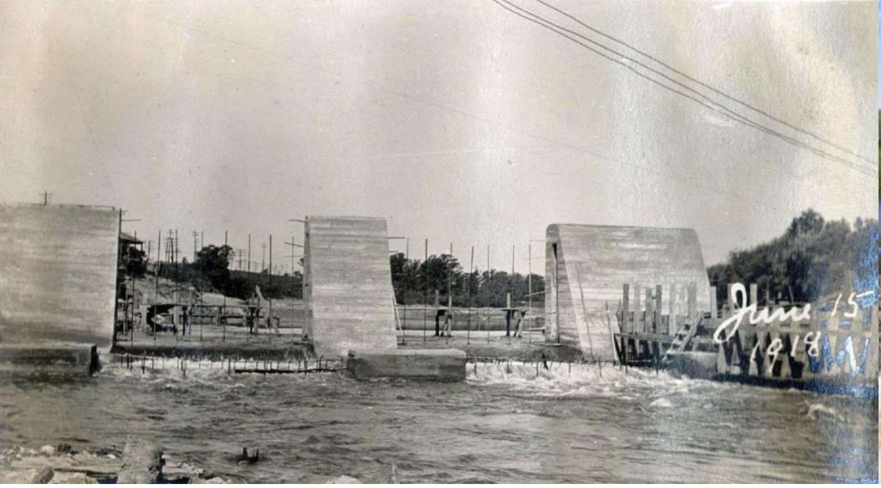

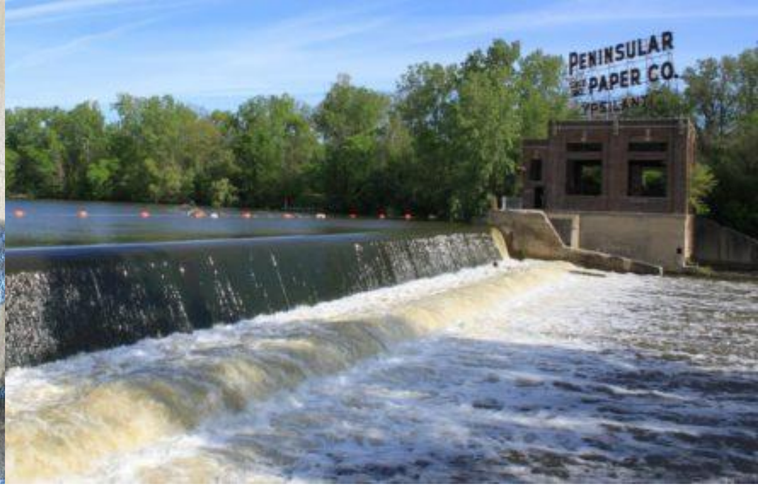

PENINSULAR PAPER DAM: DAM REMOVAL ASSESSMENT AND FEASIBILITY REPORT

HURON RIVER, WASHTENAW COUNTY, MICHIGAN

SEPTEMBER 2018

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Cover Photo Credits: Left: Ypsilanti Historic Society. Reconstruction of Peninsular Paper Dam, June 15, 1918, after full dam failure earlier that year. Right: MarkMaynard.com. Peninsular Paper Dam and powerhouse.

Introduction

The Huron River Watershed Council (HRWC) and the City of Ypsilanti are exploring the options for the future of Peninsular Paper Dam, the revitalization of the Peninsular Park, and the long-term restoration of the Huron River. The goal of this study is to assist the dam owner, who is interested in exploring dam removal, in the decision-making process by completing the initial preliminary studies to determine the feasibility of dam removal.

HRWC and the City of Ypsilanti have contracted with Princeton Hydro to assess three critical issues that strongly affect the feasibility of removing Peninsular Paper Dam: (i) sediment quality and quantity, (ii) potential infrastructure/utilities impacts, and (iii) riverfront land ownership. This study culminates in a conceptual design for dam removal and an estimate of construction cost.

To ensure community and stakeholder involvement through this process, HRWC has convened a working group with representatives from Ypsilanti Township, City of Ypsilanti, Superior Township, and Friends of Peninsular Park. Michigan DEQ has also provided guidance and background information in the planning stages of this project. From this initial feasibility assessment, HRWC anticipates continuing to work with the local community stakeholders to shape the vision of a successful river restoration project, and to identify the next steps including additional data collection and analysis.

This targeted study intentionally does not encompass all tasks that are typically completed for comprehensive feasibility assessments, alternatives analyses, engineering designs, permitting, and construction, such as: detailed professional survey of the dam, bridges, and associated structures; wetland delineation and resource assessment; bathymetric survey of the impoundment; hydraulic modeling; engineering design and plan set preparation; engineer's estimate of probable cost; permit preparation; or, construction specifications. Rather, those tasks have been deferred to a later phase, pending the outcome of this targeted assessment.

This study does not include an assessment of the feasibility for hydropower generation. The potential for hydropower generation has been considered for Peninsular Paper Dam in the past and ultimately was dismissed. From 2008 to 2010, the City of Ypsilanti had considered the potential of restoring Peninsular Paper Dam for hydropower generation and selling the power to the local Eastern Michigan University. Representatives of Eastern Michigan University expressed interest in purchasing the power at rates cheaper than their existing supplier and promoting the University's shift toward a "greener" alternative energy source. However, the City was unable to resolve the complications to restoring generating capacity of the dam, so no agreement was reached. In 2012, the City was contacted by a local business owner who was considering building a facility on the Peninsular Paper Dam site and spending up to $1 million to restore the generating capacity of the dam; however, in 2013 the business owner lost interest without reaching an agreement with the City.

While this study is not an assessment of hydropower potential, the City of Ann Arbor provides an example of regional trends in hydropower. The City owns four dams on the Huron River: Barton, Argo, Geddes, and Superior; two of the dams (Barton and Superior) generate hydroelectric power. The City commissioned a hydroelectric redevelopment feasibility study for both the Argo and Geddes Dams (Appendix A, dated 2008). At its core, the study considered the power production potential (based on hydraulic head, river flow, and plant efficiency), capital costs, indirect costs, and conceptually recommended a specific type of turbine. A follow-up study was commissioned (Appendix A, dated 2010) that entailed an economic evaluation based on current energy rates, and a present worth analysis; the report concluded that the Geddes Dam was preferable to the Argo Dam for redevelopment. To date, neither dam has been re-powered. In 2018, The City of Ann Arbor had approved over $500,000 to overhaul Barton Dam by replacing and rebuilding the turbine and equipment.

Three Critical Issues

While dam removal often encompasses multiple technical and social issues, this feasibility study is intentionally focused on three critical issues -- (i) sediment quality and quantity, (ii) potential infrastructure/utilities impacts, and (iii) riverfront land ownership -- that have the potential to render dam removal infeasible, and thus, justify no further investigation. Dam removal will likely result in the mobilization and downstream transport of impounded sediment, and the exposure of formerly inundated sediment on the floodplain. As pollutants tend to bind to and accumulate in impounded sediment, this study investigates sediment quality to assess the potential adverse impacts to living organisms and humans. Regardless of quality, excessive sediment quantity can adversely impact downstream reaches by burying stream bottom habitat, filling pools, or potentially raising flood elevations. In addition, removal of a 17 ft-high spillway has the potential to initiate changes in the river, primarily upstream of the dam, that could adversely impact existing structures, for example, by undermining bridges. This study identifies those components of public infrastructure, assesses how they could be impacted, and what counter-measures would be necessary. Finally, the impoundment of Peninsular Paper Dam has multiple riverfront landowners that could be affected by dam removal and the resulting change in the water's edge. This study identifies these properties and assesses how they would be affected by the reduction in water depth and reversion to a free-flowing river channel. Following careful assessment, this study concludes that none of these critical issues renders dam removal infeasible.

Firm Overview

Princeton Hydro, LLC is a small business enterprise that provides unparalleled consulting services for the analysis, design, and implementation of water resources engineering and ecological restoration projects. The unique skills and cumulative expertise of our experienced, multidisciplinary staff of engineers and scientists are reflected in the creative nature of Princeton Hydro's projects and our ability to deliver comprehensive ecosystem-based solutions. Our staff include individuals with academic training and project experience stakeholder engagement, hydrology and hydrogeology, aquatic and wetland ecology, fishery biology, population and community ecology dynamics, environmental planning, dam safety and decision making, green infrastructure, geotechnical design, and environmental risk analysis. Our staff's unique perspectives are apparent in the innovative nature of many of our projects, especially in the disciplines of aquatic and wetland ecology, environmental engineering, and watershed management.

Site Description

Peninsular Paper Dam is located on the Huron River in Ypsilanti, Michigan (Washtenaw County) (latitude: 42.25605, longitude: - 83.6241). The original structure was completed in 1867 to provide power for paper manufacturing. The dam failed in 1918 and was rebuilt two years later. The powerhouse is a prominent feature in the area topped by its iconic, free-standing letters spelling "PENINSULAR PAPER CO. SINCE 1867 YPSILANTI." The dam is classified as a concrete gravity dam that measures 16 feet high with crest length of 290 feet; of which 250 feet is the concrete spillway. The spillway sill extends approximately 25 feet downstream of the crest. The river left (north) end of the spillway ties into a low-level outlet structure, or "floodgate." Historic photos taken during construction show the bottom of this structure nearly equal to the bottom of the spillway, with a large metal swing gate; however, the engineering plans dated 1983 show this floodgate was replaced with a stop-log structure. The spillway and low-level outlet structure tie into the powerhouse; concrete retaining walls extend downstream from the powerhouse over 170 feet. On the river right side (south), the spillway ties into a large retaining wall that is approximately 21 feet in height, stands 5 feet above the spillway crest, extends approximately 60 feet downstream, and extends approximately 70 feet upstream around the perimeter of the impoundment. Downstream of the spillway, second retaining wall parallels the primary retaining wall, and is set 15 feet behind and extends approximately 112 feet downstream. The area of the impoundment measures 177 acres, and extends approximately 6,575 feet upstream of the spillway to approximate station 82+25 on the profile, which is 1,722 feet downstream of the Superior Dam, the next upstream dam. Approximately 37 properties abut the impoundment. The impoundment is crossed by two causeways/bridges. The Connrail Railroad Bridge crosses the impoundment approximately 3,210 feet upstream of the Peninsular Paper Dam; the Superior Road Bridge crosses the impoundment approximately 4,910 feet upstream of the dam. The dam site is accessible from the northern side on public property, Peninsular Park, from Leforge Road, which crosses the Huron River approximately 450 feet downstream of the dam.

The dam structure, Peninsular Park, and the lower portion of the impoundment lies within the City of Ypsilanti; a central portion of the impoundment lies within Ypsilanti Township; the upper portion of the impoundment lies within Superior Township. The dam no longer generates power, and all electricity-generating equipment has been removed from the powerhouse. The City of Ypsilanti now owns the dam and powerhouse.

The dam has a "*high*" hazard potential classification, as classified by the US Army Corps of Engineers. Hazard classification relates to the degree of adverse incremental consequences resulting from a failure or mis-operation of a dam. The hazard potential classification does not reflect in any way the current condition of the dam (e.g., safety, structural integrity, flood routing capacity). Dams assigned the high hazard potential classification are those where failure or mis-operation will probably cause loss of human life (2004 Federal Guidelines for Dam Safety). In the state of Michigan, high hazard dams require dam inspections by a licensed professional engineer every three years and the development of an Emergency Action Plan, that describes the actions to be taken in the event of a potential dam failure. The most recent Dam Safety Inspection Report for the dam was completed in July 2016 by the Hydrologic Studies and Dam Safety Unit of the Michigan Department of Environmental Quality. The report concluded that the dam is in "*fair*" condition and requires the City to provide a plan for how it will address the deficiencies identified in the report. An Opinion of Probable Construction Cost completed by OHM Advisors in 2014 totaled approximately $659,000 for repairs and demolition of the powerhouse, which with inflation, would now likely exceed $750,000.

The dam is being considered for removal for a variety of reasons. The dam no longer generates power or serves an economic purpose to offset the required immediate repairs and ongoing maintenance. The removal of the spillway would (i) deregulate the dam and remove any owner obligation for repair and ongoing inspections and maintenance as per dam safety regulations; (ii) greatly reduce the public safety hazard and legal liability to the owner; (iii) likely result in improved water quality for this reach of Huron River, such as temperature moderation and increased dissolved oxygen; (iv) restore the existing impoundment to over 1-mile of free-flowing river (and associated fishery) with an adjacent vegetated floodplain; and, (v) reconnect over 2 miles of river that have been isolated for over 100 years.

Review of Existing Files and Historical Documents

Princeton Hydro has received, compiled and reviewed dozens of files including plans, reports, and historic photos. An inventory of files is included as Appendix A, and digital copies can be provided upon request. Historic photos, particularly of the 1918 dam failure and subsequent re-construction have been especially informative of the current spillway material and dimensions, and provided hints of the floodplain and channel form in the existing impoundment.

Sampling and laboratory analysis of sediment impounded behind Peninsular Paper Dam has been conducted at least one time in the past. In 2013, six sediment samples were collected from throughout the impoundment and analyzed for a range of common contaminants. A sample location map, and summary table of results are included in Appendix A and discussed further in the subsequent section regarding sediment quality.

Engineering plans of the bridges that span the impoundment have been crucial in learning the depth of foundations to assess vulnerability to river channel erosion following dam removal, as discussed in subsequent sections.

Since initiating this project, HRWC has coordinated several in-person meetings with project partners and community stakeholders. An early meeting was held in May 2017 and included a site visit. Several following stakeholder meetings/conference calls were convened to discuss available data and potential concerns, to provide updates on the fieldwork and ongoing assessment, and to discuss initial findings.

Field Investigation, Survey, and Observations

Princeton Hydro fluvial geomorphologist and SME professional surveyor completed an investigation of the site and impoundment on April 15 and 16, 2018. The investigation, completed mostly from a motorized jon boat, included manual probing and survey of sediment within the impoundment, and selected survey of the dam spillway, abutments, and the two bridges crossing within the impoundment (Railroad Bridge and Superior Road Bridge).

Topographic survey shots (coordinates and elevations) were captured by SME utilizing survey-grade RTK GPS with a cell-phone connection to a local base-station. Survey coordinates and elevations were processed following a least squares adjustment that generates precision of approximately 0.02’ of a foot. Coordinates are presented in North American Datum 1983, state plane, feet (NAD83); elevations are reported North American Vertical Datum 1988, feet (NAVD88). Survey of the dam spillway established the real-world elevation of the low chords and abutments of both bridges, and the spillway crest (712.4’ NAVD88). Sediment probing was conducted by measuring with graduated range rods down from the boat to the top of sediment and manually driving the rod to resistance. Surveyed elevations of manual probings, and selected structures are depicted in the project basemap (Appendix B, Existing Conditions) and the longitudinal profile of the dam and impoundment (Appendix B, Profile); all survey data are contained within an AutoCAD Civil3D drawing file.

The field investigation identified locations of features and structures that may influence the dam removal decisions, including valley walls, slope instability, low vegetated floodplains, maintained yards, eroding banks, banks stabilized with stone or retaining wall, stormwater outfalls; all of which are plotted on the project basemap (Appendix B, Existing Conditions). Steep slopes, particularly about 4,000 feet upstream of the dam on river left, showed signs of slope failures above the normal water surface elevation. Manual sediment probing established the location of a legacy thalweg (i.e. deepest part of the original riverbed channel) and the likely former river alignment, as well as the distribution, depth and general grain size class (clay, silt, sand, gravel, cobble, boulder) of impounded sediments. Sediment in and around the legacy thalweg was coarser in nature, generally coarse sand and gravel; whereas, sediment outside of the thalweg and on the impoundment margins was finer, sand, silt, and clay. The legacy thalweg, which is plotted in the longitudinal profile, contained the least unconsolidated sediment, with the lowest elevations of top of sediment. At the dam, top of sediment was approximately 11 feet below the crest of the spillway, and was approximately 4 feet in thickness. Sediment depth in the thalweg diminished in the upstream direction, as is typical, to zero feet at approximately 6,000 feet upstream of the dam, which is approximately 1,000 feet downstream of the upstream extent of the impoundment. Interestingly, there were no deposits of unconsolidated sediment located under either of the bridges, indicating that the bridges create hydraulic constrictions that cause scour and prevent the deposition of impounded sediments. Plotting and analyzing the manual probing data in longitudinal profile (Appendix B, Profile) strongly indicates that the depth of bottom of sediment throughout the impoundment is at an original river bottom and very closely approximates the equilibrium channel profile that the river would return to following dam removal (Appendix B, Profile and Concept Dam Removal Design).

Areas away from the thalweg exhibited higher top of sediment elevations and greater sediment depth, commonly 4 to 5 feet, with a maximum of 7 feet. These sediment depths are markedly low compared to the spillway height of 16 feet. The low depths of sediment accumulated in this impoundment may be the result of the full dam failure and sediment release in 1918, as well as the presence of multiple large upstream dams on the river that serve as near total sediment traps and reduce the overall sediment load (bedload and suspended load) of the River.

Vibracoring and Sediment Sampling

Vibracoring was completed by Limnotech and a subcontractor on July 17, 2018 as detailed in the memo Appendix D. The vibracoring system, mounted to a 20-foot pontoon boat, mechanically drove 3-inch diameter polycarbonate cores into the sediment until reaching resistance. Vibracoring is an effective mechanical method of extracting full depth sediment cores from deep water and deep sediment. In addition, vibracoring can provide important confirmation regarding the depth of impounded sediment, and the depth (i.e. elevation) of reservoir bottom / original riverbed. Vibracores were completed in 10 pre-selected sampling locations, to capture the depth of impounded sediment adjacent to bridges and where the river channel is likely to reform following dam removal.

Sediment cores were characterized by soil texture, color, and composition; observations were recorded in core logs. Cores were also scanned using a photo-ionization detector (PID). Sediment thickness ranged from 0.9 to 5.9 feet; core recovery ranged from 0.8 to 5.9 feet. Samples for laboratory analysis were extracted and composited from selected core intervals. Two additional sediment grab samples were extracted directly from the river bed upstream of the impoundment and downstream of the dam; while not directly affected by dam removal, upstream and downstream sediment samples provide context for the impounded sediment and assist with categorizing background or ambient concentrations of contaminants. Sediment samples were stored in a cooler with ice and transferred to Brighton Analytical laboratories of Brighton, Michigan.

Analysis of Sediment Samples

Samples were analyzed for the following parameters based on guidance from Michigan DEQ:

- Metals: Mass-Based Analysis for metals
    - Arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc
- Polynuclear Aromatic Hydrocarbons (PNAs)
- Total PCBs
- Grain size
- Total Organic Carbon
- Moisture Content

These results have been compared against:

- Human Health Criteria: Michigan Residential Direct Contact,
- Ecological Criteria: Freshwater Sediment Probable Effect Concentrations (PEC) from MacDonald, Ingersoll, and Berger[1].

[1] MacDonald, DD, Ingersoll, CG, and Berger, TA. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology. 39:20-31.

The Freshwater Sediment Probable Effect Concentrations are the consensus-based, freshwater sediment quality guidelines compiled by MacDonald and Ingersoll[2] and compiled in the NOAA 2008 Screening Quick Reference Tables (SQuiRTs). Consensus-based Sediment Quality Guidelines (SQGs) have been developed to synthesize previously published toxicity studies and have been shown to be both accurate predictors of sediment toxicity and negative predictors for toxicity to benthic invertebrates by direct contact. The Probable Effect Concentration (PEC) is the concentration above which harmful effects are likely to be observed. These SQGs do not consider the potential for bioaccumulation and are not intended to serve as site-specific clean-up levels. Instead, they are applied to facilitate the decision-making process regarding sediment management; an absence of exceedances generally serves as a defensible basis for no further investigation.[3]

If the dam is removed, some portions of the impoundment, once dewatered, will revert to floodplain that abuts some residences, therefore residential direct criteria is applied. Residential direct contact criteria are based on conservative estimates including daily ingestion for 350 days/year and dermal exposure 245 days/year, with separate considerations for adults and children 6 years or younger. In this way, residential direct contact criteria serve as a conservative threshold for human health risk in this setting, where direct contact, especially chronic exposure, is unlikely. However, if sediment was to be excavated from the channel, concentrations relative to residential direct contact criteria would determine any limitations in its re-use or disposal.

Analytical Results

A summary table of lab results is attached, and a complete laboratory report can be provided upon request. Samples ranged from 45% to 81% solid, with corresponding percentages of moisture. Sample #1 was predominantly medium to fine sand with coarse sand and fine gravel. Samples #2, #3, #5, #6, #9, and #12 (upstream) were predominantly medium to fine sand. Samples #4, #7, #8, and #10 were predominantly fine sand, silt, and clay. Sample #11 (upstream of the impoundment) was predominantly medium to coarse sand with fine gravel. Samples #11 and #12 (downstream of the dam) contained by far the lowest percentage of TOC, 0.14% and 1.3%.

Laboratory reporting limits were below the corresponding criteria for all analytes. Results may be summarized as follows:

- PCBs were not detected.
- ***Polynuclear Aromatic Hydrocarbons (PNAs)*** were either not detected or detected below the ***human health criteria*** for nine (9) of the ten (10) impounded sediment samples; one (1) of the impounded sediment samples contained concentrations that slightly exceeded human health criteria for *benzo(a)pyrene*.
- ***PNAs*** were detected below the ***ecological criteria*** for seven (7) of the ten (10) impounded sediment samples; three (3) of the impounded sediment samples contained concentrations that exceeded ecological criteria, which are discussed below.
- ***Metals*** concentrations were detected below the ***human health criteria*** for seven (7) of the ten (10) impounded sediment samples; three (3) of the impounded sediment samples contained concentrations that slightly exceeded human health criteria for Arsenic.

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[2] MacDonald, DD, and Ingersoll, CG. 2002. A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems, Volume III – Interpretation of the Results of Sediment Quality Investigations.
[3] MacDonald, DD, Ingersoll, CG, and Berger, TA. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology. 39:20-31.

- ***Metals*** concentrations were detected below the ***ecological criteria*** for eight (8) of ten (10) impounded sediment samples; two (2) samples contained concentrations that exceeded ecological criteria, which are discussed below.
- Samples #11 (upstream of the impoundment) and #12 (downstream of the dam) contained no detections that exceeded ecological or human health criteria.

Polynuclear Aromatic Hydrocarbons (PNAs)

Samples #1, #3, and #6 from the impoundment contained concentrations that exceeded ecological criteria for multiple PNAs (3, 8, 6 PNAs respectively). Exceedances were generally within one order of magnitude of the corresponding criteria. These PNAs include Naphthalene, Fluorene, Phenanthrene, Anthracene, Flouranthene, Pyrene, Chrysene, and Benzo(a)pyrene. Sample #3 contained concentrations that slightly exceeded the human health criteria for Arsenic.

Metals / Inorganics

Sample #7 contained concentrations of Cadmium, Lead, and Mercury that exceeded ecological criteria. Sample #10 contained a concentration of Lead that exceeded ecological criteria. Samples #7, #8, and #12 contained concentrations that slightly exceeded the human health criteria for Arsenic.

Discussion of Sediment Quality

Polynuclear Aromatic Hydrocarbons are a class of compounds, generally occurring as complex mixtures, that are known contaminants and commonly occur in fine sediments (fine sand, silt, clay) in river systems. Sources of PNAs in the environment are both natural and man-made. Some PNAs are manufactured for research or for the production of dyes, plastics, and pesticides. PNAs occurring in the environment are more likely the by-product of incomplete combustion – sources include wildfires, trash burning, wood-burning stoves, furnaces, industrial emissions, energy production (i.e. coal burning), and motor vehicle engines. Recent research has identified asphalt seal-coats as concentrated sources of PNAs, particularly in stormwater runoff. PNAs enter freshwater bodies by atmospheric deposition or stormwater runoff and then bind preferentially to fine grain sizes, which settle out of suspension in backwater depositional areas and accumulate in man-made impoundments. If sediment deposition conditions remain stable, contaminant concentrations may gradually increase over time particularly since PNAs persist in the environment for long periods of time. Common modes of human exposure include breathing polluted air, eating grilled meats, and smoking. Less common sources include coming in contact with heavy oils, coal tar, roofing tar, or creosote. Research suggests that inhalation and skin contact may be associated with cancer in humans.

These PNAs are frequently detected in impounded sediments throughout the northeastern US; and likewise, they were detected in 3 of 10 impounded sediment samples. These samples contained a range of TOC percent (46%-90%). Sample #1 contained larger proportions of coarse sand and fine gravel; Samples #3 and #6 were among several samples that were predominantly medium and fine sand. As such, neither TOC nor grain size appears to correlate strongly to these detected exceedances, and thus suggests the results cannot be extrapolated to other impounded sediment of similar characteristics. PNAs were either detected at low levels or not detected at all in most (7 of 10) impounded sediment samples. The exceedances of ecological criteria indicate these pollutants may exert a minor impact to the aquatic ecosystem (most likely benthic aquatic organisms) in existing conditions. The lack of exceedances of human health criteria indicate no cause for concern toward human health.

2013 Sediment Sampling and Analysis

As stated above, six (6) sediment samples were collected by others in 2013 from throughout the impoundment and analyzed for a range of common contaminants included metals, polynuclear aromatic hydrocarbons (PNAs or PAHs), polychlorinated biphenyls, and organochlorine pesticides. A map of sample locations and tables of results are presented in the appendix; no report was ever produced. Three (3) samples were collected in the lower impoundment, two (2) in the central portion of the impoundment (between the railroad bridge and Superior Road bridge, and one (1) in the upper portion of the impoundment upstream of Superior Road bridge. All samples were collected approximately midway between opposing banks and apparently collected manually with a surface dredge sampler (i.e. clam-shell style Ponar or similar).

Laboratory analytical results were compared against ecological guidelines – threshold effect concentrations [TEC] and probable effects concentrations [PEC] for freshwater sediment. Pesticides and PCBs were not detected in any sample. Samples #1 and #2 contained low concentrations of metals and PNAs with minor exceedances of TEC, but no exceedances of PEC. Sample #3 contained no exceedances of TEC for metals but exceedances of PEC for most PNAs. Sample #4 contained no exceedances of TEC for metals, but exceedances of TEC (not PEC) for most PAHs. Sample #5 contained exceedances of TEC for metals and PNAs, but no exceedances of PEC (with the exception of Mercury, which slightly exceeded PEC). Sample #6, closest to the dam, contained exceedances of PEC for metals, but no exceedances for PNAs.

In totality, the lack of persistent exceedances of PEC for metals and PNAs in the results of the 2013 sediment sampling are not in conflict with the results of this most recent round of sampling and do not create a substantial concern for river biota or human health in the event of dam removal.

Conclusions of Sediment Quality

Sediment contaminants identified and described above provide important information to the feasibility of the removal of the Peninsular Paper Dam. The feasibility of dam removal is supported by the following conclusions:

1. Detections in a majority of impounded sediment samples were below ecological and human health criteria for Metals, PNAs, and PCBs.
2. Exceedances of ecological criteria for PNAs were infrequent (3 of 10) and low magnitude (i.e. within an order of magnitude).
3. Exceedances of ecological criteria for Metals were infrequent (2 of 10) and low magnitude (i.e. less than 5x).
4. Exceedances of human health criteria for PNAs were infrequent (1 of 10) and low magnitude (i.e. less than 2x).
5. Exceedances of human health criteria for Metals were infrequent (3 of 10) and low magnitude (i.e. less than 2x).
6. Ecological criteria are sufficiently conservative and protective, such that minor exceedances rarely exert significant adverse impacts on ecological receptors.
7. Human health criteria are sufficiently conservative and protective in this setting, such that daily direct contact is highly improbable.

Based on these conclusions, sediment analysis results (i) support dam full removal and passive, in-stream, sediment management, (ii) do not necessitate excavation and off-site disposal of impounded sediments, post dam removal, and furthermore, (iii) provide reasonable assurance that no further sediment investigation is necessary.

Sediment Quantity

Compilation of manual sediment probing data, vibracore data, and survey data in plan view basemapping and longitudinal profile provides the best means for estimating sediment volumes. The longitudinal profile includes the top and bottom of sediment in the thalweg; the thalweg is the anticipated alignment of the re-formed free-flowing channel after dam removal, and the bottom of sediment closely approximates the anticipated profile (i.e. the river bottom and channel slope) of the free-flowing channel.

As stated above, the impoundment is over 1 mile long and 177 acres; at an average of 4 feet in sediment depth, total impounded sediment volume may exceed 1 million cubic yards. However, the impounded sediment that would actually be mobilized following full dam removal would be mobilized by the new free-flowing channel; whereas, sediment offset from the channel would settle, dewater, revegetate, and revert to a naturalized floodplain. Thus, the mobile volume of sediment is significantly less than the total volume and the more relevant quantity to guide dam removal decisions.

The bankfull channel width upstream of the impoundment and downstream of the dam measures approximately 125 feet. Downstream free-flowing reaches range approximately from 125 to 160 feet in width. Bankfull width as determined by the regional hydraulic geometry curve for Southern Lower Michigan[4] is 156 feet based on a drainage area of 813 mi^2. The product of the depth of impounded sediment depicted in the profile and the anticipated bankfull channel width (accounting for a slightly convex channel bottom and sloping banks) yields the volume of mobile sediment is closer to 60,000 CY. This volume extends over the length of approximately 6,000 feet, where an average depth of 2.5 feet of sediment in the thalweg is anticipated to be mobilized (i.e. average sediment depth is lower on the anticipated channel margins). This depth of sediment is deeper at the dam but diminishes to zero at 6,000 feet upstream. This mobilization of sediment would be initiated at the downstream extent in the form of a head-cut that progresses upstream, and yet thin layers of surficial sediment may be mobilized throughout. Over this entire length, the transport of sediment would be constant but gradual. In published dam removal studies, the majority of the re-formation of the free-flowing channel, and the associated mobilization of impounded sediment, occurred within the first six to 12 months. Thereafter, sediment mobilization was primarily associated with high flow events.

The quantity of sediment that may be mobilized by dam removal is relatively small compared to the height of the dam and size of the impoundment, and thus does not preclude dam removal but does warrant further consideration of potential impacts (e.g. Ford Lake), discussion with regulatory agencies, and consideration of potential mitigation measures, some of which are discussed in the conceptual design section below.

Potential Impacts to Infrastructure and Utilities

Utilities

Overhead powerlines cross the impoundment in two locations. One set of powerlines parallel the Conrail Railroad and span the impoundment at the Conrail bridge. Also, at the upstream extent of the impoundment, high-tension overhead powerlines cross the impoundment. Neither of these lines, or the supporting poles are anticipated to be adversely affected by dam removal as they are outside of the impoundment or distal from anticipated position of the restored channel, and thus they do not limit the feasibility of dam removal.

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[4] Rachol, C.M. and Boley-Morse, K. 2009. Estimated bankfull discharge for selected Michigan rivers and regional hydraulic geometry curves for estimating bankfull characteristics in southern Michigan rivers. US Geological Survey Scientific Investigations Report 2009-5133.

None of the sources of information Princeton Hydro and HRWA obtained from the municipalities indicated any water lines, sewer lines, gas lines or similar utilities that crossed the impoundment.

Conrail Railroad Embankment

The Conrail Railroad parallels the impoundment near the Peninsular Paper Dam for several hundred feet. In this reach, the deeper water depths revealed that the river thalweg meanders to the river right side of the impoundment along the railroad embankment. If the dam were removed, the river channel is anticipated to also emerge in this location. The longitudinal profile with sediment probing data indicates that sediment depths are greatest closest to the dam and that the river channel bed may erode down by several feet along this railroad embankment. The potential for the post-removal, free-flowing river channel to erode or undermine the embankment does not preclude dam removal but does warrant additional consideration, such as hydraulic modeling (i.e. embankment scour analysis) and mitigation measures. For example, following dam removal, bank/slope stabilization will likely be necessary to provide additional protection for the embankment and Conrail rail line.

Conrail Railroad Bridge

The Conrail Railroad bridge is constructed of masonry abutments and two-central piers that create three openings for flow; engineering plans are dated 1899. The thalweg, or deepest path, passes through the central opening. Based on normal water depth, the bridge has approximately 4.5 feet of freeboard. The river right opening was shallow and armored with large riprap. It appeared that sheet-piling and riprap encased the front of the abutments and piers well below the water surface. Original engineering design plans indicate the depth of the two central piers and that they are founded on timber piles that, however, extend down to an unknown depth. The river right pier is shallow, and its bottom is several feet <u>above</u> the elevation of the adjacent thalweg, as indicated in the longitudinal profile.

With a cross-section opening width of 139 feet (150 ft span minus 2 central piers) the bridge presents a constriction of the floodplain and thus a hydraulic constriction during high flows. Manual probing revealed an absence of impounded sediment at the bridge and that the river thalweg elevation at the bridge is actually below the river bed elevation at the base of the dam (see profile), indicating no potential for head-cutting or channel degradation at the bridge. However, the post-removal, free-flowing river channel will likely create greater flow velocities, which may increase scour at the bridge, particularly the river right or river left bridge openings, and potentially damage the abutments or piers, or worse, expose the timber piles under the river right pier. Exposure of the timber piers presents a serious risk to the bridge because it introduces the potential for decomposition of the timbers and eventual collapse of the pier.

The potential for increased scour at the bridge does not preclude dam removal but does warrant additional consideration and mitigation measures. A detailed hydrologic and hydraulic model with a bridge scour analysis will be necessary to further assess the existing and post-removal conditions. Mitigation measures would likely include scour protection, the careful placement of large rock around the bridge abutments. More extensive measures may be necessary to protect the underlying timbers such as concrete encasement, which can be complicated and costly. This river right pier presents of the most complicating factor in the removal of Peninsular Paper Dam.

Superior Road Bridge

The Superior Road Bridge is a steel I-beam span with concrete abutments and two central concrete piers that create three openings for flow; engineering plans are dated 1972. The thalweg passes through the right opening. Based on normal water depth, the bridge has approximately 5 feet of freeboard. Original engineering plans indicate the depth of central piers, which according the survey/manual probing, is approximately equal to the invert of the channel at that location.

With a cross-section opening width of approximately 160 feet (170 ft span minus 2 central piers), this bridge presents a constriction of the floodplain and thus a hydraulic constriction during high flows. Manual probing also revealed an absence of impounded sediment at the bridge and that the river thalweg elevation at the bridge is approximately 1-foot above the river bed elevation at the base of the dam (see profile), indicating a slope of 0.02% and thus little or no potential for head-cutting or channel degradation at the bridge. However, the post-removal, free-flowing river channel will likely create greater flow velocities, which may increase scour at the bridge and potentially undermine the piers.

The potential for increased scour at the bridge does not preclude dam removal but does warrant additional consideration and mitigation measures. A detailed hydrologic and hydraulic model with a bridge scour analysis will be necessary to further assess the existing and post-removal conditions. Mitigation measures would likely include scour protection, the careful placement of large rock around the bridge abutments.

Riverfront Landownership

SME Surveyor completed online research of the deeds of all abutting properties; results are presented in map form (Appendix E). For most properties, the deed clearly references the edge of water as a parcel boundary. Following dam removal, the water's edge is anticipated to shift as the impoundment narrows to a free-flowing channel. Thus, most of these properties would expand in area towards the river with the laterally shifting edge of normal water.

For a subset of properties, however, a fixed boundary is defined or the water's edge is not referenced in the deed. These properties may not change in area as a result of the narrowing of the wetted width as the impoundment reverts to a free-flowing channel. The one area where the deed does not reference the river's edge is along North Huron River Drive along the R. A. Nicholl's Huron River Hills Plat. Typically, if the intent is to the edge of water, then it would be called out in the description and shown on the plat. However, a certified boundary survey may be necessary to locate the monuments to determine if the lots go to the top of bank or extend down to the water. The bank heights extend over 20 feet above the water at some properties. Many of the property owners have been using the land from the top of bank to the edge of water for some time – staircases, sitting areas, and docks were common, which raises a question about riparian rights. These properties are also identified on the map in Appendix E, which depicts a generalized river channel following dam removal.

Some riverfront landowners may initially perceive the dam removal negatively – with the loss of a lake front view, potential decrease in property values, or conversely, the expansion of property that increases the taxable area. Riverfront landowners may also question whether the land is buildable (it will likely be in the floodplain), and how they can manage the land for their view or continued use. This additional land may at first be perceived as a management burden. Some properties may expand across a municipal boundary, and thus complicate taxation. Project partners will need to continue to engage riverfront landowners with this information through a concerted and well-intentioned listening and outreach effort. In addition, both HRWC and the City of Ypsilanti will need to seek legal guidance on future considerations.

Through these discussions with riverfront landowners it will be important to note that the lake view will transition to a view of a river meandering through a floodplain meadow, which will also be scenic and offer different recreational opportunities that will enhance property values. Sediment erosion will be limited and predictable. Revegetation within the exposed floodplain will be relatively rapid. Referring to similar projects will help allay common fears and build support for the restoration of the river.

It does not appear that any existing properties would be reduced in area by the removal of the dam and re-formation of a free-flowing river. It is unclear what obligation, if any, the dam owner has to the upstream property owners with regard to the changing edge of water, and what process the dam owner must follow regarding the change in property lines. Neither the dam owner, nor the HRWC, is interested in acquiring the land that emerges between the existing water's edge and the anticipated river channel. Pending legal guidance pertaining to real estate, it seems reasonable that individual riverfront landowners (whose deeds reference the water's edge) who do not want their properties to expand, can have their deeds redefined to the current boundary. Unclaimed land may revert to the municipality, county, or state.

The prospect of the shifting edge of water and the expansion of most properties does not preclude dam removal but does warrant additional consideration of private property rights and legal obligations of the dam owner.

Conclusion of Dam Removal Feasibility

This feasibility study focused on three critical issues: (i) sediment quantity and quality, (ii) potential infrastructure/utilities impacts, and (iii) riverfront land ownership. Sediment quality was found to be generally within human health and ecological criteria and thus, supportive of the feasibility of dam removal. Sediment quantity, owing to depths much less than the height of the dam, is relatively low and can be addressed with a combination of passive and active approaches. While sediment probing reveals little potential for massive channel downcutting, the existing bridges can likely be protected and preserved in the event of dam removal, although the extent and cost of stabilization and reinforcement is unknown at this point. Finally, although riverfront landowners may gain land, their concerns will need to be addressed with more direct outreach. All three issues warrant additional consideration and follow-up, but this study concludes that these three critical issues support the feasibility of dam removal.

Conceptual Dam Removal Design and Sediment Management Approach

In concept, the design for this dam removal includes the following aspects:

1. Removal of the concrete spillway to the full vertical extent.
2. Retention of some side portion of the spillway only for the purposes of maintaining structural support for the adjacent retaining wall on river right, or the Peninsular Paper Dam building on river left.
3. Preservation of the Peninsular Paper Dam building for eventual repair and reuse.
4. Active management of sediment in the immediate vicinity of the dam.
5. Passive management of sediment in the majority of the impoundment.
6. Placement of excavated impounded sediment along the Conral Railroad embankment and adjacent area.
7. Creation / stabilization of banks in the vicinity of the dam and Peninsular Paper Dam Park.
8. Active planting and landscaping to extend Peninsular Paper Dam Park.
9. Passive revegation of large swaths of the impoundment that will revert to floodplain meadow, wetland or ultimately wooded areas.
10. Stabilization of stormwater outfalls from the Railroad embankment, upstream of Peninsular Paper Dam Park, and adjacent to the bridge crossings.
11. Scour protection / structural reinforcement of the Conrail Railroad bridge.
12. Scour protection of the Superior Road bridge.

Extensive experience in completed dam removals strongly indicates that the sediment that is laterally distal from the thalweg, outside of the anticipated edge of the river channel, would not be mobilized and transported downstream in the event of dam removal. Rather, following full removal of the spillway, water levels will drop by roughly 13 feet (at normal flows), and the majority of impounded sediment will be exposed, and gradually dewater in place. Even without intervention (e.g. grading, stabilization, planting), areas that are not vegetated at the time of removal will be rapidly colonized by herbaceous vegetation, due to the presence of a seed bank in the sediment, and achieve widespread cover within the first growing season. Full cover is often achieved by the end of the second growing season. During this period, sediment at the surface may be susceptible to some erosion by large flood events; however, higher flood flows generally spread out across the new floodplain at shallow depths and low velocities that would not mobilize the majority of impounded sediment. With no intervention, vegetation communities will gradually transition; initially as annual herbaceous vegetation, then perennial vegetation, following a plant succession trajectory from emergent vegetation community to scrub-shrub, and eventually to a forested wetland or floodplain. Active planting can be undertaken to accelerate the establishment of vegetative cover, to infuse the floodplain with desirable plant species and increase plant diversity, or to pre-empt the establishment of non-native invasive species.

While sediment *quality* supports passive sediment management, the large *quantity* of sediment proximal to the dam will likely necessitate some active sediment management near the dam. The larger deposit of sediment at the dam, if released passively following dam removal, would release rapidly potentially overwhelming the downstream reach, accumulating in the channel and burying benthic habitat, temporarily. As such, a hybrid passive/active sediment management approach is recommended and most feasible for this dam removal. This hybrid approach would entail active excavation of in-channel sediment, potentially 7,500 CY, proximal to the dam as part of dam removal construction activity, and onsite relocation/stabilization, and beneficial re-use in the Peninsular Park area. Meanwhile the hybrid approach would allow in-channel sediment upstream to transport downstream naturally over time, as the restored channel adjusts in width, depth, and slope. This sediment in upstream reaches is anticipated to transport downstream at a more gradual rate that would likely not overwhelm the downstream reach. Impounded sediment offset from the channel will settle, dewater and revegetate in place, and revert to floodplain meadow or wetland. Areas that do not require active land management should be allowed to transition through plant succession. Areas proximal to Peninsular Park, that will be actively managed for public use, should be landscaped and planted in preparation for the greater vision for the Park.

Figure 1. Artistic rendering of the vision for Peninsular Park with dam removal. (SmithGroup)

Vision for Peninsular Park

The impoundment behind Peninsular Dam is the focal point for Peninsular Park, a 7.8-acre park on the north side of the river just upstream from Depot Town and downtown Ypsilanti. With dam removal, the size of Peninsular Park would increase to include the land on the north side of the river that is currently submerged behind the dam. HRWC and its partners have begun to develop a post-dam removal vision to redevelop and revitalize the Park into a vibrant hub of recreation, dining, and community activity (Figures 1 and 2). The former powerhouse, with its distinctive architecture and landmark neon sign, could be redeveloped to provide commercial opportunities such as a riverside restaurant with outdoor dining, a canoe/kayak/bicycle livery or other ventures. HRWC commissioned an artistic rendering, completed by design firm SmithGroup, to illustrate the creation of floodplain re-utilized as public park land, as well as, the preservation and re-use of the iconic powerhouse.

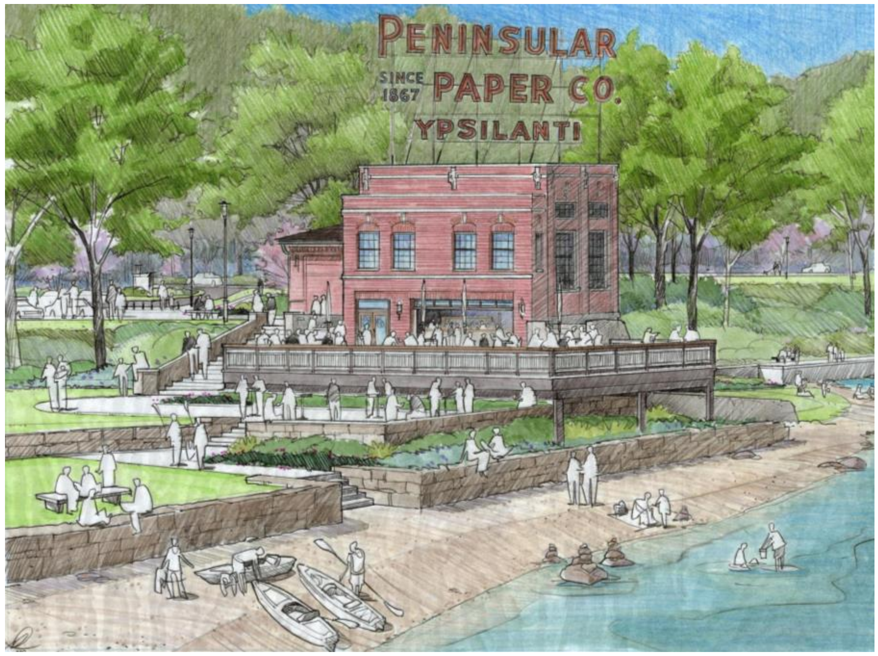

Figure 2. Artistic rendering of the vision for Peninsular Paper Dam Powerhouse with dam removal. (SmithGroup)

Peninsular Park is located on the Huron River Water Trail (HRWT), a 104-mile long paddling trail extending from Proud Lake in Oakland County to Lake Erie. The dam currently serves as a barrier to canoeists and kayakers paddling on the HRWT; the portage around the dam is challenging and discourages many paddlers from using this stretch of the river. Removing the dam would eliminate this difficult portage and provide a four-mile long, free-flowing paddling experience through Ypsilanti between the Superior Dam and Belleville Lake. Eliminating the portage could attract more paddlers to Ypsilanti, a designated Trail Town offering a variety of shopping, dining, entertainment and cultural experiences on the HRWT.

Concept-Level Dam Removal Construction Cost Estimate

A construction cost estimate is provided (Appendix F) that includes the major dam removal and sediment management steps described above: dam removal and active management of sediment at dam, scour protection and potential reinforcement of Conrail Railroad bridge, and scour protection at Superior Road bridge. Costs are based on lump sum costs and unit costs from similar projects, as well as broad quantity estimates (volume of dam, volume of sediment, volume of imported stone, etc.) that reflect the conceptual level of the dam removal design. Construction costs are best developed from final engineering design plans, as other issues can arise during final engineering design that can increase or decrease costs. Due to the inherent assumptions and uncertainties in the conceptual design, the cost estimate includes a 30% contingency. The concept-level construction cost estimate for dam removal is $1,734,000. The concept-level construction cost estimate for scour protection and reinforcement at the Railroad Bridge is $705,000. The concept-level construction cost estimate scour protection at Superior Road Bridge is $225,000. The cost estimate for dam removal does not include the cost to implement the greater vision of Peninsular Park described above, nor does it include engineering design, permitting, bidding, or construction oversight. A large component of the dam removal cost is the active management of sediment and bank stabilization, which can be adjusted in final design. A large component of the Railroad Bridge is based on the potential need for structural reinforcement, the need for which is to be determined following additional investigation.

As stated above, a previous cost for repair was estimated at approximately $659,000 in 2014 which with inflation, would now likely exceed $750,000. Repairs included work on the principal spillway, abutment walls, auxiliary spillway, and demolition of the powerhouse. Broad estimates for permitting, engineering design services, and construction engineering services are also included. After the needed dam repairs, additional costs are incurred over the long-term for ongoing maintenance, dam inspections every 3 years, as well as updates to the Emergency Action Plan. As long as the dam is in place, the dam owner retains liability.

Dam repair costs are typically incurred by the dam owner. However, due to the significant potential for environmental benefit, a variety of potential funding sources exist for dam removal, usually in the form of grants. Most dam removals are supported by some form of grant money; dam owners rarely carry the sole financial burden due to the broader benefits to the environment and public safety. Several of these sources that are relevant to Peninsular Paper Dam are identified in Appendix G.