UTAH DEPARTMENT *of* ENVIRONMENTAL QUALITY
WATER QUALITY

Utah Lake Water Quality and Trophic Indicators

Jake Vander Laan & Scott Daly

Beneficial Uses

Recreation:

- Frequent primary contact recreation (effective as of July 2, 2018)

Aquatic life:

- Warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain
- Waterfowl, shore birds and other water-oriented including the necessary aquatic organisms in their food chain

Agriculture:

- Agricultural uses including irrigation of crops and stock watering

Use Impairments

Recreation:

- HABs (2016)

Aquatic life:

- PCB in fish tissue (2010)
- Total phosphorus (1994)
- pH (Provo Bay only, 2016)
- Ammonia (Provo Bay only, 2016)

Agriculture:

- Total dissolved solids (portions other than Provo Bay, 2006)

DWQ's Utah Lake Dataset

25+ years of data

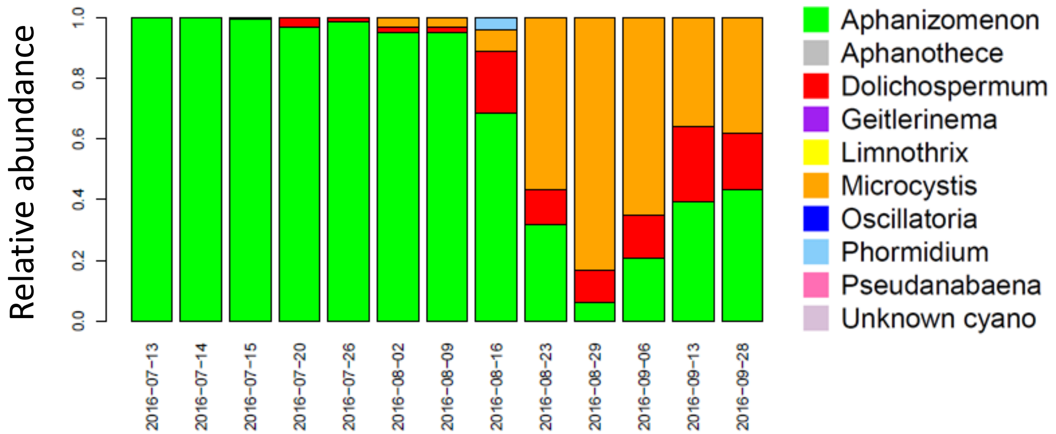
1. Trophic indicators: Nutrients, chlorophyll *a*, & *w*ater clarity (Secchi)
2. Water temperature, dissolved oxygen, pH, TDS, etc.
3. Phytoplankton

Lake elevation data from CUWCD

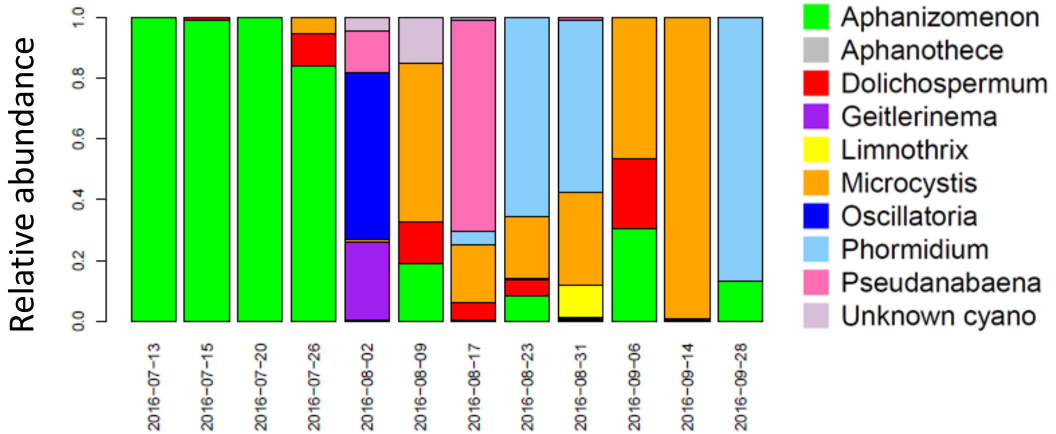
High frequency buoy network for HAB monitoring

2016 Harmful Algae Blooms

Open water



Marinas and beaches



Trophic Indicators & TSI

Tool for estimating primary productivity in lakes

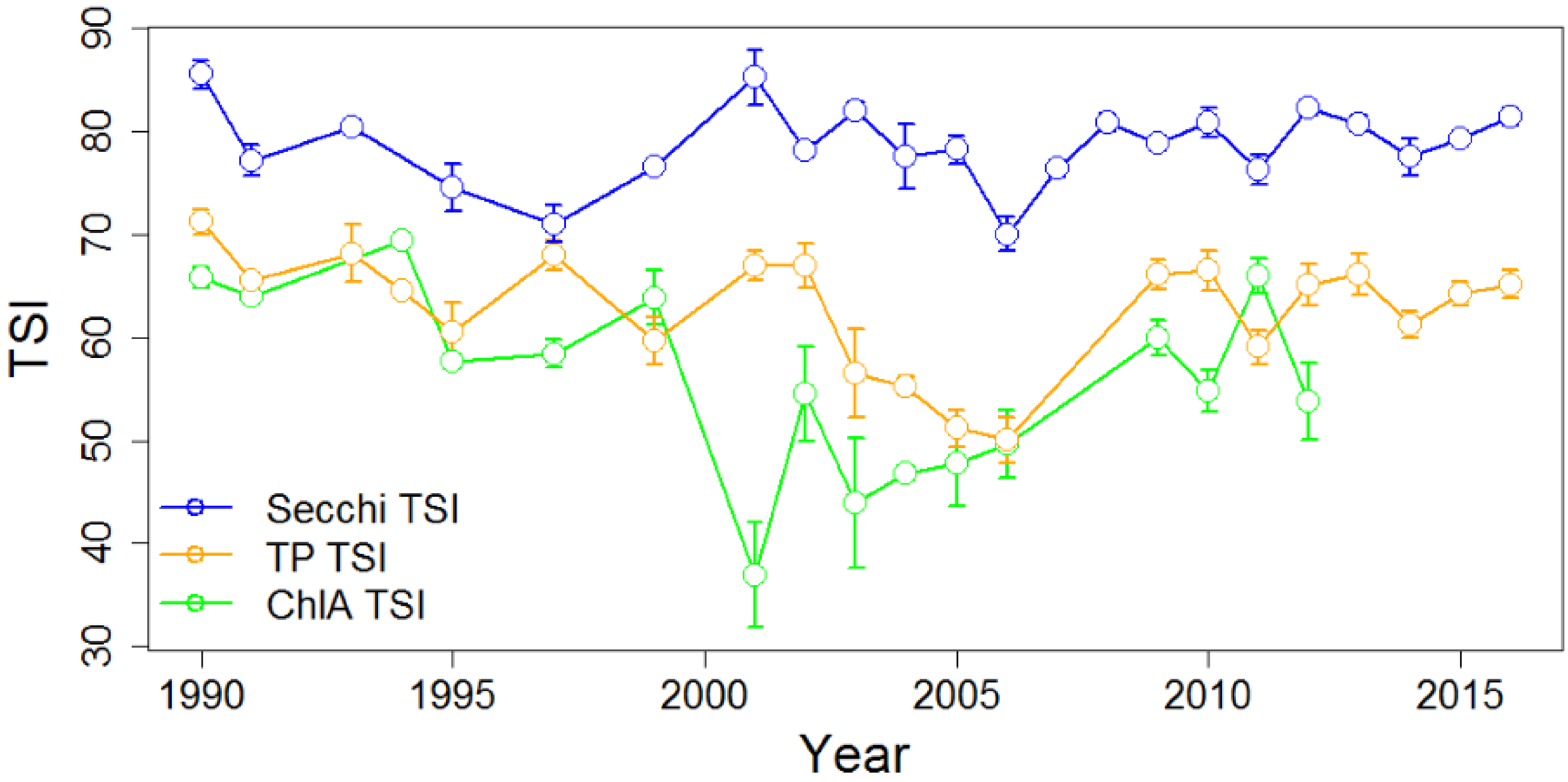
1. Chlorophyll *a*
2. Nutrients (total phosphorus)
3. Water clarity (Secchi disk depth)

Effectively re-scales trophic indicators into consistent units.

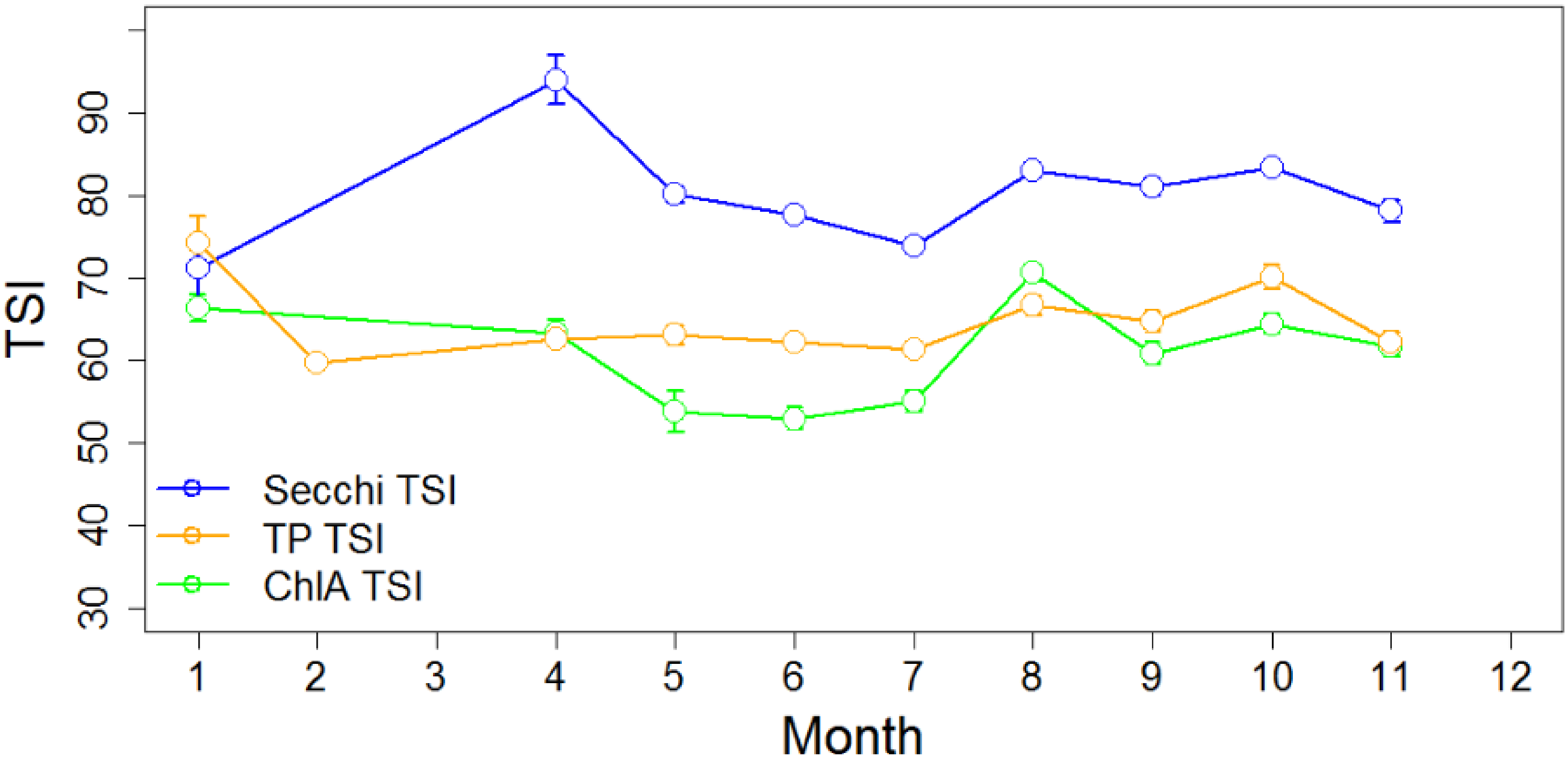
Differences or similarities in TSI values among types can be used to make inferences regarding limiting factors or lake processes.

(Carlson and Simpson 1996, Carlson and Havens 2005)

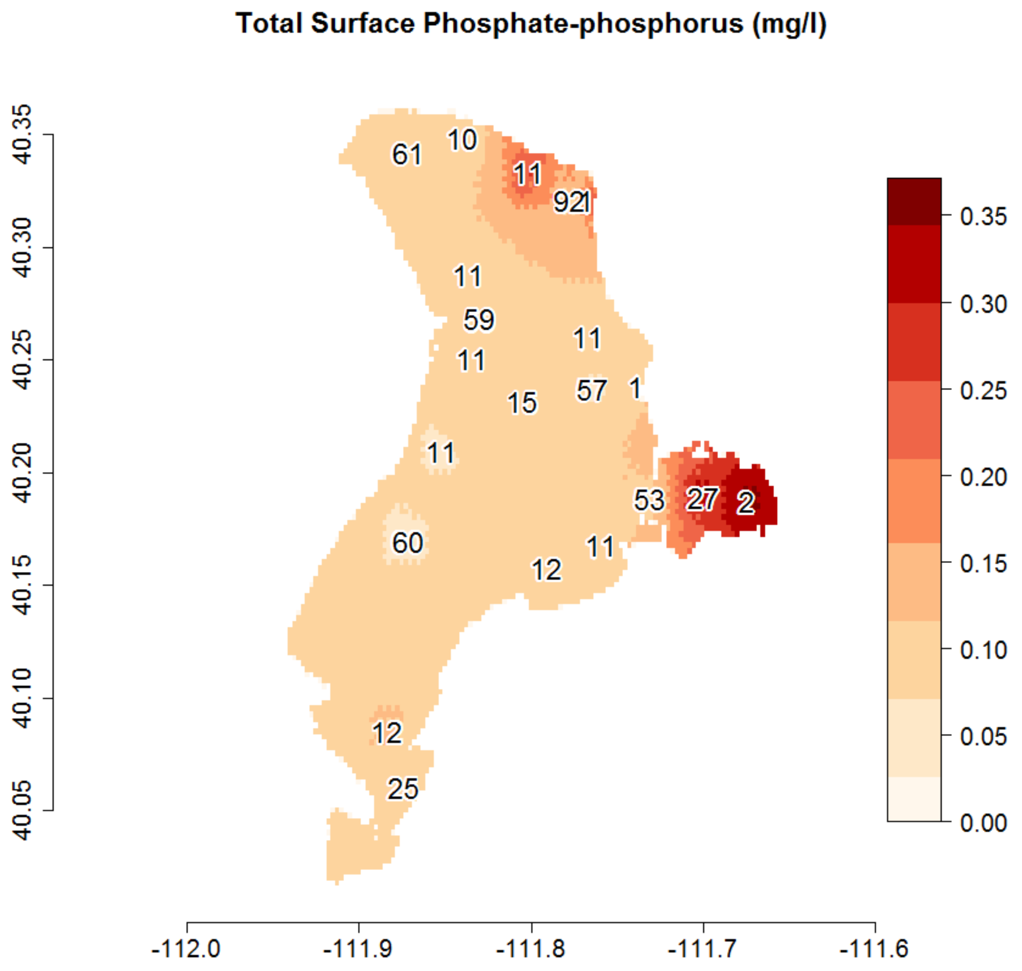
Temporal Trends



Seasonal Patterns



Spatial Patterns



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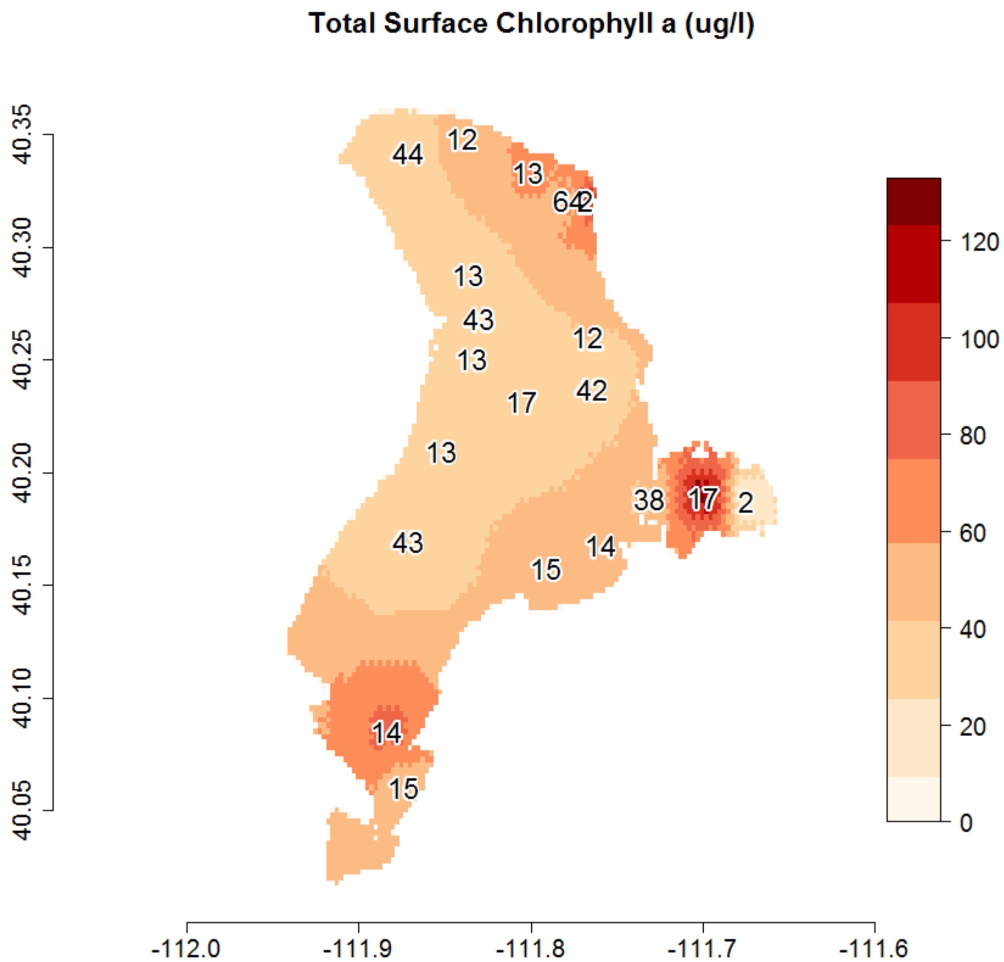

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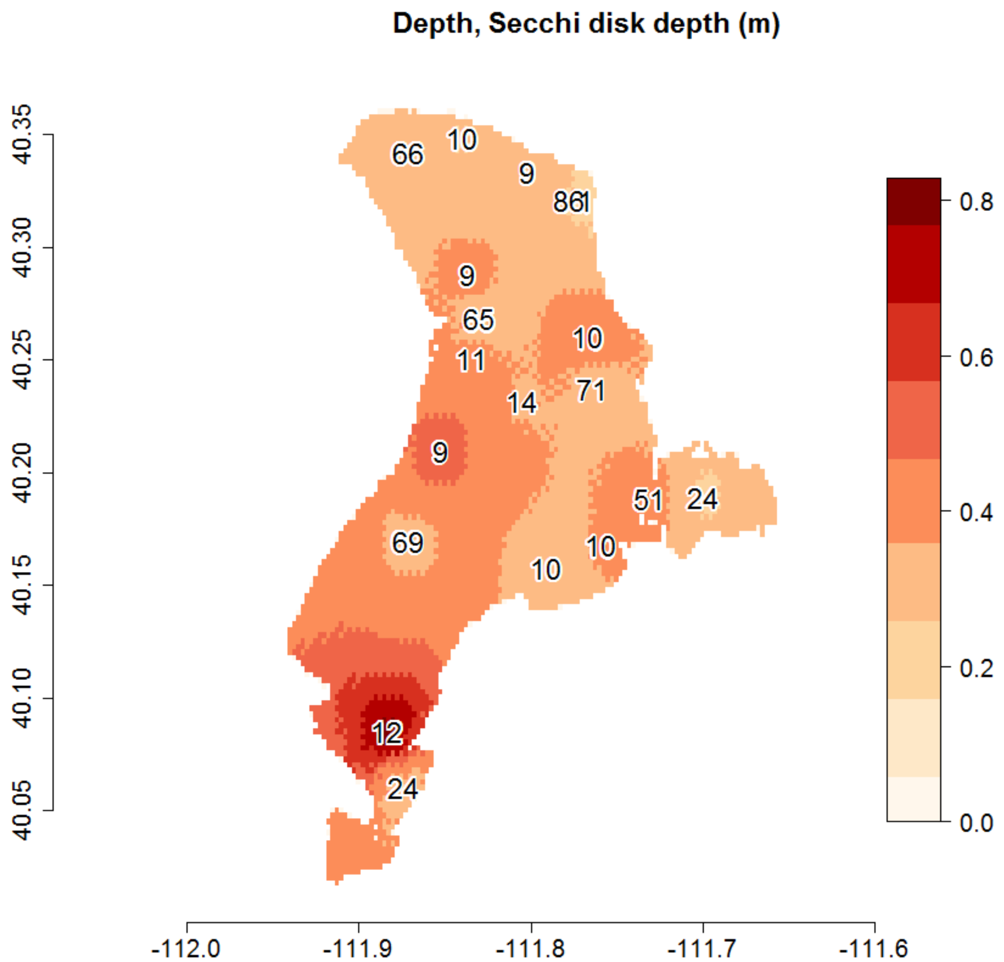
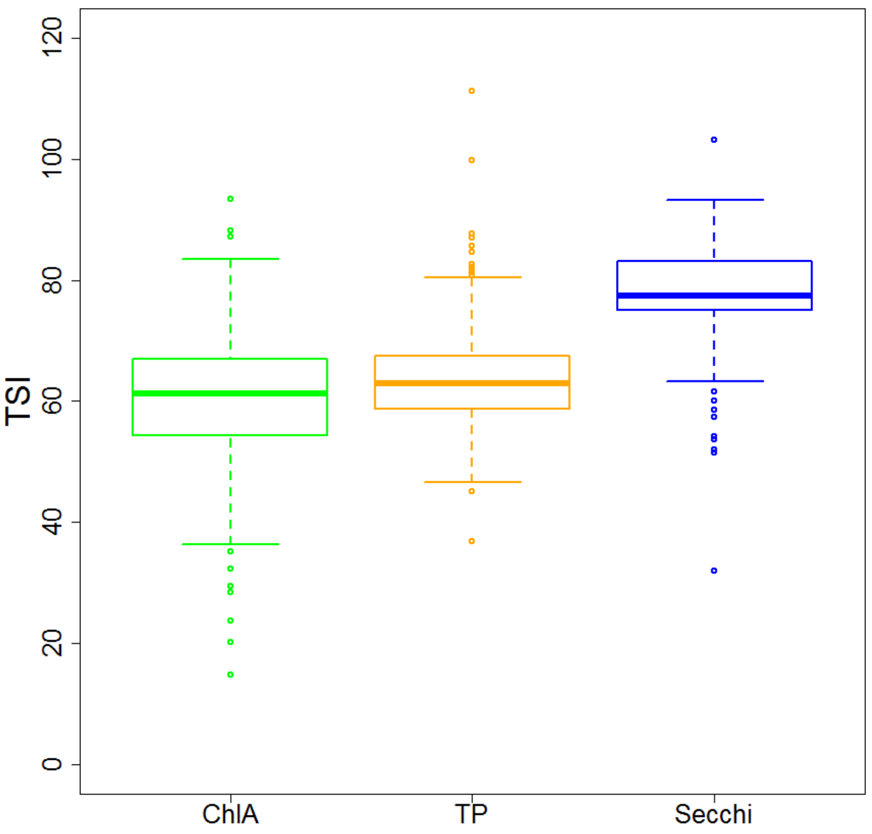


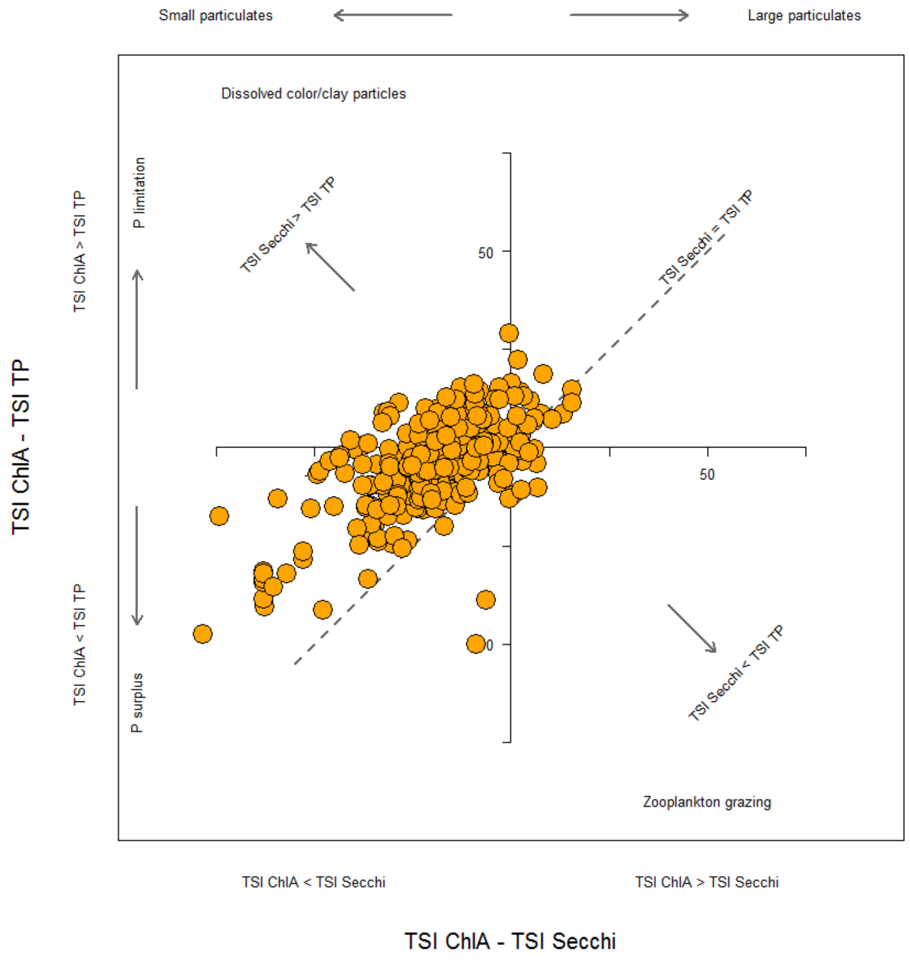
TSI Interpretations (Carlson and Havens 2005)

Table 1.–Conditions associated with differences between trophic state indices, and suggestions of how they might affect the effectiveness of nutrient or food chain manipulation.

TSI Relationships and Suggested Interpretation	Effect on Nutrient-Chlorophyll Relationships and on Manipulation
TSI (CHL) = TSI (SD) **Algae dominate light attenuation**	
TSI (SD) = TSI (CHL) = >TSI (TP) Phosphorus limits algal biomass and algae dominate light attenuation	Algal bloom occurrence may respond more rapidly to P load reduction
TSI (TP) > TSI (CHL) = TSI (SD) Some factor other than phosphorus (zooplankton grazing, nitrogen, etc.) limits algal biomass.	Algal bloom occurrence may not change rapidly in response to P loading reductions, because P concentrations are in excess of demands by phytoplankton
TSI (CHL) < TSI (SD) **Small particles, not necessarily related to algae, dominate light attenuation**	
TSI (TP = TSI (SD) > TSI (CHL) Non-algal particulate matter dominates light attenuation. Particles contain phosphorus, hence the relationship between phosphorus and transparency, but do not contain chlorophyll.	Cannot use Secchi transparency as an indicator of use-impairment related to algal blooms. Caution should be used in planning projects that might reduce levels of non-algal particles (*e.g.*, sediment removal), unless external nutrient sources also are controlled; light limitation may be preventing algal blooms.
TSI (SD) > TSI (CHL) = TSI (TP) Dissolved color affects transparency but not chlorophyll or total phosphorus concentrations.	Cannot use Secchi transparency as an indicator of use-impairment related to algal blooms. It may be possible to manipulate phosphorus concentrations and directly affect algal concentrations.
TSI (TP) > TSI (SD) > TSI (CHL) Zooplankton grazing has reduced the number of smaller particles, leaving larger particles. Biomass has been been reduced below levels predicted from total phosphorous.	There may exist a good potential to control algal blooms with biomanipulation of the planktonic food web (*e.g.*, increasing the biomass of large zooplankton).
TSI (CHL) > TSI (SD) **Large phosphorus-containing particulates dominate**	
TSI (CHL) = TSI (TP) >> TSI (SD) Large chlorophyll-containing particulates, such as *Aphanizomenon* flakes, dominate.	There does not exist a good potential to control algal blooms with food web manipulation, unless that manipulation directly affects nutrient inputs to the water column.

Aggregate TSI Patterns





TSI Interpretations (Carlson and Havens 2005)

TSI Chl-*a* < TSI SD

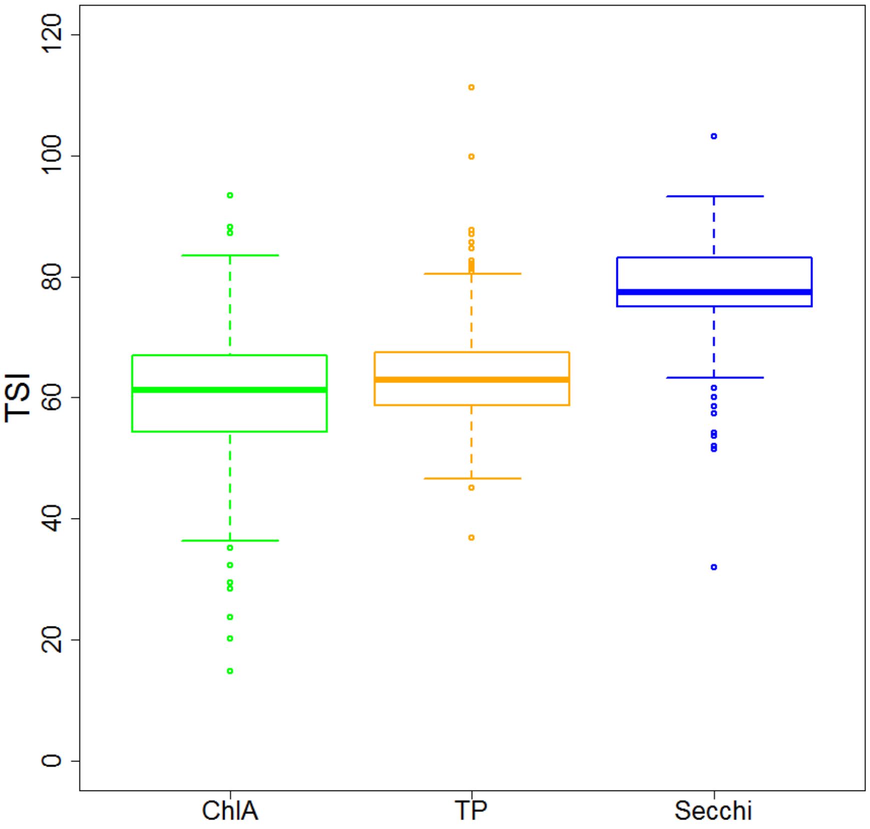
Small particles, not necessarily related to algae, dominate light attenuation

TSI Chl-*a* ≥ TSI TP

Phosphorus limits algal biomass.

TSI SD > TSI Chl-*a* = TSI TP

Dissolved color affects transparency but not chlorophyll or total phosphorus concentrations.



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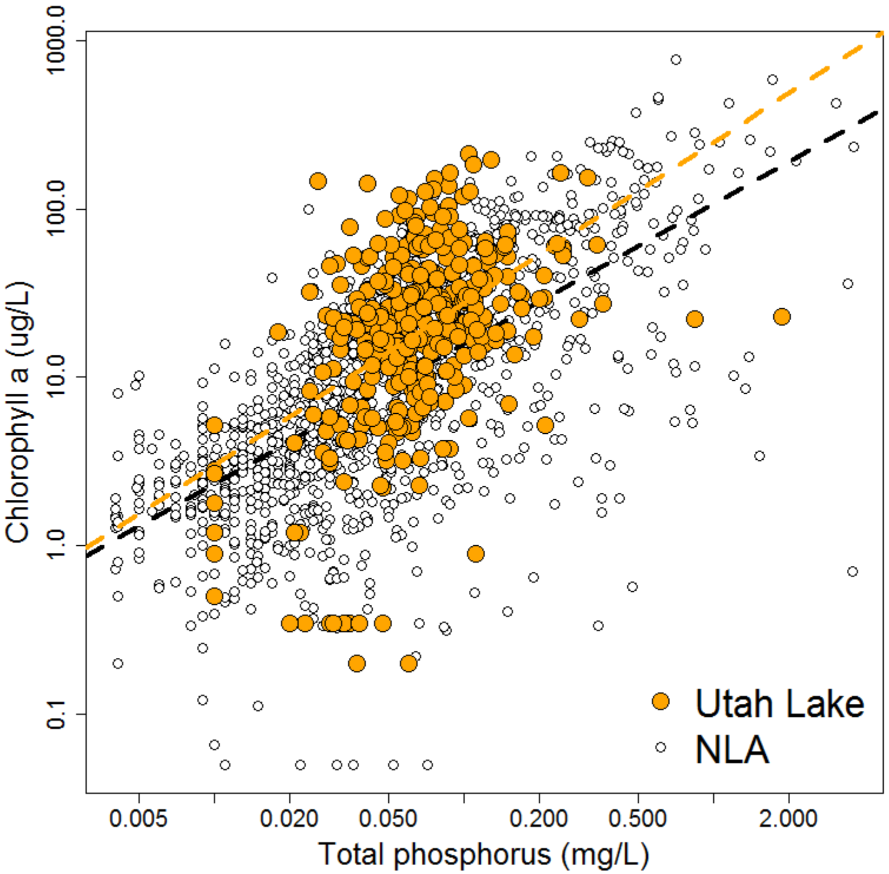
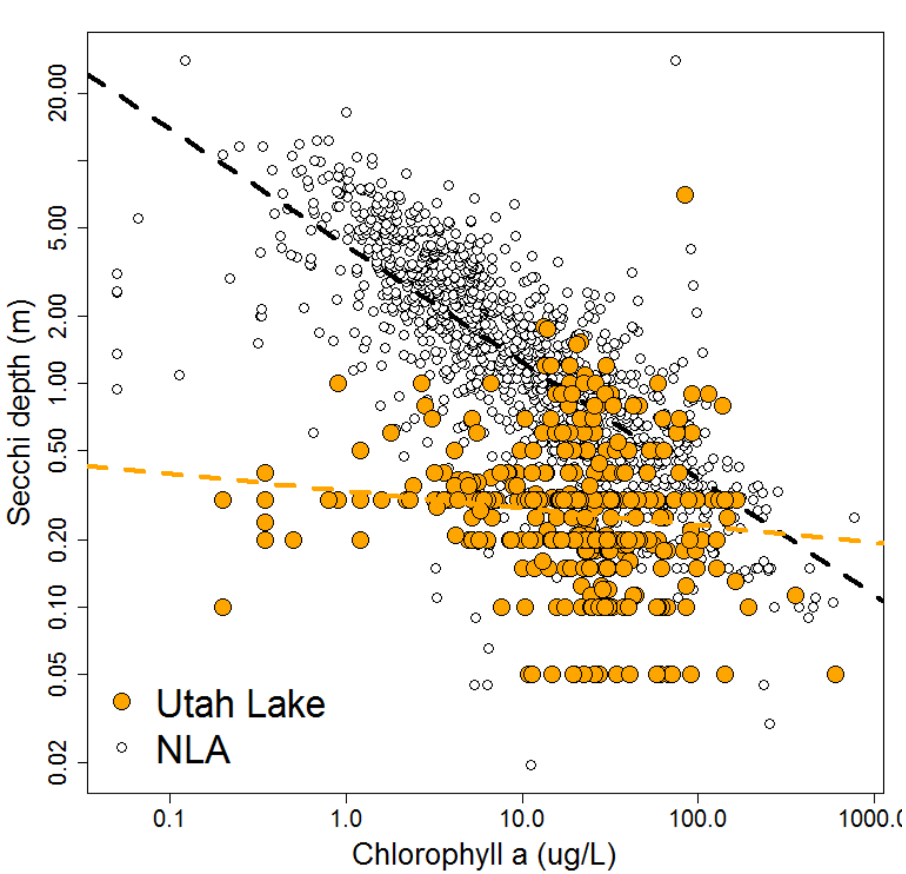
National Lakes Context





Loading to Utah Lake

2008 Loading Report:

- Water and phosphorus budget

Phase 1 Effort:

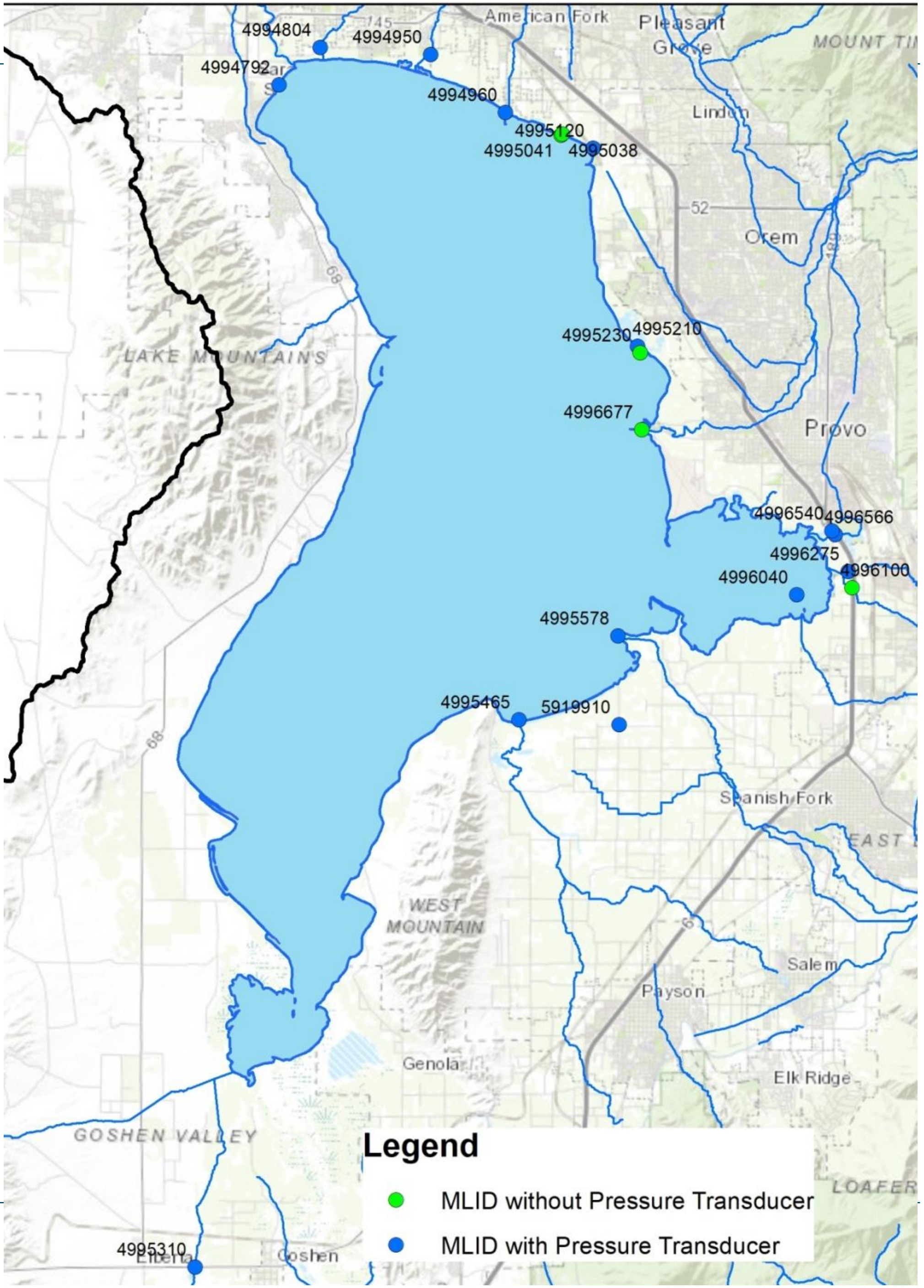
- Monitoring to improve load estimates
  - Proximity to Utah Lake
  - Improve understanding of significant sources
- Support model development

https://deq.utah.gov/legacy/programs/water-quality/watersheds/docs/2009/02Feb/Final_Draft_Task2_Task3_Memo%20_08-01-07.pdf

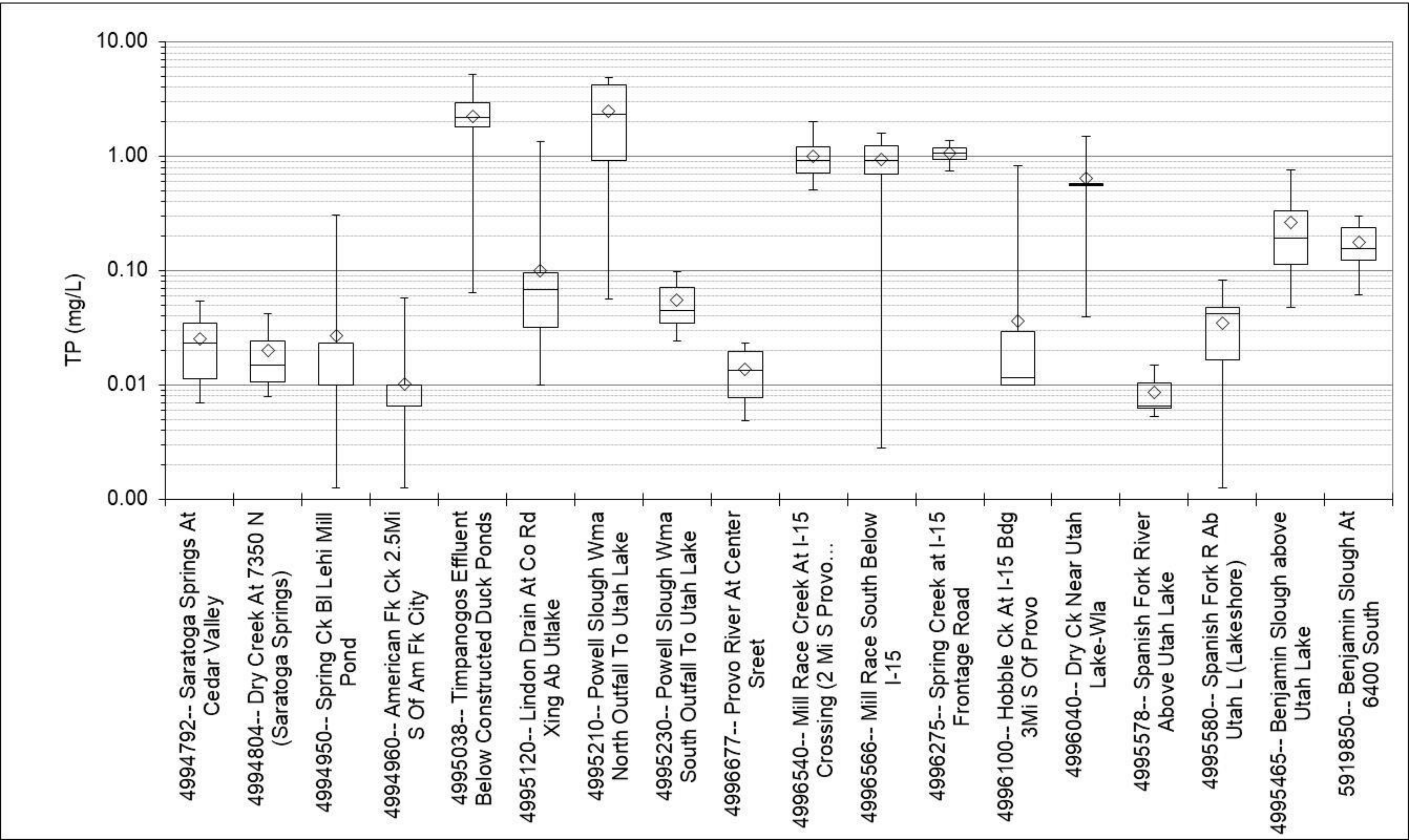
Table 5: Calculated Average Total Phosphorus Loads (tons/year) Based on Average Flows (1980-2003)

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1. INFLOWS	Inflow	Type													
Powell Slough	Powell Slough Total	Total	5.9	6.3	5.9	6.5	8	6.6	6.8	7.5	7.8	8.2	6.5	6.4	82.4
	Powell Slough (natural)	*S*	*0.3*	*0.4*	*0.3*	*0.3*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.3*	*0.3*	*3.1*
	Orem WWTP	*WWTF*	*5.6*	*5.9*	*5.6*	*6.2*	*7.8*	*6.4*	*6.6*	*7.3*	*7.6*	*8*	*6.2*	*6.1*	*79.3*
Provo River	Provo River Total	Total	0.6	0.5	0.8	0.8	1.7	1.2	0.2	0.2	0.3	0.6	0.5	0.5	7.9
	Provo River (natural)	S													
	Provo River Drain	D													
Dry Creek (Lehi)	Dry Creek (Lehi)	S	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0.2
Little Dry Creek	Little Dry Creek	S	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Dry Creek	Big Dry Creek	S	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.2
Mill Race Creek	Mill Race Creek Total	Total	6.2	5.6	5.8	5.9	6.7	6.2	6.4	6.7	7.5	6.2	6.6	4.6	74.4
	Mill Race Creek (natural)	*S*	*0.2*	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*1.4*
	Provo WWTP	*WWTF*	*5.9*	*5.4*	*5.6*	*5.7*	*6.5*	*6*	*6.1*	*6.5*	*7.3*	*5.9*	*6.3*	*4.4*	*71.6*
	Drains	*D*	*0.1*	*0*	*0.1*	*0.1*	*0.1*	*0.1*	*0.2*	*0.1*	*0.1*	*0.2*	*0.2*	*0.1*	*1.4*
Spring Creek (East of Provo Bay)	Spring Creek (East of Provo Bay) Tota	Total	0.9	1.5	1.5	1.3	1.4	1.3	1	1.1	1.3	1	1.3	0.8	14.4
	Spring Creek (natural)	*S*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0*	*0*	*0.1*	*0*	*0*	*0*	*0.1*	*0.7*
	Springville WWTP	*WWTF*	*0.8*	*1.4*	*1.4*	*1.2*	*1.3*	*1.3*	*1*	*1*	*1.3*	*1*	*1.3*	*0.7*	*13.7*
Hobble Creek	Hobble Creek	S	0.1	0.2	0.3	0.3	0.2	0.1	0	0	0	0	0.1	0.1	1.4
Dry Creek (South of Provo Bay)	Dry Creek (South of Provo Bay) Total	Total	1	1.3	1.4	0.9	1.2	1.2	0.9	0.8	0.9	1.4	1.4	1.5	13.9
	Dry Creek (natural)	*S*	*0.3*	*0.4*	*0.3*	*0.1*	*0.1*	*0.1*	*0*	*0*	*0.1*	*0.2*	*0.3*	*0.3*	*2.2*
	Spanish Fork WWTP	*WWTF*	*0.7*	*0.9*	*1.1*	*0.8*	*1.1*	*1.1*	*0.9*	*0.8*	*0.8*	*1.2*	*1.1*	*1.2*	*11.7*
Spanish Fork River	Spanish Fork River	S	1.1	1	1.5	7.7	4.7	1.8	0.2	0.3	0.6	0.8	0.7	0.8	21.2
Benjamin Slough	Benjamin Slough Total	Total	1.5	1.6	1.6	1.6	1.4	1.3	1	1	1.1	1.3	1.7	1.5	16.6
	Benjamin Slough (natural)	*S*	*0.4*	*0.4*	*0.5*	*0.4*	*0.4*	*0.2*	*0.1*	*0.2*	*0.2*	*0.4*	*0.5*	*0.4*	*4.1*
	Salem WWTP	*WWTF*	*0.3*	*0.4*	*0.3*	*0.4*	*0.3*	*0.4*	*0.4*	*0.3*	*0.3*	*0.3*	*0.4*	*0.3*	*4.1*
	Payson WWTP	*WWTF*	*0.8*	*0.8*	*0.8*	*0.8*	*0.7*	*0.7*	*0.5*	*0.5*	*0.6*	*0.6*	*0.8*	*0.8*	*8.4*
White Lake Overflow to Goshen	White Lake Overflow to Goshen	S	0.1	0.2	0.1	0.1	0	0	0	0	0	0	0.1	0.1	0.7
Minnie Creek	Minnie Creek	S	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1	0.1	1.1
Mill Pond	Mill Pond	S	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.2
Streams	Streams		18.7	19.8	20.6	26.4	26.9	21.2	17.7	18.7	20.6	21.2	20.6	18.1	250.5
	Natural Flows/Drains		*4.6*	*5*	*5.8*	*11.3*	*9.2*	*5.3*	*2.2*	*2.3*	*2.7*	*4.2*	*4.5*	*4.6*	*61.7*
	WWTPs		*14.1*	*14.8*	*14.8*	*15.1*	*17.7*	*15.9*	*15.5*	*16.4*	*17.9*	*17*	*16.1*	*13.5*	*188.8*
Springs	Springs		0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater	Groundwater		0.1	0.2	0.2	0.2	0.5	0.5	0.2	0.3	0.4	0.3	0.2	0.4	3.5
Other Surface	Other Surface		3.6	2.7	2.9	3	2.5	1.9	5.5	3.4	4.3	5.3	4.8	3.7	43.6
	Timpanogos WWTP		*3.3*	*2.3*	*2.5*	*2.7*	*2*	*1.4*	*5*	*3*	*3.9*	*5*	*4.5*	*3.4*	*39*
	Miscellaneous Surface		*0.3*	*0.4*	*0.4*	*0.3*	*0.5*	*0.5*	*0.5*	*0.4*	*0.4*	*0.3*	*0.3*	*0.3*	*4.6*
TOTAL INFLOW LOAD			**22.4**	**22.7**	**23.7**	**29.6**	**29.9**	**23.6**	**23.4**	**22.4**	**25.3**	**26.8**	**25.6**	**22.2**	**297.6**

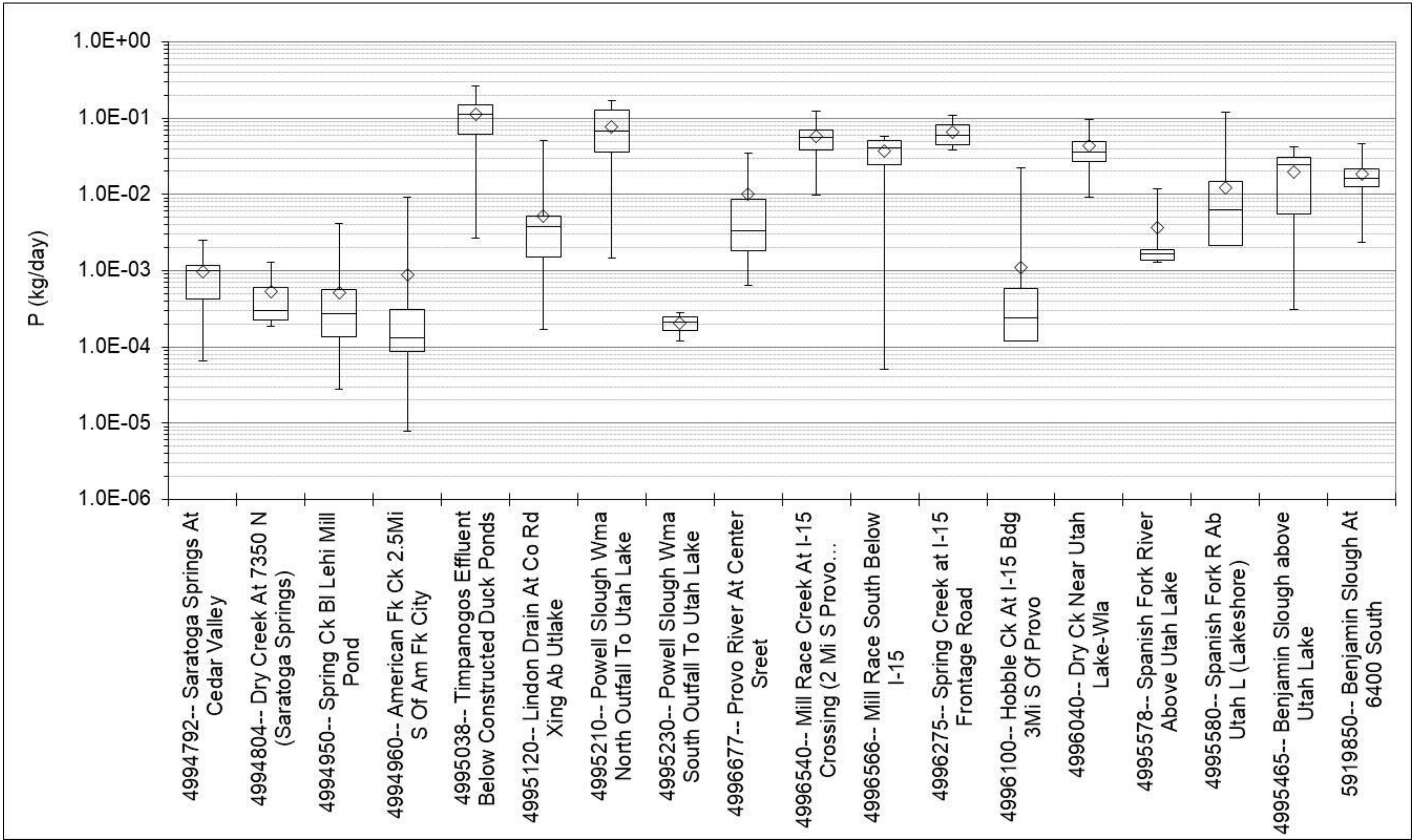
Monitoring Locations



TP Inflow Concentration



TP Loading



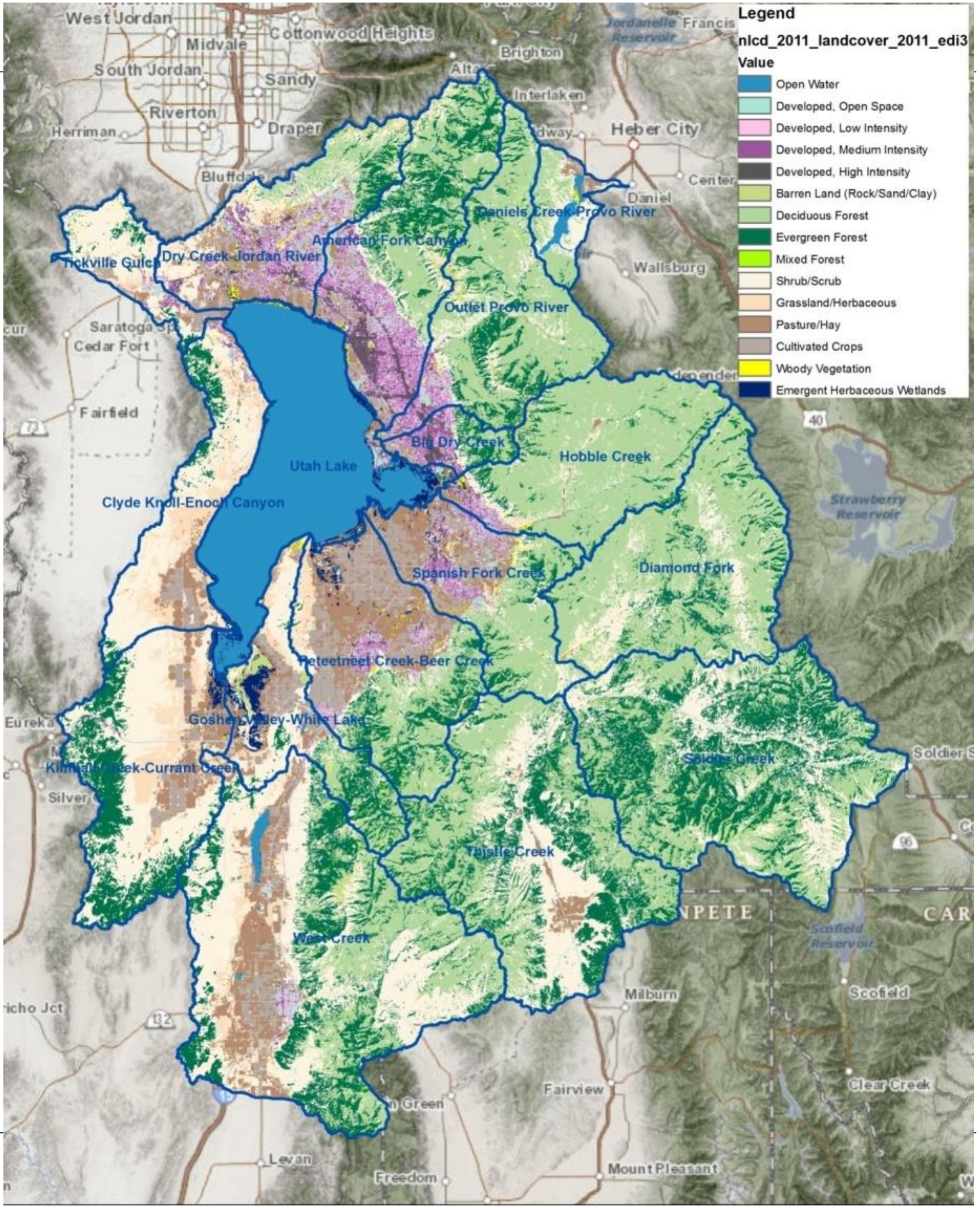
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
P (kg/day)
4994792-- Saratoga Springs At Cedar Valley
4994804-- Dry Creek At 7350 N (Saratoga Springs)
4994950-- Spring Ck Bl Lehi Mill Pond
4994960-- American Fk Ck 2.5Mi S Of Am Fk City
4995038-- Timpanogos Effluent Below Constructed Duck Ponds
4995120-- Lindon Drain At Co Rd Xing Ab Utlake
4995210-- Powell Slough Wma North Outfall To Utah Lake
4995230-- Powell Slough Wma South Outfall To Utah Lake
4996677-- Provo River At Center Sreet
4996540-- Mill Race Creek At I-15 Crossing (2 Mi S Provo...
4996566-- Mill Race South Below I-15
4996275-- Spring Creek at I-15 Frontage Road
4996100-- Hobble Ck At I-15 Bdg 3Mi S Of Provo
4996040-- Dry Ck Near Utah Lake-Wla
4995578-- Spanish Fork River Above Utah Lake
4995580-- Spanish Fork R Ab Utah L (Lakeshore)
4995465-- Benjamin Slough above Utah Lake
5919850-- Benjamin Slough At 6400 South

Source Characterization

Phase 1 Effort:

- Metadata analysis
- Characterize significant sources
  - Storm water
  - Direct drainage/ungaged tribs
  - Agricultural return flow
  - Hydrologic influence
  - Point source discharges

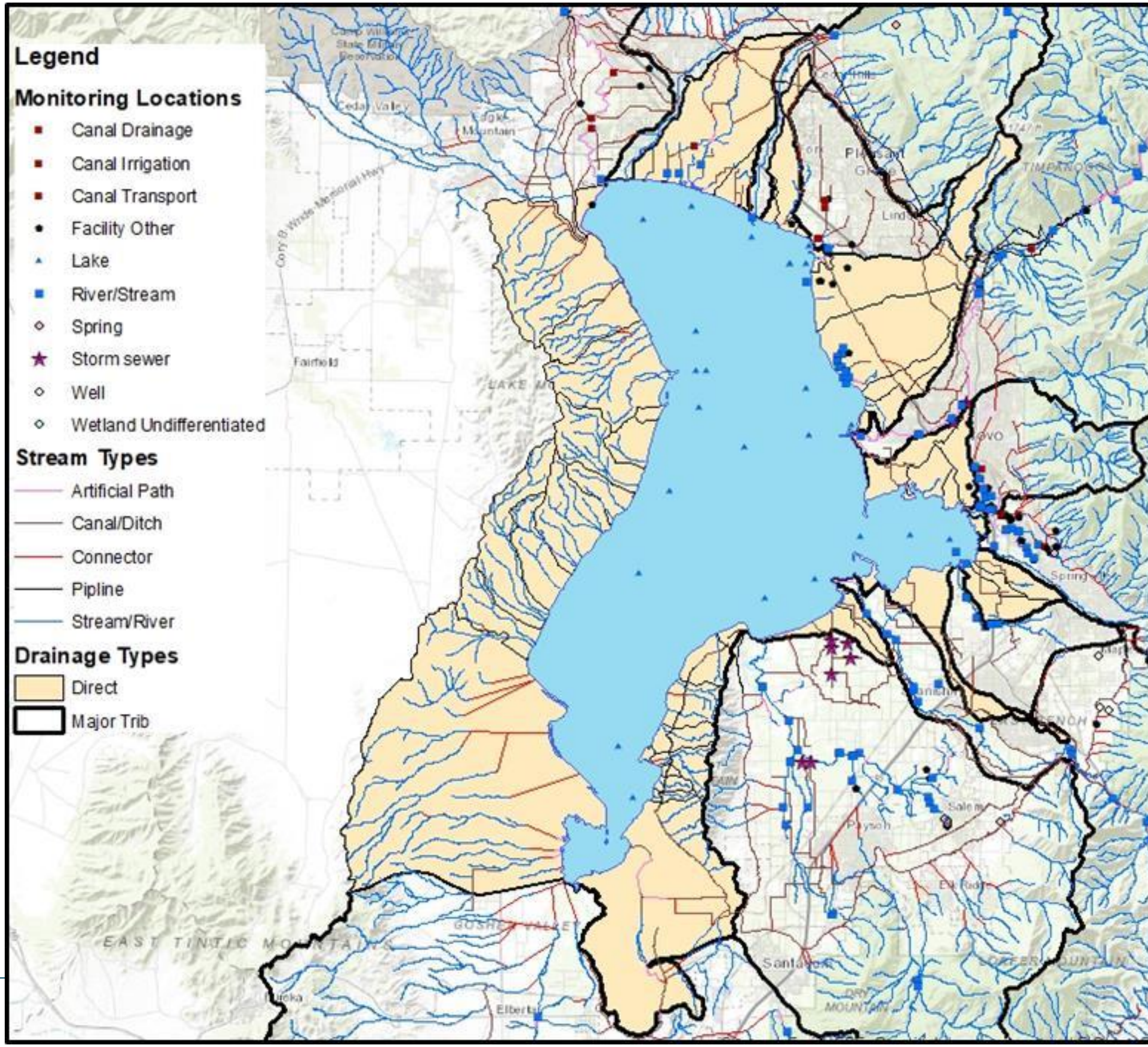
Storm water



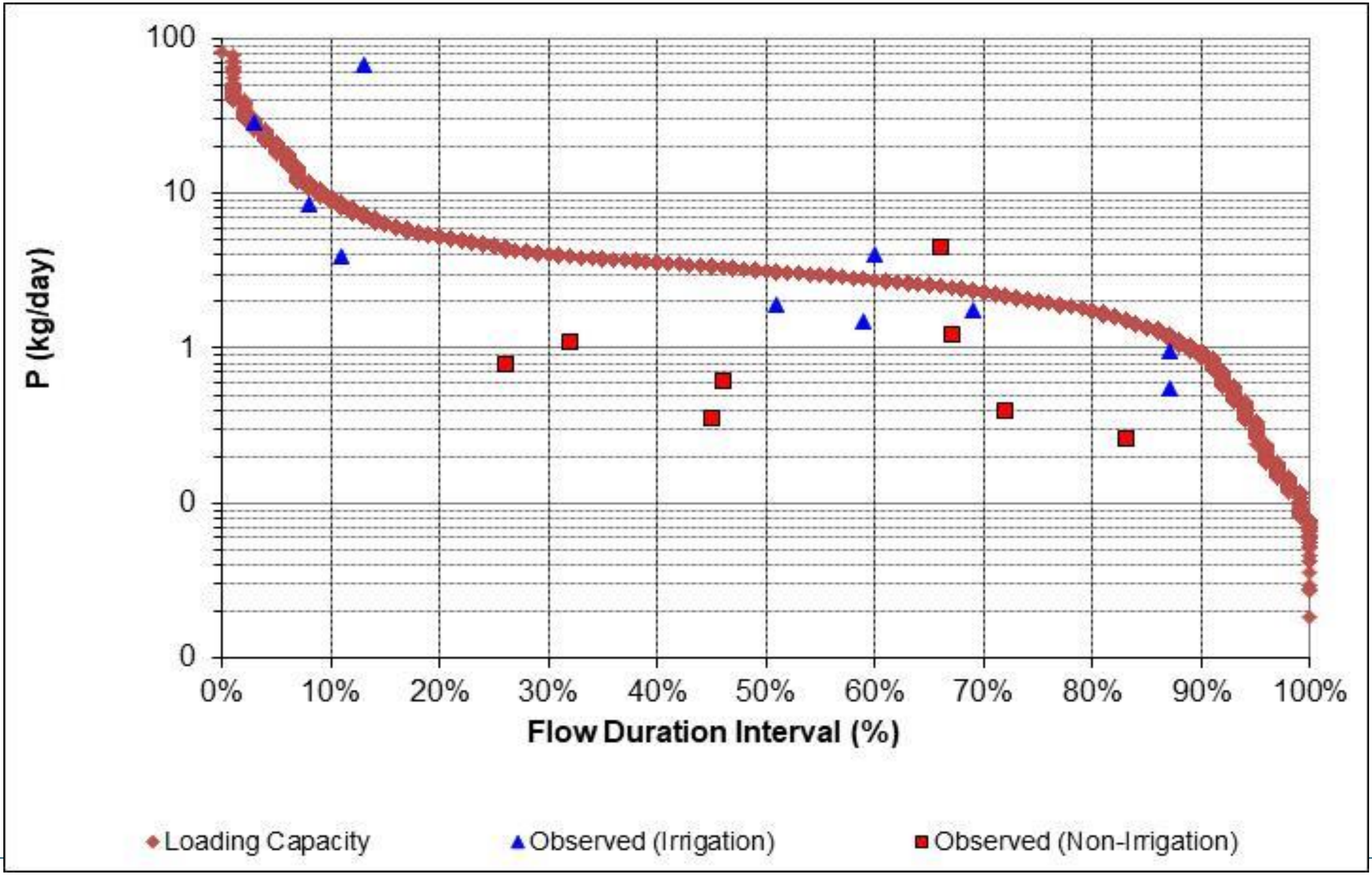
Legend
nlcd_2011_landcover_2011_edi3
Value
Open Water
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Vegetation
Emergent Herbaceous Wetlands
Dry Creek-Jordan River
American Fork Canyon
Daniels Creek-Provo River
Outlet Provo River
Big Dry Creek
Hobble Creek
Utah Lake
Clyde Knoll-Enoch Canyon
Spanish Fork Creek
Diamond Fork
Peteetneet Creek-Beer Creek
Goshen Valley-White Lake
Kimball Creek-Currant Creek
Soldier Creek
Thistle Creek
West Creek
West Jordan
Midvale
Cottonwood Heights
South Jordan
Sandy
Riverton
Herriman
Draper
Brighton
Interlaken
Heber City
Daniel
Wallsburg
Cedar Fort
Fairfield
Jordanelle Reservoir
Strawberry Reservoir
Scofield Reservoir
Scofield
Milburn
Clear Creek
Fairview
Levan
Freedom
Mount Pleasant

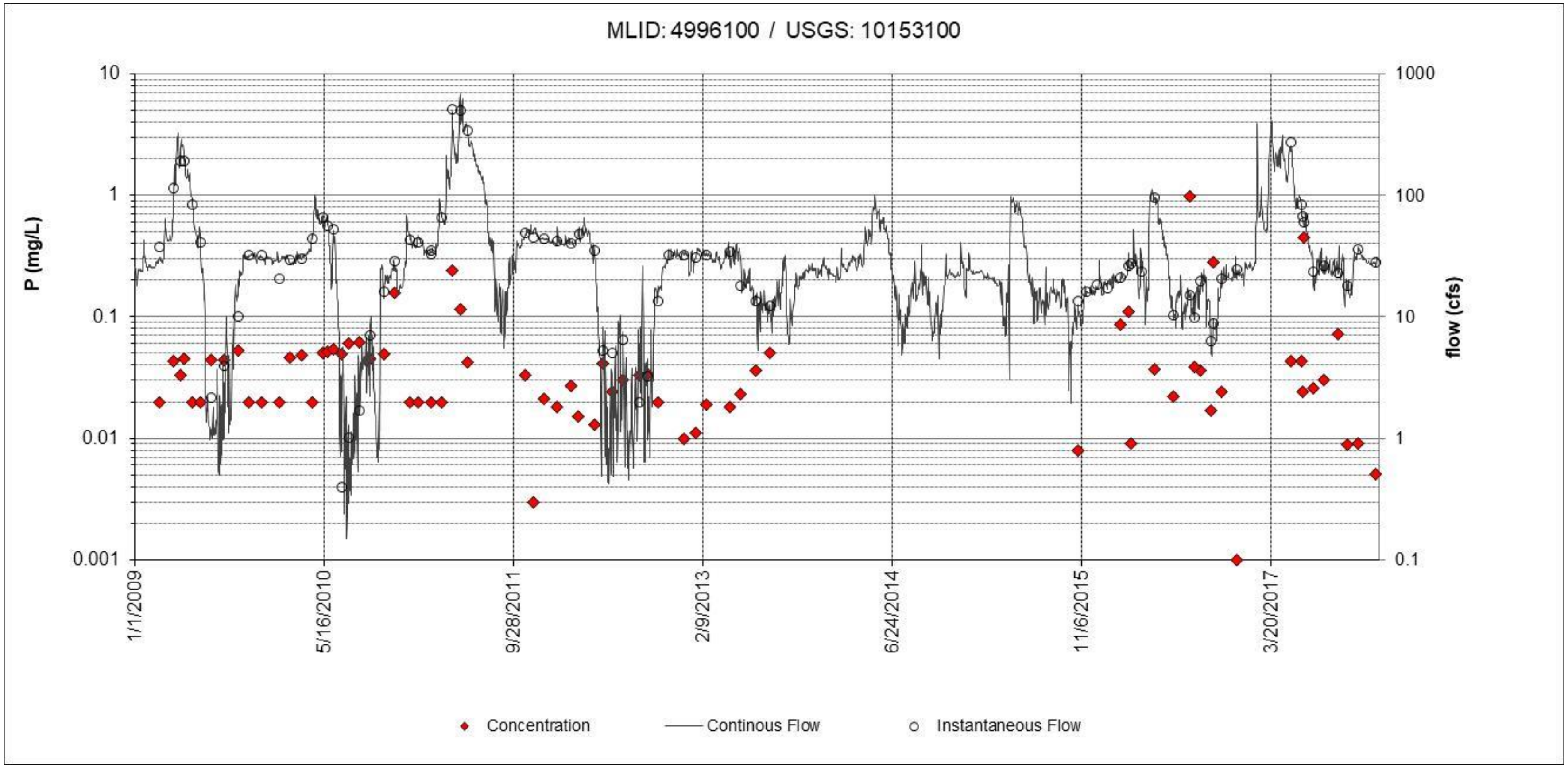
	Calculation Method	Utah Lake TP Load (tons/yr)
1	East Fork Canyon TMDL TP Load Coefficients	6
	Cutler TMDL TP Load Coefficients	27
2	Runoff/SL Co monitoring TP concentration	18
3	Jordan River TMDL Stormwater Load	13
4	Simple Method to Calculate Urban Stormwater Loads	9

Direct Drainage Watersheds



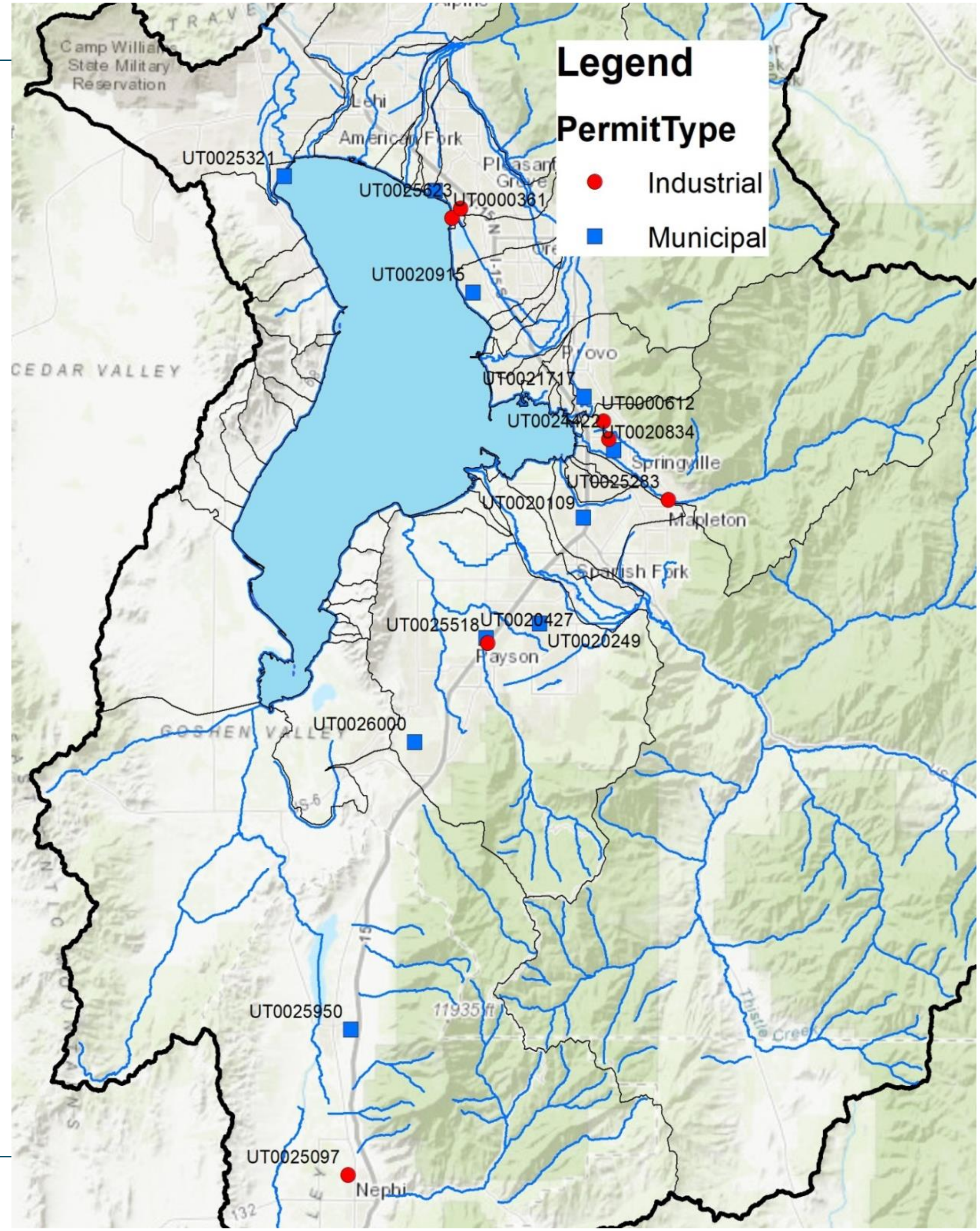
Hydrologic Influence on Load



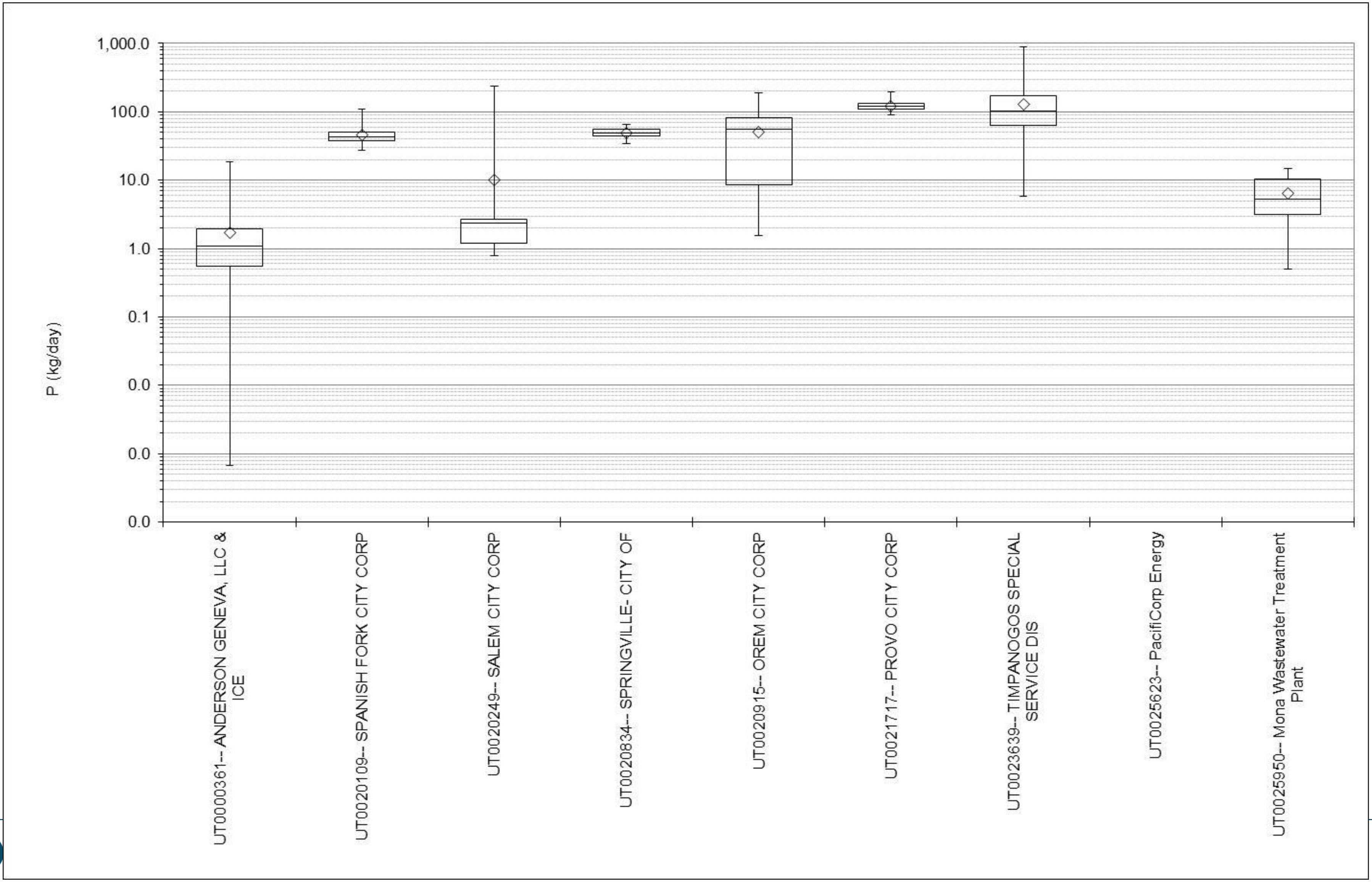


MLID: 4996100 / USGS: 10153100
P (mg/L)
flow (cfs)
10
1
0.1
0.01
0.001
1000
100
10
1
0.1
1/1/2009
5/16/2010
9/28/2011
2/9/2013
6/24/2014
11/6/2015
3/20/2017
Concentration
Continous Flow
Instantaneous Flow

UPDES Discharge Locations



Point Source Loading (2005 – 2017)



Questions

Citations

Carlson, R.E. and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Carlson, R.E. and K.E. Havens. 2005. Simple graphical methods for the interpretation of relationships between trophic state variables. Lake and Reservoir Management 21:107-118.

Downing, J.A., S.B. Watson, and E. McCauley. 2001. Predicting cyanobacterial dominance in lakes. Canadian Journal of Fisheries and Aquatic Sciences 58:1905-1908.

Rogalus, M.K., and M.C. Watzin. 2008. Evaluation of sampling and screening techniques for tiered monitoring of toxic cyanobacteria in lakes. Harmful Algae 7: 504-514.

Lindon, M. and S. Heiskary. 2009. Blue-greeen algal toxin (microcystin) levels in Minnesota lakes. Lake and Reservoir Management 25:240-252.

Yuan, L.L., A.I. Pollard, S. Pather, J.L. Oliver, and L. D'Anglada. 2014. Managing microcystin: identifying national-scale thresholds for total nitrogen and chlorophyll a. Freshwater Biology 59:1970-1981.