Summary of Previous Lower Boise River Water Quality Modeling

LBWC TAC Meeting

November 28, 2012

Presented by CH2M HILL

Topics

- Focus on methods and lessons learned
- Mass balance models:
  - The early years (mid-1990s to early 2000s)
  - The TP TMDL and implementation plan (2005 to 2008)
- Instream water quality models:
  - The really early years (1975 to 1992)
  - The algae calculator (~2000)
  - AQUATOX model (2005 – 2008)

Early History of Mass Balance Models

- Mid-1990s: “Strawman” model for potential TP TMDL
- Late 1990s to early 2000s: Model modified and adapted for sediment TMDL:
  - Programmed Excel model to allow user to select data, time periods and allocations methodologies
- 2005 to 2008: Following slides (Sherrill)

USGS Schematic

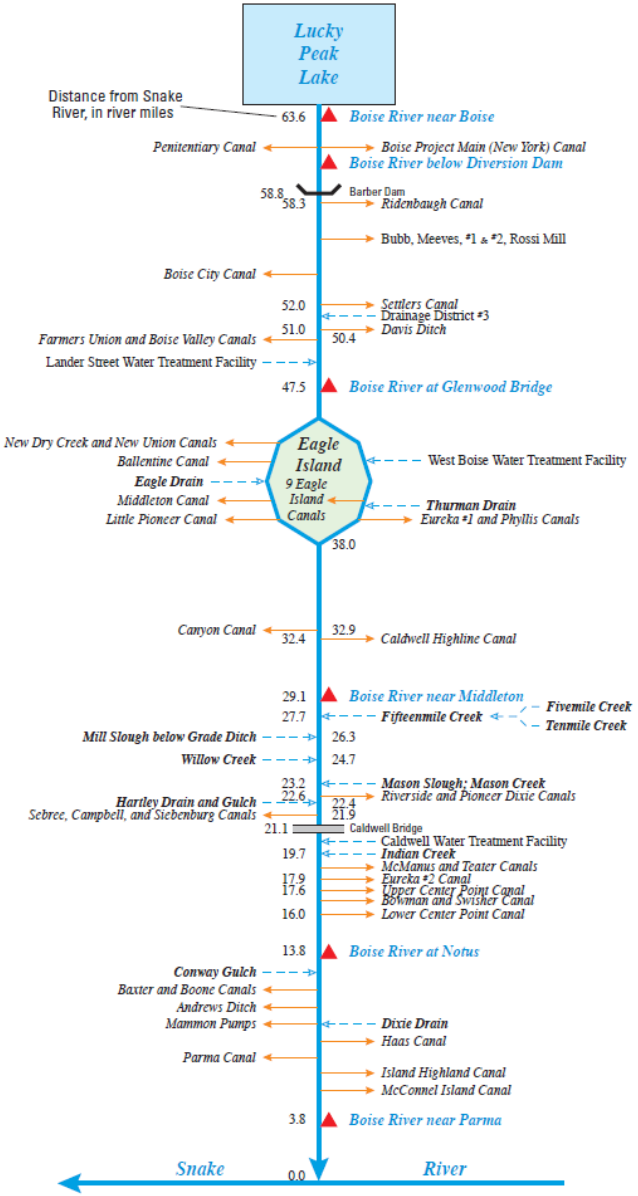


Figure 4. Schematic diagram of diversions, drains, and tributaries along the Boise River from Lucky Peak Lake to the Snake River, Idaho. (Modified from Warnick and Brockway, 1974)

Source Categories

- Point sources
  - Current mainstem and tributary WWTFs
  - Future WWTFs
  - Current MS4 stormwater
  - Future MS4 stormwater
- Non-point sources
  - Agriculture
  - Current non-MS4 stormwater
  - Groundwater
- Other sources
  - Background
  - Canal “pass-through” water

Data Sources: Flows

- Combined data from different sources:
  - Boise River: USGS and Idaho Power (1992-1996,1999-2005)
  - Canals and drains: USGS, IDWR, Watermaster, ISDA/SCC
  - Groundwater: Reclamation reports, USGS research
  - WWTFs: Typical discharges (calibration), design flows/build-out flows

Data Sources: Concentrations

- Combined data from different sources:
  - Boise River: USGS (2000-2004)
  - Canals and drains: USGS (2000-2004), ISDA (1999-2000)
  - WWTFs: DMR Data (2000-2004)
  - Groundwater: USGS Groundwater (2001)
  - Background: Reclamation (1994-2004)

Data Sources: Concentrations (con't.)

- Stormwater
  - Wet-weather: ACHD Phase 1 MS4 monitoring (2000-2006)
  - Dry-weather (urban irrigation runoff):
    - ACHD Phase 1 MS4 monitoring (2006), weighted for land use

      +

    - Reclamation Fivemile study (2001)
  - Dry-weather runoff concentration is a critical driver for projected conditions

Alpha Version (2005-2006)

Lower Boise River TMDL Mass Balance Model - Phosphorus

27-Nov-12

INPUT:		CHOICES:	Your Selection
TP Concentration Table:	2	(1 = Measured; 2 = Target)	*Target*
Flow Year:	3	(2 = MF 2000; 3 = LF 2001)	*Low Flow*
Flow Statistic May-Sept:	4	(2 = Build Out; 4 = Arithmatic Mean Actual)	*Arithmatic Mean*
Conc. Year	3	(2 = MF; 3 = LF, 4 = All)	*Low Flow*
Conc. Magnitude:	1	(1 = Arithmetic Mean; 2 = Buildout)	*Arithmatic Mean*

Scenario or Calibration Mainstem Gaging Location	Station No.	Inflow or Outflow -/+	River Mile	Measured Source Flow (cfs)	Concentration (mg/L)	Incremental Daily Mass Load (T/day)	Incremental Groundwater Flow (cfs)	Groundwater Concentration (mg/L)
Boise River Near Boise	13202000	n/a	63.6	2764.00			0.00	0.0000
Penitentiary Canal	13202995	-	61.2	-4.27			2.40	0.0000
New York Canal	13203000	-	61.2	-1325.99			0.00	0.0000
Surprise Valley Canal	13203527	-	61.2	-3.69			0.00	0.0000
Boise Below Diversion Dam	13203510	n/a	61.2		0.060	0.000	0.00	0.0000
Below Diversion Dam WWTP	158	+	-	0.00	0.000	0.000	0.00	0.0000
Ridenbaugh	13203760	-	58.3	-371.30	0.060	-0.060	2.89	0.0000
Bubb	13204005	-	57.5	-4.08	0.060	-0.001	0.80	0.0000
Meeves	13204020	-	56.8	-0.52	0.060	0.000	0.70	0.0000
Rossi Mill	13204060	-	56.4	-6.67	0.060	-0.001	0.40	0.0000
River Run	13204070	-	56.1	-18.00	0.060	-0.003	0.30	0.0000
Boise City	13204190	-	56.0	-23.10	0.060	-0.004	0.10	0.0000
Boise Water Corp.	200	-	55.9	-9.81	0.060	-0.002	0.10	0.0000
Settlers	13205515	-	52.0	-89.76	0.060	-0.014	3.89	0.0000
Davis	13205517	-	52.0	-4.81	0.059	-0.001	0.00	0.0000
Boise City Parks	13205613	-	51.5	-0.20	0.059	0.000	0.50	0.0000
Drainage District #3*	13205617	+	51.0	4.33	0.053	0.001	0.50	0.0000
Thurman Mill	13205622	-	51.0	-23.93	0.059	-0.004	0.00	0.0000
Farmers Union	13205640	-	50.4	-141.91	0.059	-0.023	0.60	0.0000
Lander Street WWTF	1	+	49.9	20.69	0.441	0.025	0.50	0.0700
BR At Glenwood Bridge	13206000	n/a	47.4	757.70	0.074	0.150	2.50	0.0200
			DIFFERENCE:	19.46	-0.004			
Boise Garden City MS4	139			0.00	0.040	0.000	0.00	0.0000

Beta Version (2006-2007)

Lower Boise River Total Phosphorus TMDL Mass Balance Model — 27-Nov-12

Macro: Ctrl+Shift+P

CONTROL PANEL

	MARK X		
Current (Measured)			
Flow (Discharge)			
Mainstem / Tribs / WWTF / NPS	X	Mean	
Current Phase I MS4	X	30%	% Acres Disconnect
Current Phase II MS4	X	30%	% Acres Disconnect
		0%	Stormwater Reuse
Concentration (TP)			
Mainstem / Tributaries / WWTFs / NPS	X	Mean	
Other Variables			
Background		= Non-detects = DL	
	X	= Non-detects = (1/2DL)	
		= Veteran's Dataset	
Groundwater		= USGS Measured Values	
	X	= Mason Creek/Ag Area C Correct	

SUMMARY OF PARMA CONCENTRATION / LOAD		
Parma Flows	**1854**	**cfs**
Parma TP	**0.074**	**mg/L**
Parma Load	**334**	**kg/day**

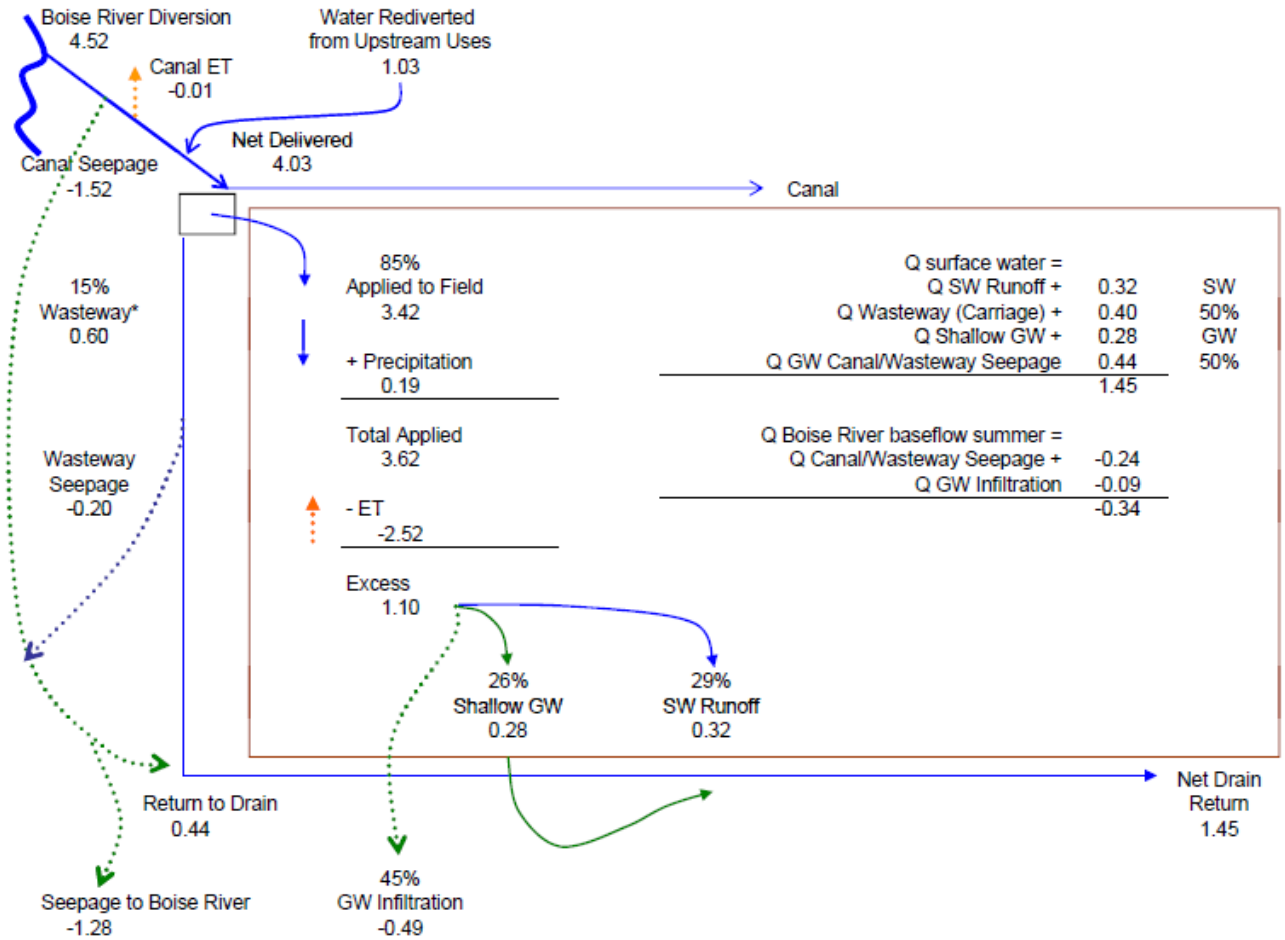
Q (cfs)	51%
C (mg/L)	-74%
kg/day	-60%

TO PARMA

TO MODEL

	MARK X				
Future (Predicted)	X				**70-Year Goal**
Build-Out Year	70	Year			
Flow (Discharge)					
Point Sources (WWTFs	X	Build-Out Flows			
	X	50%	Year 15+ Wastewater Reuse		50%
	X	Lagoon Facilities Included			(Beginning in Year 15)
Mainstem / Tribs / NPS	X	Mean			
Current MS4 (II)	X	30%	% Existing Acres Disconnect		
Future MS4 (I and II)	X	0%	% Future Acres Disconnect		0%
	X	0%	Stormwater Reuse		0%
Concentration (TP)					
Equal Concentration		0.082	(mg/L)		
Equal Percentage		78%		0.07	New WWTF (mg/L)
SR-HC Hybrid	X				
WWTF Mainstem		No Improvement		0.07	New WWTF (mg/L)
	X	0.20	(mg/L) Target		
WWTF Tributary		No Improvement			
	X	0.20	(mg/L) Target		
NPS	X	Mean			
Ag BMP Effective.	X	50%	% Effectiveness		50%
Stormwater BMP Effective.					
Current MS4 (I and II)	X	25%	% Improvement		25%
Future MS4 (I and II)	X	50%	% Improvement		50%
Groundwater					
		No Recovery			
	X	0.05	(mg/L) Target		65%

AGRICULTURAL LANDS



Total Baseflow to Boise River (summer)
-0.34 19%

Total Remaining GW = Baseflow to Boise River (winter) or deeper aquifer recharge
-1.43 81%

* Water that is diverted from the canal but is not applied can either flow down the wasteway or be returned to the canal system.

Gamma Version (2007-2008)

Load-Based Modeling

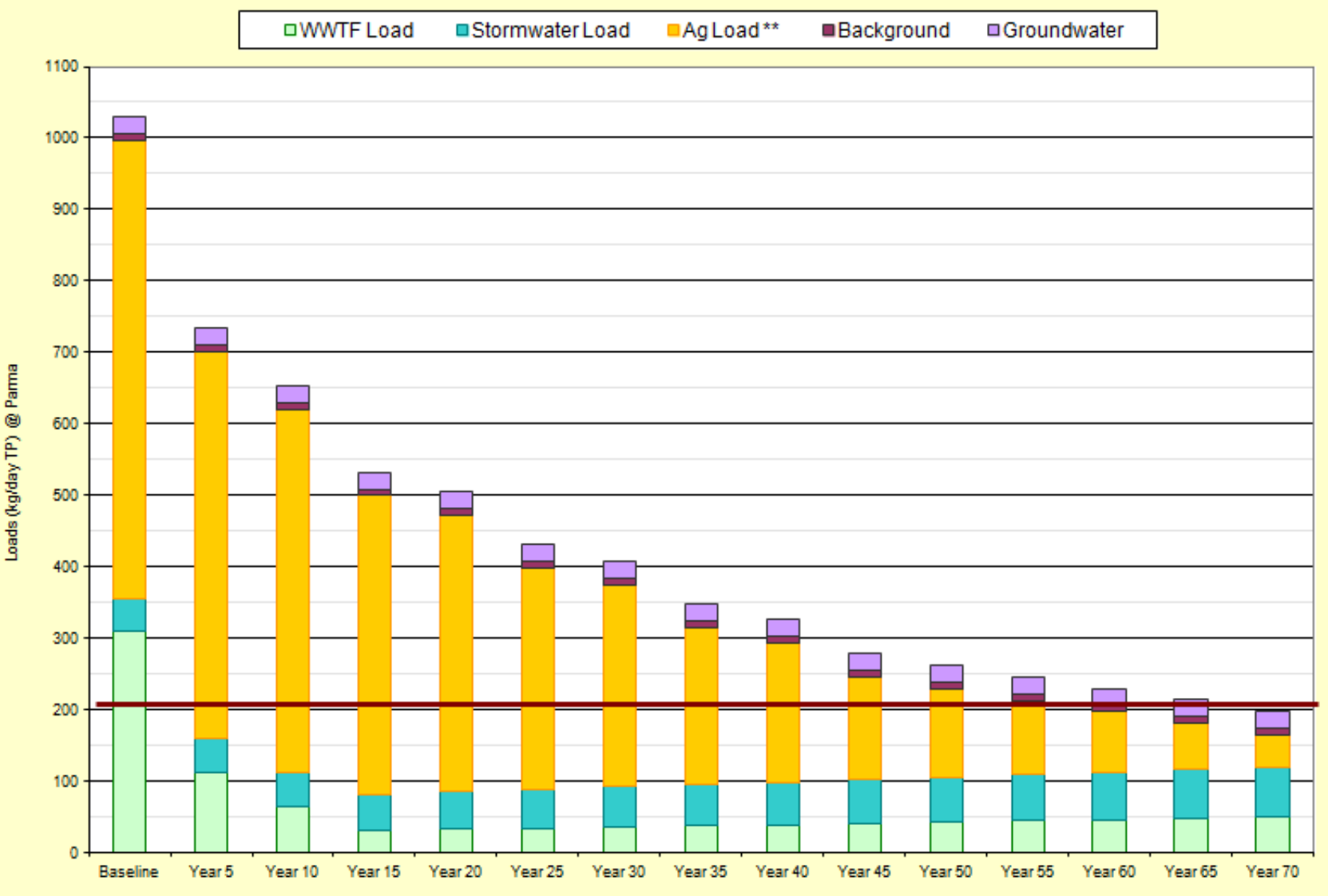
CONTROL PANEL	
Year	70
WWTF Effluent C (mg/L TP)	0.20
New Stormwater Control	50%
Ag BMP Effectiveness	50%
WWTF Reuse	50%
Groundwater Recovery	0%
Conservation/Reuse	0%

These variables are only used to predict future (Year ≠ 0) conditions.

OUTPUT PANEL			
SOURCE LOADS		L (kg/day)	
WWTFs		86	
Stormwater		116	
Agricultural		55	
Background		89	
Groundwater		31	
Sum Source Loads			376
PARMA LOADS	Rel. Cont.	L (kg/day)	
WWTFs	see K5:K17	49	
Stormwater	see X7:X39	70	
Agricultural	see AP10:AP21	44	
Background	see BB2	9	
Groundwater	see BG3	24	
			197
Target			
Q (cfs, mean)	1,225		
C (mg/L)	0.07		
Load (kg/day)			210

?

@ PARMA		
Current Monitoring		
Q (cfs, mean)	1,225	
C (mg/L)	0.28	
Load (kg/day)		835


WWTF Load
Stormwater Load
Ag Load **
Background
Groundwater
Loads (kg/day TP) @ Parma
1100
1000
900
800
700
600
500
400
300
200
100
0
Baseline
Year 5
Year 10
Year 15
Year 20
Year 25
Year 30
Year 35
Year 40
Year 45
Year 50
Year 55
Year 60
Year 65
Year 70

Instream Water Quality Models

- Simulate effects of loadings to the river
- User inputs loads based on other watershed models (e.g., mass balance models)
- Applications to LBR:
  - Chen and Wells, 1975
  - EPA R10's RNGKMOD (early 1990s)
  - Algae calculator (~2000)
  - AQUATOX (2005 – 2008)

Chen and Wells (1975)

- Contract with Corps
- Looked at various scenarios of instream flows, diversions and loadings
- Modeled Indian Creek and mainstem river
- Ecological model: Temperature, bacteria, DO, nutrients, algae, zooplankton, detritus, organic sediment, benthos, and fish
- "Floating algae could not thrive in the river due to the short hydraulic residence times of the water. This was the case for all of the hydrologic conditions tested. Algal biomass would not occur if suspended solids were removed from irrigation return waters."

EPA R10 Model (early 1990s)

- RNGKMOD initially developed and applied to LBR by John Yearsly (EPA R10)
- Focus was DO:
  - BOD
  - Mass balance
  - Dilution
  - Nitrification
  - Reaeration
  - Organic decay
  - Nutrients/algae rudimentary
- Used in 1992 by CH2M HILL on behalf of Boise City to evaluate various scenarios

Algae Calculator (Excel)

- Developed ~2000 at requet of LBWC and DEQ
- Thomann and Mueller equations
- Primary objective was to evaluate issue whether reduced sediment concentrations in the lower river would lead to problematic phytoplankton issues
- Provided to DEQ and used in SBA and 303(d)
- Answer: Confirmed Chen and Wells, flushing during growing season too high

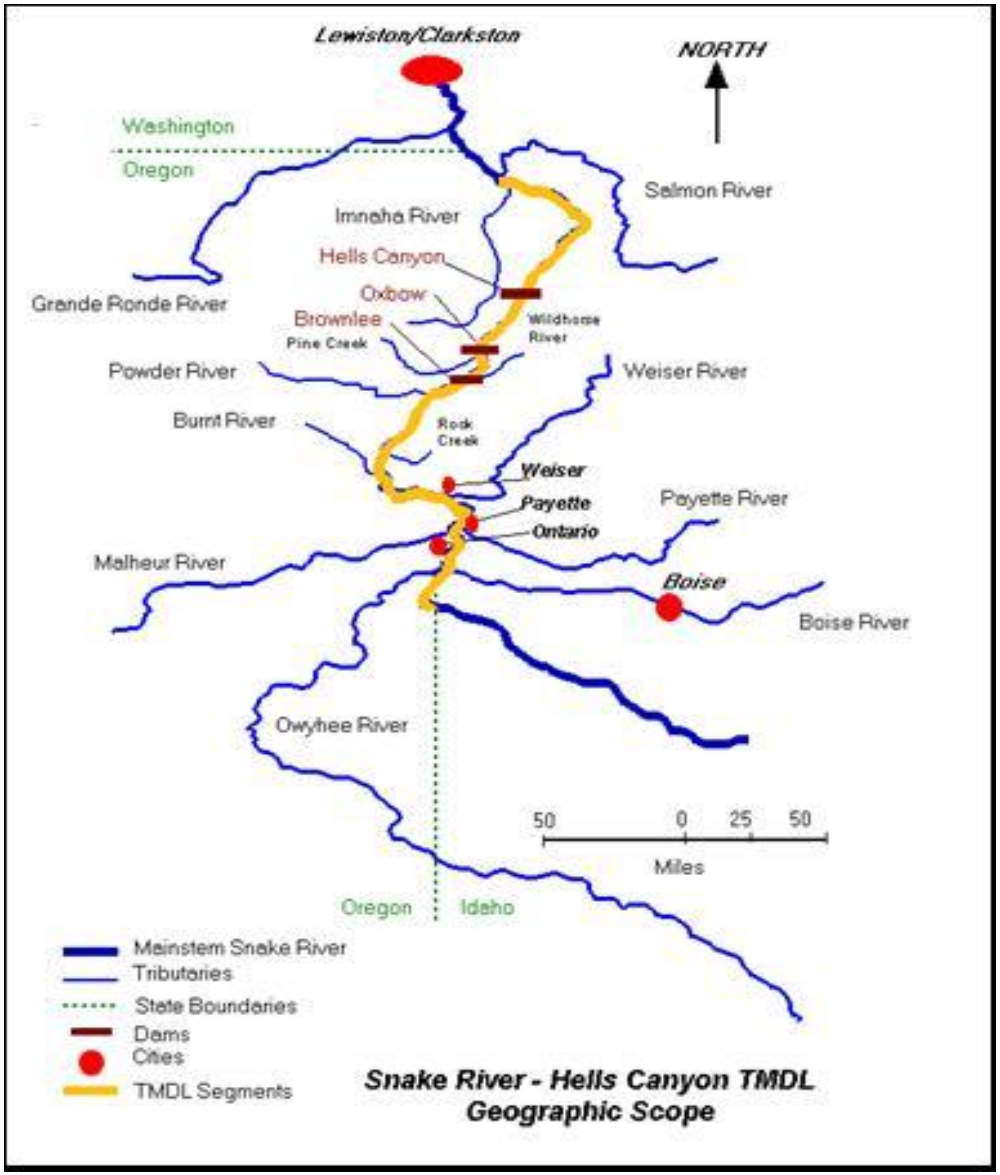
AQUATOX Application

- Background
- Description of AQUATOX
- Application of AQUATOX to LBR
  - Model Setup and Calibration
  - Scenario Runs and Results
  - Key Findings
- Potential Application for Nutrient Criteria for the LBR

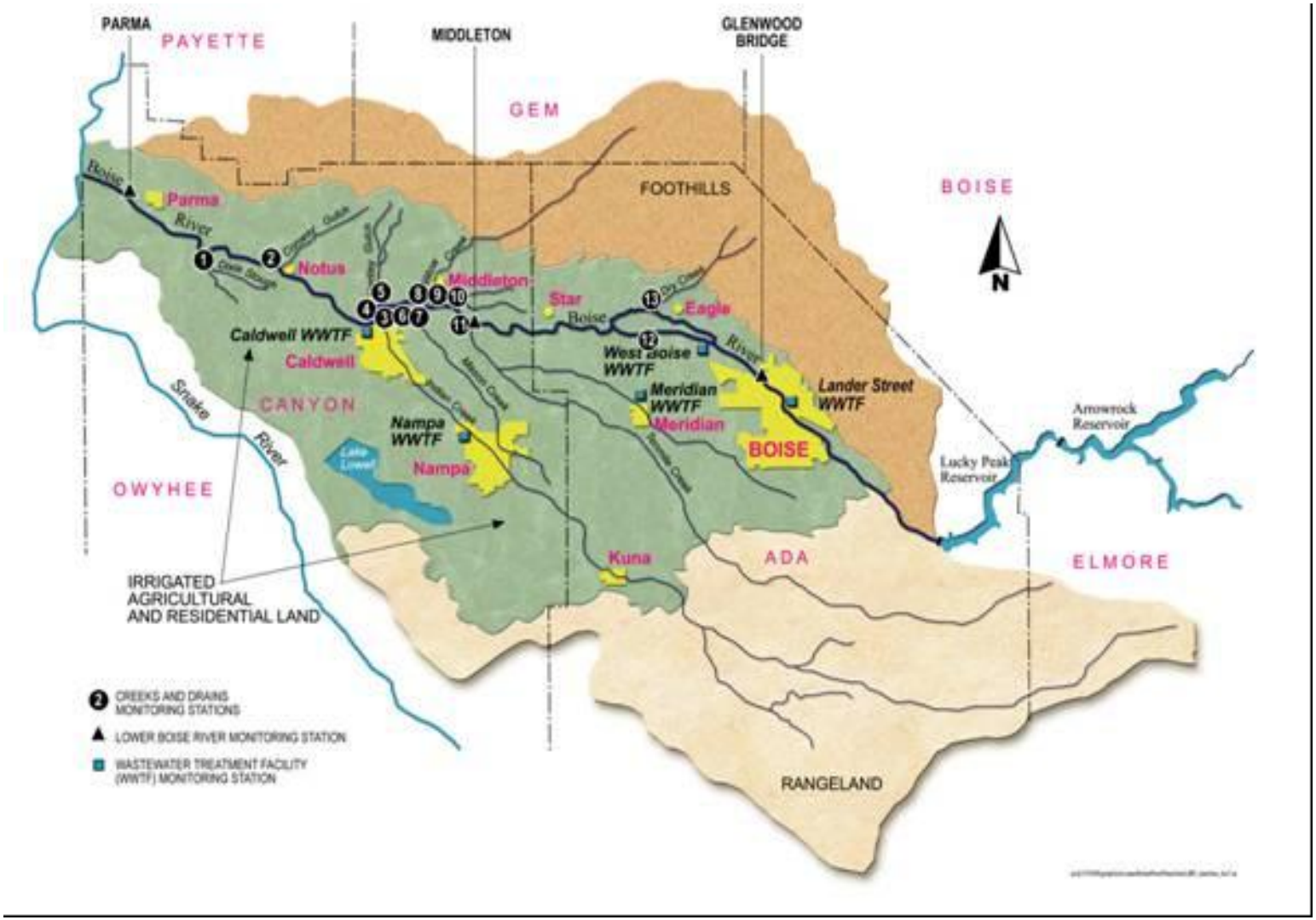
Background

- EPA Ecoregion TP criteria applicable to LBR is ~0.02 – 0.04 mg/L
- EPA HQ looking for applications of AQUATOX model for derivation of nutrient criteria
- Provide insights on how SR-HC TP allocations will affect LBR
- Provide insights on how LBR sediment allocations will affect algae at Parma
- Use to reevaluate BOD allocations for point sources to the LBR
- Potential extension of approach to SR-HC

SR-HC TMDL Area



Lower Boise Watershed



Algae Issues in SR vs. LBR

- Snake River:
  - Primary driver in final TMDL was phytoplankton in river upstream of Brownlee (seasonal target of 14 ug/L of phytoplankton chlorophyll)

- Lower Boise River:
  - DO and pH meet standards, part of basis for DEQ delisting
  - Lingering concern has been periphyton at Middleton (low flow location)
  - Additional concern has been phytoplankton at Parma when sediment TMDL increases light availability

Description of AQUATOX

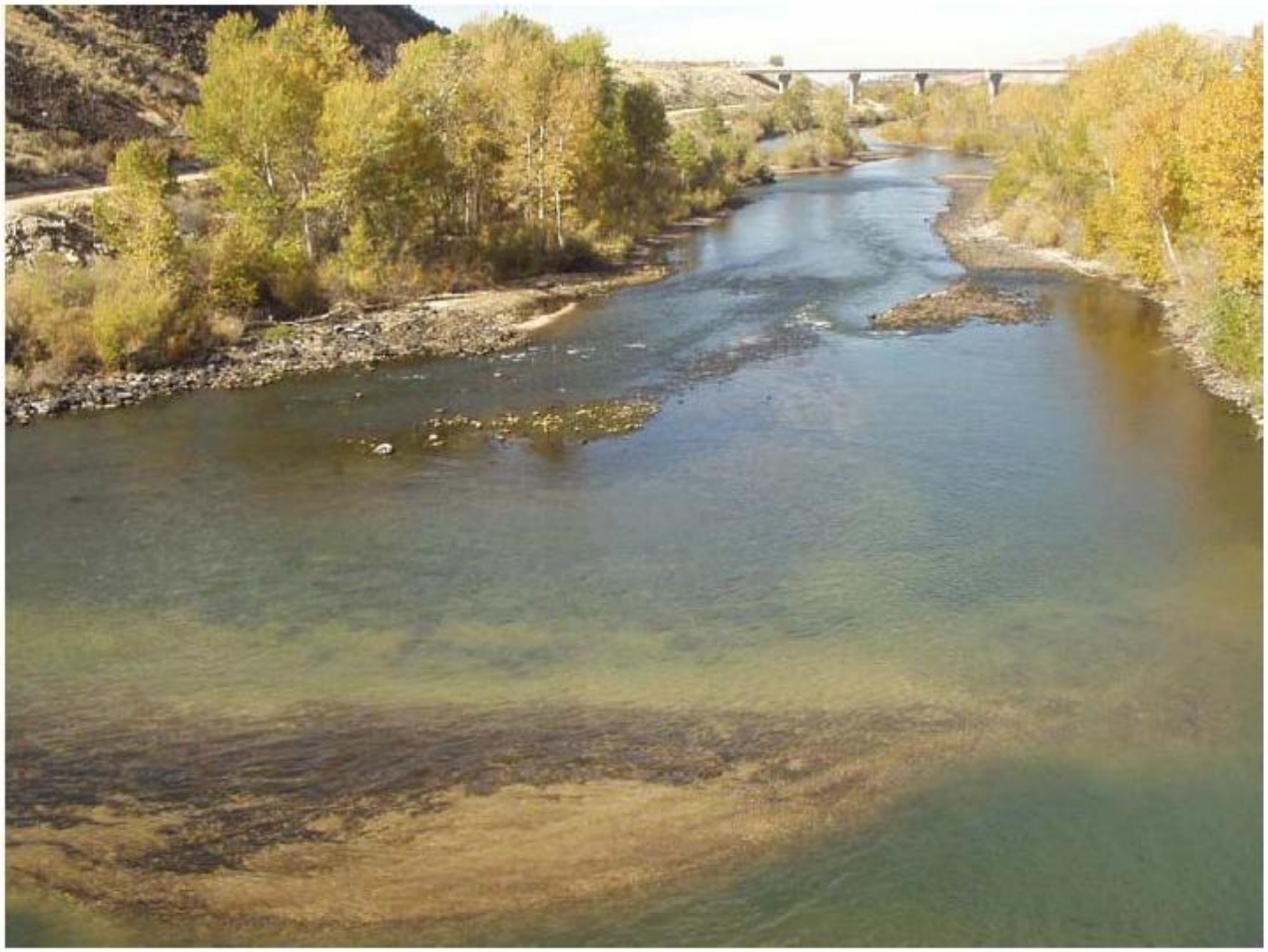
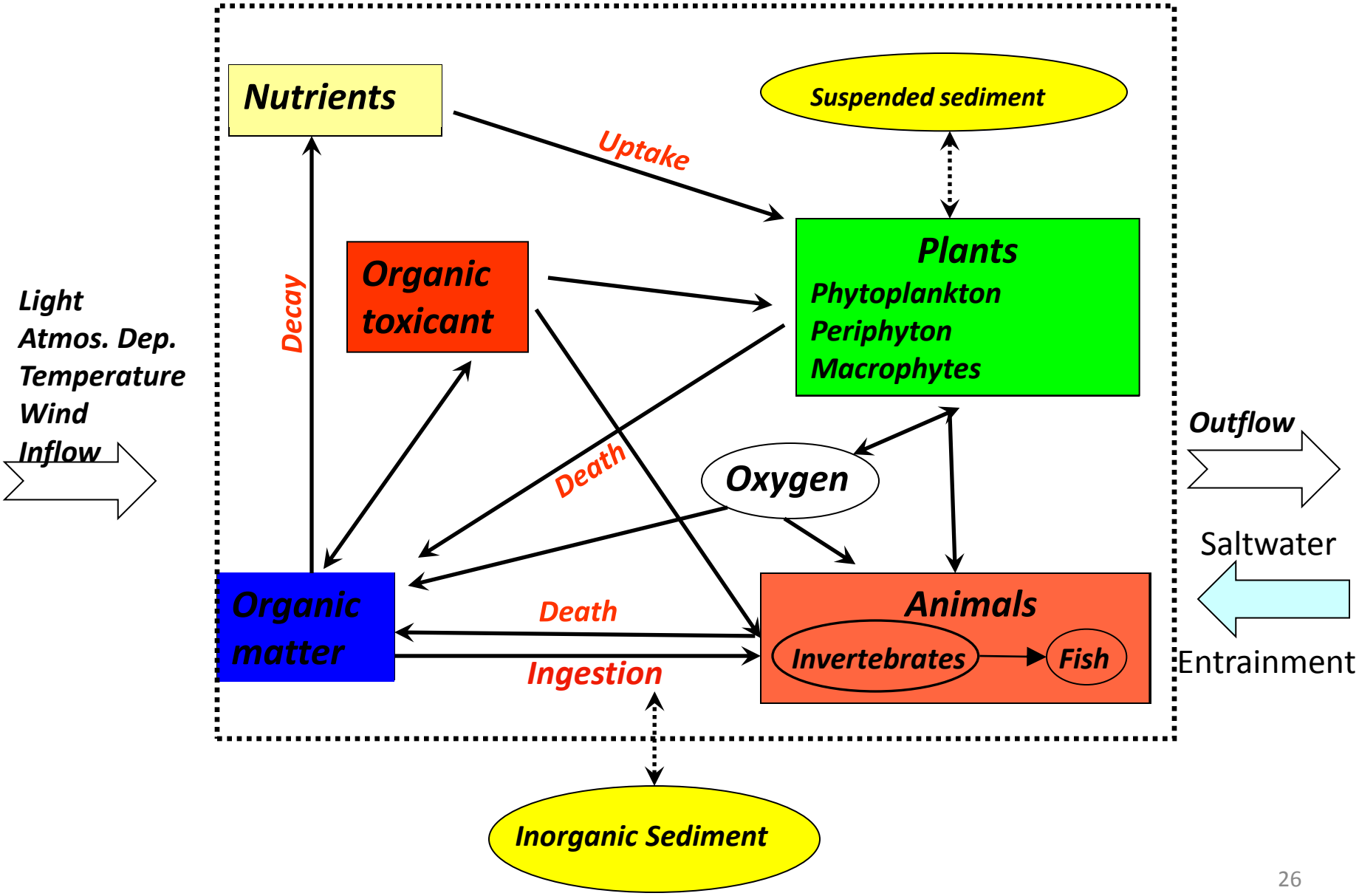


Figure 3. Below Diversion Dam at head of Lower Boise River.

What is AQUATOX?

- Simulation model that links pollutants to aquatic life
- Integrates fate & ecological effects
  - Fate & bioaccumulation of organics
  - Food web & ecotoxicological effects
  - Nutrient & eutrophication effects
- Predicts effects of multiple stressors
  - Nutrients, organic toxicants, temperature, suspended sediment, flow, salinity
- Peer reviewed by independent panel and in published model reviews
- EPA supported

AQUATOX Ecosystem Representation



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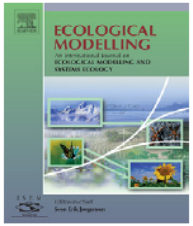

Review

AQUATOX: Modeling environmental fate and ecological effects in aquatic ecosystems☆

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Ecotoxicology

ABSTRACT

AQUATOX combines aquatic ecosystem, chemical fate, and ecotoxicological constructs to obtain a truly integrative fate and effects model. It is a general, mechanistic ecological risk assessment model intended to be used to evaluate past, present, and future direct and indirect effects from various stressors including nutrients, organic wastes, sediments, toxic organic chemicals, flow, and temperature in aquatic ecosystems. The model has a very flexible structure and provides multiple analytical tools useful for evaluating ecological effects, including uncertainty analysis, nominal range sensitivity analysis, comparison of perturbed and control simulations, and graphing and tabulation of predicted concentrations, rates, and photosynthetic limitations. It can represent a full aquatic food web, including multiple genera and guilds of periphyton, phytoplankton, submersed aquatic vegetation, invertebrates, and fish and associated organic toxicants. It can model up to 20 organic chemicals simultaneously. (It does not model metals.) Modeled processes for organic toxicants include chemodynamics of neutral and ionized organic chemicals, bioaccumulation as a function of sorption and bioenergetics, biotransformation to daughter products, and sublethal and lethal toxicity. It has an extensive library of default biotic, chemical, and toxicological parameters and incorporates the ICE regression equations for estimating toxicity in numerous organisms. The model has been implemented for streams, small rivers, ponds, lakes, reservoirs, and estuaries. It is an integral part of the BASINS system with linkage to the watershed models HSPF and SWAT.

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Why Use AQUATOX?

- When have aquatic life endpoints
  - Models hydraulic scour of periphyton
  - Most water quality models do not include animals
- When have complex ecological & biological processes
  - Feedback loops, indirect effects
  - Trophic cascades
  - Multiple factors affecting ecosystem responses
  - Non-linear relationships

Process for Application to LBR

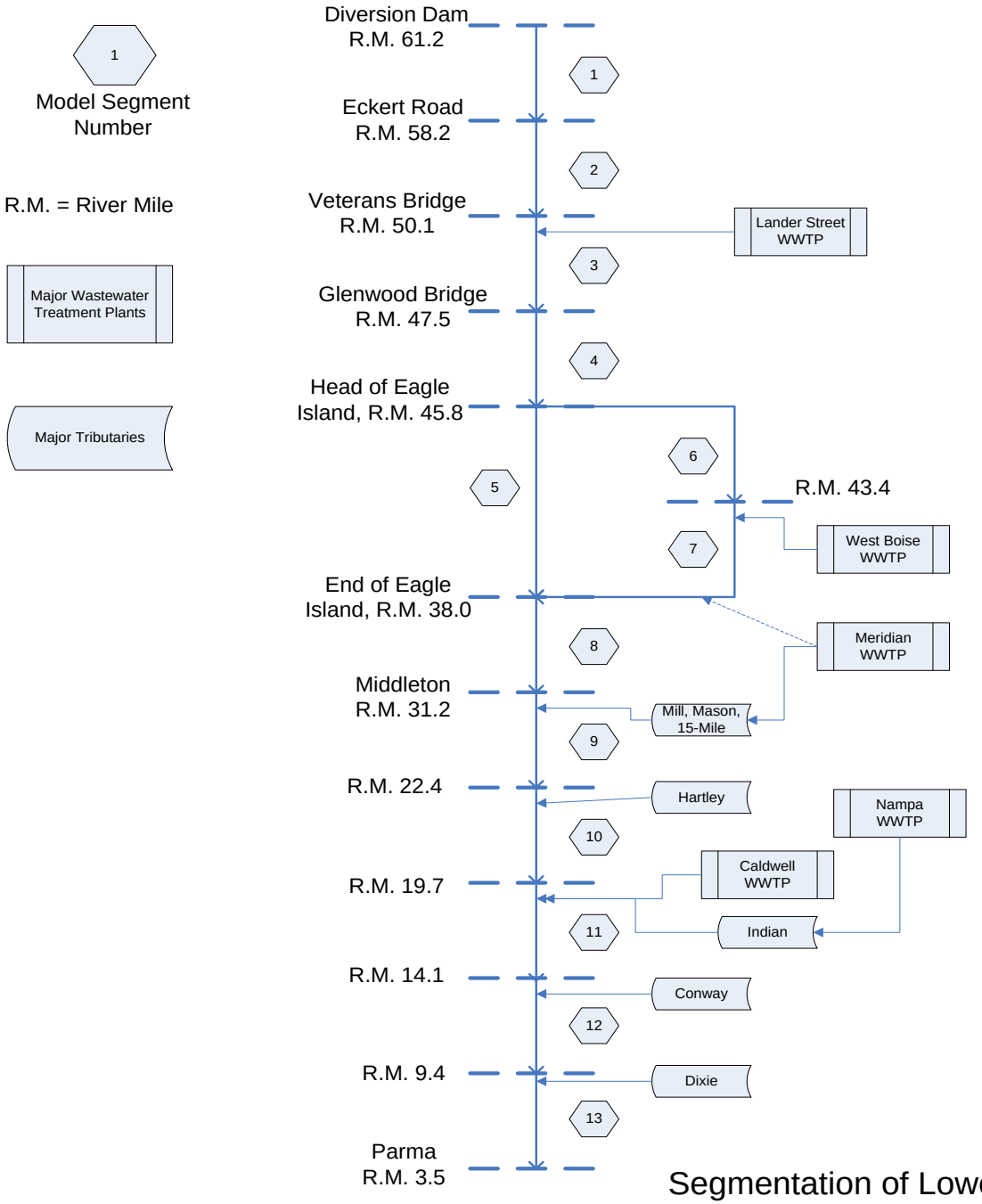
- EPA HQ contract with CH2M HILL, with Eco Modeling (Dick Park) and Warren Pinnacle (Jon Clough) (model developers) as subconsultants
- Boise City staff as technical support
- Kickoff meeting held Fall 2005 with LBWC TAC
- Boise City (Kate Harris) collected additional algae speciation data
- Model set up and calibrated for LBR by Jon and Dick
- Boise City (Ben Nydegger) ran multiple scenarios:
  - included current, LBR IP allocations, and many others above and below
- Final report submitted to EPA HQ at end of December 2008

Algae Speciation Example

Division	Species	Site					
		Eckert	Veterans	Glenwood	Middleton		
Cyanophyta	*Oscillatoria agardhii*					R	
	Phormidium inundatum				C	R	
	Phormidium species		A				
	Rivularia species				C	R	
Chlorophyta	*Cladophora glomerata*	A	R	A		R	C
	Closterium ehrenbergii				R	R	
	Cosmarium species				R/C	R	
	Oedogonium species	C				R	
	Scenedesmus quadricauda					R	
	Spirogyra species					R	
	Stigeoclonium polymorphum	R/C	R		C		C
	Ulothrix aequalis	R	R				C
	Ulothrix zonata				R		
Bacillariophyta	Diatoms, centric				C		
	Diatoms, pennate	A	A	A	A	A	A
	Fragilaria crotonensis						C
	Fragilaria virescens			R		A	
	Melosira granulata			R		R	
	Melosira varians	R	R	R	R		
	Stephanodiscus niagarae			R	R	R	

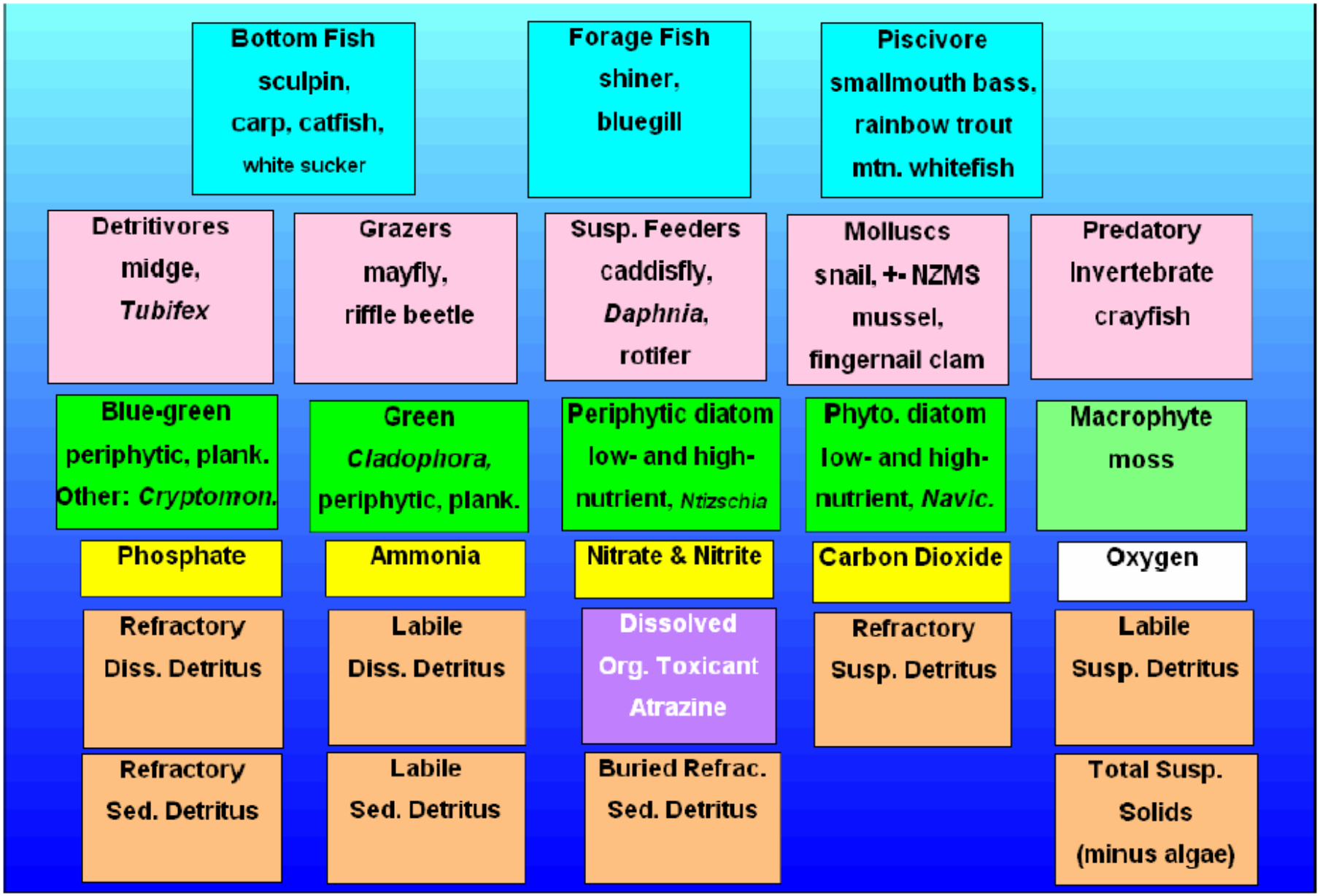
Model Setup and Calibration

Eagle Bridge over S. Channel LBR



Segmentation of Lower Boise River for Aquatox Model

Ecosystem Compartments Simulated for LBR

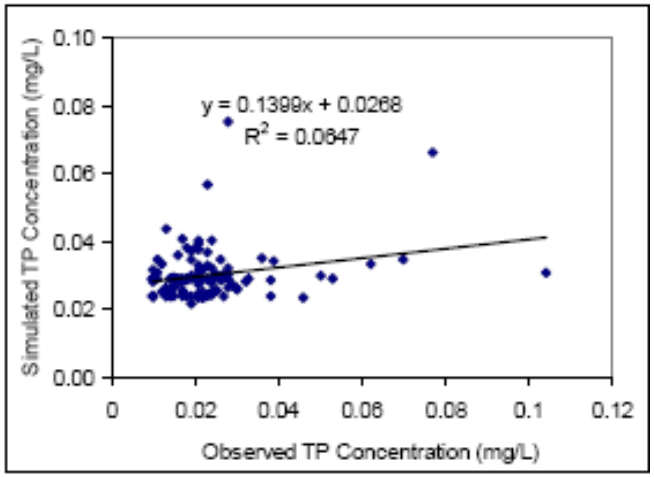


Calibration Period (1999-2001)

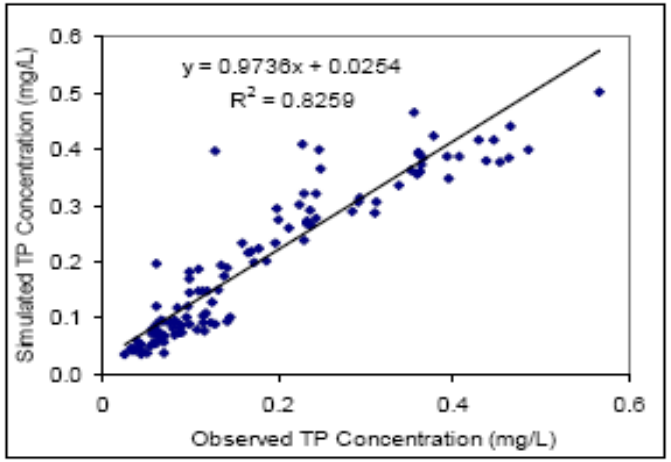
- 1999: High flow year
  - Others: 2003, 2004, 2005, 2007
- 2000: Medium flow year
  - Other: 1995
- 2001: Low flow year
  - Others: 1996,1997, 1998, 2006

TP Calibration Results

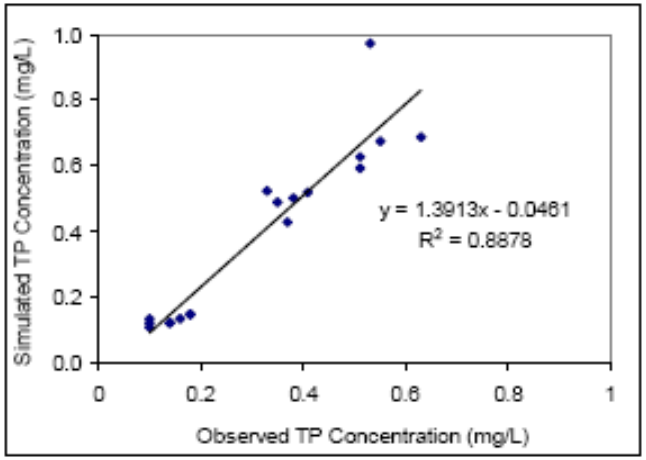
Veterans



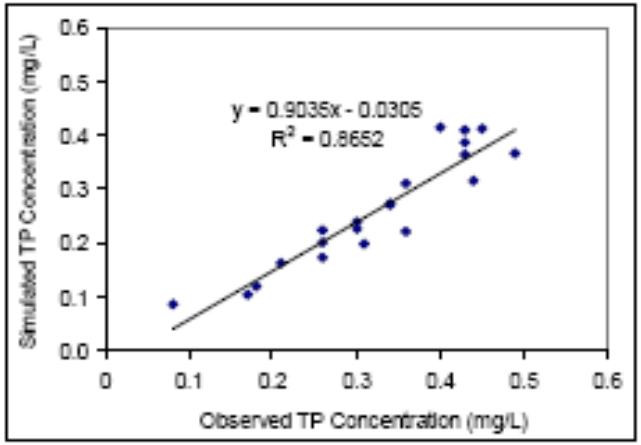
Glenwood



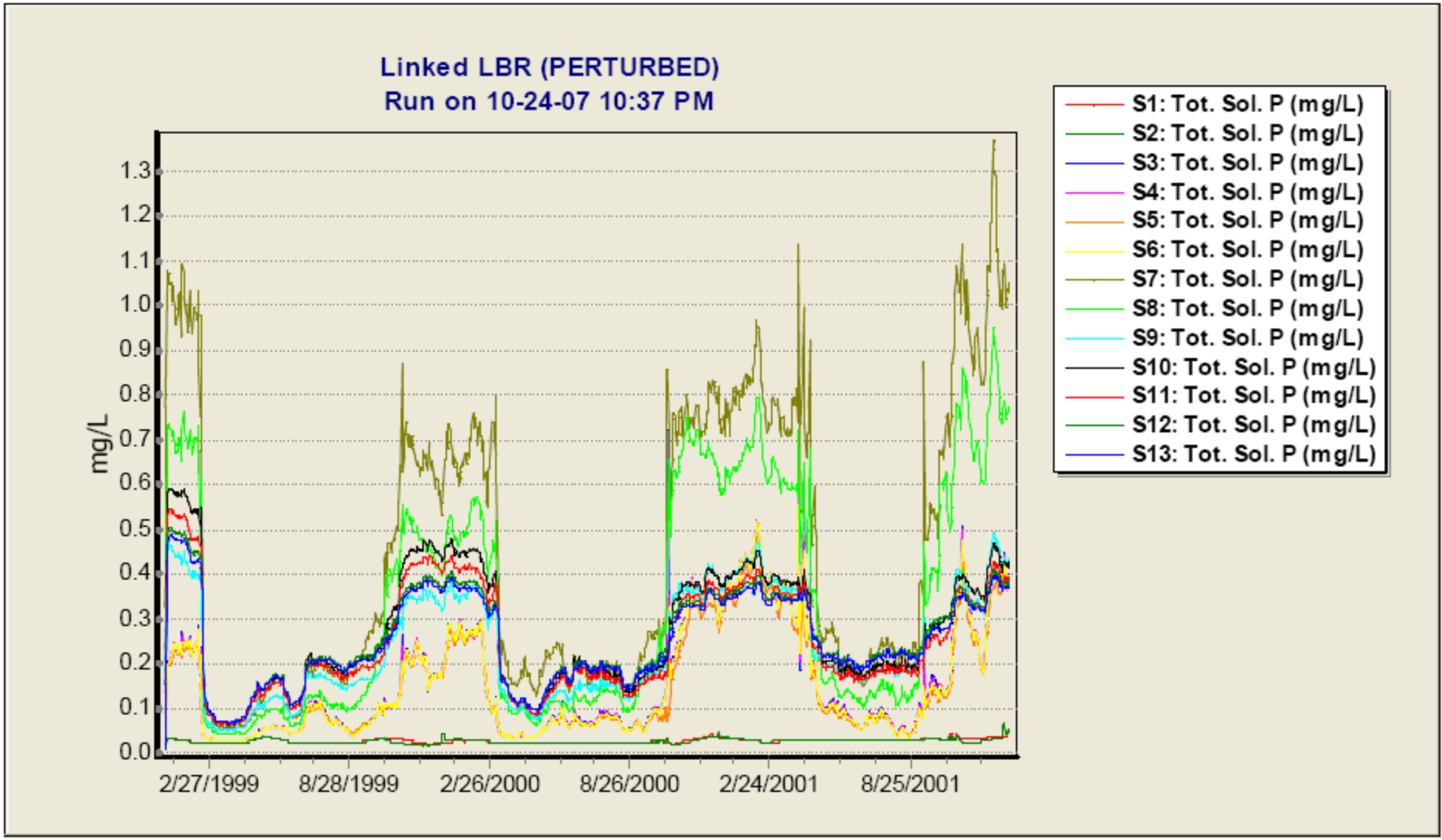
Middleton



Parma



TP for All Model Segments



Model Scenarios

Figure 5. Parma looking downstream toward confluence with Snake River.

Some Results

- Selected Scenarios:
  - 1: Current (calibrated) conditions
  - 3: DEQ-adopted Implementation Plan
  - 8: Same as 3 with point sources to 0.07 mg/L
  - 9: Same as 3 with point sources to 0 mg/L
  - 2a: Current flows with DEQ-adopted IP and 37% sediment reduction
  - 3a: Same as 3 with 37% sediment reduction

Figure 7b:

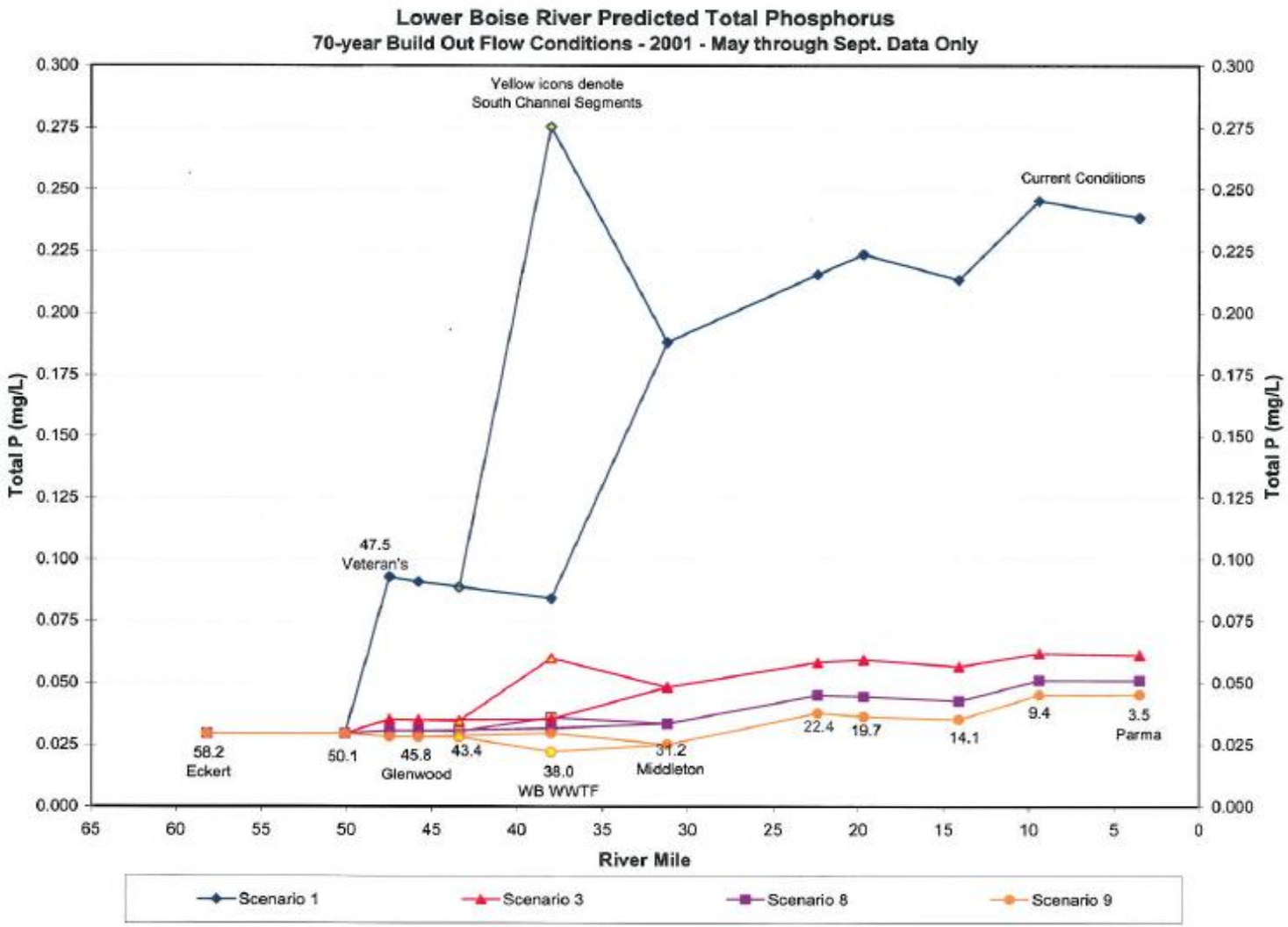

Lower Boise River Predicted Total Phosphorus
70-year Build Out Flow Conditions - 2001 - May through Sept. Data Only
Yellow icons denote
South Channel Segments
Current Conditions
47.5
Veteran's
58.2
Eckert
50.1
45.8
Glenwood
43.4
38.0
WB WWTF
31.2
Middleton
22.4
19.7
14.1
9.4
3.5
Parma
Total P (mg/L)
River Mile
Scenario 1
Scenario 3
Scenario 8
Scenario 9

Figure 7g:

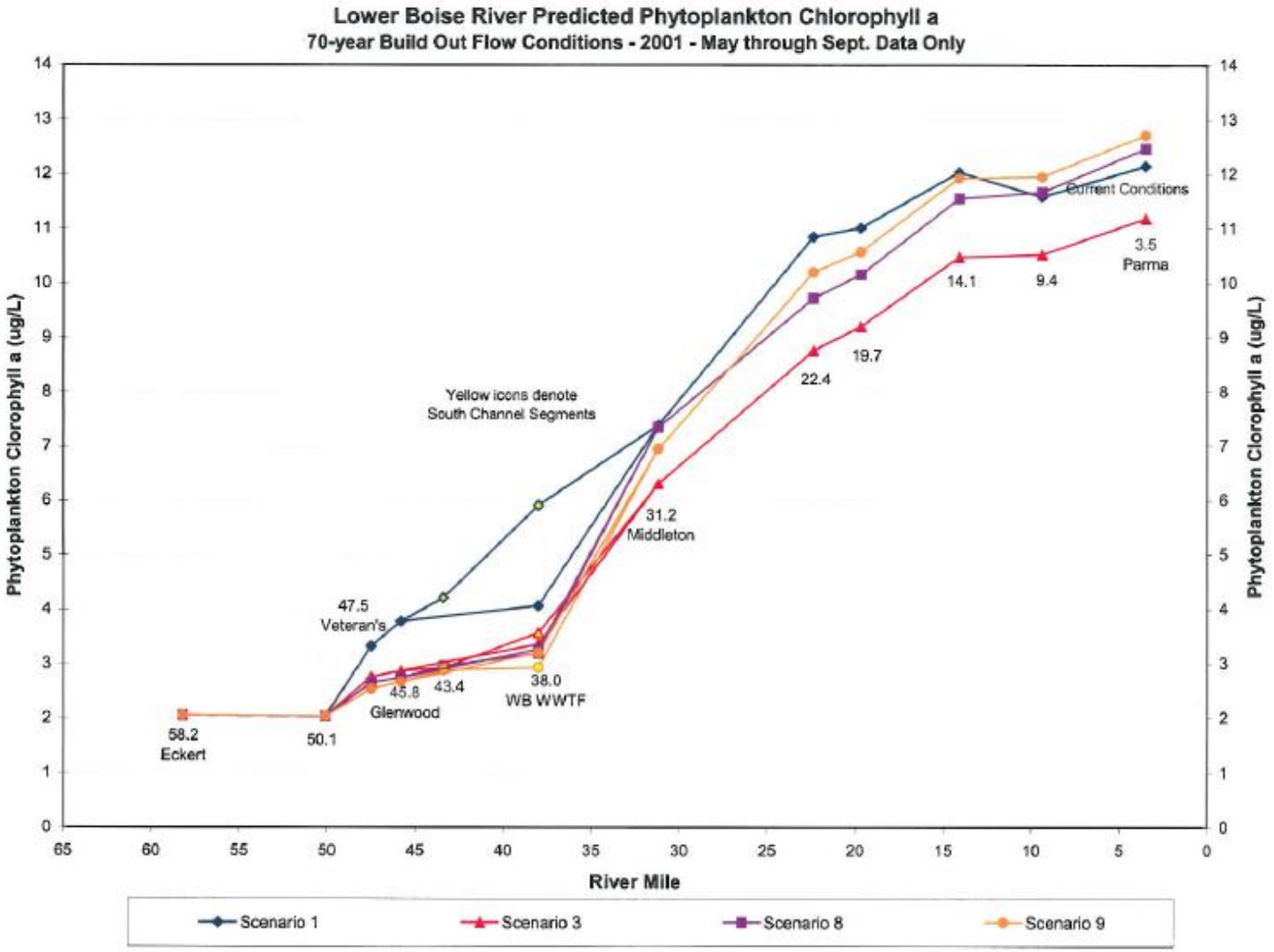

Lower Boise River Predicted Phytoplankton Chlorophyll a
70-year Build Out Flow Conditions - 2001 - May through Sept. Data Only
Phytoplankton Clorophyll a (ug/L)
River Mile
Yellow icons denote
South Channel Segments
Current Conditions
58.2
Eckert
50.1
47.5
Veteran's
45.8
Glenwood
43.4
38.0
WB WWTF
31.2
Middleton
22.4
19.7
14.1
9.4
3.5
Parma
Scenario 1
Scenario 3
Scenario 8
Scenario 9

Figure 7J:

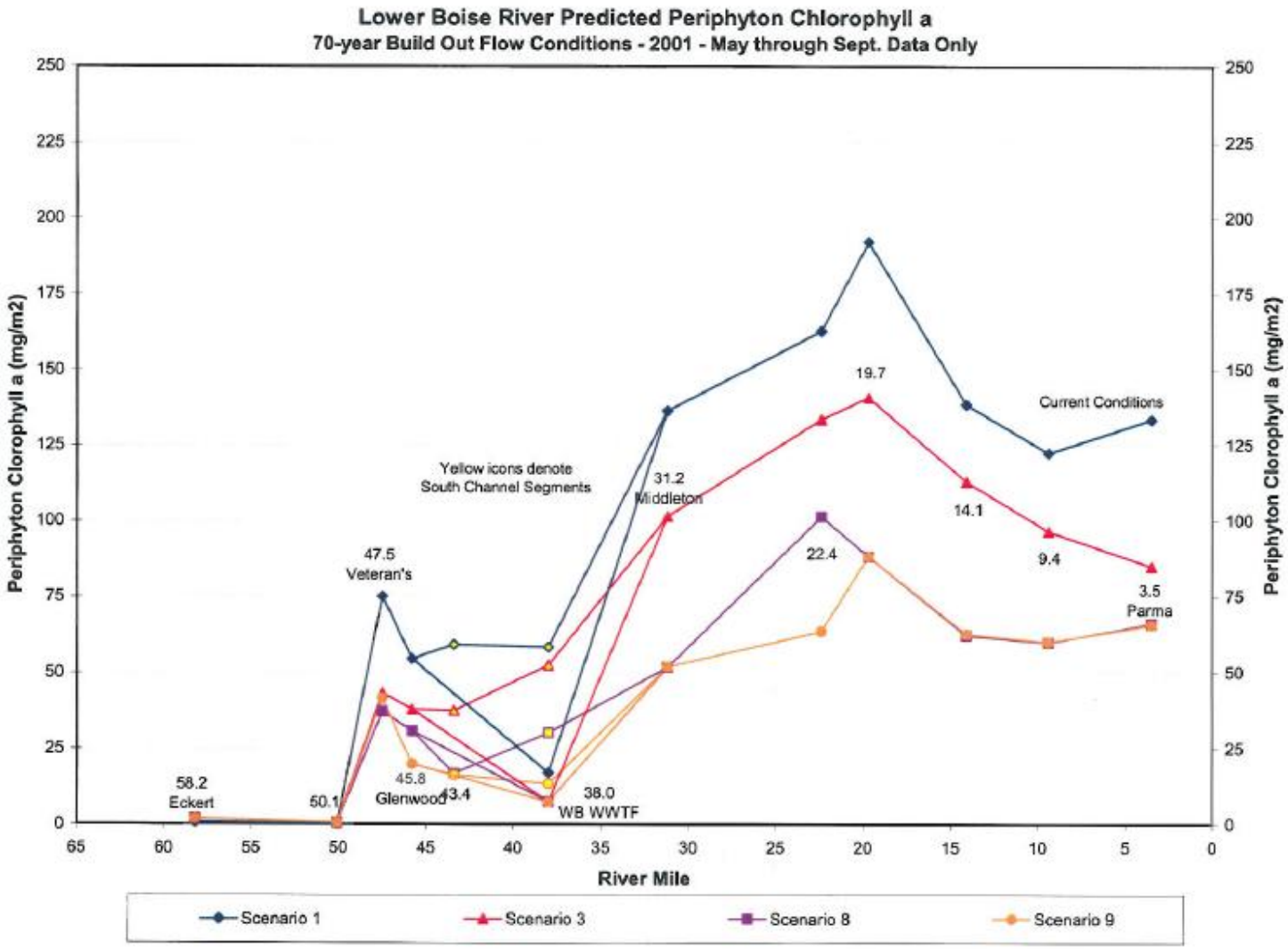

Lower Boise River Predicted Periphyton Chlorophyll a
70-year Build Out Flow Conditions - 2001 - May through Sept. Data Only
Periphyton Clorophyll a (mg/m2)
River Mile
Current Conditions
Yellow icons denote
South Channel Segments
58.2
Eckert
50.1
47.5
Veteran's
45.8
Glenwood
43.4
38.0
WB WWTF
31.2
Middleton
22.4
19.7
14.1
9.4
3.5
Parma
Scenario 1
Scenario 3
Scenario 8
Scenario 9

Figure 3b:

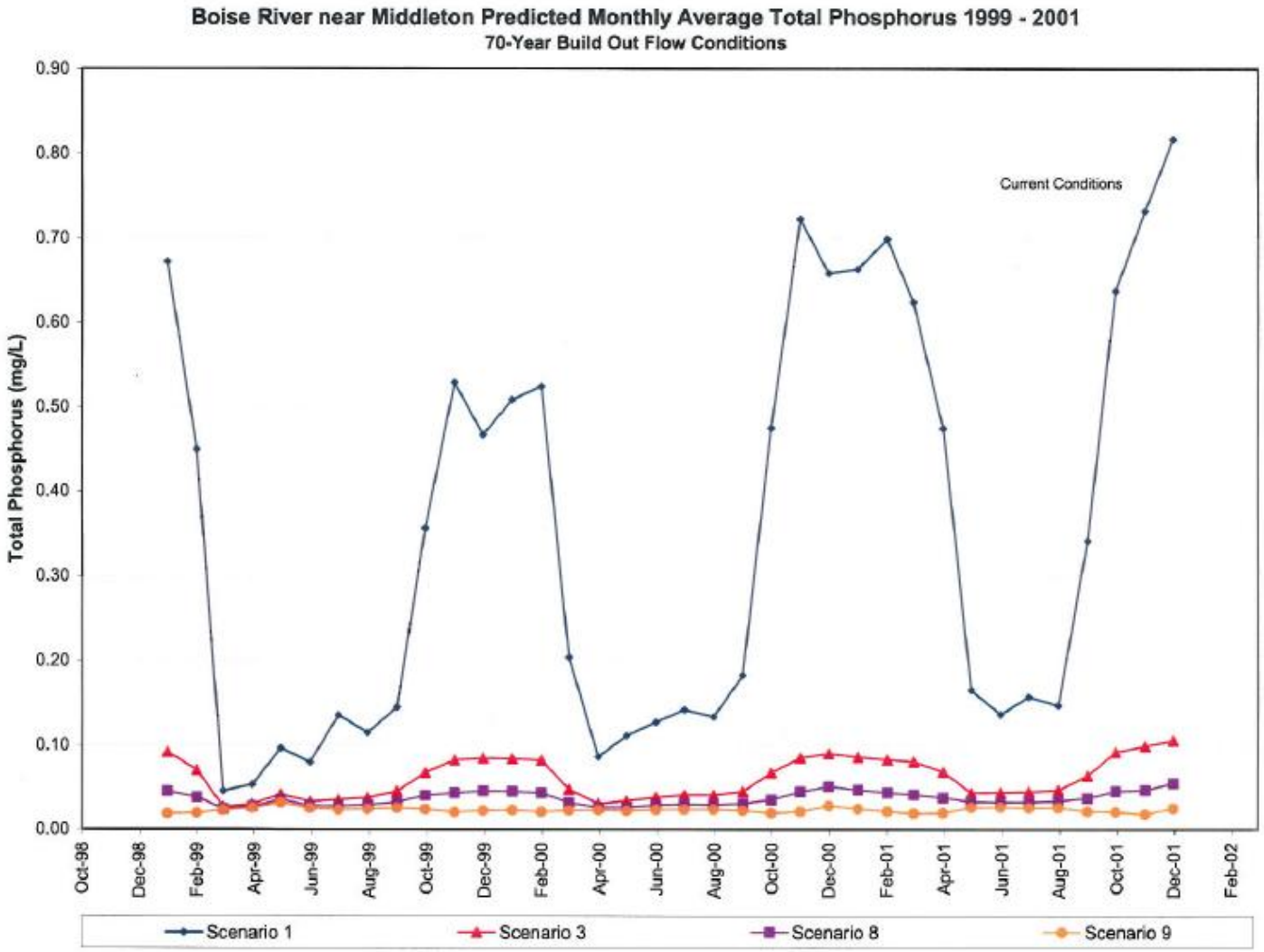

Boise River near Middleton Predicted Monthly Average Total Phosphorus 1999 - 2001
70-Year Build Out Flow Conditions
Total Phosphorus (mg/L)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Current Conditions
Oct-98
Dec-98
Feb-99
Apr-99
Jun-99
Aug-99
Oct-99
Dec-99
Feb-00
Apr-00
Jun-00
Aug-00
Oct-00
Dec-00
Feb-01
Apr-01
Jun-01
Aug-01
Oct-01
Dec-01
Feb-02
Scenario 1
Scenario 3
Scenario 8
Scenario 9

Figure 3i:

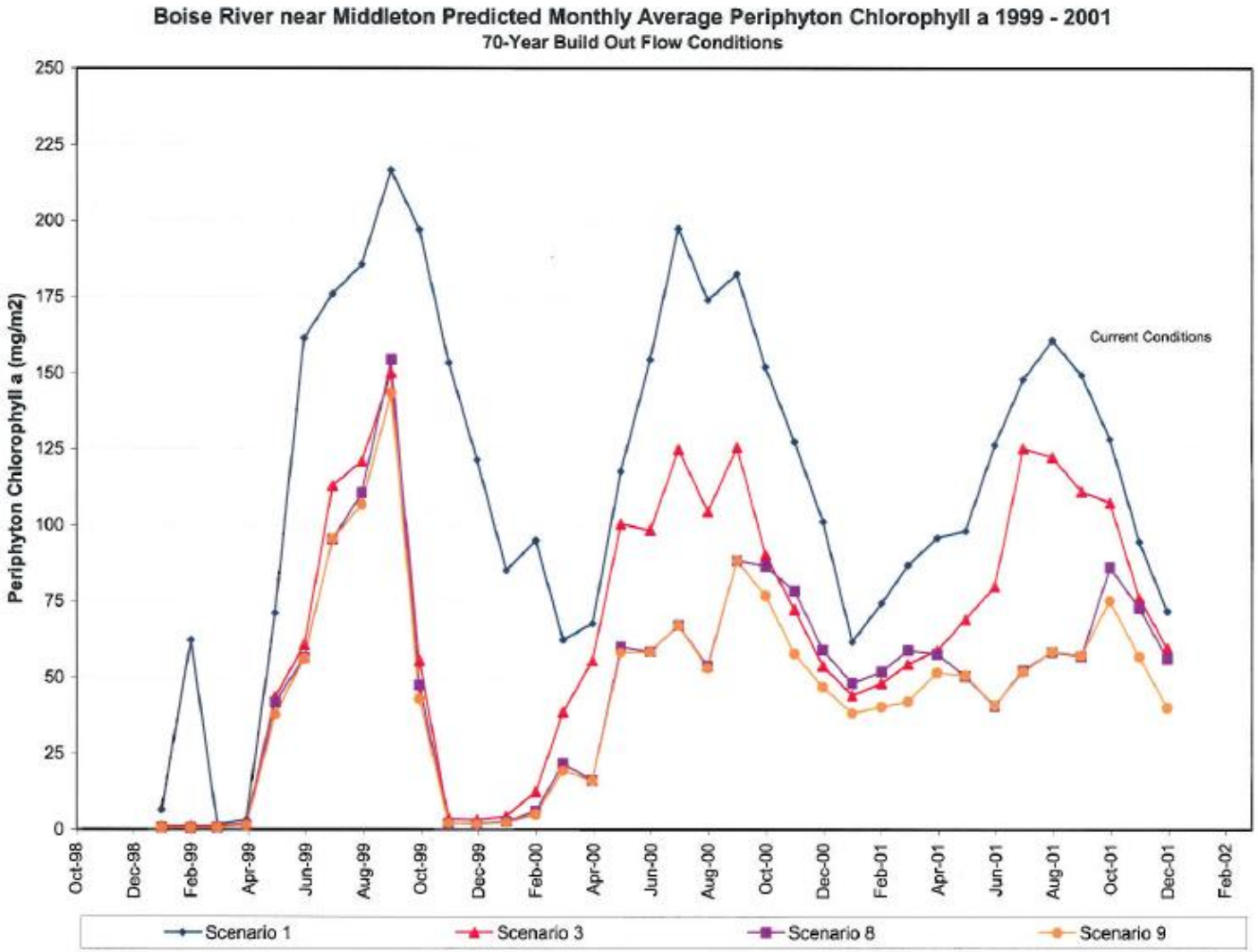

Boise River near Middleton Predicted Monthly Average Periphyton Chlorophyll a 1999 - 2001
70-Year Build Out Flow Conditions
Periphyton Chlorophyll a (mg/m2)
250
225
200
175
150
125
100
75
50
25
0
Current Conditions
Oct-98
Dec-98
Feb-99
Apr-99
Jun-99
Aug-99
Oct-99
Dec-99
Feb-00
Apr-00
Jun-00
Aug-00
Oct-00
Dec-00
Feb-01
Apr-01
Jun-01
Aug-01
Oct-01
Dec-01
Feb-02
Scenario 1
Scenario 3
Scenario 8
Scenario 9

Figure 4b:

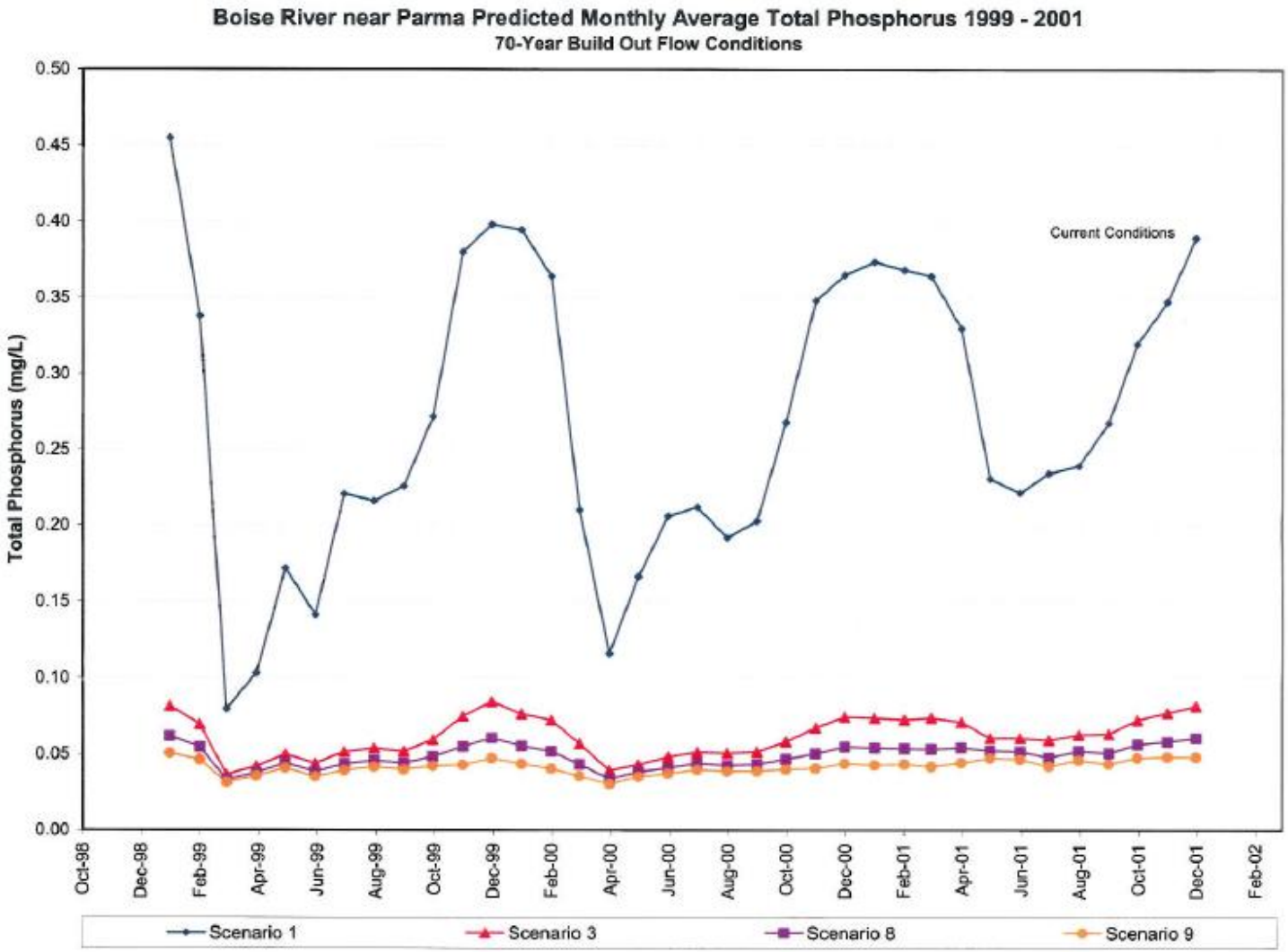
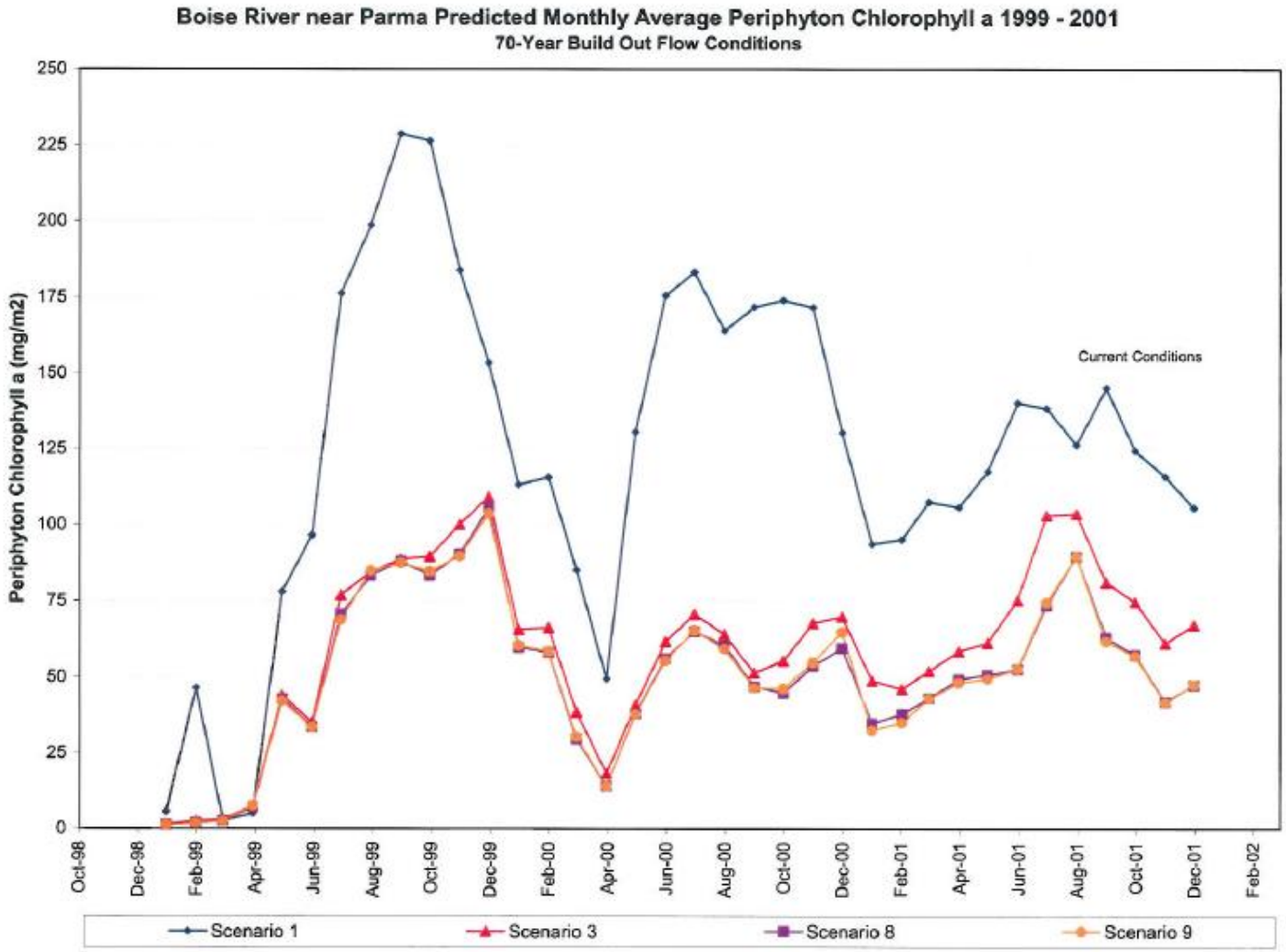

Boise River near Parma Predicted Monthly Average Total Phosphorus 1999 - 2001
70-Year Build Out Flow Conditions
Total Phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Current Conditions
Oct-98
Dec-98
Feb-99
Apr-99
Jun-99
Aug-99
Oct-99
Dec-99
Feb-00
Apr-00
Jun-00
Aug-00
Oct-00
Dec-00
Feb-01
Apr-01
Jun-01
Aug-01
Oct-01
Dec-01
Feb-02
Scenario 1
Scenario 3
Scenario 8
Scenario 9

Figure 4i:


Boise River near Parma Predicted Monthly Average Periphyton Chlorophyll a 1999 - 2001
70-Year Build Out Flow Conditions
Periphyton Chlorophyll a (mg/m2)
250
225
200
175
150
125
100
75
50
25
0
Current Conditions
Oct-98
Dec-98
Feb-99
Apr-99
Jun-99
Aug-99
Oct-99
Dec-99
Feb-00
Apr-00
Jun-00
Aug-00
Oct-00
Dec-00
Feb-01
Apr-01
Jun-01
Aug-01
Oct-01
Dec-01
Feb-02
Scenario 1
Scenario 3
Scenario 8
Scenario 9

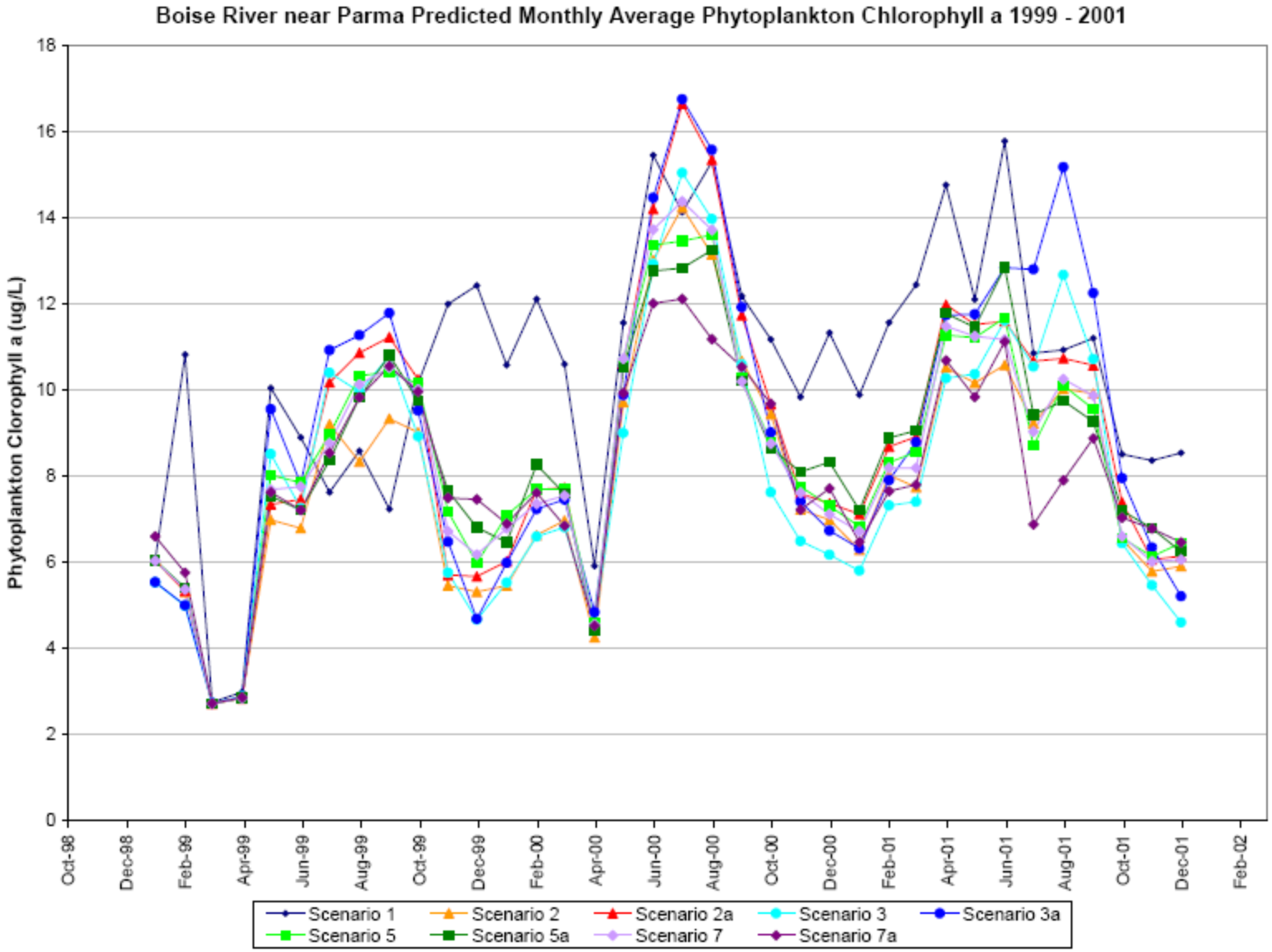
Key Finding Related to SR-HC TMDL Implementation on LBR

- DEQ-adopted Implementation Plan will meet 0.07 mg/L target at Parma even during very low flow year (2001) and even during lowest flow period

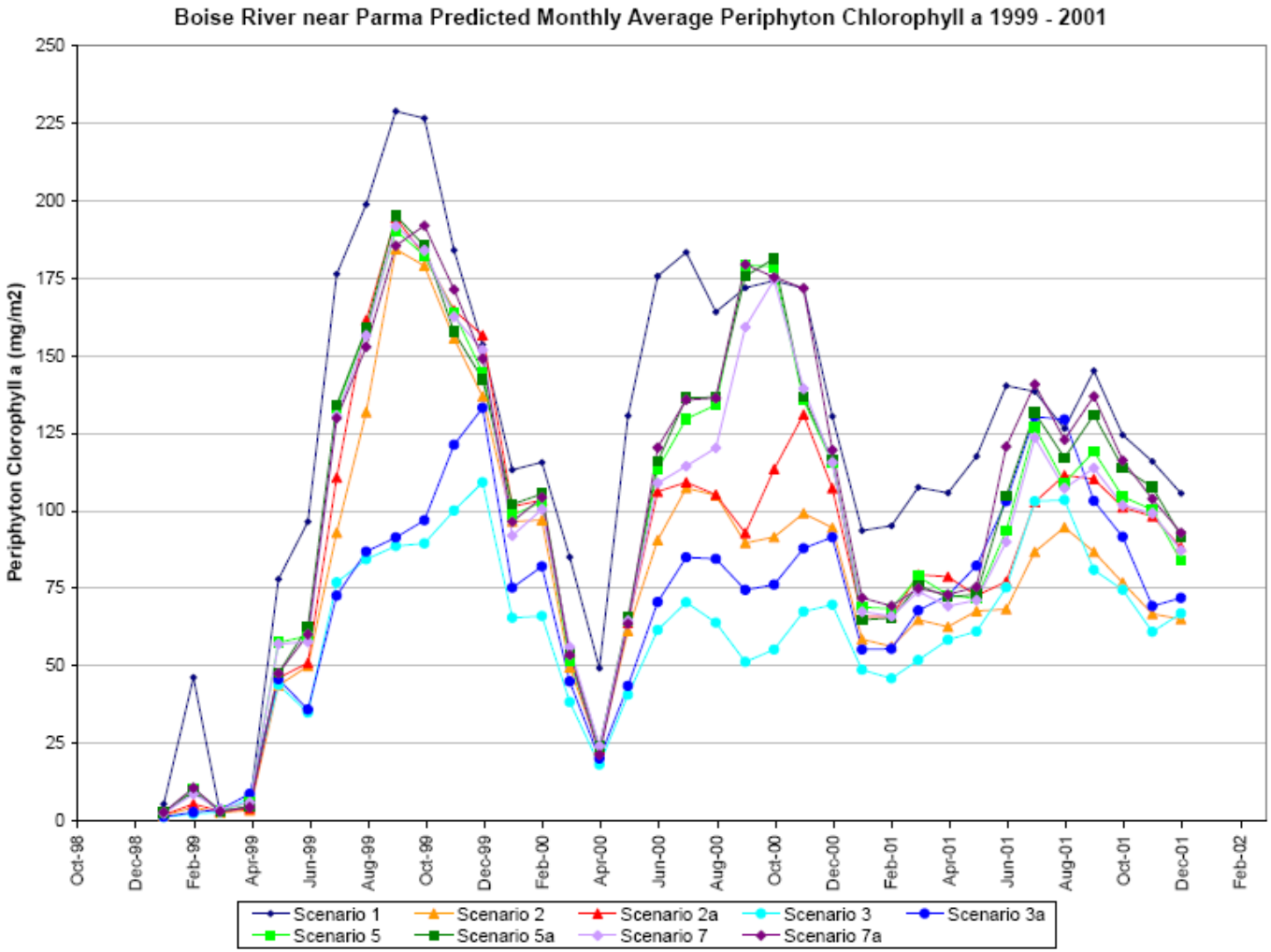
	May through September Data Only		
	Daily	**Weekly Avg**	**Monthly Avg**
1999	0/153 **0.0%**	0/22 **0.0%**	0/5 **0.0%**
2000	0/153 **0.0%**	0/22 **0.0%**	0/5 **0.0%**
2001	9/153 **5.9%**	0/22 **0.0%**	0/5 **0.0%**
1999-2001 Avg.	9/459 **2.0%**	0/66 **0.0%**	0/15 **0.0%**

- All predicted 9 daily “exceedances” had TP values < 0.075 mg/L

Effect of 37% TSS Reduction at Parma



Effect of 37% TSS Reduction at Parma



Other Key Findings Related to LBR Water Quality

- Phytoplankton chlorophyll concentration is now and will be ~ 15 ug/L at most sensitive location (Parma), even with sediment TMDL reduction goals met
- Periphyton chlorophyll will be less than 150 mg/sq.m at most sensitive location (Middleton) even during low flow year
  - 150 mg/sq.m is recent criterion developed by Montana (needs to be evaluated further for LBR)

Potential Application of AQUATOX for Nutrient Criteria for LBR

Some Key Findings for LBR Related to Potential Site Specific Nutrient Criteria

- Phytoplankton not very sensitive to nutrient concentrations
- Periphyton are sensitive to phosphorus concentrations, but not nitrogen
- Phytoplankton, blue greens, cladophora not responsive to nutrients
- Periphyton appear to be best measure of nutrient/use attainment
- Most sensitive location appears to be Middleton
- LBR TP target appears to be in the 120-130 ug/l range
- One approach to P criteria might be combination of AQUATOX with periphyton criterion similar to Montana's

Montana Criterion

- 150 mg/m2 (with allowance for statistical exceedances)

Montana Survey Results

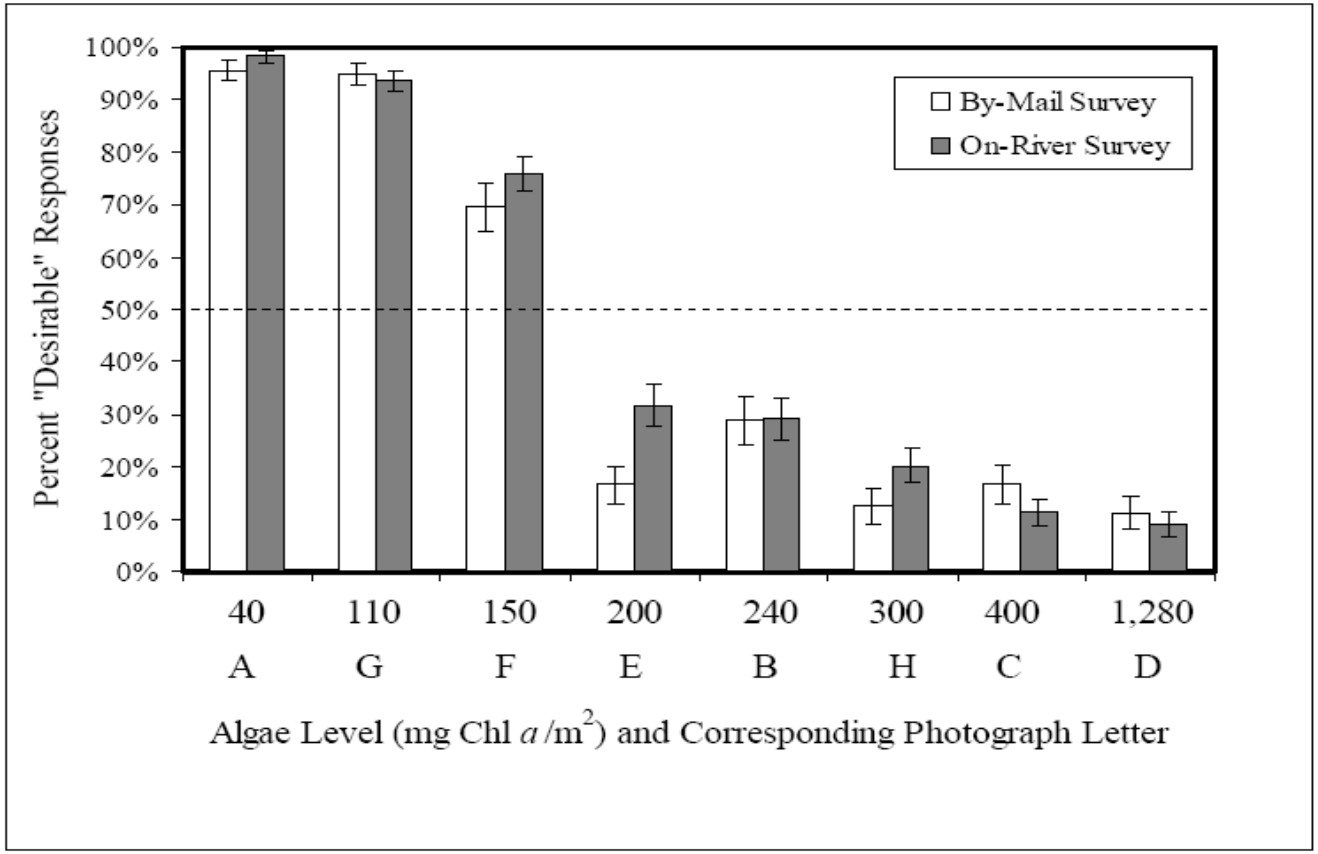
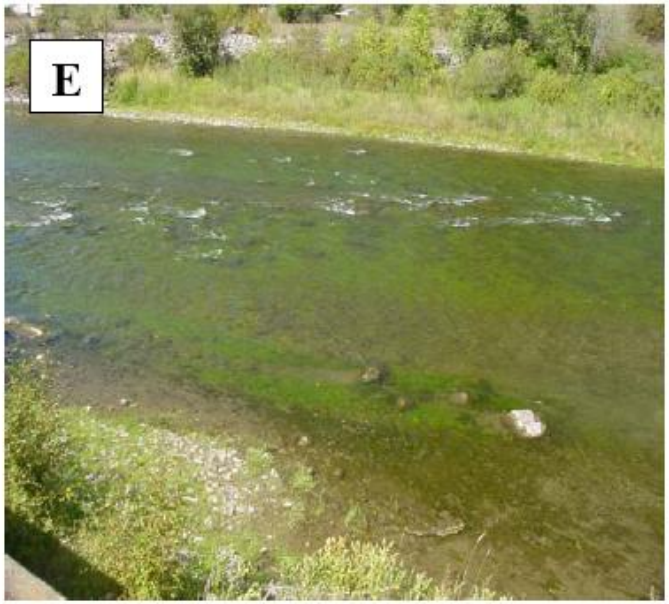
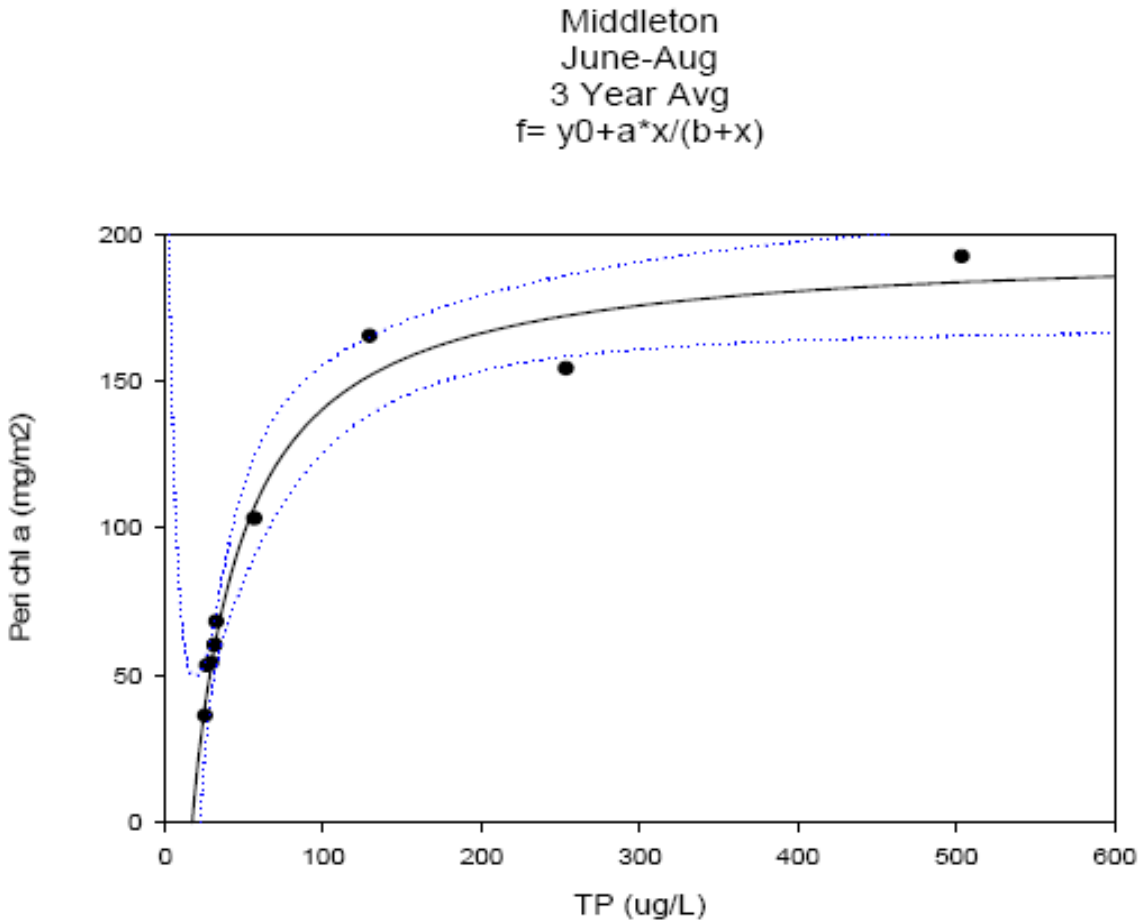


Figure 2. Percent Desirable Responses from the By-Mail and On-River Surveys. Letters designating the survey photographs are sequenced from lowest to highest algae level. Error bars are the 95% confidence level of each proportion, expressed as percent error.

Montana Survey Pics



Potential Application to LBR



Potential Application to LBR

Table 6-1. Aquatox Predicted TP concentration (µg/L) to Achieve Periphyton Chlorophyll *a* Level of 150 mg/m^2				
Water Year and Location	Season			
	May-Sep.	May-Nov.	Oct.-Nov.	Jun.-Aug.
Three-Year (1999 to 2001) Average				
Middleton	160	361	N/A	124
Parma	351	297	208	315