Maple River Dam Removal Project

August 2015
Limnology

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Introduction

Dams dominate waterways throughout the U.S., yet in recent years efforts have been made to remove these structures to restore ecosystem continuity and negate damage from structures lacking integrity. Studies on the geomorphic impact of dams show that dams increase sediment storage upstream of the impoundment, creating a large reservoir. Degradation occurs downstream because channel flows and water chemistry are altered by the reservoir feeding the channel below the dam. Thus, the river ecology changes above and below the dam in response to dam removal (Doyle et al., 2005).

Few studies have compared a river system before and after dam removal (Doyle et al., 2005). Thus, little is known regarding the extent to which rivers recover relative to pre-removal ecosystem conditions, the potential recovery timeframe, and how far from the dam impacts occur. The Maple River provides a unique opportunity to study a river system pre-dam removal.

The Maple River Dam was constructed in 1906 at the joining of the East and West branches of the Maple River (Crowe, 1958). The dam was washed out in 1952 and reconstructed in 1967 creating the current structure (Godby, 2012). The dam has no fish ladders and acts as a barrier for fish, including invasive sea lamprey. Additionally, the habitat upstream of the dam supports the endangered Hungerford's Crawling Water Beetle (Ableson, 2012). Lake Kathleen, the reservoir formed behind the dam, covers 48 acres and supports a variety of biology found only in non-flowing systems. While removal of the Maple River dam will restore habitat continuity, the loss of Lake Kathleen and the changes to habitat upstream and downstream are significant.

Given the lack of empirical studies on dam systems before and after dam removal, our study aims to fill this gap by researching the physical and biological compositions of the East, West, and Main Branches of the Maple River. By examining sites at varying distances upstream and downstream of the Maple River dam, we are creating an inventory of pre-dam removal conditions that will serve as a reference for ecological scientists, dam owners, sportsmen, and local municipalities involved in the processes and potential outcomes of dam removal. Our data includes discharge rates, temperature, conductivity, functional feeding groups and aquatic organisms. These data inform our predictions about potential ecological impacts of the Maple River dam removal.

We predict several temporal stages of river development highlighting geomorphological, physical, and biological changes in the river system. We present our predictions as an initial impact of dam removal, predictions one year after removal and predictions five to ten years post-removal. Our predictions were informed by a 2005 study by Doyle et al., which suggests possible scenarios for stream systems after dam removal.

In the initial weeks and months following the dam removal, we will observe the most drastic habitat changes in Lake Kathleen. The lake will drain and push sediment downstream leading to scouring and increased sediment suspension, which will result in a loss of macroinvertebrates and aquatic plants. This increase of water downstream will lead to an increase in erosion, having many ecological implications for aquatic life, food webs, and the surrounding riparian terrestrial habitats. Macroinvertebrate and macrophyte populations will decrease sharply due to scouring of the benthic zone of the river, which will subsequently lead to a decrease in organisms higher on the food chain (Doyle et al., 2005). Additionally, sediment deposition on the inside of river bends will create larger sandy areas for early successional weedy plant species to inhabit, leading to a larger riparian zone.

One year after the dam removal, early successional wetland plants and trees will colonize the newly formed riparian zone around the former site of Lake Kathleen because these pioneer species are able to survive in recently disturbed environments (Doyle et al., 2005). Macroinvertebrate populations will be nearly indistinguishable between the newly formed river branch and downstream of the dam removal and will reestablish relatively quickly due to their short life cycle and mobility (Doyle et al., 2005). For example, shredders will rebound in the system first because of the high inputs of allochthonous carbon from the riparian zones and Lake Kathleen. However, scrapers and gathering and filtering collectors will rebound soon after shredders when algae and primary producers establish in the system and contribute autochthonous carbon. Additionally, sand deposition downstream will lead to the growth of aquatic and riparian plants that favor sand substrate.

In the five to ten year period following the dam removal, the river channel will stabilize. Stabilization involves the full reestablishment of stable substrate and full re-colonization of macroinvertebrate populations. The riparian zone at the former Lake Kathleen site and downstream of the dam removal will eventually consist of later successional species, including adult trees and woody shrubs.

The Maple River provides us with an invaluable opportunity to study a river before and after dam removal. We hope our study inspires more dam-removal projects and sets a precedent for future river restoration studies. Although we have our set of predictions about the restoration of the Maple River, further empirical studies will be needed to account for the variation between river systems.

Methods

Sites

The sites we studied on the West Branch of the Maple River included an upstream site near the Pellston Regional Airport (site 104, see appendix, attachment A for site map and attachment F for GPS coordinates), a midstream site near East Robinson Road (site 103), a site farther downstream off of Highway 31 (site 102), a site above the delta of the West Branch (site 101), and a transitional site where the West branch and Lake Kathleen meet (site 100). On the East Branch of the Maple River, we measured an upstream site (204), a midstream site (203), a site farther downstream near East Branch Road (202), a site above the delta of the East Branch (201), and a transitional site where the East Branch of the Maple River meets Lake Kathleen (200). On the Main Branch of the Maple River, we measured nine sites that were increasingly farther away from the dam (sites 14, 14.5, 18, 21, 22, 24, 26, 27, and 28). We selected these sites to provide an inventory of pre-dam removal conditions for sites that were at a variety of distances away from the dam, as well as to make predictions about areas of the river that would experience the most changes in response to the dam removal.

Physical measurements

Temperature (°C) and conductivity were recorded using a YSI Model 30 Conductivity and Temperature Meter. Readings were taken at the surface of the river at each site on the Maple River. Flow measurements were taken using a Flo-Mate at each site on the Maple River. At each site the width of the river was recorded and divided into 10 cells. The depth of each cell was measured and a flow meter was used to take velocity measurements at 60% of the total depth from the bottom of each cell. These measurements collected by the Flo-mate were then used to calculate a total discharge for each site (L/s) by multiplying the depth (cm) and width (cm) of each cell by the velocity in cm/s. The discharge informed us how much water was moving through the system and if the river was growing or shrinking in volume.

Macroinvertebrates

Aquatic invertebrates were sampled in all aforementioned sites of the Maple River. Four samples were collected from different habitats within a sampling site. Each of the sub-habitats would either represent a sandy, gravel, bark, vegetated or rocky area of the river to account for as much of the available macroinvertebrate life at the site as possible. A Surber sampler was placed in the benthos facing upstream so that the water current helped deposit sediment and organic material in the nets. Once the nets were sufficiently filled the samples were transferred in enamel pans for examination. We searched the sediment thoroughly for aquatic invertebrates and the specimens were placed in bottles of 95% ethanol for preservation.

A 10-minute sampling effort was used to standardize the search for organisms in each of the four sub-habitats. Once the search time had lapsed the sediments were returned to the river and the specimens transported to the limnology lab located in the University of Michigan Biological Station. The invertebrates were observed under a dissecting microscope in the laboratory and categorized according to functional groups. The following are the possible functional feeding groups into which an invertebrate could fall: scraper, filterer, gatherer, shredder, and predator (Dodds et al., 2010). These functional groups reflect the source and transfer of energy in these rivers and their primary productivity. After the specimens were identified they were placed in separate scintillation vials according to their functional group in 95% ethanol for preservation. Different ratios were calculated as a proxy of ecosystem stability and carbon flow. Table 2 displays the ratios calculated and the specific function represented by the ratio. For more information as to what the ratios represent, please refer to the Hauer & Lamberti, 2011 Methods in Ecology.

Table 1 displays formulas used to calculate ratios to determine conditions of the ecosystem.

Formula	Function
$\frac{\#\ of\ Scrapers}{\#\ of\ shredders + total\ collectors}$	Autotrophy to Heterotrophy index
$\frac{\#\ of\ Shredders}{Total\ collectors}$	Coarse particulate organic matter (CPOM) to fine particulate organic matter (FPOM) index
$\frac{\#\ of\ filtering\ collectors}{\#\ of\ gathering\ collector}$	Transport FPOM (TFPOM) to benthic FPOM (BFPOM)
$\frac{\#\ of\ Scrapers + \#\ of\ filtering\ collectors}{\#\ of\ shredders + gathering\ collectors}$	Substrate stability
$\frac{\#\ of\ Predators}{Total\ of\ all\ other\ groups}$	Top down control

Macrophytes

On the Maple River, we conducted a riparian and aquatic macrophyte sampling at sites 100-102 and 200-202. At each site we described the amount of each aquatic macrophyte species found in the river by using a ranking system ranging from 1-5. A ranking of 1 indicates relatively low plant presence, and a 5 indicates that a plant species is plentiful at the site. We used the same ranking system for wetland plants in the riparian zones for the northeast riparian zone of site 200, the north and south riparian zones of site 100, the north riparian zone of site 201, and the east and west riparian zones of site 101.

We qualitatively described the macrophytes by categorizing the habitat as herbaceous or woody, determined the approximate length of the riparian zone, and distinguished layers of the zone if present for the north and south riparian zones at sites 102 and 202, the southwest riparian zone of site 200, and the south riparian zone of site 201. We also noted general stream attributes and the species compositions of the riparian zones, noting if any plants were dominant. Macrophytes that we could not identify in the field, we placed a sample of the plant in a Whirl Pak to be identified later in the lab.

Results

Physical

Conductivity

Conductivity was highest at the delta on the west branch of the Maple River (site 100) at 344.8 µS (Figure 2). On the East Branch, conductivity was highest above the delta (site 201: 309.2 µS). Below the dam, conductivity was only taken at site 7, where it was 320.9 µS (Figure 2).

Figure 2

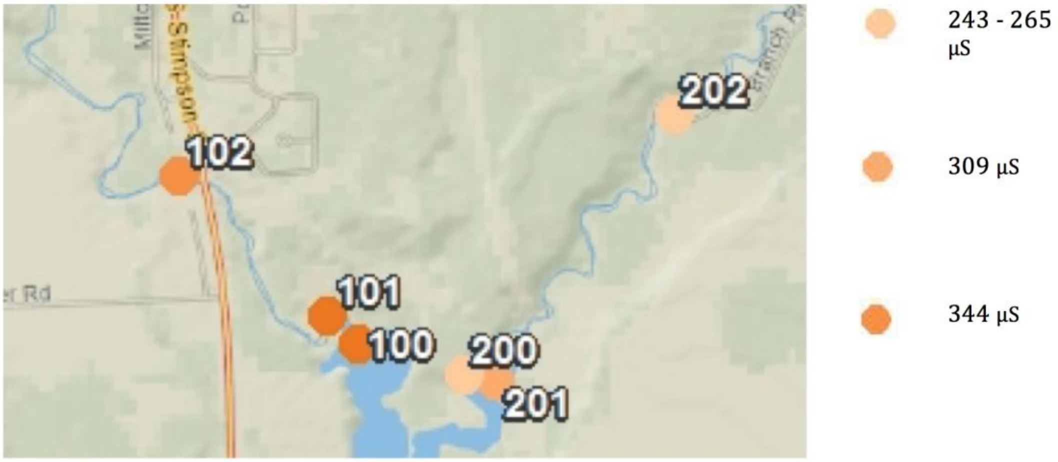

Figure 2 displays the conductivity in µS using a color gradient at each of the sites on the Maple River; increments are listed in the key. Only the upstream sites are shown.

Discharge

On the West Branch, discharges decreased from site 104 to site 103. From site 103 to 102 there was an increase in discharge (site 103: 819.78 L/s; site 102: 906.30 L/s, Figure 3), however, there was a three-week drought between the times at which we collected data from these sites. The increase in discharge despite the drought indicates that there was a large influx of groundwater between sites 103 and 102. Discharge increased from site 102 to 101 (site 101: 1176.86 L/s, Figure 3). Lastly, there was no significant change from site 101 to 100 (site 100: 1101.40 L/s, Figure 3).

From site 204 to 203 there was an increase in discharge on the East Branch of the Maple River (site 204: 814.21 L/s; site 203: 1294 L/s, Figure 4). Between sites 203 to 202 discharges decreased substantially (site 202: 244.20 L/s, Figure 4); however this may be attributed to the three-week drought. Between sites 202, 201, and 200 discharge increased (site 201: 312.54 L/s; site 200: 314.81 L/s, Figure 2).

Only three measurements were taken downstream of the dam. From site 4 to site 31 there was a substantial increase in discharge (site 4: 1287 L/s; site 31: 2121.09 L/s, figure 3). From site 31 continuing downstream discharge leveled off (2015.44 L/s, figure 3).

Figure 3

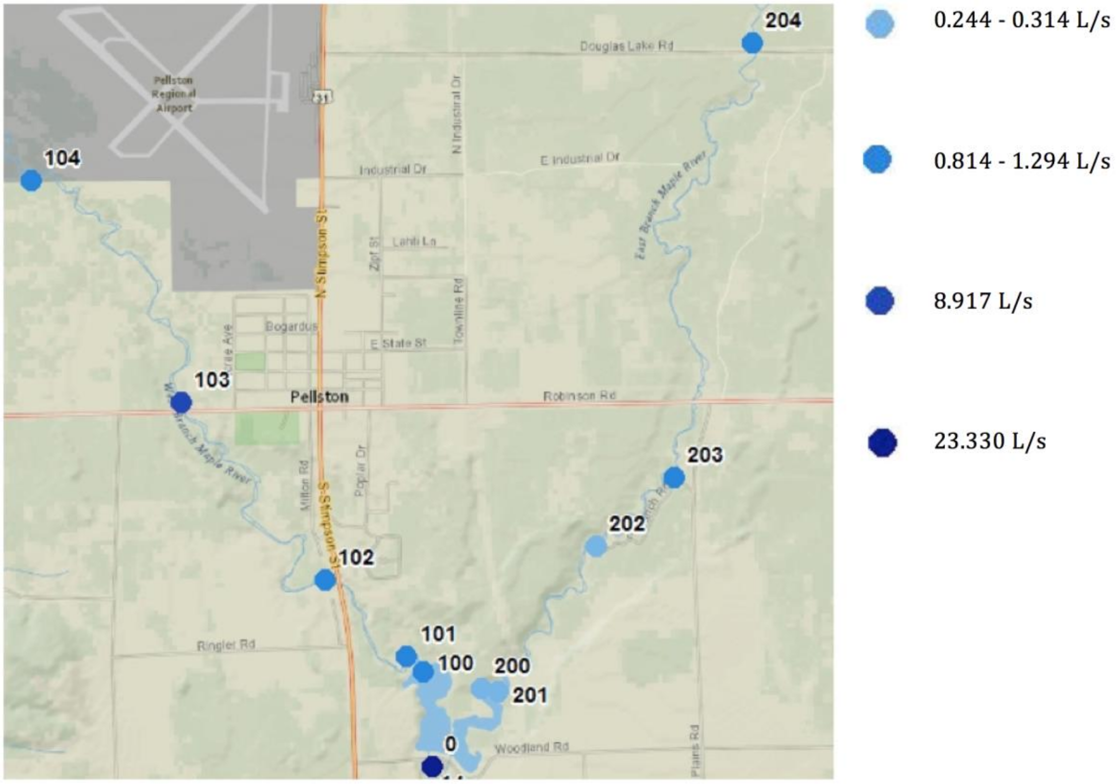

Figure 3 shows the discharge in L/s at every site on the maple river. Increments are listed in the key to the left.

Temperature

In the West Branch of the Maple River temperature decreased 2.5 ºC as we moved downstream (site 104: 17.5ºC, site 100: 15ºC; Figure 4). On the East Branch, temperature dropped from 17ºC to 12.5ºC from site 204 to 200 (Figure 4). Temperature was only taken at one site at the combined branch, close to site 14; the temperature was 18ºC (Figure 4).

Figure 4

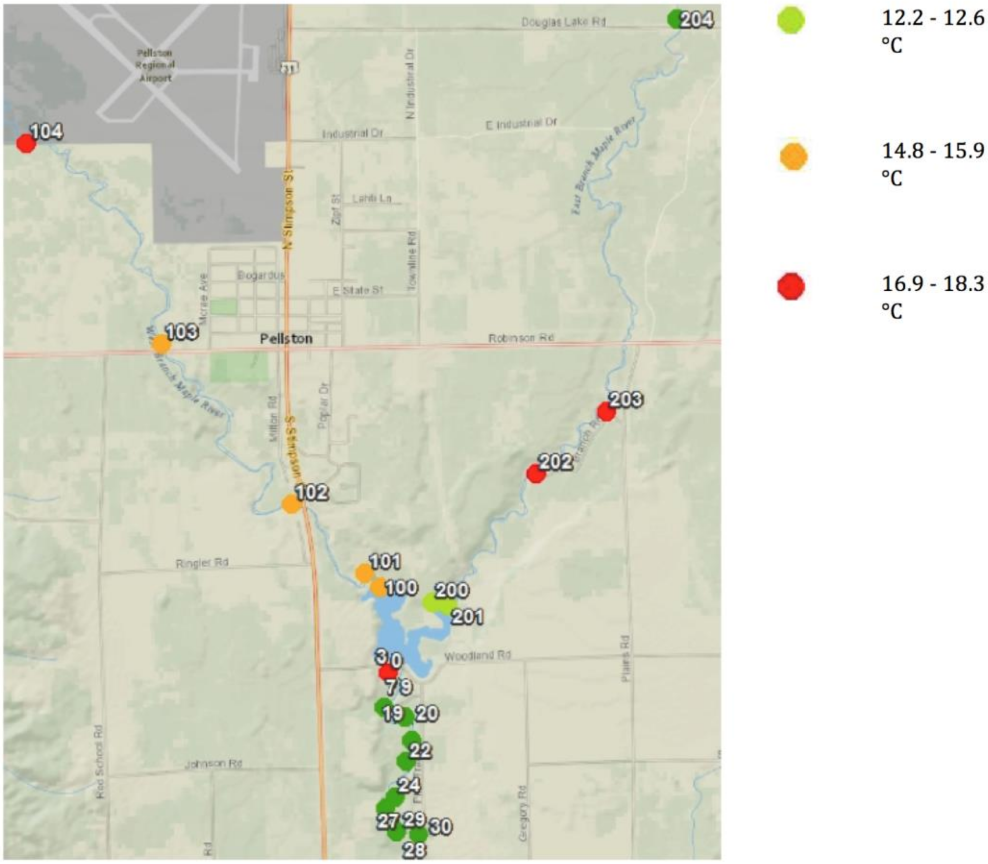

Figure 4 shows the temperature change (ºC) at every site on the maple river. Increments are listed in the key.

Macroinvertebrates

East Branch

The ratio of scrapers and shredders to total collectors revealed that only one site on the East Branch above the dam was autotrophic (Site 202, Table 2). All other sites above the dam appeared to be heterotrophic (Table 2). Every site had a ratio of shredders to total collectors higher than 0.75, which indicated a functioning riparian zone. The ratio of TFPOM to BFPOM was higher than 0.50 based on the ratio of filtering collectors to gathering collectors. Farther upstream the ratio of scrapers and filtering collectors to shredders and gathering collectors was higher than 0.50 indicating the presence of stable substrate. Closer to the delta, the ratios suggested that substrate became unstable (Table 2). Top-down predator control only appeared to be significant at Site 204 based on the ratio of predators to all other functional feeding groups (Table 2).

Figure 5

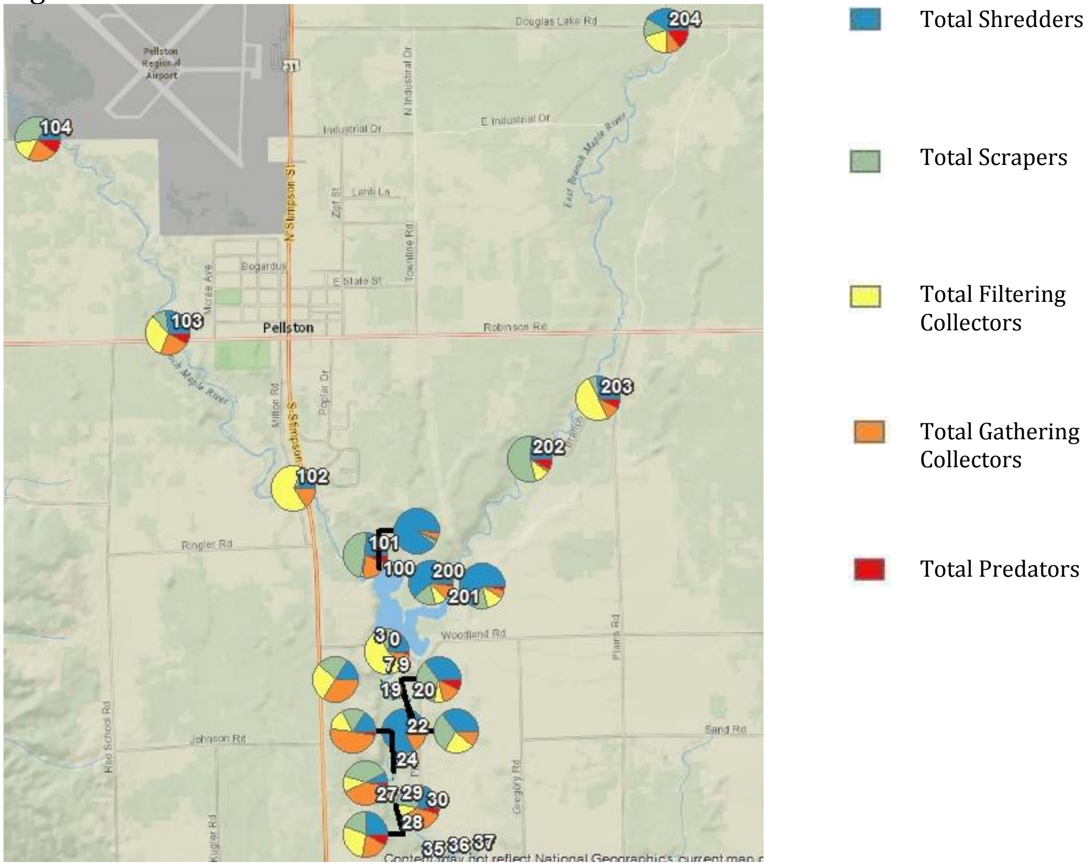

Figure 5 displays the totals of each functional feeding group at each site.

Table 2 shows the macroinvertebrate ratios for the east branch of the Maple River

Functional Feeding Group	**Ratio at Site 200**	**Ratio at Site 201**	**Ratio at Site 202**	**Ratio at Site 203**	**Ratio at Site 204**
Scrapers to Shredders + Total Collectors	0.2069	0.1404	1.5	0.0672	0.1875
Shredders to Total Collectors	3.1429	3.75	1.75	0.4167	1.2857
Filtering Collectors to Gathering Collectors	0.75	2	4.3333	4.6	1.8
Scrapers + Filtering Collectors to Shredders + Gathering Collectors	0.3462	0.3265	2.5484	1.54	0.6522
Predators to Total of all other Groups	0.019	0.0308	0.0818	0.0709	0.1579

West Branch

Above the dam, two sites (Site 101 and 104) were autotrophic and had ratios of scrapers to shredders and total collectors above 0.75 (Table 3). All other sites were heterotrophic. Only one site had a low ratio of shredders to total collectors (Table 3), which indicated a low functioning riparian zone (Merritt and Cummins, 1996). Three sites (102, 103, and 104) had more fine particulate organic matter in the water column than in the two sites closer to the lake (sites 100, and 101). According to the ratios, site 100 was the only location on the West Branch that had unstable substrate (Table 3). None of the sites had top-down predator control, although the site farthest from the delta (site 104) had a ratio of 0.1182, which was the highest of all ratios on the West Branch.

Table 3 shows the macroinvertebrate ratios for the west branch of the Maple River

Functional Feeding Group	**Ratio at Site 100**	**Ratio at Site 101**	**Ratio at Site 102**	**Ratio at Site 103**	**Ratio at Site 104**
Scrapers to Shredders + Total Collectors	0.326	1.0455	0.1068	0.1299	0.746
Shredders to Total Collectors	14.3333	1.0952	0.1134	0.4808	0.4
Filtering Collectors to Gathering Collectors	0.2	0.1053	4.1053	1.4762	0.7308
Scrapers + Filtering Collectors to Shredders + Gathering Collectors	0.044	1.1429	2.9667	0.8913	1.5
Predators to Total of all other Groups	0.0105	0.0667	0	0.092	0.1182

Combined Branch

All sites were heterotrophic downstream of the dam, based on the ratio of scrapers to shredders and total collectors (Table 4). Eight of the nine sites sampled (excluding Site 26) had a high ratio of shredders to total collectors and functioning riparian zones. Site 22, 24, and, 26 had low TFPOM to BFPOM ratios, meaning there was low dissolved carbon. Sites 22 and 24 had unstable substrate due to low ratios of scrapers and filtering collectors to shredders and gathering collectors (Table 4). Top-down control was absent in all of the sites below the dam, based on the ratio of predators to the total of all other groups (Table 4).

Table 4 shows the macroinvertebrate ratios for the combined downstream branch of the Maple River

Functional Feeding Group	**Ratio at**	**Ratio at**	**Ratio at**	**Ratio at**	**Ratio at**	**Ratio at**	**Ratio at**	**Ratio at**	**Ratio at**

	Site 14	**Site 14.5**	**Site 18**	**Site 21**	**Site 22**	**Site 24**	**Site 26**	**Site 27**	**Site 28**
Scrapers to Shredders + Total Collectors	0.28	0.15	0.46	0.41	0.00	0.22	0.63	0.26	0.62
Shredders to Total Collectors	0.26	0.49	1.21	1.32	9.18	0.25	0.14	0.48	0.38
Filtering Collectors to Gathering Collectors	0.79	4.18	2.80	0.46	0.10	0.31	0.28	1.32	0.31
Scrapers + Filtering Collectors to Shredders + Gathering Collectors	0.98	1.51	1.19	0.63	0.01	0.50	1.01	1.04	0.96
Predators to Total of all other Groups	0.01	0.04	0.01	0.09	0.03	0.03	0.02	0.08	0.02

Macrophyte Composition

West Branch

At site 100, *Potamogeton zosteriformis* was dominant and *Elodea canadensis* was also present. Additionally at site 100, we observed a riparian zone to the north with a gradual slope upwards from the riverbank consisting of two layers of plant types. The first layer closest to the river bank was made up of herbaceous plants while the second layer further away from the bank consisted of tall, trembling Aspen (*Populus tremuloides*) trees. The southern riparian zone exhibited a semi-steep slope upwards from the bank and plant life consisting of woody plants, some tall grasses and flat sandy channels. See table 5 for riparian and aquatic plant species and abundances for this site.

At site 101, *Potamogeton frisii* and *Elodea* were the most dominant aquatic plant species. However, many other species were present in the area in relatively high numbers such as *Chara* spp., *Sagittaria latifolia*, *Hippuris vulgaris*, *Vallisneria americana*. The east riparian zone exhibited a very gradual slope and plant life consisting of woody plants and tall grasses. The western riparian zone was dominated by *Carex stricta* and *Phalaris arundinacea* (reed canary grass) both of which are wetland plants (table 5).

At site 102, *Potamogeton friesii* was the most dominant aquatic plant with lower levels of *Chara* also present. The north riparian zone, or the channelizing side of the river, was made up of woody and herbaceous plants with many exposed roots and overhanging northern white Cedar (*Thuja occidentalis*) trees. The depositional side of the river was made up of three layers. The first layer consisted of sand and soil, the second contained tall grasses and herbaceous plants, and the third was made up of woody shrubs, including Speckled Alder (*Alnus incana*).

Table 5 Maple River West Branch Sites 100-102 Riparian Zone and Aquatic Macrophytes

Site	Habitat Type	Plant Species	Ranking
Site 100	Aquatic	*Elodea canadensis*	2
		Potamogeton zosteriformis	3
	Riparian (North)	*Alnus incana*	3
		Myrica gale	3
		Phalaris arundinacea	2
		Fern A	3
		Centaurea maculosa	2
		Solidago altissima	3
		Equisetum spp.	4
		Eleocharis erythropoda	2
	Riparian (South)	*Carex stricta*	4
		Myrica gale	3
		Equisetum spp.	2
		Alnus incana	3
		Asclepias syriaca	2
		Solidago altissima	2
Site 101	Aquatic	*Vallisneria americana*	2
		Elodea canadensis	3
		Potamogeton frisii	3
		Chara spp.	2
		Nitella spp.	1
		Sagittaria latifolia	2
		Nasturtium officinale	1
		Hippuris vulgaris	2
	Riparian (East)	*Alnus incana*	4
		Carex stricta	4
		Phalaris arundinacea	3
		Asclepias syriaca	1
		Cladium mariscoides	1
		Equisetum spp.	1
		Carex bebii	1
	Riparian (West)	*Carex stricta*	4
		Asclepias syriaca	2
		Alnus incana	2
		Scirpus cyperinus	1
		Carex bebii	1
		Phalaris arundinacea	3
		Sagittaria latifolia	1

Site 102	Aquatic	*Vallisneria americana*	1
		Nasturtium officinale	1
		Plant B	1
		Potamogeton frisii	3
		Chara spp.	2

East Branch

At site 200, the northeast riparian zone was about 2 meters wide with a mix of herbaceous and woody wetland plants. *Solidago altissima* (Common Goldenrod) and *Myrica gale* (Sweet gale) were dominant (Table 6). The southwest riparian zone was roughly 10 meters wide and had a very steep slope. The southwest riparian zone was found on the channelizing side of the river; thus, the river cut into the soil along the riverbank, causing trees to angle toward the water along the erosion line. Tall trees with a mix of woody shrubs and herbaceous plants were dominant at the southwest riparian zone, including ferns, *Calamagrostis canadensis* (bluejoint grass), *Pinus strobus* (white pine), *Alnus incana* (speckled Alder), and Genus *Quercus* (Oak). *Elodea canadensis* was dominant in the aquatic habitat and found near cold seeps in which groundwater enters the system through the depositional layer (see table 6 for aquatic habitat plant abundances).

At site 201, *Vallisneria americana* (water celery) was most abundant in the aquatic habitat (table 6). The north riparian zone characterized by a large, sandy bank with tall grasses and other wetland plants. *Eleocharis II* was dominant in the north riparian zone as well (table 6). The south riparian zone was a 2-meter wide slope with overhanging woody trees and shrubs mixed with a small amount of herbaceous plants. *Alnus incana* (speckled Alder) was dominant, *Calamagrostis canadensis* (bluejoint grass) and *Asclepias syriaca* (common Milkweed) were also present, and *Populus tremuloides* (trembling Aspen) was found higher up the riverbank from the riparian zone.

At site 202, *Vallisneria americana* (water celery) was dominant and *Potamogeton richardsonii* (Richardson's pondweed) was also plentiful in the aquatic habitat (table 6). The first layer of the north riparian zone within the floodplain was mainly herbaceous with *Calamagrostis canadensis* (bluejoint grass), *Asclepias syriaca* (common Milkweed), *Phalaris arundinacea* (reed canary grass), tall grasses, ferns, and sparse woody shrubs present. Woody shrubs, including *Alnus incana* (speckled Alder) dominated layer 2 of the north riparian zone. The south riparian zone was on the depositional side of the river and was split into three sloped layers. The first layer consisted mainly of soil with herbaceous plants, including short grasses and *Sagittaria latifolia* (common arrowhead). The second layer was a mix of woody and herbaceous plants, including tall grasses, small amounts of *Asclepias syriaca* (common Milkweed), and *Phalaris arundinacea* (reed canary grass). Woody shrubs, including *Alnus incana* (speckled Alder), dominated layer 3.

Table 6 Maple River West Branch Sites 200-202 Riparian Zone and Aquatic Macrophytes

Site	Habitat Type	Plant Species	Ranking
Site 200	Aquatic	*Vallisneria americana*	2
		Potamogeton richardsonii	3
		Elodea canadensis	5
		Sagittaria latifolia	1
		Potamogeton zosteriformis	3
	Riparian (NE)	*Carex stricta*	2
		Asclepias syriaca	1
		Calamagrostis canadensis	2
		Solidago altissima	4
		Myrica gale	4
		Centaurea maculosa	2
		Alnus incana	2
Site 201	Aquatic	*Vallisneria americana*	3
		Potamogeton richardsonii	2
		Elodea canadensis	2
		Potamogeton frisii	2
		Plant B	1
		Chara spp.	1
		Nitella spp.	1
	Riparian (North)	*Carex stricta*	5
		Eleocharis palustris	2
		Scirpus validus	2
		Phalaris arundinacea	3
		Scirpus cyperinus	1
		Eleocharis erythropoda	4
		Typha latifolia	1
		Cladium mariscoides	1
		Sagittaria latifolia	1
Site 202	Aquatic	*Vallisneria americana*	4
		Potamogeton richardsonii	3
		Elodea canadensis	2
		Potamogeton frisii	2
		Chara spp.	3

Discussion

Physical Changes

An immediate and noticeable change after the removal of the Maple River Dam will be the disappearance of Lake Kathleen. As the lake drains, sediment will be washed downstream and we expect erosion in the bed and on the banks of the of the newly formed river channel as well as on riverbanks downstream. The newly exposed areas of the lakebed will become part of the riparian zone. Additionally, the delta areas in the transitional zone between the river and lake will be washed free of fine sediment. When the dam is initially removed, high velocity water will suspend fine particulate matter, and deposit that sediment in bends of the river where water slows.

We predict that erosion of the newly formed riverbed will lead to increased suspension of sediments and fine particulate organic matter. When these suspended particles enter the combined branch downstream of the dam, we predict that they will erode the outside of the bend and sedimentation will form a slip-off slope on the inside of the bend. The sedimentation and erosion may change the meandering pattern of the river. Additionally, the increase in ion and nutrient concentration in the water column will lead to increased conductivity and primary productivity. Scouring and sedimentation from the suspended matter will disrupt habitats. Algal blooms may result from nutrients released by soil erosion.

Currently, discharge increases from upstream to downstream in both branches and is highest in the combined river after the dam, due to combined groundwater input and surface water input from Lake Kathleen. We predict that after dam removal, the combined river discharge will decrease resulting from the loss of Lake Kathleen.

Upstream of Lake Kathleen, the river branches have relatively low temperatures associated with groundwater input. Conversely, Lake Kathleen has higher temperatures due to high residence time and prolonged solar heat exposure. This warm surface water from the lake flows into the river causing increased temperatures below the dam. On the other hand, pressure from Lake Kathleen forces water to seep through the berm supporting the lake into the river below as cold groundwater.

Therefore, the predicted temperature of the river is not straightforward as both the reduction of surface water and reduction of groundwater seepage will affect the temperature of the river downstream. The temperature of the combined branch will be directly related to the average temperature of the two upstream branches because the downstream combined branch is fed solely by the joining of the west and east branches.

Another possible prediction is that the temperature directly after the dam will decrease, due to decreased surface water input, while temperatures farther downstream will increase due to decreased groundwater input.

Macroinvertebrates

Macroinvertebrate functional feeding groups reflect the substrates, microhabitats and carbon sources available in a given area of the river. Thus, the data collected and ratios calculated help us understand the current river ecosystem. We can predict changes to macroinvertebrate communities based on predicted physical changes.

Upstream of the dam, macroinvertebrate populations will not be affected as severely by the dam removal. However, the channelization of the East and West Branch deltas will likely alter the existing ratios of functional feeding. We predict that the initial erosive changes at the deltas will result in higher levels of fine particulate organic matter transport reflected by a greater than 0.50 ratio of filtering collectors to gathering collectors. Later, we expect to see an increase in stable substrate, which will result a ratio of scrapers and filtering collectors to shredders and gathering collectors to be less than 0.50.

Macroinvertebrate communities are not a dominant characteristic of Lake Kathleen as there is little oxygen and sunlight available to the benthic zone of the lake. However, once the lake drains, the newly established river channel will support habitat for macroinvertebrates. We expect lower ratios of scrapers to shredders and total collectors, indicating a heterotrophic system. Further the substrates present will be sandy sediments and ratios less than 0.50 of scrapers and filterers to shredders and gatherers will reflect low substrate stability. The establishment of macroinvertebrate communities will reflect the establishment of the new riparian zone, as new allochthonous input replaces the autochthonous lake.

The first risk to macroinvertebrate populations below the dam will be the influx of sediment moving from the lake into the combined branch. Increased sedimentation will lead to macroinvertebrate habitat loss, suffocation or starvation. Starvation may occur if the nets of filtering collectors fill with sediment, algae is scoured off of rocks, or macrophages are buried. These outcomes result in high death rates across all functional feeding groups.

Despite the initial decrease in population, macroinvertebrates have fast recovery rates due to their short life history and high reproduction rates (Doyle, et al. 2005). Macroinvertebrate recovery will also depend on the rate at which habitats recover, or new ones become available. Some macroinvertebrates, such as mussels, have long life spans and low turnover rates. The impact of the disturbance will be most severe on macroinvertebrates with low turnover rates because the population will not recover as quickly from the initial impact of sedimentation and scouring that results from the loss of the dam (Doyle, et al. 2005).

Macrophytes

The loss of stagnant water when the dam is taken out will alter the habitat that was formerly occupied by lake plants such as *Myriophyllum spicatum* (Eurasian watermilfoil) and *Nuphar polysepala* (spatterdock). The loss of flowing-water habitats near the delta will also negatively impact aquatic plant species. For submerged aquatic plants in zones susceptible to drying out, the dam removal will likely lead to decreases in habitat size. Macrophytes such as *Elodea canadensis* or *Vallisneria americana* (water celery), which must be submerged in order to thrive, will likely suffer extreme population drops. Previous studies have shown that disturbed areas with low vegetation and nutrient rich soil are vulnerable to invasive species (Orr & Stanley, 2006).

Once the dam is removed, previously submerged reservoir sediments will be exposed due to narrowing of the riverbed (Shafroth et al., 2002). Years of carbon and nutrient deposition at the bottom of Lake Kathleen should leave behind rich soil, which will support vegetation. Initial vegetation is likely to be fast proliferating weeds with high reproductive rates and effective dispersal mechanisms (Doyle et al., 2005). Following initial repopulation we predict two distinct scenarios could occur in the area left behind when Lake Kathleen is drained. Reeds, sedges, or other emergent vegetation could proliferate in the new riparian zone. In this case, the area will become a floodplain and have a wetland ecosystem, without much bank stabilization (Doyle et al., 2005). Another possibility is succession by terrestrial plants such as grasses, shrubs, and ferns. After many years, the area could become forested, leading to much greater bank stabilization and thereby less erosion (Doyle et al., 2005). Continued sampling will reveal what successional pathway the new riparian zone will follow.

Depending on the riparian vegetation that takes over once the dam is removed, substrate stability will change following dam removal (Doyle et al., 2005). If the riparian zone along the Maple River becomes dominated by r-selected vegetation like grasses, the substrate would be less stable compared to if more k-selected plant species like trees dominate. The substrate stability will have a strong effect on what kinds of aquatic plants will be able to thrive following dam removal.

Furthermore, the removal of the Lake Kathleen will cause high levels of erosion and deposition of fine-grained sediment downstream. For the aquatic macrophytes we sampled upstream, the primary ecosystem changes will be determined by riparian activity following dam removal. However, downstream from the dam, the deposition and scouring of sediment will likely reduce available sunlight and oxygen required for aquatic plant life. Following sediment deposition from the dam removal, we predict that the previous aquatic macrophytes will be lost, and a new fine-substrate—substrate with smaller overall grain size—habitat will be available for succession. It is possible that some algae and aquatic plants seen upstream will quickly colonize this new habitat through downstream transportation (Hart et al., 2002).

It should be noted that riparian succession and vegetation dynamics will be unique to each site on the Maple River and are also river-specific. Differences in soil composition, surrounding vegetation, and location from the former site of the dam will factor into how quickly the riverbanks are restored (Orr & Stanley, 2006).

Future Research

Chemical analysis of the river and lake would complete our understanding of this system's nutrient cycle. Groundwater measurements would allow us to predict the change in total discharge after the dam removal. Finally, analysis of the fish community composition would contribute a fuller understanding of the trophic and non-trophic interactions between fish and macroinvertebrates. This paper inventories the Maple River ecosystem in hopes that this information will be used in the future to track the changes of dam removal. Therefore, the most valuable additional research will be the future studies completed after the dam has been removed.

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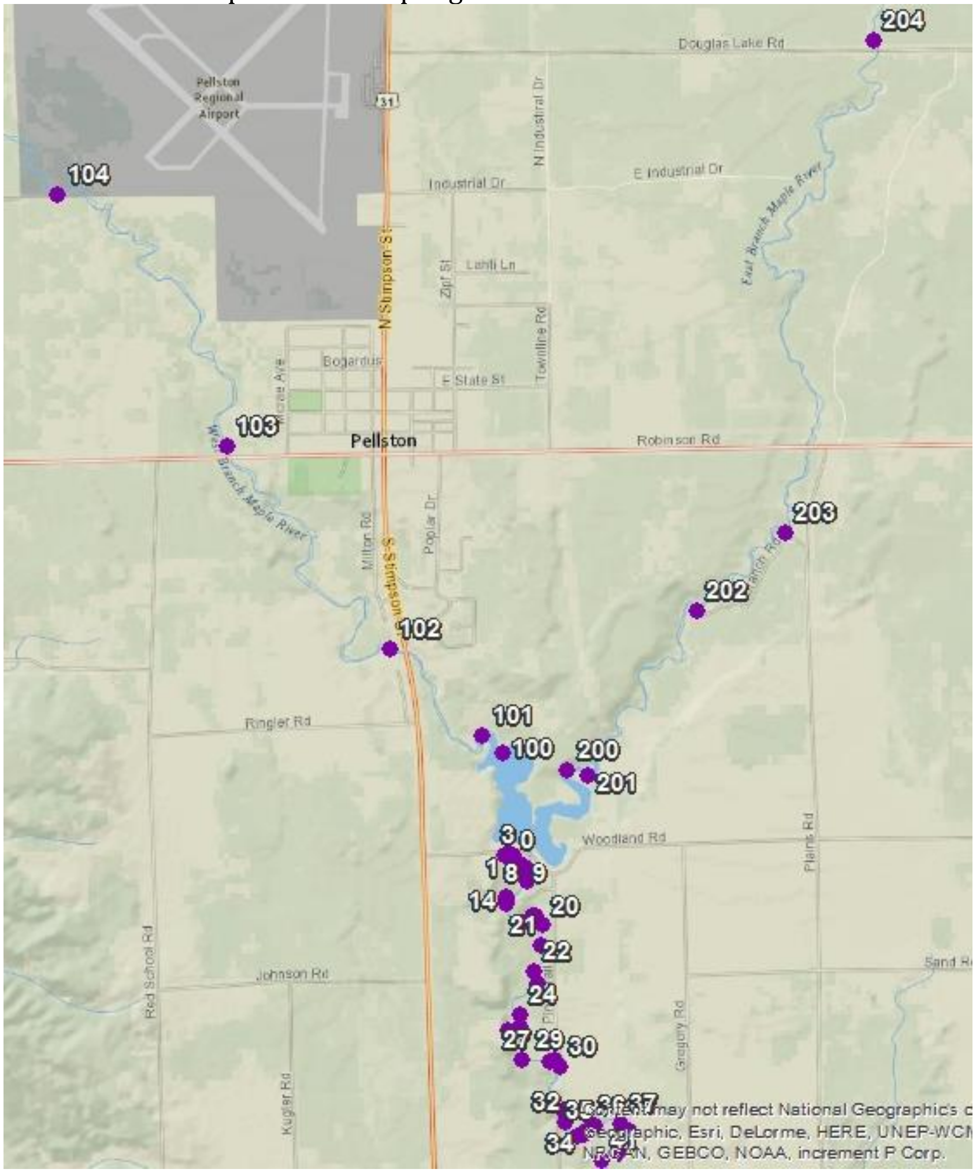
Appendix

Attachment A: Maple River Sampling Sites



Attachment B: Autotrophic to Heterotrophic Ratio

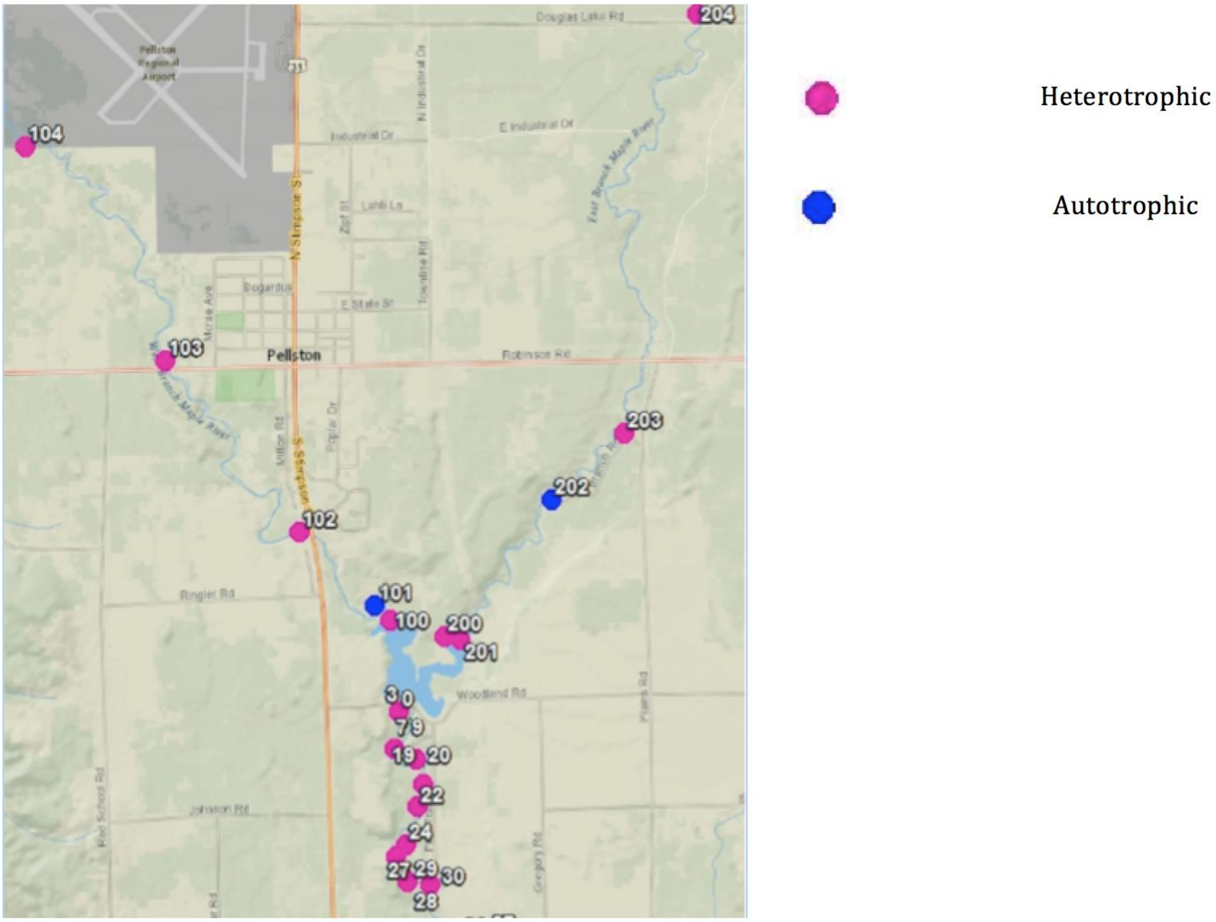


Figure Notes: The ratio of scrapers to shredders + total. Heterotrophic is considered less than 0.75, autotrophic greater than 0.75

Attachment C: Suspended Particulates

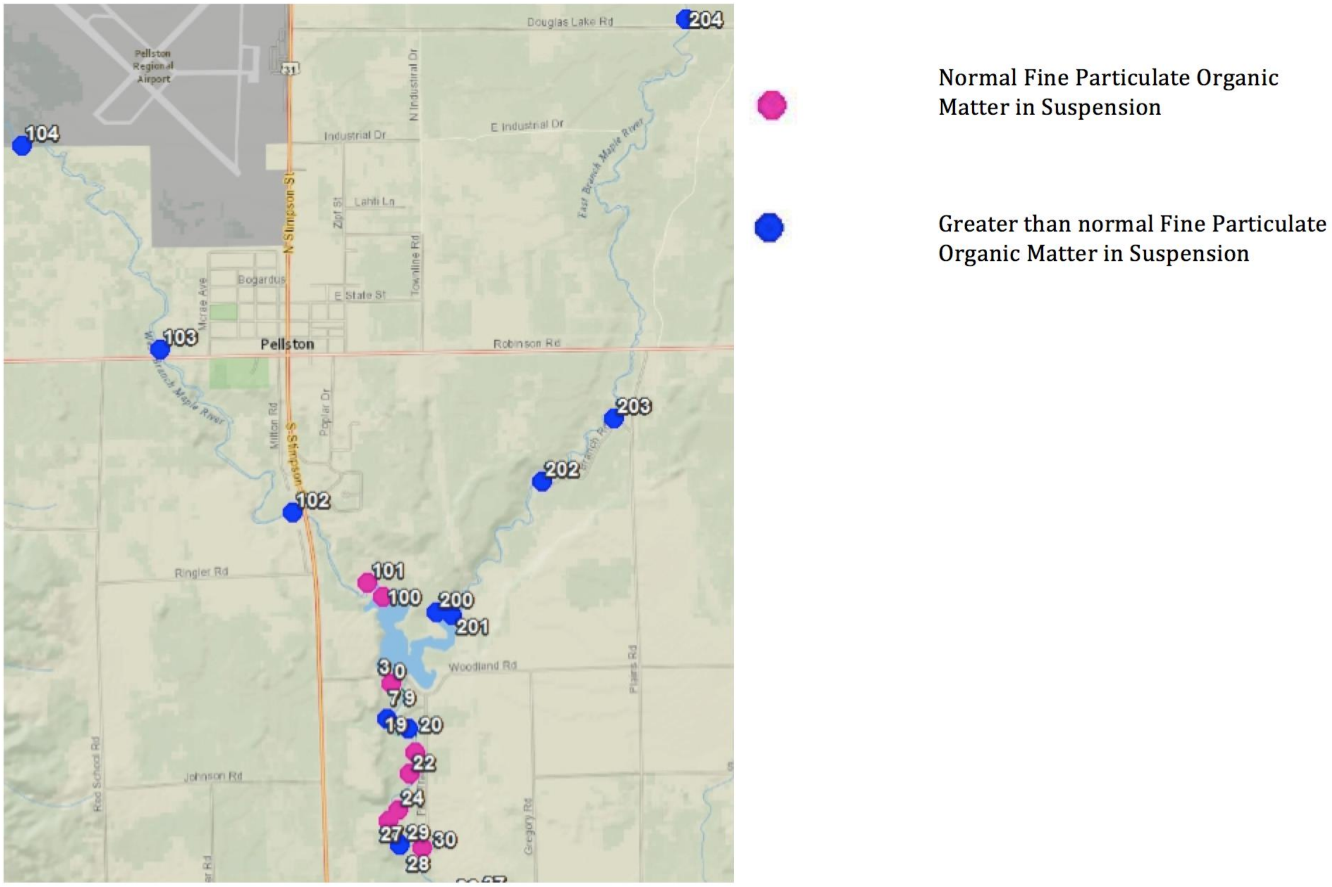


Figure Notes: The ratio of filterers to total collectors. A ratio over 0.5 is considered to have high fine particulate matter in the water column rather than on the riverbed.

Attachment D: Riparian zone

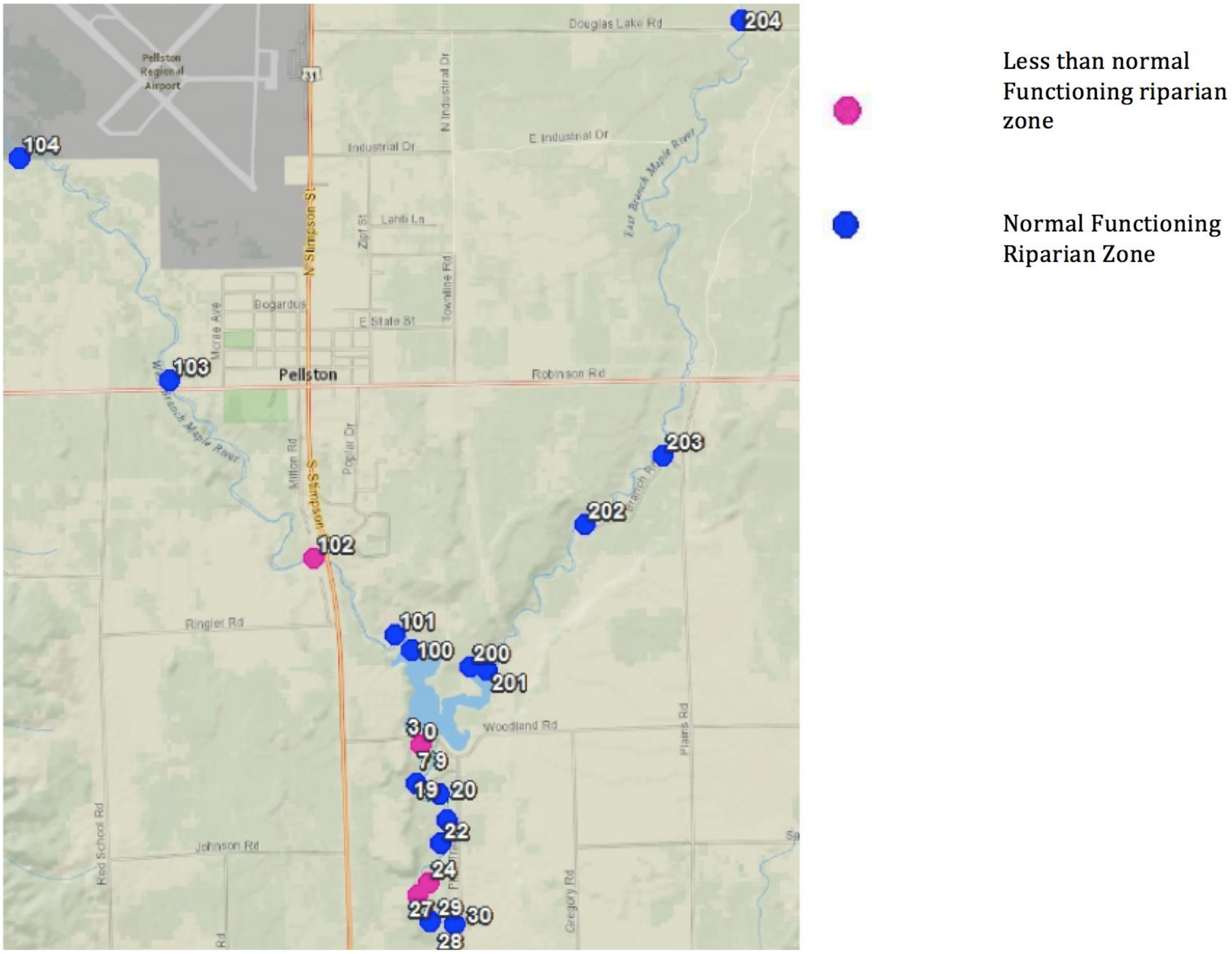


Figure Notes: Ratio of shredders to total collectors. A ratio of greater than 0.25 indicates a normally functioning riparian zone.

Attachment E: Substrate Stability

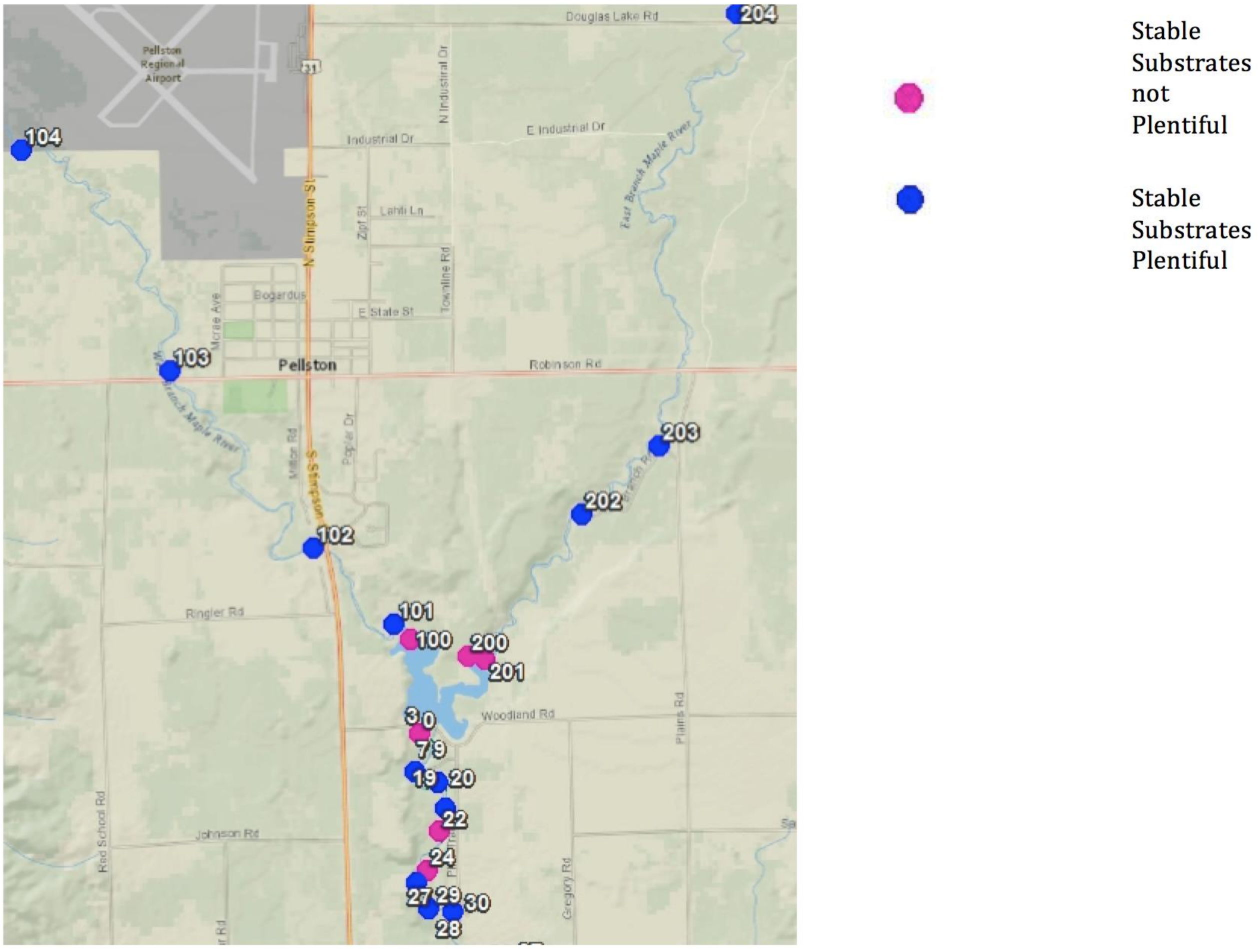


Figure Notes: Ratio of scrapers and filterers to shredders and gatherers. A ratio greater than 0.5 indicates stable substrates.

Attachment F: GPS coordinates for each site sampled

Site 100	45.534475, -84.775587
Site 101	45.535472, -84.777128
Site 102	45.540095, -84.783707
Site 103	45.550944, -84.796472
Site 104	45.572778, -84.745167
Site 200	45.533227, -84.770669
Site 201	45.533186, -84.768440
Site 202	45.541862, -84.759971
Site 203	45.541917, -84.760194
Site 204	45.572778, -84.745167
Site 14	45.526171, -84.775514
Site 14.5	45.526212, -84.775456
Site 18	45.525507, -84.773475
Site 21	45.523895, -84.772776
Site 22	45.522443, -84.773392
Site 24	45.520046, -84.774553
Site 26	45.519217, -84.775430
Site 27	45.517603, -84.774411
Site 28	45.517440, -84.772230