Quantitative Systems Modeling for Participatory Watershed Management and Decision Making in the Coeur d'Alene Basin

(http://www.coeurdalene.org/discover-cda/photo-gallery)

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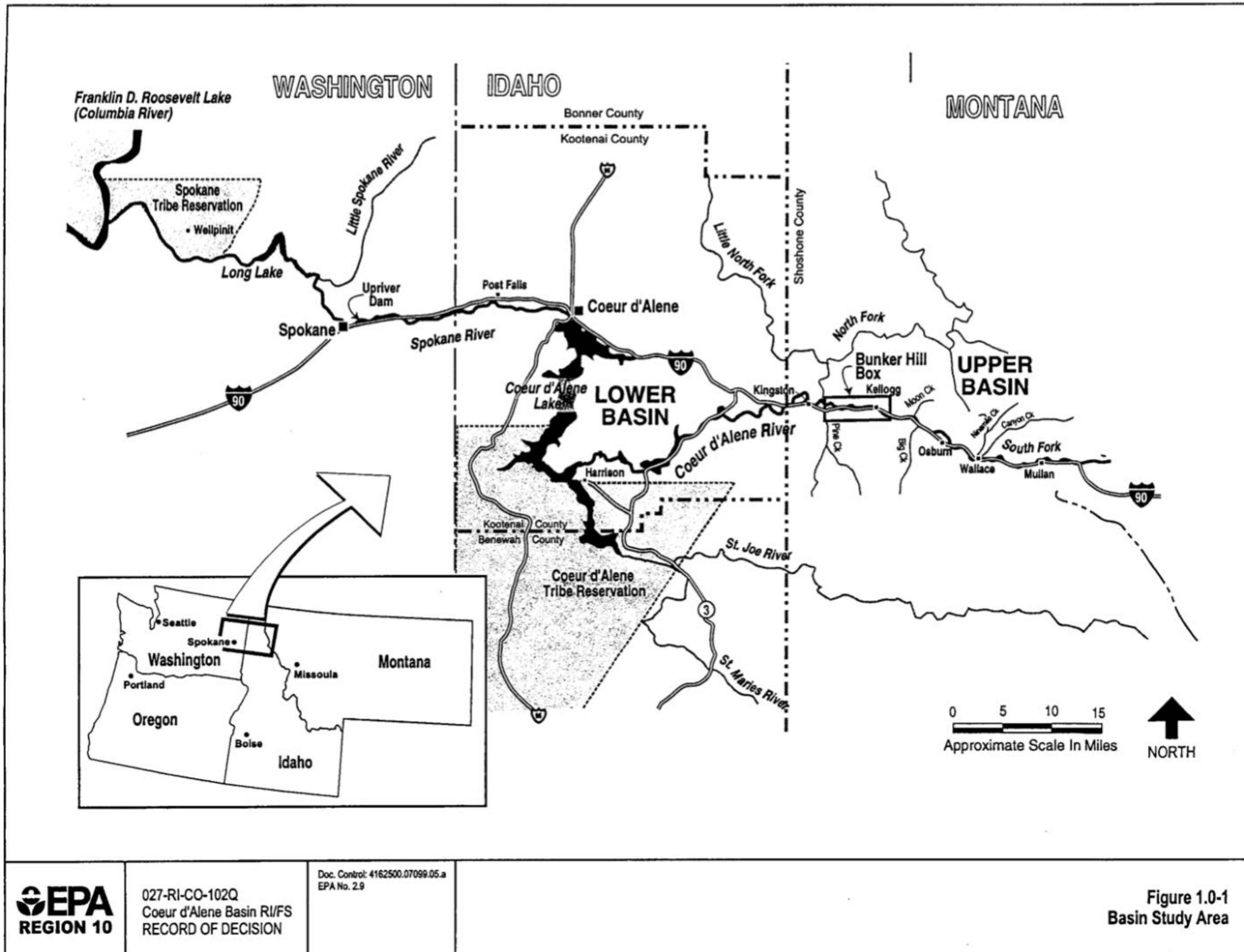
University of Idaho

MILES Managing Idaho's Landscapes for Ecosystem Services

IDAHO EPSCoR


WASHINGTON
IDAHO
MONTANA
Franklin D. Roosevelt Lake (Columbia River)
Bonner County
Kootenai County
Spokane Tribe Reservation
Wellpinit
Little Spokane River
Long Lake
Upriver Dam
Post Falls
Coeur d'Alene
Spokane
Spokane River
Shoshone County
Little North Fork
North Fork
Bunker Hill Box
Kellogg
UPPER BASIN
LOWER BASIN
Coeur d'Alene Lake
Kingston
Coeur d'Alene River
Pine Ck
Big Ck
Moon Ck
Osburn
Wallace
Mullan
South Fork
Harrison
Kootenai County
Benewah County
Coeur d'Alene Tribe Reservation
St. Joe River
St. Maries River
Seattle
Spokane
Washington
Montana
Missoula
Portland
Oregon
Boise
Idaho
0 5 10 15
Approximate Scale In Miles
NORTH
EPA REGION 10
027-RI-CO-102Q
Coeur d'Alene Basin RI/FS
RECORD OF DECISION
Doc. Control: 4162500.07099.05.a
EPA No. 2.9
Figure 1.0-1
Basin Study Area

(EPA, 2002)

(Unknown, 1904)

(Unknown, 1905)

(IDEQ/CDA Tribe, 2009)

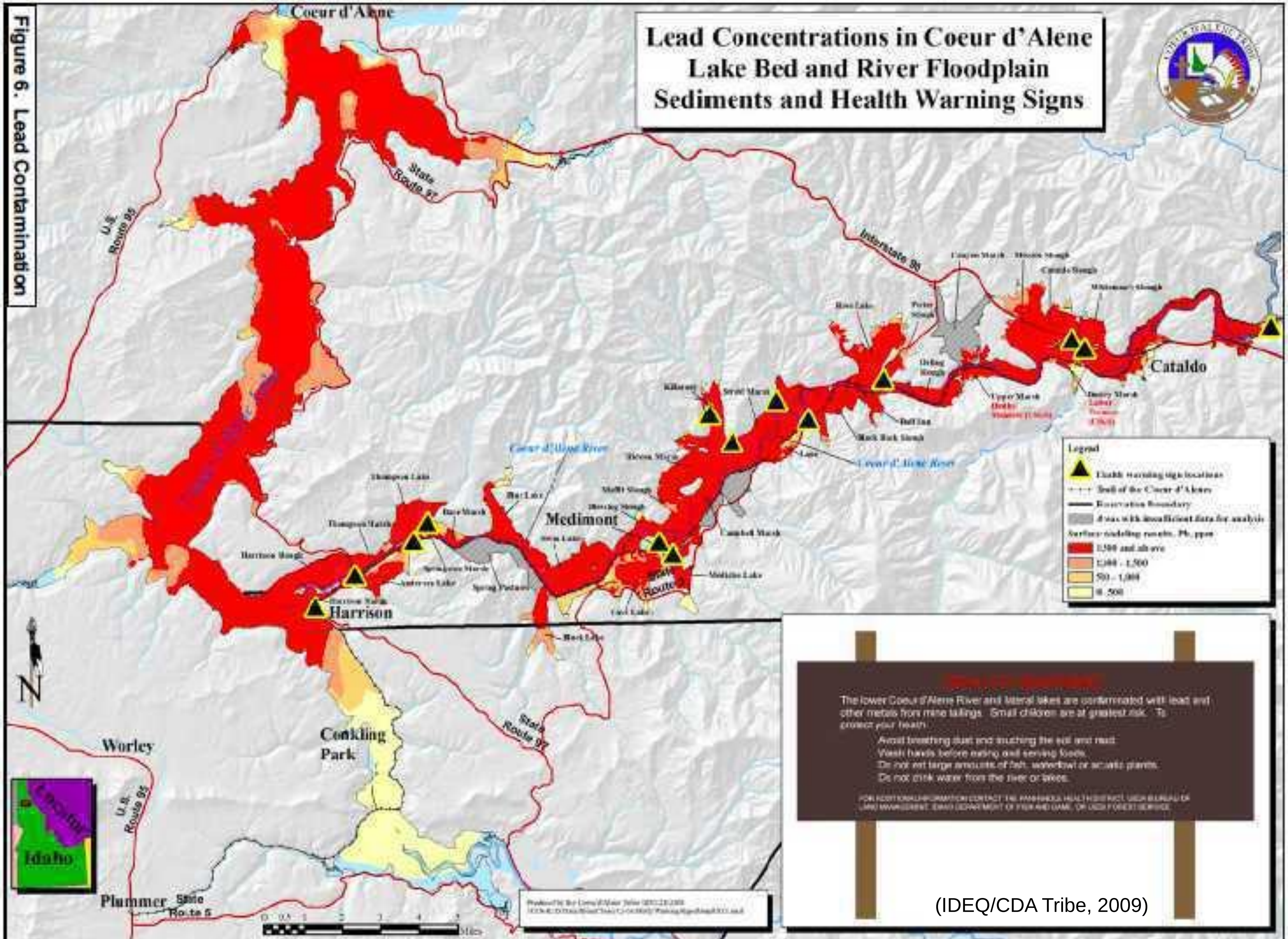
(http://www.cdaresort.com/discover/resort/gallery)

(http://www.cdaresort.com/discover/resort/gallery)

Population	1990	2000	% Increase 1990-2000	2006	% Increase 2000-2006
Coeur d'Alene	24,561	34,527	40.5%	41,328	19.8%
Hayden	4,888	9,167	87.4%	12,349	35.6%
Post Falls	7,349	17,333	135%	24,515	41.5%
Kootenai County	69,795	108,685	55.7%	131,507	21%
State of Idaho	1,006,749	1,293,953	28.5%	1,467,465	13.3%
United States	248,765,170	273,643,273	13.1%	299,389,484	9.4%

Idaho was the fifth fastest growing state in the 1990s, and Kootenai County was the third fastest growing county in Idaho. Source: *U.S. Census Bureau*

(IDEQ/CDA Tribe, 2009)



(IDEQ/CDA Tribe, 2009)

Surface area =	31,875 acres
Lake volume =	2.3 million ac-ft
Max depth =	64 m
Mean depth =	22 m
Mean hydraulic residence =	0.5 years
Watershed area =	2.4 million acres
Shoreline length =	150 miles

(IDEQ/CDA Tribe, 2009)

Table 2-1
Preliminary Estimate of Mill Tailings Produced in the Coeur d'Alene Mining Region

Disposal Method[a]	Dates	Tailings (tons)	Metals Contained in Tailings (tons)		
			Silver	Lead	Zinc
To creeks	1884-1967	61,900,000	2,400	880,000	>720,000
To dumps	1901-1942	14,600,000	400	220,000	>320,000
Mine backfill	1949-1997	18,000,000	200	39,000	22,000
To impoundments	1928-1997	26,200,000	300	109,000	180,000
Total	1884-1997	120,700,000	3,300	1,248,000	>1,242,000

a. Long (1998) defines dumps as unsecured stockpiles of tailings. Impoundments are secured by dams or other structures. Many impoundments were built over and from older tailings dumps.

Source: Long, 1998.

(LeJeune et al, 2000)

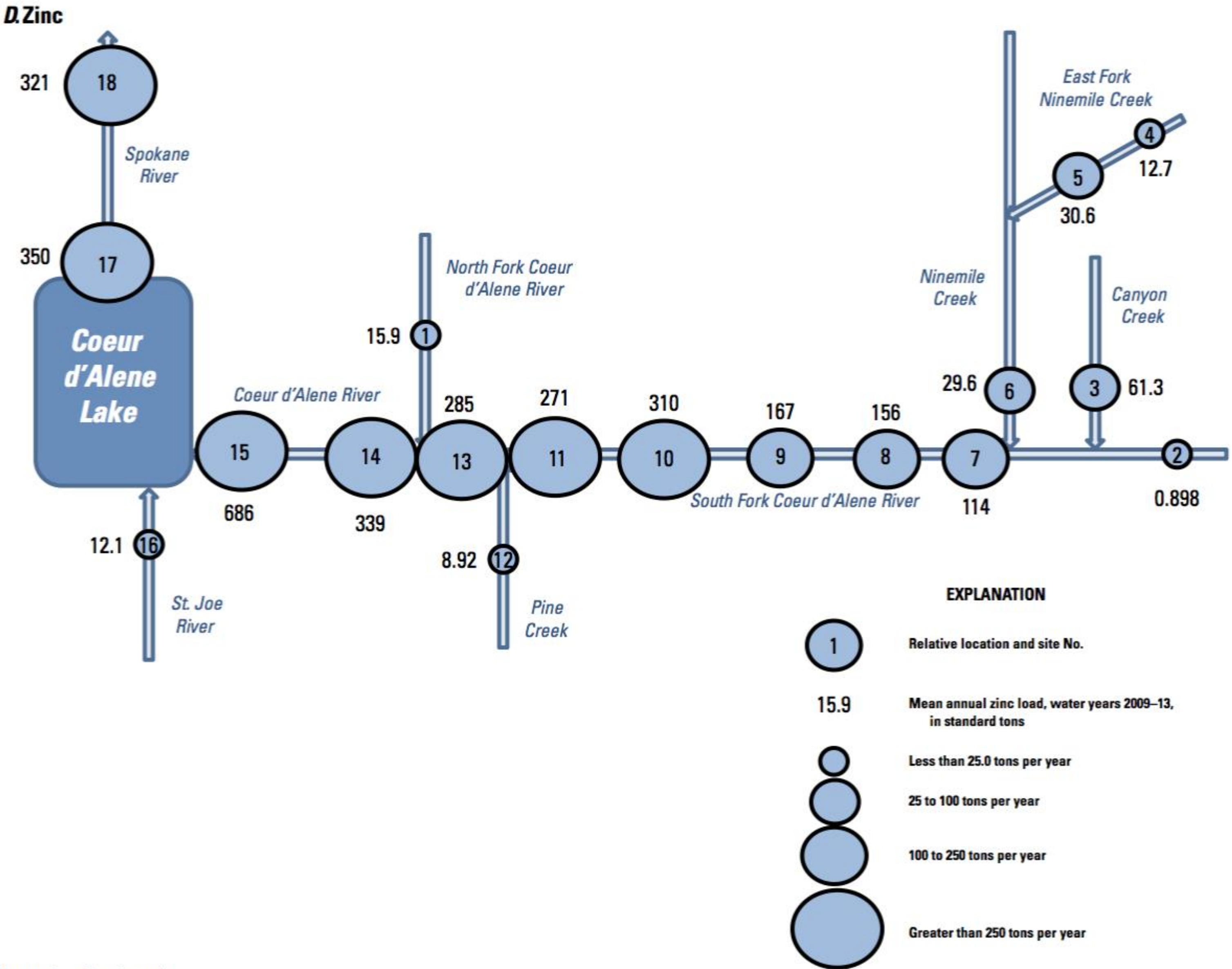
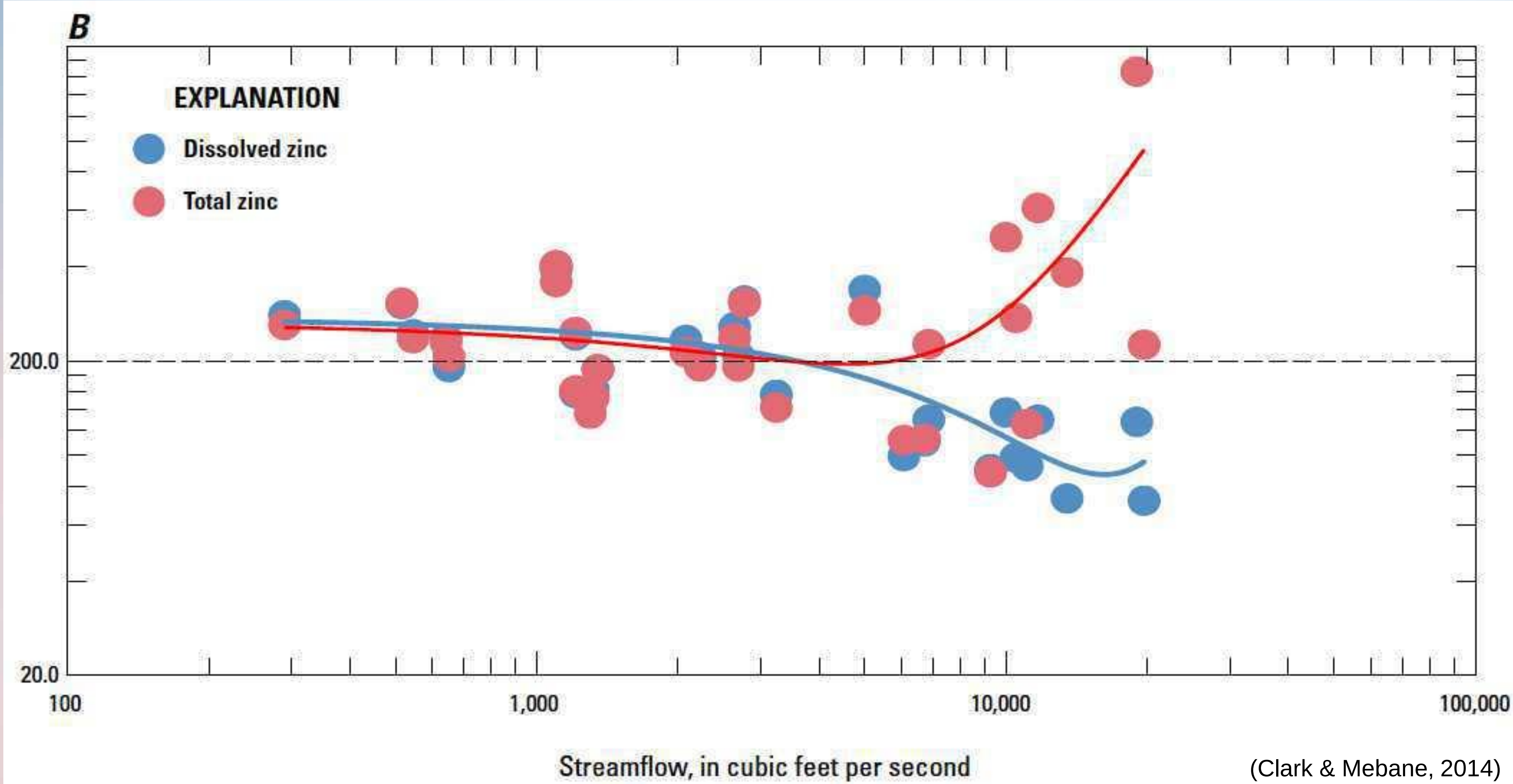
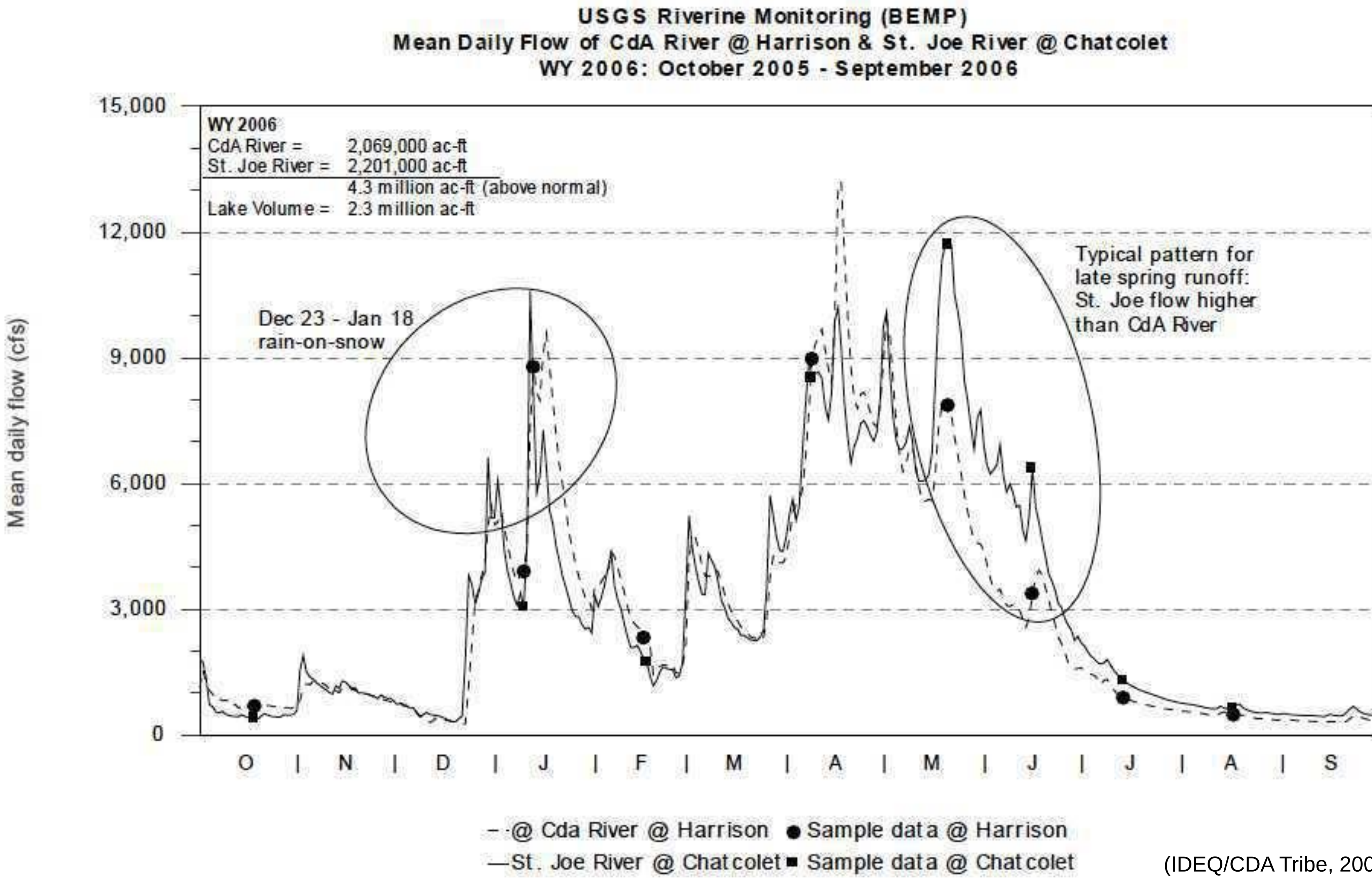


Figure 8.—Continued

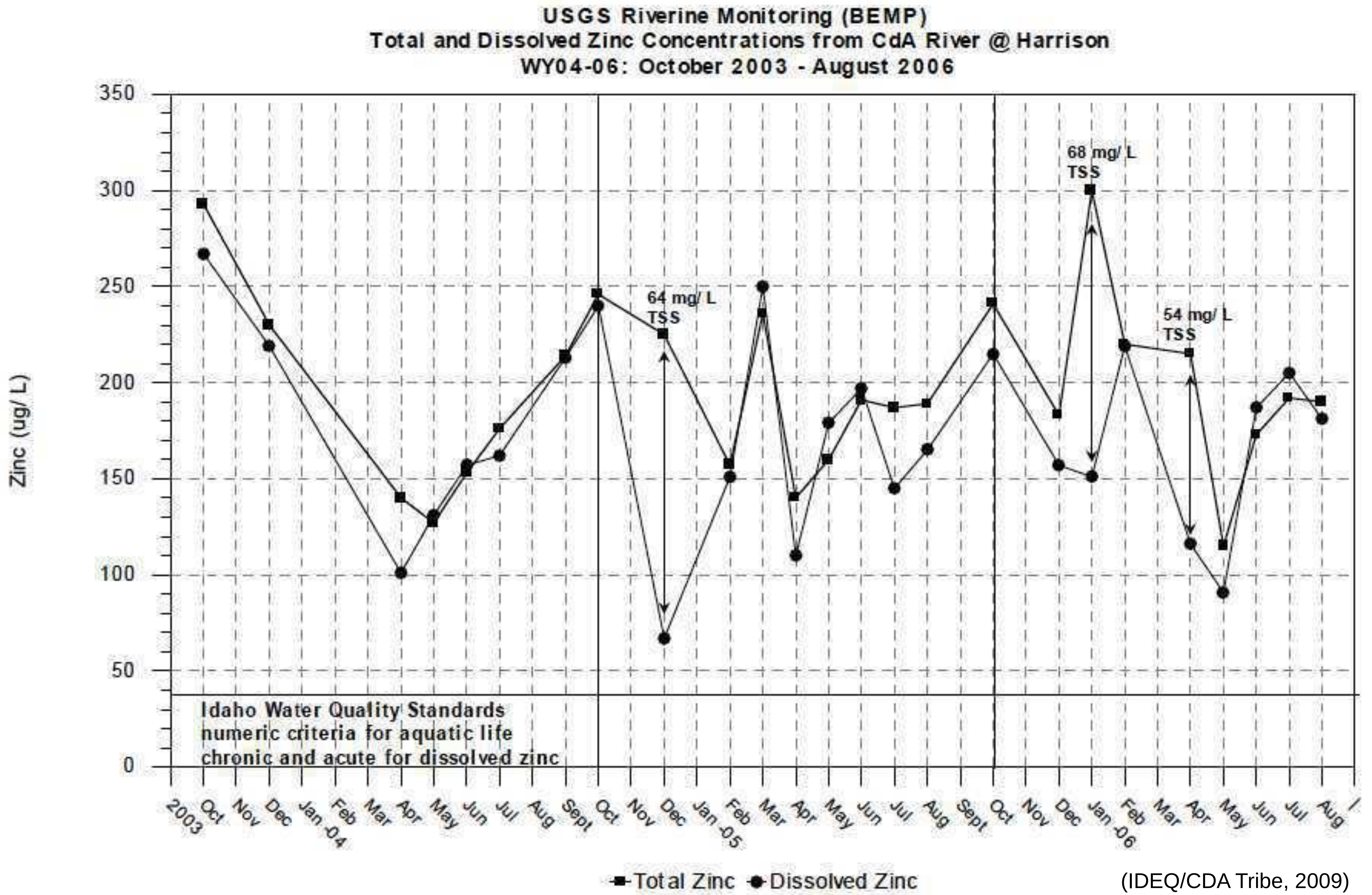
(Clark & Mebane, 2014)



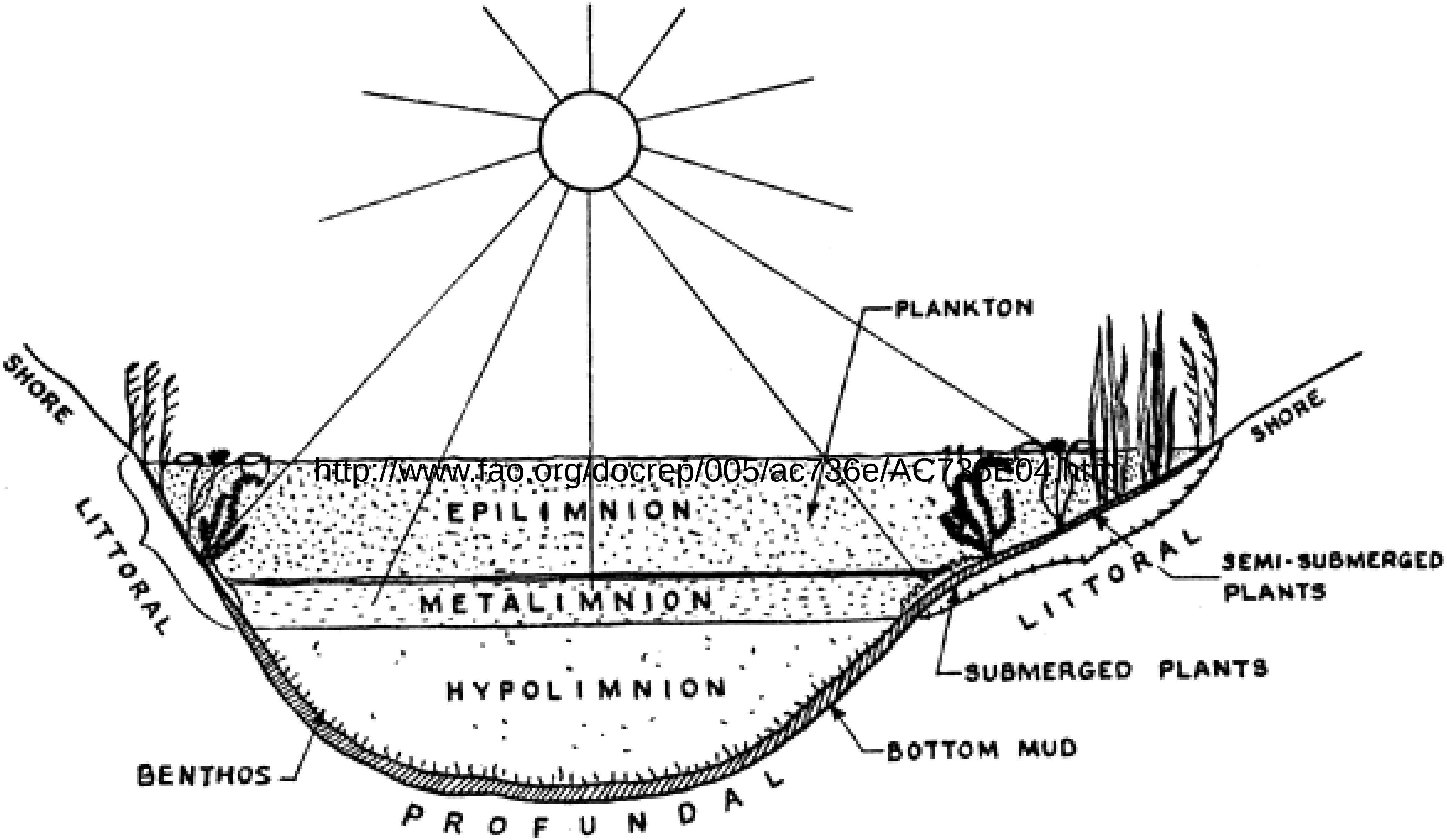
(Clark & Mebane, 2014)



(IDEQ/CDA Tribe, 2009)



(IDEQ/CDA Tribe, 2009)



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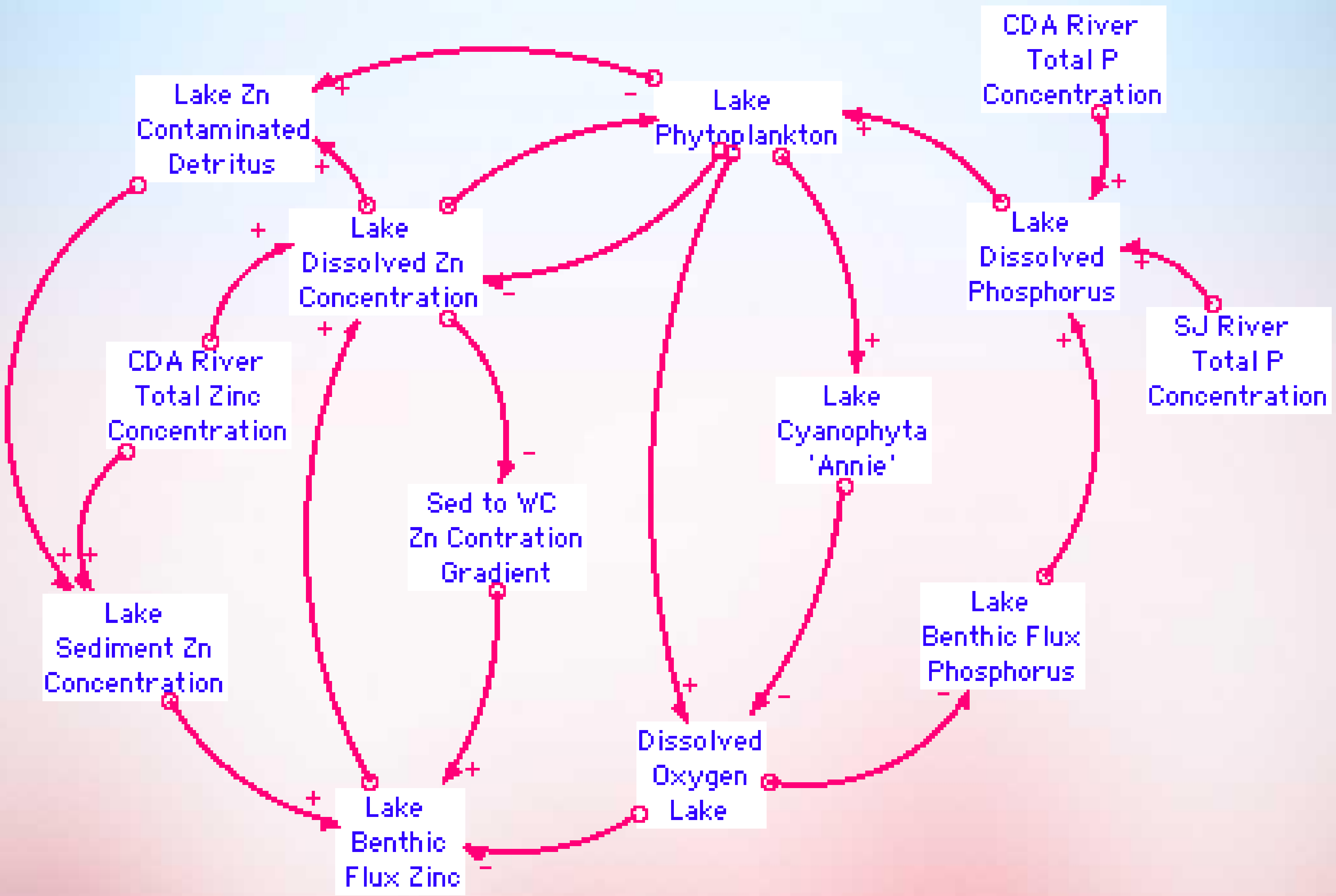

Lake Zn Contaminated Detritus
Lake Phytoplankton
CDA River Total P Concentration
Lake Dissolved Zn Concentration
Lake Dissolved Phosphorus
SJ River Total P Concentration
CDA River Total Zinc Concentration
Lake Cyanophyta 'Annie'
Sed to WC Zn Contration Gradient
Lake Sediment Zn Concentration
Lake Benthic Flux Phosphorus
Dissolved Oxygen Lake
Lake Benthic Flux Zinc

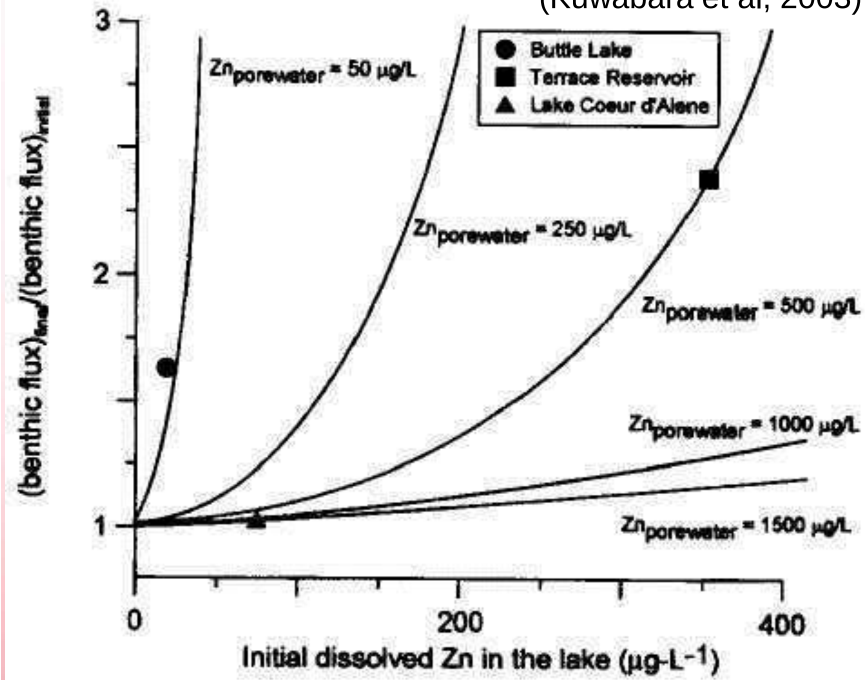
Source	Zn flux (tonnes/km^2/yr)	Orthophosphate flux (tonnes/km^2/yr)
Benthic Flux		
Mica Bay	3.5 ± 1.5	0.20 ± 0.20
Main Channel	2.8 ± 0.8	0.07 ± 0.02
Diffusive estimate	1.3 ± 0.3	—[b]
Coeur d'Alene River	5.3	0.09
St. Joe River	0.04	0.09

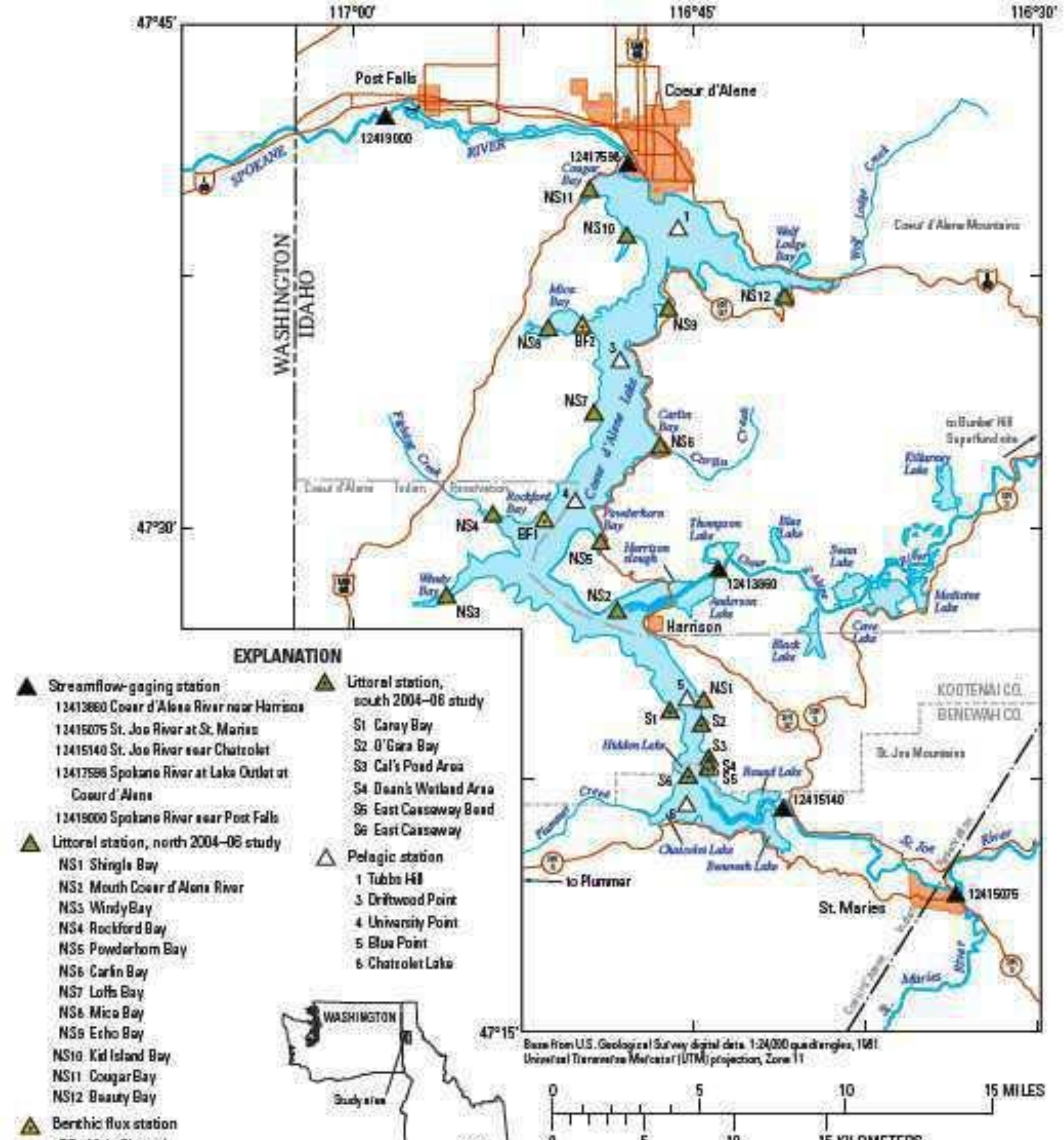
(Kuwabara et al, 2003)

Constituent and units	Sample type	Median	Range		n
			Maximum	Minimum	
No significant difference between SWI and LH					
Dissolved inorganic nitrogen	LH	86	200	36	22
	SWI	92	220	28	22
SWI significantly greater than LH					
Total phosphorus	LH	7.5	41	3.0	22
	SWI	26	49	6.0	22
Dissolved organic carbon, mg/L	LH	1.3	1.5	1.2	12
	SWI	1.6	3.3	1.2	12
Total cadmium	LH	.32	.48	.22	22
	SWI	.85	1.6	.31	22
Total zinc	LH	76	110	66	22
	SWI	140	340	77	22
Total iron	LH	54	310	19	22
	SWI	630	1,600	58	22
Total lead	LH	1.8	17	.54	22
	SWI	35	120	2.5	22
Total manganese	LH	5.9	40	2.5	22
	SWI	160	830	6.6	22

(Wood & Beckwith, 2008)

(Kuwabara et al, 2003)





(IDEQ/CDA Tribe, 2009)

(Kuwabara, 2007)

2004

Site 6

Site 1 **Location: 47° 23.391' N 116° 45.256' W**

Depth (m)	Zn (nM)	95% Conf. Interval	DOC (µM)	95% Conf. Interval
2.0	**< 3**		**136.4**	2.3

Site 5

Site 2 **Location: 47° 25.161' N 116° 45.400' W**

Depth (m)	Zn (nM)	95% Conf. Interval	DOC (µM)	95% Conf. Interval
2.0	**254**	1	**124.3**	0.2
8.5	**515**	1	**146.7**	3.1
15.0	**513**	3	**144.3**	6.8

2005

Site 5

Site 2 **Location: 47° 25.161' N 116° 45.400' W**

Depth (m)	Zn (nM)	95% Conf. Interval	DOC (µM)	95% Conf. Interval
2.0	**94**	0	**116.8**	1.0
10.0	**379**	4	**128.3**	4.1
16.0	**702**	3	**137.8**	0.3

		Site 6						Site 5					
Sampling Site Number		1		1		1		2		2		2	
Replicate		A	A	B	B	C	C	A	A	B	B	C	C
Density (cell concentration in cells-mL^{-1})													
Biovolume (µm^3-mL^{-1})		Density	Biovolume	Density	Biovolume	Density	Biovolume	Density	Biovolume	Density	Biovolume	Density	Biovolume
CYANOPHYTA	**Acronym (Use in Fig. 2)**												
Anabaena flos-aquae	Anabflos	632	74485	1019	120074	587	69184						
Anabaena spiroides var. *crassa*	Anabspir	32	7916	30	11385	37	14055						
Aphanothece minutissima	Aphaminu	12590	8813	5212	3648	7869	5508	439	307	516	361	1548	1084
Dactylococcopsis sp.	Dactsp.	14	149	32	347	36	396	14	122	5	41	5	41
Pseudanabaena limnetica	Pseulimn	0	0	29	445	0	0						
Synechococcus capitatus	Synecapi							12642	99872	6966	55031	6992	55237
Woronichinia klingae	Woroklin							0	0	180	2556	0	0
BACILLARIOPHYTA													
Asterionella formosa	*A. formosa*	8	1738	12	2728	5	990	757	413831	912	498718	964	526977
Aulacoseira granulata var. *angustissima*	Aulagran	0	0	0	0	7	4005	34	13300	23	11927	1	742
Aulacoseira italica var. *tenuissima*	Aulaital	61	31628	28	9110	25	13005						
Aulacoseira sp.	Aulasp.	0	0	5	793	3	599						
Aulacoseira subarctica	Aulasuba	0	0	10	18300	0	0	4	4524	0	0	0	0
Fragilaria crotonensis	Fragcrot	0	0	45	47250	0	0	25	24180	61	59280	16	15405
Nitzschia draveillensis	Nitzdrav	5	352	5	352	5	352	0	0	0	0	2	276
Nitzschia sp.	Nitzsp.							1	120	0	0	0	0
Stephanodiscus agassizensis	Stepagas	36	14137	5	2368	9	4736	1	126	0	0	5	866
Synedra rumpens var. *fragilarioides*	Synerump							9	2430	8	2133	8	2466
Synedra ulna var. chaseana	Syneulna							0	0	1	4964	0	0
Synedra ulna var. *ulna*	Syneulna	1	1762	0	0	0	0						
Tabellaria fenestrata	Tabefene							0	0	5	7776	0	0
Urosolenia eriensis	Uroserie	32	11907	18	6804	18	6804	14	15506	14	15506	14	15506
CHLOROPHYTA													
Ankyra judayi	Ankyjuda	5	175	1	45	0	0						
Chlamydomonas sp.	Chlasp.	155	650	27	113	26	108	5	19	5	19	9	38
Chlorella minutissima	*C. minutissima*	1548	6502	1548	6502	1419	5960	258	1084	258	1084	258	1084
Choricystis minor	Chormino	568	908	310	495	258	413	1187	1068	516	464	387	348
Crucigenia tetrapedia	Cructetr	9	273	18	371	5	93	0	0	18	545	0	0
Crucigeniella apiculata	Crucapic	108	3272	18	731	36	1091	18	425	0	0	0	0
Dictyosphaerium pulchellum	Dictpulc							0	0	7	769	0	0
Euastrum boldtii	Euasbold	5	2539	0	0	1	624	0	0	0	0	1	621
Kirchneriella irregularis	Kircirre	18	151	0	0	5	38						
Koliella sp.	Kolisp.	1	83	0	0	0	0						
Monoraphidium minutum	Monominu	0	0	1	100	0	0						
Pediastrum tetras	Peditetr							4	472	0	0	0	0
Pseudodictyosphaerium sp.	Pseusp.	243	1021	414	1739	243	1021	0	0	0	0	72	302
Raphidocelis microscopica	Raphmicr	23	68	23	68	41	122						
Scenedesmus arcuatus	Scenarcu	0	0	5	327	0	0						
Scenedesmus communis	Scencomm					9	339						
Scenedesmus ecornis	Scenecor	18	189	0	0	0	0	9	198	0	0	0	0
Scenedesmus intermedius	Sceninte	0	0	0	0	3	89	5	170	0	0	0	0

(Kuwabara, 2007)

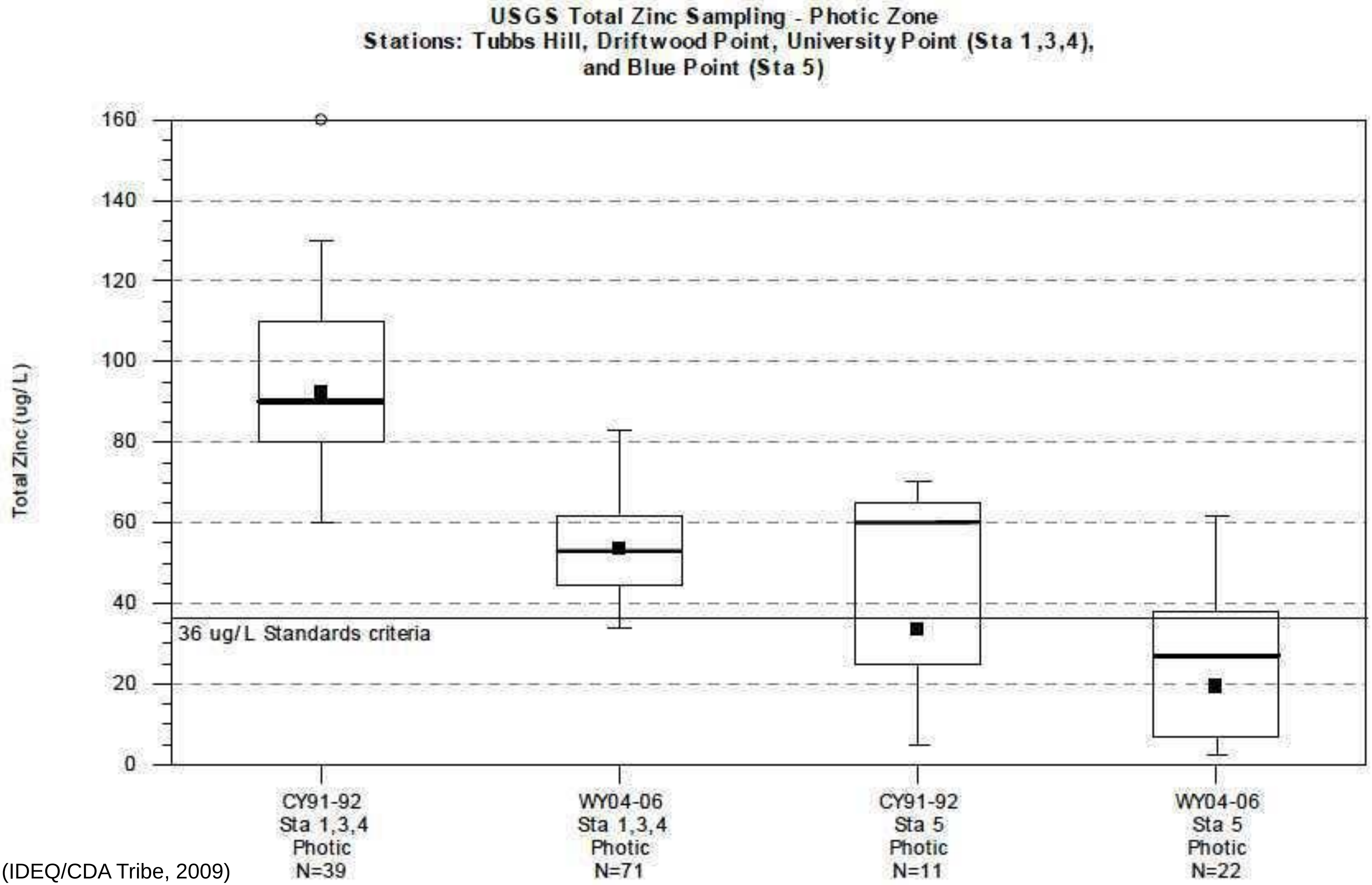
Test organism: ***Chlorella minutissima***

Ortho-P	Zinc	Basis	Growth Rate (d-1)	± CI	Lag time (d)	r^2	Log Cell Yield (μm^3-mL^{-1})	± CI
Basal	Basal	Cell Conc.	1.02	0.03	0.02	0.99	6.48	0.09
		Biovolume	0.99	0.04	0.50	0.98		
Mid	Basal	Cell Conc.	1.27	0.02	0.09	1.00	6.83	0.03
		Biovolume	1.08	0.03	0.33	0.99		
High	Basal	Cell Conc.	1.00	0.05	0.00	0.96	6.93	0.19
		Biovolume	0.84	0.03	0.34	0.98		
Basal	Mid	Cell Conc.	0.15	0.02	1.77	0.87	5.62	0.23
		Biovolume	0.12	0.01	1.98	0.76		
Mid	Mid	Cell Conc.	0.64	0.02	1.45	0.99	6.40	0.03
		Biovolume	0.50	0.02	1.43	0.98		
High	Mid	Cell Conc.	0.69	0.02	1.05	0.98	6.70	0.33
		Biovolume	0.52	0.02	1.12	0.97		
Basal	High	Cell Conc.	0.00	0.02	> 6	0.01	5.28	0.16
		Biovolume	0.01	0.03	> 6	0.00		
Mid	High	Cell Conc.	0.00	0.02	> 6	0.00	5.41	0.25
		Biovolume	0.01	0.03	> 6	0.01		
High	High	Cell Conc.	0.02	0.01	> 6	0.16	5.40	0.07
		Biovolume	0.00	0.02	> 6	0.00		

Test organism: ***Asterionella formosa***

(Kuwabara, 2007)

Ortho-P	Zinc	Basis	Growth Rate (d^{-1})	± CI	Lag time (d)	r^2	Log Cell Yield (μm^3-mL^{-1})	± CI
Basal	Basal	Cell Conc.	0.53	0.04	0.00	0.96	6.57	0.03
		Biovolume	0.56	0.02	0.12	0.99		
Mid	Basal	Cell Conc.	0.88	0.03	0.00	0.99	6.85	0.16
		Biovolume	0.73	0.03	0.00	0.98		
High	Basal	Cell Conc.	0.69	0.06	0.00	0.91	6.95	0.13
		Biovolume	0.82	0.03	0.00	0.98		
Basal	Mid	Cell Conc.	0.37	0.03	1.91	0.95	6.46	0.09
		Biovolume	0.30	0.04	0.39	0.84		
Mid	Mid	Cell Conc.	0.54	0.03	1.15	0.97	6.77	0.14
		Biovolume	0.72	0.05	1.42	0.95		
High	Mid	Cell Conc.	0.56	0.04	1.29	0.95	6.81	0.07
		Biovolume	0.59	0.03	1.23	0.96		
Basal	High	Cell Conc.	0.26	0.03	1.75	0.89	6.46	0.11
		Biovolume	0.37	0.03	1.62	0.93		
Mid	High	Cell Conc.	0.51	0.06	0.82	0.90	6.48	0.12
		Biovolume	0.59	0.10	0.57	0.84		
High	High	Cell Conc.	0.59	0.02	0.82	0.98	6.71	0.18
		Biovolume	0.61	0.03	0.95	0.97		



(IDEQ/CDA Tribe, 2009)

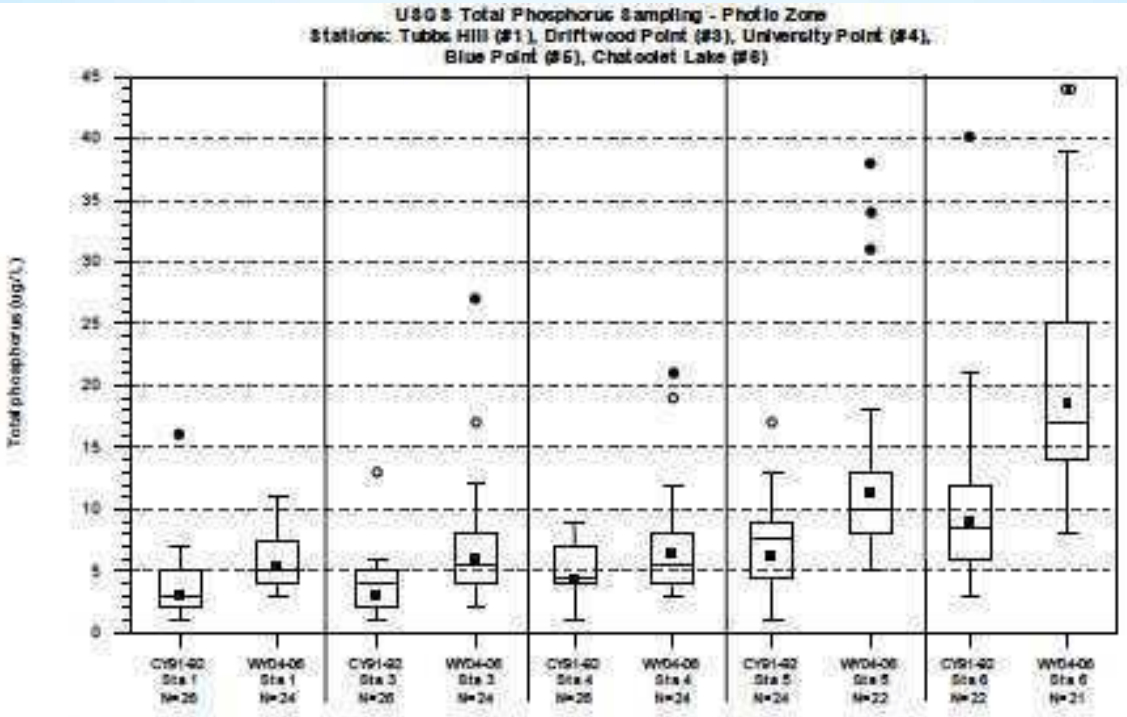
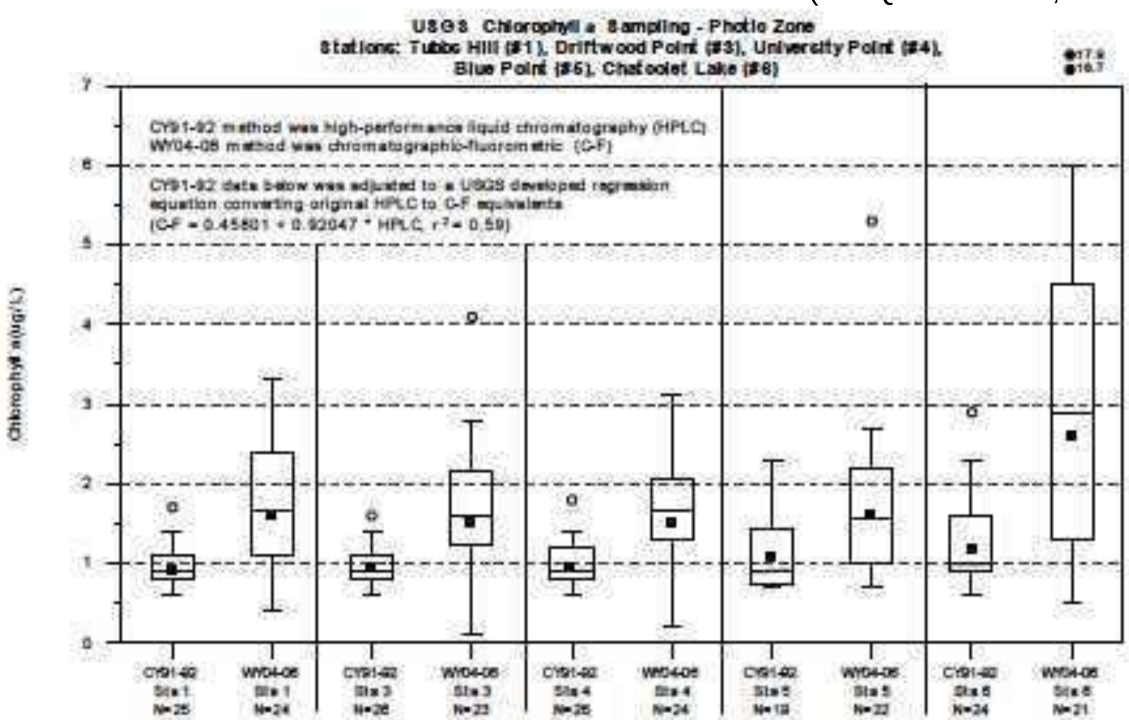


Figure A9. USGS photic zone data for total phosphorus at five pelagic sampling stations in Coeur d'Alene Lake. Data is compared between study periods CY91-92 and WY04-06.

(IDEQ/CDA Tribe, 2009)



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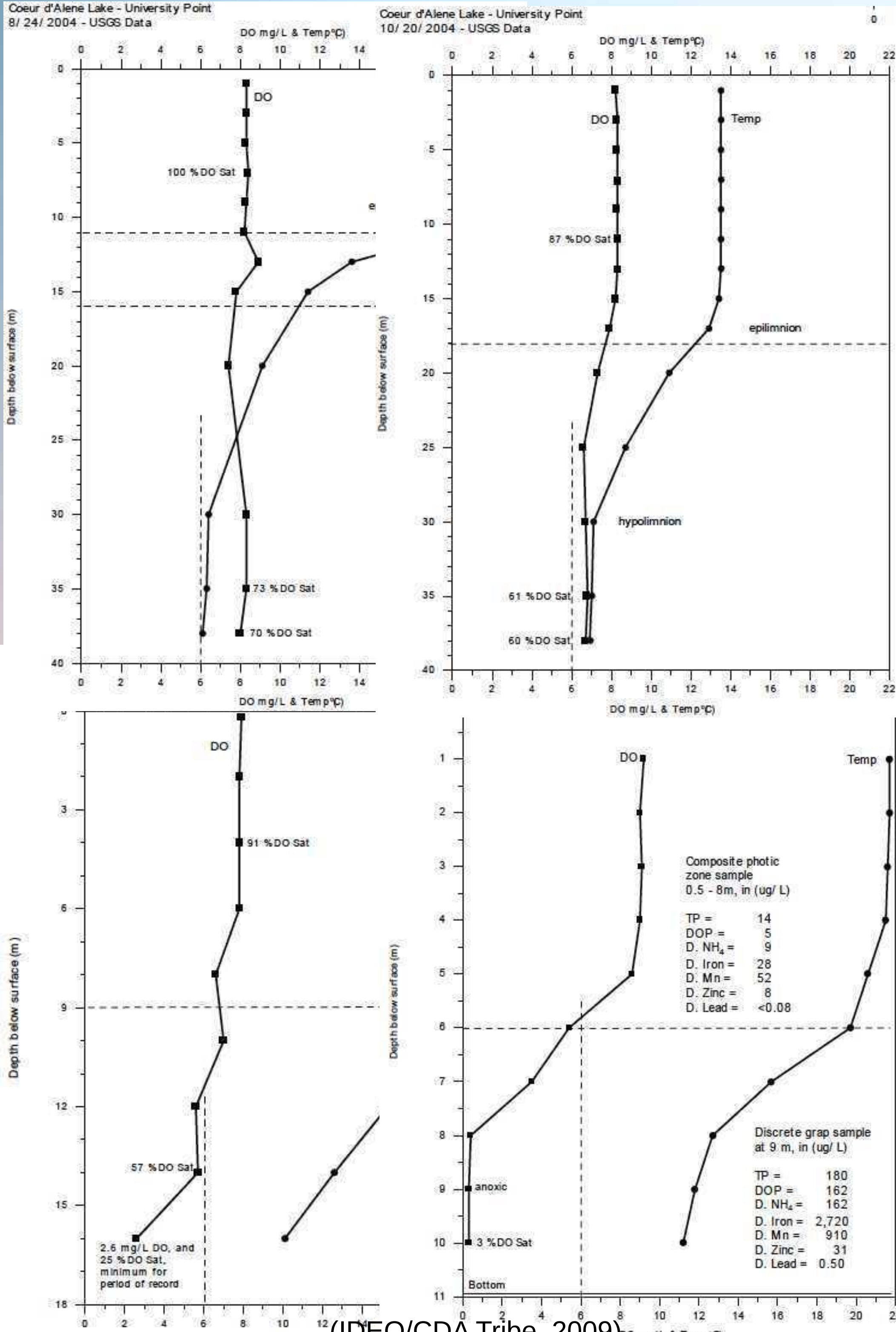
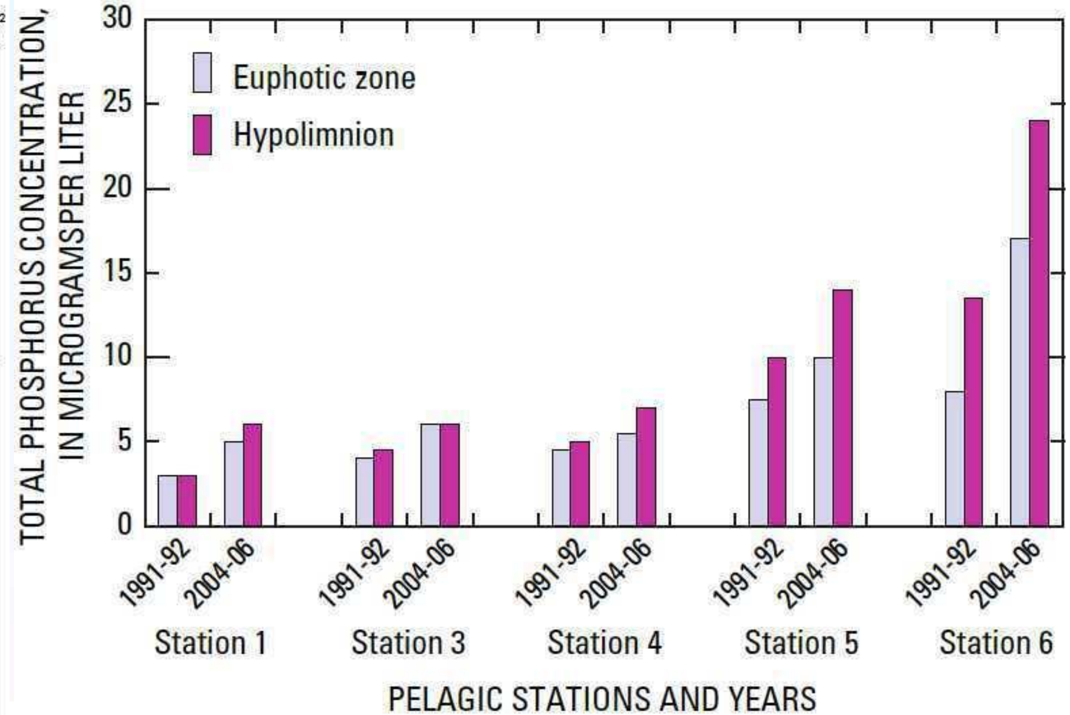
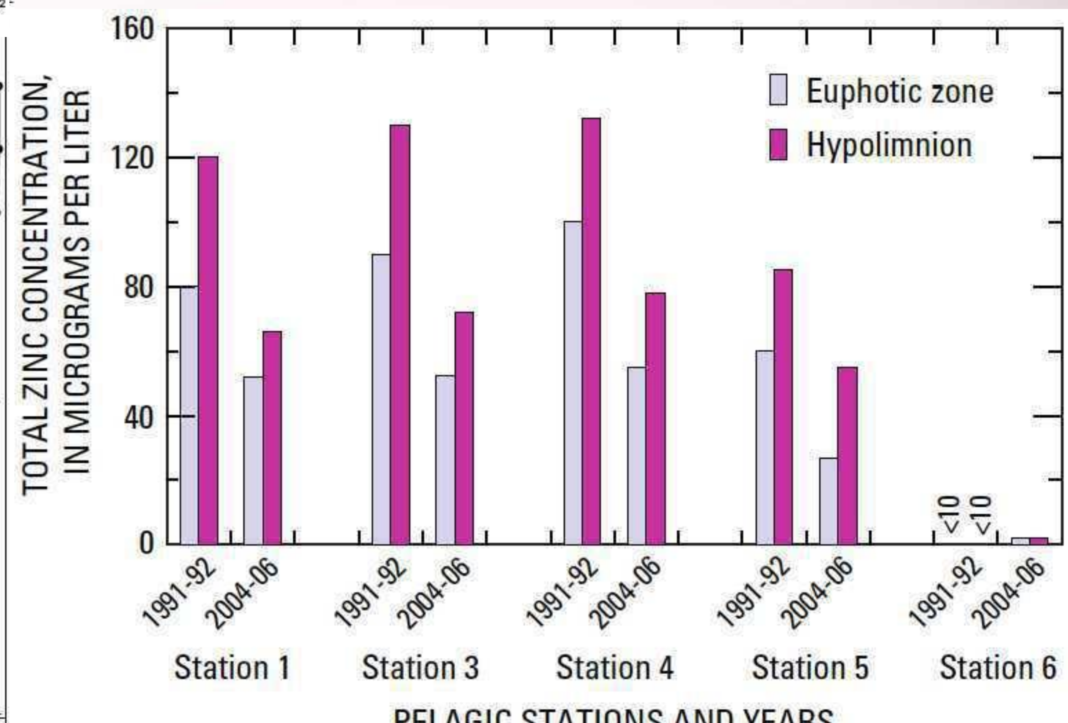


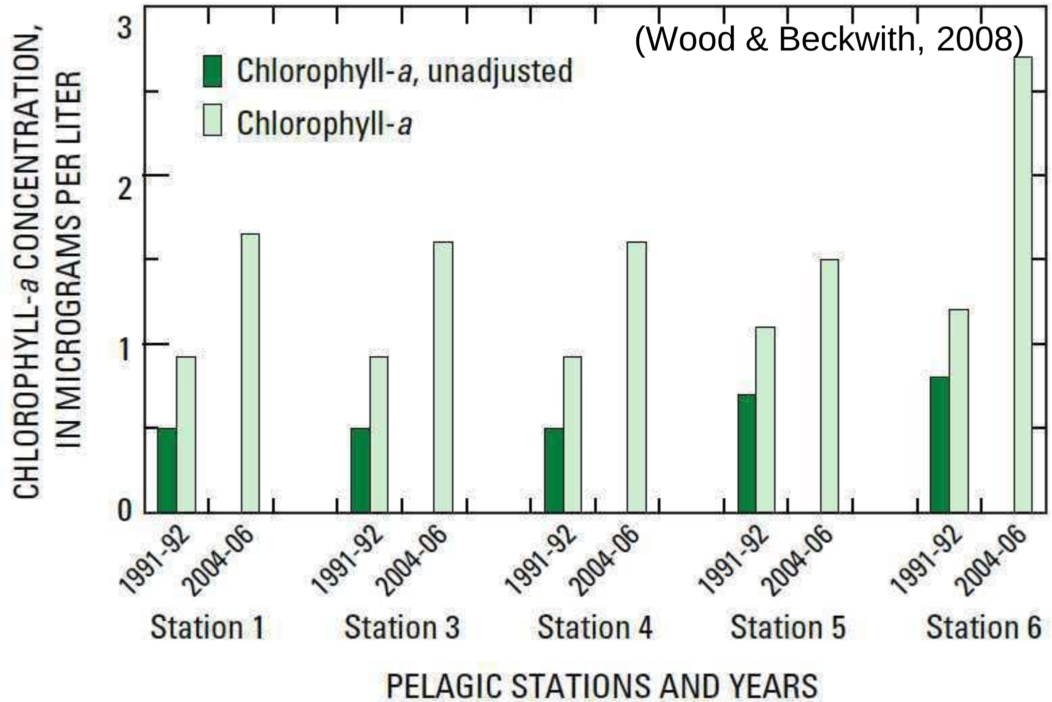
(IDEQ/CDA Tribe, 2009)



(Wood & Beckwith, 2008)



(Wood & Beckwith, 2008)



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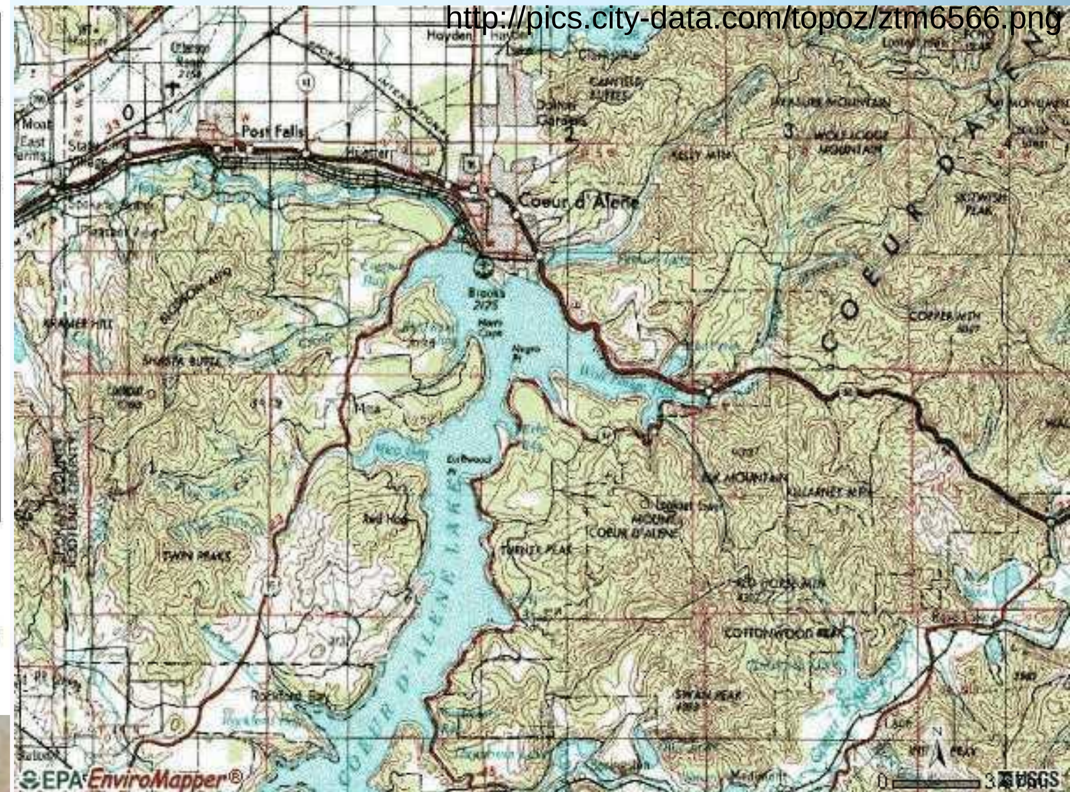

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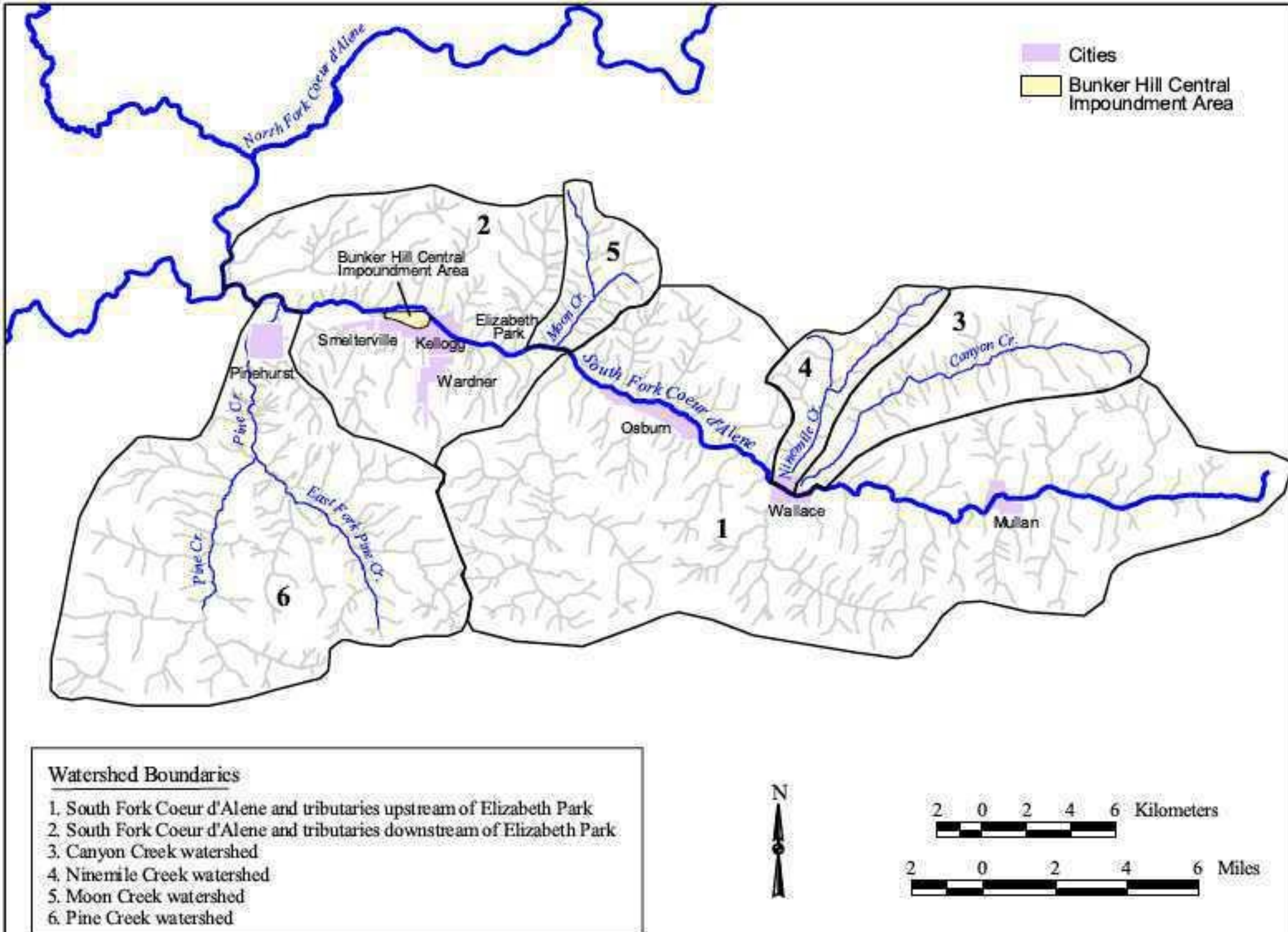
http://kealliance.org/2012/09/06/toxic-blue-green-algae-in-six-lakes-this-summer/

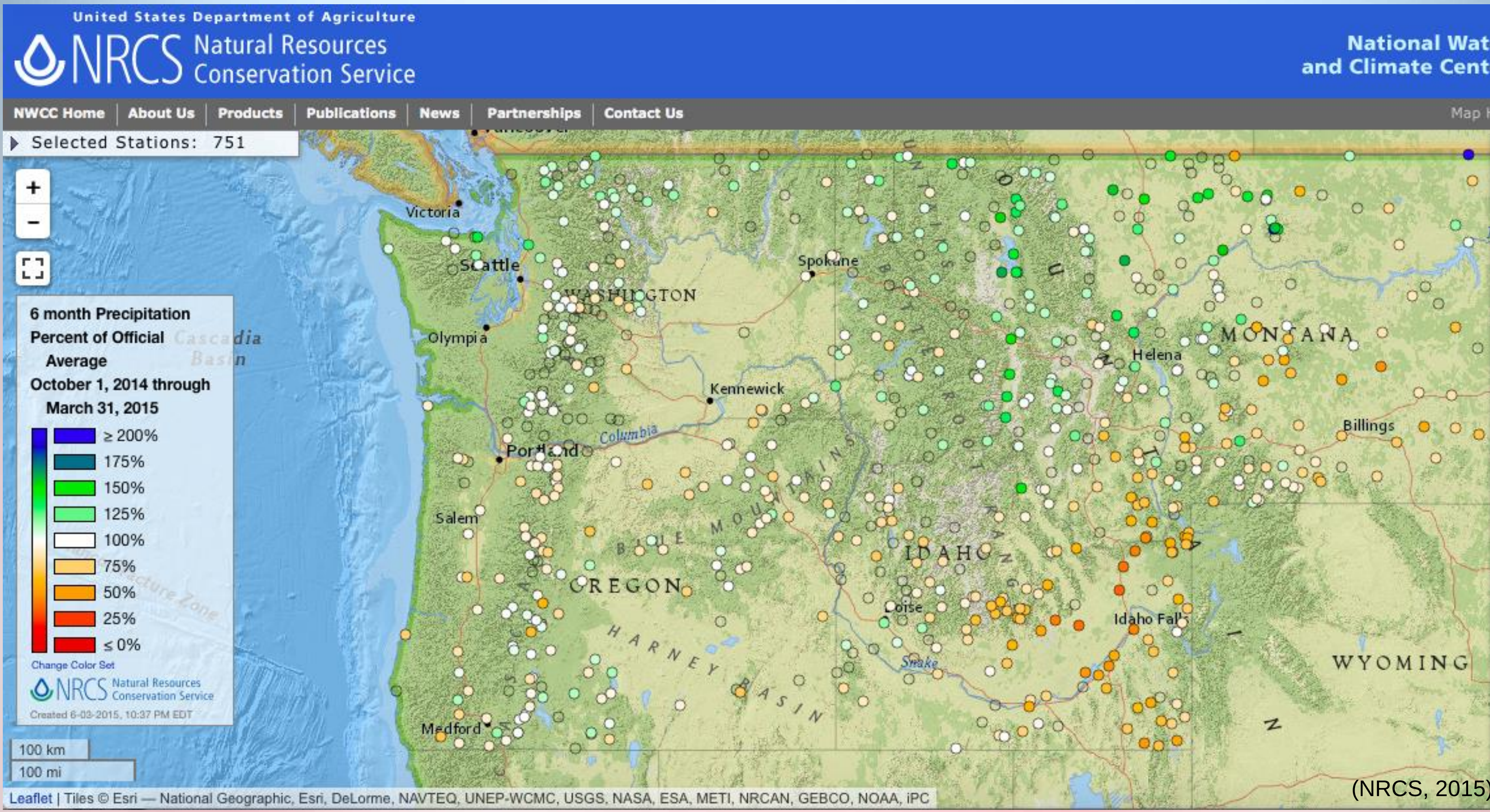


(LeJeune et al, 2000)

Table 5: Metal Concentration Comparison (µg/L)

Source	Zn (total)	Cd	Pb	Mn	Average/ Max Flow (gpm)	Average Zn Loading (lb/day)
Existing Influent (Kellogg Tunnel from Sept, Oct, Nov 2011 DMRs)	>100,000	>100	>400	>50,000	>1200	>1,400
Existing Discharge (avg. Sept, Oct, Nov 2011 DMRs)	197	4	10	13,250	1,300/5,000*	3 (>99.5percent reduction)
Existing Discharge Limit (monthly avg.)	730	50	300	NS	-	-
Proposed Discharge Limit (monthly avg.)	244	2.8	85.2	81.9	-	-
SFCDR Water Quality at Kellogg (USGS 2006 SF-269 unfiltered median)	621	4.17	9.54	NA	50,000 min 72,0000 max ~200,000 avg	1492
SFCDR Sewer District Limits, (avg. monthly)	802	5.3	63	NS	3,000 (Page, Idaho WWTP)	-
OU2 Groundwater (avg.)	24,452	-	-	-	3,900/4,400	1146
OU3 Woodland Park, Osburn Drain, Gem #3	4,123	-	-	-	4,701/5,623	233
Other OU3 ROD Amendment H2O	2,543	-	-	-	7,602/11,538	232
Hecla Lucky Friday Mine NPDES Permit, Mullan (Discharge Limits)	71	0.7	30	NS	-	-

(EPA, 2013)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Percent of Official
Average
October 1, 2014 through
March 31, 2015
≥ 200%
175%
150%
125%
100%
75%
50%
25%
≤ 0%
Change Color Set
NRCS Natural Resources Conservation Service
Created 6-03-2015, 10:37 PM EDT
100 km
100 mi
Victoria
Seattle
WASHINGTON
Olympia
Spokane
Kennewick
Portland
Columbia
Salem
OREGON
HARNEY BASIN
Medford
IDAHO
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Snake
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Billings
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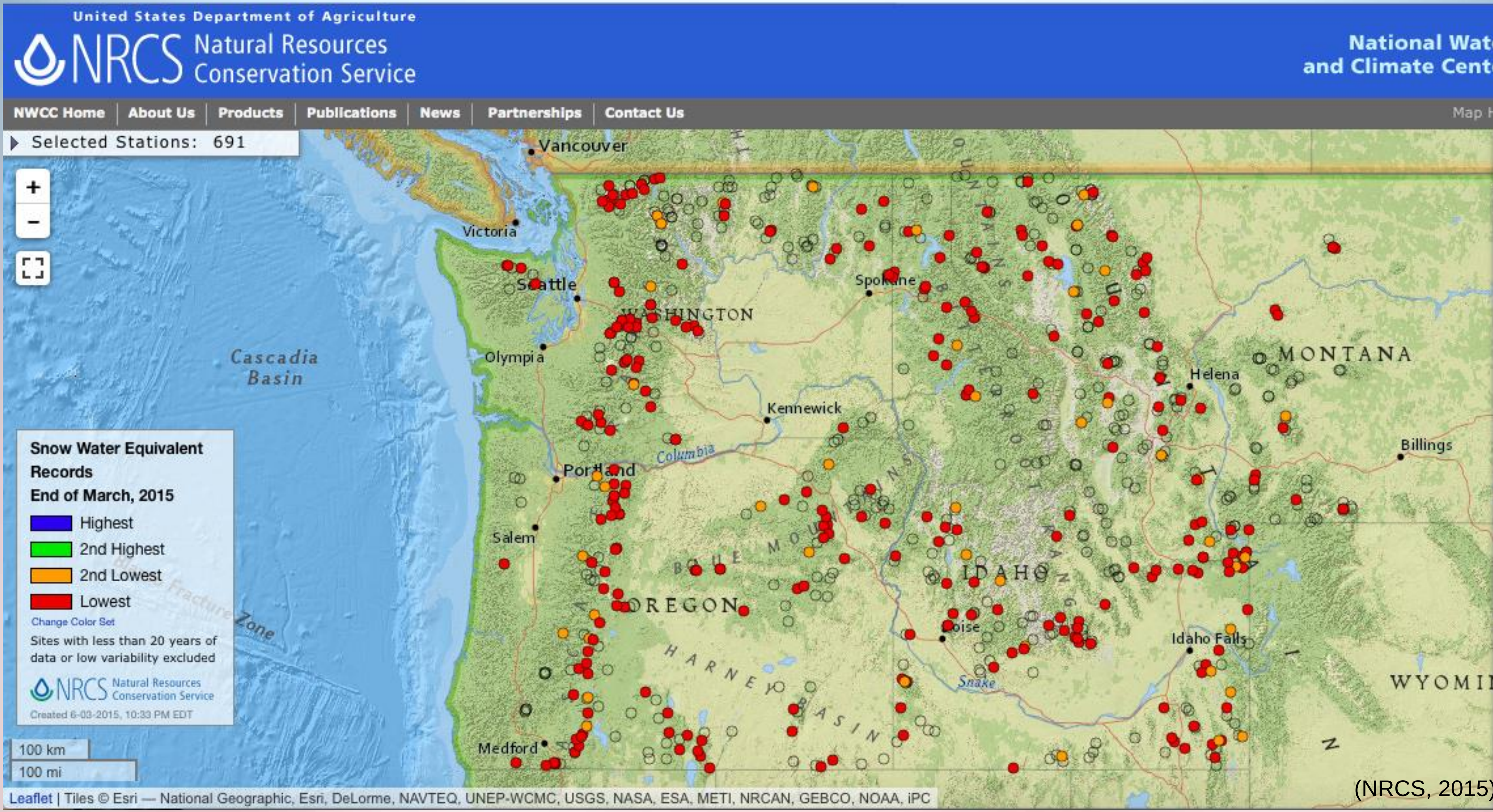
(NRCS, 2015)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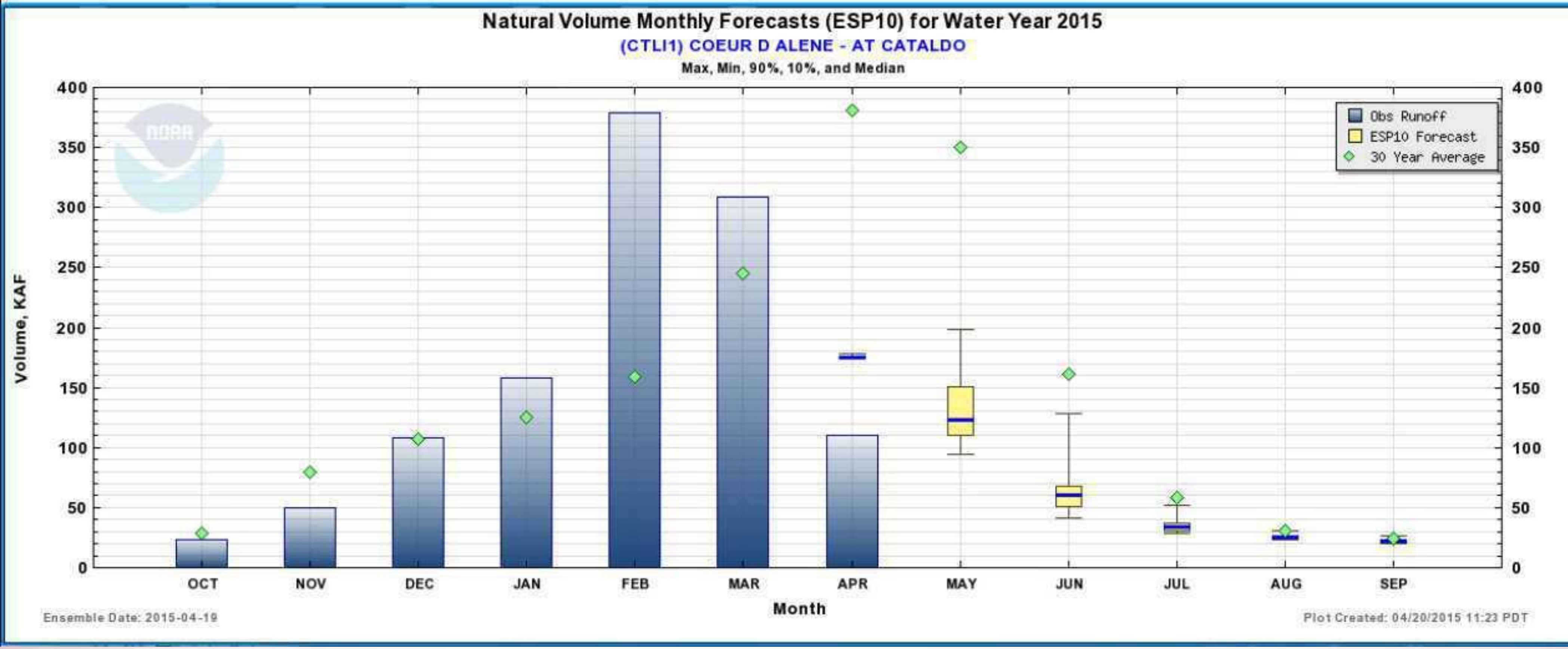
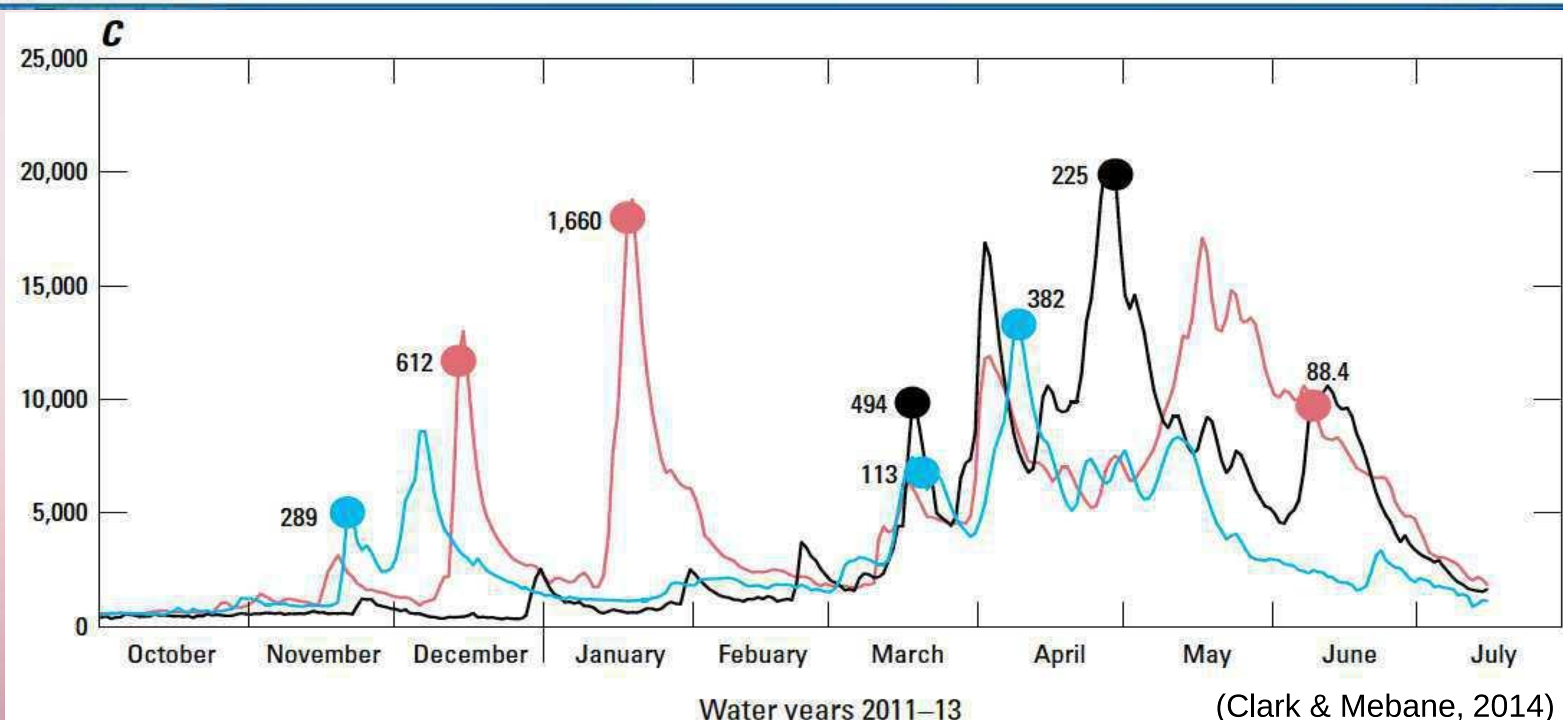
Contact Us
Map H
Selected Stations: 691
Vancouver
Victoria
Seattle
Olympia
WASHINGTON
Spokane
Kennewick
Columbia
Portland
Salem
OREGON
BLUE MOUNTAINS
HARNEY BASIN
Medford
IDAHO
Boise
Snake
Idaho Falls
MONTANA
Helena
Billings
WYOMI
Cascadia Basin
Blanco Fracture Zone
Snow Water Equivalent Records
End of March, 2015
Highest
2nd Highest
2nd Lowest
Lowest
Change Color Set
Sites with less than 20 years of data or low variability excluded
NRCS Natural Resources Conservation Service
Created 6-03-2015, 10:33 PM EDT
100 km
100 mi
Leaflet | Tiles © Esri — National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

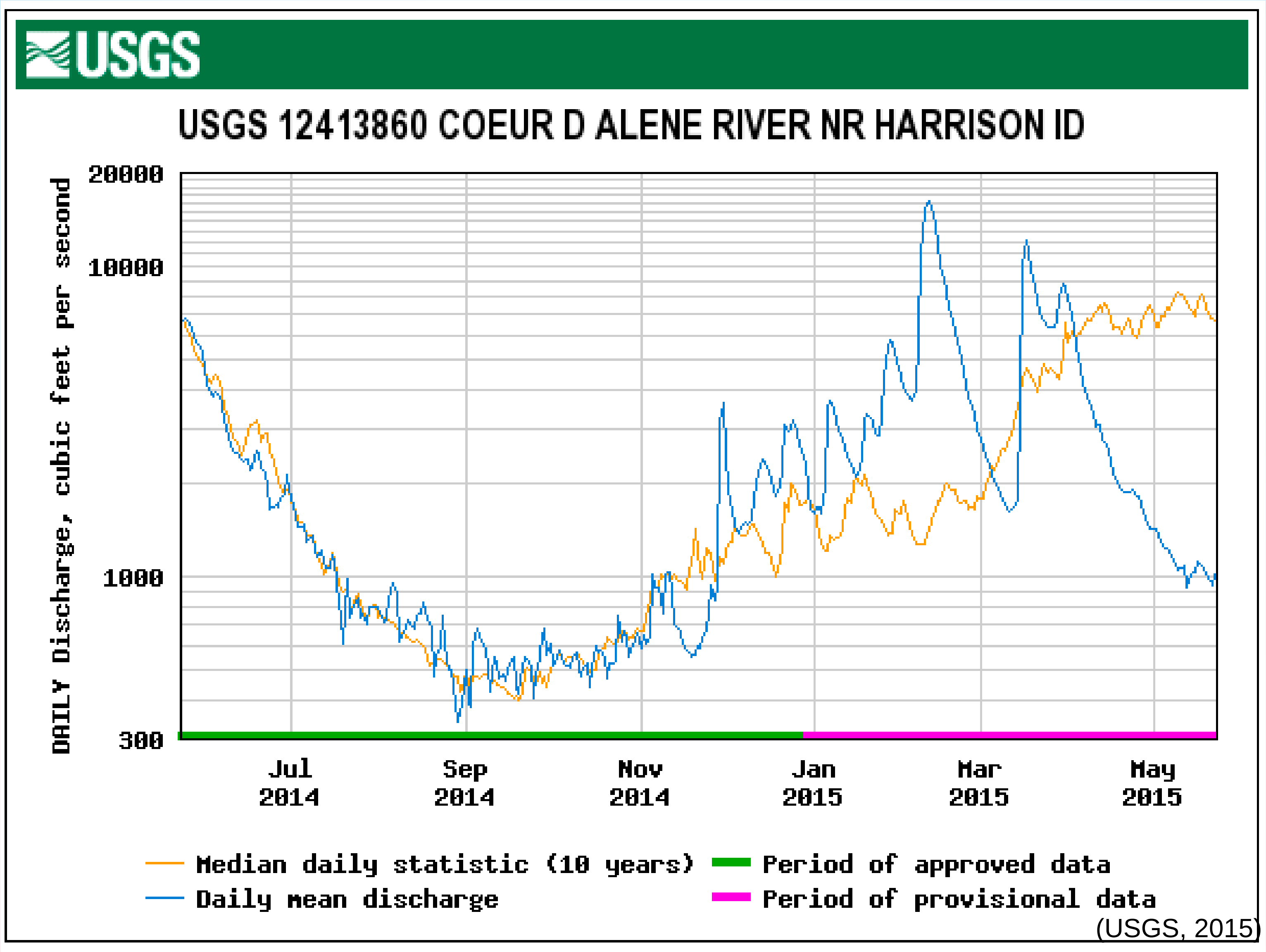
(NRCS, 2015)

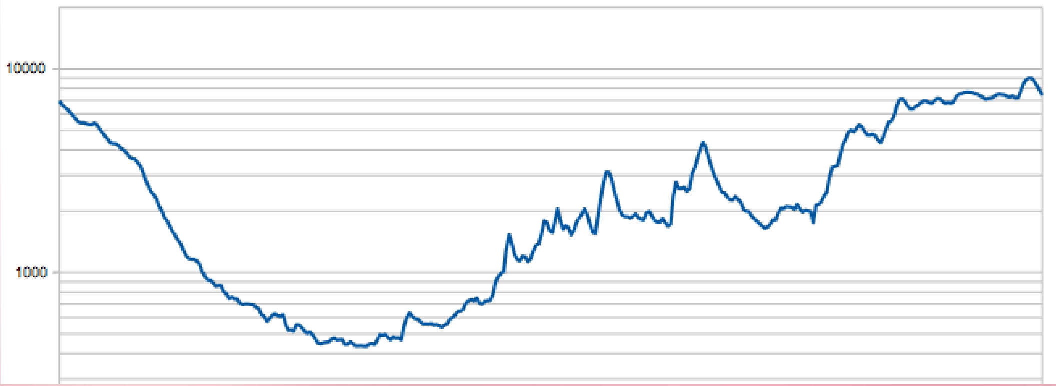


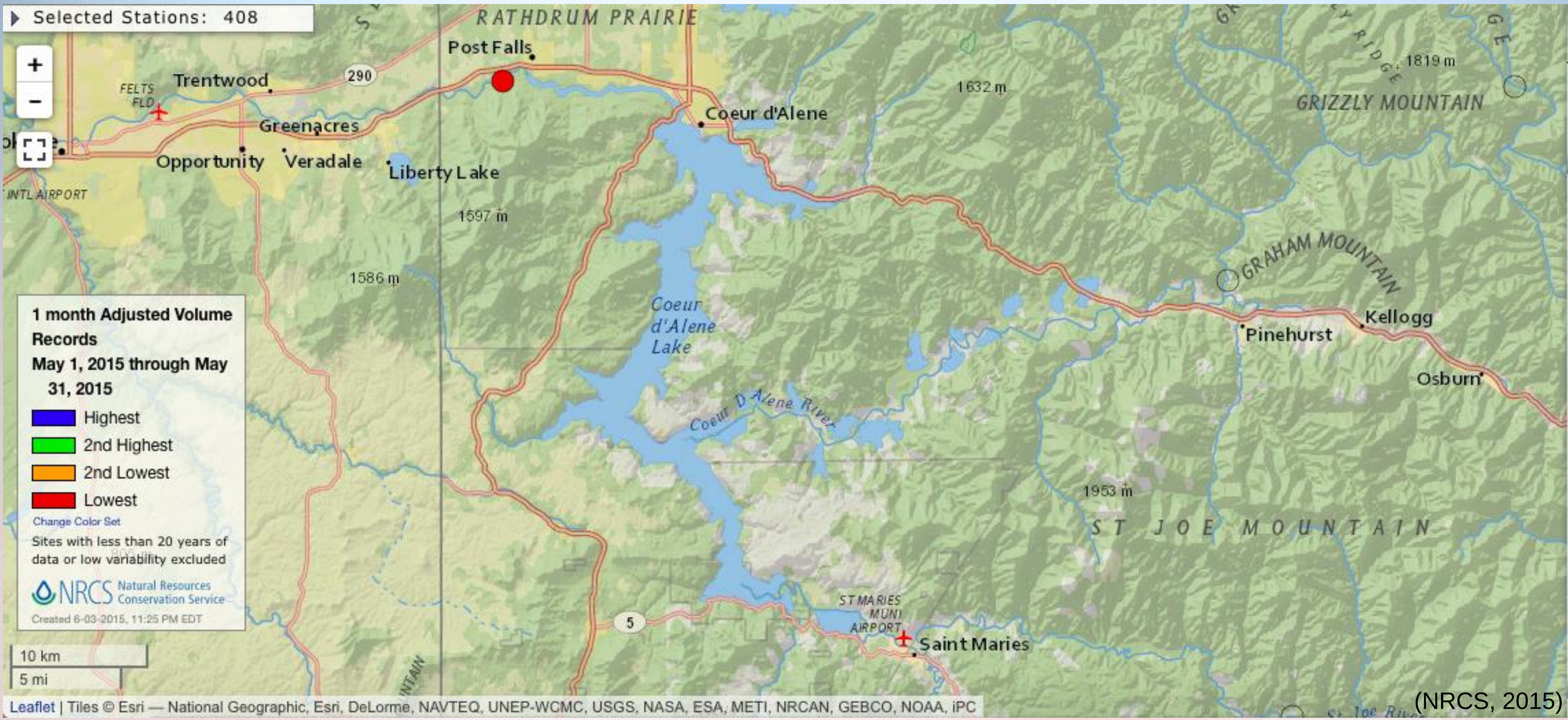
(Rowden, 2015)

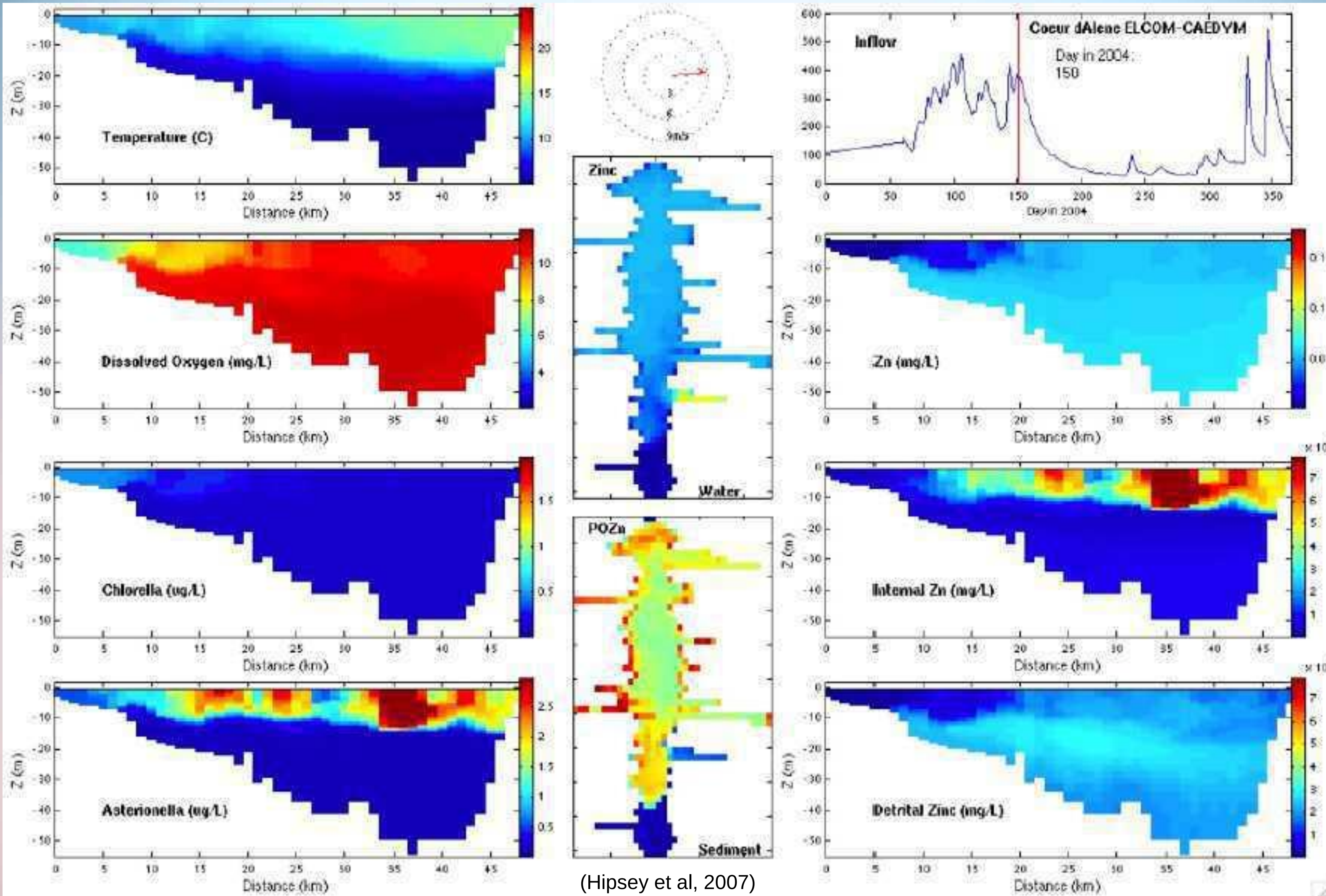


(Clark & Mebane, 2014)


USGS
USGS 12413860 COEUR D ALENE RIVER NR HARRISON ID
DAILY Discharge, cubic feet per second
20000
10000
1000
300
Jul 2014
Sep 2014
Nov 2014
Jan 2015
Mar 2015
May 2015
Median daily statistic (10 years)
Daily mean discharge
Period of approved data
Period of provisional data
(USGS, 2015)

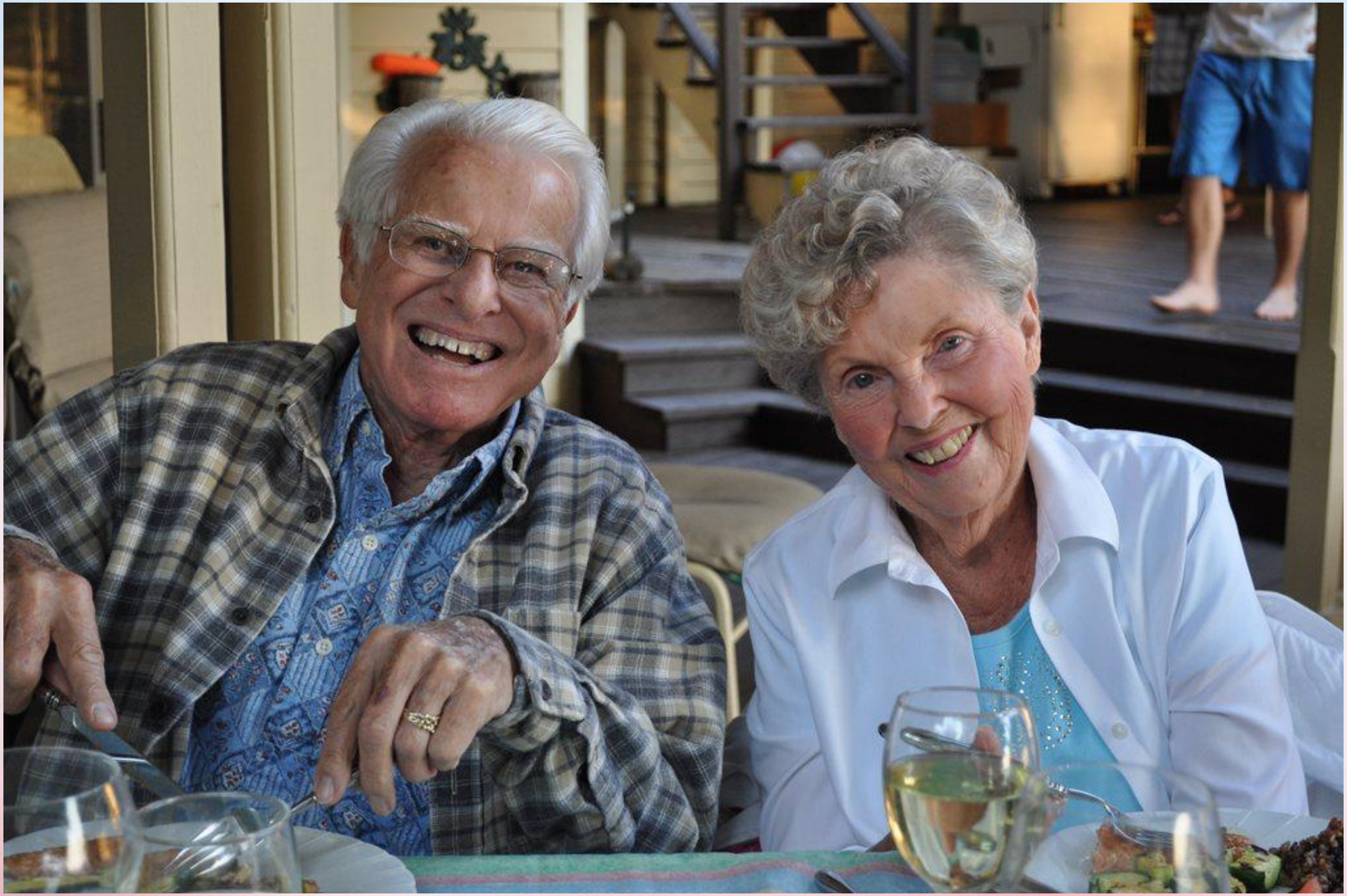

10000
1000


Selected Stations: 408
RATHDRUM PRAIRIE
Post Falls
Trentwood
Greenacres
Opportunity
Veradale
Liberty Lake
Coeur d'Alene
Coeur d'Alene Lake
Coeur D'Alene River
GRIZZLY MOUNTAIN
GRAHAM MOUNTAIN
Kellogg
Pinehurst
Osburn
ST JOE MOUNTAIN
Saint Maries
ST MARIES MUNI AIRPORT
INTL AIRPORT
1632 m
1819 m
1597 m
1586 m
1953 m
1 month Adjusted Volume Records
May 1, 2015 through May 31, 2015
Highest
2nd Highest
2nd Lowest
Lowest
Change Color Set
Sites with less than 20 years of data or low variability excluded
NRCS Natural Resources Conservation Service
Created 6-03-2015, 11:25 PM EDT
10 km
5 mi
Leaflet | Tiles © Esri — National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
(NRCS, 2015)



(Hipsey et al, 2007)

Participatory?



https://www.senioradvisor.com/local/north-star-coeur-d-alene-id

Next Steps

I. Further understanding of geochemistry and sulfate-reducing bacteria in CDA Lake and River sediments.

II. Further understanding of cyanophyta and other phytoplankton relationship with dissolved zinc, and phosphorus in CDA Lake.

III. Further understanding of stratification, dissolved oxygen, and depth effects on processes listed above.

IV. Collect and review data for WY 2015 and other low-SWE year data available to further understanding of potential climate change impacts to CDA systems.

Dissertation Research

I. Connect with a diverse group of stakeholders invested in the future of the CDA Lake, either personally or professionally.

II. Use knowledge and resources gained through preliminary CDA work to facilitate participatory model-building with the stakeholders.

III. Build trust, confidence, capacity, communication, and understanding in the development of a system dynamics modeling tool for CDA decision making.

IV. Convert the model into an online format that is accessible to the public and can be manipulated by the user to apply strategies and view scenarios.

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Idaho Department of Environmental Quality

Washington State University

United States Environmental Protection Agency

Spaghetti Diagram