Environment and Natural Resources Trust Fund (ENRTF)

Project: Assessing Ecological Impact of St. Anthony Falls Lock Closure

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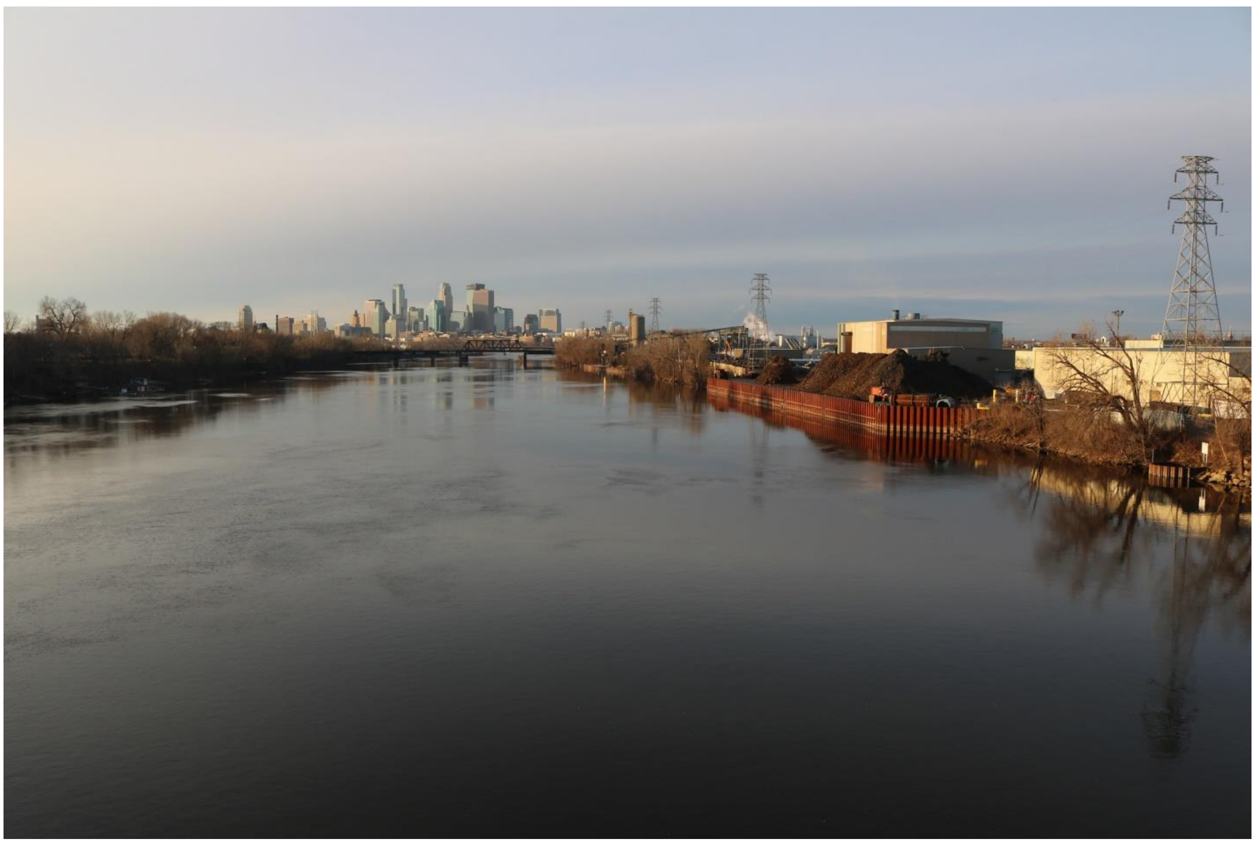
Final Report



Written by: Jane Mazack

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Introduction

On June 10, 2014, the Water Resources Reform and Development Act (WRRDA) was signed into law. This law has broad impacts on inland waterway management throughout the United States; it included a clause requiring that the Upper St. Anthony Lock be closed by June 10, 2015. The closure of the lock itself is expected to be accompanied by management changes such as the end of channel dredging by the US Army Corps of Engineers, both of which are expected to alter the Mississippi River as it flows though Minneapolis.

To better understand the implications of lock closure on the Mississippi River, it is necessary to both quantify the condition of the river at the time of lock closure and continue collecting additional monitoring data into the future. This project was undertaken to develop physical, chemical, and biological indicators that establish the current state of the Mississippi River and that can be tracked over time as it responds to major changes in management activities.

With the closure of the lock, the Mississippi River upstream of St. Anthony Falls is closed to commercial navigation, including barge traffic. The Army Corps of Engineers (USACE) previously maintained a 9-foot navigation channel through dredging activity; an average of 45,000 cubic yards of sediment were annually removed upstream of the St. Anthony Falls[1]. However, it will no longer be necessary to dredge the river to maintain this shipping channel. Without dredging, sediment may re-distribute in the river, changing the shape of the river channel and affecting the habitat available to aquatic organisms such as fish, mussels, and invertebrates.

This project focused on the impact of the lock closure on the Mississippi River between the Coon Rapids Dam and Lock & Dam #1 (Ford Dam). The first part of the project focused on establishing the physical, chemical, and biological condition of the river at the time of lock closure; data were both gathered from outside sources and agencies and collected in the field during the course of this project. The second part of the project analyzed these data and selected indicators that may be used to efficiently track future changes in the river. Results from this project were disseminated online and through public presentations (Appendix II).

Reaches

The study area (Coon Rapids Dam to Lock & Dam #1) was divided into four distinct reaches for analytical purposes, based on dredging history and lock and dam locations (Figure 1). We researched what data have been collected in each of these reaches, gathering previously established data sets and undertaking new data collection where necessary. Data were collected using broadly established protocols. Figure 1 illustrates the location of our study area and the specific reaches under evaluation.

[1] Source: USACE (http://www.mvp.usace.army.mil/Portals/57/docs/Navigation/CMMP/Tab_4_1_2014.pdf)

Reach 1

Reach 1 extends from the Coon Rapids Dam (river mile (RM) 866.2) downstream to the former head of navigation (RM 857.6). This 8.6 mile stretch of river is shallow and wide, with three islands present in the river. Reach 1 has been less managed than any other reach of the Mississippi in our study area; no dredging has occurred in this reach and it has not been open to commercial navigation.

Reach 2: Upper St. Anthony Falls Pool

Reach 2 extends from the former head of navigation (RM 857.6) downstream to the Upper St. Anthony Falls Dam (RM 853.9). This 3.7 mile stretch of the river is set within a low-cut bedrock gorge. Reach 2 was formerly open to commercial navigation and was dredged by the US Army Corps of Engineers to contain a 9-foot channel; an estimated 45,000 cubic yards of material were annually removed from this reach[2]. Following closure of the Upper St. Anthony Falls lock in 2015, dredging has stopped in this reach and it is no longer open to commercial navigation.

Reach 3: Lower St. Anthony Falls Pool

Reach 3 extends from Upper St. Anthony Falls Dam (RM 853.9) downstream to Lower St. Anthony Falls Dam (RM 853.3). This 0.6 mile stretch of the river is a channel incised within a bedrock gorge, and is characterized by erosive turbulence at its upstream end. Reach 3 was formerly open to navigation and has undergone limited dredging. Following the closure of the Upper St. Anthony Falls lock in 2015, Reach 3 is no longer open to commercial navigation and no dredging is planned.

Reach 4: Lock & Dam #1 Pool

Reach 4 extends from Lower St. Anthony Falls (RM 853.3) downstream to Lock and Dam #1 (RM 847.9). This 5.4 mile stretch of the river is set deeply within the Twin Cities gorge, with 100-foot bedrock cliffs on each bank. Like Reach 2, this stretch of the river contains a 9-foot navigation channel, which has been historically maintained through dredging; unlike Reach 2, this stretch of the river is still open to commercial navigation, because Lock & Dam #1 is still operational, and may be dredged as needed in the future.

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[2] Source: USACE (http://www.mvp.usace.army.mil/Portals/57/docs/Navigation/CMMP/Tab_4_1_2014.pdf)

Data Collection

Monitoring Sites

A total of eight monitoring sites were selected as the focus of data-gathering activities. These sites are currently monitored for water quality data on a bi-weekly basis by the Mississippi Watershed Management Organization (MWMO). We chose to focus our additional sampling efforts (including mussel, invertebrate, and sediment samples) at these same locations, to more completely and accurately assess the relationships between multiple data sources.

The eight monitoring sites are located in Reaches 1, 2, and 4, with multiple sites located in each reach (Figure 1). Reach 3 was not monitored due to the turbulence of the river and restrictions to access. The monitoring sites (and the reach each is located in) are as follows:

1) Upper Camden (Reach 1)
2) Upstream Shingle Creek (Reach 1)
3) Downstream Shingle Creek (Reach 2)
4) MWMO (Reach 2)
5) Boom Island (Reach 2)
6) Washington Ave (Reach 4)
7) Meeker (Reach 4)
8) Ford Dam (Reach 4)

Field-collected data

We collected bathymetry, water chemistry, sediment, invertebrate, and mussel data from the above monitoring sites in 2015. These data establish the physical, chemical, and biological condition of the river at the time of lock closure.

Bathymetry

Bathymetry data were collected in Fall 2014 (Reaches 1, 2, & 4) and Spring 2015 (Reaches 1 & 2) by MWMO between Coon Rapids Dam and Lock and Dam #1. Data were collected with a Lowrance HDS-5 Gen2 Fishfinder/Chartplotter (Navico, Inc., Minneapolis, MN) and stored on an SD card. A Lowrance Point-1 GPS/HDG Antenna (Navico, Inc., Minneapolis, MN) was used in combination with the HDS-5 to increase position accuracy. To facilitate efficient coverage of the area to be mapped, a tablet with a tracking application and plotted course was utilized. The boat was steered along a course of parallel tracks 82 feet apart covering the area between river banks. The speed of the boat was kept at or below five mph to ensure data quality. The recorded data files were uploaded to a BioBase server and merged. Data processing is near completion; initial, unadjusted maps of 2-foot contours and water depths from Fall 2014 are shown in Figures 2-4. No map is included for Reach 3; no bathymetry data were collected in this reach due to logistical concerns.

Water Quality

River water quality samples are collected at each of the eight monitoring sites by MWMO twice per month during April through November and once per month between December and February. Samples are collected from the middle of the river, 3 feet below the surface. Samples are collected progressively from the most downstream site to the most upstream site. Sampling is conducted using a Wildco® Beta Plus Horizontal Water Sampler (Wildco, Yulee, FL). The physical parameters of the river are measured using a YSI ProPlus sonde (YSI Inc., Yellow Springs, OH) and the chemical parameters of the river are measured by laboratory sample analysis. Physical parameters measured include water temperature and dissolved oxygen; chemical parameters include nitrates and total phosphorous (Tables 1-3).

Sediment

Sediment samples were collected in December 2015 at each of the 8 monitoring sites using a Wildco® Petite Ponar sampler. Three samples were collected at each monitoring site to allow for finer-scale analysis of changes within (1 sample) and outside (2 samples) of the main navigation channel. Sediment samples were dried at 200 degrees Fahrenheit to remove water; the dried sediment was sieved through a graduated stack of sieves to determine the weighed grain size distribution of each sample.

Sediment size distributions varied widely among samples taken from Reach 1, which is undredged (Figure 5). Reach 2 samples showed less variation, especially within the dredged channel, which was primarily coarse sand (Figure 6). Reach 4, which is impounded by Lock & Dam #1, had the least variation among samples, with most samples being medium sand (Figure 7). As in Reach 2, dredging channel samples within Reach 4 were similar to each other; however, dredging channel samples in Reach 4 (medium sand) had finer sediment than those in Reach 2 (medium sand). No samples were collected in Reach 3 due to a lack of access.

Invertebrates

Invertebrate samples were collected at each monitoring site using Hester-Dendy samplers. These multi-plate, artificial substrate samplers were suspended 3.2 feet below the water surface for 4 weeks to allow for invertebrate colonization of the sampler. At the end of the sampling period, the Hester-Dendy was retrieved and invertebrates were scraped off the sampler. Collected invertebrates were preserved in ethanol and processed, sorted, and identified in the laboratory.

Total invertebrate abundance ranged from 228 (Upper) to 1115 (Shingle Down) individuals per sample. With the exception of the Upper site, invertebrate abundance decreased moving downstream (Figure 8). Taxa richness varied from 12 to 16 taxa collected per site (Figure 9).

Caddisflies (Trichoptera) and mayflies (Ephemeroptera) were the most common orders found in the invertebrate samples (Figure 8). The four most common genera overall were *Hydropsyche* and *Cheumatopsyche* caddisflies and *Isonychia* and *Maccaffertium* mayflies. In most sites, the three most common genera at a site composed over 70% of total abundance; in the "Upper" site, they only were 42.5% of the total, indicating that the "Upper" site likely has the most diverse invertebrate community.

Mussels

Samples were collected at multiple locations from Coon Rapids Dam to Lock and Dam #1. Sites to be sampled were identified from previous sample events, with the addition of our monitoring sites. Timed qualitative samples, catch per unit effort (CPUE; one person hour/site), were collected at all sites by hand collecting all live and dead mussels found along the river bottom. Divers searched all microhabitats at a particular site with the intent of locating areas of high mussel density. Collected mussels were placed in mesh bags, brought to the surface, identified to species, counted, and assigned to age classes. Within each age class, maximum and minimum lengths were recorded. All mussels collected were returned to the river.

The total number of live mussels collected at a site ranged from 0 to 142 mussels; this shows an overall decrease from 2001 where the total number of mussels at a site ranged from 0 to 358 (Figure 10). The number of live mussel species collected ranged from 0 to 13 per site (Figure 11). In general sites, sampled within the dredging channel had limited mussel populations or mussels were not present.

Existing Data

We also sourced previously collected data from state and local agencies, such as the USACE, Department of Natural Resources (DNR), Pollution Control Agency (MPCA), and Metropolitan Council (Met Council). These organizations conduct ongoing monitoring programs in order to study the condition of the river. In addition to the below data, amphibian, reptile, and bird data have been collected in the Mississippi Natural River and Recreation Area. We did not include these data in our analyses; however, these data types may still be indirectly affected by dredging changes, and the sources of these data are listed in Appendix I.

Dredging & Bathymetry

Historically, an average of 45,000 cubic yards of material was removed from the Mississippi River each year above St. Anthony Falls (Reach 2) by the USACE. Of that total, just under 35,000 cubic yards are removed annually upstream of the Lowry Avenue bridge in Reach 2, at river miles 856.4 to 857.6 (Figure 12). An estimated 34,000 cubic yards of material were annually removed from Reach 4[3]. The last dredging operations occurred in 2014, before the lock was closed in 2015.

The USACE has also collected bathymetry data, focusing on dredged areas, on an annual basis through 2014. These data are based on the low control pool levels, and provide a detailed picture of the shape of the river bottom.

Invertebrates

The Met Council has collected long-term biomonitoring data near Ford Dam in Reach 4 from 1979 to 2013, using Hester-Dendy quantitative and Ponar method samples (Figure 13).

Minnesota Pollution Control Agency (MPCA) collected invertebrate data from two sites in 2013; one in Reach 1 (upstream of Shingle Creek) and the other in Reach 2 (at the Boom Island monitoring site; Figure 13), as part of a larger-scale monitoring project. The upstream site (Reach 1) showed a higher quality invertebrate community; Index of Biological Integrity (IBI) scores in Reach 1 were higher for both quantitative Hester-Dendy (90 vs. 75) and qualitative multihabitat (43.8 vs. 31.7) than the Boom Island site (Reach 2)[4]. These results indicate that the undredged habitat in Reach 1 may provide better habitat to invertebrates than the impacted habitat in Reach 2.

Mussels

In 2000 and 2001, the Minnesota DNR sampled a 72-mile stretch of the Mississippi River, which included our study area (between Coon Rapids Dam and Lock and Dam 1). The mussel fauna of Pool 1 (along with Pools 2 and 3) appeared to be recovering from previously low population levels. In the 1970s, The USACE found no live mussels between the St. Anthony Falls Pool and Pool 1.

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[3] Source: USACE (http://www.mvp.usace.army.mil/Portals/57/docs/Navigation/CMMP/Tab_4_1_2014.pdf)

[4] Index of Biological Integrity (IBI) is used in biological assessments to measure the condition of biological communities such as invertebrates and fish. IBI scores typically range from 100 (high, indicating good biological integrity) to 0 (low, indicating poor biological integrity). Biological integrity is “the ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms...comparable to that of a natural habitat.” Because invertebrates and fish respond to stressors in their environments, IBIs effectively integrate the cumulative impacts to aquatic systems from sources such as chemical pollutants, agricultural runoff, and habitat alteration. Source: MPCA (https://www.pca.state.mn.us/water/index-biological-integrity)

Their findings also indicated that mussels have expanded their range above St. Anthony Falls as a consequence of fish passing through the two navigation locks. Larvel mussels rely on hose fish for development; therefore, fish movement through locks allows mussel species to expand their ranges[5]. 16 live species were collected upstream of the St. Anthony Falls Pool, including 10 not previously reported above the falls. The community was similar to those found below the falls, and was also relatively young (71% of individuals were <11 years old) (Figure 14).

Fish

In 2009, the Minnesota DNR assessed the St. Anthony Falls Pool, which stretches for 12.3 miles upstream of the Lower St. Anthony Falls Dam to the Coon Rapids Dam. 18 species were found using standard electrofishing protocol. Smallmouth Bass and Common Carp were the numerically dominant species. In comparison to 1995, smallmouth bass were significantly more abundant, and walleye were present in 2009 but not in 1995. Shoreline seining netted 17 species, the dominant of which was the Sand Shiner. Bluntnose Minnow and Spotfin Shiner were also abundant.

Pool 1, extending from the Ford Dam upstream to lower St. Anthony Falls, was also assessed by the DNR in 2009. Similarly to the St. Anthony Falls pool, Smallmouth Bass and Common Carp were the most abundant species. Walleye were not recorded in 2009, although they were found in previous sampling; however, this may be an artifact of sampling method.

Additional historical records show the locations of fish presence data from 1900 to present, which most data occurring after the St. Anthony Falls Lock was built in 1963, allowing for fish passage upstream of St. Anthony Falls (Figure 15).

In 2003, MPCA sampled fish populations in two locations, corresponding to invertebrate sampling locations (Figure 13). The upstream site, in Reach 1 near Shingle Creek, was visited in August and September, which 25 and 23 species found at each visit, respectively. However, the IBI score decreased from 49.68 to 36.93 between visits. The downstream site, located at Boom Island, had an IBI score of 26.37, and only 12 species of fish were recorded.

Summary & Discussion

As proposed, we gathered available current and historical data from numerous sources. Through the evaluation of these data, we determined key missing data and collected them in Fall 2015. These data include bathymetry, sediment, mussel, and invertebrate data. The table in Appendix I summarizes the physical, chemical, and biological data available between Coon Rapids Dam and Lock & Dam #1.

[5] Source: Minnesota DNR (http://dnr.state.mn.us/mussels/howlive.html)

Fish, mussel, and invertebrate data previously collected in Reaches 1 and 2 generally indicate that the free-flowing stretch of the Mississippi River in Reach 1 supports larger and more diverse communities than the river in impounded and dredged Reach 2. Reach 4 appears to perhaps support a more intermediate mussel community. Water quality data appear to remain relatively constant throughout all reaches, indicating that the main stressors may lie upstream of our study area.

Indicator Analysis

The data gathered do not predict what impacts to the river might accompany changes in lock and stream bed management (i.e. closure of the lock and cessation of dredging). Additionally, the wide range of data available does not, by itself, direct the utilization of scarce time and funds for future monitoring.

In order to consider expected changes in the river, we developed ecologically-based hypotheses to identify reaches and data types that may be most immediately affected by management changes. However, hypotheses alone are not adequate to identify and prioritize indicators; many other considerations come into play. Accordingly, we developed the following set of metrics, and have attempted, as described below, to assign values that will allow future managers to make analytical decisions on which indicators to monitor. As explained below and in the following table, each potential indicator has its benefits and drawbacks (i.e. a specific data type may be highly relatable to the public, but be of low value as an indicator due to its signal:noise ratio).

Hypotheses

We developed focused, ecologically-based hypotheses to predict future changes in the river, which will occur at a variety of scales. Figure 12 indicates that significant dredging activity has impacted Reaches 2 and 4; therefore, we expect that physical changes will be concentrated in Reach 2, where dredging has stopped, and Reach 4, where dredging may potentially be reduced. By focusing indicators on ecologically expected changes, we can optimize future sampling efforts.

1) Changes in channel morphology will be most significant upstream of St. Anthony Falls to the head of navigation (Reach 2), because dredging activity and barge traffic will end in this stretch of the river.

2) Total suspended solids (TSS) and total phosphorus (TP) will be reduced in Reach 4. The lack of dredging and barge traffic in Reach 2 will allow it to act as a sink rather than a source, reducing the amount of TSS and TP that is transported to Reach 4.

3) Changes in sediment composition will be greatest in Reach 2 in formerly dredged areas.

4) Mussel and invertebrate abundances in Reaches 1 and 2 will become more similar as the habitat of the formerly dredged channel in Reach 2 becomes more similar to that of Reach 1.

5) The presence and distribution of fish and mussel species above (Reach 2) and below (Reach 4) the lock will become less similar; the closed lock will prevent movement. Those mussel species dependent on fish movement may become less abundant or absent in Reach 2.

Description of Metrics

We critically evaluated the available physical, chemical, and biological data to identify key indicators of changes in river health. To do so, we developed the following set of metrics that can be used to characterize the effectiveness of a set of data as an indicator; the potential values for each metric are listed. Each data type was evaluated against these metrics to determine if it is a useful indicator.

Category

Each of category of data (physical, chemical, biological) is likely to be impacted by changes in lock management and dredging; therefore, indicators should be selected from each category for comprehensive future monitoring.

- **Physical** data include bathymetry, sediment size, and water temperature data
- **Chemical** data include water quality data such as nitrogen and phosphorous levels
- **Biological** data include invertebrate, mussel, and fish data

Data type

The data type describes the general subject of the data (e.g. mussels, sediment).

Measurements

Measurements identifies the specific metric(s) that would be quantified and tracked over time within a data type.

Response time

Response time describes the time frame within which changes would be expected to occur as a result of lock closure and stopping dredging. In the case of biological data types, the response time is often correlated to life cycles of the organisms of interest; for example, invertebrates with a year-long life cycle would experience population-level changes much faster than mussels, which live for decades.

- **<1 year**
- **1-5 years**
- **5-10 years**

- **10+ years**
- **NA** indicates that changes are not expected

Sampling frequency

Sampling frequency describes how often samples/data would need to be collected in order to observe and quantify changes in response to lock closure. Therefore, sampling frequency will generally correspond to response time; data types with a fast response time would need to be sampled more often than those with a slow response time.

- **Biweekly**
- **Annually**
- **5 years**
- **10 years**

Spatial density/scale

Spatial density/scale describes the density at which data is collected and the scale for which the results are valid.

- **Grid/meter** scale data are collected in a grid over the entire area of interest (e.g. bathymetry)
- **Point/reach** data are collected at a specific point, but the results are applied to the entire reach
- **Reach** data are collected over a larger reach rather than a specific point

Sampling effort

Sampling effort describes the effort required for field collection of data, and is influenced by both the required number of samples and amount of time and equipment.

- **Low** effort data can be quickly collected at a single point; multiple sites can be sampled in a single day
- **Medium** effort data can be collected at a single point or reach; however, more time and equipment is required and limited samples can be collected on a single day. Multiple days of fieldwork would be required
- **High** effort data are collected at multiple points or on a grid, requiring significant time and equipment. Multiple days of fieldwork would be required

Processing cost & time

Processing describes the cost and time associated with processing and analyzing samples in order to obtain quantitative results and metrics.

- **Low** processing occurs for samples where data are recorded in the field and no laboratory processing is required
- **Medium** processing occurs for samples which need to be sorted, identified, or analyzed in the lab
- **High** processing occurs for samples with large volumes of data which require significant time for computational processing

Signal:noise ratio

The signal:noise ratio compares the signal (strength of response) and noise (confounding variability in metric/data) ratio.

- **Strong signal** indicates that significant change is expected as a result of lock closure
- **Moderate signal** indicates that moderate change is expected as a result of lock closure
- **Weak signal** indicates that weak or undetectable change is expected as a result of lock closure. Changes that do occur may not be associated with lock closure
- **Low noise** indicates that the value of the metric has high statistical validity and is expected to be an accurate representation of the actual condition of the river
- **Medium noise** indicates that the value of the metric has moderate statistical validity, but may not be an overall representation of the condition of the river (eg. due to spatial variability and sampling techniques)
- **High noise** indicates that the value of the metric may not be an accurate representation of the actual condition of the river, or the accuracy is not known

Public relatability

Public relatability describes the importance of the data category to the general public.

- **High** relatability data are generally visible to and valued by the public. These data may have compelling stories or practical implications to health
- **Medium** relatability data are less visible, but may still be considered relevant by the public
- **Low** relatability data are least visible to the public, and may be poorly understood

Related work

Related work identifies any work currently being done or data being collected by other agencies or organizations. The presence of other current work indicates a larger relevance beyond this specific project; additionally, future monitoring plans may already be established

Indicator Matrix

Category	Data type	Measurements	Response time	Sampling frequency	Spatial density/ scale	Sampling effort	Processing cost & time	Signal : noise ratio	Public relatability	Related work
Physical	Bathymetry	Max depth, diversity of depth	5-10 years	5 years	Grid/ meter	High	High	Strong : low	Medium	MWMO, USACE
Physical	Sediment size	D50, D90-D10, sample variability	5-10 years	5 years	Point/ reach	Low	Medium	Moderate : high	Low	NA
Physical/ Chemical	Water Quality	N, P, total suspended solids (TSS)	TSS: <1 yr P: 1-5yr N: NA	Biweekly	Point/ reach	Low	Medium	Strong : medium	High	MWMO
Biological	Invertebrates	IBI, species diversity	1-5 years	Annually	Point/ reach	Low	Medium	Moderate : medium	Medium	MPCA
Biological	Mussels	CPUE, diversity, rare species	5-10+ years	10 years	Point/ reach	Medium	Low	Strong : medium	High	DNR
Biological	Fish	diversity	5-10 years	5 years	Reach	Medium	Low	Weak : very high	Very high	DNR, MPCA

Conclusions

We expect significant changes to the Mississippi River in response to the St. Anthony Falls lock closure. However, not all data types are equally effective as indicators; we do not expect them to change equally in response to management changes, or to be equally representative of changes. Although it would be simplest to prioritize indicators based on this signal:noise ratio, there are numerous other practical considerations to be included. Therefore, we evaluated potential indicators using a suite of metrics, including response time, sampling effort, and public relatability.

As shown in the above indicator matrix, no single indicator can provide a complete measurement of changes in the river. For example, fish are highly relatable to the public; however, it is difficult to accurately assess mobile fish populations. In considering the above matrix, we suggest that monitoring within each category of data (physical, chemical, and biological) would allow for the most complete assessment of future river changes. In the physical category, bathymetry data, although requiring high sampling effort and processing time, would still be an effective indicator to assess the impacts of stopping dredging on river habitat. In the chemical category, water quality data, although expected to show smaller changes, are relatively simple to monitor and are part of ongoing programs. In the biological category, mussels are publicly relatable and also integrate physical (habitat) and chemical (total suspended solids) parameters in their responses to the riverine environment.

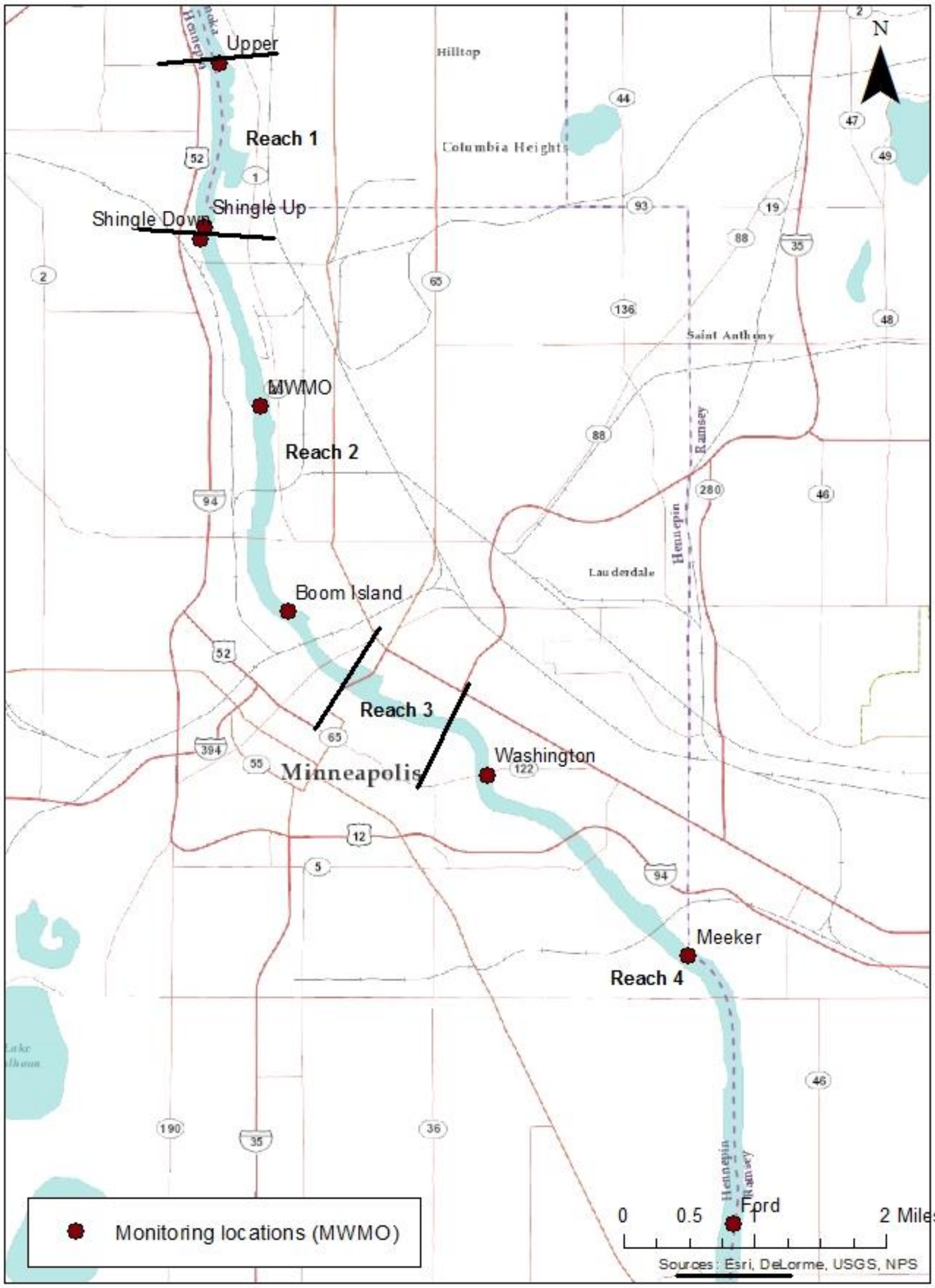

Figure 1. Monitoring sites for water chemistry, sediment, invertebrate, and mussel data.

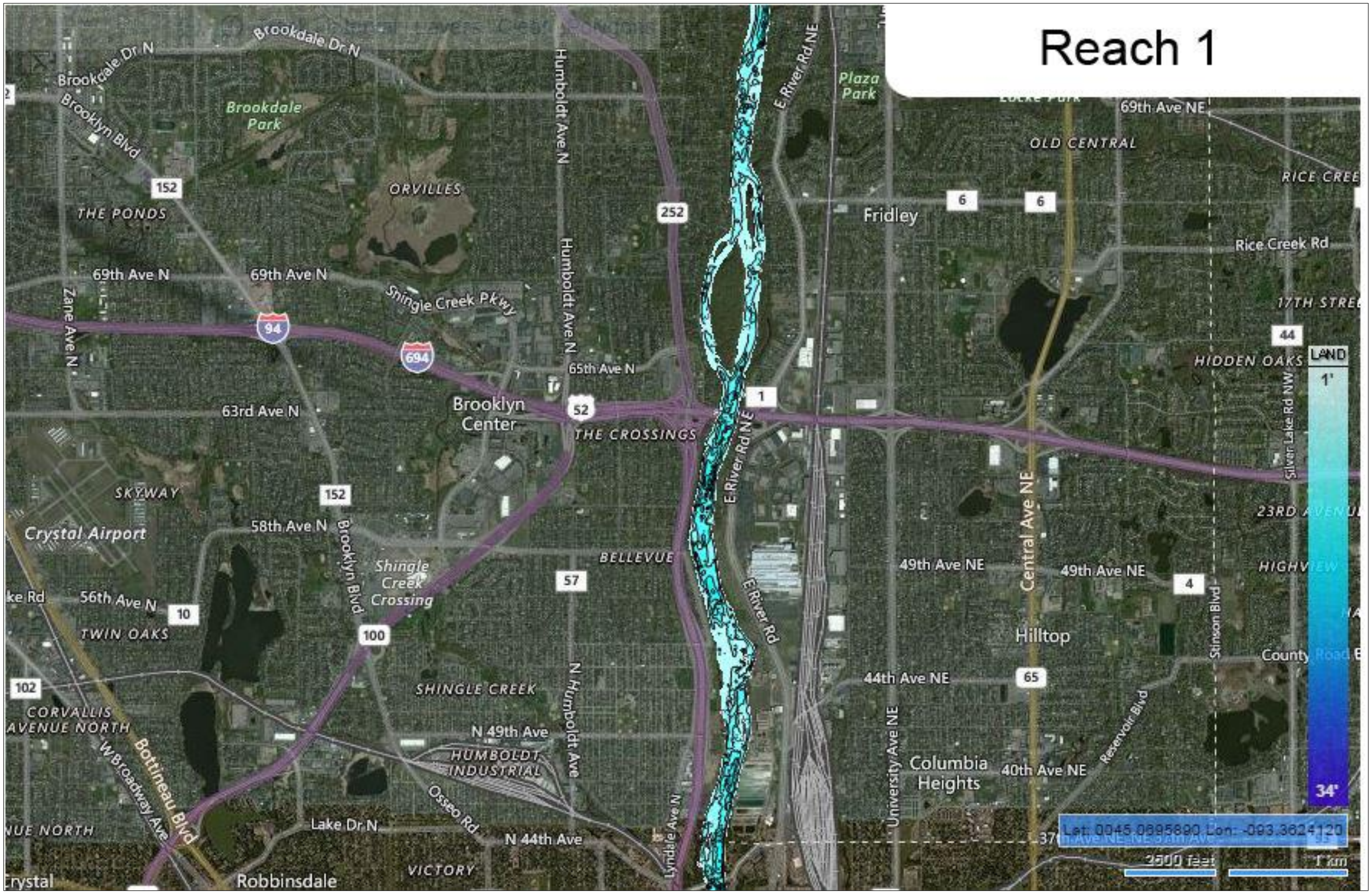

Figure 2. Fall 2014 bathymetry data for the downstream portion of Reach 1. Source: MWMO

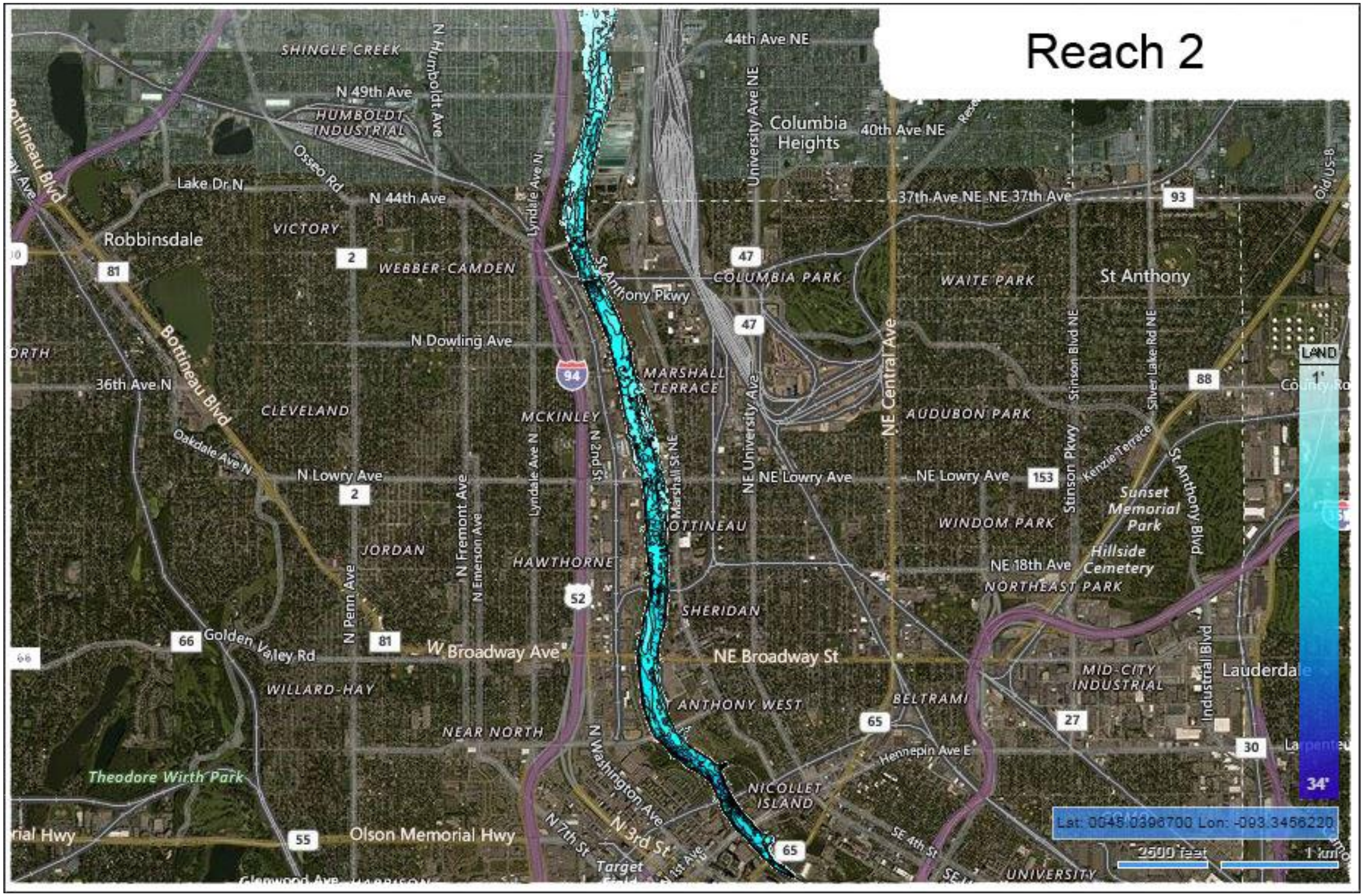

Figure 3. Fall 2014 bathymetry data for Reach 2. Source: MWMO

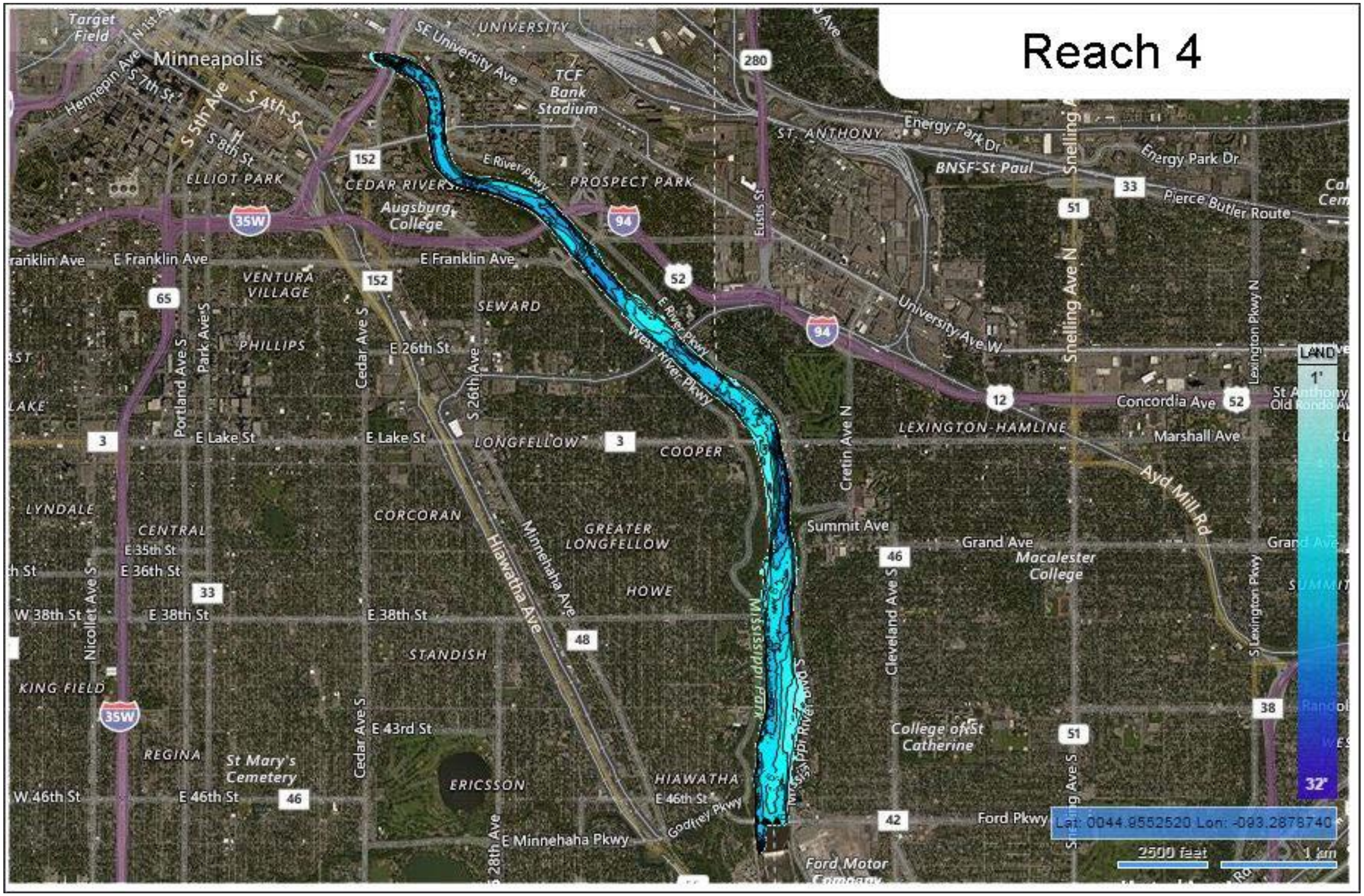

Figure 4. Fall 2014 bathymetry data for Reach 4. Source: MWMO

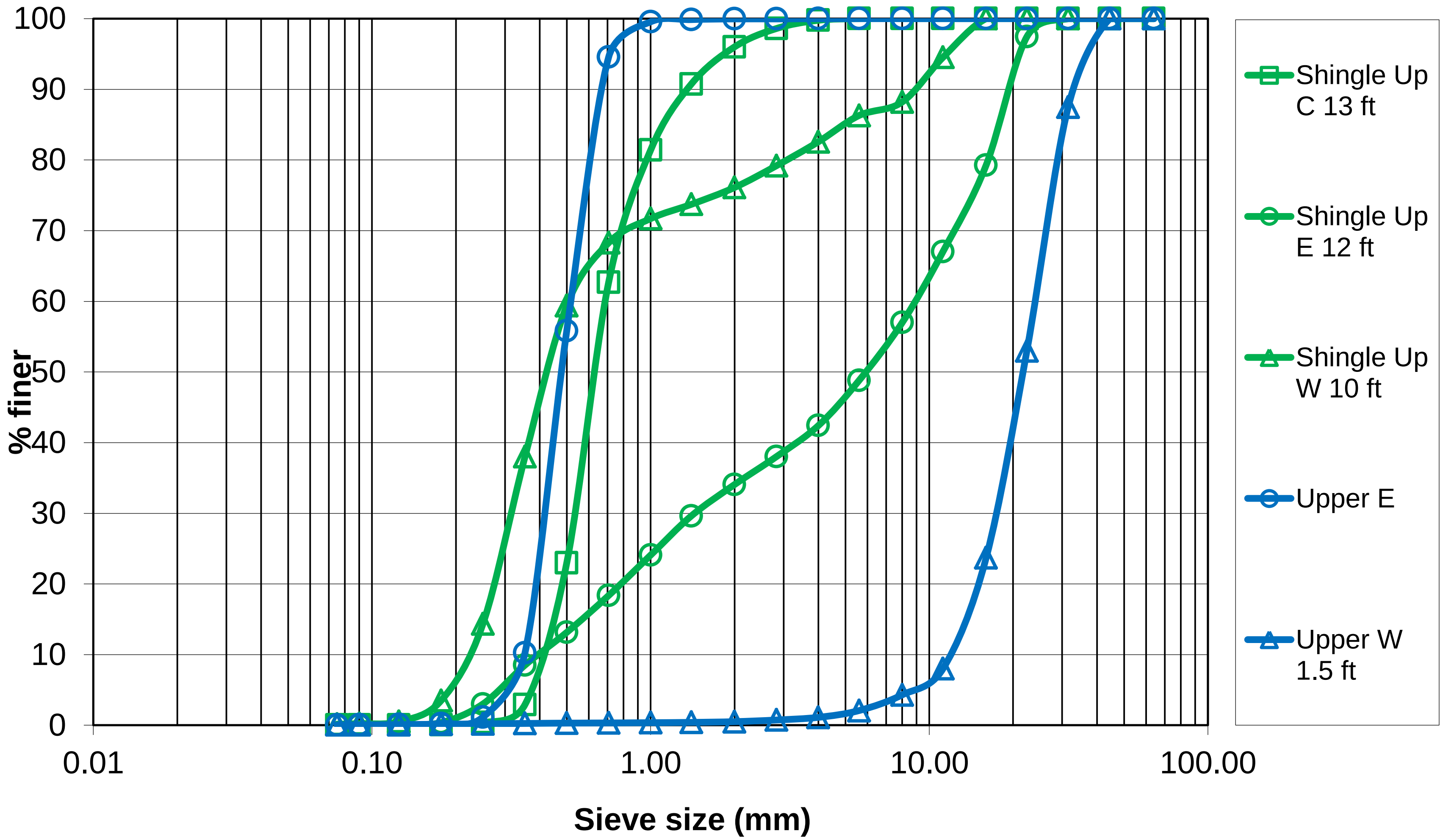

Figure 5. Cumulative grain size distribution for sediment samples collected from Reach 1. Legend identifies monitoring site, in-channel location (C=center, E=east, W=west), and water depth on collection date.

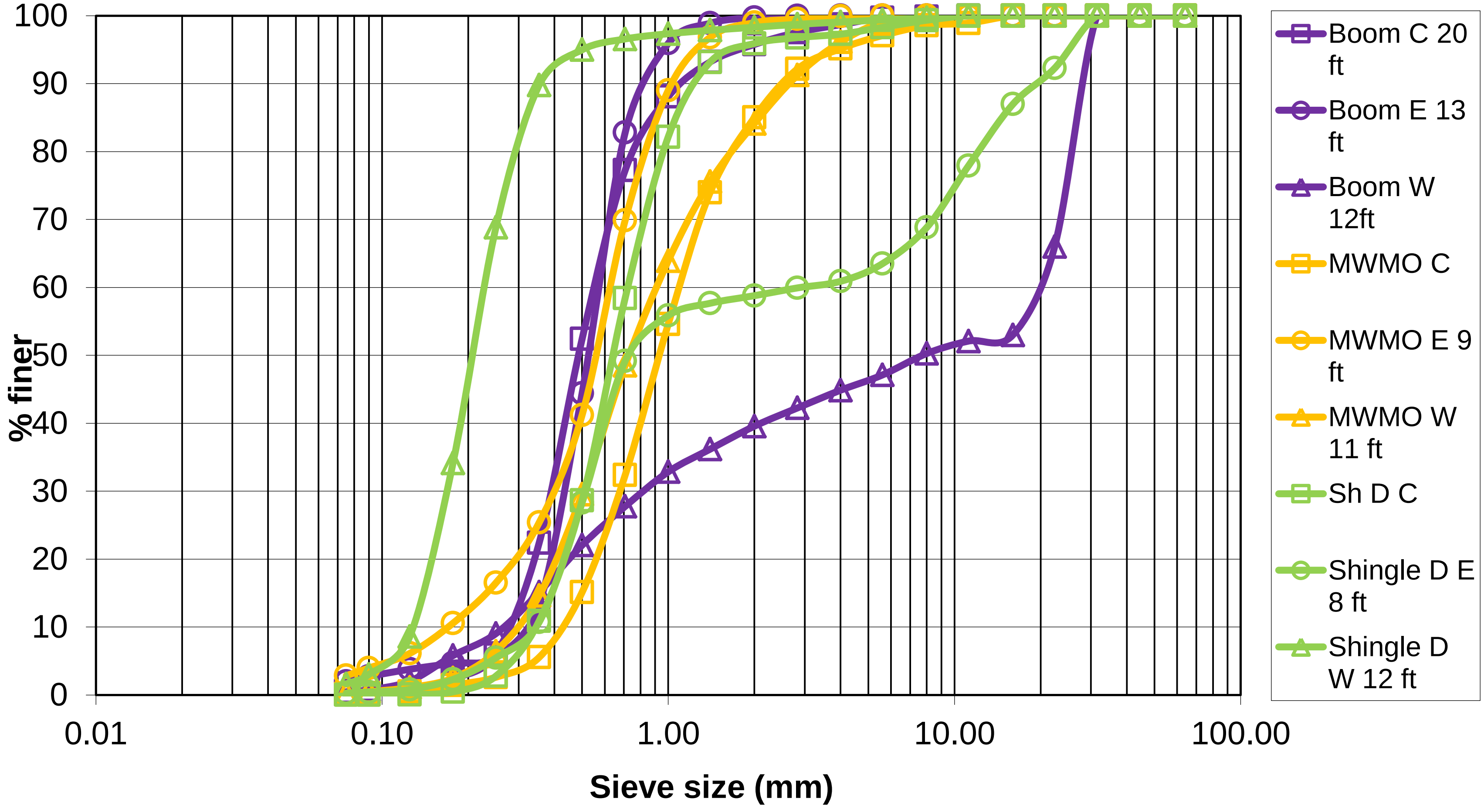

Figure 6. Cumulative grain size distribution for sediment samples collected from Reach 2. Legend identifies monitoring site, in-channel location (C=center, E=east, W=west), and water depth on collection date.

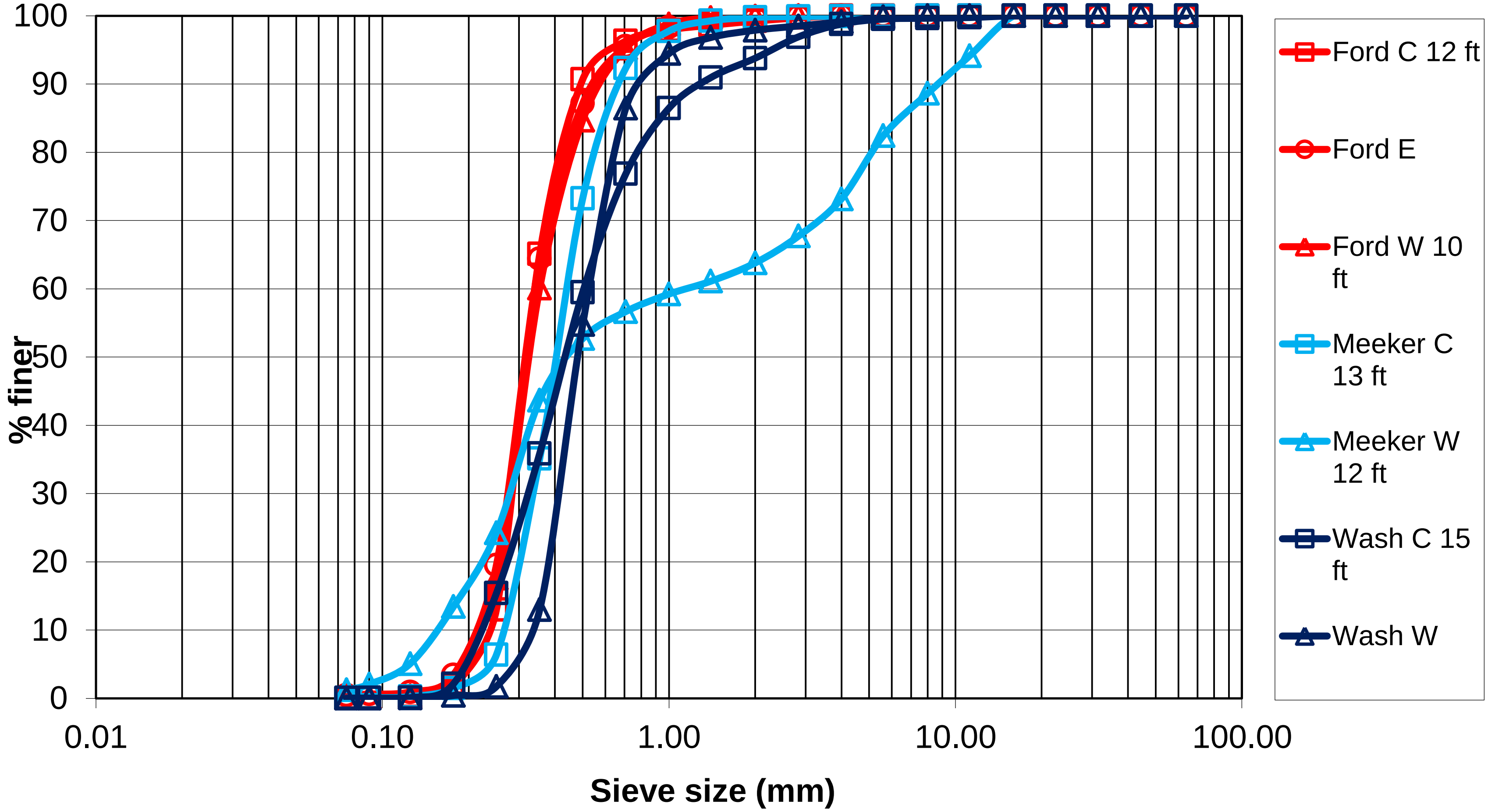

Figure 7. Cumulative grain size distribution for sediment samples collected from Reach 4. Legend identifies monitoring site, in-channel location (C=center, E=east, W=west), and water depth on collection date.

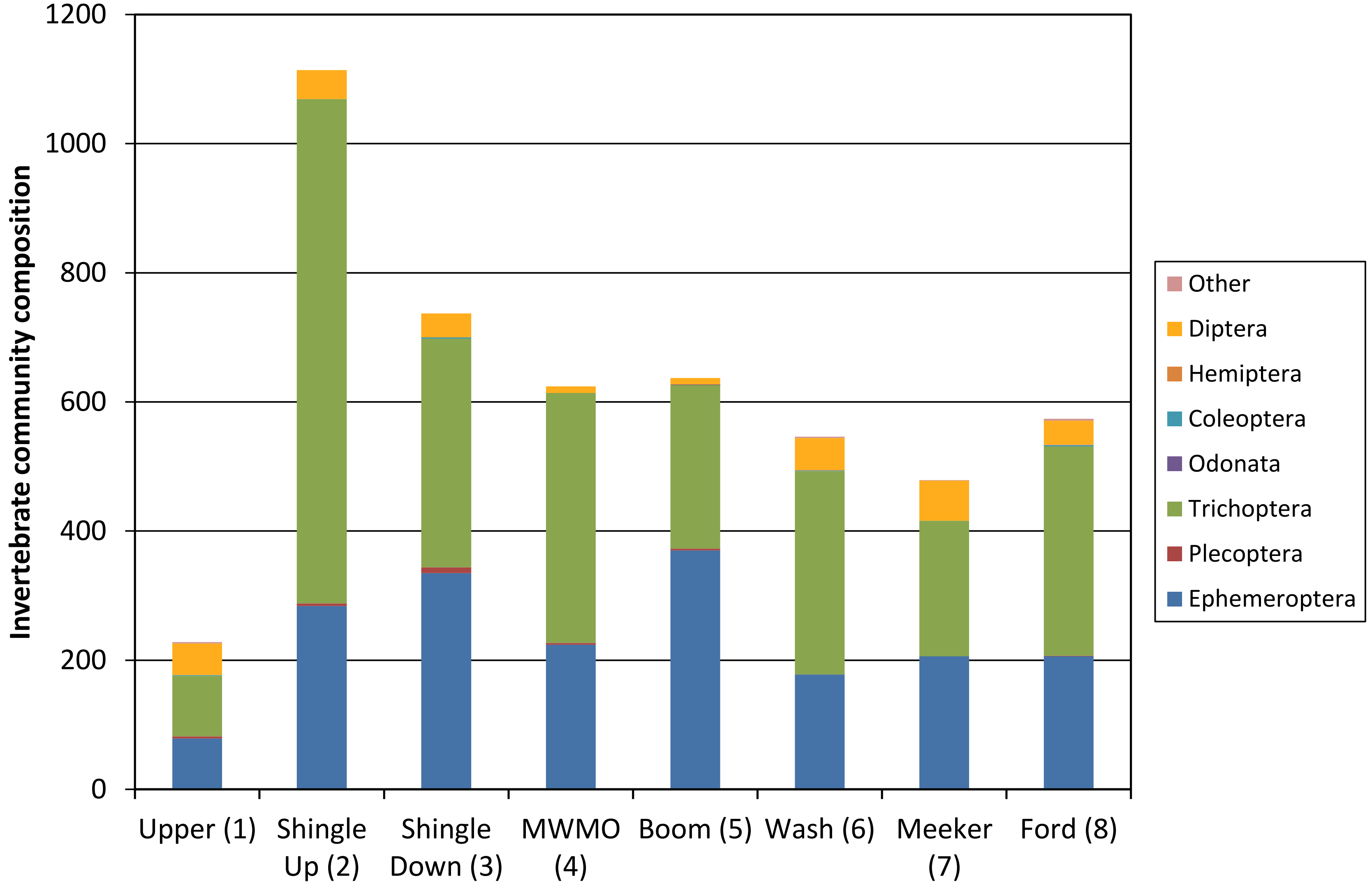

Figure 8. Invertebrate community composition by order at each monitoring site, from upstream (left) to downstream (right).

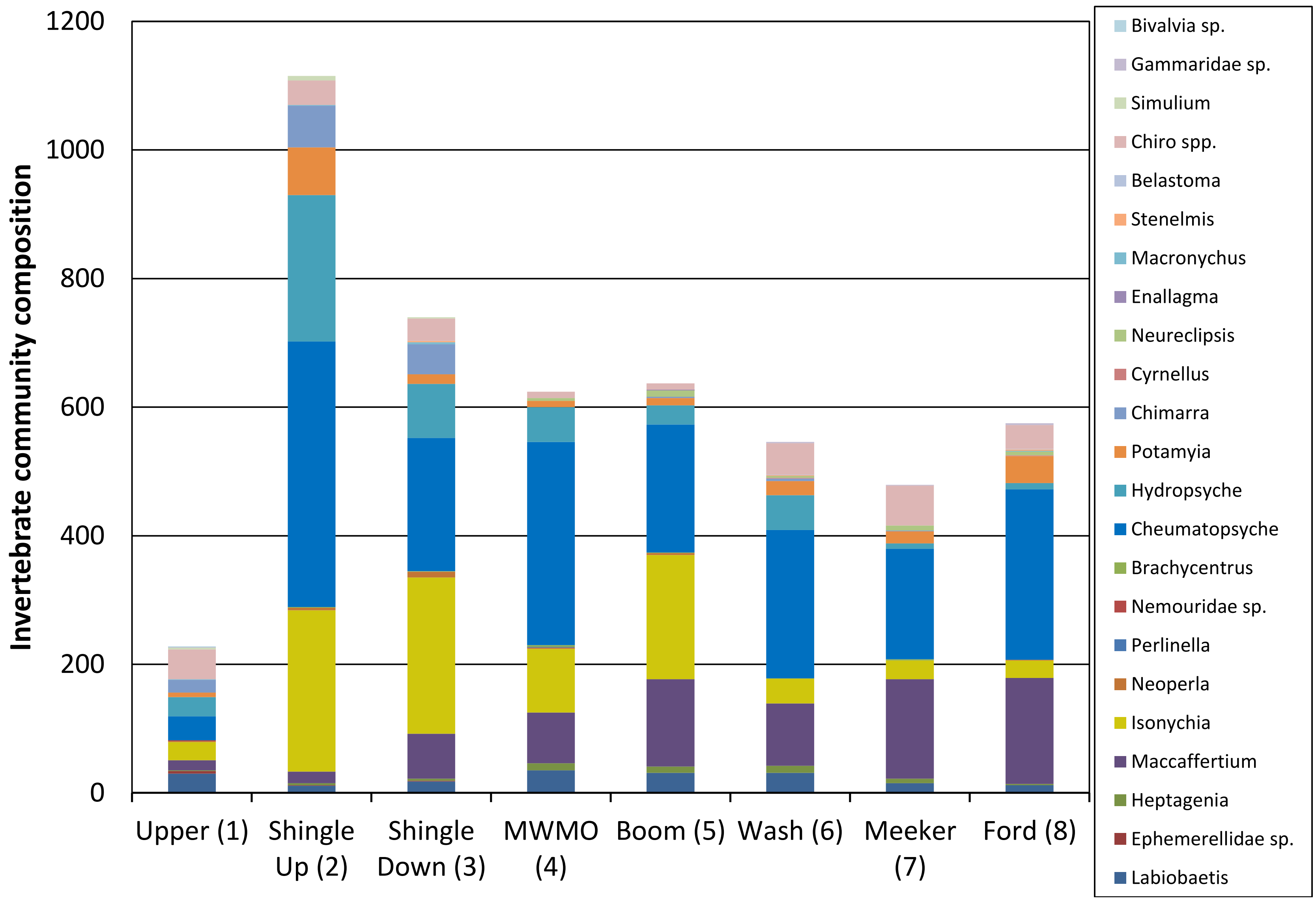

Figure 9. Invertebrate community composition by genus at each monitoring sites, from upstream (left) to downstream (right).

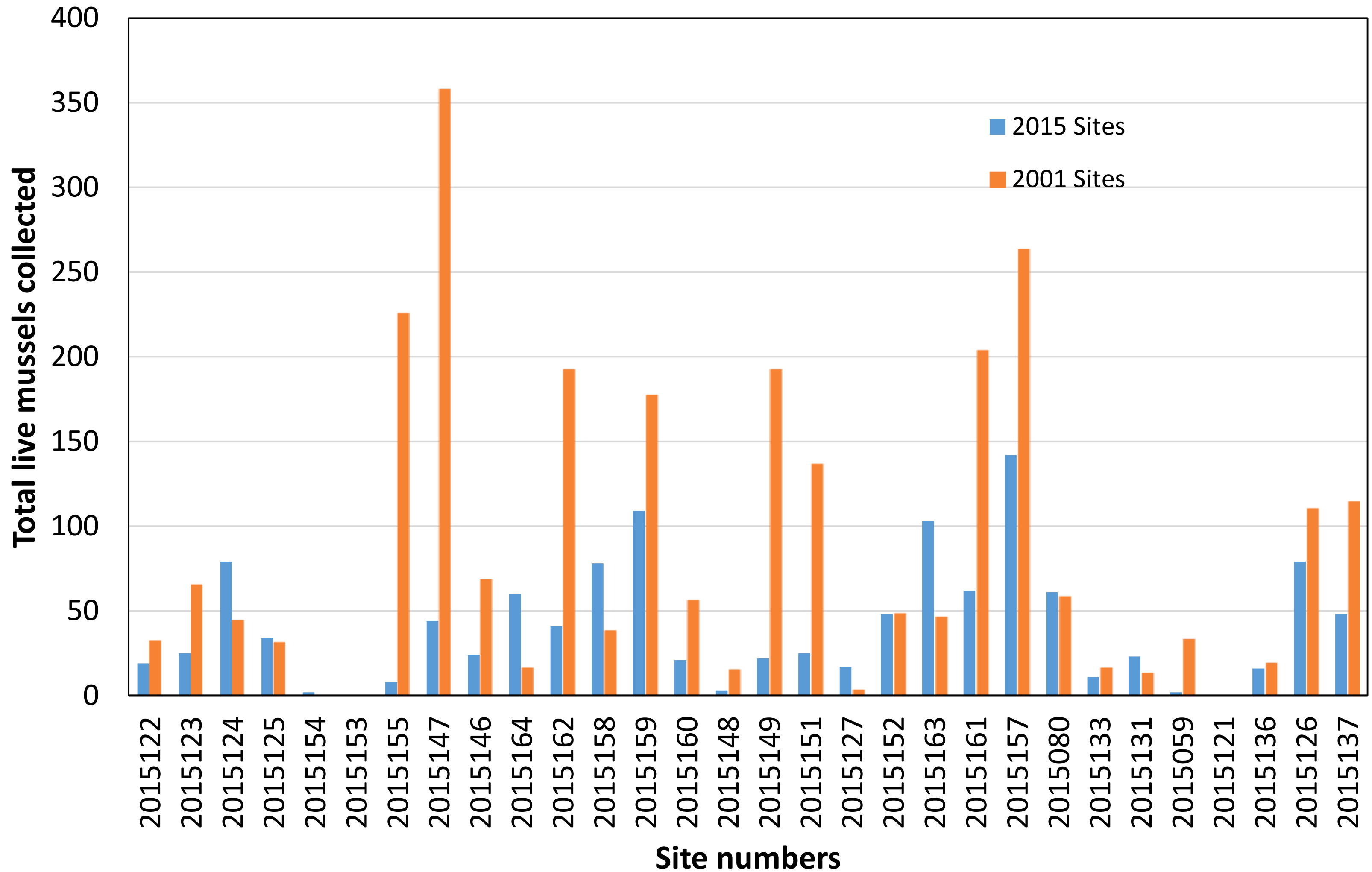

Figure 10. Total live mussels collected at each site for sites sampled in both 2001 and 2015 by the Minnesota DNR.

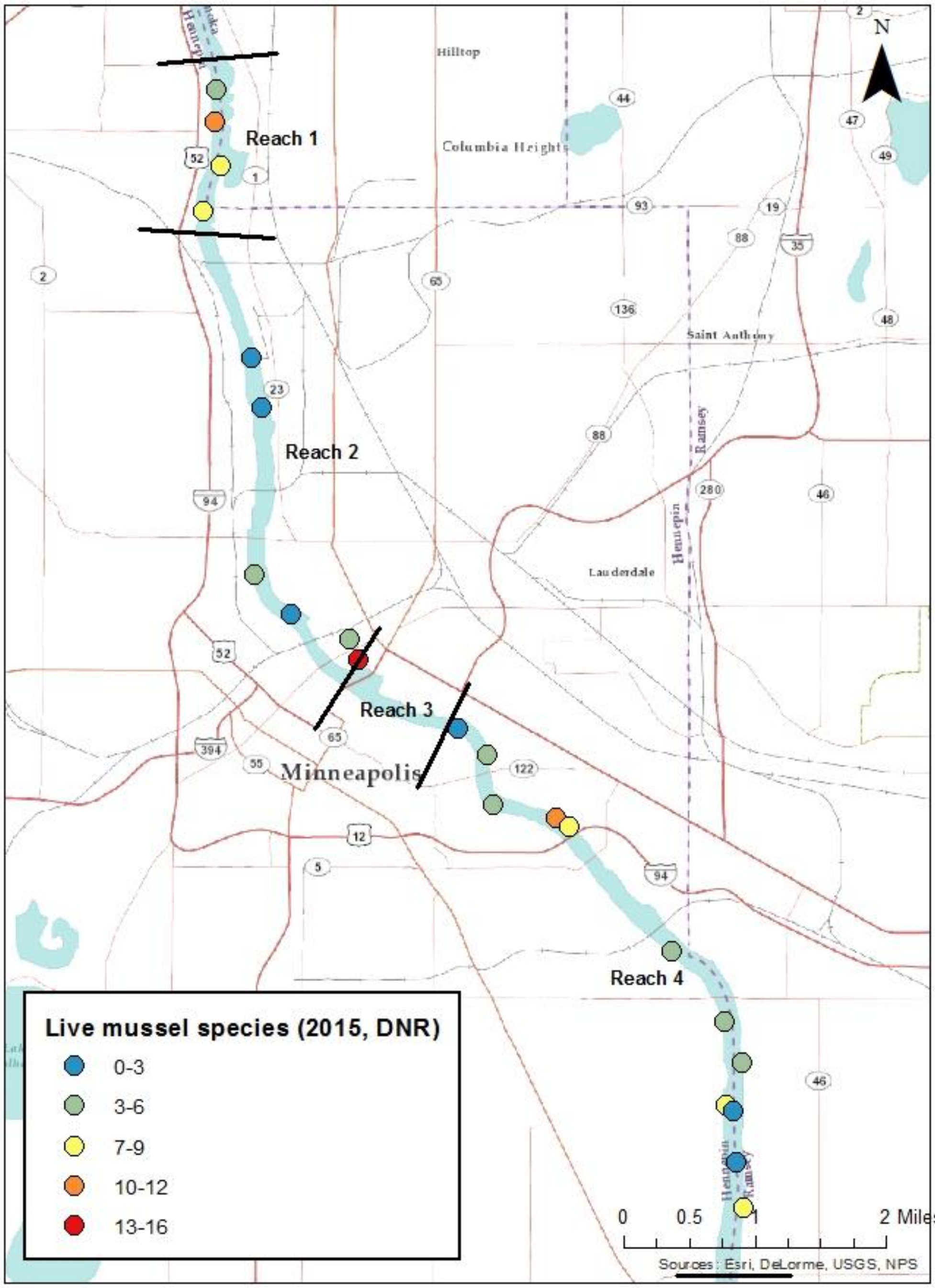

Figure 11. Live mussel species by site collected in 2015.

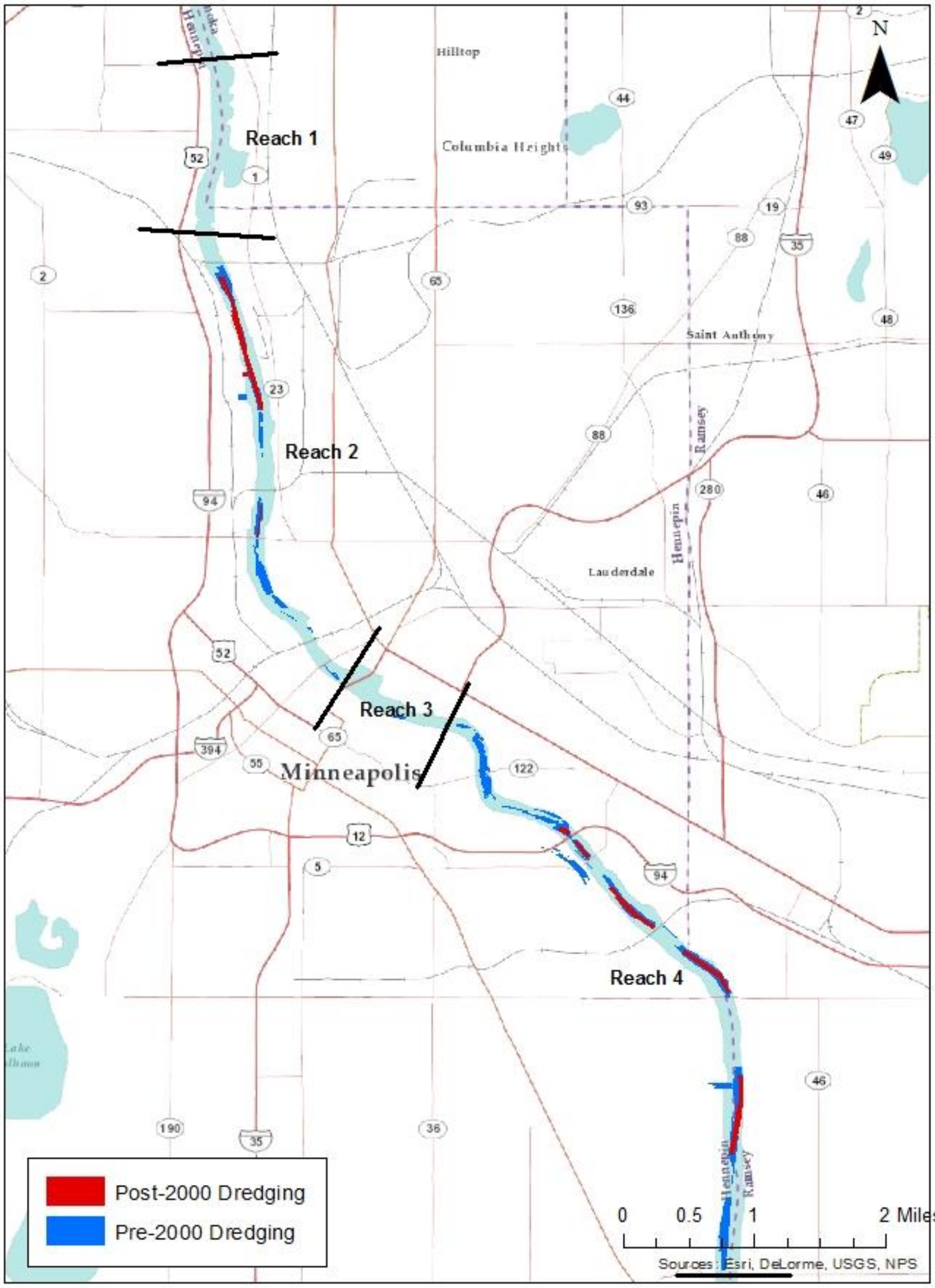

Figure 12. Location of recent (post-2000) and historical (pre-2000) dredge cuts (USACE).

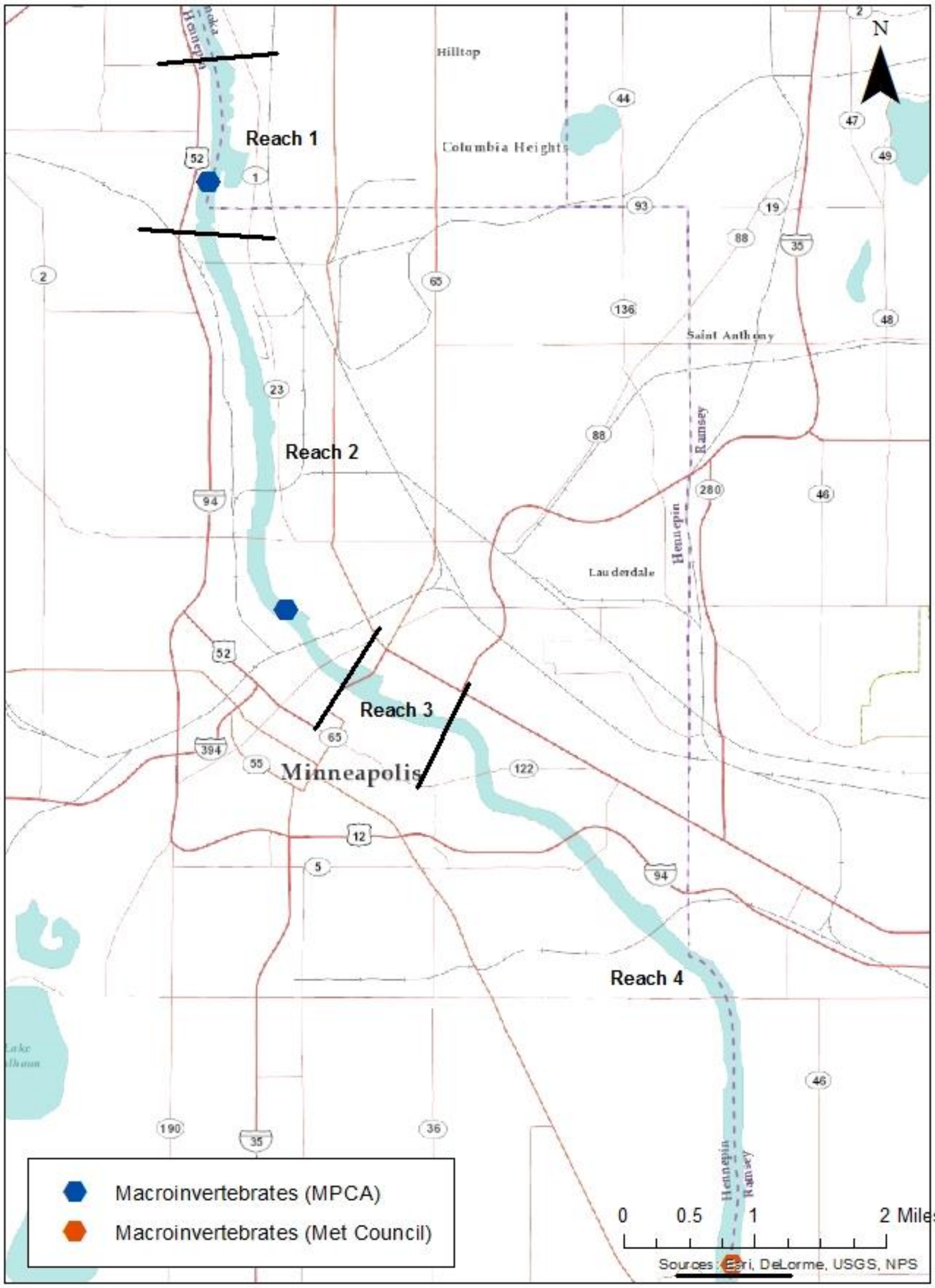

Figure 13. MPCA and Met Council invertebrate monitoring sites.

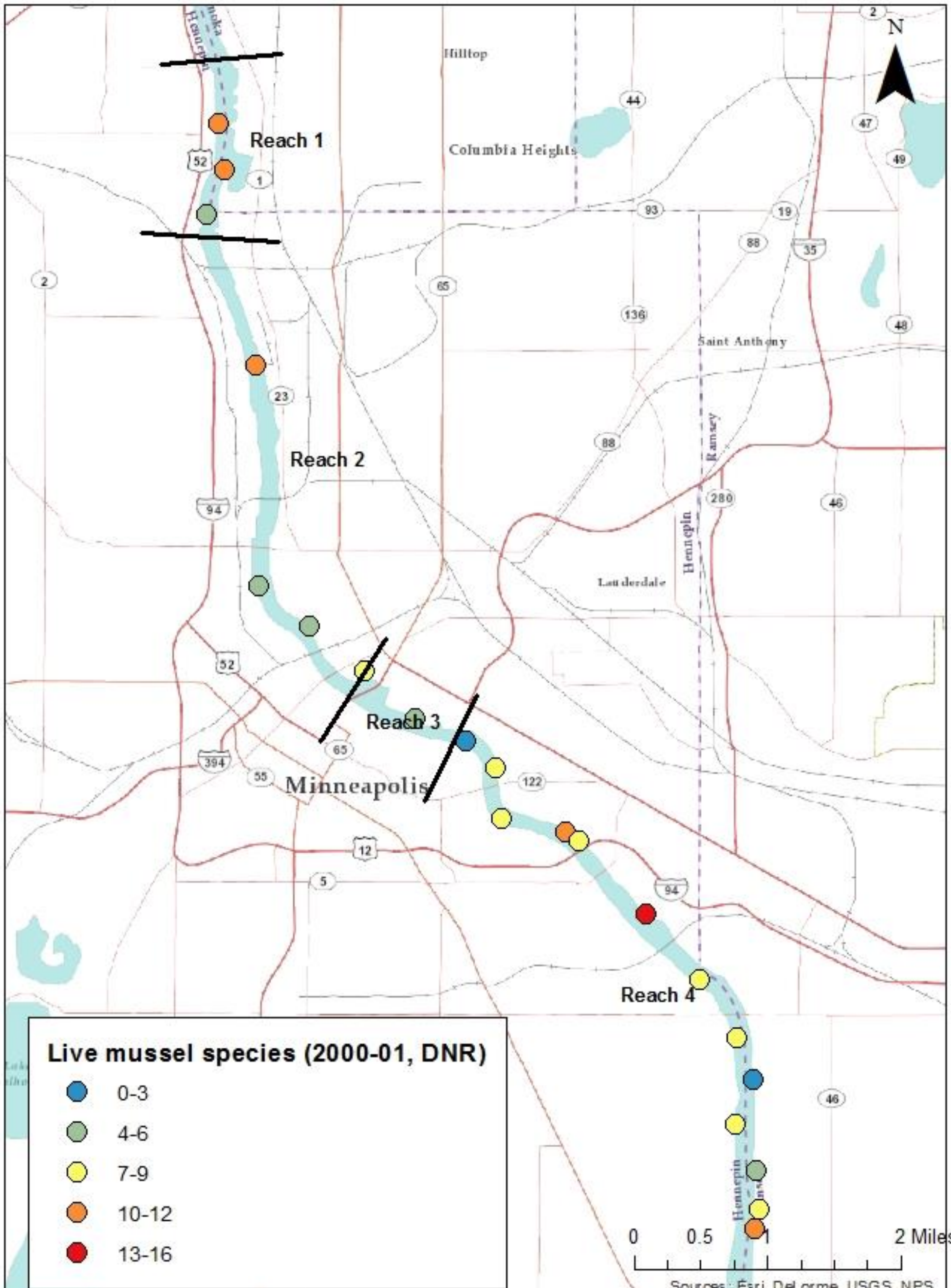

Figure 14. Live mussel species by site collected in 2000-01.

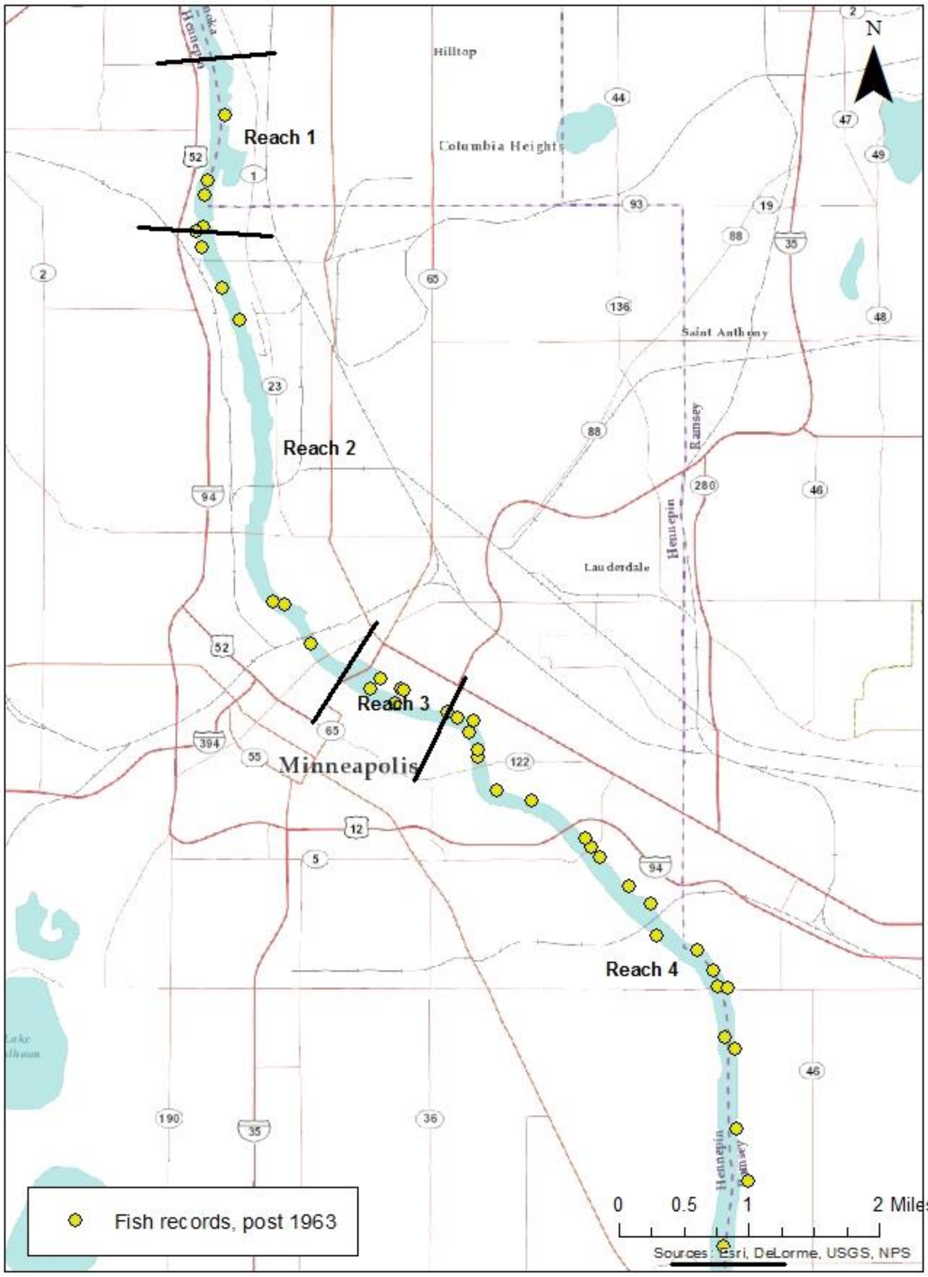

Figure 15. Locations of fish data records, post St. Anthony Falls Lock construction (1963)[6].

[6] Source: Fishes of Minnesota database (http://www.dnr.state.mn.us/maps/fom/index.html)

Table 1. 2015 water quality data for nitrate (N, mg/L), from upstream (left) to downstream (right). Source: MWMO

	Upper	Shingle Up	Shingle Down	MWMO	Boom Island	Washington	Meeker	Ford Dam
1/23/2015	0.81	NA	0.87	NA	0.95	0.96	NA	NA
2/24/2015	NA	NA	NA	NA	1.1	1.07	NA	NA
3/16/2015	0.86	0.85	0.86	NA	0.85	0.86	NA	0.79
4/23/2015	0.37	0.37	0.36	NA	0.35	0.40	NA	NA
5/8/2015	0.27	0.30	0.29	NA	0.29	0.30	NA	NA
5/22/2015	0.40	0.59	0.57	NA	0.50	0.64	NA	NA
6/8/2015	0.74	0.71	0.62	NA	0.54	0.63	NA	0.60
6/29/2015	1.06	0.96	0.78	NA	0.88	0.83	NA	NA
7/10/2015	0.40	0.34	0.38	NA	0.35	0.34	NA	NA
7/24/2015	0.36	0.36	0.35	NA	0.34	0.35	NA	NA
8/10/2015	0.35	0.34	0.38	NA	0.37	0.38	NA	NA
8/21/2015	0.45	0.46	0.43	0.44	0.43	0.46	0.47	NA
9/8/2015	0.17	0.21	0.21	0.21	0.21	0.20	0.20	0.14
9/16/2015	0.29	0.29	0.31	0.30	0.29	0.34	0.33	NA
9/30/2015	0.43	0.44	0.46	0.45	0.45	0.43	0.40	NA
10/12/2015	0.32	0.33	0.35	0.35	0.36	0.40	0.36	NA
10/27/2015	0.40	0.89	0.39	0.37	0.40	0.43	0.42	NA
11/10/2015	0.52	0.43	0.48	0.44	0.41	0.41	0.54	NA
11/25/2015	1.46	1.11	0.89	0.76	0.73	1.00	0.98	NA
12/7/2015	1.11	0.86	0.73	0.73	0.72	0.78	0.77	0.75
12/21/2015	1.62	1.09	1.55	1.02	1.38	1.13	1.13	NA

Table 2. 2015 water quality data for total phosphorous (P, mg/L), from upstream (left) to downstream (right). Source: MWMO

	Upper	Shingle Up	Shingle Down	MWMO	Boom Island	Washington	Meeker	Ford Dam
1/23/2015	<0.020	NA	<0.020	NA	~0.026	<0.020	NA	NA
2/24/2015	NA	NA	NA	NA	~0.022	0.069	NA	NA
3/16/2015	~0.033	~0.038	~0.038	NA	~0.036	~0.036	NA	~0.024
4/23/2015	0.054	~0.037	~0.049	NA	0.058	~0.043	NA	NA
5/8/2015	~0.048	~0.048	0.050	NA	~0.048	~0.046	NA	NA
5/22/2015	0.121	0.118	0.117	NA	0.125	0.123	NA	NA
6/8/2015	0.096	0.088	0.096	NA	0.089	0.081	NA	0.082
6/29/2015	0.080	0.084	0.090	NA	0.081	0.088	NA	NA
7/10/2015	0.078	0.076	0.076	NA	0.076	0.076	NA	NA
7/24/2015	0.098	0.108	0.101	NA	0.089	0.096	NA	NA
8/10/2015	0.084	0.078	0.086	NA	0.089	0.081	NA	NA
8/21/2015	0.090	0.089	0.093	0.094	0.094	0.089	0.093	NA
9/8/2015	0.074	0.075	0.079	0.071	0.059	0.059	0.070	0.067
9/16/2015	0.055	0.061	0.059	0.058	0.054	0.070	0.060	NA
9/30/2015	~0.049	0.056	0.063	0.052	0.079	0.052	0.052	NA
10/12/2015	~0.029	~0.035	~0.030	~0.031	~0.038	~0.037	~0.034	NA
10/27/2015	0.050	<0.020	~0.032	~0.037	~0.031	~0.033	~0.045	NA
11/10/2015	~0.024	~0.023	~0.032	~0.033	~0.034	~0.030	~0.042	NA
11/25/2015	0.094	0.087	0.084	0.084	0.082	0.091	0.084	NA
12/7/2015	0.068	0.066	0.065	0.065	0.065	0.050	0.066	0.065
12/21/2015	0.080	~0.039	0.059	0.077	0.054	0.127	0.073	NA

Table 3. 2015 water quality data for total suspended solids (TSS, mg/L). Source: MWMO

	Upper	Shingle Up	Shingle Down	MWMO	Boom Island	Washington	Meeker	Ford Dam
1/23/2015	~1	NA	~2	NA	~1	~1	NA	NA
2/24/2015	NA	NA	NA	NA	~1	14	NA	NA
3/16/2015	3	4	4	NA	3	3	NA	~2
4/23/2015	3	5	5	NA	5	5	NA	NA
5/8/2015	7	6	7	NA	6.5	6	NA	NA
5/22/2015	40	39	40	NA	43	44.5	NA	NA
6/8/2015	26	26	25	NA	23	23.5	NA	22
6/29/2015	13	14	12	NA	15	16.5	NA	NA
7/10/2015	7	8	8	NA	8	9	NA	NA
7/24/2015	10	11	11	NA	12	14	NA	NA
8/10/2015	9	11	10	NA	11	10	NA	NA
8/21/2015	7	11	13	12	11	11	11	NA
9/8/2015	10	10	11	12	10	12	11	12
9/16/2015	5	8.5	8	8	8	8	9	NA
9/30/2015	5	5	8	7	7	7	6	NA
10/12/2015	~2	~2	3	~2	3	4	~2	NA
10/27/2015	~1	~2	~2	~2	~2	4.5	3	NA
11/10/2015	4	4	5	5	4	4	4	NA
11/25/2015	11	13	13	13	13	13	13.5	NA
12/7/2015	5	5	5	4	5	5	4	5.5
12/21/2015	5.5	8	6	8	8	17	3	NA

Appendix 1: Data Summary

Field-collected Data				
Type	**Source(s)**	**Date**	**Location**	**Data Figures & Tables**
Bathymetry	MWMO	2014-2015	Reaches 1-4	Figures 2-4
Water Chemistry	MWMO	2014-2015	8 monitoring sites (Figure 1)	Figure 1, Tables 1-3
Sediment	Activity 1 (MWMO)	Fall 2015	8 monitoring sites (Figure 1)	Figures 5-7
Invertebrates	Activity 1	Fall 2015	8 monitoring sites (Figure 1)	Figures 8-9
Mussels	Activity 1 (Minnesota DNR)	Fall 2015	Multiple sites	Figures 10-11
Existing Data				
Type	**Source(s)**	**Date**	**Location**	**Data Figures & Tables**
Dredge cut locations	USACE	1956-2012	Multiple sites	Figure 12
Bathymetry	USACE	2003-2015	Reaches 2-4	NA
Invertebrates	Met Council & MPCA	1979-2013	3 monitoring sites (Figure 13)	NA
Mussels	Minnesota DNR	2000-2011	Multiple sites	Figure 14
Fish	Fishes of MN database	1900-2011	Multiple sites	Figure 15
Fish	Minnesota DNR	1999-2014	Multiple sites	NA
Fish	MPCA	2013	2 monitoring sites (Figure 13)	NA
Amphibians & Reptiles	Great Lakes Eco	2015	Multiple sites	NA
Birds	Audobon MN	2010	Entire	NA
Birds	National Park Service	2015	Reach 1	NA

Appendix 2: Dissemination of Results

The project team felt that dissemination of study results would be a vital part of the overall success of the study. The Mississippi River corridor in Minneapolis has received a great deal of public investment over the past few decades, which has been met with tremendous private investment and growing populations visiting the river's network of parks and trails. Dozens, if not hundreds, of people and organizations are committed to the future of the Minneapolis riverfront, and the results of a scientific study conducted at the point of the lock closure, a historic event by nearly any measure, would be important for many of the planning and program efforts going forward.

Accordingly, the study team took a multifaceted approach to dissemination of project results; these efforts will continue beyond the end of the actual grant period itself. The discussion that follows details three major areas of community engagement, sketching out each through intended audience, major themes developed, interactivity/questions discussed, and potential impact.

In-person presentations

Project staff took part in two events dedicated to disseminating the results of the study. Lead scientist Jane Mazack presented preliminary findings at the "Sip of Science" program held May 11, 2016 at the Aster Café in Minneapolis. Approximately 75 people attended; this is an unusually large crowd for this series, a monthly science-oriented talk put on by the St. Anthony Falls Laboratory at the University of Minnesota. The audience was generally "science literate" (recruitment was primarily through a mailing list maintained by the Lab), and included a range of age groups. Mazack was also part of a program held at Mill City Museum in Minneapolis on May 26, 2016. Approximately 100 people attended this program, "River Ecology after the lock closure: return to a more natural river?" The crowd at this event tended to be older, although there were people from all age ranges. The event was promoted by the Minneapolis Riverfront Partnership as part of its "Riverfront Vitality Indicators" series.

Both presentations began from a foundational understanding that treated the lock closure as the latest in a long series of river manipulations that have taken place on the Minneapolis stretch of the river. The presentations then detailed the study's methodology, key components of what was being sought, and the preliminary results. As befit the variation in the audiences, the Sip of Science presentation had more attention to scientific results of the study. Both presentations touched on the issue of what "scientific indicators" means and how the study's results could be used by various parties going forward.

As expected, the audiences at these programs were highly engaged with lots of questions and comments. At Mill City, perhaps because the program included a presentation by Mike Davis, mussel ecologist from the DNR, many questions explored precisely how mussels would be indicators of change in the river system, including inquiry about the relations of mussels to river bed materials, which would perhaps be different with no dredging by the Corps of Engineers. At Sip of Science the questions were more focused on technical issues pertaining to water quality, relations to previous studies and legislation related to water quality such as the federal Clean Water Act, and how fish populations are (or are not) important indicators of river health.

Anticipated impact from the two programs is slightly variable. Both sessions for the nontechnical public achieve, at the very least, greater literacy on how the Mississippi River in Minneapolis works as a system of many component elements. We hope that the scientists in the audience at Sip of Science will gain knowledge that might inform their future research and teaching on urban river systems. We hope that the "interested public" from the Mill City event will better recognize the complexity of the Mississippi River as part of their urban environment and will be moved to pay more specific attention to the river's health in the future.

Digital/social media

The dissemination of project results through digital social media has been awaiting final development of project results. Project team members from the River Life program manage a blog "River Talk," http://riverlife.umn.edu/rivertalk/ as well as a digital map, the River Atlas http://riverlife.umn.edu/river-atlas/ and Twitter and Facebook feeds. We expect the map of project results to be posted to the River Atlas once the Atlas staff member returns from summer leave. The blog, which posts twice weekly on average, will address variable particular subjects from the study as they are pertinent. The social media feeds through Twitter and Facebook will likewise be activated through at least December 2016. At this particular point in time, the River Life Twitter feed reaches nearly 2,000 followers; response rate on any given material is around 1%. There are approximately 150-200 regular correspondents to the feed, which constitute people from scientific and other academic realms, people in the spheres of water advocacy and planning, and agency personnel from the federal, state, and local levels.

This report, as well as significant supplemental material and links to project data, will be posted on the River Life web site http://riverlife.umn.edu/ , as well as the sites of other project partners. It is part of the mission and regular work of the River Life program to serve as a trusted source of reliable information concerning the Mississippi River.

Digital journal publication

During the time this study was conducted, River Life commenced publication of a quarterly digital publication, Open Rivers: Rethinking the Mississippi River http://editions.lib.umn.edu/openrivers/ . At this time, planning is under way to have Issue 4, published in October 2016, focus on the results and studies of the project. Articles in Open

Rivers are produced in PDF format as well as directly on the web, facilitating download for teaching and research purposes. Active promotion of Open Rivers is part of the ongoing work plan of the River Life program; we reach out particularly to academics and river management agencies.