Assessment of Lake Murray Water Quality and Reservoir Releases

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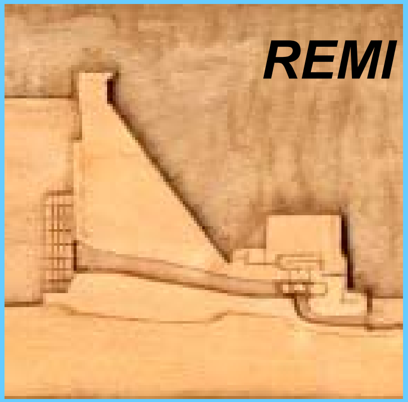
***REMI** Reservoir Environmental Management, Inc*



Reservoir Environmental
Management, Inc

- **Focus on large reservoirs and rivers**
- **Water quality modeling and assessments, including in-lake aeration systems**
- **Assessments of alternative aeration systems**
- **Assessments of alternative temperature control systems**
- **Evaluations, testing, and modeling of turbine aeration systems**
- **Predictions of operational effects on water quality**
- **Site-specific water quality standards**
- **Assessment of watershed effects on water quality**
- **Assessment and management of anoxic products (e.g., sulfides, ammonia, iron, manganese, methane)**
- **Assessment of sediment/water interactions**
- **Over 115 projects nationwide, over 65 involving enhancements to water quality**

Selected Projects

TVA RRI/LIP Principal Technical Advisor (26 projects)

Bureau of Reclamation

- Grand Canyon water quality program review
- Upper Klamath Lake—assess DO demands and proposed aeration system
- Salton Sea—estimate DO demands and develop conceptual oxygenation system

Corps of Engineers

- Savannah District—RBR/JST oxygen diffuser modeling
- Mobile District—Buford, Walter F George, Allatoona, West Point
- Nashville District—Wolff Creek, Center Hill, Dale Hollow, Percy Priest

Duke Catawba-Wateree System (11 projects)—nine CE-QUAL-W2 models (five used to evaluate nutrient reductions), 15 turbine venting models, 4 RMS models

Consumers Energy Projects (MI)—Hodenpyl (CE-QUAL-W2 model with upwelling diffuser system...installed/tested 2007), Hardy (CE-QUAL-W2), Croton (CE-QUAL-W2), Mio (CE-QUAL-W2), Alcona, Tippy

Osage Hydro (MO)—CE-QUAL-W2 and the turbine aeration model was used to evaluate various alternatives to increase DO in the releases. Recently developed the first operational turbine aeration model to operate turbine venting systems on eight large hydropower units

Wallenpaupack (PA)—turbine venting, lake aeration for sulfides, operations for tailwater temperature enhancement

Shepaug (CT)—CE-QUAL-W2 was used to design an oxygen diffuser system

Brownlee (ID)—assessed sediment effects on water quality and developed recommendations for aeration systems for turbine releases

Lake Murray/Saluda Hydro (SC)—site-specific DO standard, turbine venting systems, CE-QUAL-W2 model for Striped Bass habitat and revised operations (also for nutrient reductions), develop minimum flow operations for temperature enhancement for the tailwater, assessment of sediment and water interactions

Current and Previous Clients

Corps of Engineers—Mobile, Nashville, Little Rock, Savannah, Tulsa

Connecticut L&P

SCE&G

Duke Energy, Nantahala Power and Light

Consumers Energy

PP&L

Georgia Power

Alabama Power

AmerenUE

Entergy—Arkansas

Idaho Power Company

Appalachian Power

Mirant—New York

University of Nebraska—Lincoln

US Bureau of Reclamation

TVA

Brazos River Authority

Kleinschmidt Associates

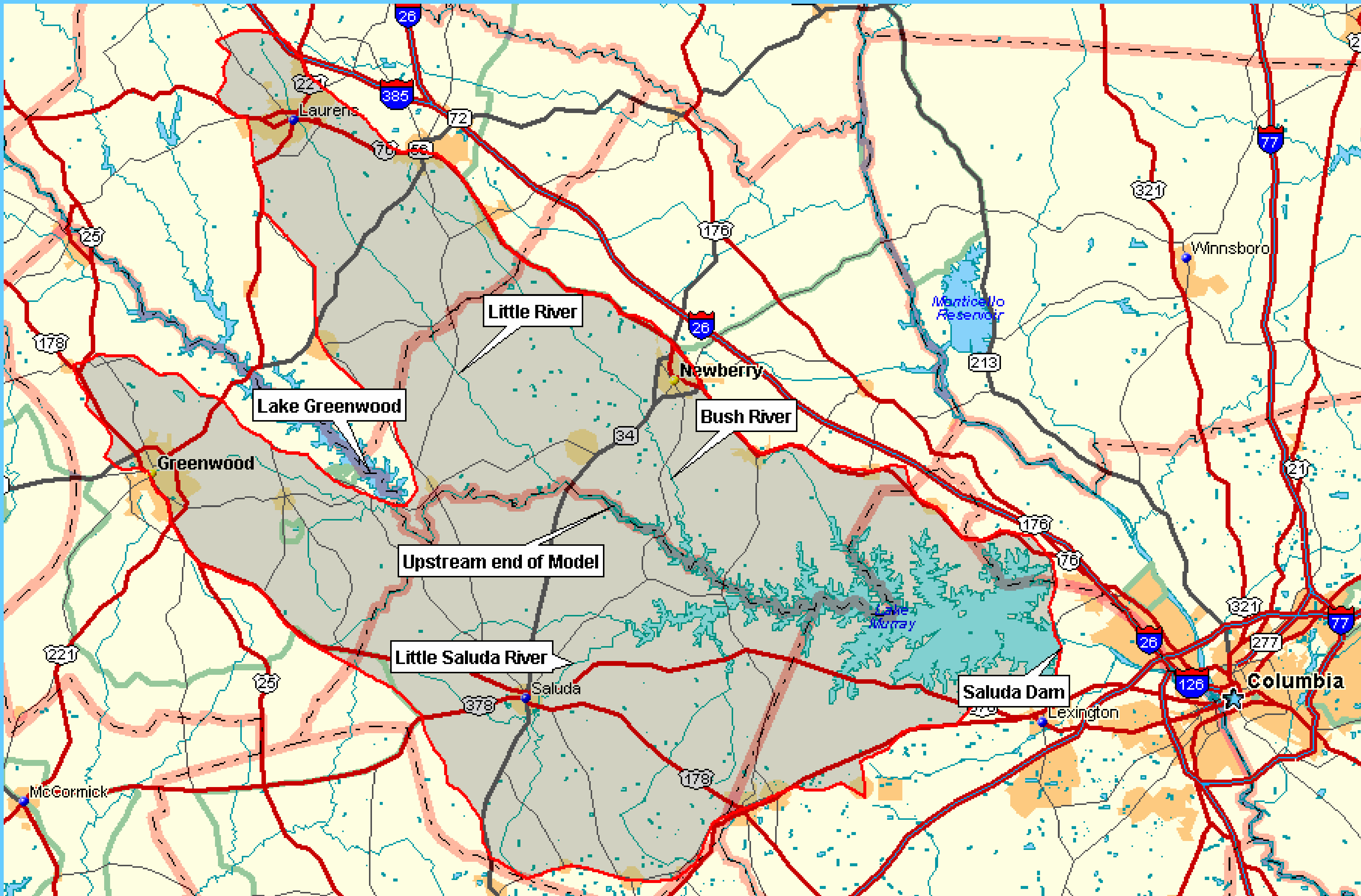
Devine Tarbell and Associates

USGS—Grand Canyon Monitoring and Research Center

MEC Water Resources

Water Supply Utilities—three in CA, one in GA

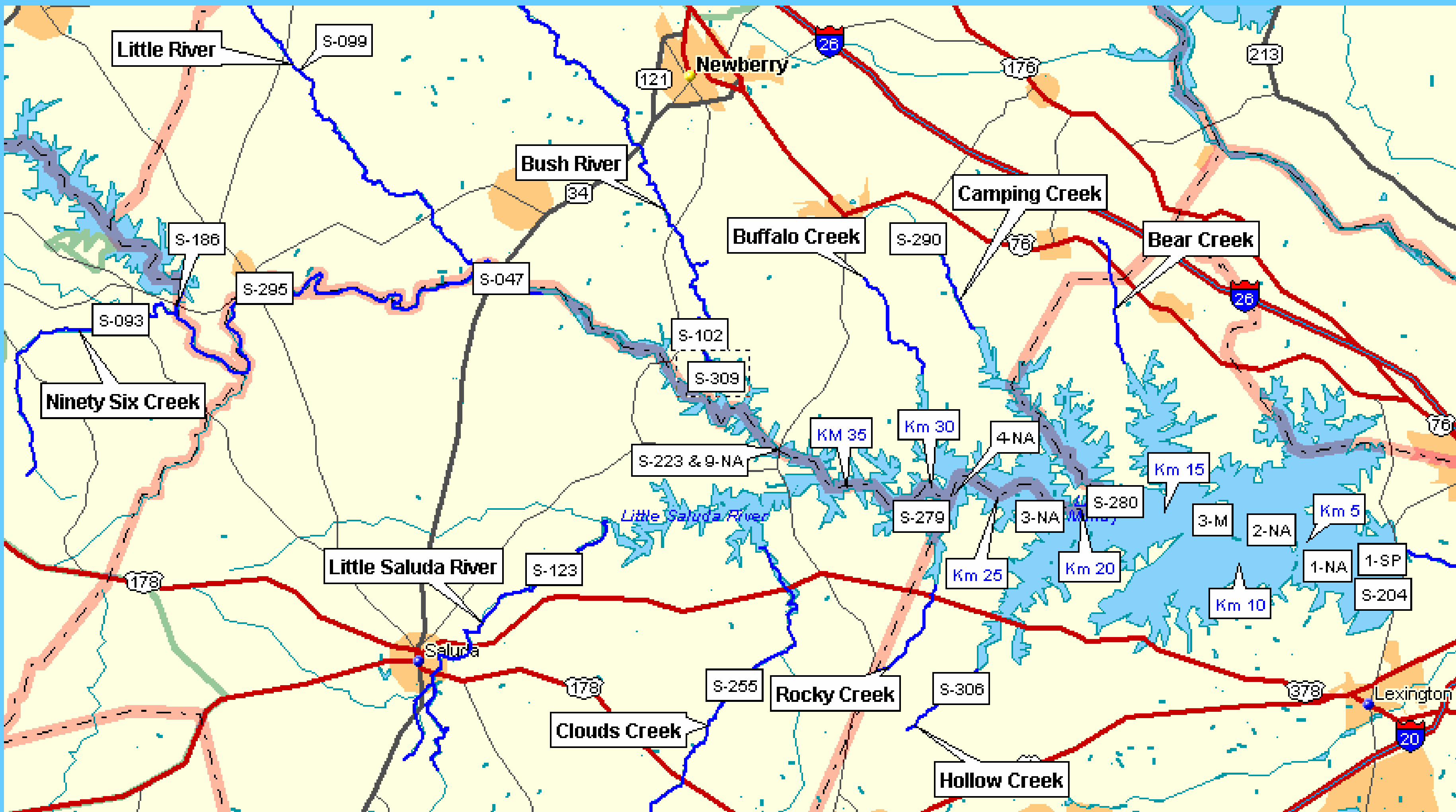
Lake Murray Watershed



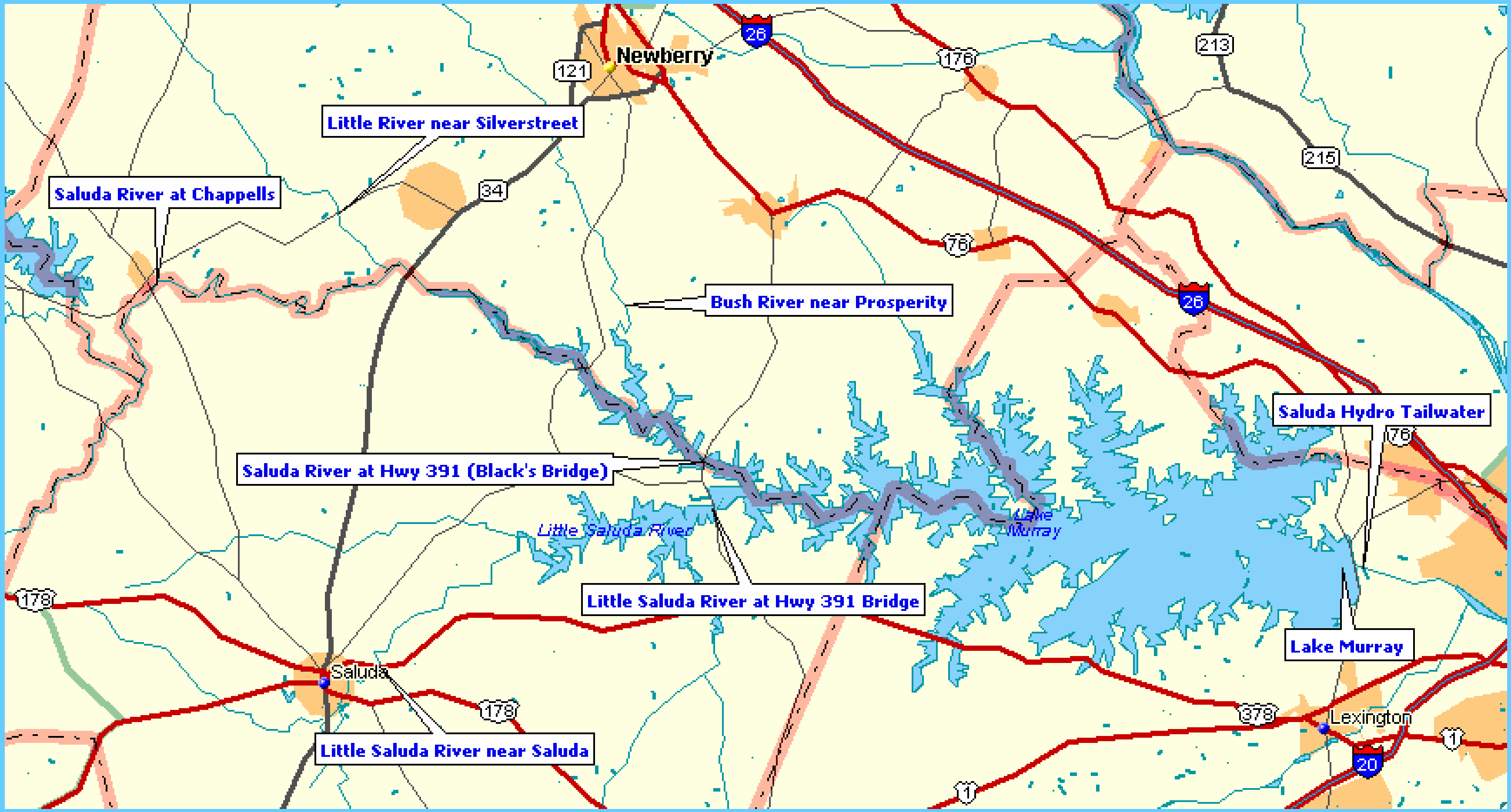
Physical Characteristics of Lake Murray

	U.S. Customary System	Metric System
Maximum depth	175 feet	53.3 m
Total lake volume	2,317,000 ac-ft	2,636 hm^3
Average Annual Flow	2778 cfs	78.7 cms
Nominal Residence Time	417 days	417 days
Depth of outlets, Units 1-4	175 feet	53 m
Depth of outlets, Unit 5	78 feet	23.5 m
Flow Capacity - Units 1-4	3000 cfs (each)	85 cms
Flow Capacity, Unit 5	6000 cfs	170 cms

Primary SCDHEC and SCE&G Monitoring Stations used for Lake Murray Water Quality Analyses



Lake Murray Watershed Showing Location of USGS Monitors



Relicensing Issues Identified by the Water Quality Technical Working Committee

- The causes of striped bass fish kills reported in previous years, especially factors related to Saluda Hydro operations
- The effects of Unit 5 operations on striped bass habitat and entrainment of blue-back herring
- Determination of operational changes that might increase habitat for striped bass and blue-back herring
- Assessment of pool level management alternatives
- Track any impacts that could occur to the tailwater cold-water fishery due to potential operational changes

Plan for Using CE-QUAL-W2 to Address the Water Quality TWC Relicensing Issues

1. Analyze water quality, meteorological, flow, and operations data for the period of study
2. Calibrate CE-QUAL-W2 model for 1996, 1992, 1997
3. Set up CE-QUAL-W2 for the years when major striped bass fish kills occurred and selected years when they did not occur
4. Use the models to develop temperature and DO criteria for tolerable striped bass habitat
5. Run models to identify the causes that apparently contributed to the fish kills
6. Use the models to explore ways to minimize such fish kills in the future, evaluate effects of proposed pool operations, and develop unit operations protocol to improve water quality

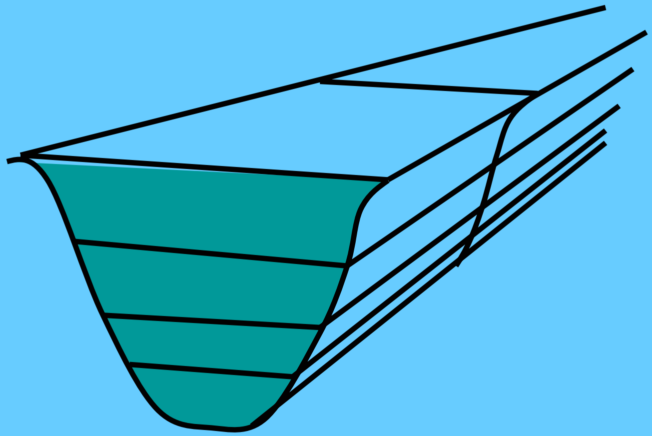
CE-QUAL-W2 is a mechanistic model based on physics of fluid flow and heat/mass transport

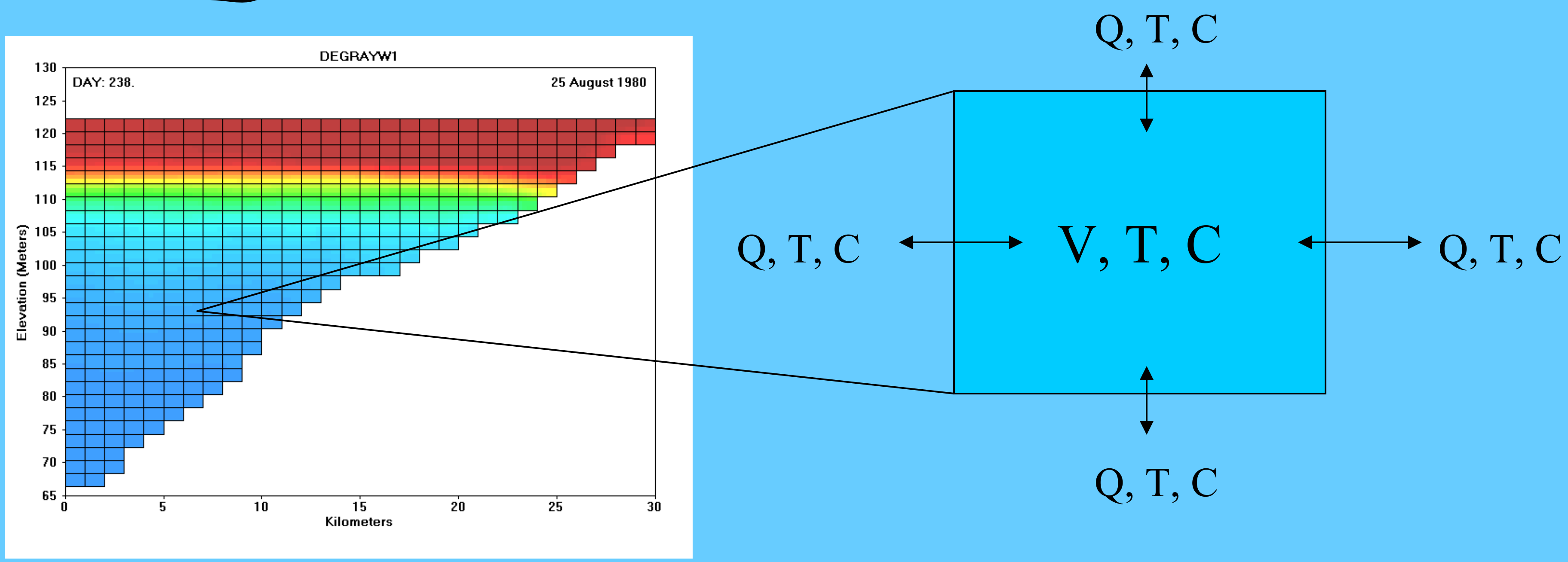
Two-dimensional (vertical, longitudinal) reservoir hydrodynamics and water quality

Laterally-averaged conservation of water mass, water momentum, and transported constituents (heat, WQ)

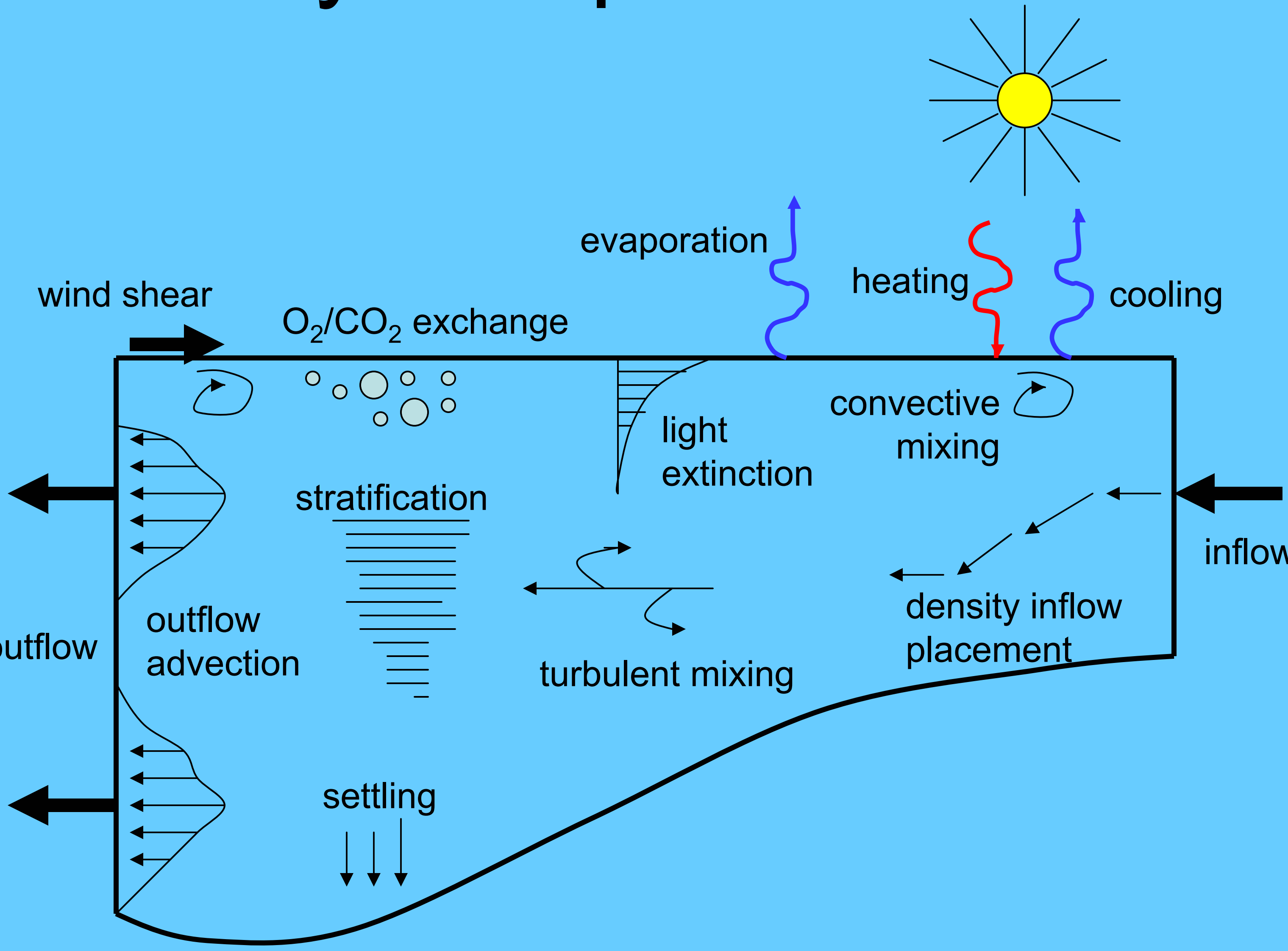
Kinetic fluxes of heat and WQ within cells, between cells, and across boundaries

Forcing functions: meteorology, inflow/outflow, inflow temperature/WQ

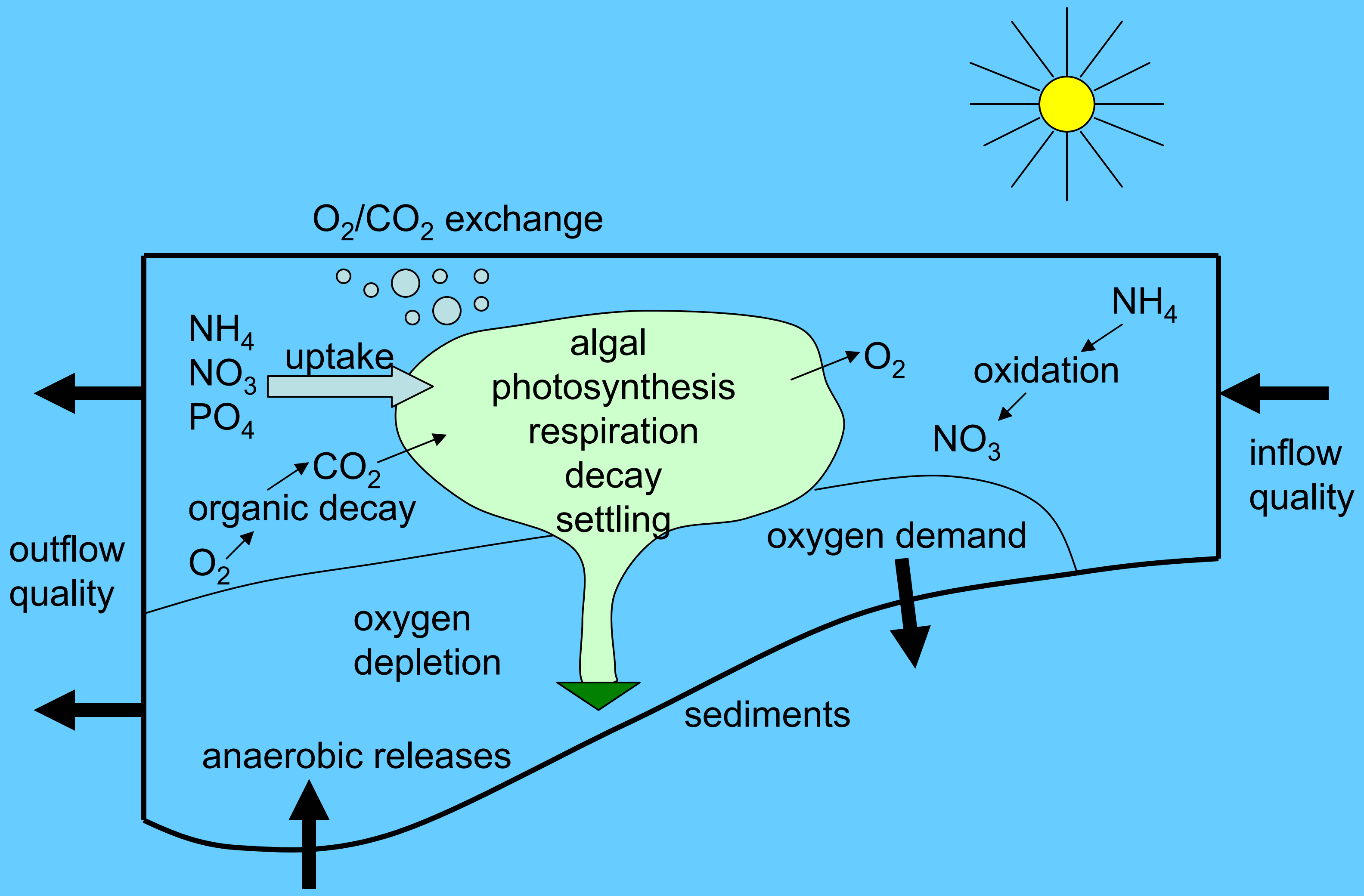




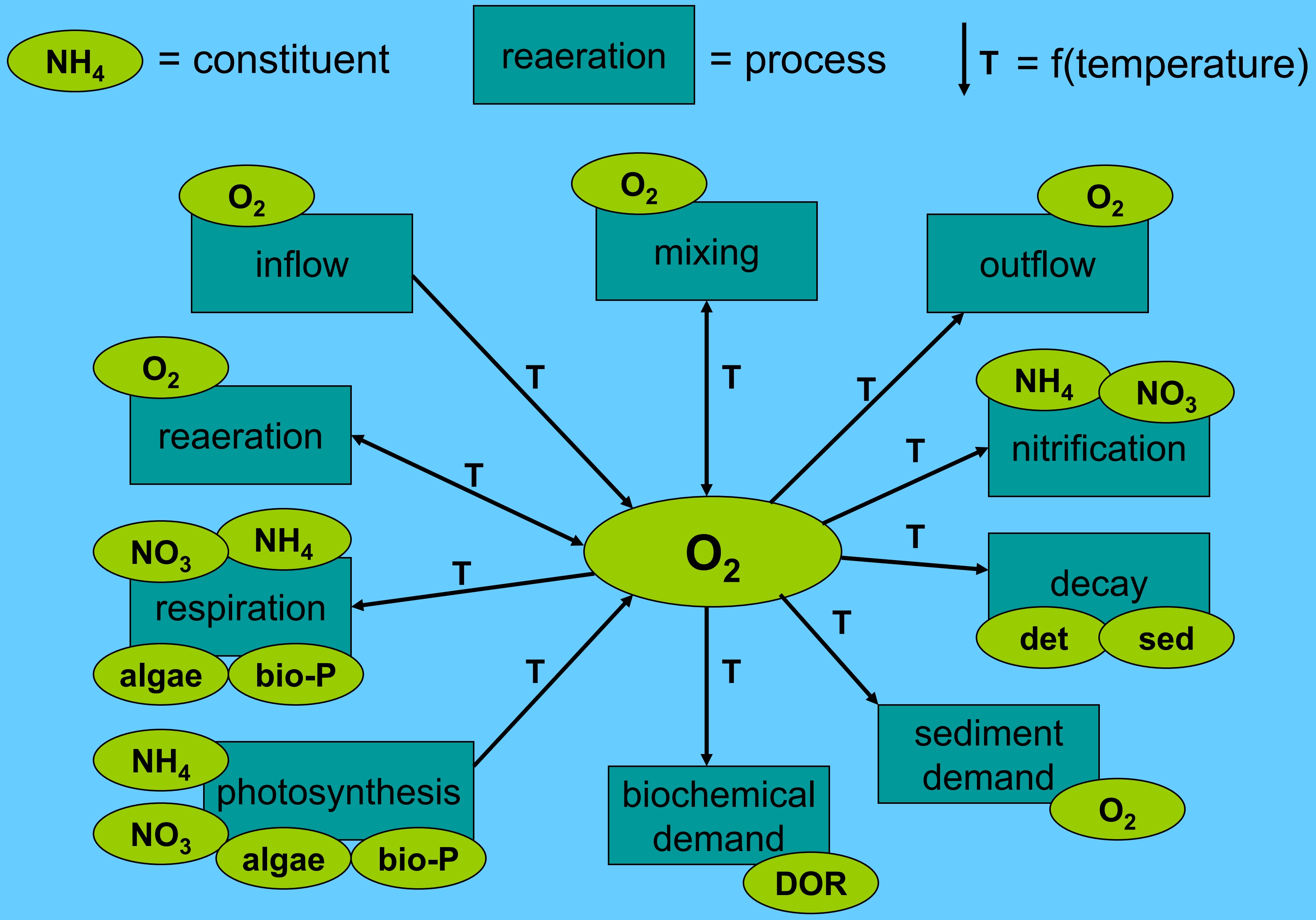
Physical processes



Biochemical processes



Highly coupled constituents



Overview of Findings for Fishery Issues

- Nutrient loads are the primary cause for impacts to striped bass habitat, blue-back herring entrainment, and low DO in the turbine releases.

- High flow, especially during March-June, is the primary cause for fish kills considering current nutrient loads (higher flows introduce greater mass of nutrients and organic matter to the lake, cause the bottom of the lake to warm, reducing habitat and increasing the rate of DO depletion)

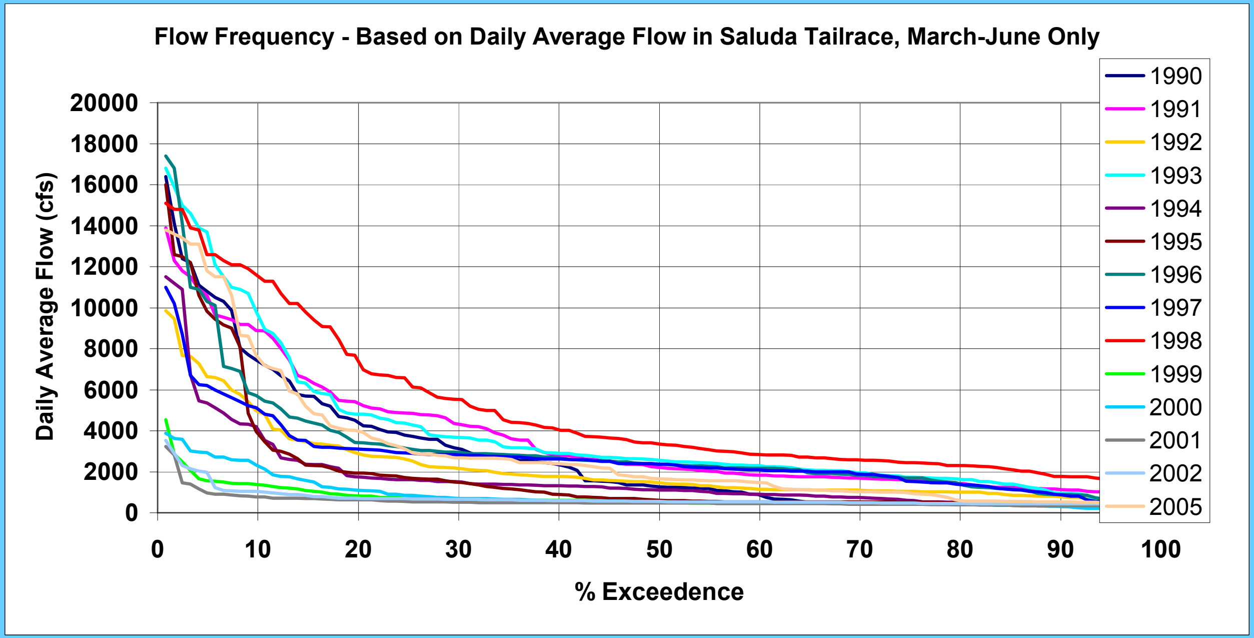
- Meteorological conditions can affect striper habitat

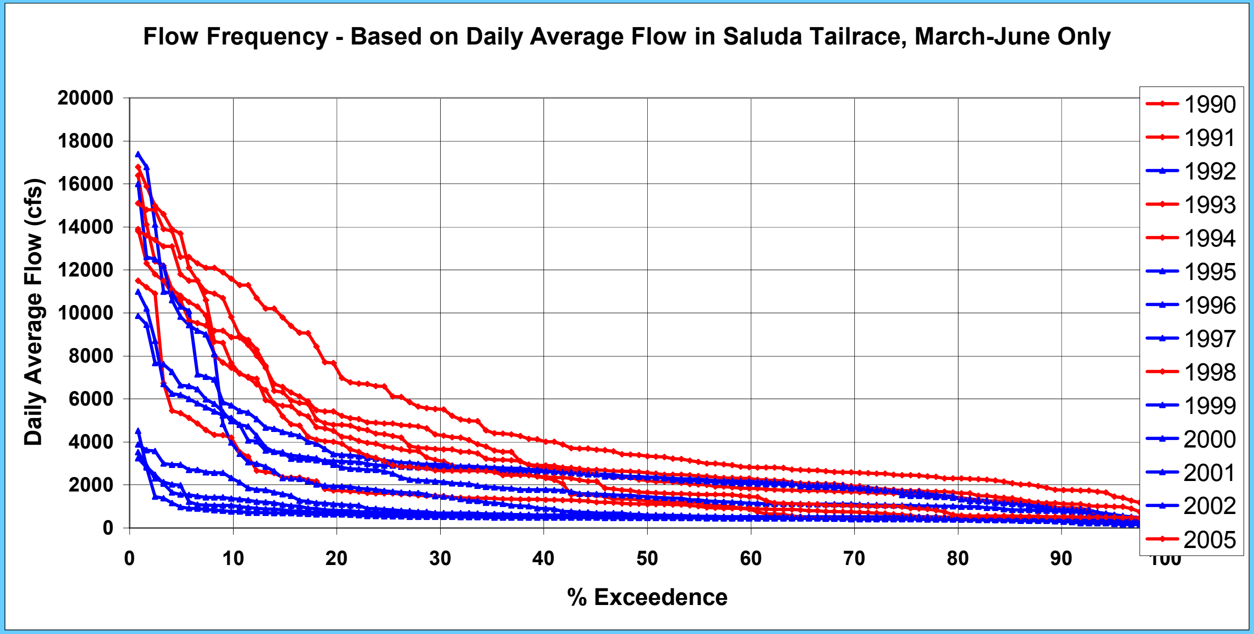
- Model results indicate that the temperature and DO range of tolerable striper habitat in Lake Murray is approximately:

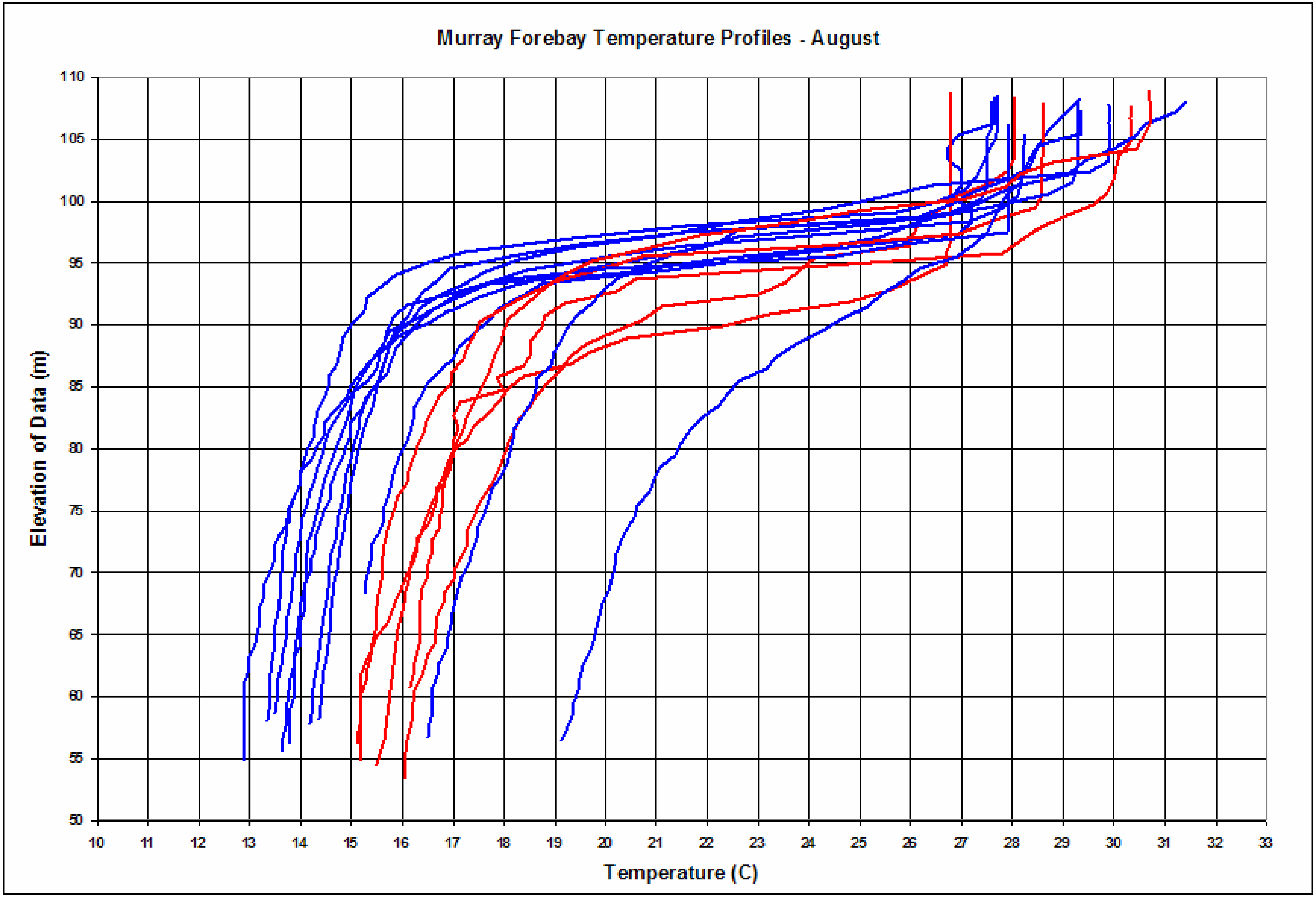
  $T < 27^{o}C$ and $DO > 2.5$ mg/l

- Higher summer pool levels and preferential use of Unit 5 helps preserve colder bottom water and was predicted to improve DO, increase striper habitat, and enhance temperature in the tailwater

Flow Frequency – Saluda River Below Lake Murray







Murray Forebay Temperature Profiles - August
Elevation of Data (m)
110
105
100
95
90
85
80
75
70
65
60
55
50
10
11
12
13
14
15
16
17
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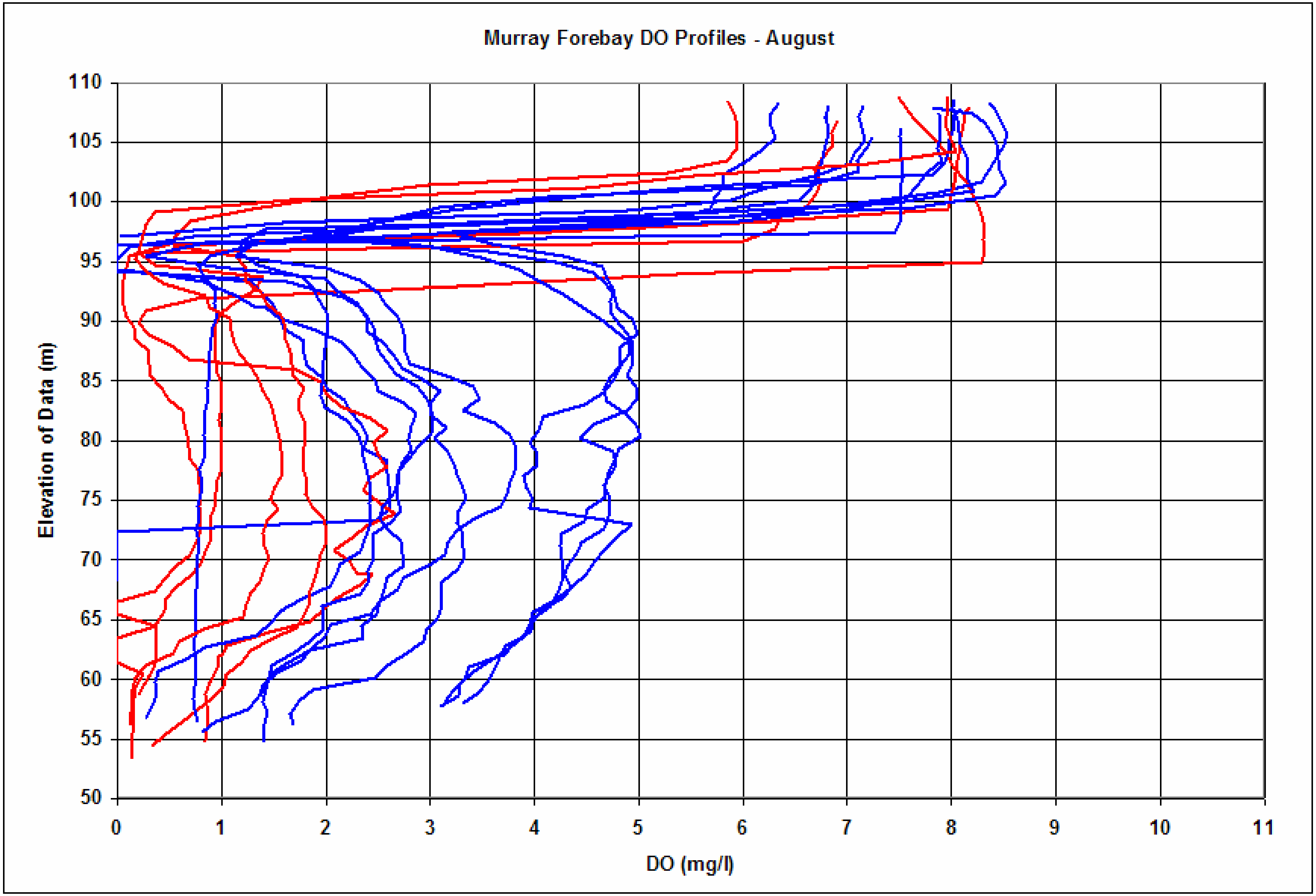
28
29
30
31
32
33
Temperature (C)



Murray Forebay DO Profiles - August
Elevation of Data (m)
110
105
100
95
90
85
80
75
70
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55
50
0
1
2
3
4
5
6
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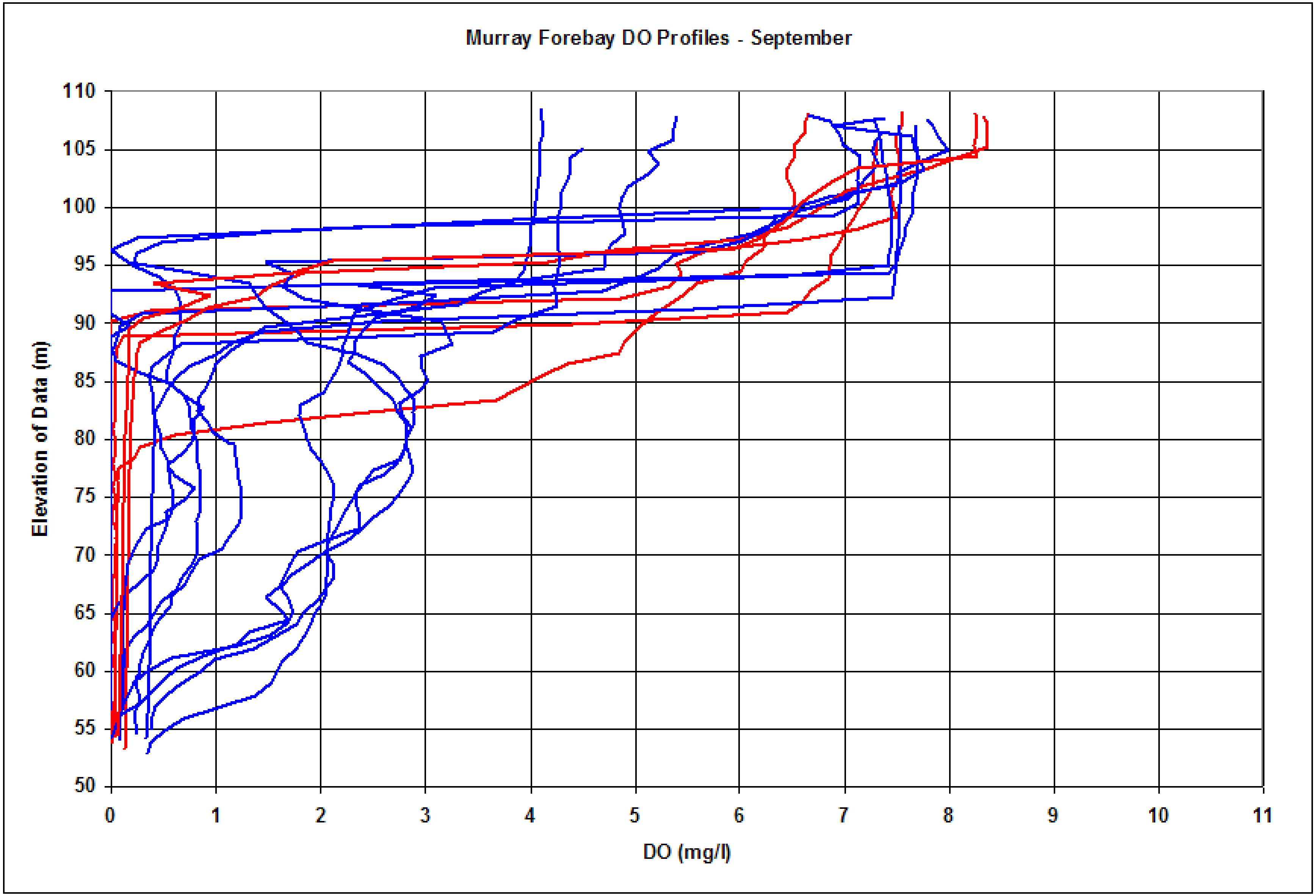
8
9
10
11
DO (mg/l)


Murray Forebay DO Profiles - September
Elevation of Data (m)
110
105
100
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85
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60
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3
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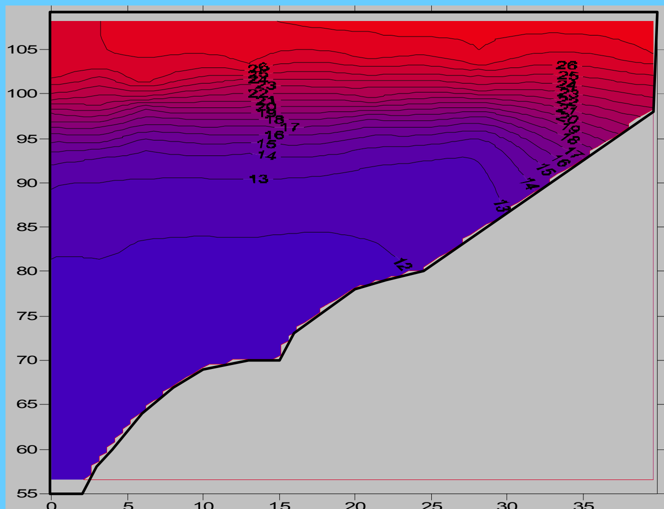
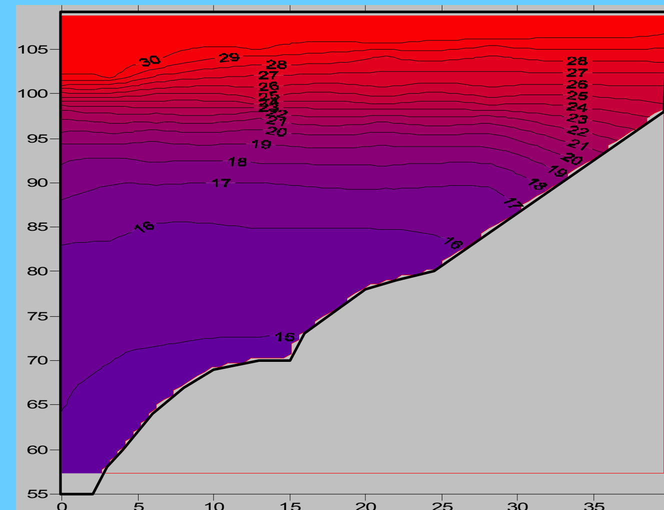
6
7
8
9
10
11
DO (mg/l)

Lake Murray Contour Plots

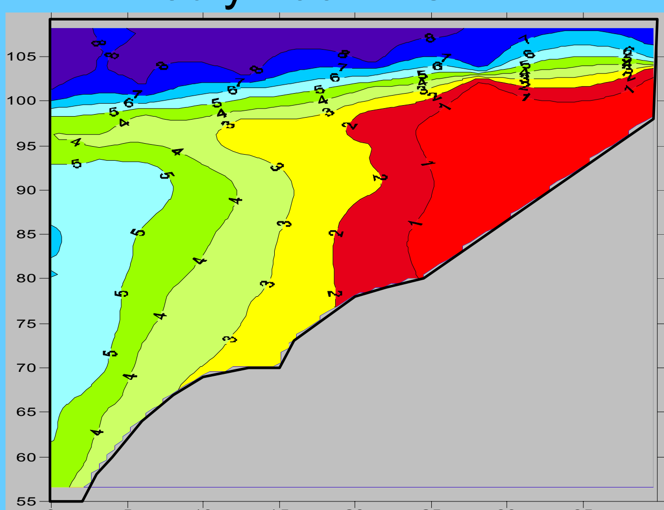
July 2002 Temperature



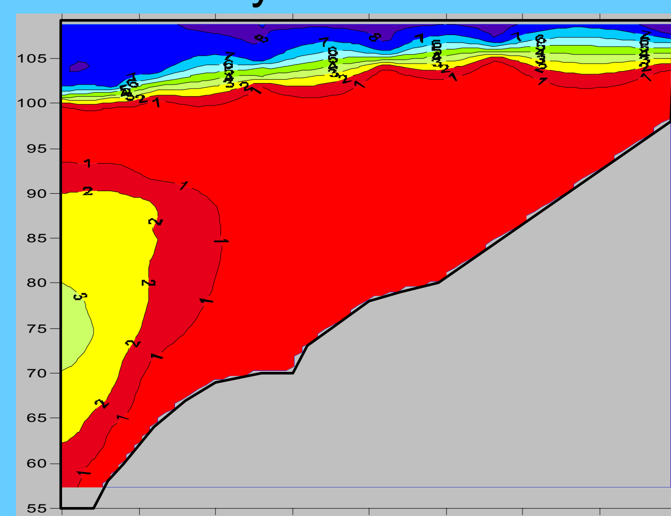
July 2005 Temperature



July 2002 DO

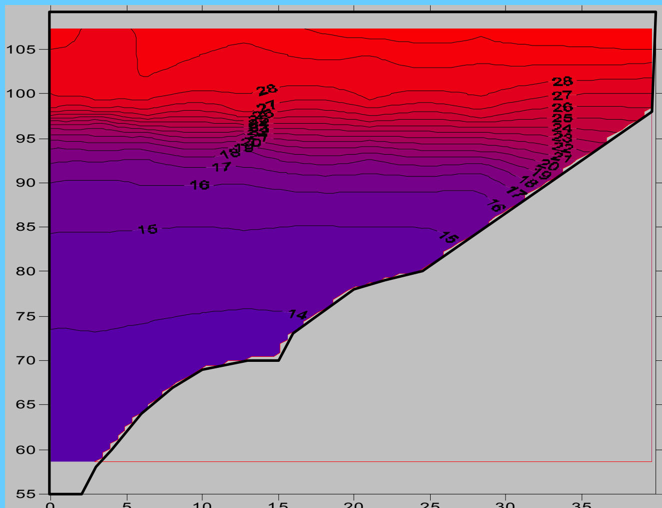


July 2005 DO

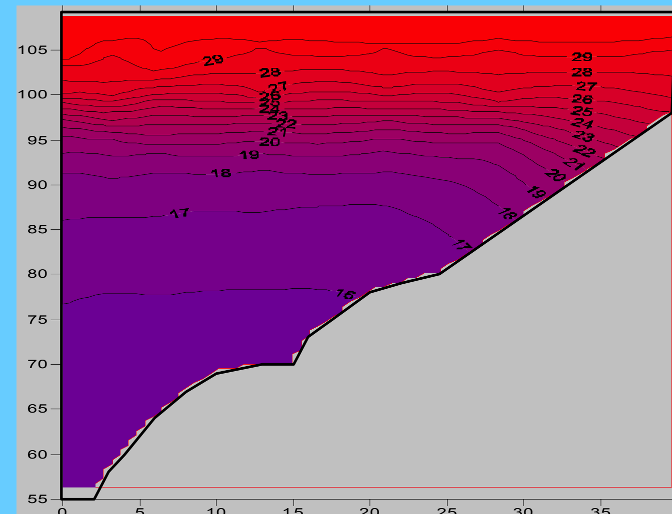


Lake Murray Contour Plots

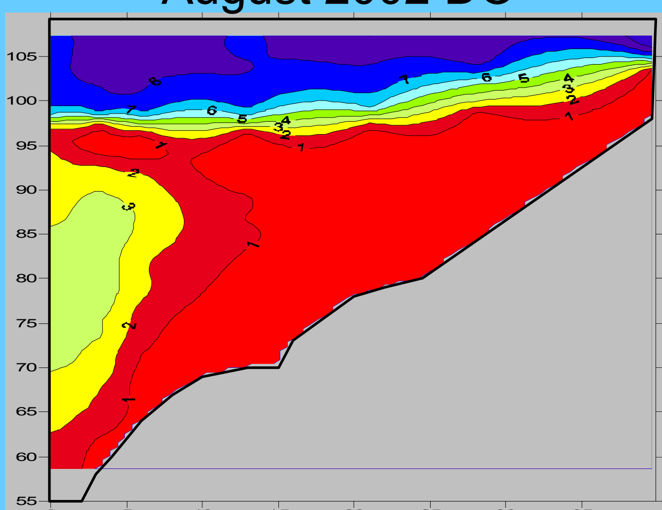
August 2002 Temperature



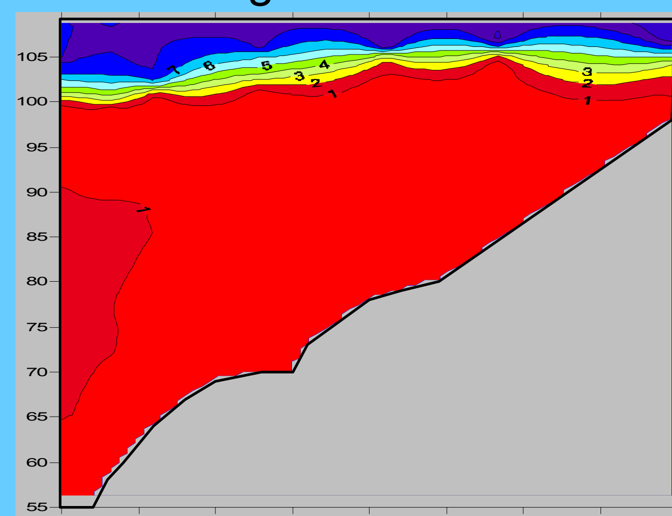
August 2005 Temperature



August 2002 DO

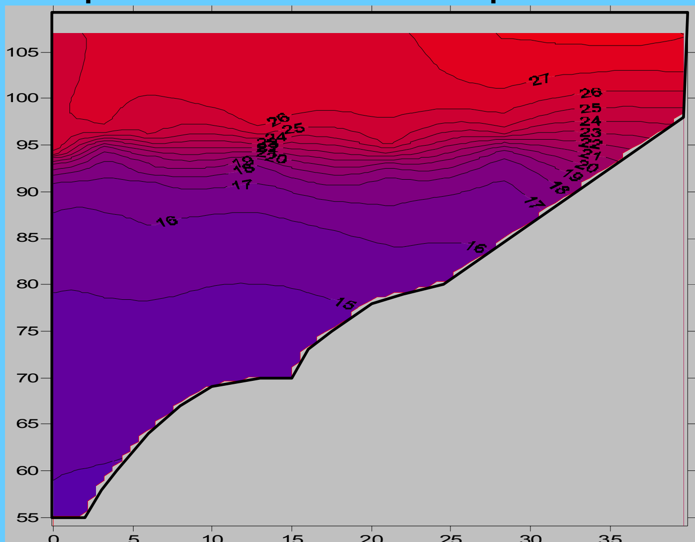


August 2005 DO

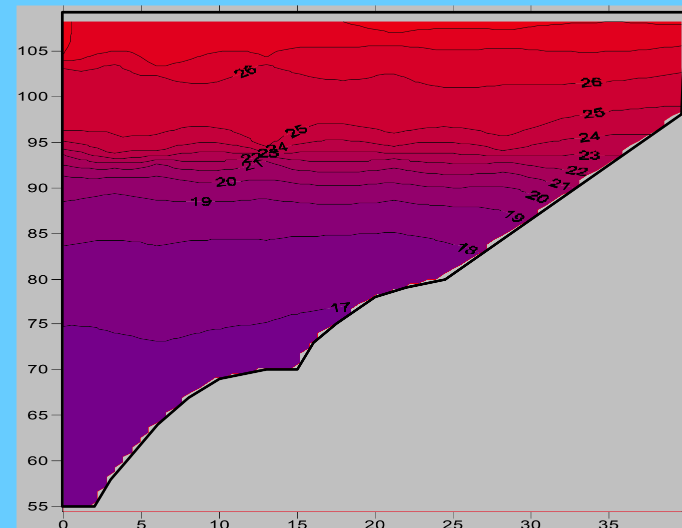


Lake Murray Contour Plots

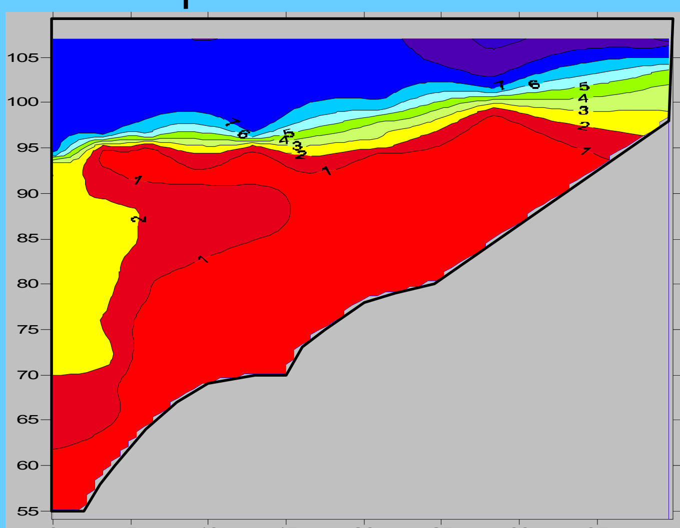
September 2002 Temperature



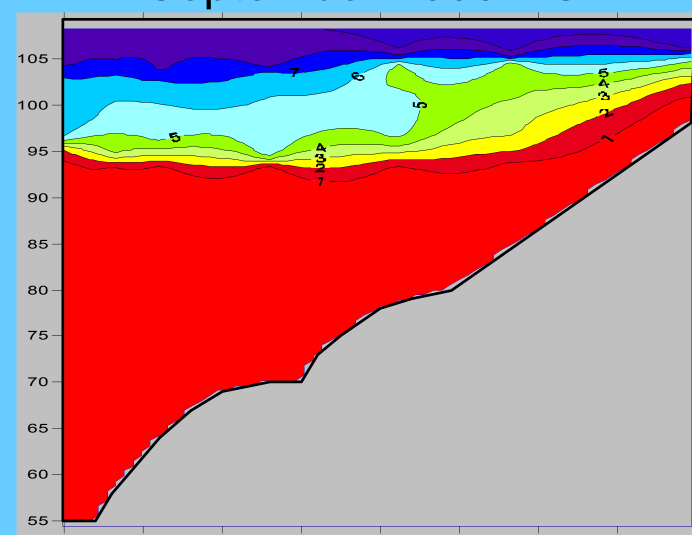
September 2005 Temperature



September 2002 DO



September 2005 DO

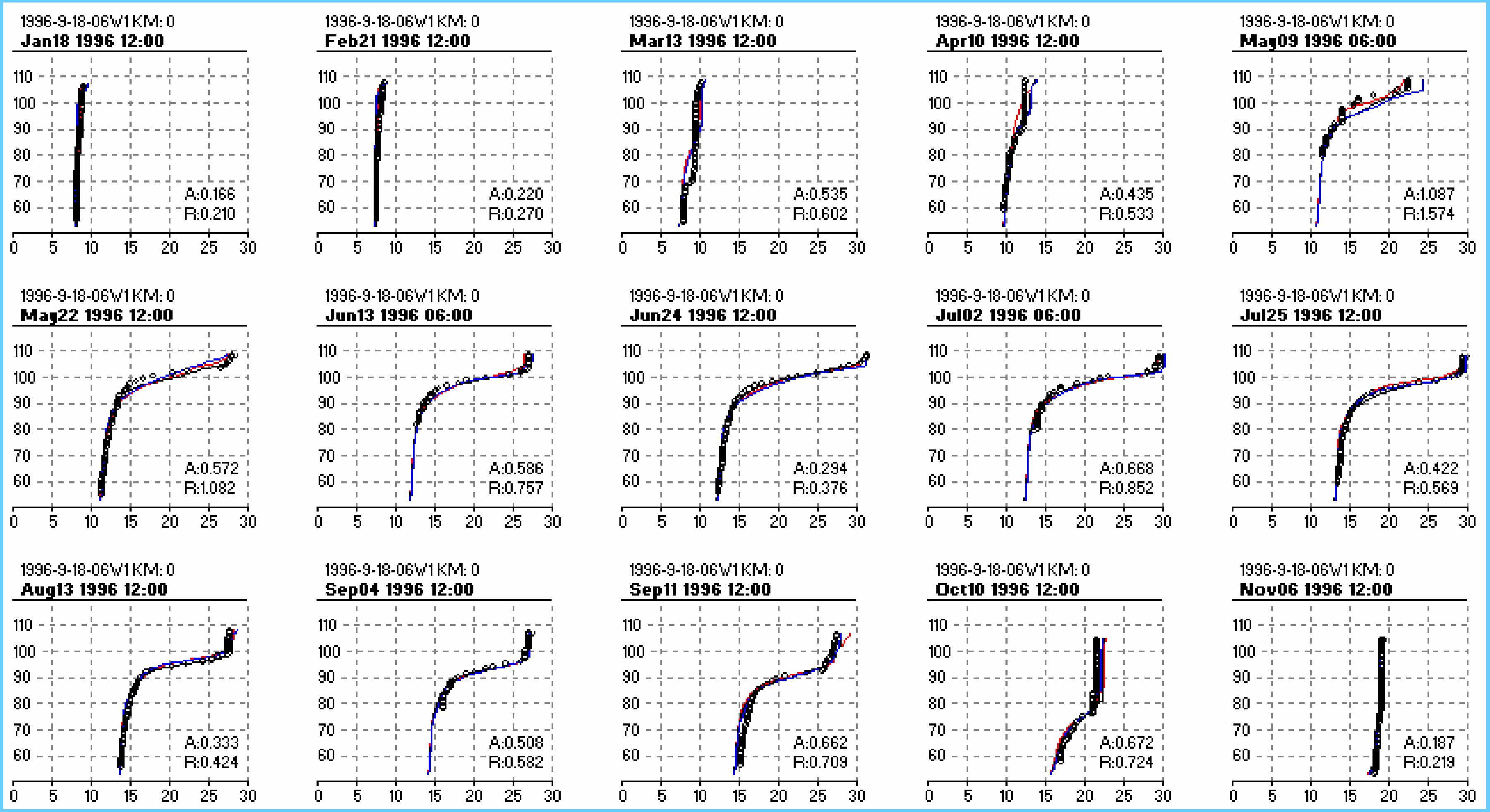


CE-QUAL-W2 Model Calibration

- Model was originally calibrated to 3 years: 1992, 1996 and 1997; then confirmed for 1991, 1998, 2000, 2001, and 2005

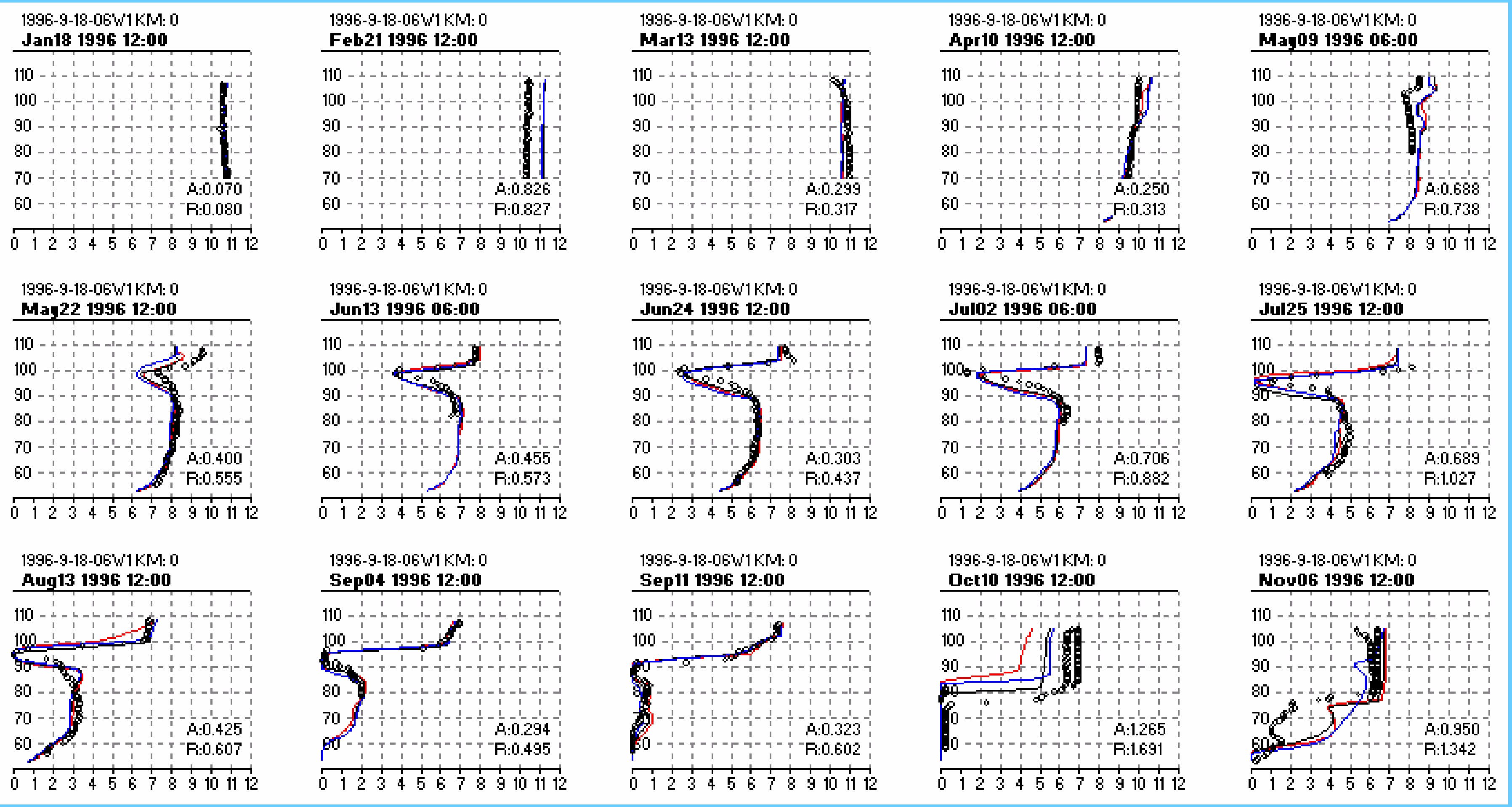
1996 Lake Murray Forebay Temperature Profiles

Model vs. Data [Overall Statistics: ABS = 0.46, RMS = 0.66]



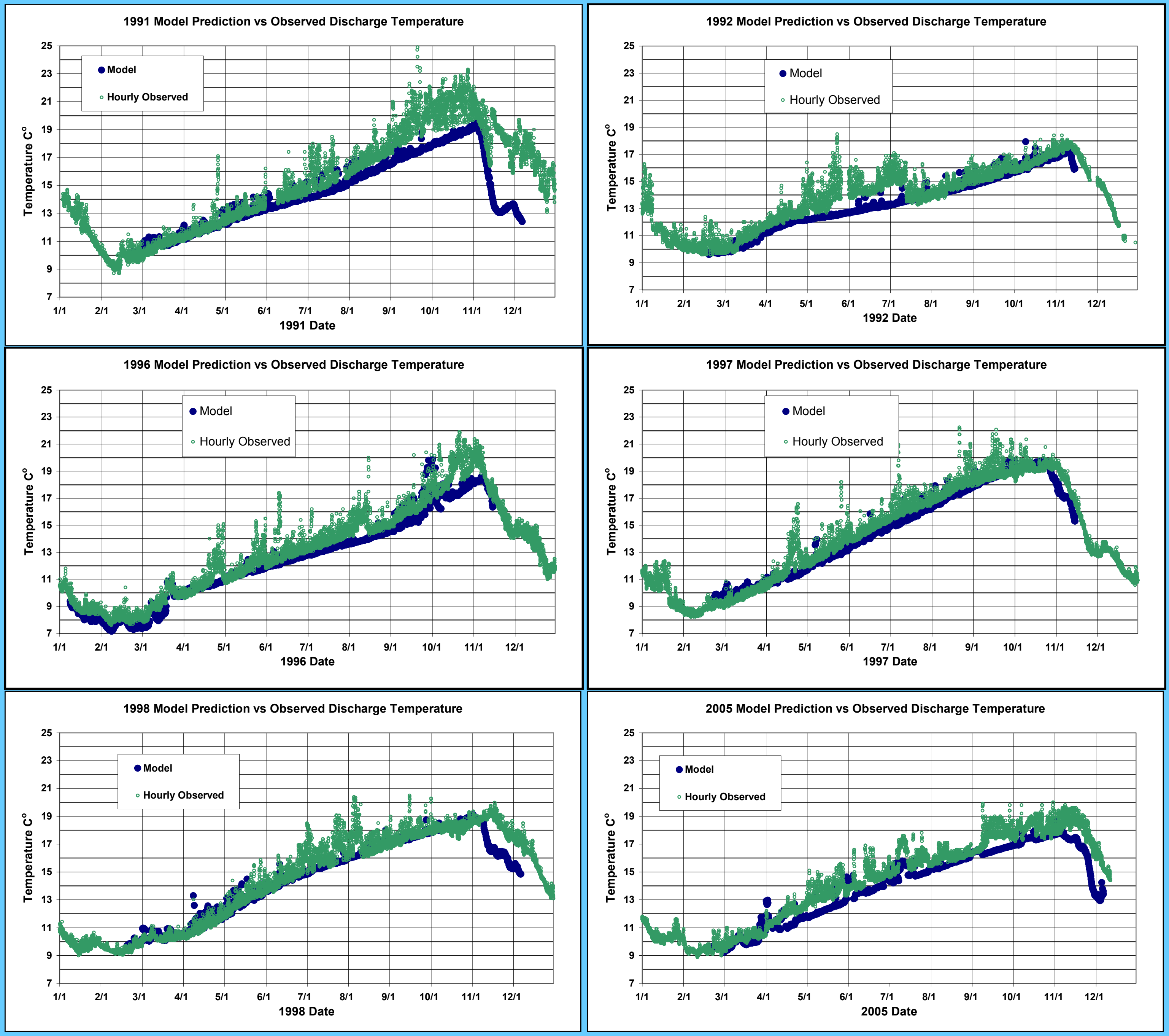
1996 Lake Murray Forebay DO Profiles

Model vs. Data [Overall Statistics: ABS = 0.57, RMS = 0.89]



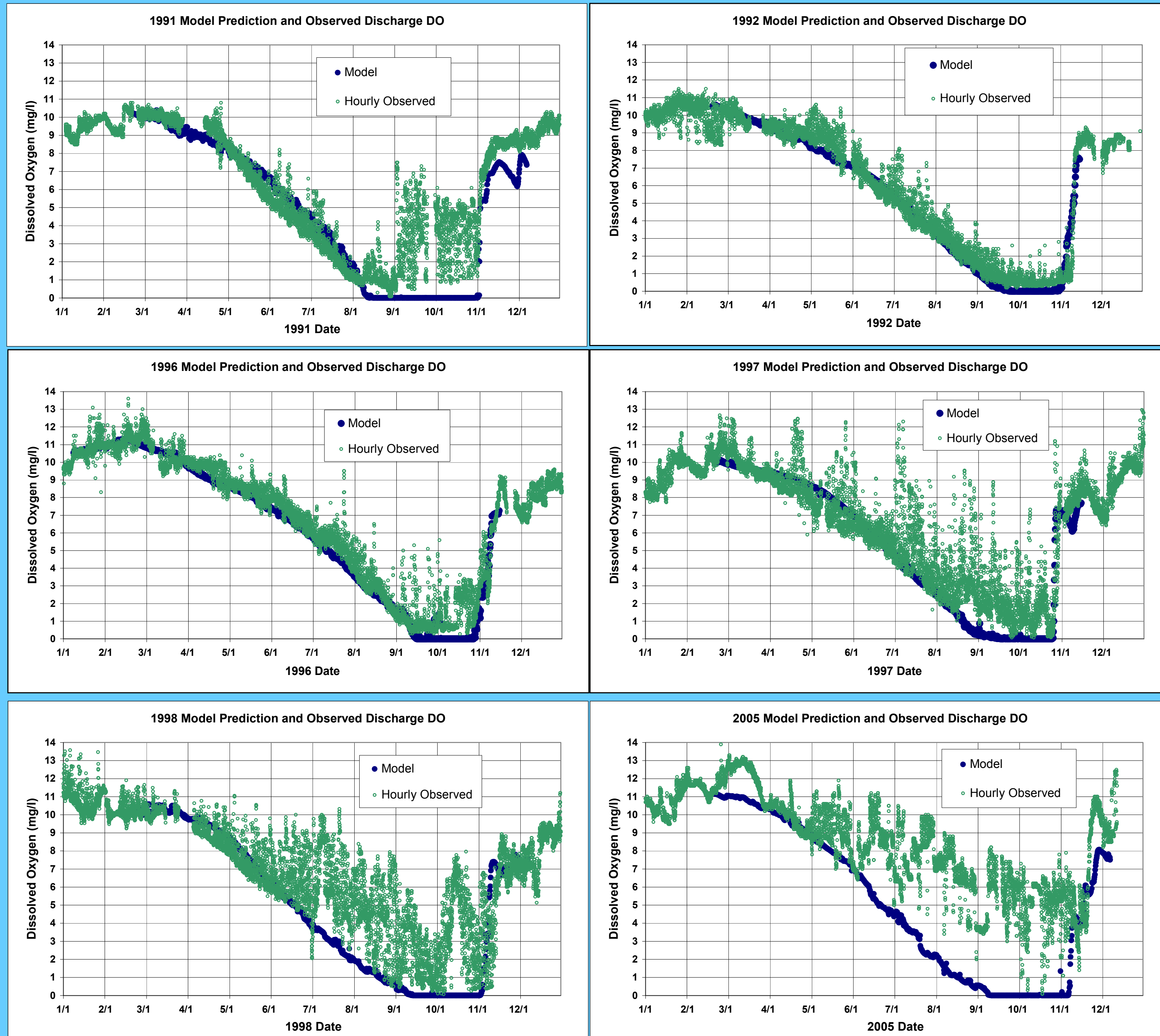
Release Temperature

Model vs. Data

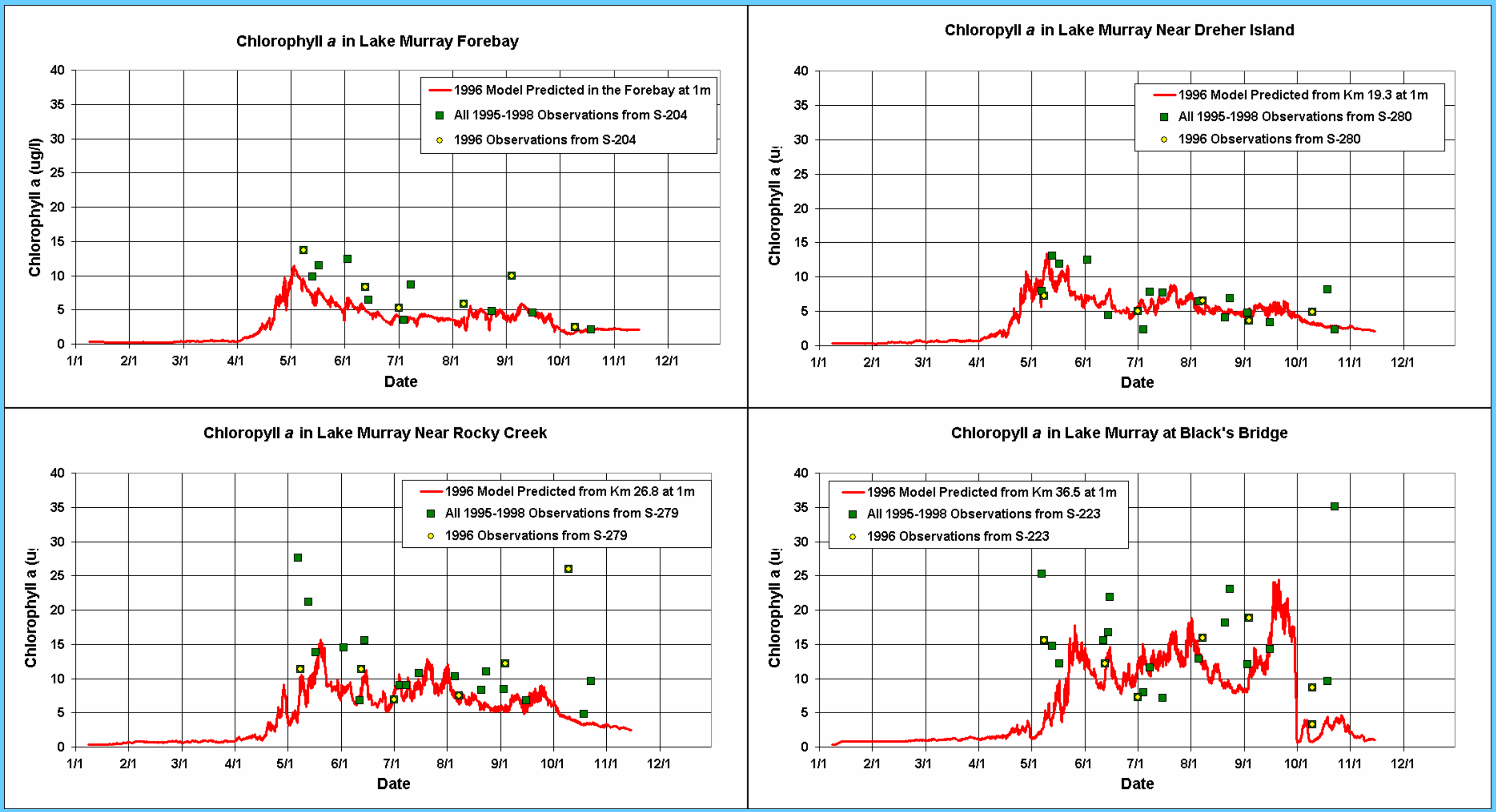


Release DO

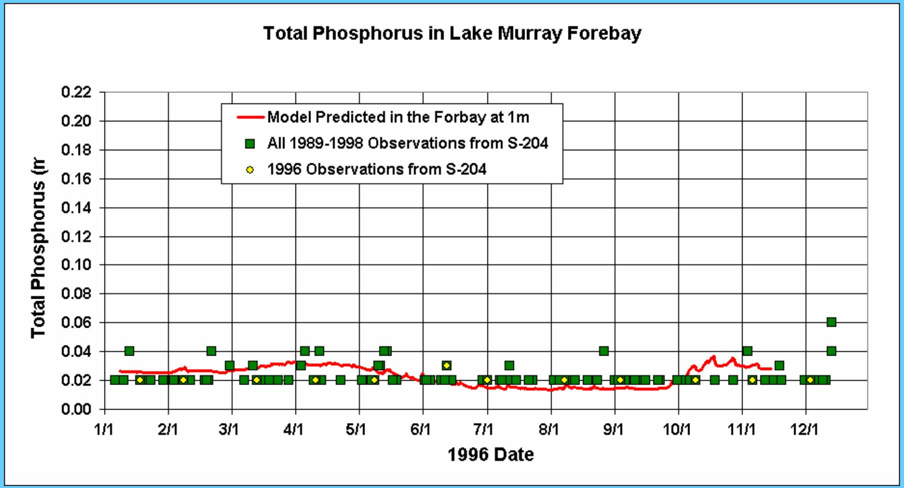
Model vs. Data

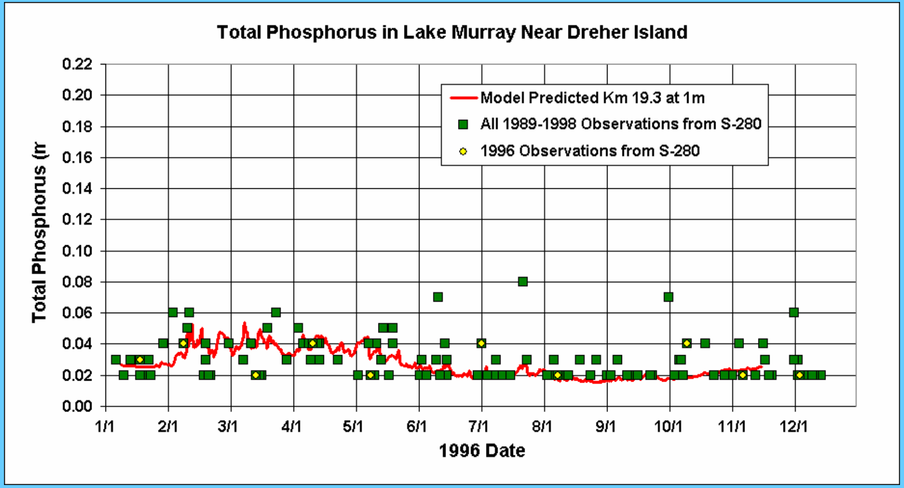


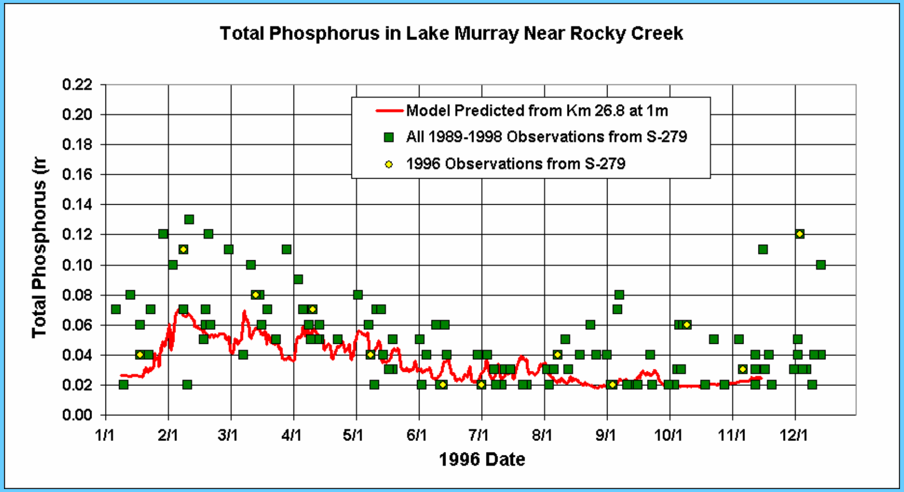
1996 Chlorophyll *a* at Four Locations in Lake Murray Model vs. Data

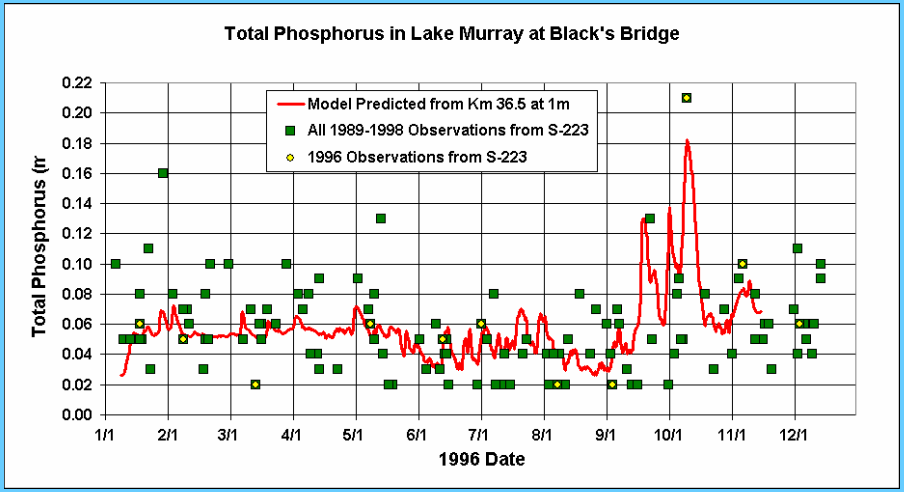


Comparison of Modeled Derived versus Measured Total Phosphorus for 1996 at Four Locations in Lake Murray



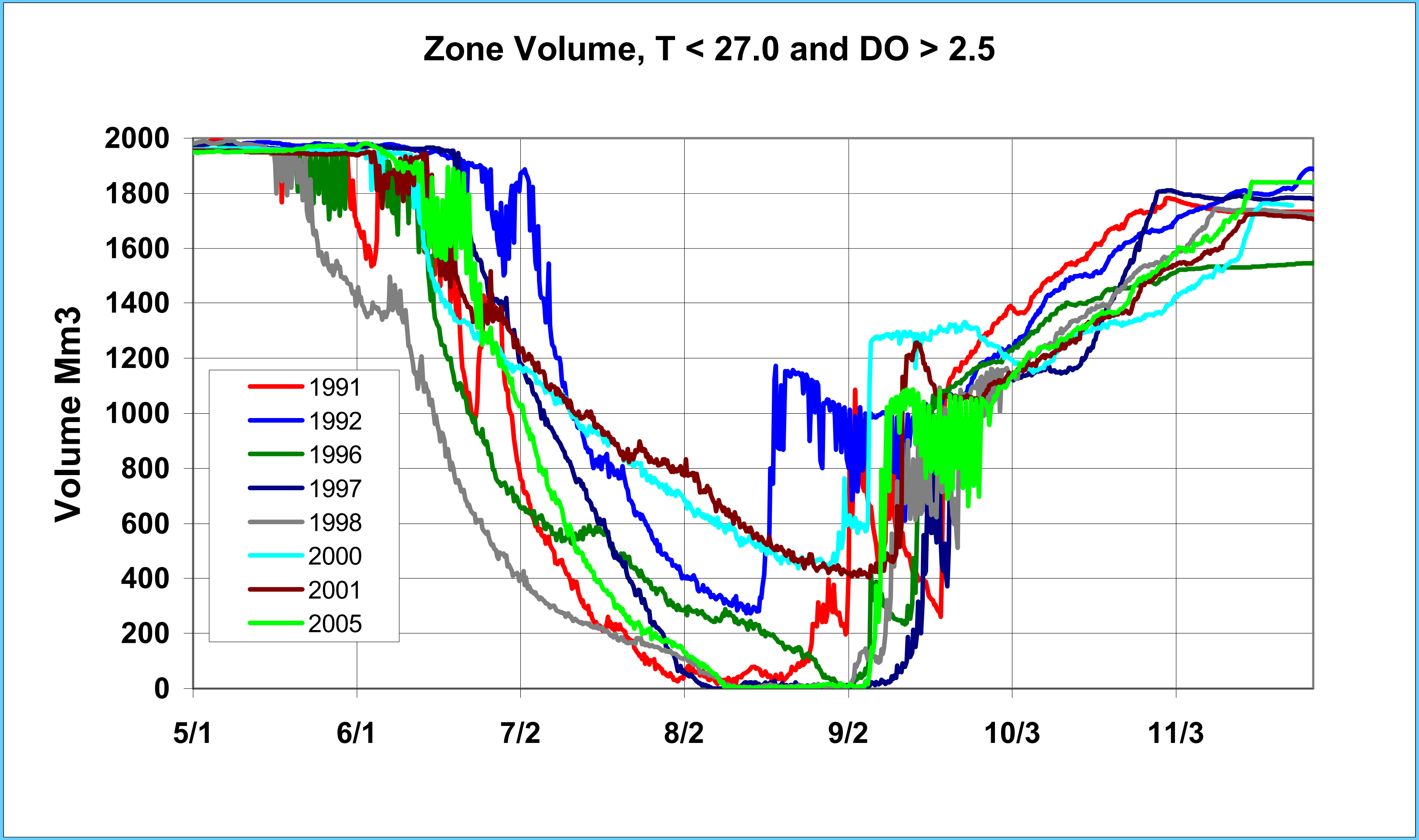






Zone Volume Plot - "Sub-optimal" Habitat

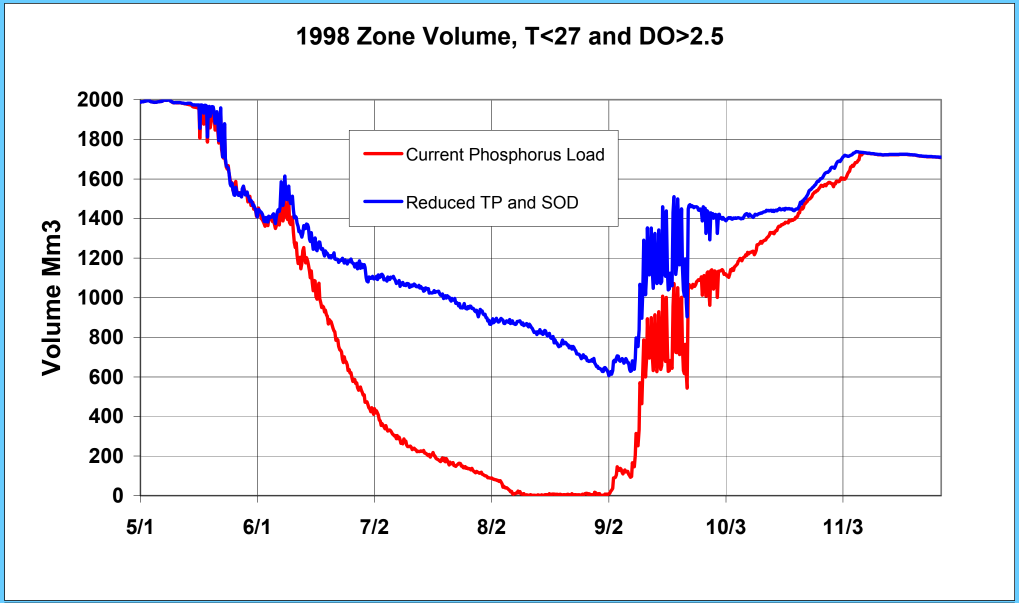
Year	Documented Dates of Fish Kills	Fish Kill Count
1991	7/19 - 8/16	3139
1998	7/30 - 8/10	456
2005	August	742

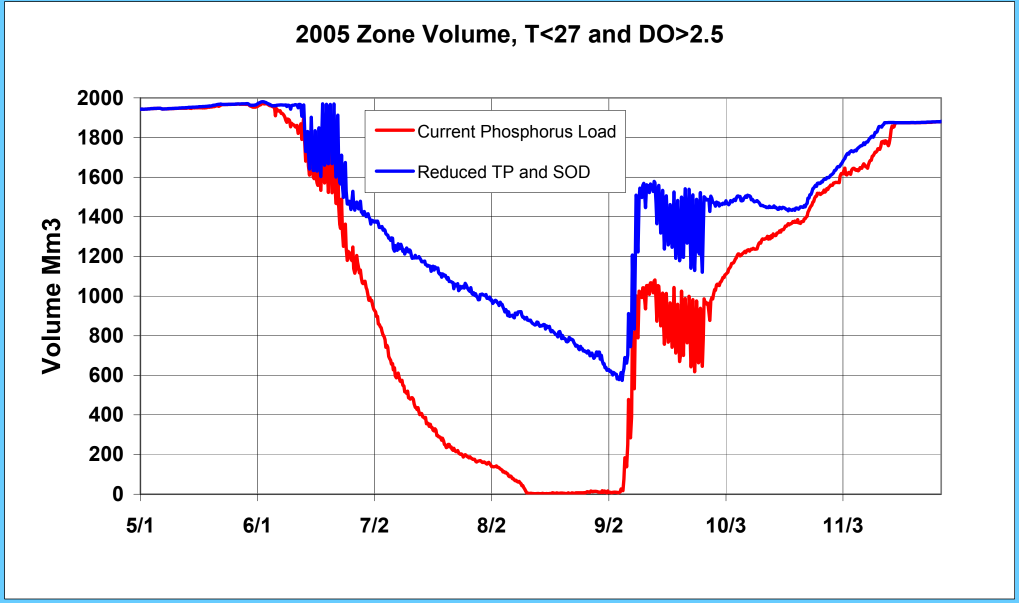


Issues Addressed by Predicting the effects of Reduced Phosphorus Using the W2 Water Quality Model

- low DO in the releases from Saluda Hydro,
- restrictions for operating Unit 5 due to entrainment of blue-back herring,
- eutrophication in the upper regions of Lake Murray,
- DO less than the State standard in the inflow regions of the lake,
- reduced striped bass habitat in the lake due to low DO in the regions of the lake where their temperature preferences occur, and
- low pH in Lower Saluda River (LSR)

Comparison of Current Phosphorus Load and Reduced Phosphorus Scenario





Relicensing Issues Identified by the Water Quality Technical Working Committee

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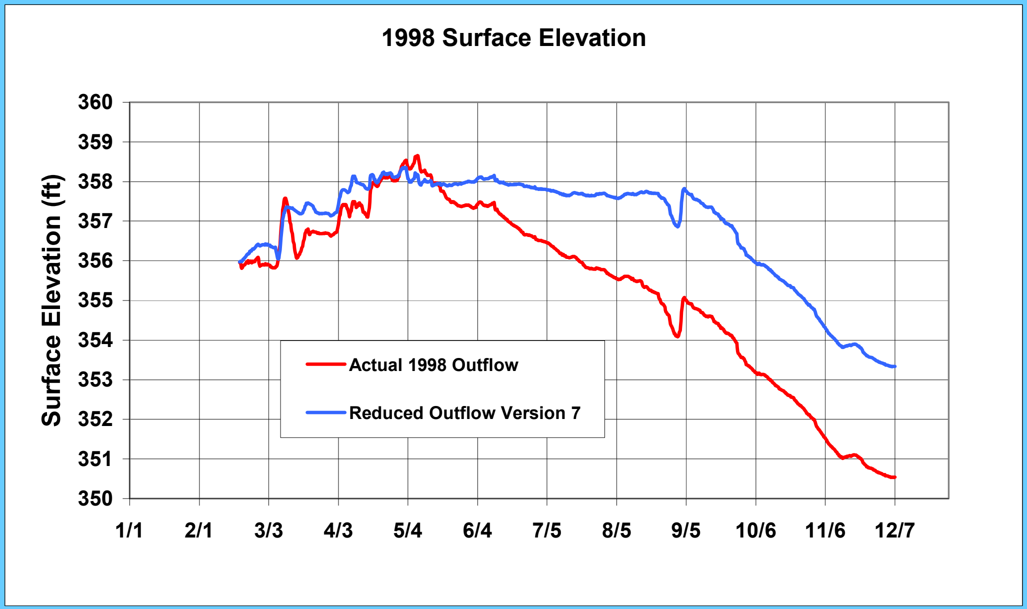
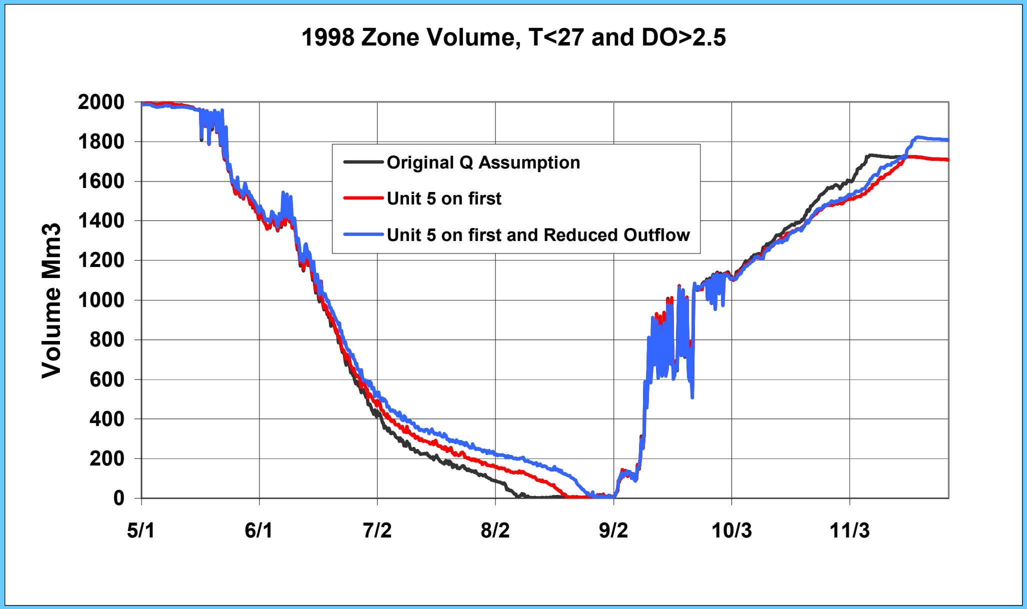
Pool Level Management with 1998 Model





Animations

1998 with and without operational enhancements—to be shown at the end as time allows

Striped Bass Habitat—Comparison of Current Operations and Promising Operational Changes

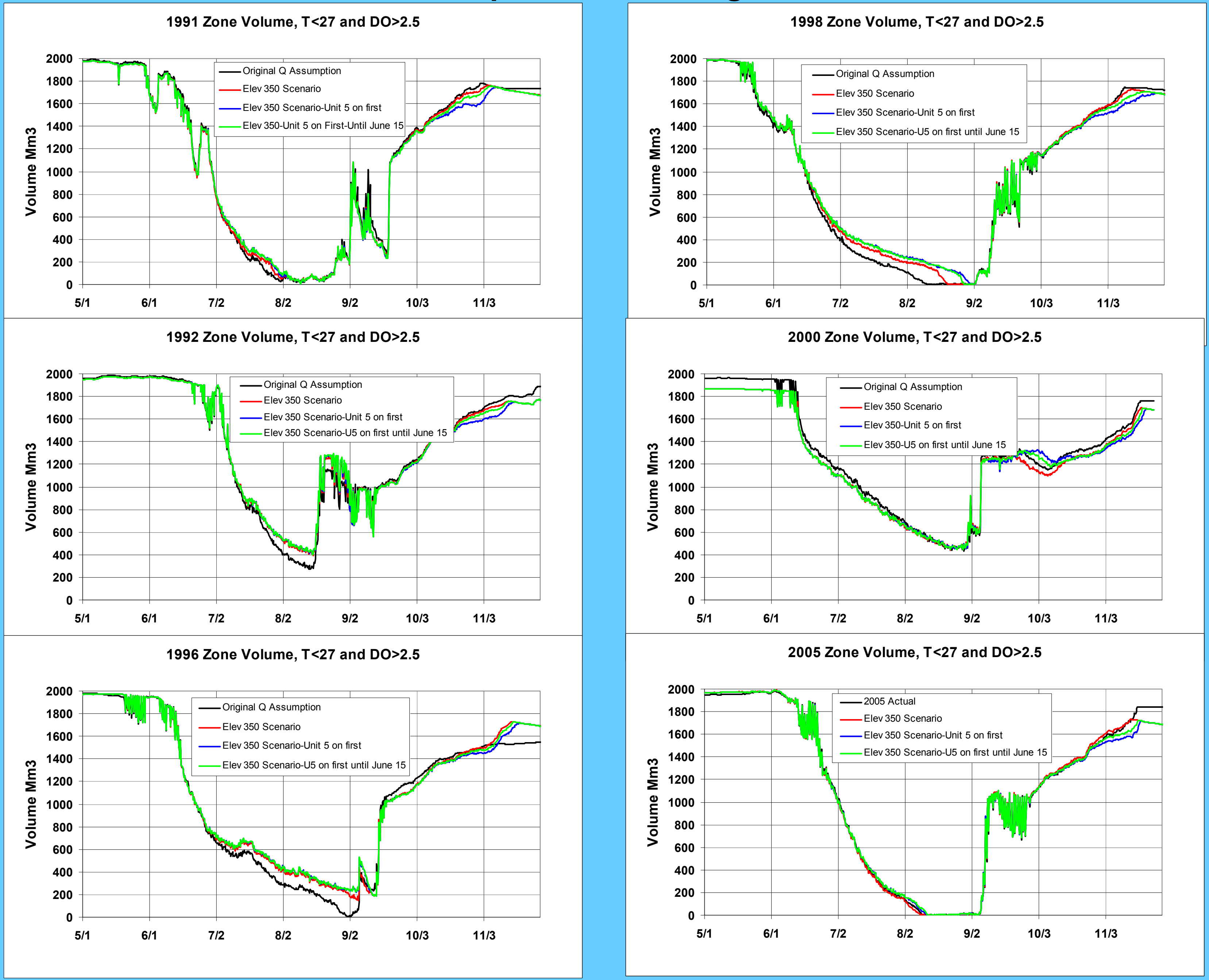
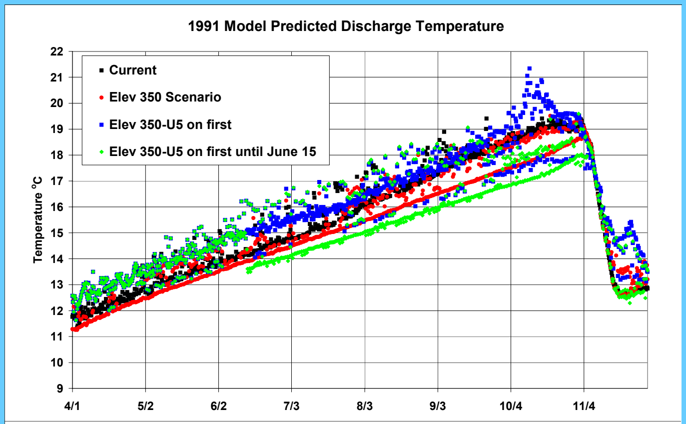
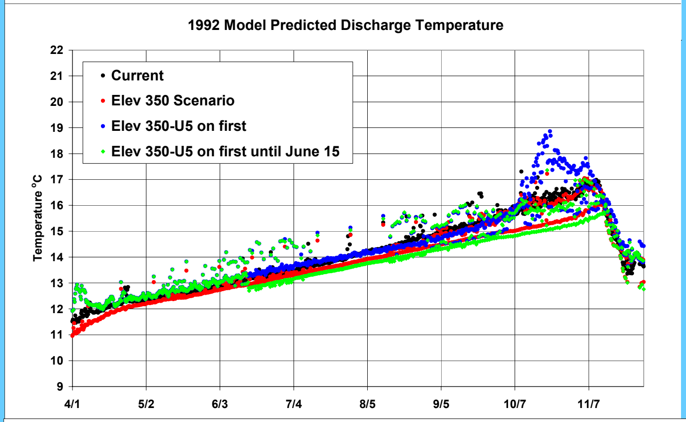


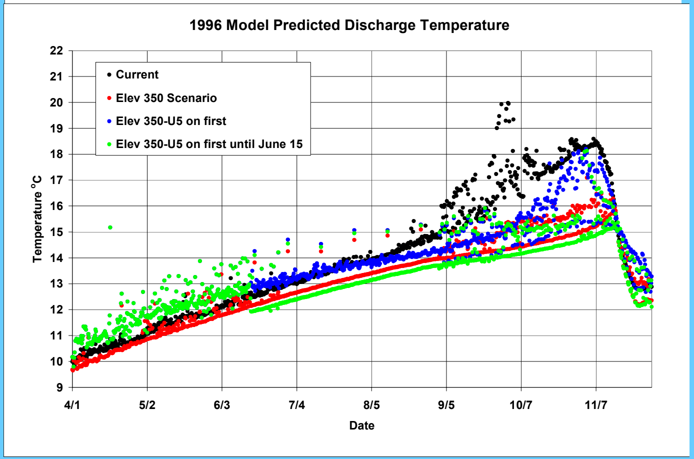
Table 4-1. Temperature increases in the tailwater between Saluda Hydro and the USGS monitor at Columbia.

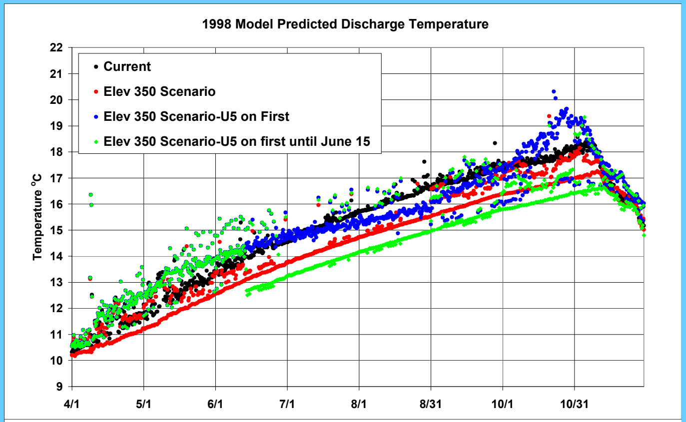
Generation levels and months of operation	Mean temperature increase, ^oC	Mean temperature increase + 2*Std Deviation, ^oC
Less than 1000 cfs, May-Sept	3.2	6.4
2500-3000 cfs, May-Sept	1.3	2.9
5000-6000 cfs, May-Sept	1.0	2.0
2500-6000 cfs, Oct	0.7	1.5

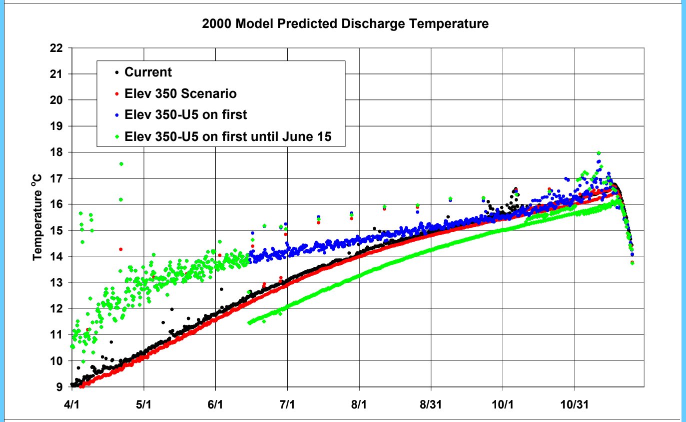
Tailwater Temperature—Comparison of Current Operations and Promising Operational Changes

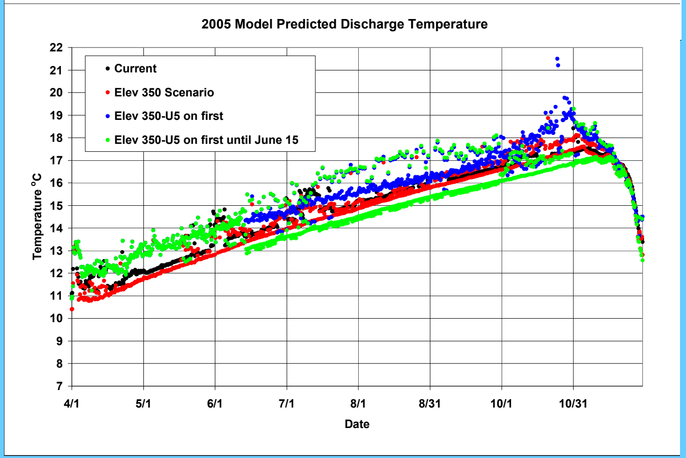












Conclusions for In-lake Water Quality and Fish Habitat

- Nutrients loads to Lake Murray are the single dominant factor that can enhance striped bass habitat
- High flow, especially during March-June, is the primary cause for fish kills, but cannot be controlled to avoid fish kills
- Model results indicate that the temperature and DO range of tolerable striper habitat in Lake Murray is approximately: $T < 27\ ^oC$ and $DO > 2.5$ mg/l
- Model results show that preferential use of Unit 5 helps preserve cooler bottom water resulting in improved DO and increased striper habitat in some years
- Maintaining the summer pool level at 358 either increases or has no effect on striped bass habitat.
- The combination of Unit 5 preferential operations and maintaining the summer pool level at 358 can further increase striped bass habitat.
- The combination of Unit 5 preferential operations and maintaining the summer pool level at 358 can improve water quality in the releases.

Recommendations for Saluda Unit Operations for Fishery Issues

The following protocol for unit operations was developed:

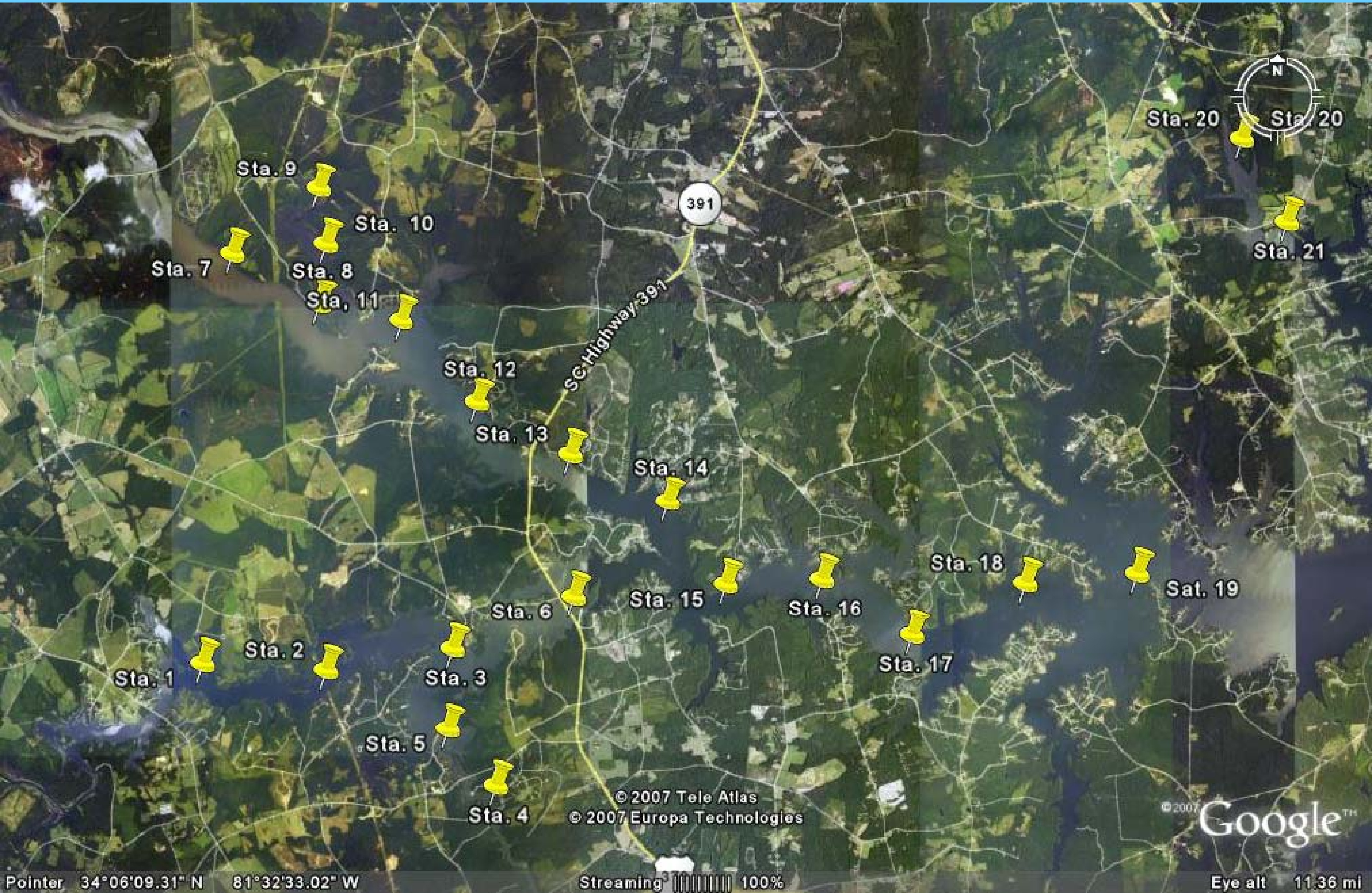
1. for minimum flows, use units 1,3,or4 June 15 thru Dec 1 and U5 for Dec 1 to June 15.
2. For generation flows (i.e., flows > minimum flow)**,** use Unit 5 preferentially for 11 months of the year: November 1 until October 1 of the following year, and use Units 1-4 preferentially in October.

Considerations About Raising the Winter Minimum Pool

- **Sediment sampling and analyses conducted in November 2007**
- **Areas of the lake that are inundated by increasing the pool level from 350’ to 354’**
- **Aquatic macrophytes**
- **Little Saluda River Embayment**
- **The likelihood to fill pool each year**

Sediment sampling and analyses on Lake Murray, November 2007

Locations of Sediment Samples



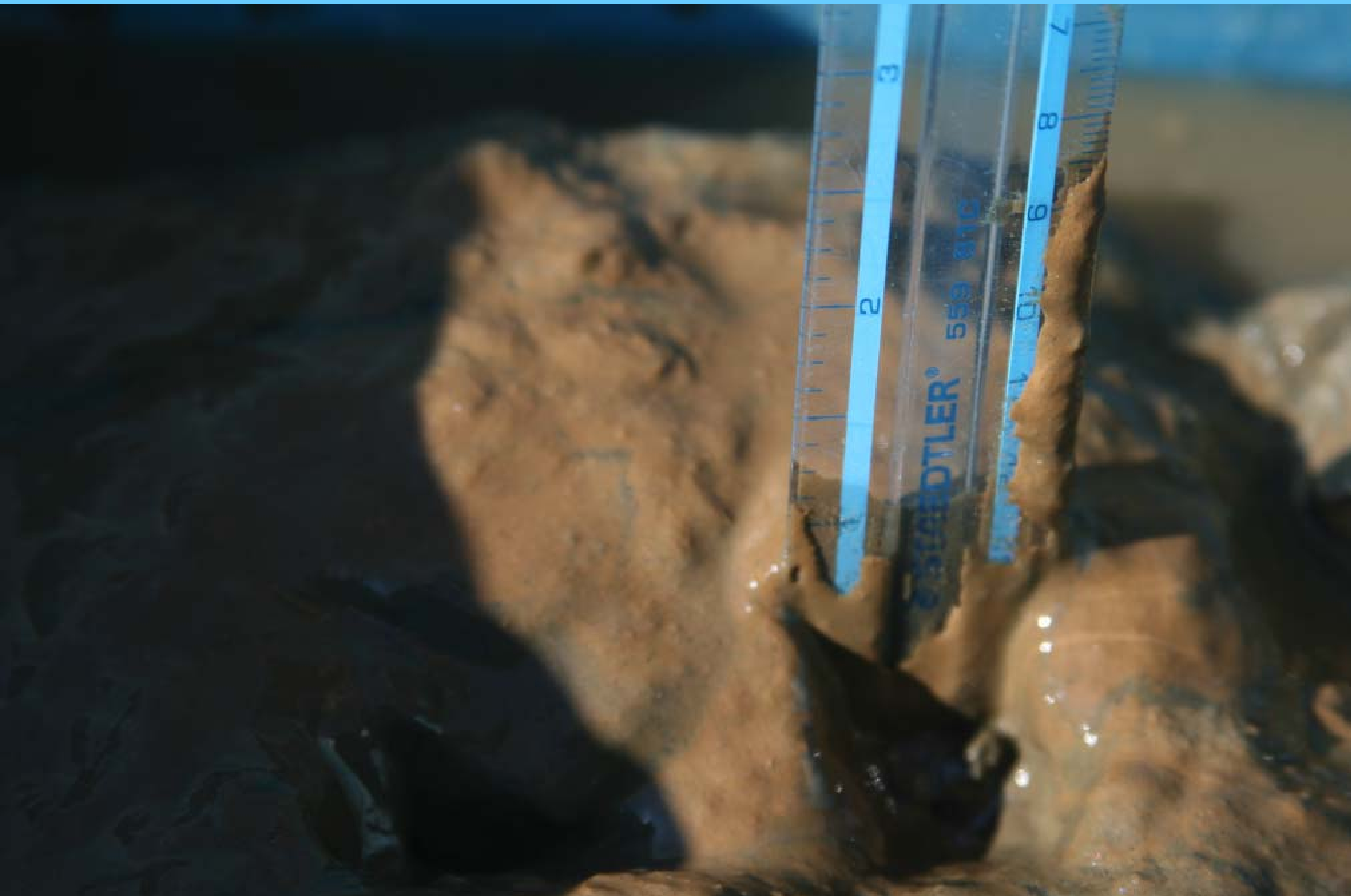
Sta. 3, LSR at Cloud Cr—ooze on top of cohesive sediment

Sta. 4, Cloud Cr inflow—ooze on top of cohesive sediment

sta 11, 2 miles below Sta 7 showing ooze on top of sample

sta 11, 2 miles below Sta 7 showing ooze scraped from top of sample

Sta. 15, 6 miles below Sta. 7



Camping Cr inflow station

Camping Creek Inflow

Results of Sampling

SampleID	CollectDate	Depth, m	Depth, ft	Ooze layer thickness, in	% Solids	% Volatile Solids	TOC	TKN	Phosphorus	Ammonia
Sta. 1Upstrm Little Saluda River	**11/15/2007**	**0.8**	**2.6**	**0.25**	**32.4**	**5.2**	**13,000**	**1,600**	**450**	**230**
Sta.2 Little Saluda River 1 Mile fr.Sta.1	11/15/2007	2.8	9.2	0.25	21.2	5.4	19,000	2,200	710	490
Sta. 3 Little Saluda R @ Mouth Clouds Cr	11/15/2007	4	13.1	0.25	20.7	7	19,000	2,300	720	380
Sta.4 Upstrm.Clouds Crk	**11/15/2007**	**0.9**	**3.0**	**0.25**	**28.8**	**6**	**13,000**	**2,100**	**450**	**260**
Sta.5 Midpt.Clouds Crk.	11/15/2007	4.3	14.1	0.25	23.8	6.6	12,000	2,200	660	550
Sta.6 200 ft above 391 Bridge	11/15/2007	8.7	28.5	0.38	16.6	7.6	25,000	2,500	1200	590
Sta.7 Upstrm.Saluda River Furtherest Pt	**11/19/2007**	**0.5**	**1.6**	**0**	**44.9**	**3.8**	**11,000**	**950**	**230**	**130**
Sta.8 Saluda River 1 mile Below Sta.7	11/19/2007	3.3	10.8	0.25	23.6	7.8	16,000	1,700	770	370
Sta.9 Bush River Furtherest Upstream	**11/19/2007**	**0.9**	**3.0**	**0.25**	**37.7**	**4.8**	**15,000**	**1,500**	**670**	**200**
Sta.10 Midpoint Bush River	11/19/2007	1.6	5.2	0.31	30.7	6.9	19,000	2,400	840	300
Sta.11 Saluda River 2 miles below Sta.7	11/19/2007	5	16.4	0.38	21.9	9.7	19,000	3,000	900	360
Sta.12 Saluda River 3 miles below Sta.7	11/19/2007	5.5	18.0	0.38	22.4	8.9	13,000	2,000	770	340
Sta.13 Saluda Rvr.4 miles downstrm Sta.7	11/19/2007	7.6	24.9	0.38	18.3	10	*6,600*	2,700	1100	440
Sta.14 Saluda Rvr.5 miles downstrm Sta.7	11/20/2007	6.4	21.0	0.62	48.8	*2.7*	29,000	*580*	260	100
Sta.15 Saluda Rvr.6 miles downstrm Sta.7	11/20/2007	8	26.2	0.88	21.3	8.6	35,000	1,600	970	350
Sta.16 Saluda Rvr.7 miles downstrm Sta.7	11/20/2007	9.9	32.5	0.88	30.3	6.6	22,000	1,600	770	330
Sta.17 Saluda Rvr.8 miles downstrm Sta.7	11/20/2007	15	49.2	1	21.3	9.7	22,000	2,300	1100	440
Sta.18 Saluda Rvr.9 miles downstrm Sta.7	11/20/2007	17	55.8	1.5	27.4	12	34,000	2,000	940	330
Sta.18 Saluda Rvr.9 miles downstrm Sta.7	11/20/2007				27.4	12	34,000	2,000	940	330
Sta.19 Saluda Rvr.10 miles below Sta.7	11/20/2007	18.8	61.7	2.75	23.3	9.7	25,000	2,700	980	510
Sta.20 Camping Cr Furtherest Upsteam	**11/20/2007**	**0.5**	**1.6**	**0**	**41.3**	**8**	***31,000***	**1,400**	**210**	**220**
Sta.21 Camping Crk 1 mi below Loc.20	11/20/2007	5	16.4	0.38	31.4	6.1	26,000	2,100	240	290
Mean values for inflow sites					**37.0**	**5.6**	***13,000***	**1,510**	**402**	**208**
Mean values for in-lake sites					25.3	*8.4*	*23,063*	*2,206*	816	382
Percent Increase between inflow sites and in-lake sites					**-32**	**51**	**77**	**46**	**103**	**84**

Observations about sediment survey on Lake Murray

NOTE: two inflow stations had zero ooze, and no ooze was observed on the exposed shoreline sediments

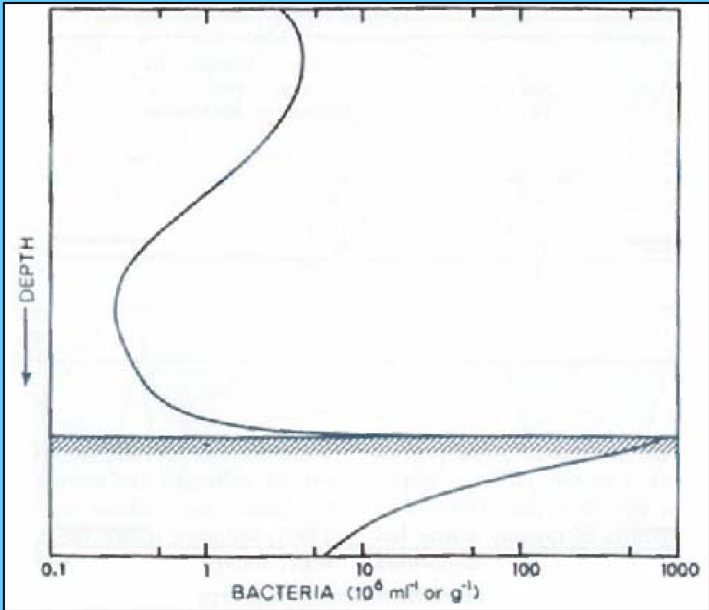
NOTE: the first location downstream from the inflow points increased in TOC, P, TKN showing that there would be more accumulation of org matter nearer the surface of the lake unless the pool drops more and allows this matter to redeposit deeper into the lake

		Carbon 45 40	Nitrogen 7 7	Phosphorus 1 1	
labile stoichiometry	C = 45	**C/N**	**6.4**	**45**	**C/P**
labile stoichiometry	C = 40	**C/N**	**5.7**	**40**	**C/P**
data for inflows		**C/N**	**8.6**	**32.3**	**C/P**
data for in-lake sites		**C/N**	**10.5**	**28.3**	**C/P**
			still labile, but less than in typical water column		

Effects of Sediment Processes on Water Quality

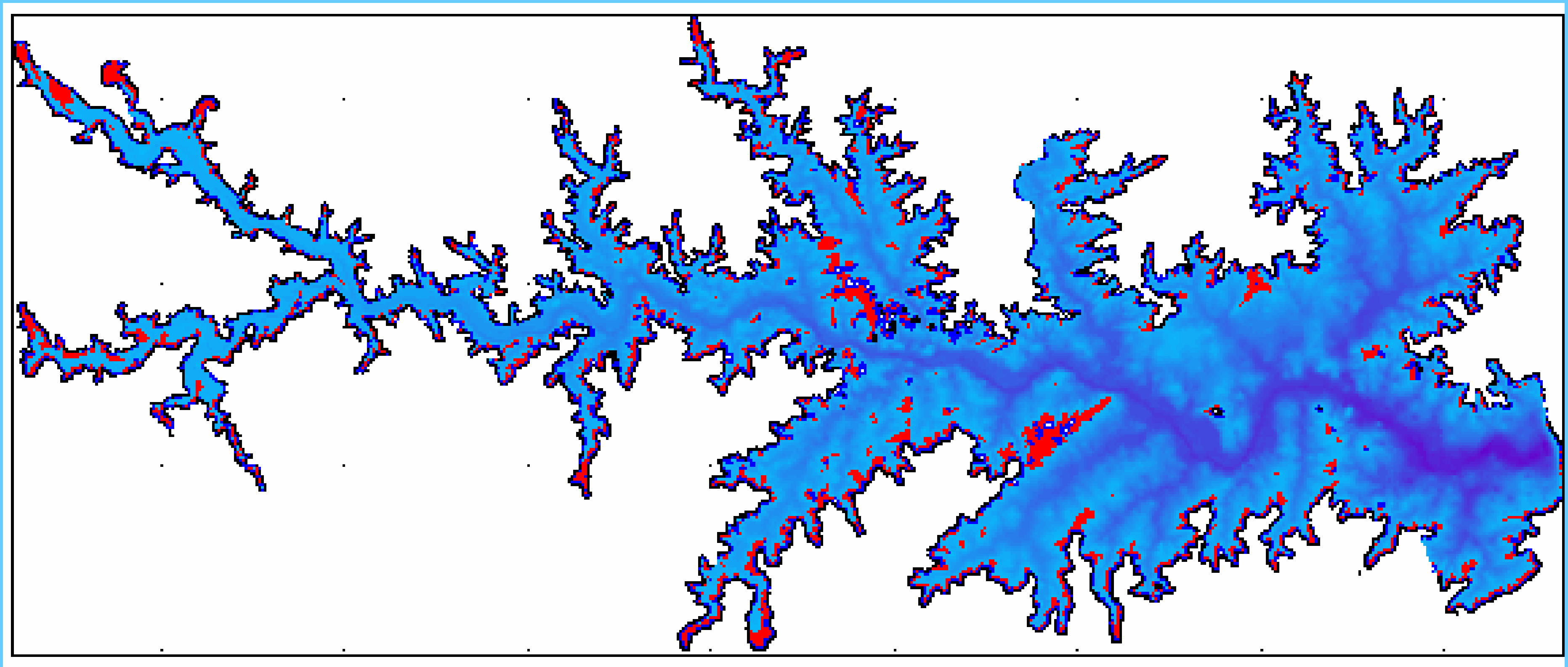
- The sediment/water interface usually is the area of highest rates for biochemical processes
- Shallow water areas are impacted more than deep water areas due to less volume of water over the sediments
- Organic matter created by algal growths and aquatic weeds settles to the sediments where it decomposes and releases phosphorus and nitrogen back into the water column
- The ooze layer in the upper part of Lake Murray is labile, so the biochemical process rates are high
- Commonly used water quality models do not account for shoreline ecosystem processes

- Bacterial activity is proportional to organic matter concentrations
- Organic matter levels are proportional to the amount of algae and plant growth in areas of lakes, especially littoral areas
- Numbers of bacteria are lower in organic-poor, wave swept areas of the lake
- The rates of nutrient cycling from sediments to overlying water is proportional to organic matter and the number of bacteria

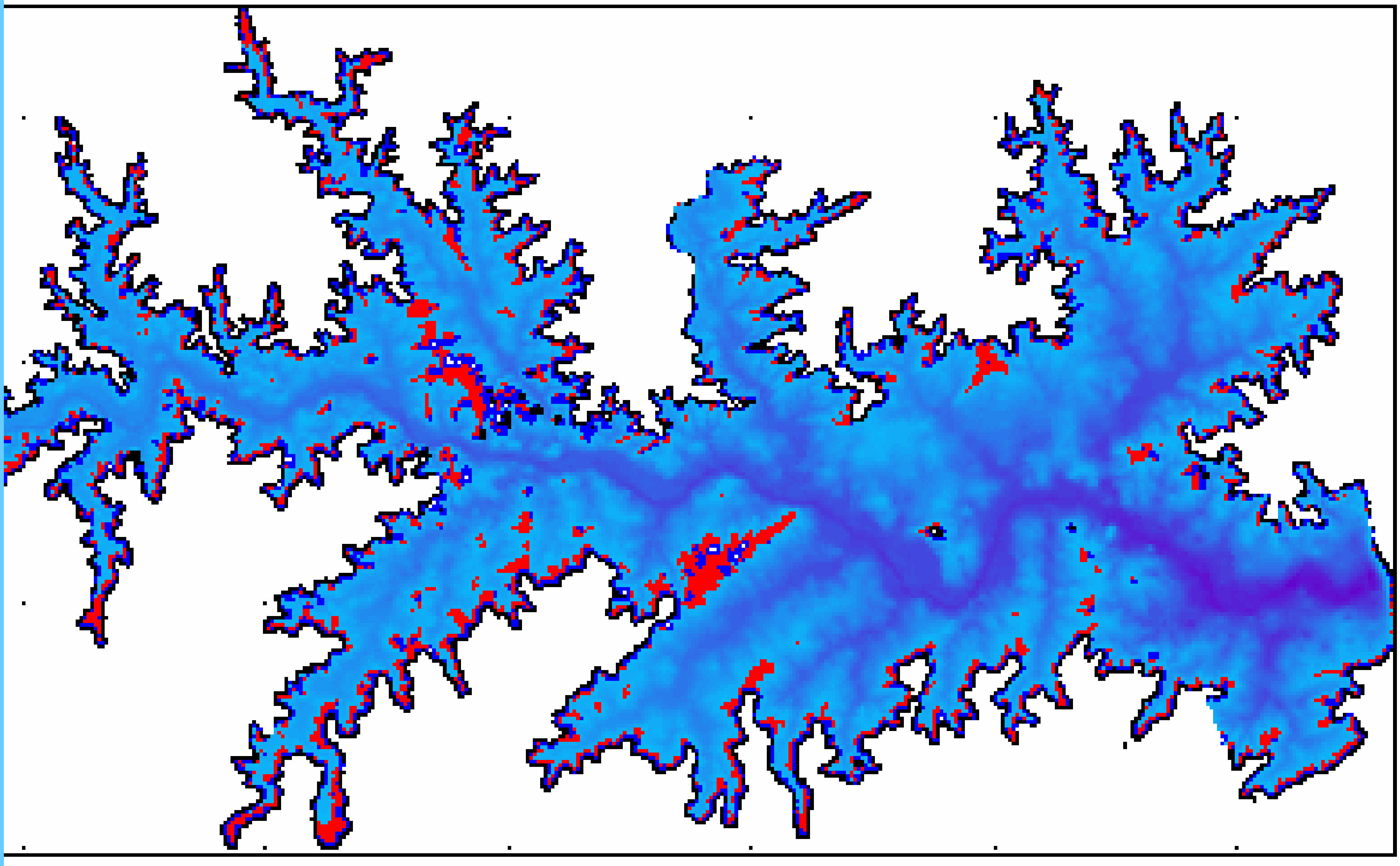


Map of Lake Murray showing the area of the lake between elevations 350 ft and 354 ft. When the minimum pool elevation in the winter is at 350 ft, the red regions of the lake are exposed. If the minimum pool elevation in the winter was raised to 354 ft, the red areas would no longer be exposed. The red regions are a concern if the minimum pool is raised to 354 ft: 1. aquatic weeds are likely to take root in some of these areas and not be controlled by winter freeze conditions; 2. sediment would accumulate in these areas since deposition would be increased and erosion would be reduced, especially those areas where tributaries enter the lake; 3. algal growths would increase in embayments because more phosphorus would be released from the lake sediments, especially in the Spring.

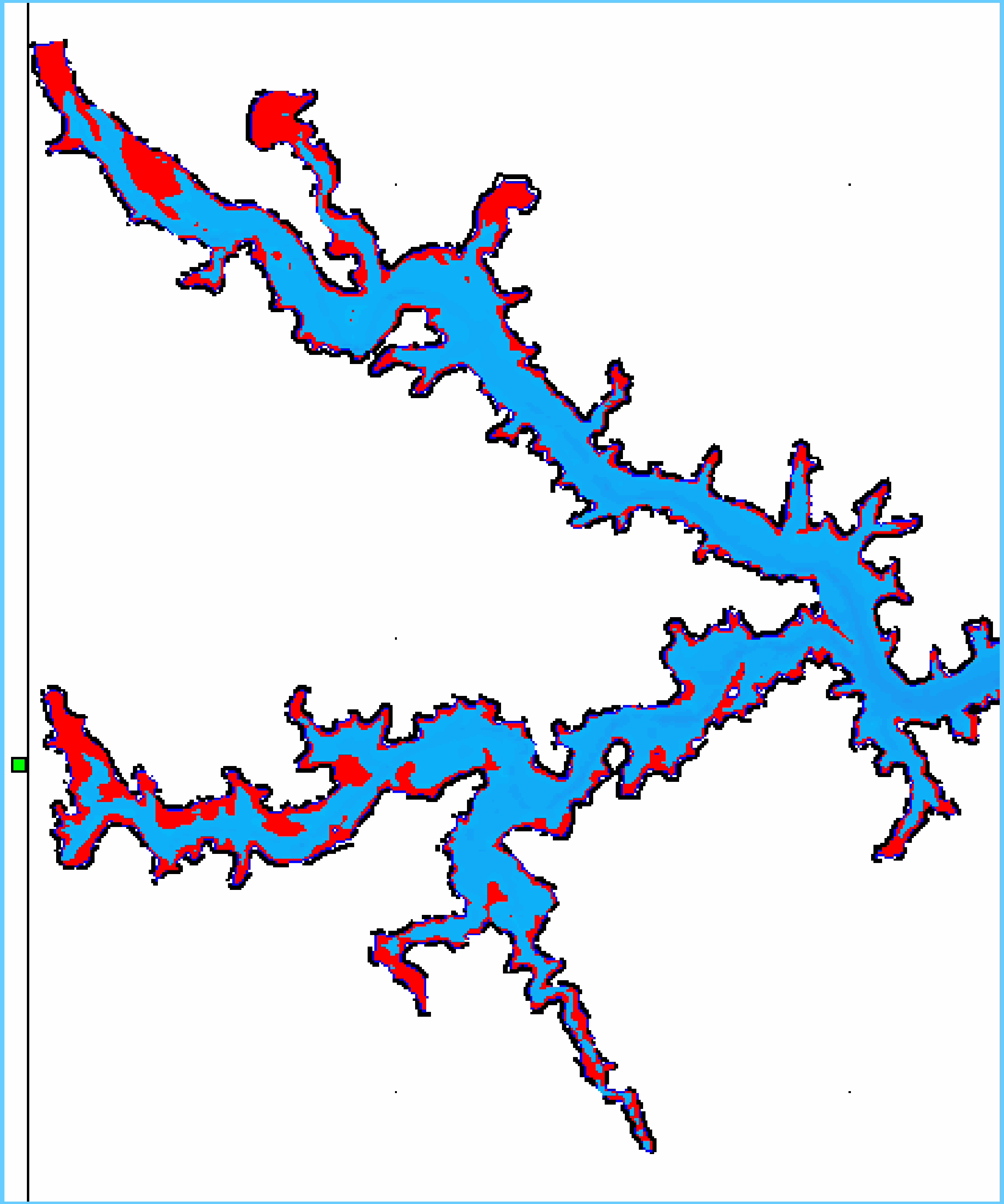
The following 2 slides show zoomed-in images of the upper region of the lake and the main body of the lake.



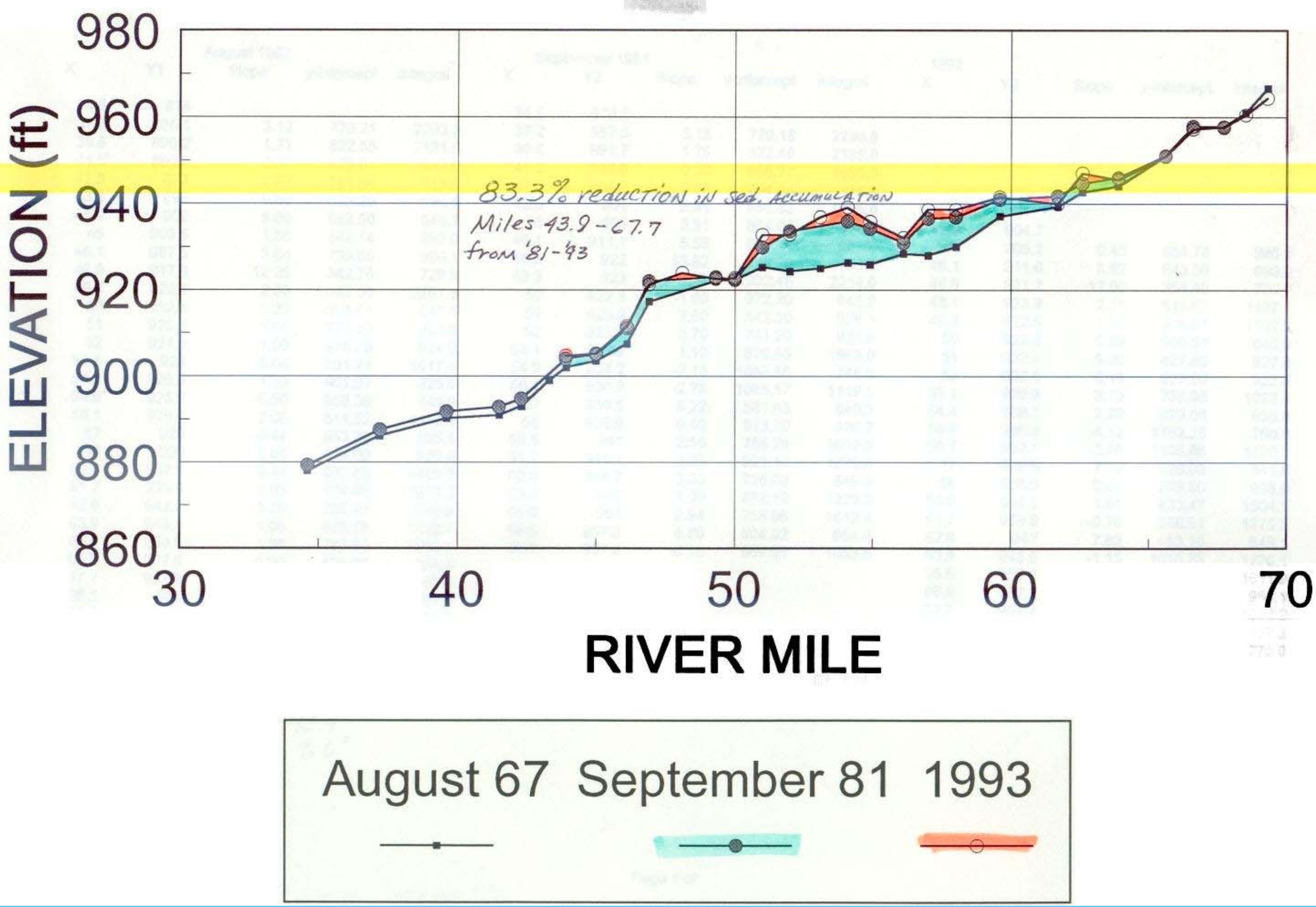
The main body of the lake



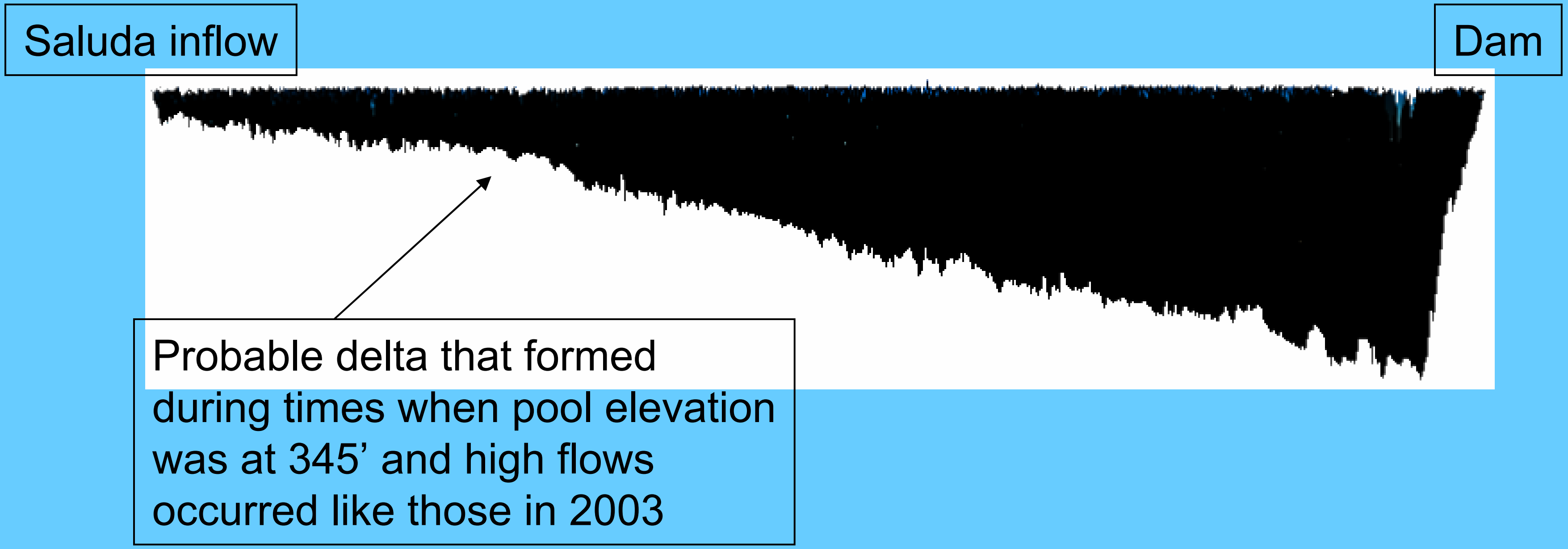
Upper end of Lake Murray showing Little Saluda R and Saluda R inflow regions. Data were not available for further upstream on the Little Saluda R, so the area between Elevation 350 and 354 is not shown; however, most all the area of the Little Saluda R embayment that is not shown is between elevation 350 and 354.



DOUGLAS RESERVOIR STREAMBED PROFILE



Display of hydrographic data used to develop bathymetry of Lake Murray showing possible sediment accumulation upstream from Rocky Creek



Increase in Sediment Deposition vs. Elevation at Claytor Lake (VA)

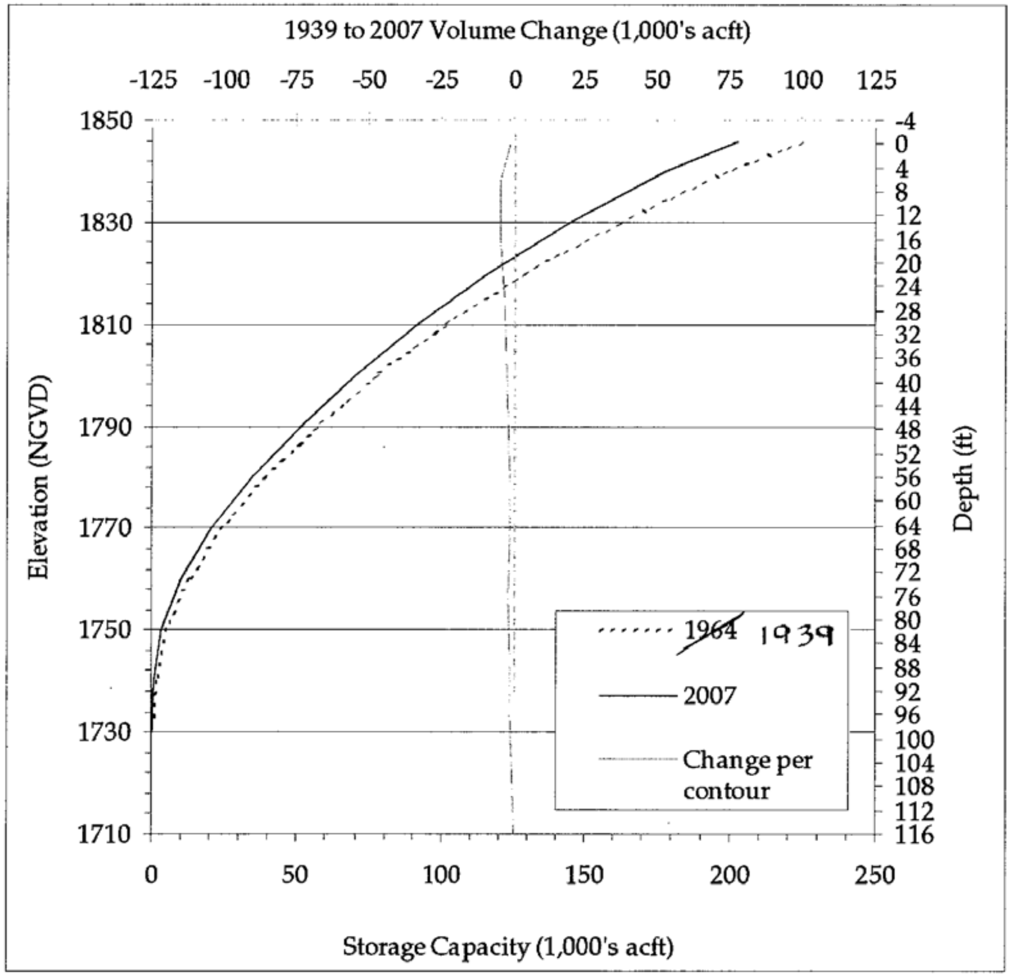


Figure 3: Updated storage volume curve for Claytor

Increase in Sediment Deposition vs. Elevation at Claytor Lake (VA)

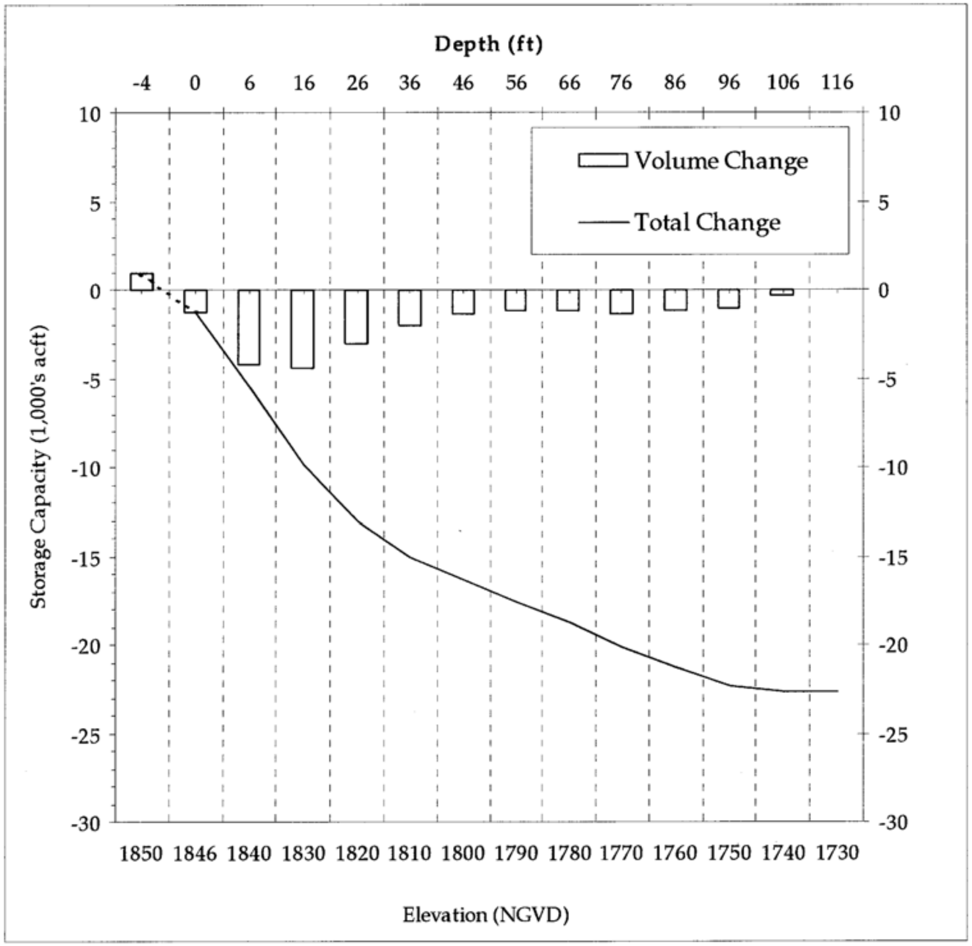


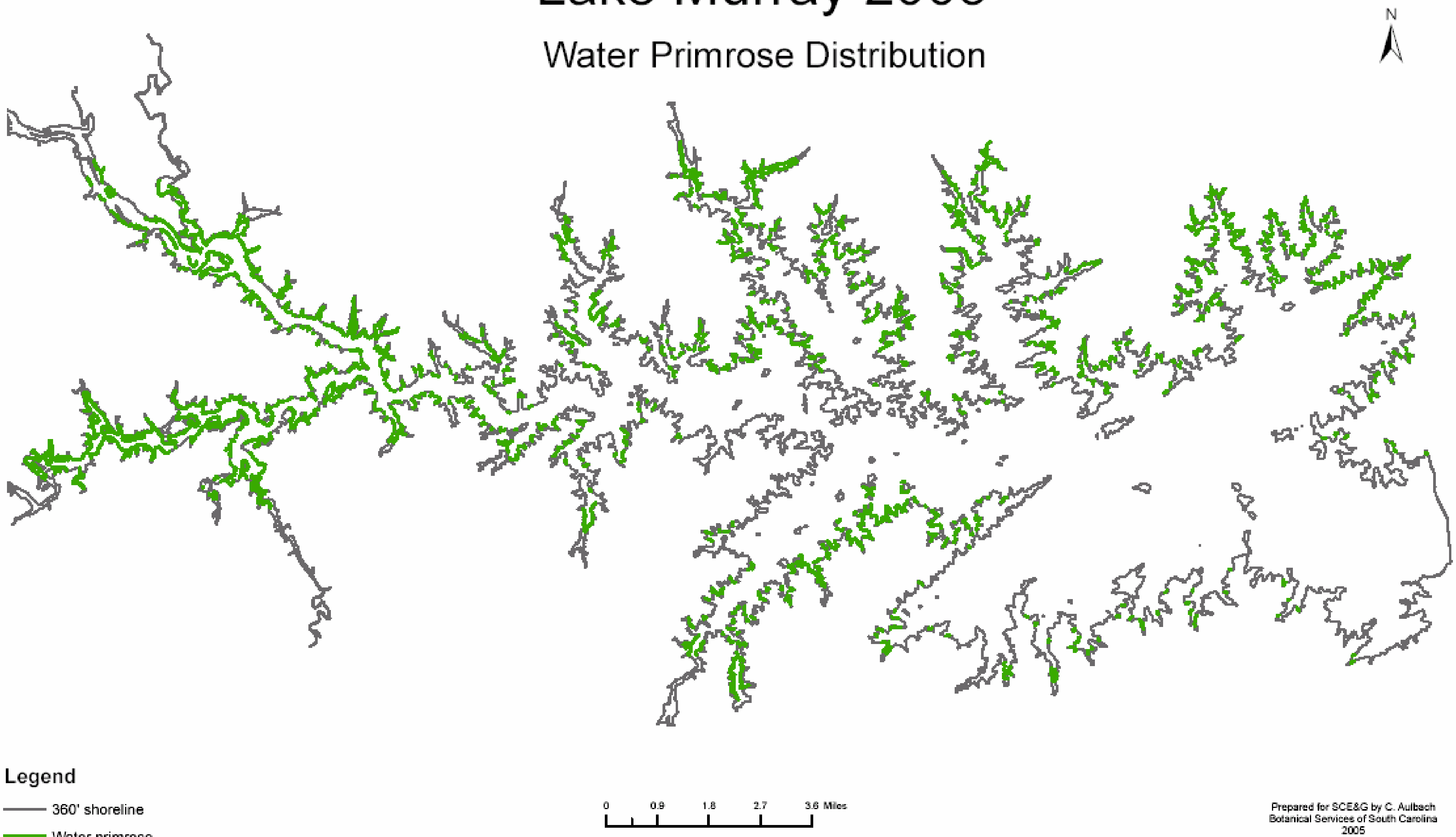
Figure 4: Change in storage volume capacity by elevation. Data above 1,846 feet are for illustrative purposes only. These data are preliminary and will be revised when final terrain data become available.

Aquatic Plants

- Affected by depth of water
- Affected by clarity of water
- Preferred by some fishermen (mainly large mouth bass?), disliked by other lake users
- Surface area exposed by dropping minimum pool to 350’ instead of 354’
- Exposure of plants to dry and freezing conditions causes plants to be reduced

Lake Murray 2005

Water Primrose Distribution



Primrose growing at elev 346 due to 2003-4 low summer pool levels

North of LSR on west side

LSR embayment

Considerations for Minimum Pool Elevation for Controlling Aquatic Plants

Considering that summer pool elevation can drop to < 358 ft even when May-June elevation starts at 358 ft due to low inflows, evaporation, and minimum flow provision, aquatic plants could take root at elevation ~ 350-352 when summer pools are low. Therefore, the minimum winter pool should be dropped to about elevation 350 periodically to freeze these plants.

Little Saluda Embayment

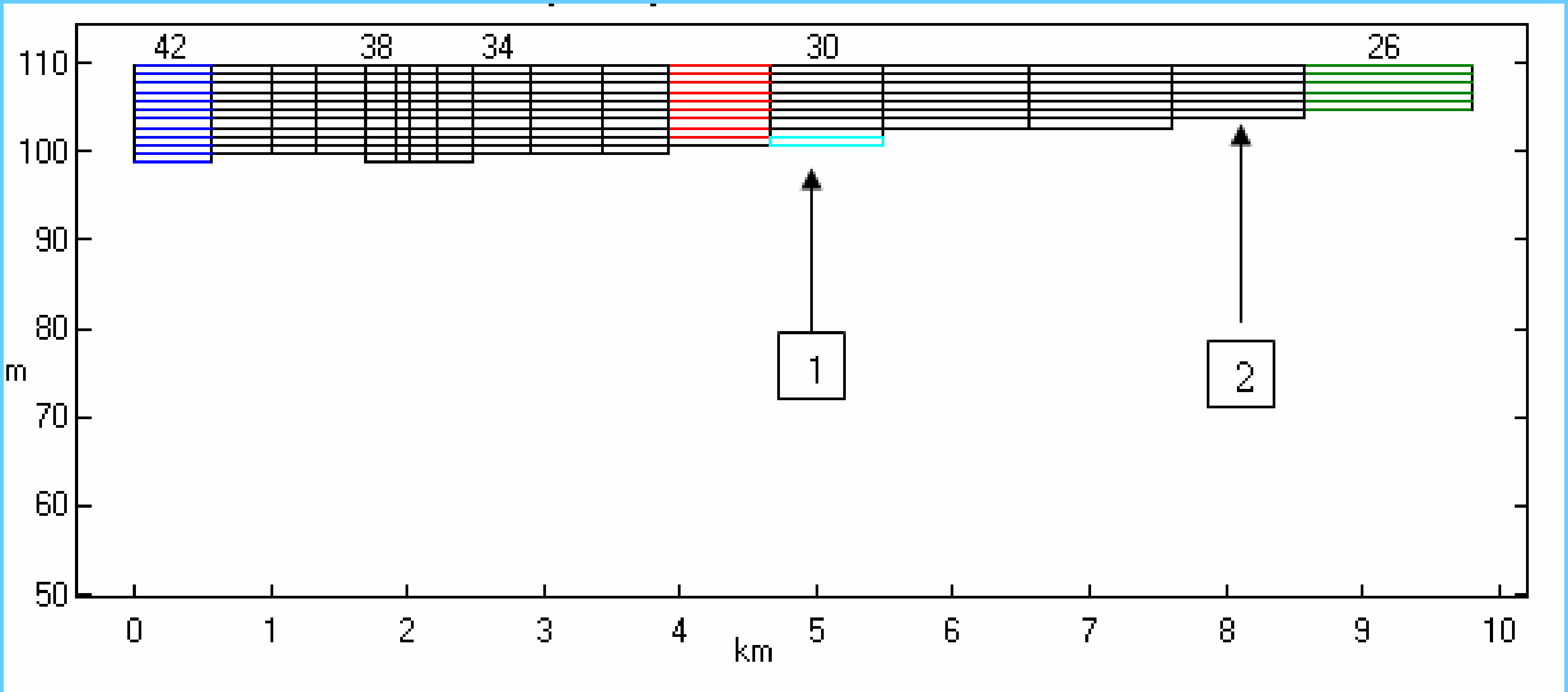
- Greater impact on water quality is expected to occur in the Little Saluda River embayment, especially upstream from the bridge on SC Hwy 391.
- This is a relatively large embayment with a small watershed; therefore, the residence time of water in this embayment can be longer than the comparable region of the upper part of the main stem of Lake Murray.
- If minimum pool elevation is raised, there would be less scouring of organic and inorganic sediments during the winter months.
- This would lead to increased “internal cycling” of nutrients in this embayment to the point that it may become insensitive to nutrient loads from the watershed because the release of nutrients in the sediments of the embayment could be sufficient to support eutrophic conditions in the embayment.
- In some cases this condition can lead to the formation of algal mats on the water, and these mats of algae are known to significantly affect water quality and water uses.

Model Application to Little Saluda Embayment

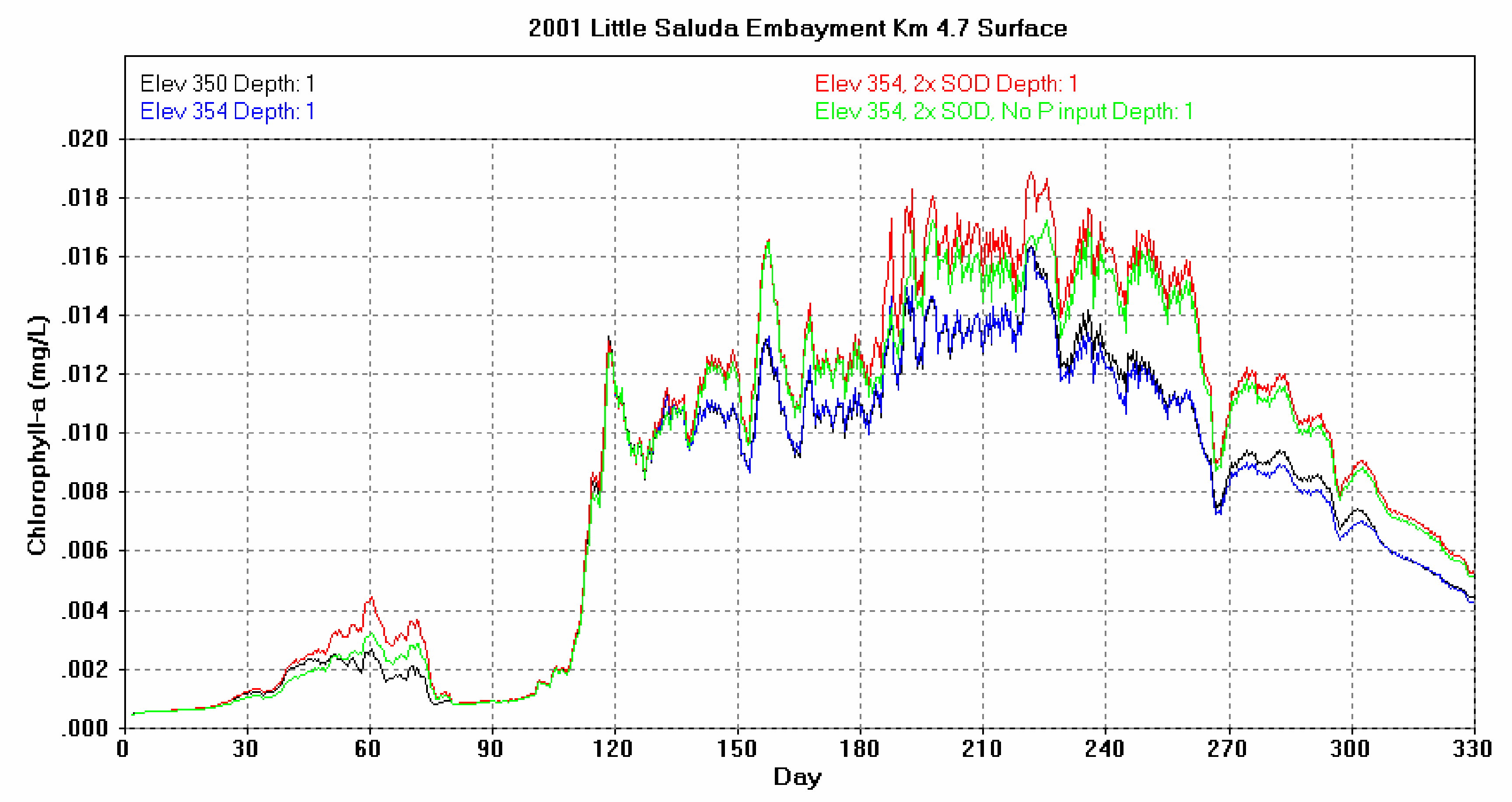
2001 Comparison of:

- Calibration case,
- Case with SOD doubled in the Little Saluda Embayment and upper Lake Murray , and
- The last case with SOD doubled with no phosphorus inputs from inflows.

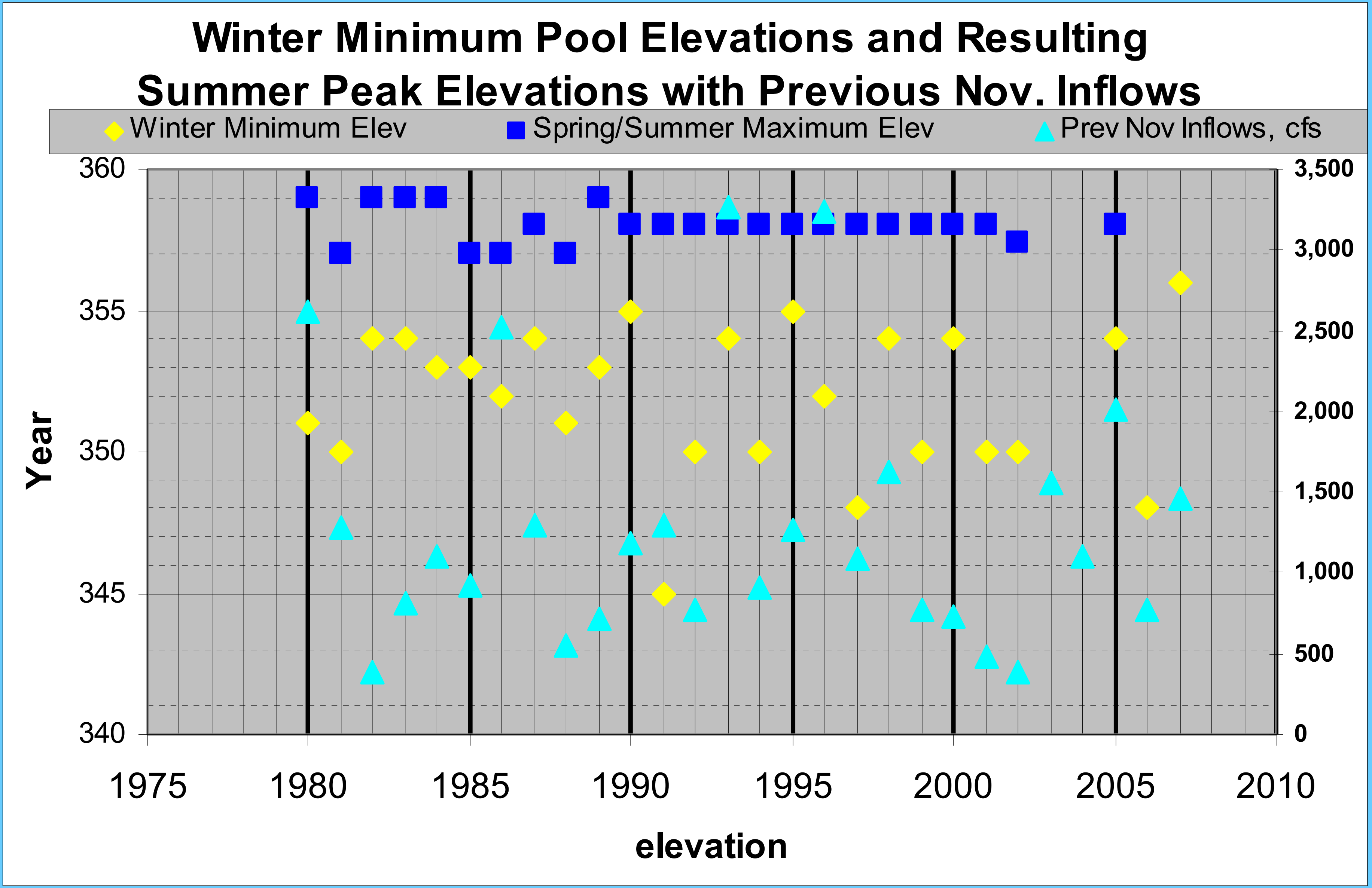
Side View of Little Saluda Bathymetry



Chlorophyll *a* near the surface at location 1



The likelihood to fill pool each year



Winter Minimum Pool Elevations and Resulting Summer Peak Elevations with Previous Nov. Inflows
Winter Minimum Elev
Spring/Summer Maximum Elev
Prev Nov Inflows, cfs
Year
360
355
350
345
340
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1975
1980
1985
1990
1995
2000
2005
2010
elevation

Considerations for the frequency of dropping the winter minimum pool elevation to 350 feet above msl

Year	Nov. Flow		Jan-Apr flow the next year	
1950	1175	1495	1590	
1928	1189	2716	4572	
1989	1190	1555	3357	half of nov flows are greater; 79/39 = 2.0 yr frequency
1963	1203	1838	4458	
1936	1223	3481	4095	
1945	1234	1541	3796	
1965	1262	2177	2624	
1994	1267	1901	3003	
1980	1282	2113	1358	
1986	1293	893	2647	
1990	1293	1937	2662	40% of nov flow are greater; 79/(79-47) = 2.5 yr frequency
1930	1356	1405	1708	
1969	1424	2232	1706	
1959	1443	1624	4050	
1962	1459	2052	2753	
1935	1486	1681	6878	
1937	1492	2647	1846	33% of nov flows are greater; 79/(79-53) = 3.0 yr frequency
1946	1519	2333	2345	
1940	1534	1263	1313	
2002	1555	1029	3182	
1973	1570	2721	3162	28% of nov flows are greater; 79/(79-57) = 3.6 yr frequency
1997	1621	1865	4623	
1972	1727	2251	3917	
1970	1739	1269	2917	

This is best since this frequency is what has happened historically and especially considering freezing effects are needed for weed control

Also, the frequency of dropping the pool level to 350 is not that important to the pool level reaching ~ 358 each year.

Concerns for Increasing the Winter Minimum Pool Level from 350’ to 354’ Every Year

- Sediment accumulation in coves, especially Little Saluda River
- Aquatic plants increasing around the lake, especially the Little Saluda River embayment, and especially following years with low summer pools
- Organic and nutrient accumulation in sediments of embayments, especially the Little Saluda River embayment and the shallow shoreline around the lake
- Water quality and algae in the Little Saluda River embayment could already be controlled by internal-cycling (i.e., insensitive to nutrients in inflows creeks), and increasing the minimum winter pool to 354’ could cause worse conditions
- Probable impact on the TMDL process on the Little Saluda River embayment
- Modeling at this point can involve only sensitivity analyses since data are inadequate to calibrate the model

Water Quality Issues that are Related to Effects of the Winter Minimum Pool Elevation that can affect Lake Users

- Increased eutrophication around shoreline that would result in increased algae levels, aquatic plants, turbidity, and sediment deposition
- Internal nutrient cycling in the Little Saluda River embayment so that external sources cannot control algae
- Increased sediment deposition at inflow sites that would impact boating and enhance aquatic plant growths, especially when summer pool elevations were less than full pool

Conclusions Regarding the Minimum Winter Pool Level

- Regarding considerations for developing a policy for winter minimum pool levels, based on data for 1980 through 2007, the winter pool level was down to about 350 ± 2' about half the time. It would be best to maintain this frequency of drawing the lake down to this level each year or risk poorer water quality compared to current conditions.
- Maintaining the frequency of drawing the lake down to ~ 350' for an average of every two years should not be difficult based on historical inflows and pool level data as well as taking advantage of using November flows to predict the years when Jan-Apr flows would likely be sufficient.
- The minimum winter pool level has little to do with attaining and maintaining a summer pool level at elevation 358 ± 1'. It is the lack of sufficient inflows, evaporation, and minimum flows during the summer period that cause the pool elevation to drop like it did in 2007 to elevation 352'.
- A reservoir operations model would be best for developing alternative operating policies with associated pros and cons for each policy. Quantifiable as well as intangible pros and cons would be included.

The End