data

Location	Start	End
Benecia	10/1/2011	3/31/2012
Brentwood - not compiled	08/01/10	03/31/12
Central San	3/1/2011	3/31/2012
Davis - not compiled	11/01/10	03/31/12
DeltaDiablo	06/01/11	03/31/12
Discovery Bay	10/1/2010	3/31/2012
FF-Suisun	11/1/2011	3/31/2012
Lodi - not compiled	07/01/10	03/31/12
Manteca	7/1/2010	3/31/2012
Montain House	1/1/2011	3/31/2012
Rio Vista Beach	10/1/2010	3/31/2012
Rio Vista NW	11/1/2011	3/31/2012
Sac Regional - compiling	2009	2012
Shell-MTZ	6/1/2011	3/31/2012
Stockton - compiling	03/01/09	03/31/12
Tesoro	3/1/2011	3/31/2012
Tracy	8/1/2010	3/31/2012
Vacaville - not compiled	07/01/10	03/31/12
Valero	6/1/2011	3/31/2012
Woodland - not compiled	04/01/10	03/31/12

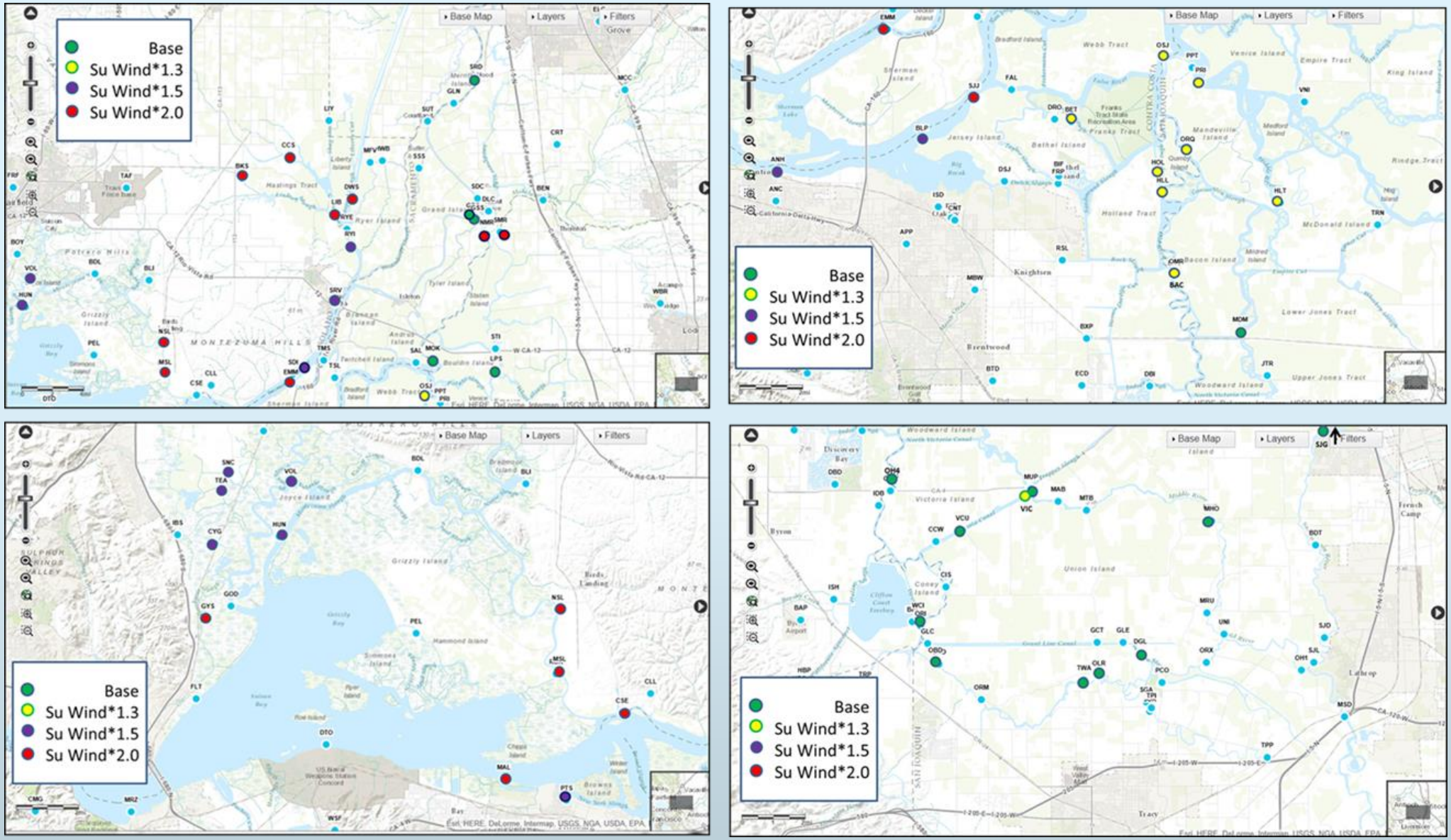
EMP Data Locations & DICU Regions



QUAL Water Temperature Re-calibration

- Previous nutrient calibration focus was on Sacramento River:
  - Lodi-area meteorological station data set used for “historical reasons”
  - Wind speed data increased in summer by factor of two to calibrate Sac. River temperature
- Current nutrient calibration was Delta-wide, so implemented “sensitivity” runs:
  - Base case - no increase in summer wind speed
  - Increase summer wind speed by a factor of 1.3
  - Increase summer wind speed by a factor of 1.5
  - Increase summer wind speed by a factor of 1.6
  - Increase summer wind speed by a factor of 2.0
- Calibration statistics from residuals showed (wind speed)*1.5 in the summer as best:
  - Minimized 4 residual statistics, focused on absolute value of % bias statistic
  - Half of the temperature data locations had a positive bias, half had a negative bias

MODELNAME	CDEC	Region	N	mean resid	st dev resid	rmse	pbias	mean resid	st dev resid	rmse	pbias	mean resid	st dev resid	rmse	pbias	mean resid	st dev resid	rmse	pbias	mean resid	st dev resid	rmse	pbias
Simulation factor				Base				1.3				1.50				1.6				2			
RSAC092	EMM	Sac	4403	1.1	1.3	1.7	7.1	0.74	1	1.2	4.7	0.55	0.95	1.10	3.50	0.48	0.85	0.98	3	0.15	0.75	0.76	0.95
RSAC081	CSE	Sac	4413	1.3	1.5	2	8.2	0.86	1.2	1.4	5.4	0.65	1.10	1.30	4.10	0.56	1	1.1	3.5	0.2	0.86	0.89	1.3
RSAC075-MALLARD	MAL	Sac	4382	1.1	1.9	2.2	6.8	0.68	1.7	1.8	4.3	0.49	1.70	1.70	3.10	0.41	1.6	1.7	2.6	0.081	1.5	1.5	0.5
BARKER-SL	BKS	Cache/Yolo	370	1.8	2	2.7	11	1.1	1.6	2	6.8	0.83	1.50	1.70	5.00	0.67	1.4	1.6	4.1	0.15	1.3	1.3	0.92
SLCCH016	CCS	Cache/Yolo	4376	1.4	2	2.5	8.8	0.82	1.6	1.8	5	0.55	1.50	1.60	3.40	0.43	1.4	1.5	2.6	-0.037	1.3	1.3	-0.23
LIBERTY-D	LIB	Cache/Yolo	467	0.66	1.4	1.5	4.7	0.38	1.1	1.2	2.7	0.25	1.00	1.00	1.80	0.19	0.95	0.96	1.3	-0.027	0.8	0.8	-0.19
DWSC-DWS	DWS	Cache/Yolo	440	0.76	1.3	1.5	5.3	0.42	1	1.1	2.9	0.27	0.90	0.94	1.90	0.19	0.84	0.86	1.3	-0.061	0.7	0.7	-0.42
GOODYEAR-SL	GYS	SM	4269	0.94	1.7	1.9	5.8	0.49	1.4	1.5	3	0.29	1.40	1.40	1.80	0.2	1.3	1.3	1.2	-0.16	1.2	1.2	-1
RORR_512_MONTEZUMA	MSL	SM	1034	1.1	1.7	2	7.1	0.66	1.4	1.5	4.3	0.47	1.20	1.30	3.00	0.37	1.2	1.2	2.4	0.013	0.97	0.97	0.086
MONTEZUMA-NURSE	NSL	SM	1045	1.5	1.6	2.2	9.6	0.96	1.2	1.6	6.2	0.74	1.10	1.40	4.80	0.62	1.1	1.3	4	0.22	1	1	1.4
RSAN018	SJJ	SJR	4462	1.1	1.3	1.6	6.5	0.57	0.95	1.1	3.5	0.35	0.92	0.98	2.10	0.25	0.81	0.85	1.6	-0.13	0.75	0.76	-0.83
RSMKL024_SFMOKE	SMR	ED	467	0.39	0.83	0.92	2.9	0.37	0.82	0.9	2.7	0.36	0.82	0.90	2.70	0.35	0.82	0.89	2.6	0.34	0.81	0.88	2.5
NMR-RMKL019	NMR	ED	472	0.16	1.2	1.2	1.2	0.15	1.2	1.2	1.1	0.14	1.20	1.20	0.99	0.13	1.2	1.2	0.95	0.11	1.3	1.3	0.82
CACHE_RYER-RYI	RYI	Cache/Yolo	845	0.48	0.97	1.1	3.3	0.24	0.76	0.79	1.6	0.13	0.68	0.69	0.88	0.07	0.64	0.65	0.48	-0.13	0.55	0.56	-0.87
RSAC101	SRV	Sac	1576	0.57	0.9	1.1	3.7	0.27	0.68	0.73	1.7	0.14	0.61	0.63	0.88	0.062	0.58	0.59	0.4	-0.19	0.56	0.6	-1.2
DECKER	SDI	Sac	784	0.52	1.1	1.2	3.5	0.27	0.84	0.89	1.8	0.16	0.76	0.77	1.10	0.1	0.71	0.72	0.68	-0.1	0.6	0.6	-0.7
RSAC077-PITTSBURG	PTS	Sac	1547	0.63	1.4	1.5	4	0.23	1.1	1.1	1.5	0.06	1.00	1.00	0.38	-0.035	0.95	0.95	-0.22	-0.35	0.82	0.89	-2.2
CORDELIA	CYG	SM	702	0.86	1.7	1.9	5.4	0.35	1.4	1.5	2.2	0.14	1.30	1.30	0.85	0.019	1.3	1.3	0.12	-0.36	1.2	1.2	-2.3
SLMZU003-HUNTER	HUN	SM	723	0.88	1.5	1.7	5.6	0.45	1.2	1.3	2.8	0.26	1.10	1.10	1.70	0.16	1.1	1.1	1	-0.17	0.97	0.99	-1.1
SUNRISE-CLUB	SNC	SM	1580	1	1.6	1.9	6.6	0.48	1.3	1.4	3.1	0.25	1.20	1.30	1.60	0.13	1.2	1.2	0.84	-0.27	1.2	1.2	-1.7
TEAL-CLUB	TEA	SM	661	0.86	2	2.2	5.4	0.28	1.7	1.7	1.8	0.05	1.50	1.50	0.30	-0.079	1.5	1.5	-0.5	-0.48	1.3	1.4	-3
SLSUS012-VOLANTI	VOL	SM	4101	0.97	1.5	1.8	5.9	0.46	1.2	1.3	2.8	0.25	1.10	1.10	1.50	0.13	1	1	0.8	-0.26	0.97	1	-1.6
BLIND-POINT-BLP	BLP	SJR	756	0.74	1.3	1.4	4.7	0.3	1.1	1.1	1.9	0.12	1.00	1.00	0.77	0.017	0.98	0.98	0.11	-0.32	0.98	1	-2
RSAN007	ANH	SJR	4424	0.8	1.4	1.6	4.9	0.31	1.1	1.1	1.9	0.08	1.00	1.00	0.50	-0.008	0.91	0.91	-0.049	-0.4	0.8	0.9	-2.4
HOLLAND-TRACT	HLL	SD	4453	0.6	0.96	1.1	3.6	0.11	0.79	0.79	0.67	-0.11	0.81	0.82	-0.66	-0.2	0.78	0.81	-1.2	-0.59	0.89	1.1	-3.5
SLPPR003-BETHEL	BET	SD	1583	0.51	1.2	1.3	3.1	0.021	0.95	0.95	0.13	-0.18	0.88	0.90	-1.10	-0.3	0.86	0.91	-1.8	-0.68	0.89	1.1	-4.2
HOLLAND-CUT	HOL	SD	1492	0.31	1.1	1.1	2	-0.13	0.86	0.87	-0.8	-0.32	0.83	0.89	-2.00	-0.42	0.83	0.93	2.6	-0.77	0.93	1.2	-4.8
RMID005-HOLT	HLT	SD	2059	0.31	0.75	0.81	1.9	-0.14	0.58	0.6	-0.86	-0.34	0.59	0.68	-2.00	-0.45	0.62	0.77	-2.7	-0.82	0.81	1.2	-4.9
OLD-AT-FRANKS	OSJ	SD	1563	-0.38	0.99	1.1	2.4	0.019	0.79	0.79	0.12	-0.14	0.74	0.75	-0.86	-0.22	0.73	0.76	-1.4	-0.52	0.76	0.92	-3.3
OLD-R-QUIMBLY	ORQ	SD	1557	0.32	0.99	1	2	-0.12	0.8	0.81	-0.77	-0.31	0.78	0.84	-1.90	-0.41	0.78	0.88	-2.6	-0.76	0.89	1.2	-4.7
ROLD024	BAC	SD	3615	0.35	0.88	0.95	2.1	-0.12	0.73	0.74	-0.72	-0.32	0.73	0.80	-1.90	-0.43	0.75	0.87	-2.6	-0.8	0.9	1.2	-4.8
RMID023-VIC-ISLE	VIC	SD	4468	*0.24*	*0.66*	*0.71*	*1.4*	*-0.25*	*0.55*	*0.6*	*-1.4*	-0.47	0.66	0.81	-2.70	-0.56	0.65	0.86	-3.2	-0.95	0.89	1.3	-5.5
PRIS-PT-TERM	PRI	SJR	1568	0.22	0.79	0.82	1.4	-0.13	0.61	0.62	-0.79	-0.28	0.58	0.64	-1.70	-0.36	0.57	0.68	-2.3	-0.65	0.65	0.92	-4.1
RSAC123-BLW-DCC	GES	Sac	849	-0.2	0.29	0.35	-1.4	-0.23	0.28	0.36	-1.6	-0.25	0.28	0.37	-1.70	-0.26	0.28	0.38	-1.8	-0.3	0.28	0.42	-2.1
SLGEO-GEORG-SAC	GSS	Sac	847	-0.14	0.29	0.32	-0.94	-0.17	0.28	0.33	-1.2	-0.19	0.28	0.33	-1.30	-0.2	0.27	0.34	-1.4	-0.24	0.28	0.36	-1.7
RSAC142	SRD	Sac	4441	-0.17	0.4	0.43	-1.1	-0.22	0.41	0.46	-1.4	-0.24	0.42	0.49	-1.50	-0.25	0.42	0.49	-1.6	-0.3	0.44	0.53	-1.9
MOKEATSJR	MOK	SJR	1371	-0.04	0.47	0.47	-0.25	-0.19	0.4	0.45	-1.2	-0.26	0.39	0.47	-1.60	-0.3	0.4	0.49	-1.9	-0.44	0.44	0.62	-2.8
RSAN063-GARWOOD	SJG	SJR	851	-0.71	0.5	0.87	-4.5	-0.83	0.6	1	-5.3	-0.88	0.66	1.10	-5.70	-0.92	0.7	1.2	-5.9	-1	0.86	1.3	-6.6
LIT-POT-SL-TERM	LPS	ED	850	-0.17	0.53	0.56	-1.1	-0.31	0.46	0.56	-2.1	-0.38	0.45	0.59	-2.50	-0.42	0.45	0.61	-2.8	-0.56	0.49	0.74	-3.7
DOUGHTY-CUT	DGL	SD	1581	-0.35	0.66	0.75	-2.2	-0.61	0.65	0.89	-3.7	-0.72	0.70	1.00	-4.40	-0.79	0.75	1.1	-4.8	-1	0.95	1.4	-6.2
RMID015_144_MIDATMID	MDM	SD	850	-0.14	0.7	0.71	-0.88	-0.5	0.55	0.74	-3.1	-0.65	0.56	0.86	-4.10	-0.74	0.59	0.94	-4.6	-1	0.76	1.3	-6.4
RMID041-UNION	MUP	SD	711	-1.2	1.7	2.1	-6.9	-1.3	1.7	2.1	-7.5	-1.30	1.60	2.10	-7.80	-1.3	1.6	2.1	-7.9	-1.4	1.6	2.2	-8.6
MIDDLE-R-HOWARD	MHO	SD	511	-0.41	0.42	0.59	-2.8	-0.45	0.43	0.63	-3.2	-0.48	0.44	0.65	-3.30	-0.49	0.45	0.66	-3.4	-0.53	0.49	0.72	-3.7
ROLD040-CCFB	ORI	SD	393	-0.79	0.36	0.87	-4.9	-0.97	0.38	1	-6	-1.00	0.42	1.10	-6.50	-1.1	0.45	1.2	-6.8	-1.2	0.6	1.4	-7.6
ROLD046-DMC	OBD	SD	821	-0.12	0.75	0.76	-0.79	-0.39	0.51	0.64	-2.5	-0.50	0.45	-0.67	-3.20	-0.57	0.43	0.71	-3.6	-0.79	0.49	0.95	-5
ROLD034	OH4	SD	848	-0.19	0.72	0.75	-1.2	-0.53	0.59	0.79	-3.3	-0.68	0.60	0.90	-4.30	-0.76	0.62	0.98	-4.8	-1	0.78	1.3	-6.5
ROLD059-TRACY	OLR	SD	2551	0.082	0.94	0.94	0.49	-0.26	0.93	0.97	-1.5	-0.40	0.98	1.10	-2.40	-0.48	1	1.1	-2.9	-0.77	1.2	1.4	-4.6
OLD-R-TWA	TWA	SD	441	-0.46	-0.36	0.58	-3.1	-0.53	0.33	0.62	-3.6	-0.56	0.33	0.65	-3.80	-0.58	0.33	0.66	-3.9	-0.64	0.35	0.73	-4.3
AIP_229-VICT-BYRON	VCU	SD	1923	0.2	0.7	0.73	1.2	-0.29	0.54	0.61	-1.7	-0.49	0.57	0.76	-2.90	-0.6	0.62	0.87	-3.6	-0.99	0.87	1.3	-6.6

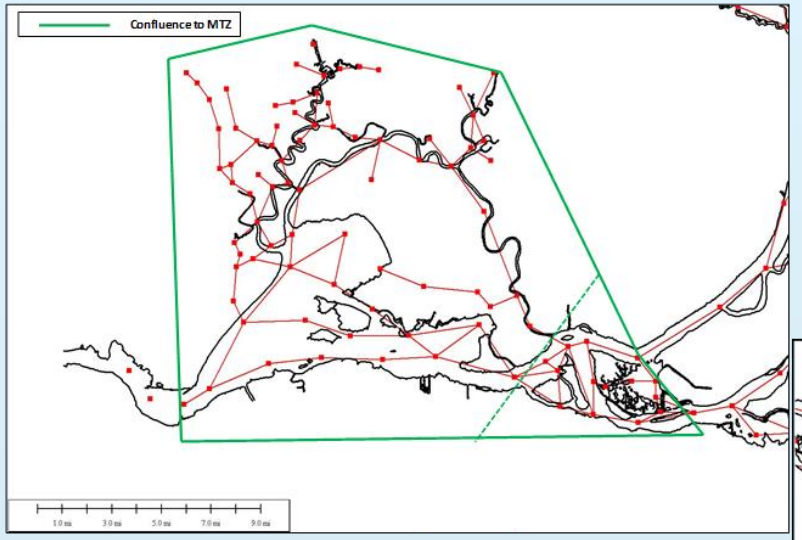


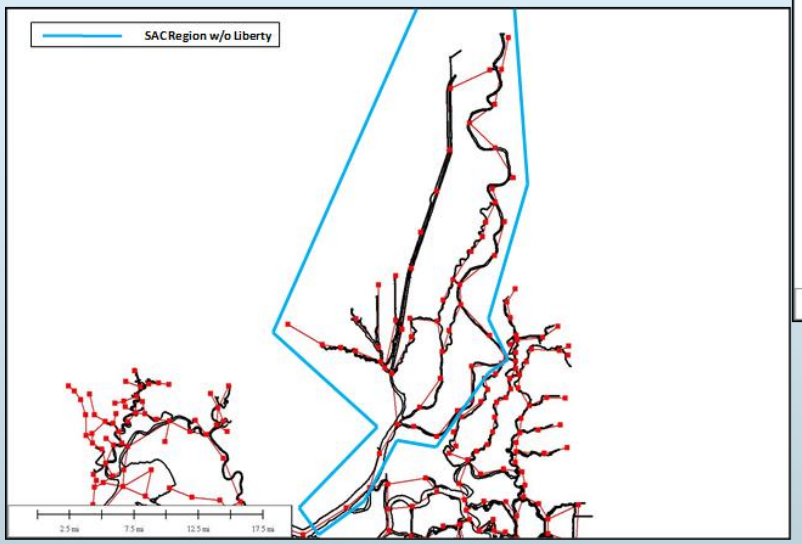
Spatial distribution of locations where model residuals of Percent Bias (Model – CDEC water temperature data) was minimized for four dominant simulations – this graphic and explanation is in a DSM2UG 2015 Newsletter

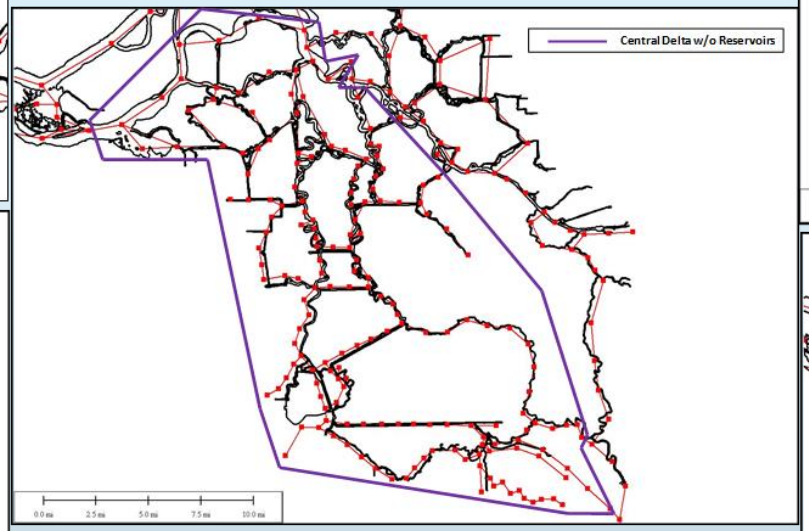
QUAL Nutrient Model Re-calibration

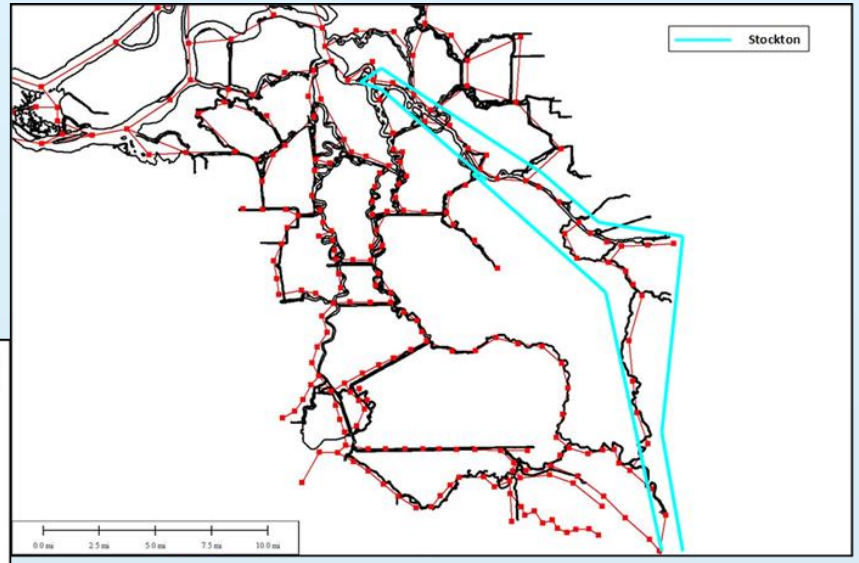
- Very difficult compared to previous recalibration efforts – why?
  - Possibly temperature recalibration
  - Possibly new version of QUAL with changes to QUAL and to HYDRO codes
- Calibration – varied parameters by region to minimize residual statistics, strategy focus was minimizing model bias for EMP and Stockton WTP data locations
  - Reservoirs varied separately, Liberty "special" reservoir w/data
- Calibration of residuals based on previous work and (Moriasi *et al.*, 2007)
  - Calculated for All Years, Wet WYs (Wet+Above Avg.) and Dry WY's (all others)
- Results –
  - DO along SJR much improved, w/calibration parameters in more acceptable range
  - Calibration of NH_3, NO_3+NO_2, Organic-N much harder everywhere
  - Two stations in East Delta – EMP stations MD10 and P8 – calibration very poor (same as previously)
  - No EMP station data in South Delta during modeled time span, 01/2000 – 03/2012

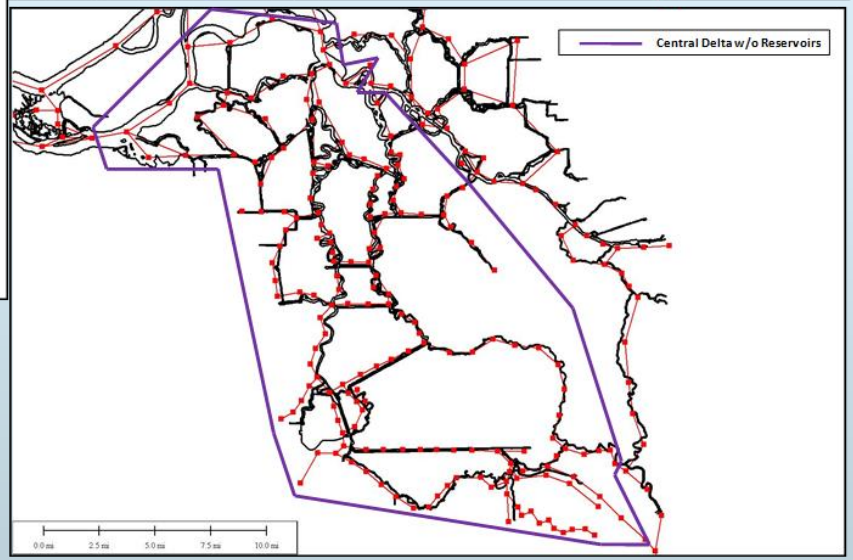
Moriasi, D.N., J.G. Arnold, M.W. Van Liew, R.L. Bingner, R.D. Harmel, and T.L. Vieth. 2007 Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Transactions of the ASABE. Vol. 50(3)







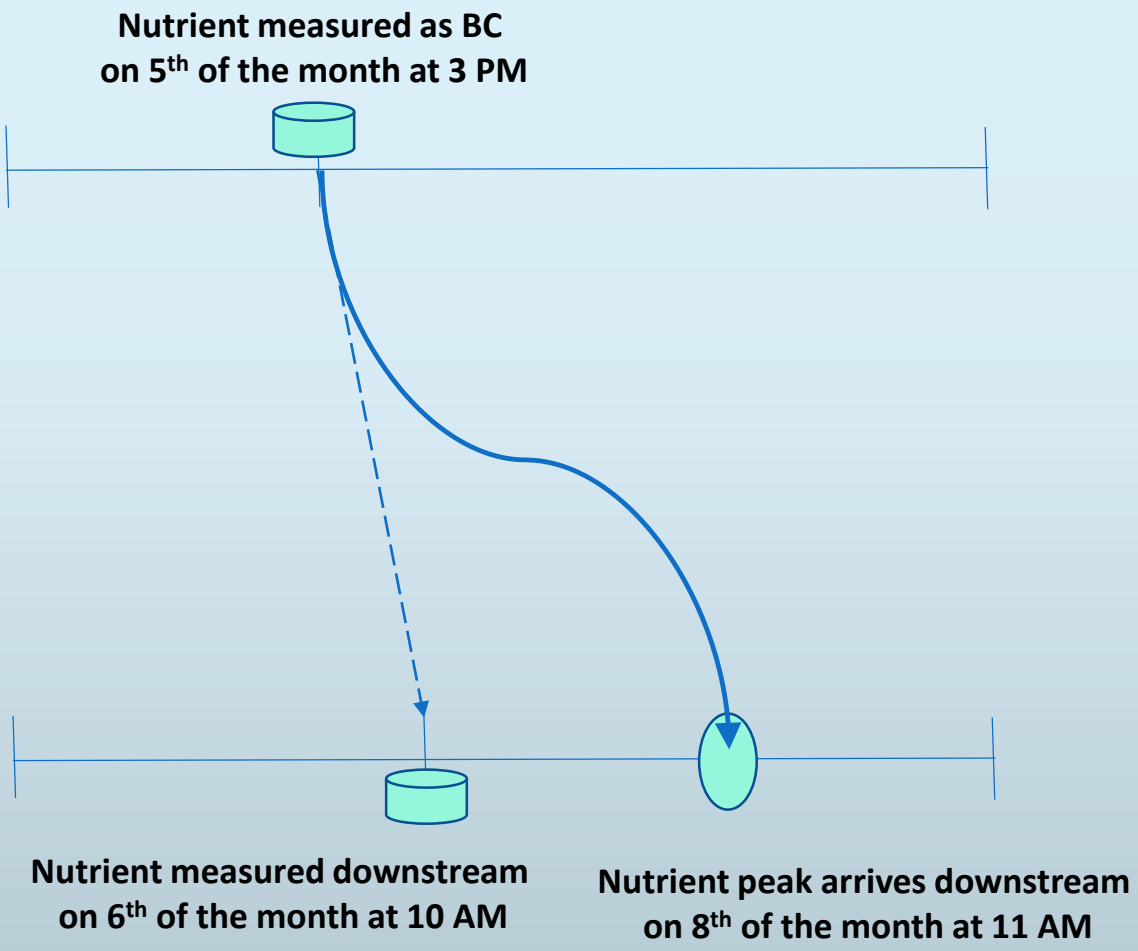




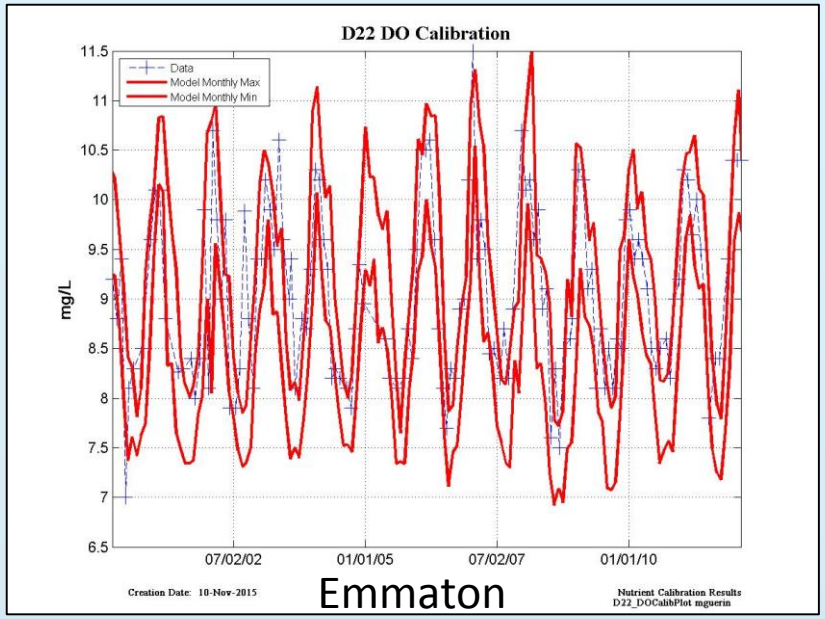
Parameter Regions – Parameters initially uniform in each of these regions, then varied during calibration

Problem – timing mismatch of data

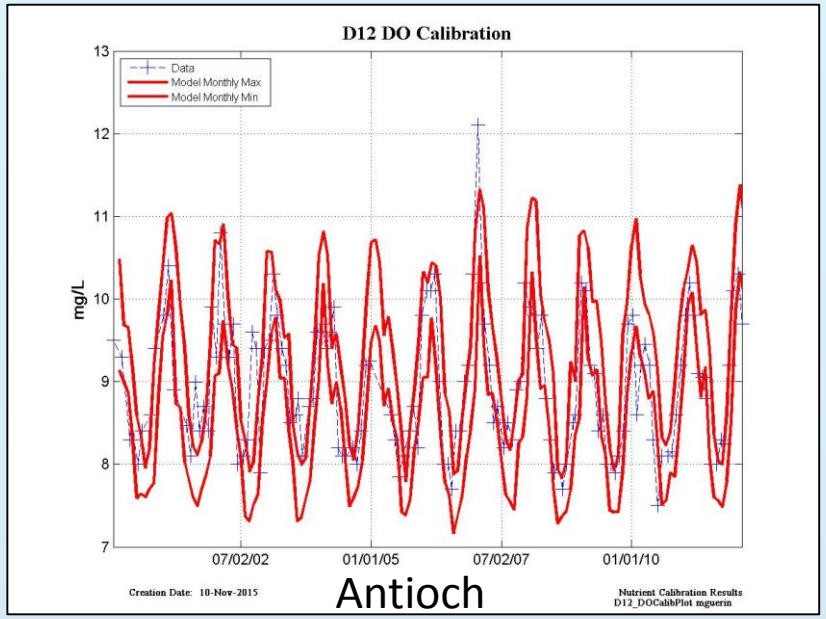
- Most BC nutrient data is monthly or sometimes 2x monthly
- Most in-Delta calibration data is also monthly
- But, the measurement dates don't relate to travel time
- Also – grab samples are single sample, single site measures - really need several samples to get a measure of local variability



Methodology – modeled monthly max/min creates an envelope, measurement inside envelope is zero residual, outside yields a residual statistic, the difference (model – data)

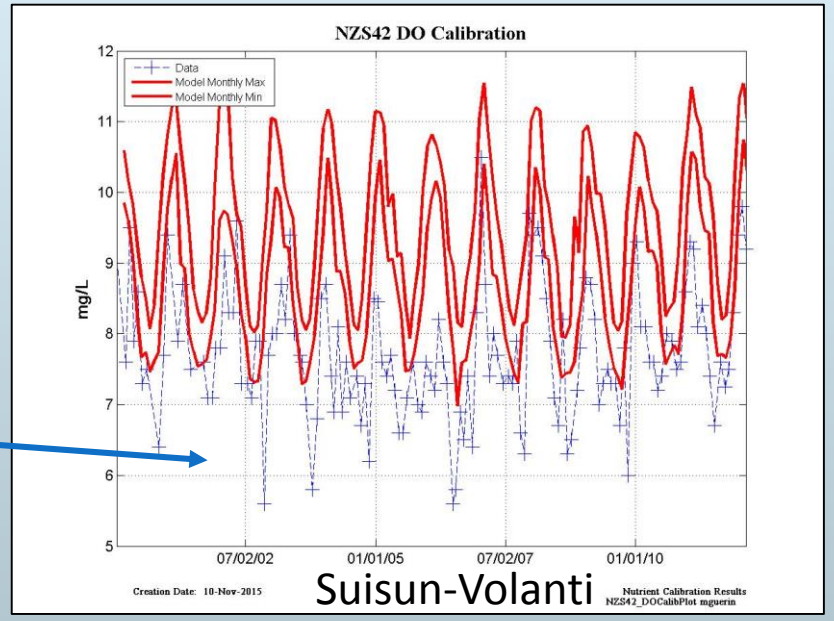


Emmaton

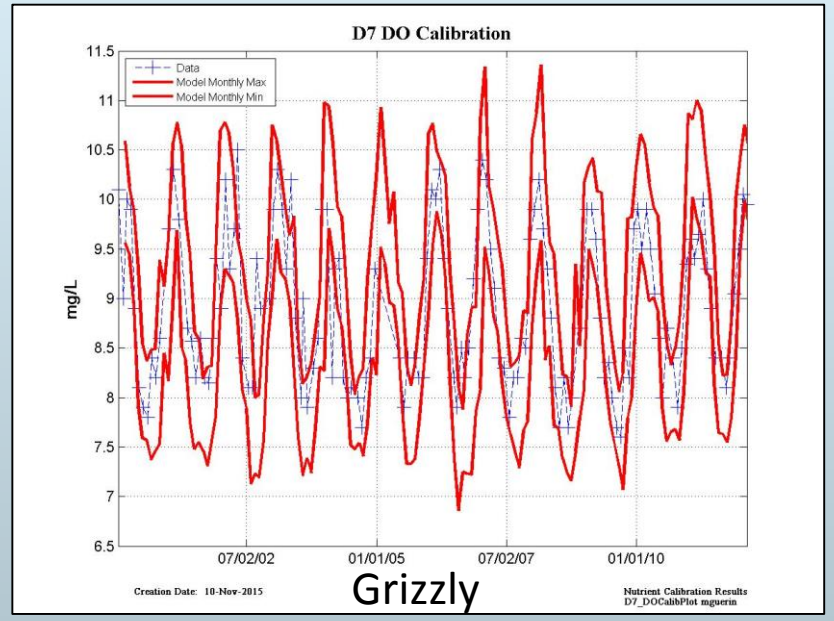


Antioch

Model Overestimates Data



Suisun-Volanti



Grizzly

Calibration parameters and categorical statistics used in residual analysis and model skill assessment

Performance Rating	RSR	NSE	PBIAS (%)	Categorical Rating
Very Good	0.00 ≤ RSR ≤ 0.50	0.75 < NSE ≤ 1.00	PBIAS < +/- 25	**1**
Good	0.50 < RSR ≤ 0.60	0.65 < NSE ≤ 0.75	+/- 25 ≤ PBIAS < +/- 40	**2**
Satisfactory	0.60 < RSR ≤ 0.70	0.00 ≤ NSE ≤ 0.65	+/- 40 ≤ PBIAS < +/- 70	**3**
Unsatisfactory	RSR > 0.7	NSE < 0.0	PBIAS ≥ +/- 70	**4**

D10 - ALGAE	NSE	PBIAS	Bias	RSR
ALL	S	VG	Underestimate	S
Dry WY Calibration	G	VG	Underestimate	G
Wet WY Calibration	S	VG	Underestimate	S
Dry WY Validation	S	VG	Underestimate	U
Wet WY Validation	S	VG	Underestimate	S

D10 - DO	NSE	PBIAS	Bias	RSR
ALL	S	VG	Underestimate	U
Dry WY Calibration	U	VG	Underestimate	U
Wet WY Calibration	U	VG	Underestimate	U
Dry WY Validation	U	VG	Underestimate	U
Wet WY Validation	G	VG	Overestimate	S

D12 - ALGAE	NSE	PBIAS	Bias	RSR
ALL	G	VG	Underestimate	G
Dry WY Calibration	VG	VG	Underestimate	VG
Wet WY Calibration	S	VG	Underestimate	U
Dry WY Validation	S	VG	Underestimate	S
Wet WY Validation	VG	VG	Underestimate	VG

D12 - DO	NSE	PBIAS	Bias	RSR
ALL	VG	VG	Underestimate	VG
Dry WY Calibration	VG	VG	Underestimate	VG
Wet WY Calibration	VG	VG	Underestimate	VG
Dry WY Validation	VG	VG	Underestimate	VG
Wet WY Validation	VG	VG	Underestimate	VG

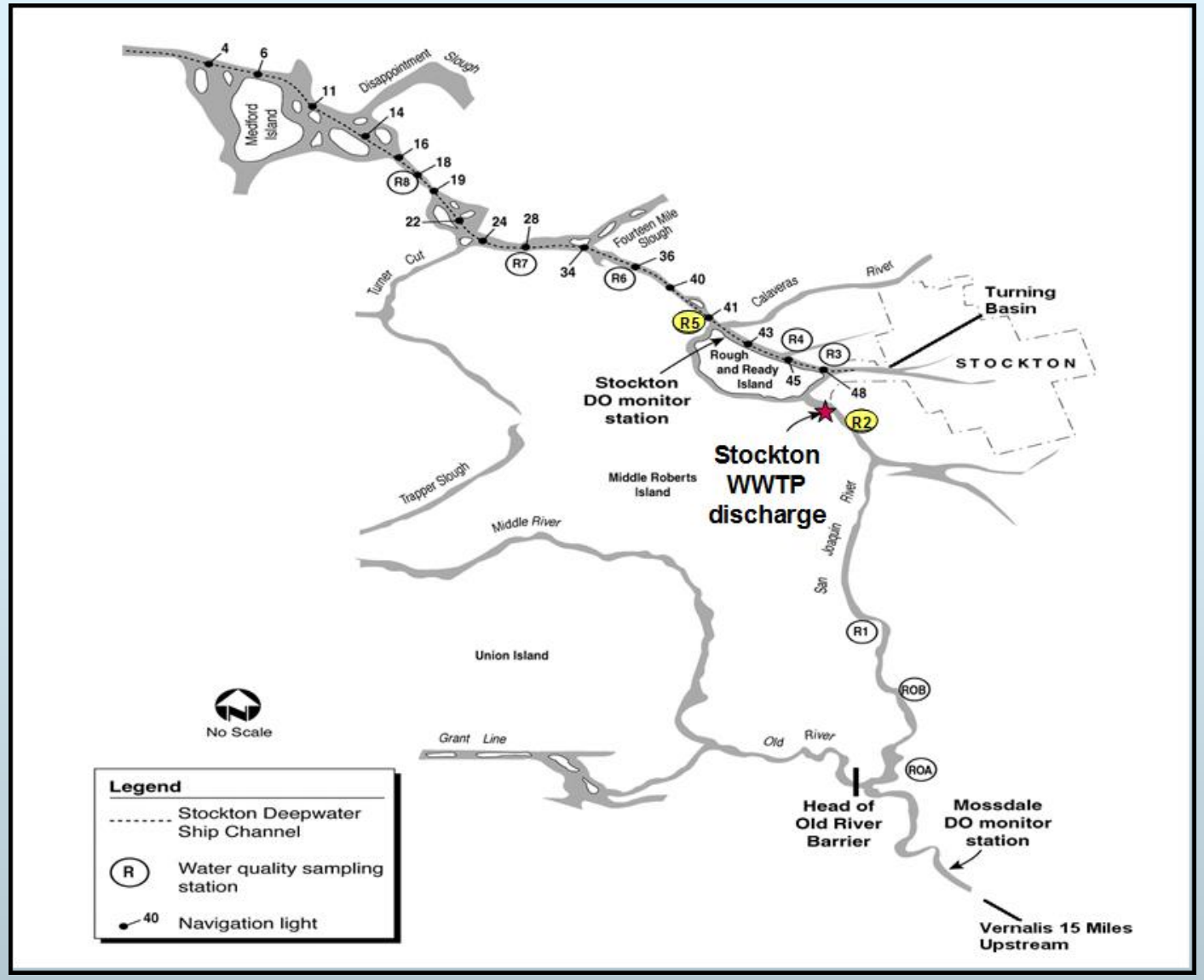
D16 - ALGAE	NSE	PBIAS	Bias	RSR
ALL	S	VG	Underestimate	U
Dry WY Calibration	S	VG	Underestimate	S
Wet WY Calibration	S	G	Underestimate	U
Dry WY Validation	S	VG	Underestimate	U
Wet WY Validation	VG	VG	Underestimate	VG

D16 - DO	NSE	PBIAS	Bias	RSR
ALL	VG	VG	Underestimate	VG
Dry WY Calibration	VG	VG	Underestimate	VG
Wet WY Calibration	VG	VG	Underestimate	G
Dry WY Validation	VG	VG	Underestimate	VG
Wet WY Validation	VG	VG	Underestimate	VG

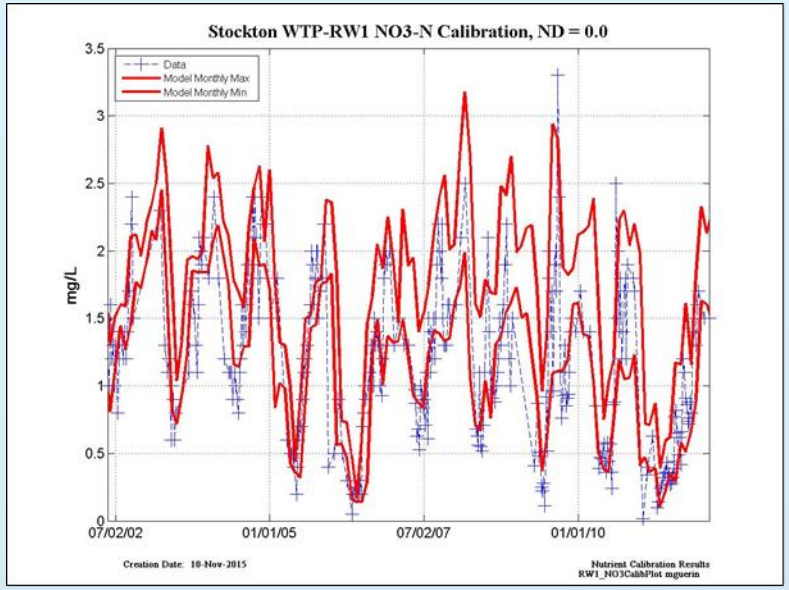
D22 - ALGAE	NSE	PBIAS	Bias	RSR
ALL	S	VG	Underestimate	U
Dry WY Calibration	S	VG	Underestimate	S
Wet WY Calibration	S	VG	Underestimate	U
Dry WY Validation	S	VG	Underestimate	U
Wet WY Validation	S	VG	Underestimate	U

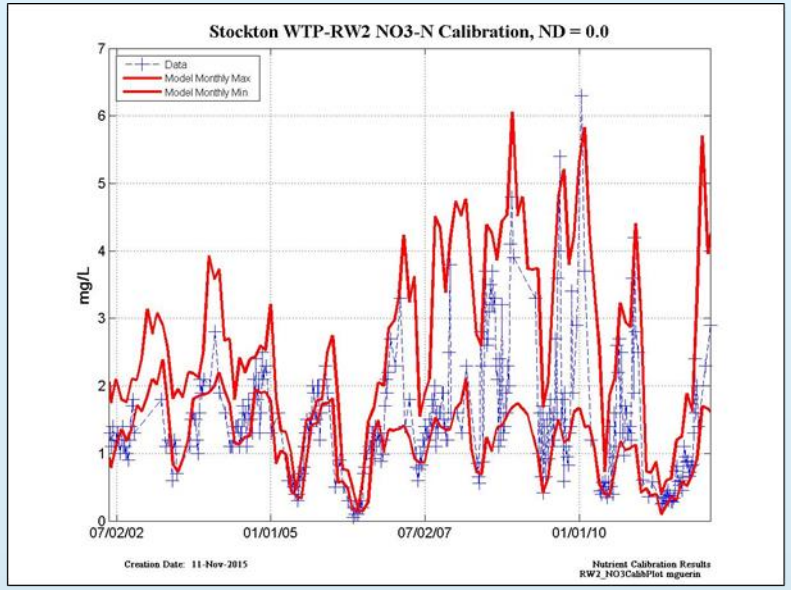
D22 - DO	NSE	PBIAS	Bias	RSR
ALL	VG	VG	Underestimate	VG
Dry WY Calibration	VG	VG	Underestimate	VG
Wet WY Calibration	G	VG	Underestimate	G
Dry WY Validation	VG	VG	Underestimate	VG
Wet WY Validation	VG	VG	Underestimate	VG

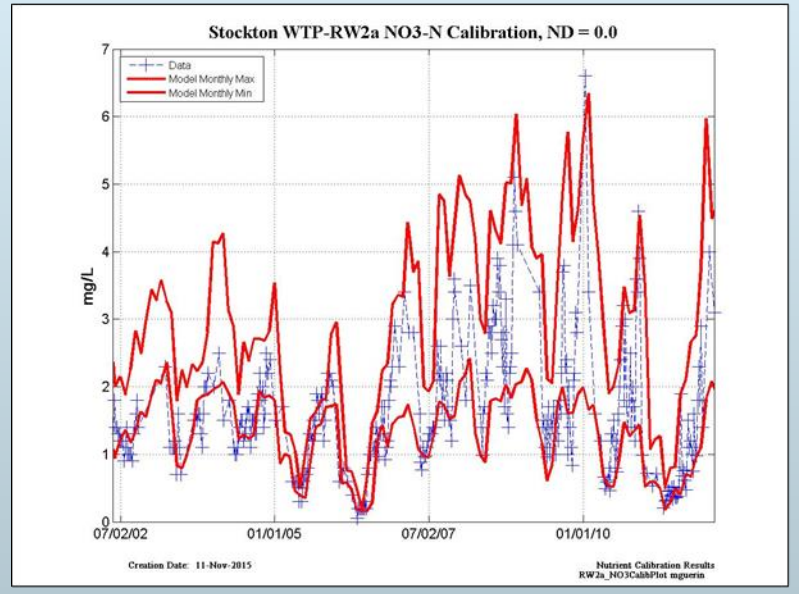
Stockton WWTP Receiving Water Measurement Locations

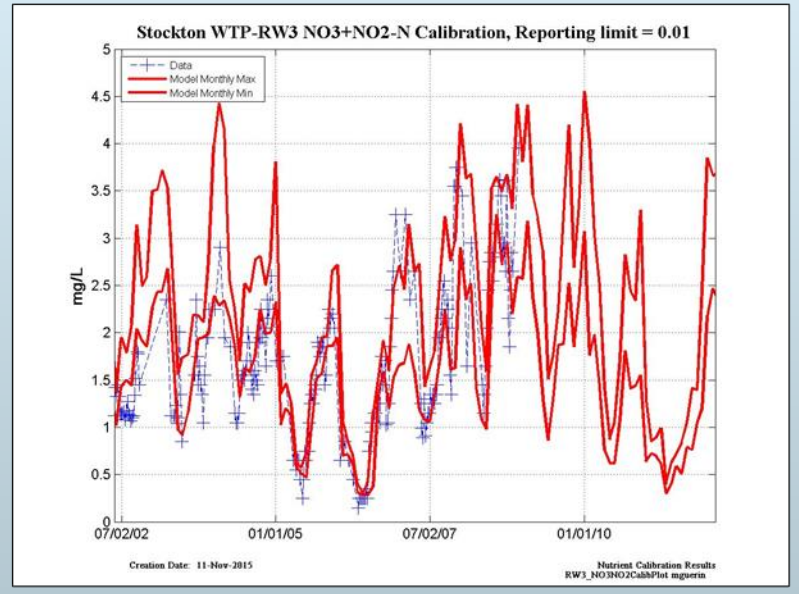


Stockton Effluent Receiving Water Measurement Calibration

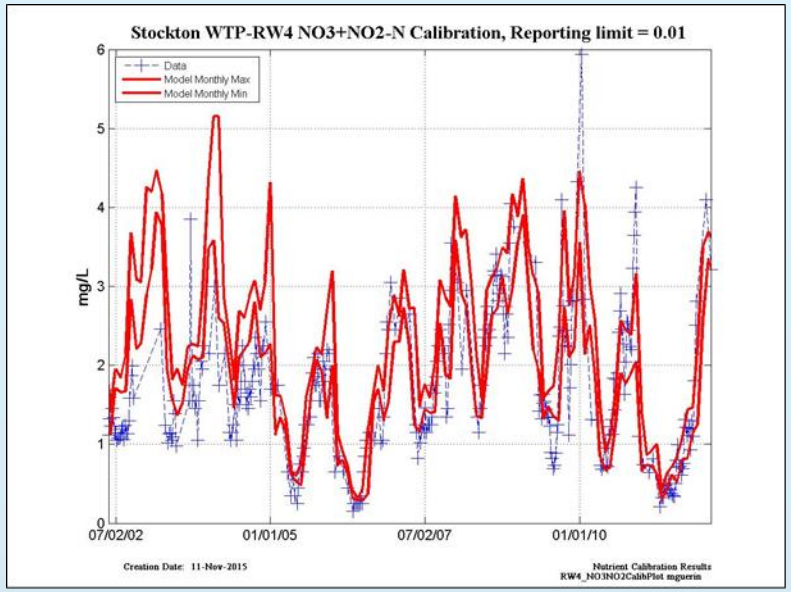


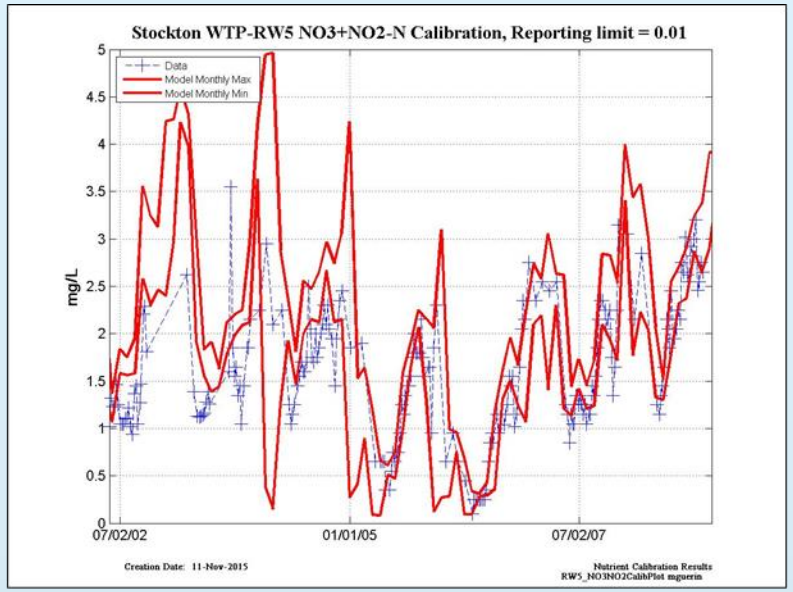


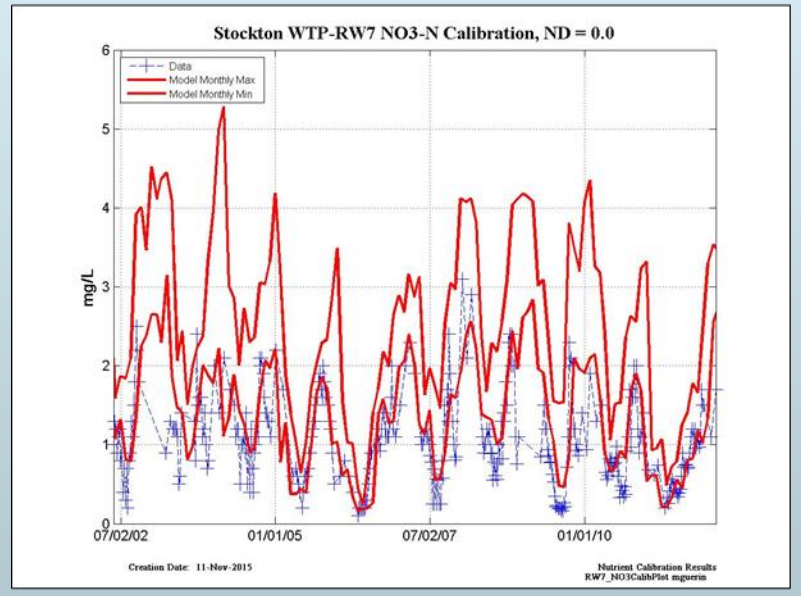


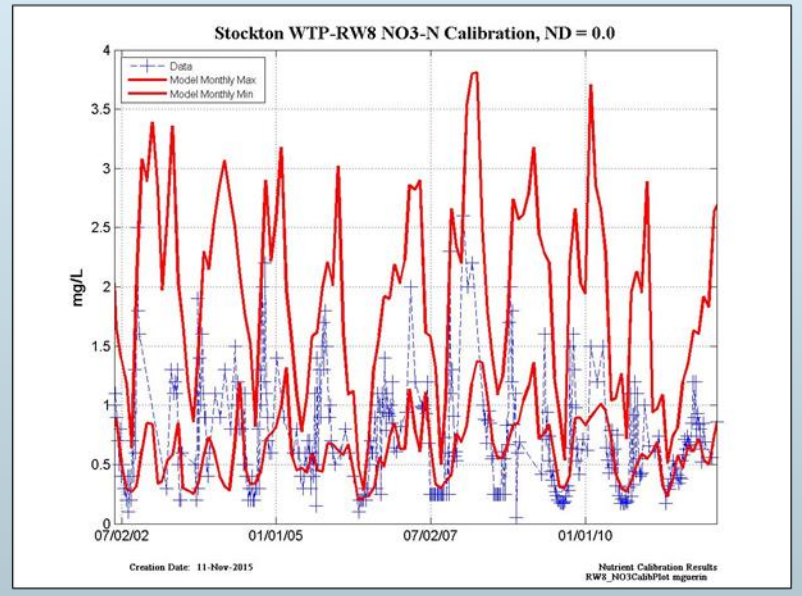


Stockton Effluent Receiving Water Measurement Calibration

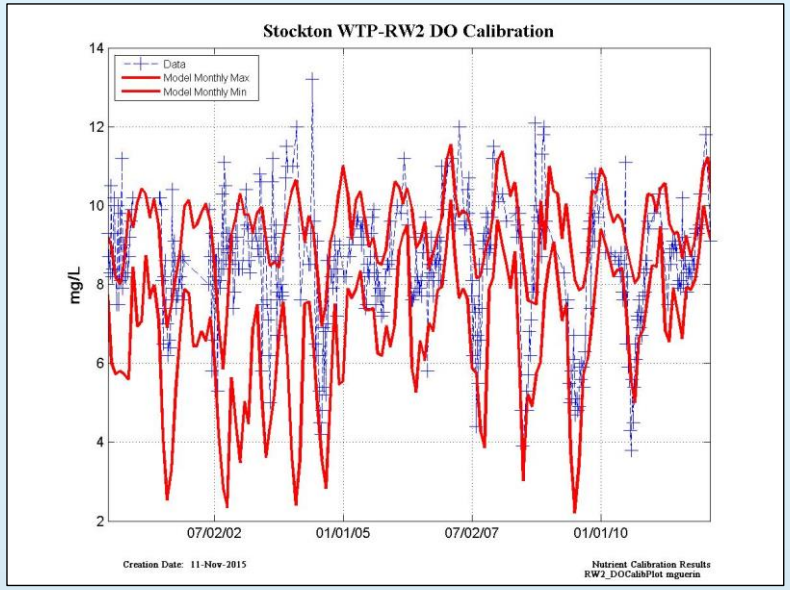


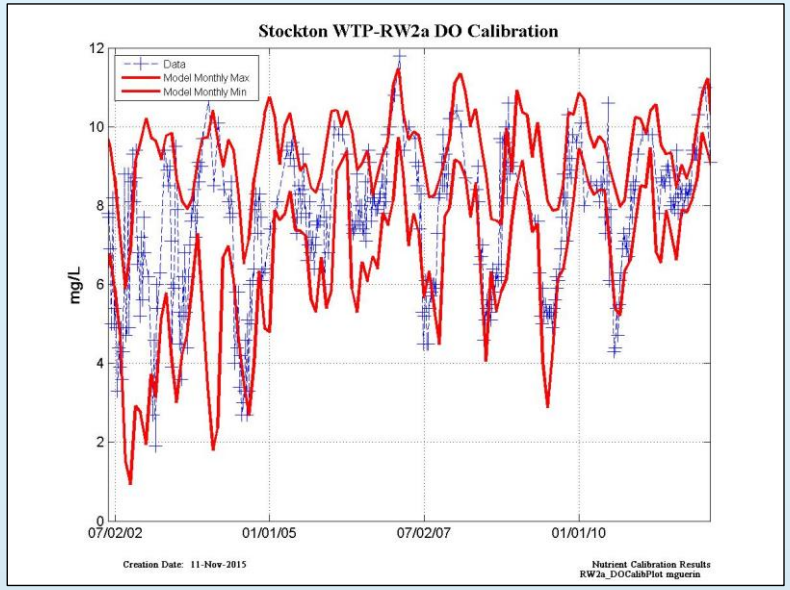


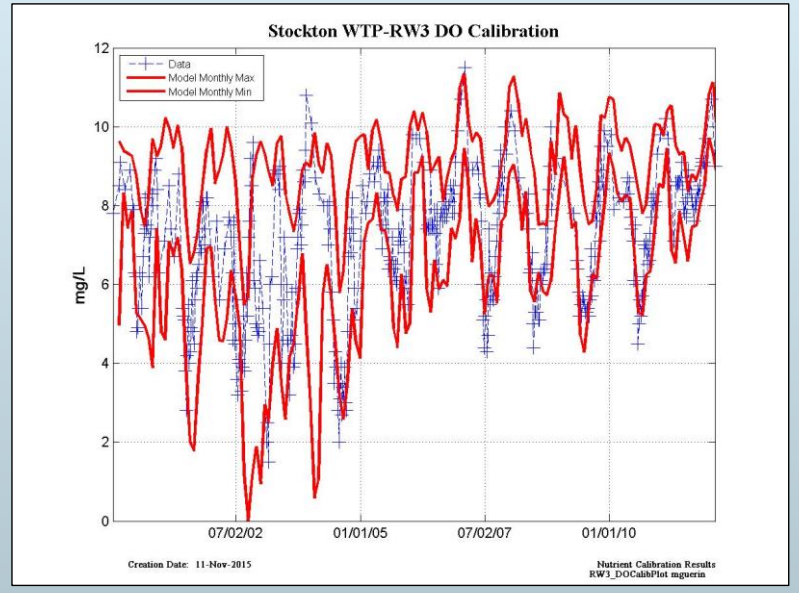


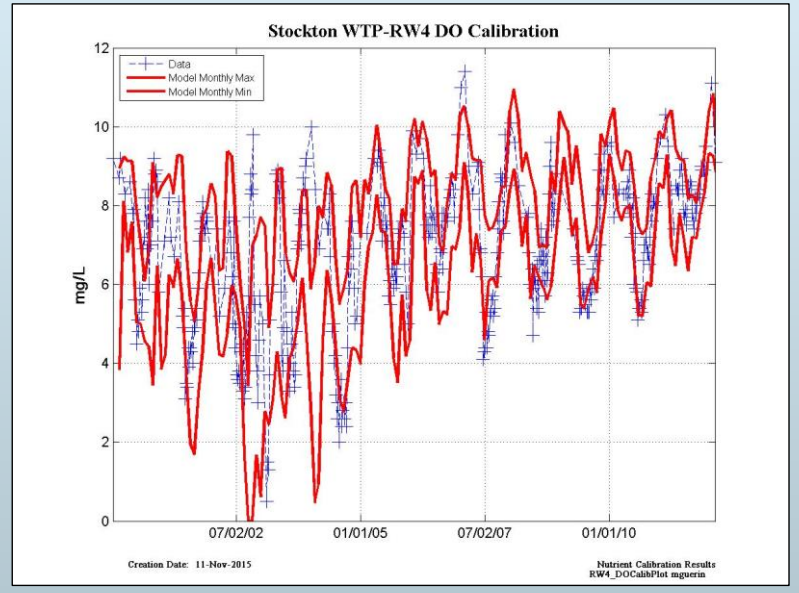


Stockton Effluent Receiving Water Measurement Calibration

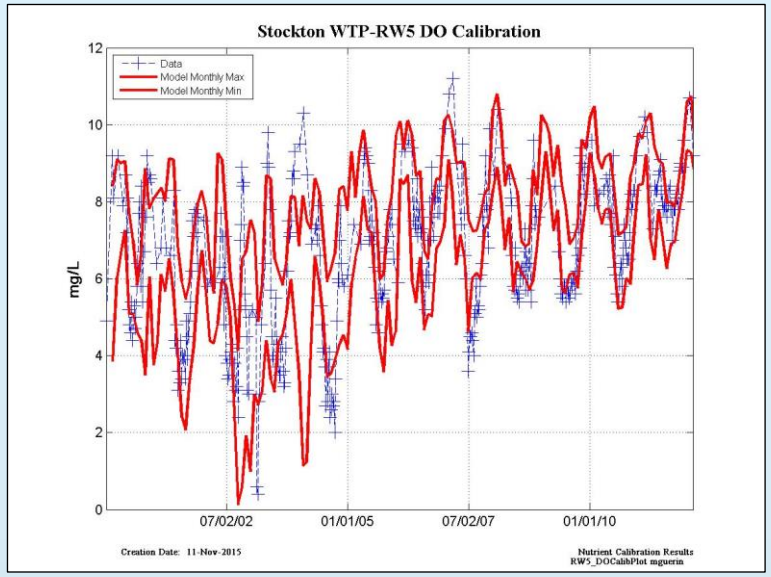


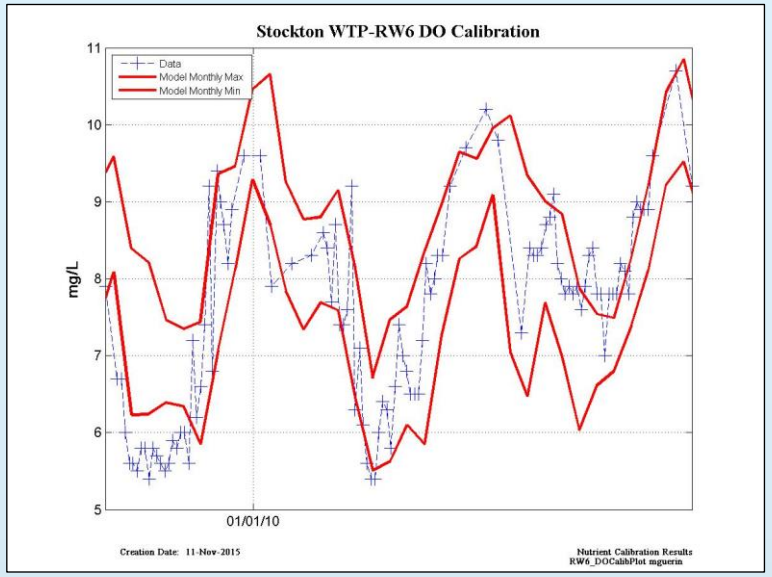


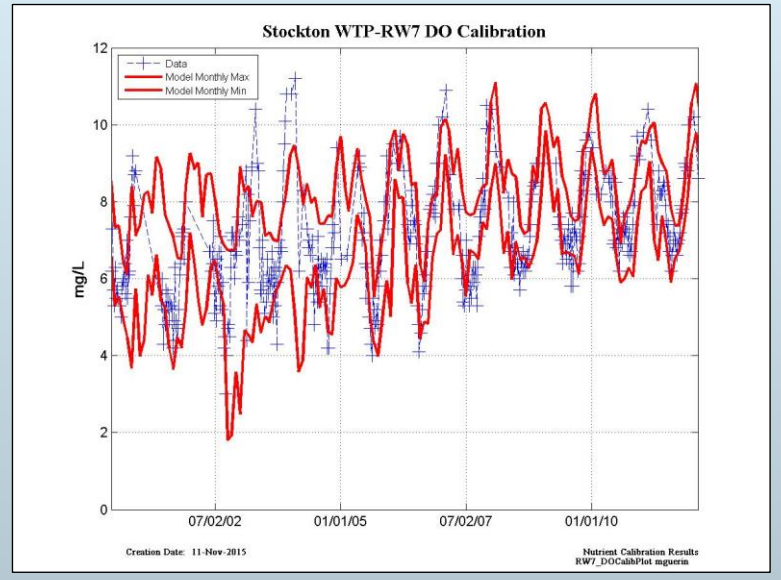


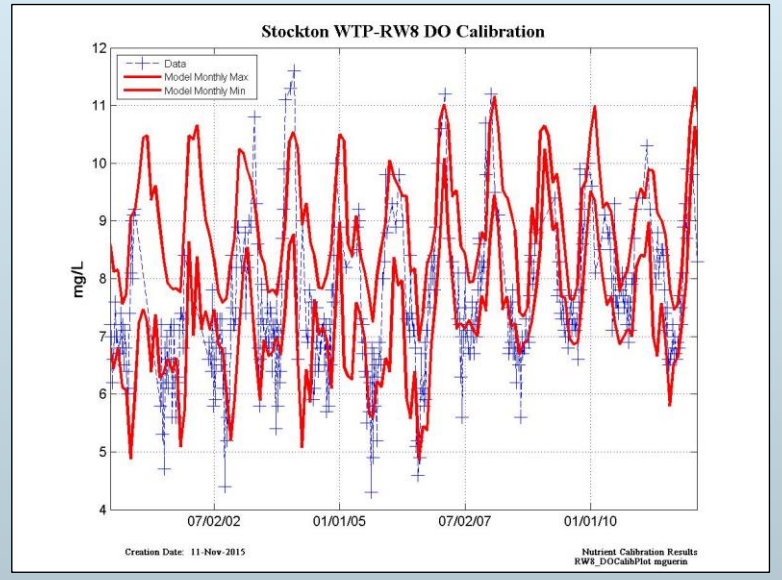


Stockton Effluent Receiving Water Measurement Calibration









“Model Skill” Calculated for All Water Years:

All WYs - NH3	NSE	PBIAS	Bias	RSR
C10	VG	VG	Underestimate	VG
C3A	VG	VG	Overestimate	VG
D19	VG	VG	Underestimate	VG
D26	VG	VG	Underestimate	VG
D28A	S	G	Overestimate	U
D4	VG	VG	Underestimate	G
D6	VG	VG	Underestimate	VG
D7	VG	VG	Overestimate	VG
MD10	S	U	Overestimate	U
P8	S	S	Underestimate	U

NH3	NSE	PBIAS	RSR
C10	1	1	1
C3A	1	1	1
D19	1	1	1
D26	1	1	1
D28A	3	2	4
D4	1	1	2
D6	1	1	1
D7	1	1	1
MD10	3	4	4
P8	3	3	4
MODEL	Good	Good	Good
SKILL	2	2	2

All WYs - NO3+NO2	NSE	PBIAS	Bias	RSR
C10	VG	VG	Overestimate	VG
C3A	VG	VG	Underestimate	VG
D19	VG	VG	Overestimate	G
D26	VG	VG	Overestimate	S
D28A	G	G	Overestimate	U
D4	VG	VG	Overestimate	G
D6	VG	VG	Overestimate	VG
D7	VG	VG	Overestimate	VG
MD10	S	S	Overestimate	U
P8	VG	VG	Overestimate	VG

NO3+NO2	NSE	PBIAS	RSR
C10	1	1	1
C3A	1	1	1
D19	1	1	2
D26	1	1	3
D28A	2	2	4
D4	1	1	2
D6	1	1	1
D7	1	1	1
MD10	3	3	4
P8	1	1	1
MODEL	Very Good	Very Good	Good
SKILL	1	1	2

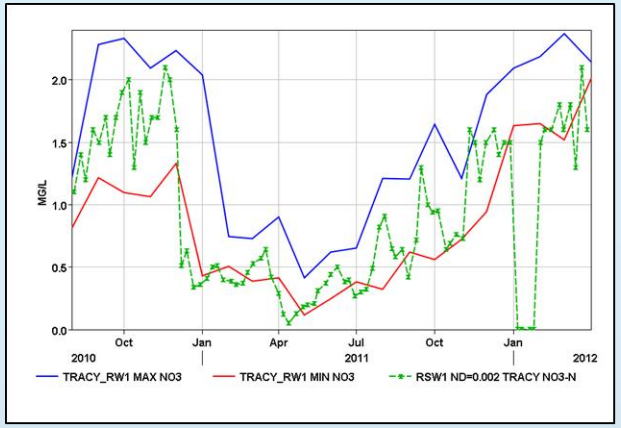
All WYs DO	NSE	PBIAS	Bias	RSR
C10	VG	VG	Overestimate	VG
C3A	VG	VG	Overestimate	VG
D10	S	VG	Underestimate	U
D12	VG	VG	Underestimate	VG
D16	VG	VG	Underestimate	VG
D19	VG	VG	Underestimate	VG
D22	VG	VG	Underestimate	VG
D6	VG	VG	Underestimate	VG
D7	VG	VG	Underestimate	VG
MD10	G	VG	Overestimate	G
NZ032	G	VG	Overestimate	G
NZS42	S	VG	Overestimate	U
P8	S	VG	Overestimate	S

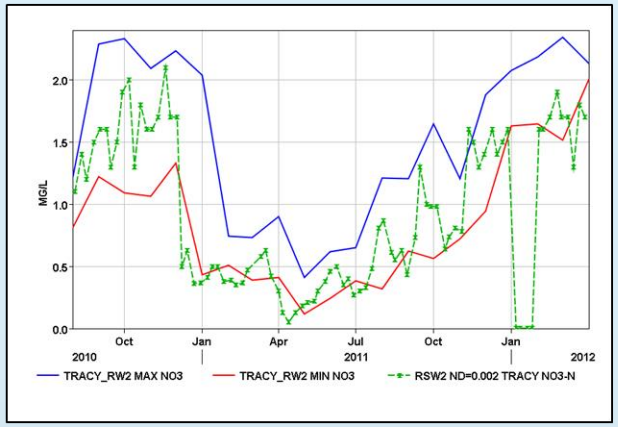
DO	NSE	PBIAS	RSR
C10	1	1	1
C3A	1	1	1
D10	3	1	4
D12	1	1	1
D16	1	1	1
D19	1	1	1
D22	1	1	1
D6	1	1	1
D7	1	1	1
MD10	2	1	2
NZ032	2	1	2
NZS42	3	1	4
P8	3	1	3
MODEL	Good	Very Good	Good
SKILL	2	1	2

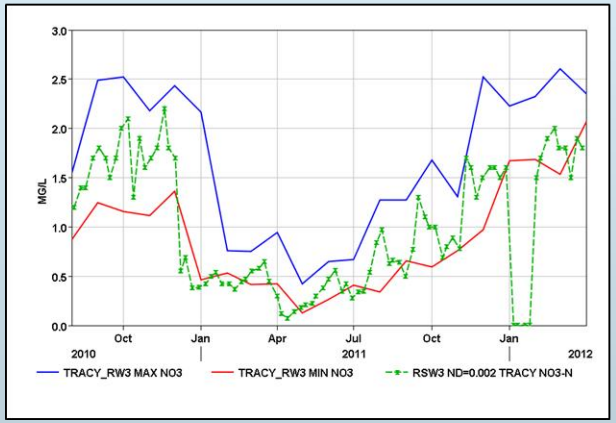
All WYs - ALGAE	NSE	PBIAS	Bias	RSR
C10	VG	VG	Underestimate	VG
C3A	VG	VG	Underestimate	VG
C7	G	VG	Underestimate	G
D10	S	VG	Underestimate	S
D12	G	VG	Underestimate	G
D16	S	VG	Underestimate	U
D19	S	VG	Underestimate	S
D22	S	VG	Underestimate	U
D24A	VG	VG	Underestimate	VG
D26	S	VG	Underestimate	U
D28A	S	VG	Underestimate	U
D4	G	VG	Underestimate	S
D6	VG	VG	Underestimate	VG
D7	S	VG	Overestimate	S
MD10	S	U	Overestimate	U
NZ032	S	VG	Underestimate	U
NZS42	S	VG	Underestimate	U
P8	S	G	Underestimate	U

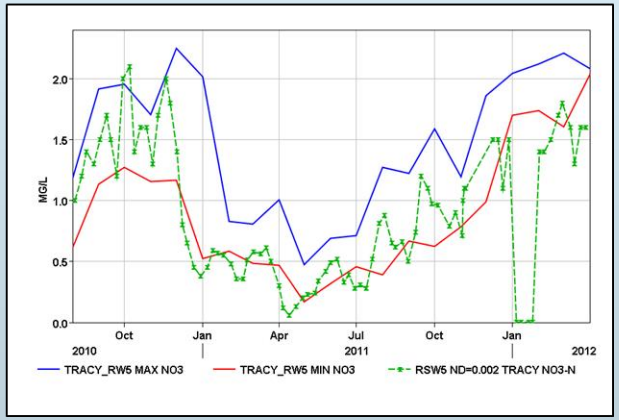
ALGAE	NSE	PBIAS	RSR
C10	1	1	1
C3A	1	1	1
C7	2	1	2
D10	3	1	3
D12	2	1	2
D16	3	1	4
D19	3	1	3
D22	3	1	4
D24A	1	1	1
D26	3	1	4
D28A	3	1	4
D4	2	1	3
D6	1	1	1
D7	3	1	3
MD10	3	4	4
NZ032	3	1	4
NZS42	3	1	4
P8	3	2	4
MODEL	Good	Very Good	Satisfactory
SKILL	2	1	3

WWTP Receiving Water Data Examples

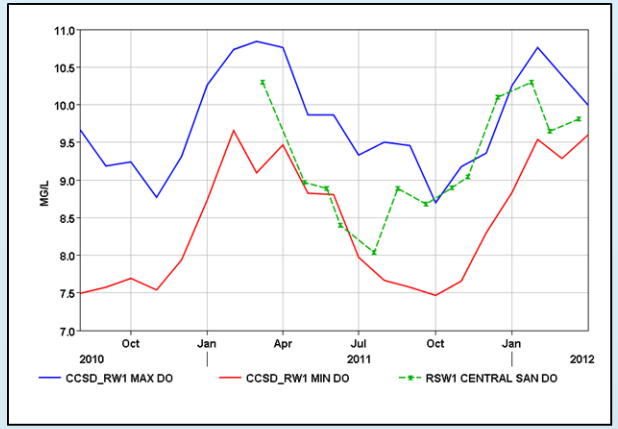


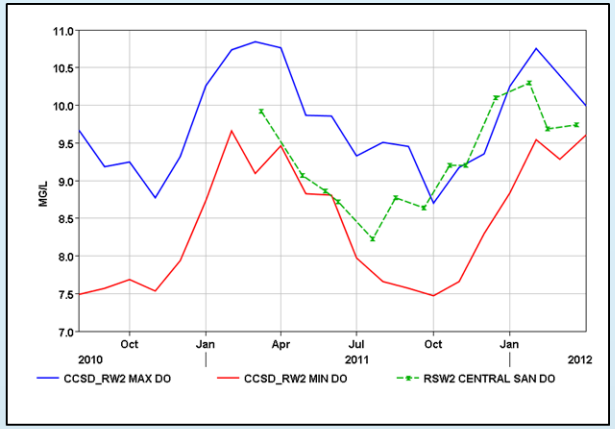


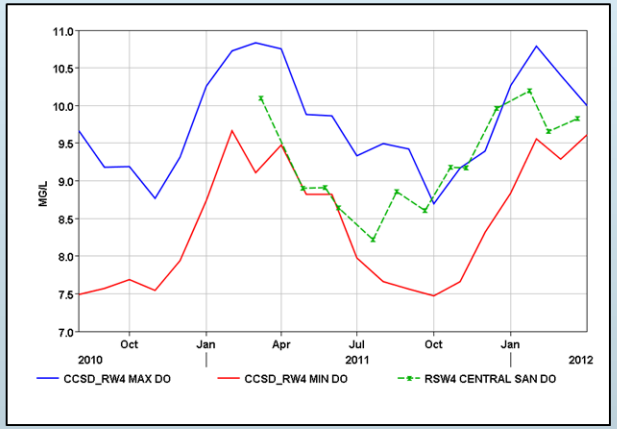




Tracy NO_3 at 4 locations



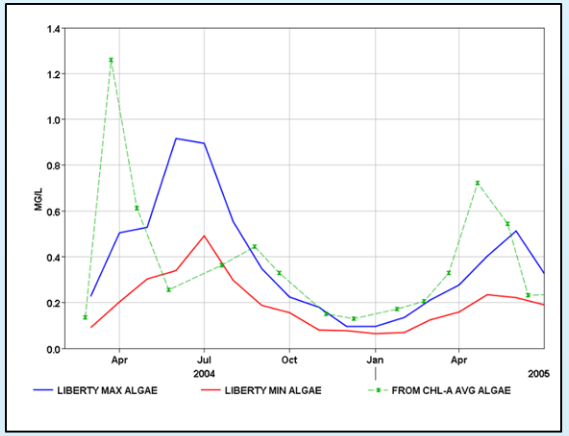


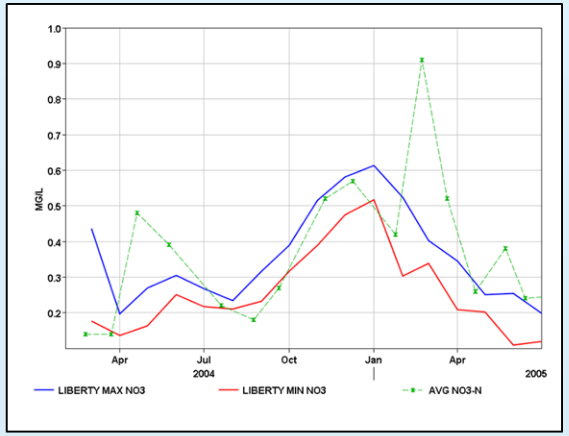


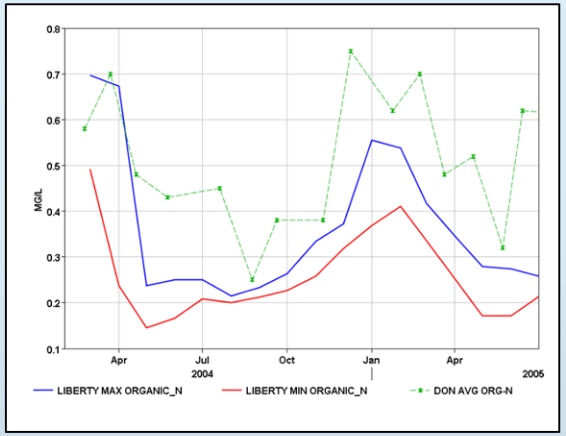
CCSD DO at 3 locations

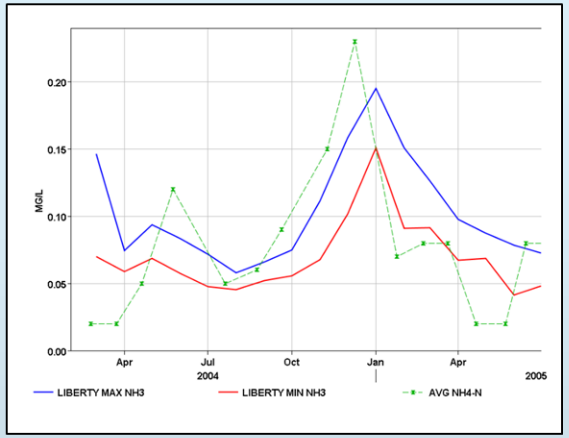
Liberty Island

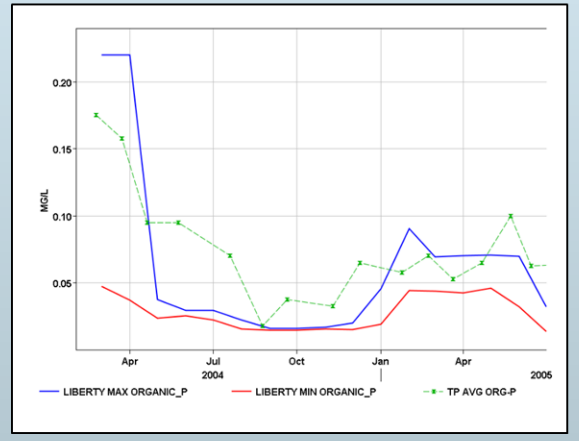
- Used data from Peggy Lehman experiments to set upstream BCs
- And to set calibration parameters

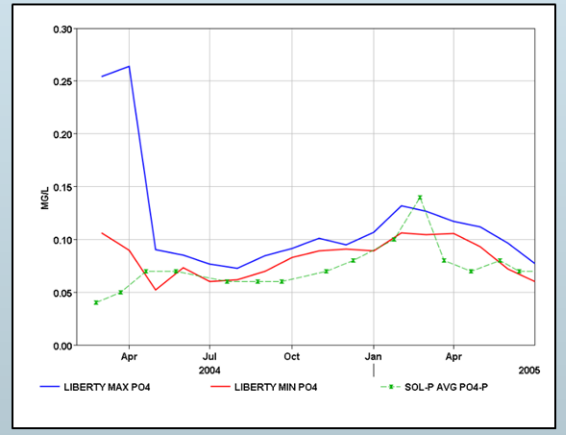












Thank-you for your attention!

See Hari or Min Yu for Documentation and Model Setup