Monitoring Program on the Potomac River at Chain Bridge:

Past and Future

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Outline

- Brief History
  - Operational Nuts and Bolts
  - Rationale
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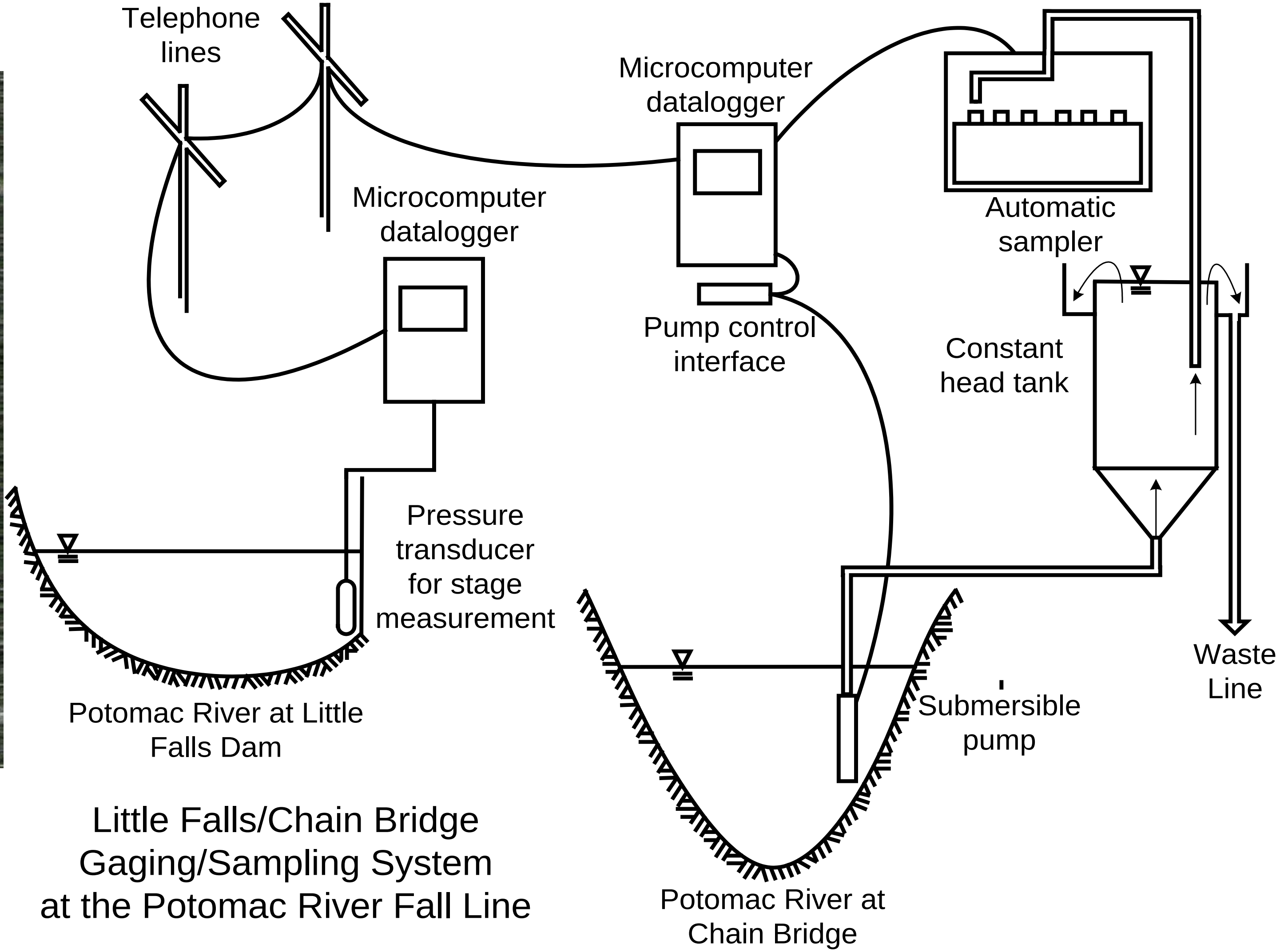
    - Since 2000
- Benefits of the Program
  - Water quality data
  - Water quality trends
  - Load computations
- Results of a Recent Load Computation and Comparison Study
- Future Scenarios

Brief History—Operational Nuts and Bolts



Little Falls/Chain Bridge Gaging/Sampling System at the Potomac River Fall Line

Brief History – Sampling Frequency

- First sample taken on 03 January 1983
- A total of 2,427 individual samples (composites count as one) taken to 21 February 2018
- Baseflow: 1/week [biweekly in winter]
- Stormflow:
  - All storms, composite
  - Up to five storms per year, up to 5 discrete samples per storm

Brief History – Measurements Taken

- Monitored continuously:
  - Flow
  - Dissolved oxygen
  - Temperature
  - pH
  - Conductivity
- Via sample analysis:
  - Total organic carbon
  - Dissolved organic carbon
  - Carbonaceous oxygen demand
  - Total suspended solids
  - Oxidized nitrogen (nitrate & nitrite)
  - Ammonia nitrogen
  - Total Kjeldahl nitrogen
  - Soluble Kjeldahl nitrogen
  - Total nitrogen
  - Total soluble nitrogen
  - Soluble and reactive phosphorus (orthophosphate phosphorus)
  - Total phosphorus
  - Total soluble phosphorus
  - Turbidity
  - Total hardness
  - Total alkalinity
  - Fecal coliforms
  - E. coli
  - Soluble reactive silica

Brief History – Rationale (Original) I

- Fluvial [Constituent] Load Definition:
  - The **mass** of a constituent of interest transported by a stream in a given **time**
- Importance
  - Indicator of watershed conditions
  - Predictor of receiving waterbody conditions
  - Easy to understand
  - Important for management policy
    - Accuracy of load measurement is important determinant when loads are used to decide remediation strategies, including reduction of loads

Implications

- Loss of ability to have an accurate and independent data set

- Inaccuracies in load calculations may lead to regulatory requirements that are more stringent than necessary
  - May result in additional costs for nutrient removal

Brief History – Rationale (Original) II

Load = flow x concentration over time

$$L = \int_0^t Qc\, dt$$

$$\approx \sum_{i=0}^{n} Q_i c_i \Delta t_i \qquad (1)$$

$t = load\ computation\ time, s$

$L = fluvial\ load\ over\ the\ time\ t, kg$

$Q = instantaneous\ flow\ rate, \frac{m^3}{s}$

$c = instantaneous\ concentration\ of\ the\ constituent\ of\ interest, \frac{kg}{m^3}$

$n = number\ of\ steps\ such\ that \sum_{i=0}^{n} \Delta t_i = t$

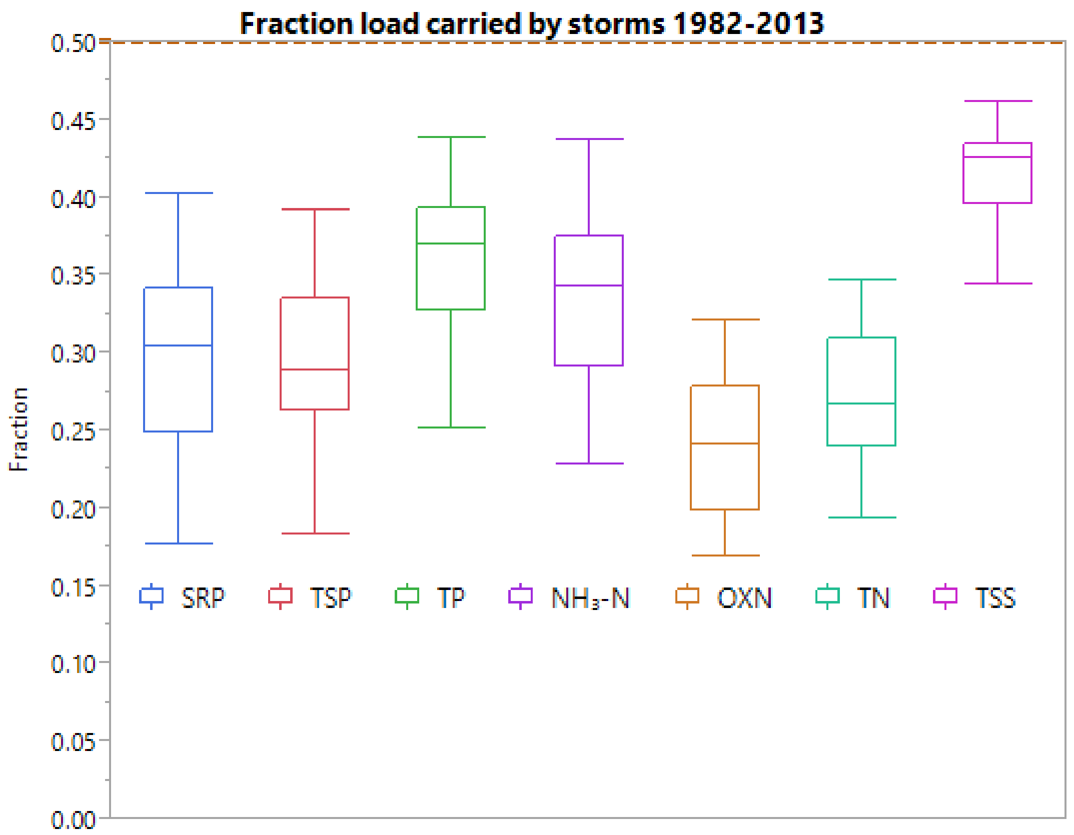
$Q_i = representative\ flow\ rate\ for\ interval\ \Delta t_i, \frac{m^3}{s}$

$c_i = representative\ concentration\ for\ interval\ \Delta t_i, \frac{kg}{m^3}$

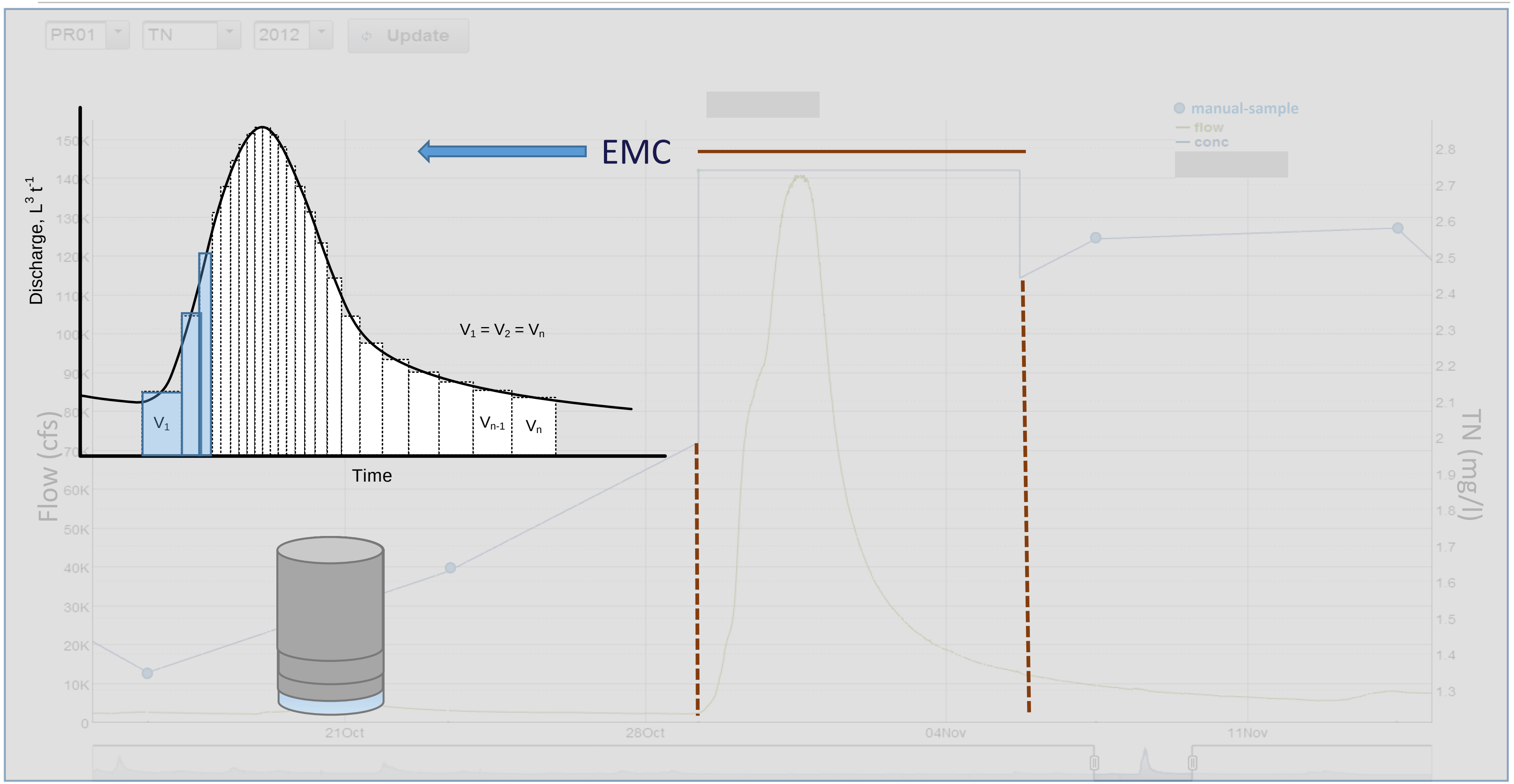
- **Wide river problem – the Potomac is the only fall line station where this is possible**

Why is Storm Flow Important?

- Variability in Q and C
- Large storm loads
- Wide range of values associated with storms



Flow Composite Grab Sampling



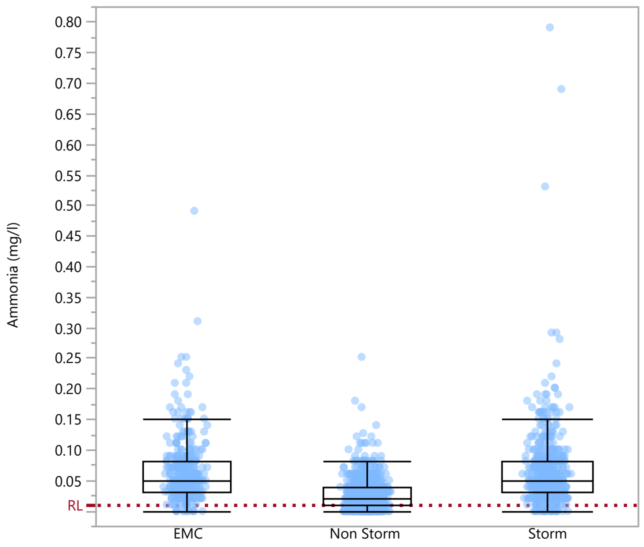
Load Estimation Methods

- OWML method : Basically computes exact storm loads, and estimates baseflow loads between weekly/biweekly sampling events
- WRTDS Method: *concentration may be estimated from flow*
  - $\ln(c) = \hat{\beta}_0 + \underbrace{\hat{\beta}_1 \ln(Q)}_{\text{flow}} + \underbrace{\hat{\beta}_2(t)}_{\text{trend}} + \underbrace{\hat{\beta}_3 \sin(2\pi t) + \hat{\beta}_4 \cos(2\pi t)}_{\text{seasonality}} + \underbrace{\varepsilon}_{\text{randomness}}$
  - New βs are computed for every day based on weighted calibration points
  - Weight of every calibration point is based on the product of distances
    - Experience to get <u>half-width</u>:
      - Trend distance 10 years
      - Seasonal distance 0.5 years
      - Flow distance 2 log units
      - e.g. 6 July 2000, flow 10×10^6 cfs
- WRTDS: Weighted Regressions on Time, Discharge and Season

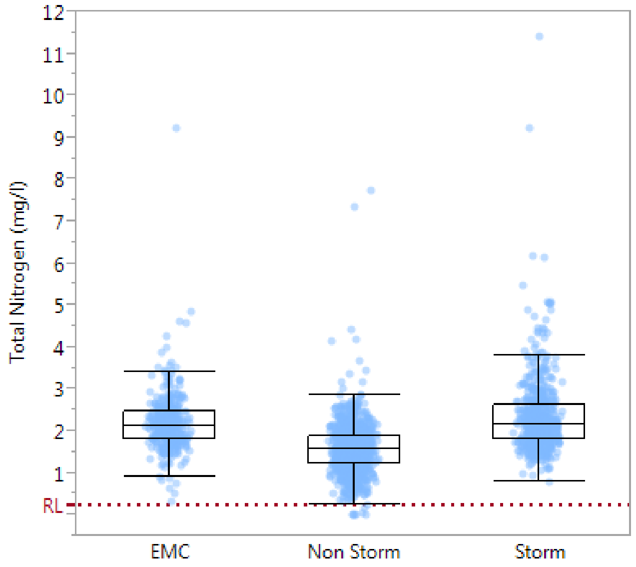
Brief History – Rationale (After 2000)

- To provide comparison between composite and non-composite storm load computations
- To continue to provide accurate loads by using the dense (frequent) sampling scheme that OWML provided
  - "…monitoring at the Chain Bridge location allows for the most complete estimate of upstream nutrient and sediment loads to the upper Potomac estuary, to the middle and lower Potomac River segments, and ultimately to the Chesapeake Bay."
- To provide "an independent and long-term check on the accuracy of the Bay Program's monitoring results at the Potomac fall line and its use in calibrating the watershed model." We believe that this is still necessary!

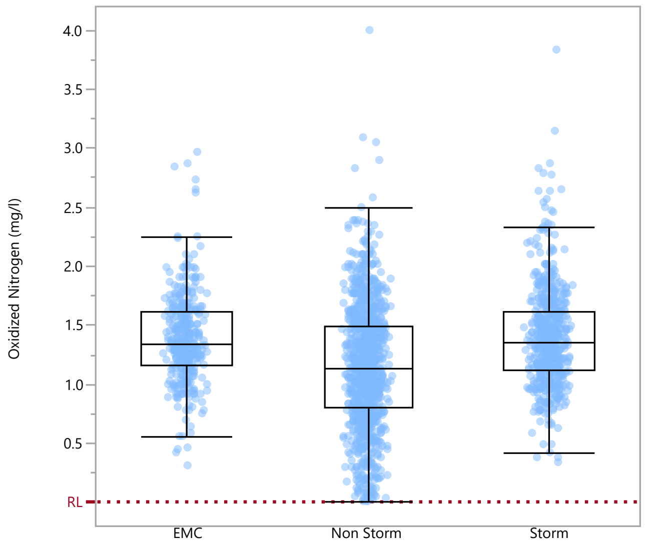
Water Quality Data – Nitrogen



Ammonia Nitrogen



Total Nitrogen



Oxidized Nitrogen

EMC (event mean concentration) computations of storm loads provide the same range of values as discrete sampling at a fraction of the cost, and do not necessitate the use of statistical techniques to compute loads.

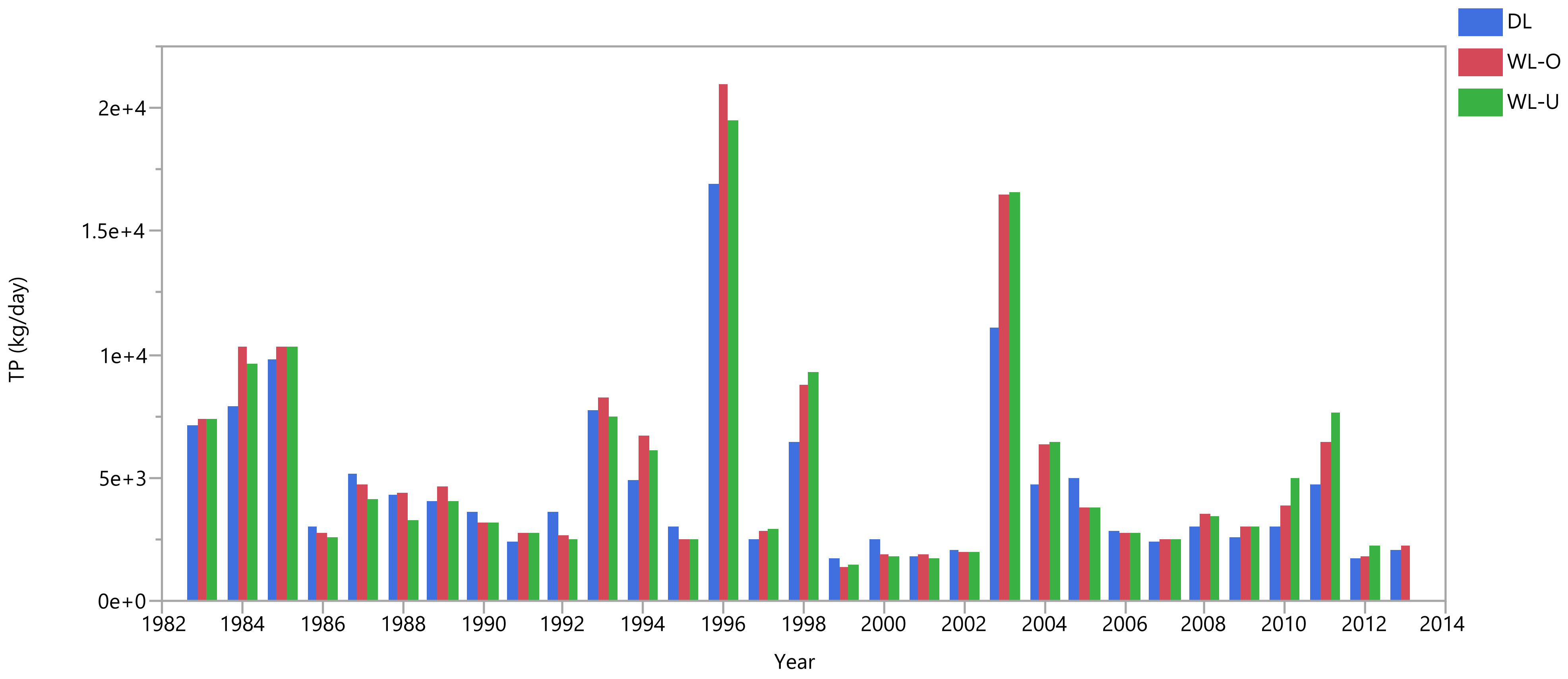
Benefits of the Program – Load Computations

- Accurate load computations due to dense (frequent) sampling using the OWML method
- COG commissioned the analysis to directly compare the new WRTDS results from USGS to the OWML results
- Results of the study are available in the Chain Bridge Data Analysis Report (see link on meeting materials for this event).

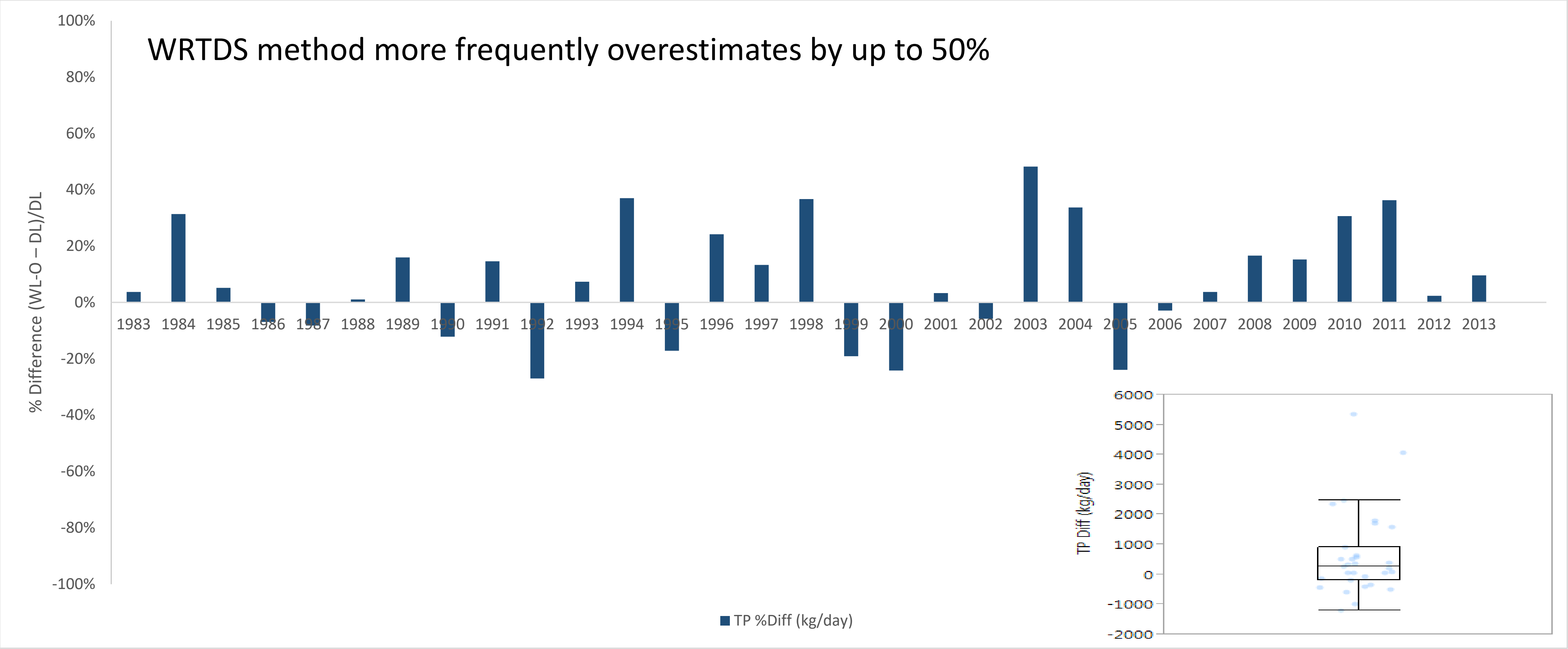
Load Computations

- We used the OWML/COG dataset to compare two load computation methods:
    - Direct load (DL): using OWML method
    - Estimated load: using WRTDS method
    - Applied WRTDS method to:
        - OWML data (WL-O)
        - USGS data (WL-U)
- Let’s look at some results comparing DL and WL-O only, so that we factor out the effects of different data sources
    - DL (blue bars, on left); WL-O (red bars, in middle or right); WL-U (green bars, on right)
    - Please look at the report for a fuller discussion and comparison of all three

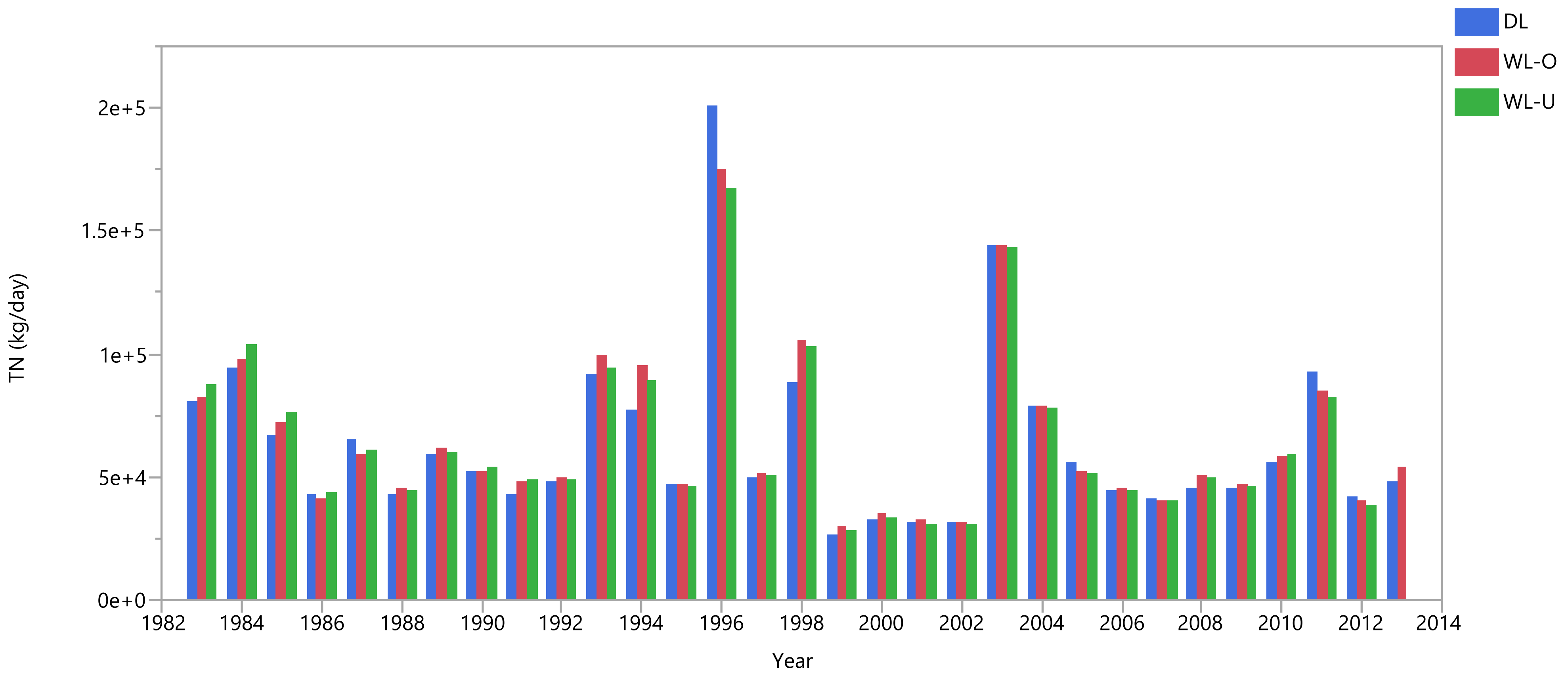
Results of Load Study – TP



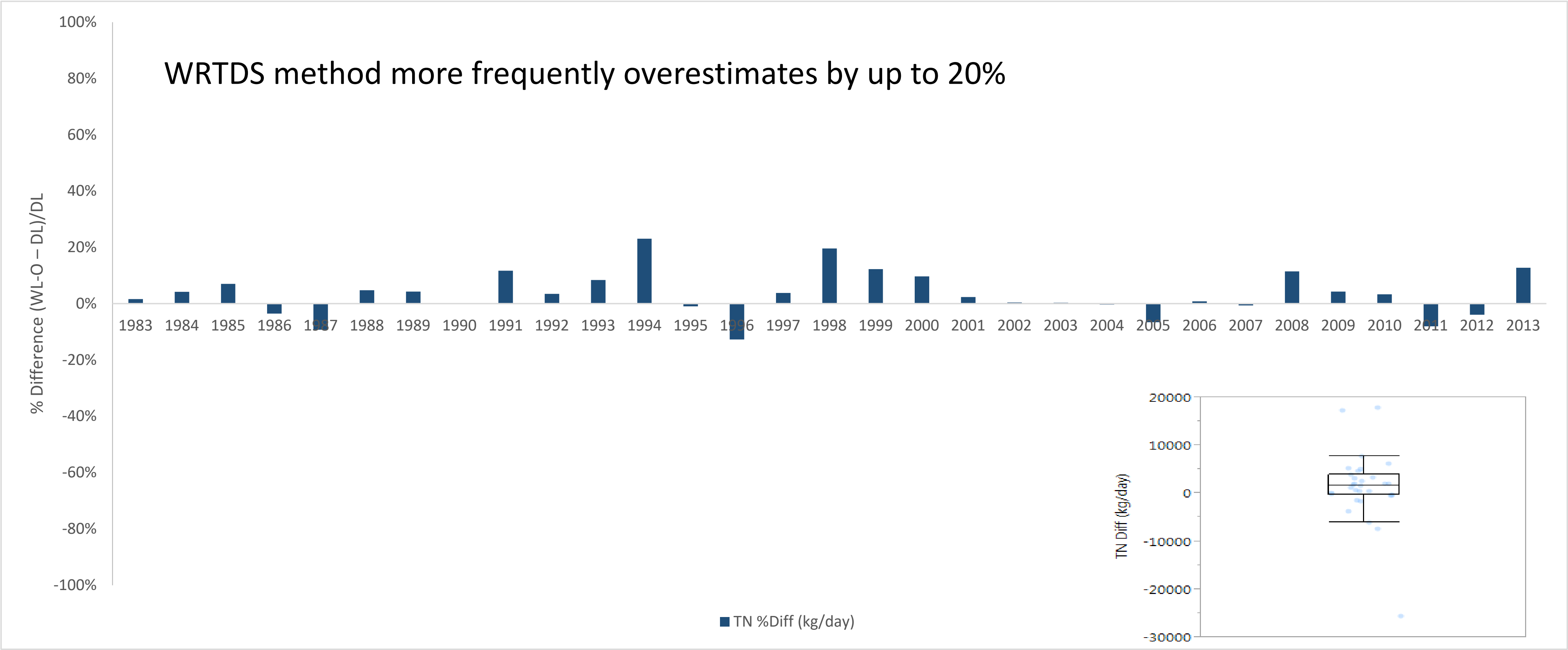
Results of Load Study – TP load differences



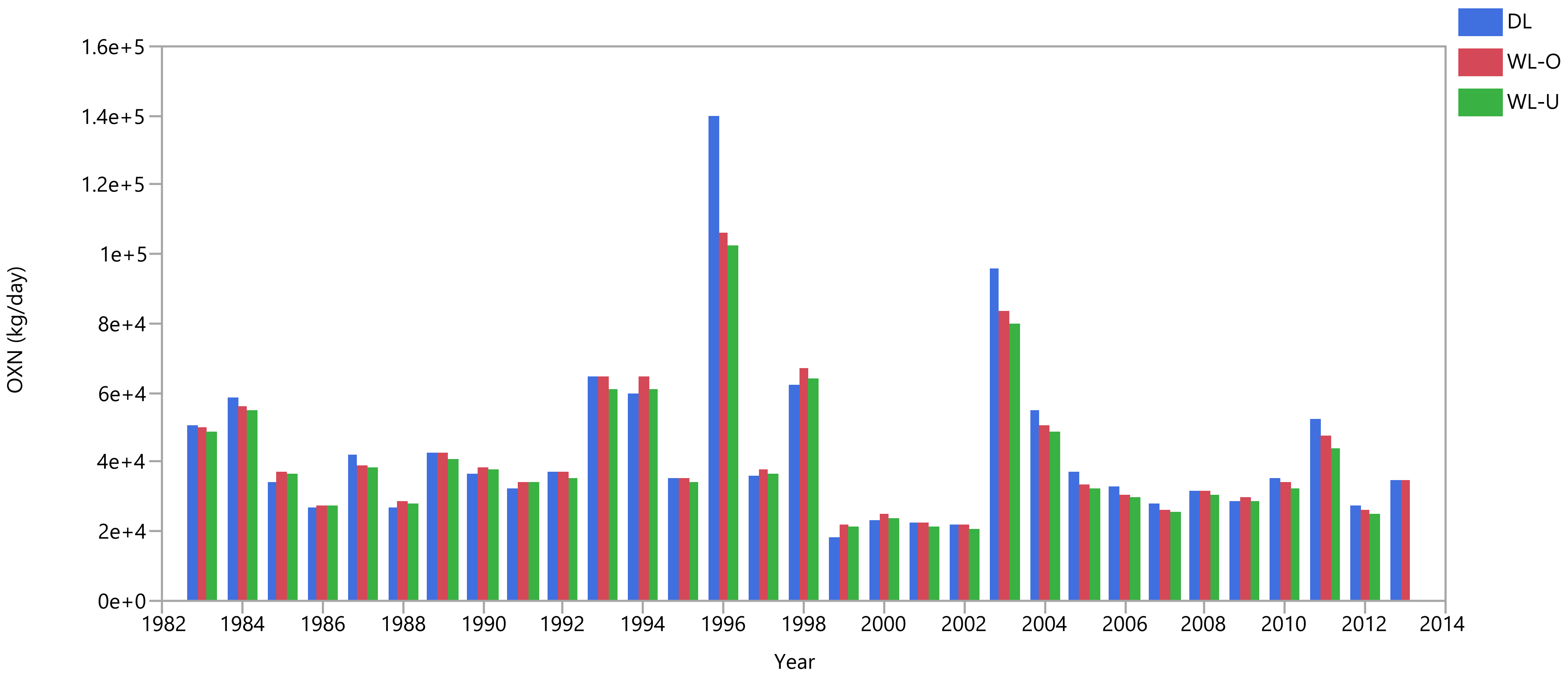
Results of Load Study – TN



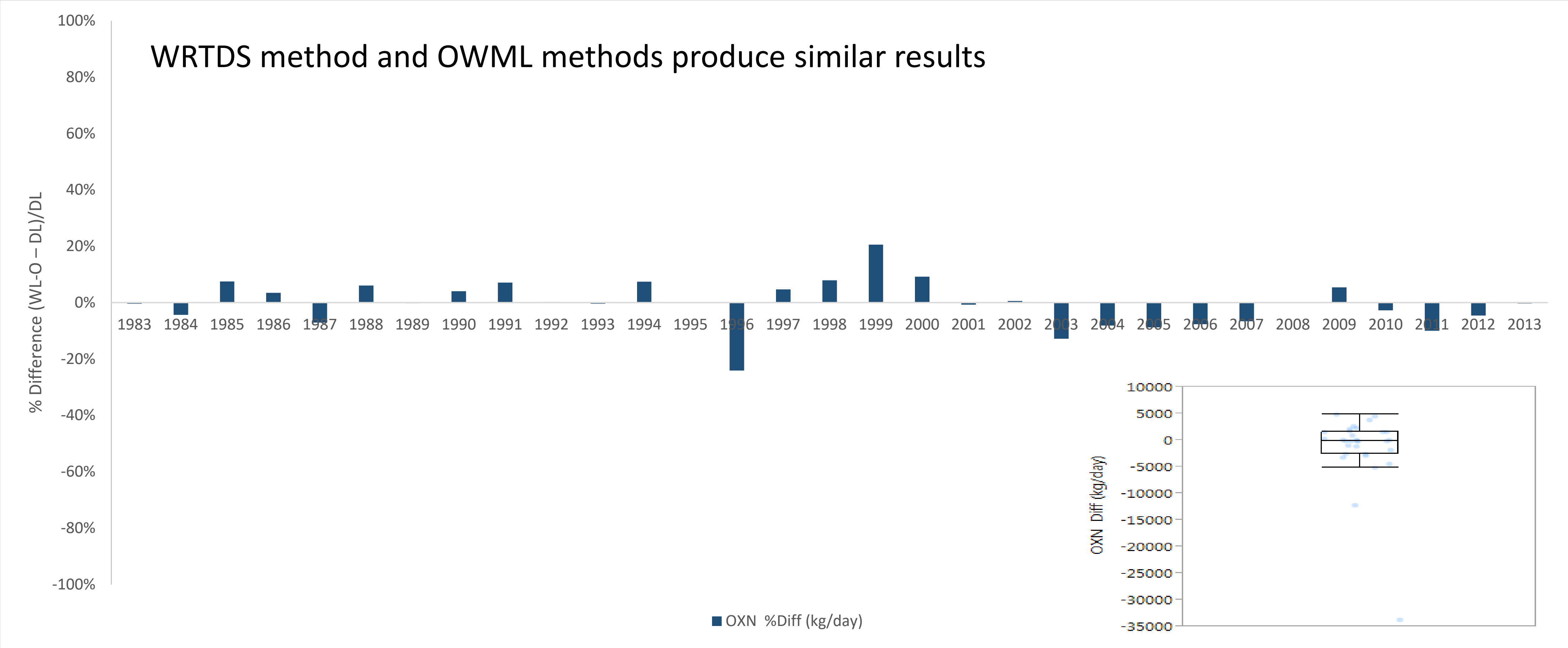
Results of Load Study – TN load differences



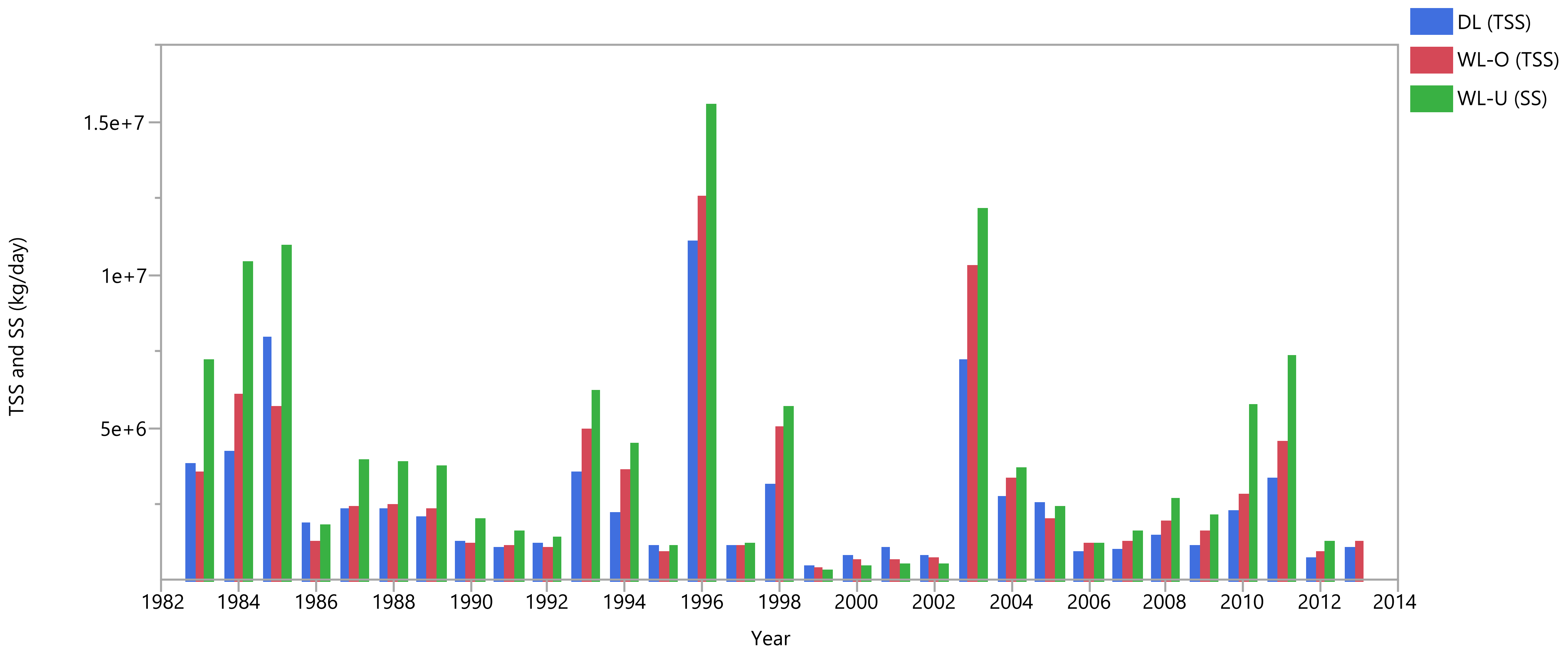
Results of Load Study – Ox-N



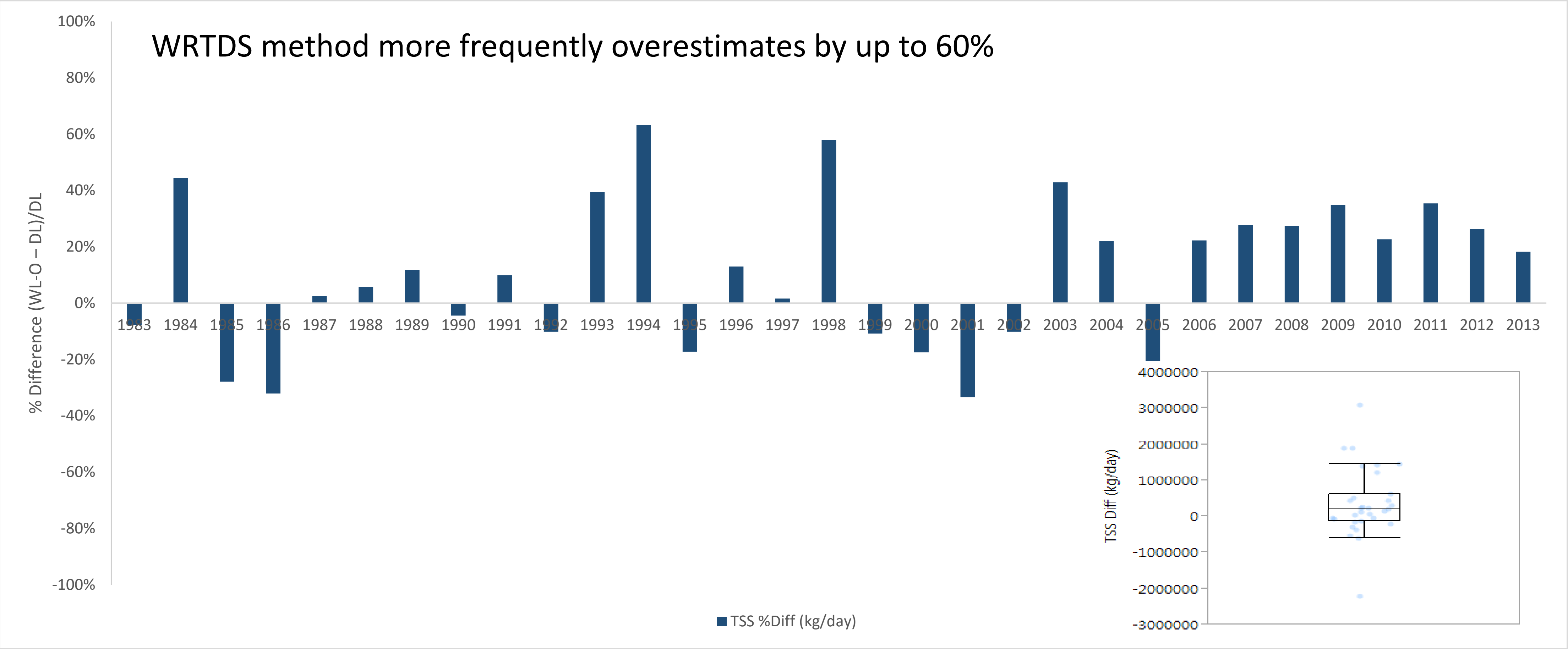
Results of Load Study – Ox-N load differences

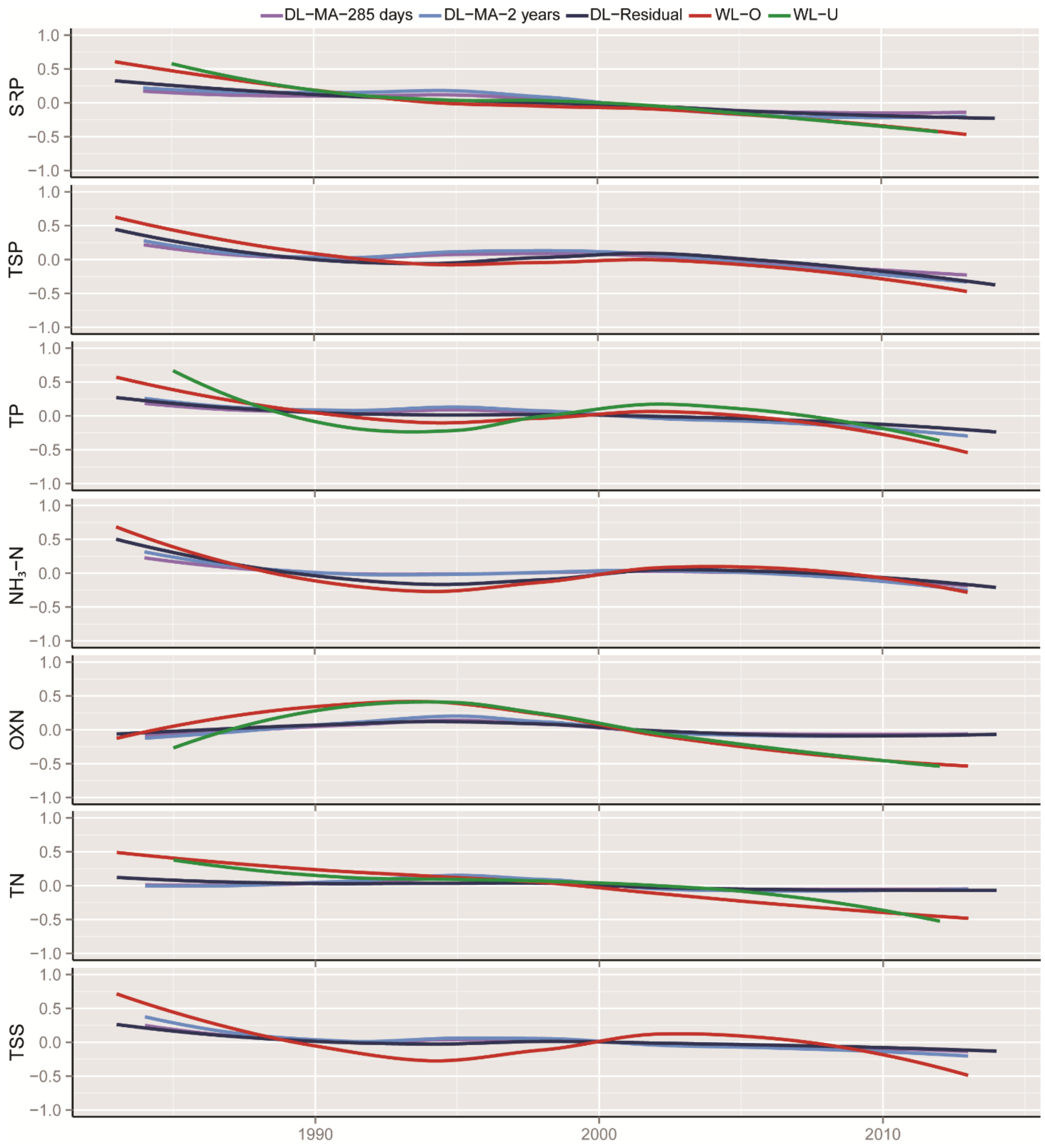


Results of Load Study – TSS



Results of Load Study – TSS load differences





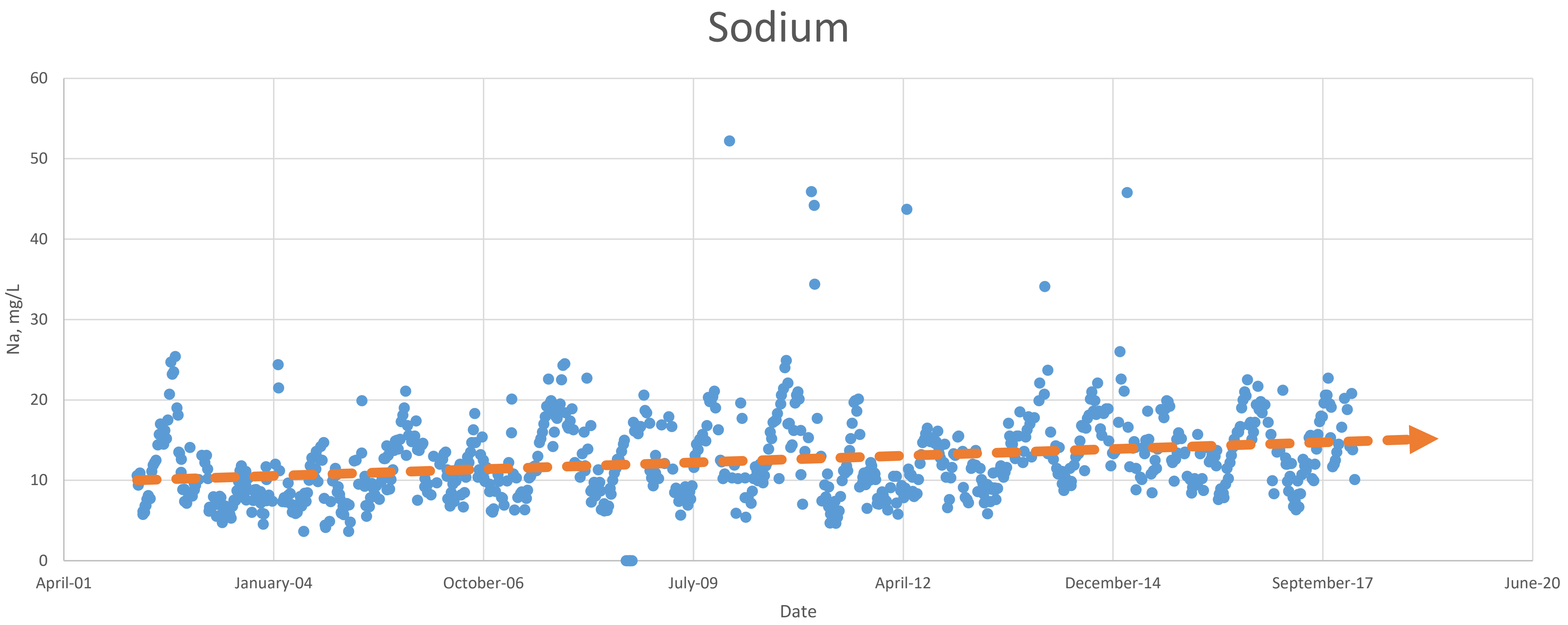
Flow-independent trends estimated by various methods:

- *DL-MA-285 days (purple) is the trend line estimated for DL with a moving average window width of 285 days.*
- *DL-MA-2 years (blue) is the trend line estimated for DL with a moving average window width of 2 years.*
- *DL-Residual (black) is the trend estimated from residuals after adjusting for streamflow variations.*
- *WL-O (red-orange) is the WRTDS estimate using OWML data.*
- *WL-U (green) is the WRTDS estimate using USGS data.*

Results – Two Questions and One Observation

- What, if any, are the implications for the Chesapeake Bay TMDL of the strengths and weaknesses of current fall-line estimation methods?
- How can we better use COG's Chain Bridge data set to inform management decisions?
- "[T]he current Bay modeling framework and the watershed model in particular are not accurate enough to set wasteload allocations at the local level."

Bonus Constituent Plot



Future Scenarios

Three broad categories:

- Continue independent program as is or with no or minor changes
    - Drop some constituents (e.g., silica) in favor of adding others (e.g., chloride)
- Continue independent program at location but revamp it more fully
    - Do a top-to-bottom analysis of the current program and revamp it to include other constituents of interest, for example, endocrine disrupting compounds and other organics, metals of interest, bacterial source identification, etc.
    - Drop constituents that are not considered to be of long-term interest.
    - Reduce analytical frequency of some constituents.
- Implement other programs or studies with the funds
    - This is wide open. Some areas are mentioned in the COG memo, but there are others such as targeted BMP monitoring, CSO overflow monitoring with bacterial source tracking, particular streams or stream segments, etc.

Contact

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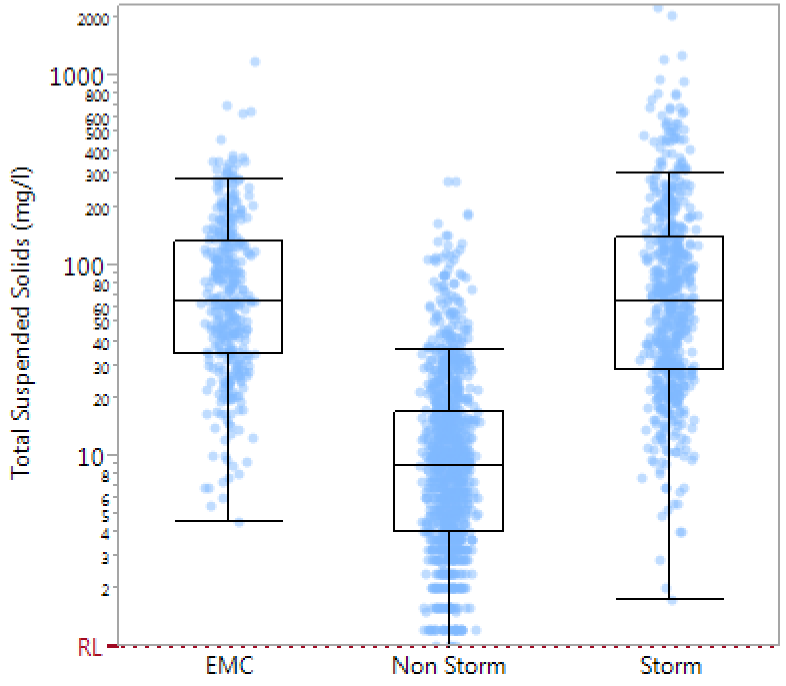
Websites for Chain Bridge data:

1. wqdata.owml.vt.edu – contains up-to-the-hour continuously monitored data (flow, pH, temperature, etc.) at OWML monitored sites (Occoquan watershed and Potomac River).
2. mwcog.owml.vt.edu – contains loading plots and other water quality data, updated as data become available.

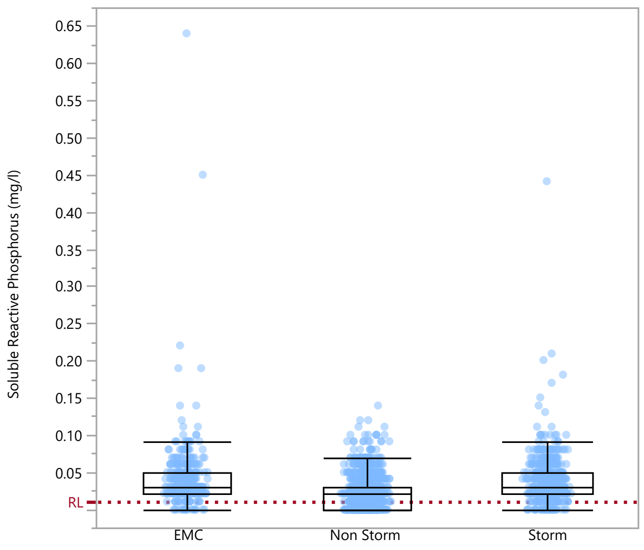
Extras

Benefits of the Program—Water Quality Data

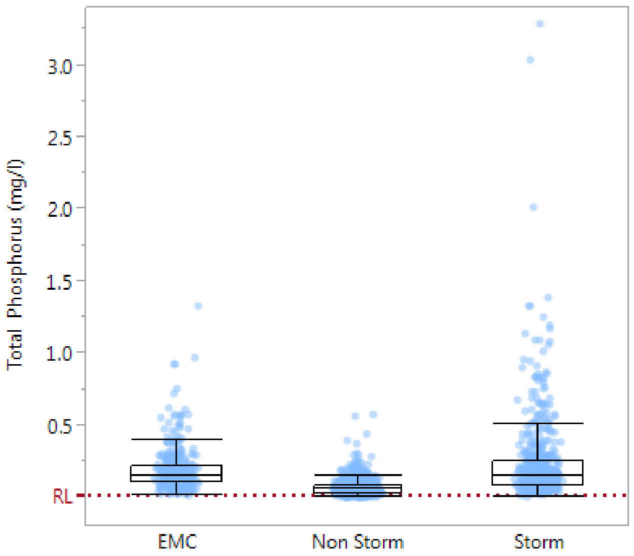


Total Suspended Solids

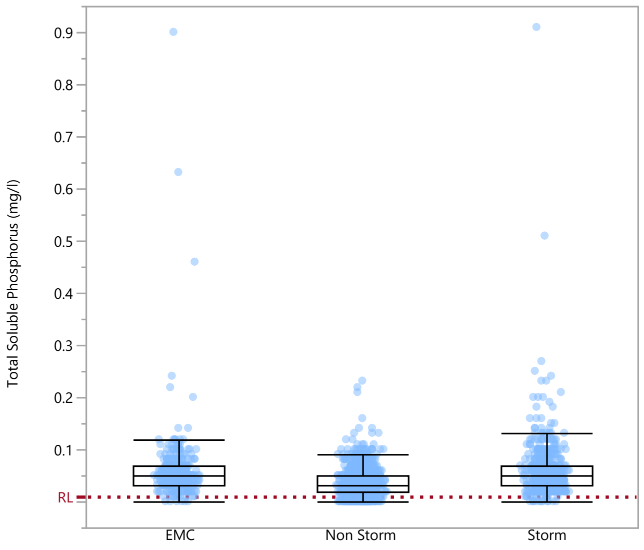
Water Quality Data III



Soluble Reactive Phosphorus

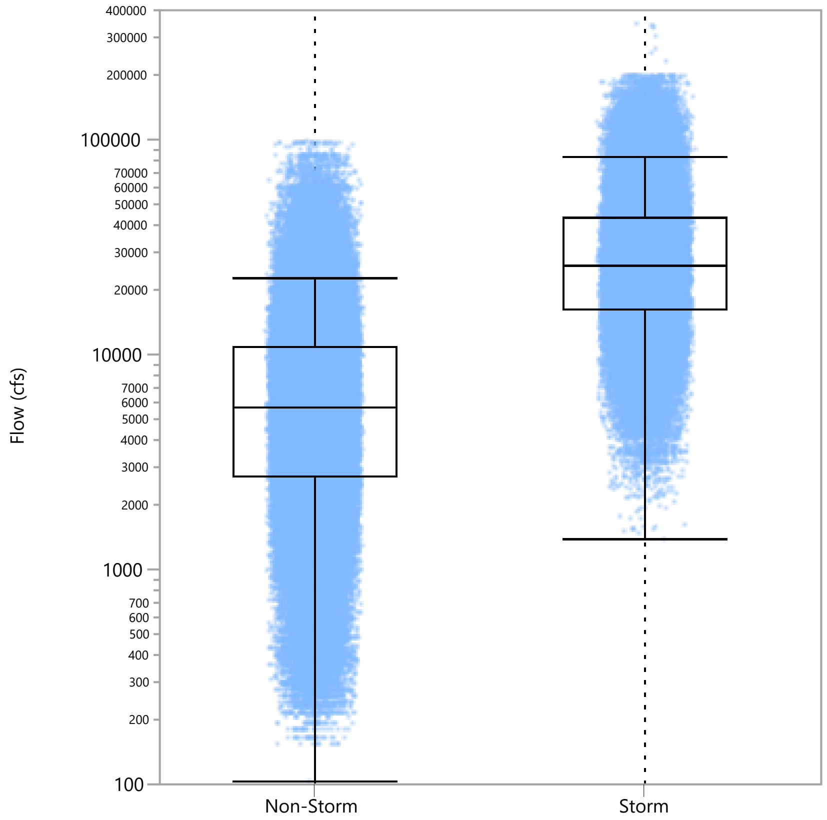


Total Phosphorus

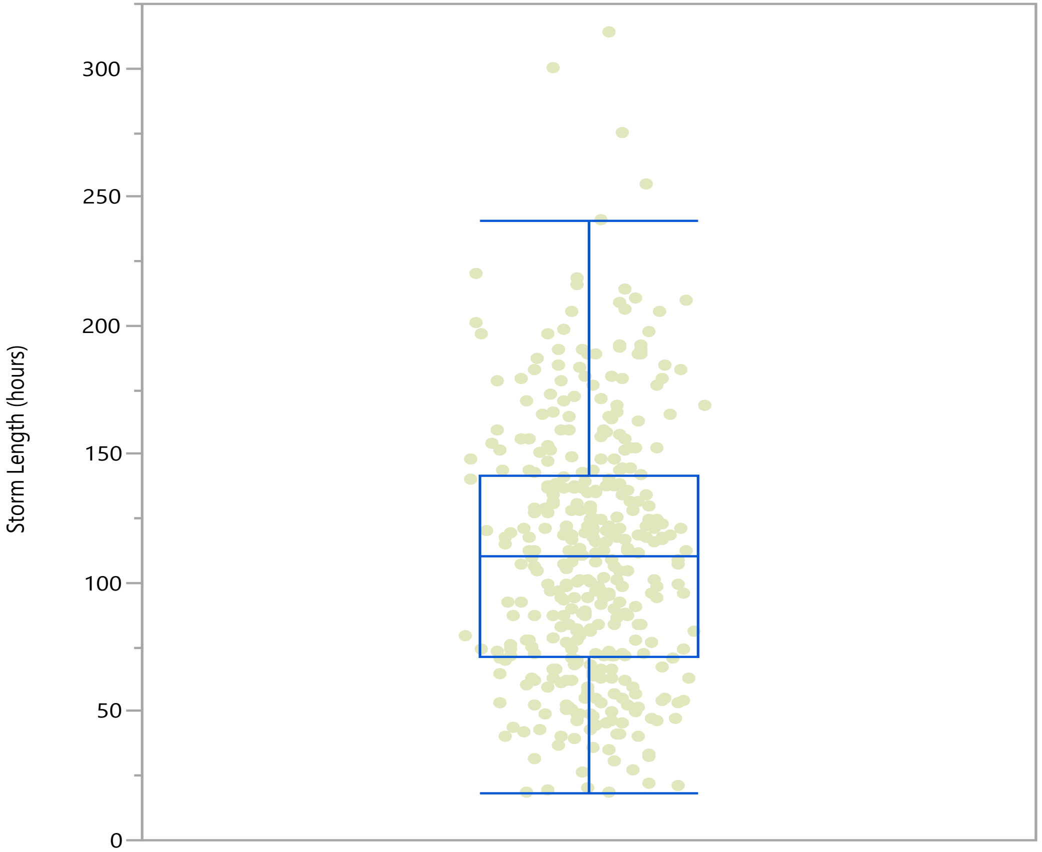


Total Soluble Phosphorus

Flow and Storm Length

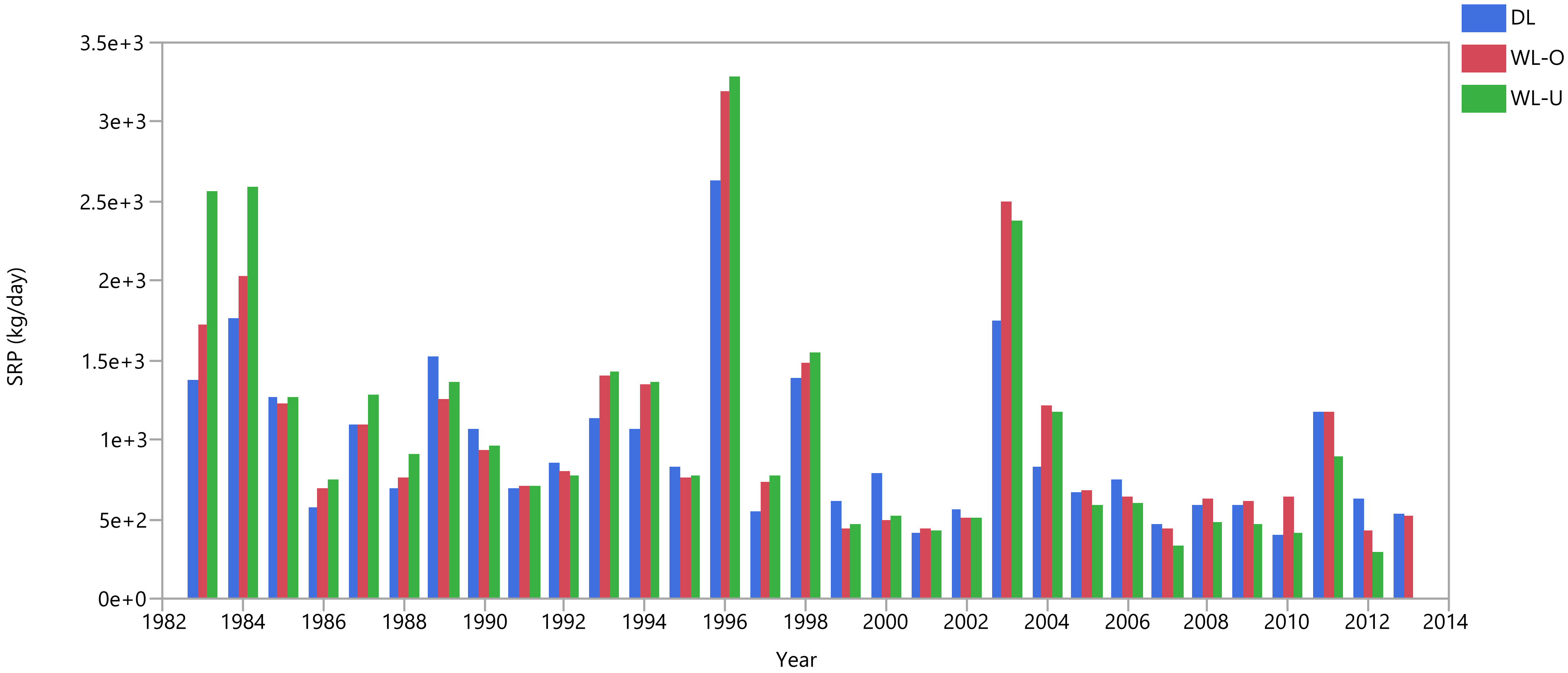


Flows

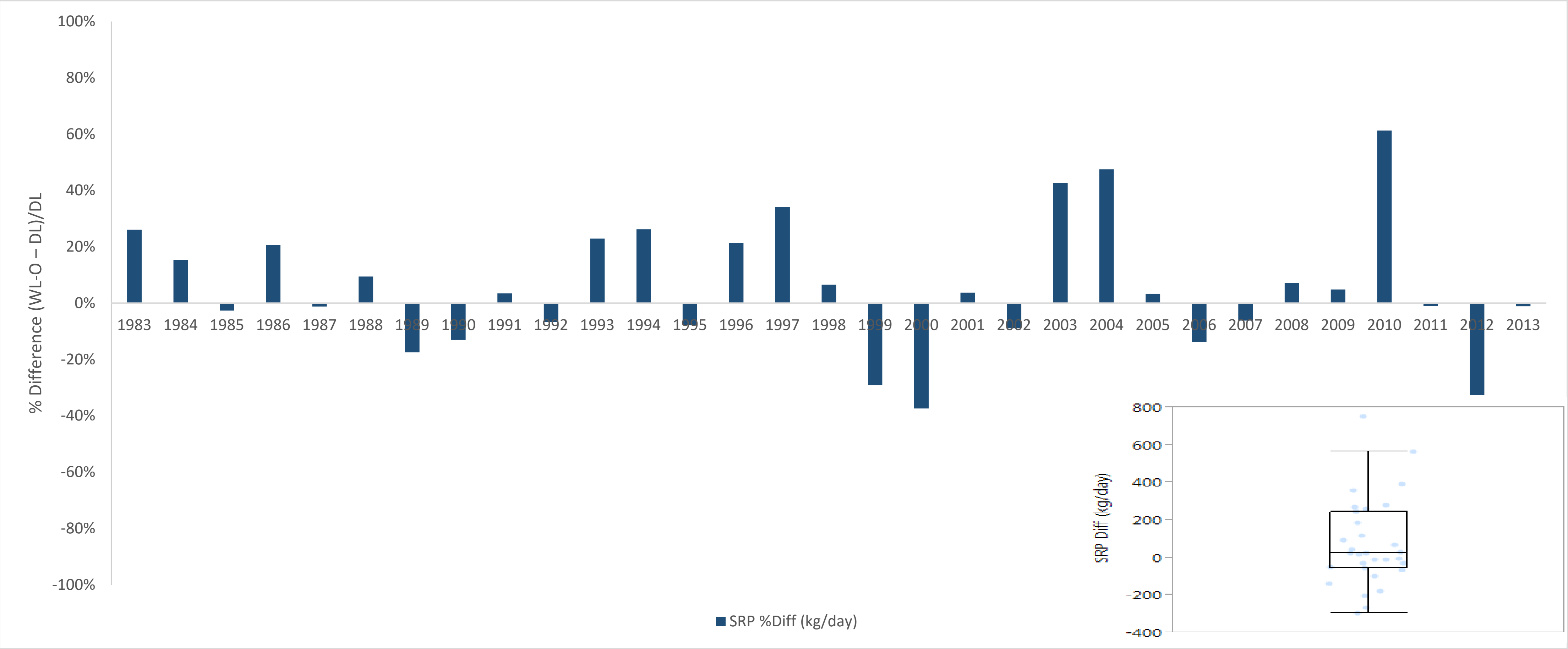


Storm Length

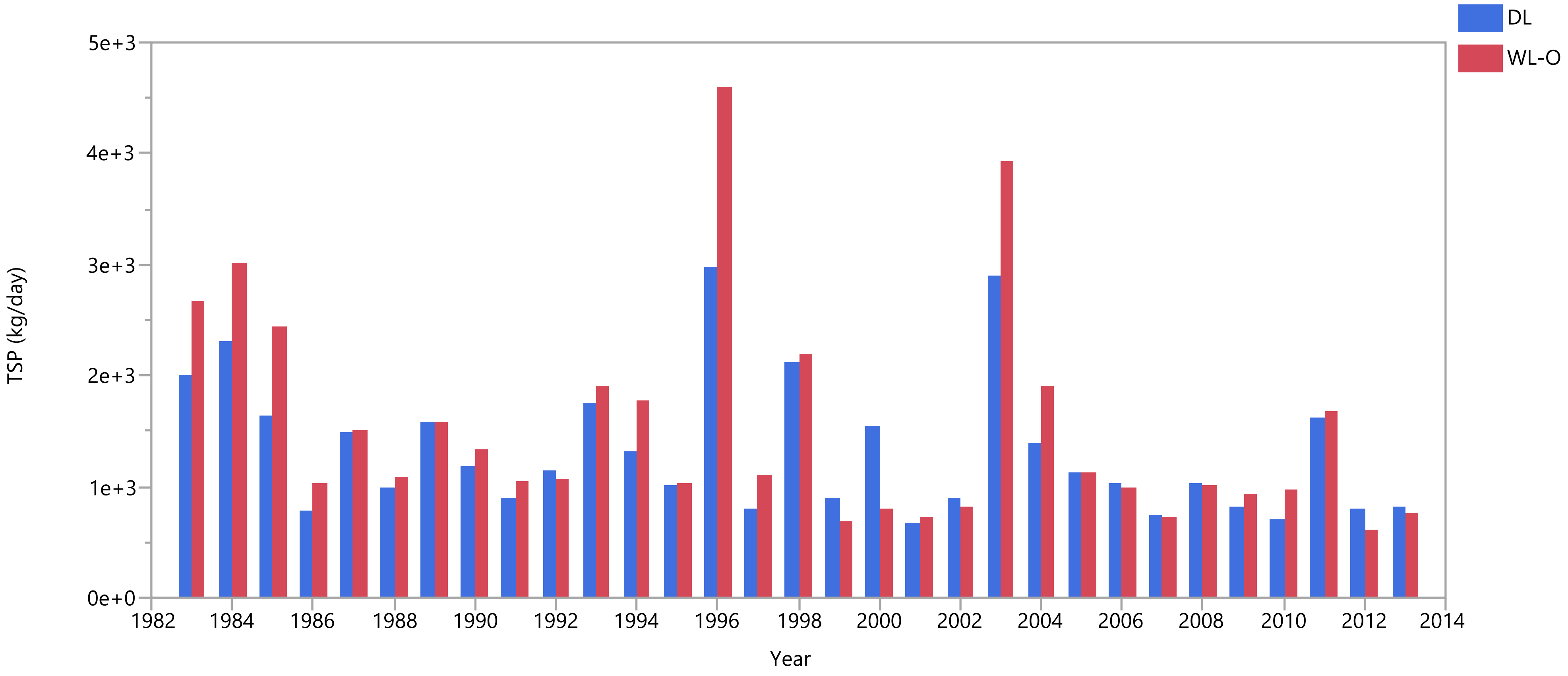
Results of Load Study – SRP



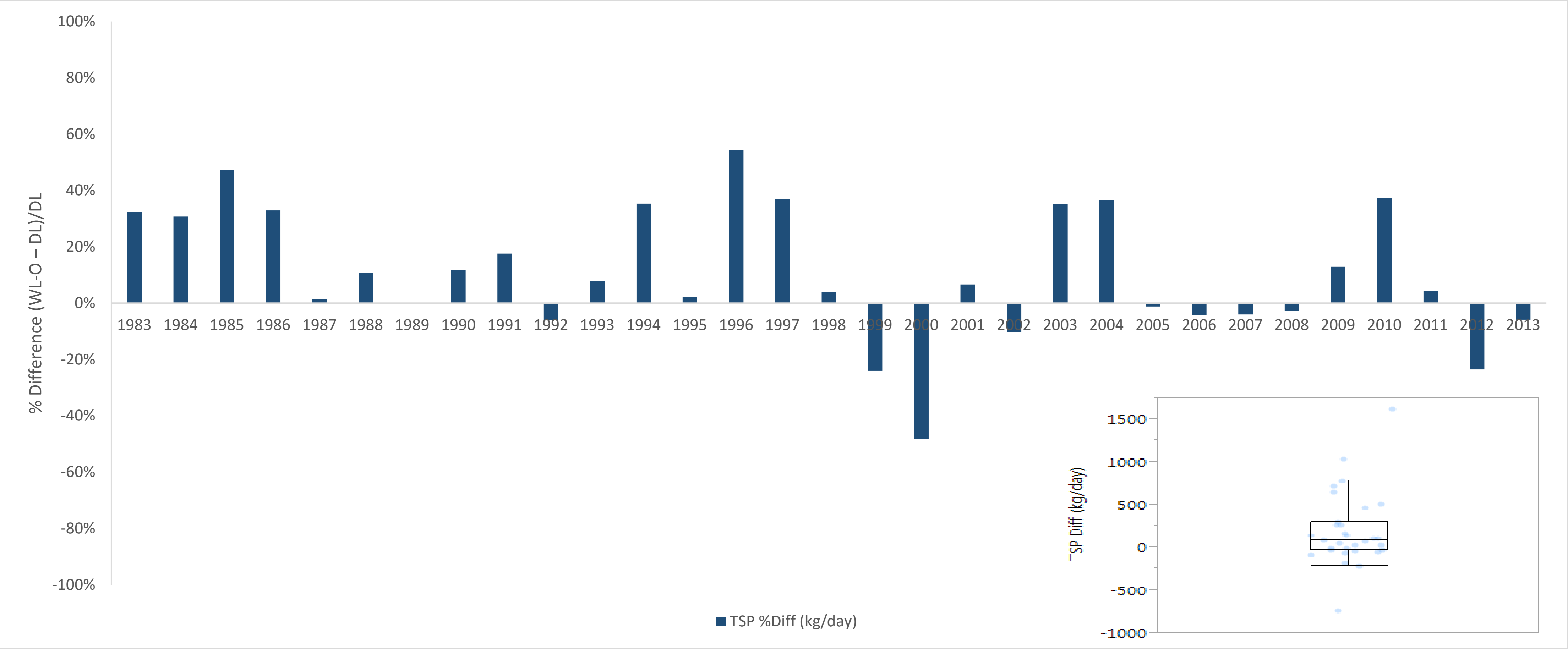
Results of Load Study – SRP load differences



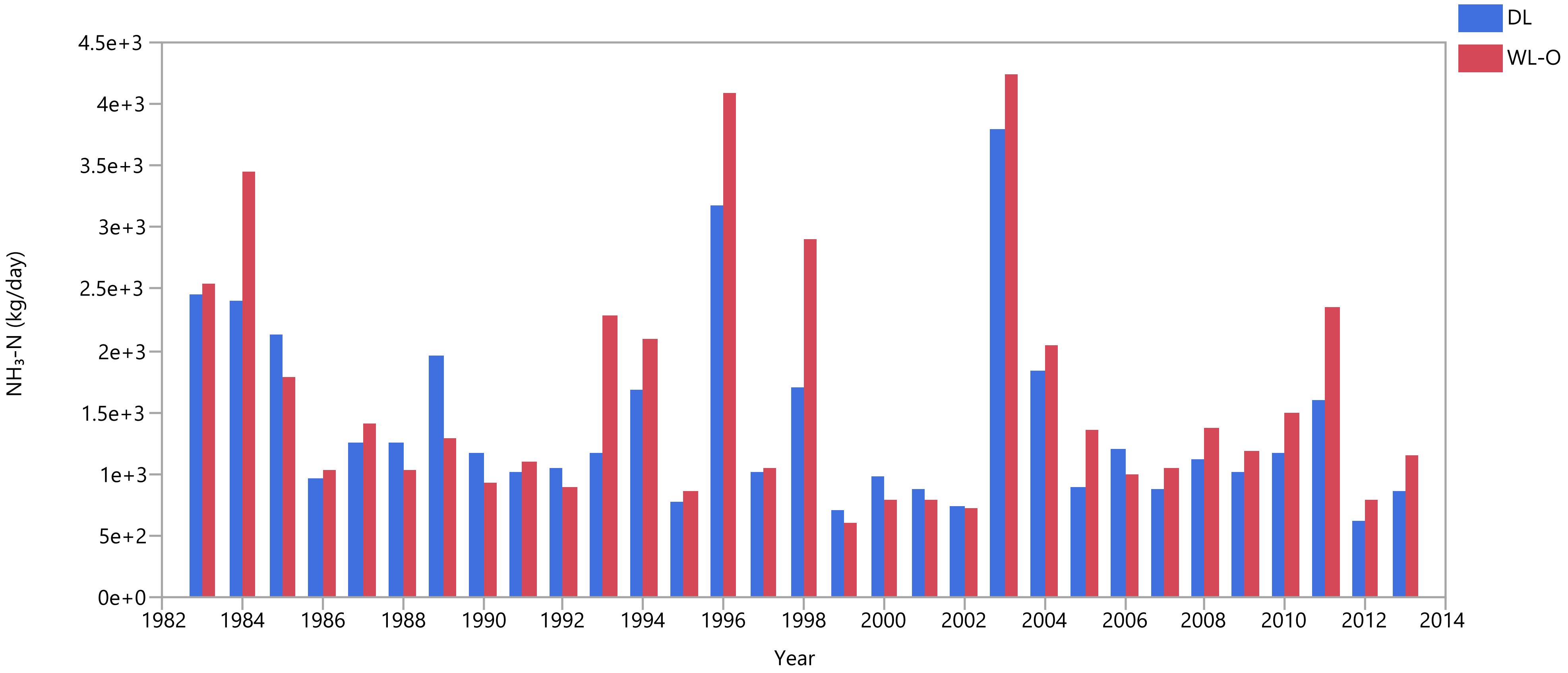
Results of Load Study – TSP



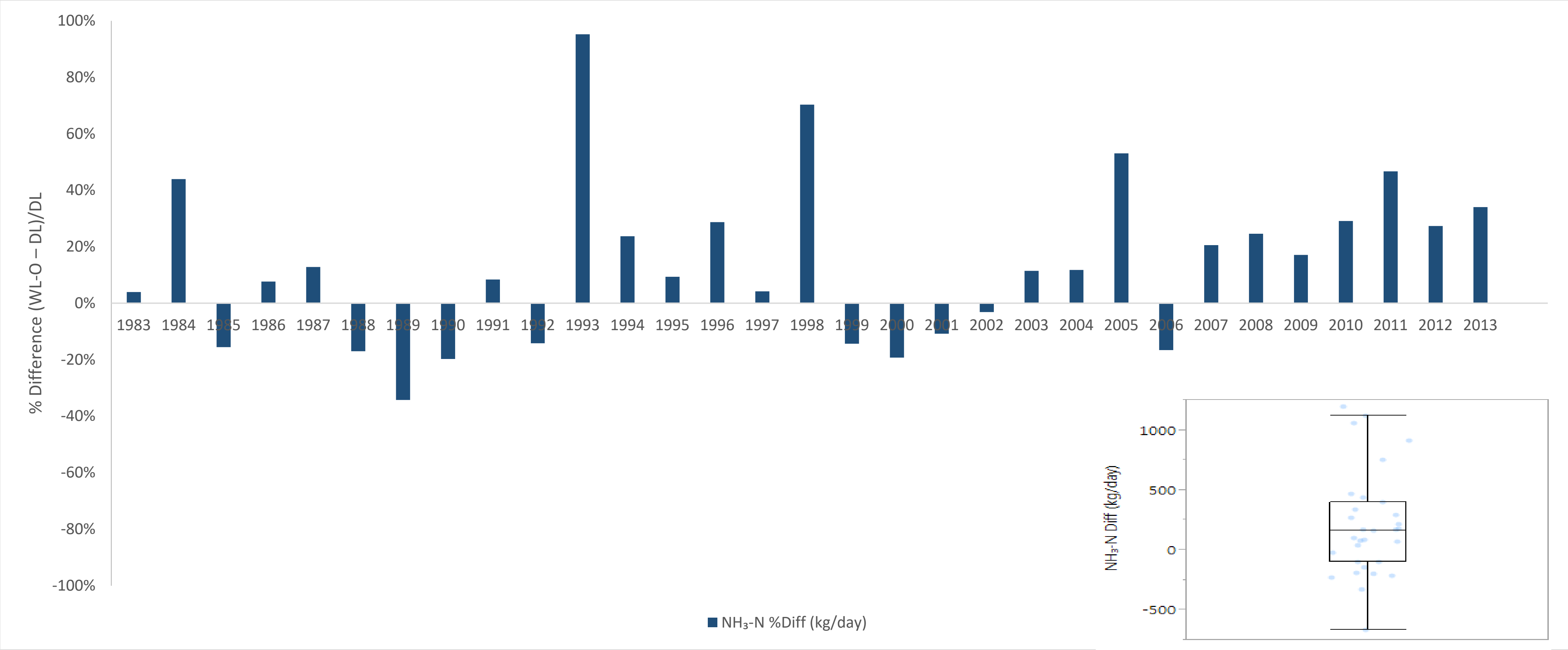
Results of Load Study – TSP load differences



Results of Load Study – NH3-N



Results of Load Study – NH3-N load differences



Results of Load Study – Summary

Year	Percent difference (WL-O–DL)/DL						
	SRP	TSP	TP	NH_3-N	OXN	TN	TSS
1983	26%	32%	4%	4%	0%	2%	-8%
1984	15%	31%	31%	44%	-4%	4%	44%
1985	-3%	47%	5%	-16%	8%	7%	-28%
1986	21%	33%	-7%	8%	3%	-3%	-32%
1987	-1%	1%	-8%	13%	-7%	-9%	2%
1988	9%	11%	1%	-17%	6%	5%	6%
1989	-17%	0%	16%	-34%	0%	4%	12%
1990	-13%	12%	-12%	-20%	4%	0%	-4%
1991	3%	18%	15%	8%	7%	12%	10%
1992	-7%	-6%	-27%	-14%	0%	3%	-10%
1993	23%	8%	7%	95%	0%	8%	39%
1994	26%	35%	37%	24%	7%	23%	63%
1995	-8%	2%	-17%	9%	0%	-1%	-17%
1996	21%	54%	24%	29%	-24%	-13%	13%
1997	34%	37%	13%	4%	5%	4%	2%
1998	7%	4%	37%	70%	8%	20%	58%
1999	-29%	-24%	-19%	-14%	21%	12%	-11%
2000	-37%	-48%	-24%	-19%	9%	10%	-17%
2001	4%	7%	3%	-11%	-1%	2%	-33%
2002	-9%	-10%	-6%	-3%	1%	0%	-10%
2003	43%	35%	48%	11%	-13%	0%	43%
2004	48%	37%	34%	12%	-8%	0%	22%

Year	Percent difference (WL-O–DL)/DL						
	SRP	TSP	TP	NH_3-N	OXN	TN	TSS
2005	3%	-1%	-24%	53%	-9%	-7%	-21%
2006	-14%	-4%	-3%	-17%	-8%	1%	22%
2007	-6%	-4%	4%	21%	-7%	-1%	28%
2008	7%	-3%	17%	25%	0%	11%	27%
2009	5%	13%	15%	17%	5%	4%	35%
2010	61%	37%	31%	29%	-3%	3%	23%
2011	-1%	4%	36%	47%	-10%	-8%	35%
2012	-33%	-24%	2%	27%	-5%	-4%	26%
2013	-1%	-6%	10%	34%	0%	13%	18%
Max	61%	54%	48%	95%	21%	23%	63%
Min	-37%	-48%	-27%	-34%	-24%	-13%	-33%