

# The Effect of Water Discharge on Suspended Sediment Concentrations in the St. Croix River, MN/WI

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## Introduction

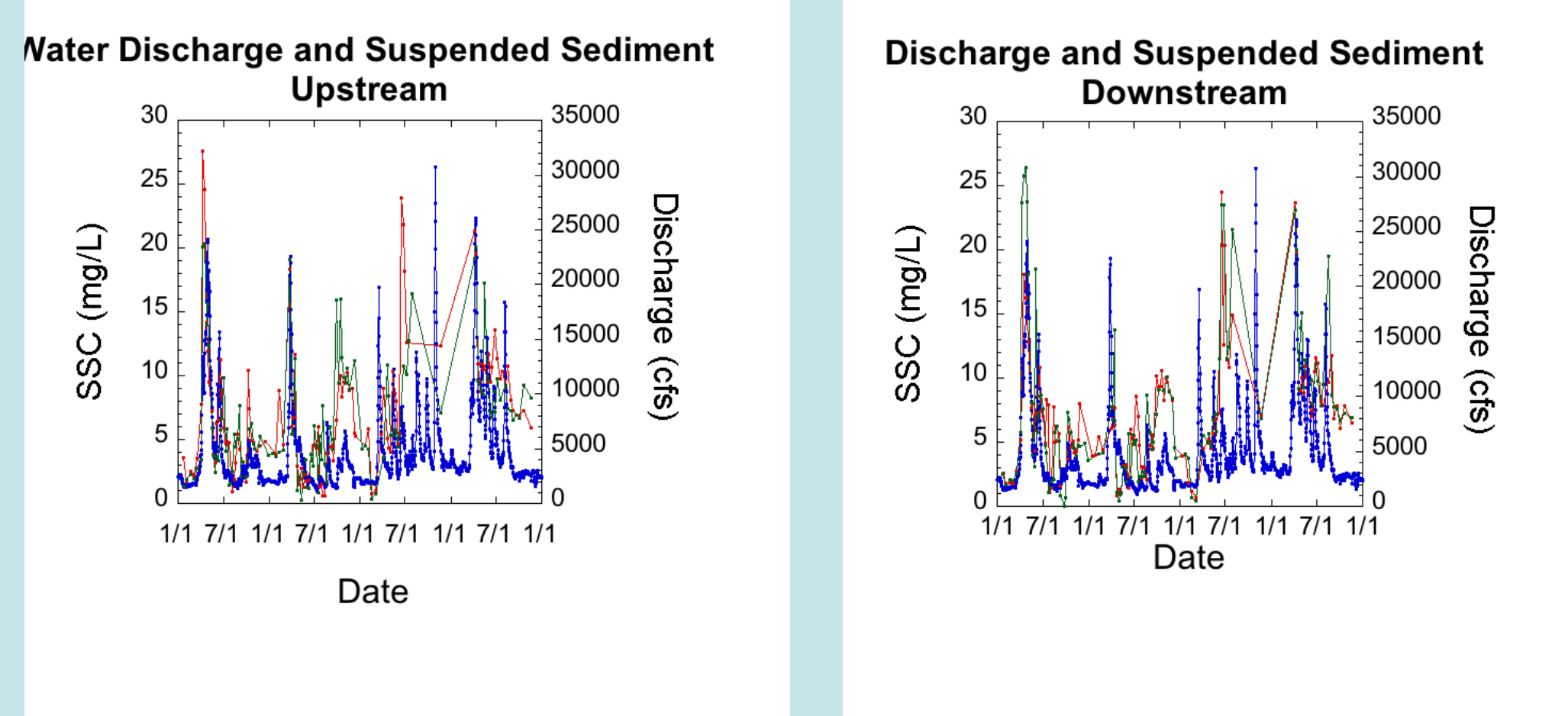
Suspended solids transport is essential for maintaining healthy and dynamic fluvial ecosystems. It is essential for native freshwater mussels in the St. Croix River because they are filter feeders that depend on suspended organic material in the water column. In addition, they burrow into bed sediment and are sensitive to grain size distribution there. Dams like the St. Croix Falls Dam can impede and alter the rate of suspended solid transport. Due to a decline in juvenile mussel density below the dam over the past two decades, dam operations have been subject to scrutiny.

We examined suspended sediment concentration (SSC) and water discharge data collected at four sites (two above the dam and two below) during a four year period between 2008 and 2012. We focused on determining if relationships between these two variables changed seasonally or annually, as well as comparing the relationships between sites. In addition, we constructed an annual sediment budget each site to consider the role the St. Croix Falls Dam has on the mussel beds downstream.

## Results and Discussion

### Water Discharge and SSC

- Every year at each site there is a peak in water discharge due to spring snowmelt.
- In 2008 and 2011, the SSC peaks prior to peak water discharge (hysteresis).
- Total annual water discharge was low in 2009; peaks in SSC were not always coincident with peak water discharge. This suggests a threshold must be reached before SSC responds to increasing water discharge.
- High annual water discharge and multiple storms occurred in 2010. However, storm peaks in water discharge did not correspond with peaks in SSC. This suggests the system may be periodically supply limited.



Above: Water discharge (blue) and suspended sediment concentration above the dam at Nevers (red) and HQ (green) and below the dam at USGS (red) and Franconia (green). Suspended sediment concentration peaks occur at or just before peaks in water discharge.

## Field Setting

The St. Croix River is a sixth-order stream bordering east-central Minnesota and northwestern Wisconsin. The St. Croix Falls Dam is located in St. Croix Falls, Wisconsin. Nevers Dam (removed in the 1950's) is approximately six miles above the dam. The NPS headquarters site is in the reservoir created by the dam. The USGS gauging station is directly below the dam, and Franconia is miles downstream from the dam.

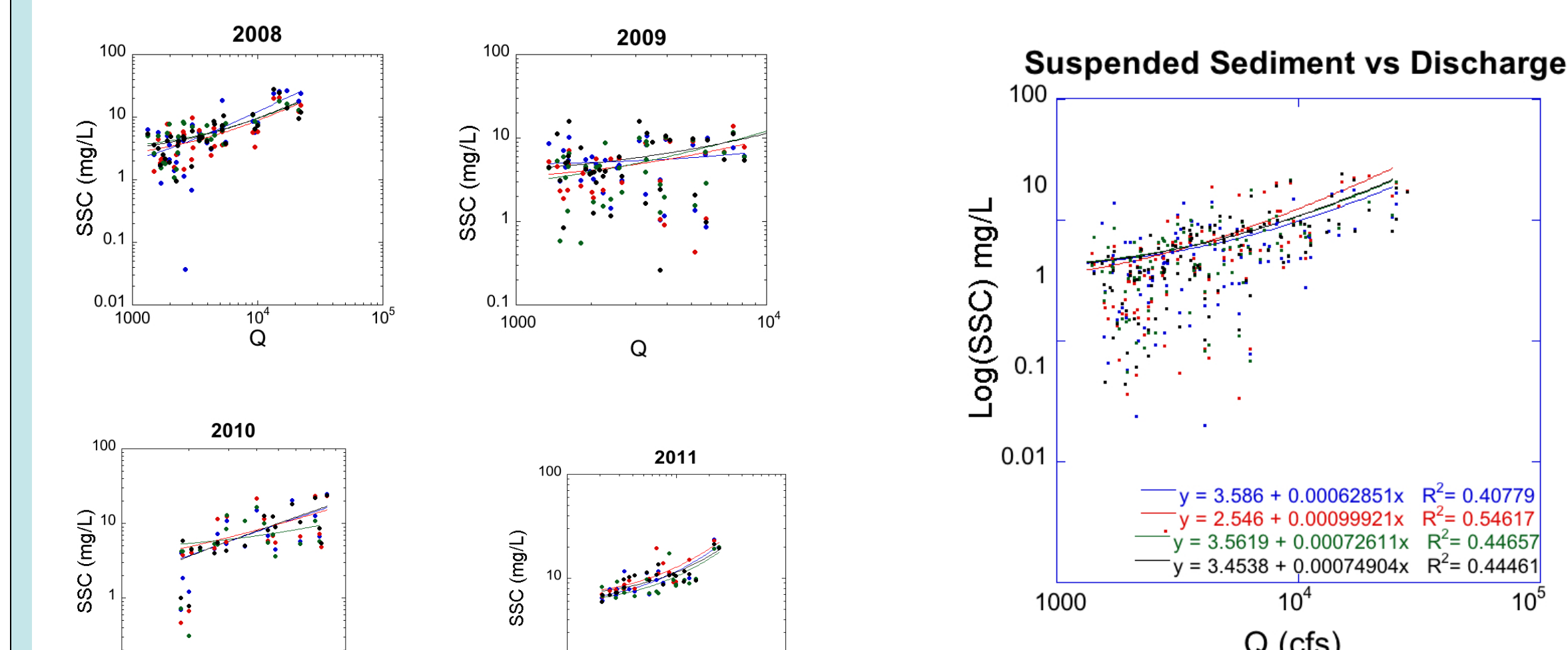


Above: View of the St. Croix River near Nevers Dam. Right: Map of SSC sampling sites along the St. Croix River. Sampling was conducted every 1-2 weeks at all four sites by NPS personnel between 2008 and 2012.



## Suspended Sediment Concentration

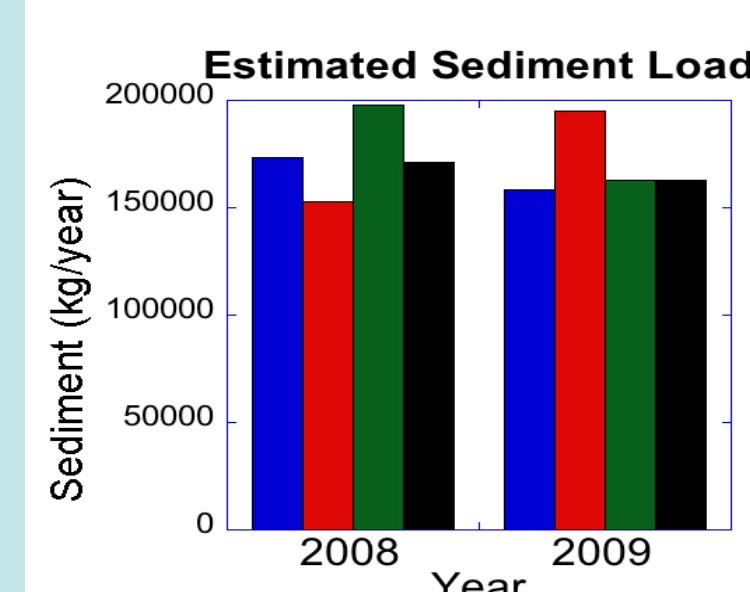
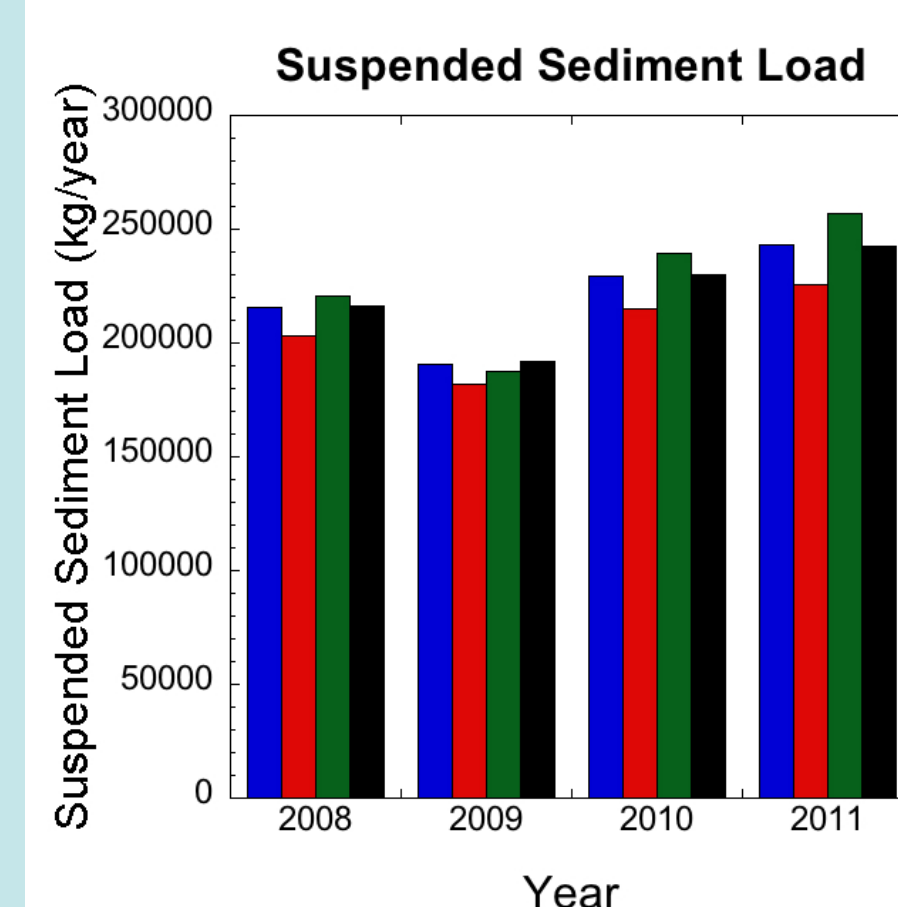
- The relationship between water discharge and SSC (rating curves) changes from year to year, and is different at each site.
- 2009 and 2010 show poor correlation between SSC and water discharge, possibly due to low overall water discharge (dry climate years) and the high number of storms.
- In 2008 and 2011 water discharge and SSC are well-correlated.
- Water discharge and SSC are positively correlated in all years for all sites, suggesting water discharge is a key control on SSC.
  - Franconia and Nevers have roughly the same correlation; these sites are furthest downstream and upstream of the dam, respectively.
  - HQ has the lowest correlation, and USGS has the best correlation.



Above: Rating curve for all four years. Franconia and Nevers are very similar. 2009 and 2010 have low correlations.

## Estimated Sediment Load: Rating Curve Method

- Assuming water discharge is the primary control on SSC, we can use a linear regression line to determine daily suspended sediment load. The sum over the year is annual sediment load.
- Sediment load at Nevers Dam is always greater than that at HQ, suggesting a loss of sediment between the two sites (likely in the reservoir behind the dam).
- HQ shows a consistently lower annual load than any site.
- Sediment load below the dam (at USGS) is always higher than at HQ, but it is also higher than at Franconia further downstream.
- The difference in suspended load between HQ AND USGS ranges from ~3% to 11% each year.



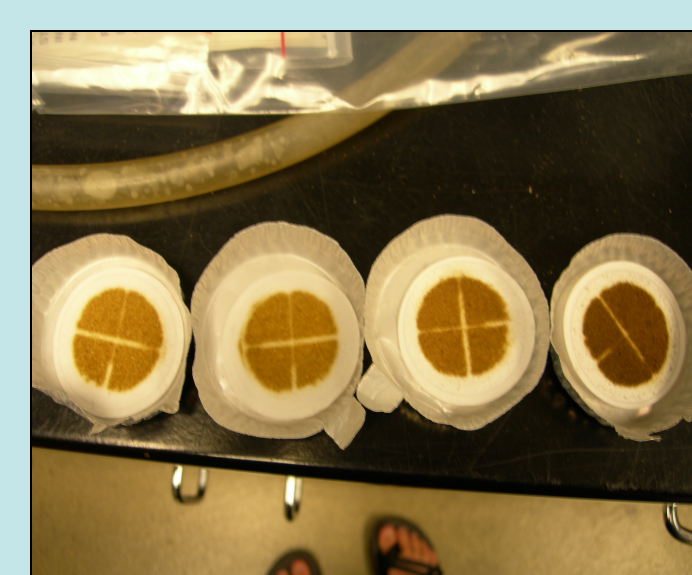
Above: Suspended load for Nevers (blue), HQ (red), USGS (green), and Franconia (black).

## Estimated Sediment Load: Representative Data Method

- Weekly sediment load can be estimated by assuming the SSC data collected at each site is representative of SSC for the time window between measurement. In 2008 the relationships between each site are the same as they are using the rating curve.
- In 2008, sediment load is lowest at HQ, suggesting sediment trapping in the reservoir.
- In 2009, sediment load is highest in the reservoir, suggesting it may be a source of downstream sediment. This is in contrast with sediment load results using the Rating Curve Method, and suggests further investigation is needed to determine sediment sources and sinks in the region.

## Methods

- Surface water samples were collected bi-weekly at four sites: two above and two below the St. Croix Falls dam.
- The water was pumped through filters to separate outorganic material and suspended sediment.
- The filters were dried at 105° for 1 1/2 hours and weighed to quantify organic content.
- The filters were burned at 500° for 1 hour to remove organic material and weighed again to determine sediment concentration (SSC).



Left: Four filters filled with suspended solids from the river. Right: Native mussel (wartyback) from St. Croix River



## Conclusions

- Results suggest it is likely that suspended sediment settles in the reservoir created by the dam. This is supported by bathymetric changes in the reservoir between the 1960's and 2010, and by sediment core analyses.
- Despite trapping of sediment by the dam, suspended sediment may be periodically transported across the dam, and could account for the increase in SSC directly below the dam. It is also possible there is a source of suspended sediment in the area between the dam and the USGS gaging site.
- Water discharge and rainfall events both influence SSC. Periods of low water discharge do not correlate well with SSC at any site, and flashy discharge (storminess) years appear to diminish correlations between water discharge and SSC.