Erosion Potential of the Huron River Downstream of Argo Dam Following a Dam Removal

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Huron River Watershed Council

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1.0 Introduction

Barr Engineering Co. has been retained by the Huron River Watershed Council to evaluate the potential for erosion or shifting of the Huron River channel downstream of the Argo Dam following a removal of Argo Dam. The evaluation presented herein is based on a review of readily available relevant information on this stretch of the Huron River, namely “Visions of Argo” (Beltemacchi et al., 2008), the HEC-RAS hydraulic model created as part of the Visions of Argo report, engineering plans for the existing Argo Dam, and river flow data from the USGS gaging station on the Huron River at Ann Arbor. Additional data has not been collected as part of this evaluation. This evaluation is also based on a site visit and a semi-quantitative analysis of the morphodynamic response of the Huron River to the proposed dam removal.

2.0 Background

2.1 Site History

The length of time the river has been in its current alignment can shed light on the geomorphologic stability of the current system. Therefore, an initial assessment of the geomorphologic stability of the existing river channel downstream of Argo Dam involves a review of the history of civil works projects along the study reach.

Before construction of the Argo Dam at its current location, a first dam was built immediately north of the confluence of Allen’s Creek in 1830. This first dam serviced several mills for approximately 60 years; no information is available on the date of removal of this first dam. In 1913, the Argo Dam was reconstructed at its current location to serve an electrical power generation station (Beltemacchi et al., 2008). Other sources indicate the Argo Dam was built at its current location in 1920. In 1915, the alignment of the Huron River immediately downstream of the dam was altered as the original natural channel was filled and the river was rerouted to its current configuration. In 1926, Allen’s Creek was contained in a stormwater sewer pipe. The existing Argo Dam was used for hydropower generation until 1959, when the operational costs of the hydropower station became too high. A fact sheet published by the Huron River Watershed Council states that the Argo Dam was retired from hydroelectric production in 1963. In 1963, the City of Ann Arbor purchased the Argo Dam. In 1972, major repairs were completed to address dam safety concerns.

In summary: 1) the reach of the Huron River upstream of the Argo Dam has been impounded for 180 years; 2) the realigned 90-degree bend to the east in the Huron River immediately downstream of the dam has been in place for almost 100 years; and 3) Allen’s Creek has been piped (and we assume in its current location) for almost 85 years. Given these time scales and that there are no records of the channel shifting appreciably after its realignment in 1915, as an initial assessment it appears that the reach of the Huron River immediately downstream of the Argo Dam is morphodynamically stable under current conditions. The remainder of this study examines the stability of the channel based on the site hydrology and channel geometry.

2.2 Flow Conditions

The geomorphologic stability of a river channel depends primarily on the forces exerted by the flowing water, which in turn are a function of the range of discharges and flow velocities. Therefore, a review of the existing flow record is needed to first evaluate the geomorphologic stability of the current system, and then to estimate the potential impacts on the geomorphologic stability following a removal of Argo Dam. The flow record from the USGS gage station #04174500 Huron River at Ann Arbor, MI has been reviewed. This gage station is located roughly 3,000 feet (ft) downstream of Argo Dam.

A visual inspection of the daily flow data for the period 1914-2010 has been conducted to evaluate the appropriateness of using the entire flow record for assessing erosion potential. The result of this exercise clearly shows a greater variation of flows (i.e., higher peaks and lower lows) before than after approximately 1955. The reason for the variation in flows post-1955 is unclear. The decrease in the variation in flows after 1955 is not accompanied by a decrease in annual average flows post-1955. There appears to be a small but positive increase in the water yield, which is supported by the results of the double mass curve analysis[1] by Bovee et al. (1998) and their suggestion that the change was due to the failure of two small flood control reservoirs in the headwaters of the Huron River in 1968. In any case, neglecting a shift in precipitation or runoff patterns, one possible explanation for the more pronounced fluctuation in flows before 1955 may be related to the operational rules of the Argo Dam when it served for power generation, which ceased in 1959. Another possible explanation could be a change in the location and the type of flow measurements taken. According to the Water Data Report 2009 from the USGS, the first part of the flow record at the USGS gage (1914-1940) may correspond to stage measurements at Barton Dam (2.6 miles upstream of the USGS gage) combined with flow computations from records of operation of power plants and records of flows passing the upstream dams. No information is provided about the accuracy of these indirect measurements. Furthermore, some adjustments to the values reported in the flow record were included to account for a greater upstream diversion for Ann Arbor municipal supply beginning in 1955, but such adjustments were focused on the annual mean discharge and runoff figures and not necessarily on the daily flows. In summary, although there are still some questions about the validity of the greater variation of recorded flows before 1955, a relatively well established flow pattern (statistically speaking) exists for at least the past 40 years (i.e., after 1968).

A preliminary evaluation of the series of annual peak flows was conducted to estimate the bankfull flow at the project reach. The bankfull flow is a critical factor in assessing the geomorphologic stability of the river channel. The review the USGS flow record showed that the annual peak flows

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[1] A double mass curve analysis “is a technique commonly employed to determine corrections to hydrometeorological data to account for changes in data collection procedures or other local conditions” (NOAA’s website).

are mostly limited to the range 2,000-3,500 cubic feet per second (cfs) after 1975, whereas before 1975 at least ten events corresponded to peak flows in the range 3,500-6,000 cfs. The reason for the change in annual peak flows after 1975 is unclear. According to the Water Data Report 2009 from the USGS, extensive regulation of flows has occurred since 1975 following automation of gates at the dams located upstream of the USGS gage. Our understanding is that both Barton Dam and Argo Dam currently operate as run-of-river facilities. The combined operation of these two reservoirs seems to have an attenuation effect on the peak flows in the Huron River at the USGS gage. However, such attenuation effect is likely dominated by the operation of the larger Barton Dam; hence removal of the Argo Dam would not necessarily translate into larger peak flows in the Huron River immediately downstream of the Argo Dam. In summary, the statistics of peak annual flows appear to change after 1975. Therefore we will use two different data sets in our computation of flows statistics as it relates to channel stability: 1) the full record (1902 to 2009), and 2) the abbreviated record (1975 to 2009).

A preliminary flood frequency analysis of the series of annual peak flows was performed to estimate the flood associated with a return period of 1.5 years (i.e., the flow value with a 1 in 1.5 chance of being exceeded each year). The 1.5-year flow is a proxy for the bankfull flow, and will be used to evaluate the geomorphologic stability of the river channel (see Section 3.1). The flood associated with a return period of 1.5 years is approximately 1,900 cfs when using the full record, whereas the estimate is approximately 2,400 cfs when using the abbreviated record.

The record of the USGS gage also includes field measurements taken during the period 1983-2010 (i.e., after 1975). The field measurements can be used to infer the range of flow velocities near the channel banks. The USGS measurements include stage (as a proxy for water depth), discharge (i.e., flow), channel top width, wetted cross sectional area, and cross section-averaged flow velocity. Measured discharges at the station ranged between approximately 50 and 2,700 cfs, the channel top width ranged between approximately 115 and 150 ft, and the cross section-averaged flow velocity ranged between 1 and almost 4 feet per second (fps). The field measurements encompass flood events that bracket the estimated 1.5-year flow (using either the full record or the abbreviated record). Since, for a straight reach the typical distribution of flow velocity across the channel is of higher values near the center of the channel and smaller values (close to zero) near the channel banks (Graf, 1998), the field measurements of cross section-averaged flow velocity close to 4 fps could correspond to flow velocity values in the order of 1 fps near the channel banks. The risk of bank erosion at these near-bank velocities is very low.

2.3 Site Characterization

A site visit was conducted on August 16, 2010. It included an inspection of the Argo Dam infrastructure, a walk along approximately 1 mile of the Huron River downstream of the Argo Dam, a gross estimation of the typical gradation of the channel bed sediment, and an inspection of the sheetpile wall protection at the confluence of Allen's Creek into the Huron River. The geometry files for the HEC-RAS hydraulic model used in preparation of the Visions of Argo report were also used to assess the shape and slope of the river upstream and downstream of the dam.

At the time of the visit the flow at the site was in the range of 300-350 cfs, corresponding to cross section-averaged flow velocities of 1.5-2.0 fps (USGS records). Flow velocities were considerably higher near the center of the channel than near the channel banks, consistent with the USGS records discussed above in Section 2.2. It is important to note that this distribution of cross-sectional flow velocity applies only to the straight reach of the Huron River downstream of the confluence of Allen's Creek. At the confluence of Allen's Creek where the river bends 90-degrees to the east, strong secondary currents and increased flow velocities will likely appear at the outer bank (French, 1985), especially during high flows. Higher velocities near the banks under higher flows may lead to increased erosion potential in this area.

Some signs of erosion behind the sheetpile wall were evident, but these signs of erosion are not expected to compromise the physical stability of the sheetpile wall. Additional studies must be conducted to evaluate this initial assessment. The erosion of the Huron River outer bank continued 30-50 ft downstream from the sheetpile wall, as the roots of some big trees were partially exposed in this area. The impact of the Allen's Creek discharge on this erosion is unknown based on this initial assessment; additional investigations during periods of high flow through the dam and from Allen's Creek should be conducted. The existing signs of erosion does not imply that the Huron River will shift to its natural, old alignment (i.e., pre 1915) or that the erosion is so severe that the channel is getting wider. If the channel were unstable, there would be signs of bank erosion everywhere, not just at the sheetpile immediately downstream of Argo Dam. Additional, or different, erosion protection measures might be required for this area following the proposed dam removal. Potential mitigation measures are discussed in Section 3.2.

In the straight reach downstream of the dam, the bankfull depth was roughly 4 ft and the bankfull width is approximately 140 ft, according to the HEC-RAS model. Bankfull geometry is used to assess geomorphologic stability of the river (see Section 3.1). These dimensions from the HEC-RAS model appear to be reasonably consistent with observations in the field. The cross sectional shape of the Huron River channel is basically rectangular, with no bars, and relatively steep (almost vertical) channel banks. The channel bed sediment appears to consist of coarse sand, gravel, some cobbles and a few large boulders. The longitudinal slope of the reach downstream of the Argo Dam is approximately 0.10 percent.

A profile view of the study reach is shown in Figure 1. Elevations of the channel thalweg, bankfull, and secondary top of bank were taken from the HEC-RAS model. Elevations of the dam sill and apron were taken from the dam engineering plans. Elevations of the silt/sand interface were computed by subtracting the depth of sediment (Barr, 2002) from the channel thalweg (HEC-RAS model). The bed elevation drop at the Argo Dam is approximately 7 ft. There are more than 184,000 cubic yards (CY) of fine sediment (finer than sand) accumulated behind the Argo Dam (Barr, 2002). From Figure 1, it appears that some amount of sand and gravel (in addition to the 184,000 CY of fines mentioned above) may have settled in the Argo impoundment following construction of the Argo Dam, as can be seen by the higher elevation of the silt/sand interface at the dam location as opposed to 1,000 ft upstream of the dam. The deposition of sands and gravels immediately upstream of the dam is a typical response to an obstruction constructed in a river.

Furthermore, it is reasonable to hypothesize that starting with the construction of the first Argo Dam 180 years ago, that the channel bed of the downstream reach of the Huron River has degraded (channel bed lowering) and armored (channel bed coarsening), driven by sediment starvation as sediments settled upstream in the Argo Dam reservoir. This is supported by the elevation difference of 4 ft between the dam spillway apron and the channel thalweg downstream of the dam. Such a response may have been become more pronounced after construction of Barton Dam in 1913. Barton Dam is larger and would have increased the combined sediment trap capacity of the two impoundments. Additionally Barton Dam appears to dampen the peak flows more than Argo Dam, therefore further reducing mobilization of the coarser sediment.

In general, the natural sediment yield of the Huron River watershed is greatly affected (reduced) by the series of impoundments built along its upper and middle course. This plays a role in the shape of the channel cross sections and the overall geomorphologic characteristics of this river.

3.0 Semi-Quantitative Morphodynamic Assessment

3.1 Bankfull Geometry

A preliminary semi-quantitative assessment of the geomorphologic stability of a river channel (including the erosion potential of the channel banks) can be made based on the relationship between the bankfull geometry of a channel and the corresponding bankfull flow.

Since publication of the pioneering works by Wolman and Leopold (1957) and Schumm (1960), the scientific and engineering communities have continued investigating and trying to develop relationships between prevailing flow conditions and the characteristics of morphodynamically stable river channels. An excellent review in this regard is provided by Copeland et al. (2000), in which the concepts of bankfull, specified recurrence interval, and effective discharges are offered as possible representations of the channel-forming discharge. More specifically, this technical note from the U.S. Army Corps of Engineers states that "an annual flood recurrence interval of approximately 1 to 2.5 years and the 1.5-year recurrence flood has been shown to be a representative mean" (understood as a representative estimate of bankfull flow) "of many streams (Leopold, 1994)." The important assumption used in this type of representation, which is very popular in stream restoration projects, is that any of the above referred three measures of the channel-forming discharge (i.e., the bankfull, specified recurrence interval, and effective discharges) is "a theoretical discharge that if maintained indefinitely would produce the same channel geometry as the natural long-term hydrograph." In this regard, a comprehensive review of historical flow and sediment transport data in a wide variety of eco-regions across the United States was conducted by Simon et al. (2004). The results of this review suggest that the 1.5-year discharge provides a reasonably good measure for purposes of defining long-term transport conditions. Therefore, representation of the channel-forming discharge with the 1.5-year discharge could provide an indication of geomorphologic stability for the Huron River. As indicated in Section 2.2, the 1.5-year discharge is estimated to be approximately either 1,900 cfs (based on the full record) or 2,400 cfs (based on the abbreviated record). Both values will be used in the assessment of geomorphologic stability presented below, but it is the latter one (i.e., the abbreviated record) that is most representative of the current conditions.

Evolving from the initial works by Luna Leopold (Leopold and Maddock, 1953; Leopold et al., 1964), Parker et al. (2007) have proposed greatly improved quasi-universal relations for bankfull hydraulic geometry of single-thread gravel-bed rivers. The methodology developed includes a series of relationships between the bankfull discharge, the channel bed sediment median size, the bankfull channel width and height, and the river longitudinal slope, among other variables. The application of this methodology to the Huron River was first based in estimation of the channel bed sediment median size as a function of the bankfull discharge (1,900 cfs based on the full record, or 2,400 cfs based on the abbreviated record) and the river longitudinal slope of 0.10 percent. The resulting channel bed sediment median size was one-half to two-thirds of an inch, which is bracketed by the material visually observed from the channel banks (but this would need confirmation after a more comprehensive field and laboratory survey of the channel bed sediment).

Using this range of input values for the channel bed sediment median size and the bankfull discharge of 1,900 cfs (based on the full record) translates into an estimated geomorphologically stable bankfull width of approximately 116 ft, and the bankfull height would be approximately 3.9 ft. When the bankfull discharge of 2,400 cfs is used (based on the abbreviated record), the estimated geomorphologically stable bankfull width is approximately 127 ft, and the bankfull height is approximately 4.3 ft. In practical terms, the change in the magnitude and scatter of the peak annual flows after 1975 would not lead to a different stable bankfull geometry of the river channel downstream of Argo Dam. These estimates of stable bankfull geometry are similar to the observed values of approximately 140 ft for the bankfull width and of approximately 4 ft for the bankfull height. Therefore, the main conclusion of this semi-quantitative preliminary assessment is that the existing riverine system downstream of Argo Dam can be considered morphodynamically in equilibrium.

3.2 Discussion on Erosion Potential

Under current conditions (i.e., with the Argo Dam in place), the reach of the Huron River downstream of the Argo Dam is geomorphologically stable. Although there are signs of erosion behind the sheetpile wall protecting the southern bank of the Huron River at the confluence of Allen’s Creek as well as localized bank erosion for a 30-50 ft stretch immediately downstream, such erosion appears to be limited in extent and it does not appear to compromise the southern bank of the Huron River. In other words, in its current configuration it appears highly unlikely that the Huron River will shift to its natural pre-1915 alignment. This assessment is valid as long as the stilling basin and apron weir downstream of the Argo Dam help to evenly distribute the flow across the channel, reducing spot areas of high velocities. We have assumed the stilling basin and weir can dampen peak flow velocities even for high discharges (i.e., for discharges similar to or larger than the bankfull discharge), but additional monitoring during those times is encouraged.

With the dam removed, the potential for erosion of the southern bank downstream of the dam depends on the resulting alignment of the river following the dam removal, and on the mitigation measures employed. The alignment of the river following the dam removal will be influenced by the manner in which the dam removal is staged. If the dam removal occurs over a relatively short time scale (in the order of 1-2 days), a first outcome could be a massive re-deposition of the sediment impounded behind the Argo Dam to right in front of Allen's Creek outlet, especially if the removal occurred during high flow seasons (i.e., late-winter, spring). More critical, following dam removal, the alignment of the streamlines from the now longitudinally steeper Huron River would be directed toward the DTE brownfield site. The risk of extensive erosion, even with the sheetpile wall in place would be relatively high. Velocity calculations using Manning's equation suggest that flow velocities at the outer bend could result in high erosion potential during large flood events. For sharp bends, like the one analyzed here, the entire cross section could become unstable (Julien, 2002). It may be possible to mitigate potential bank erosion with additional armoring. Barr does not recommend this strategy.

Alternatively, if the dam removal was coordinated to promote a smoother meandering channel at the dam site, the risk of erosion at the DTE brownfield site can be low. The process would involve a gradual drawdown (on the order of 1-2 months) of the Argo impoundment prior to the actual removal of the concrete dam structure. The drawdown would be followed by mechanical dredging to help define the desired alignment of a meandering channel in the impoundment matching the existing Huron River channel downstream of the Argo Dam with a smooth bend. Barr recommends this strategy. Figure 2 shows a possible conceptual layout. The initial configuration of the channel excavated in the impounded area does not need to be as wide as that of the Huron River downstream. Physical modeling and field studies have shown that the channel will widen as a channel-bed-erosion front moves upstream until it reaches a geomorphologically stable longitudinal slope (Cantelli et al., 2007). A complete restoration proposal could include a more natural bank erosion protection, such as rock vanes, and the construction of a long riffle beginning upstream of the current dam location and extending a few hundred feet downstream. The goal of these combined measures is to deflect the flow away from the outer bank at the outlet of Allen's Creek, therefore reducing the potential for high flow velocities near the southern channel bank of the Huron River.

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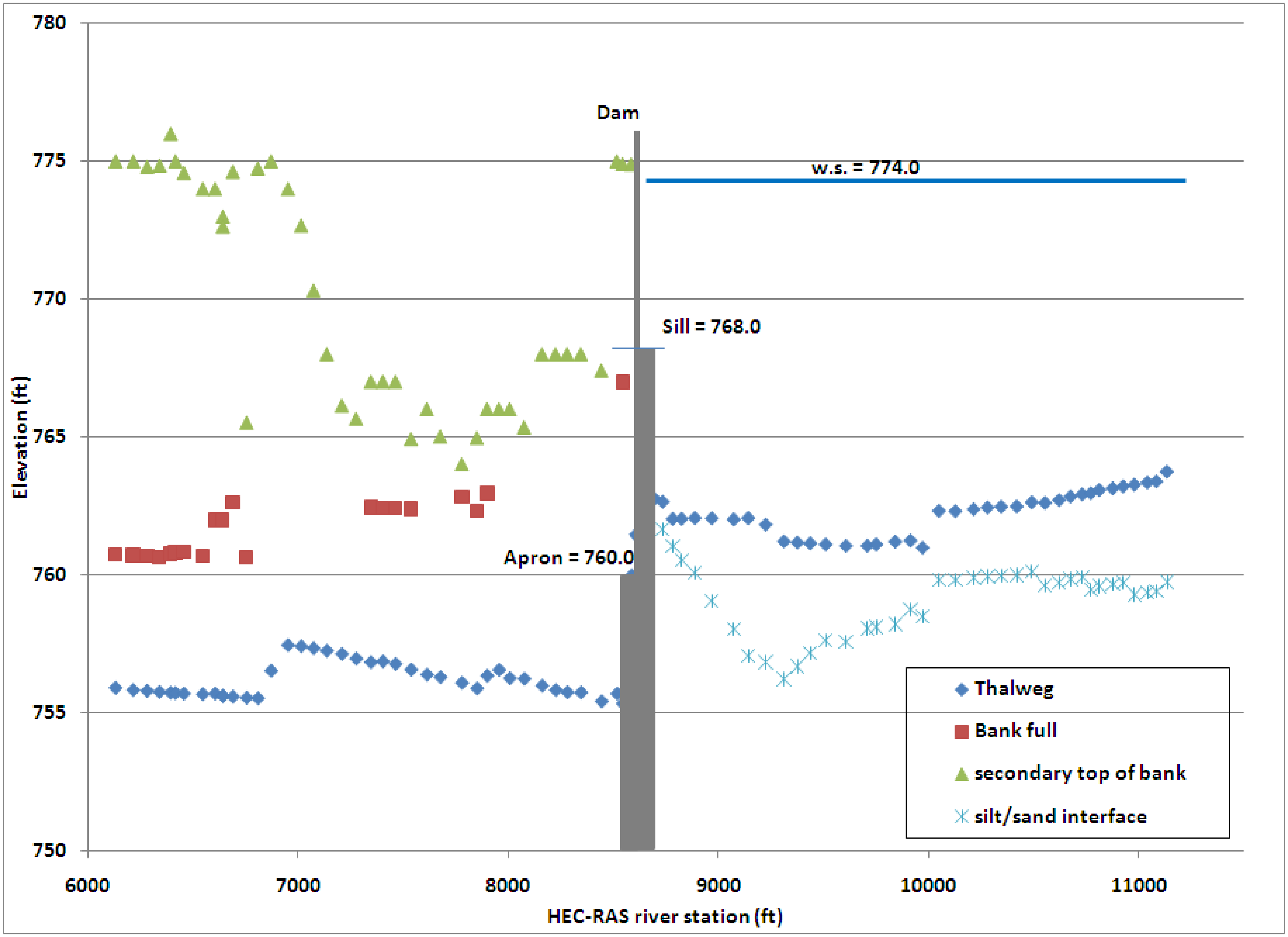
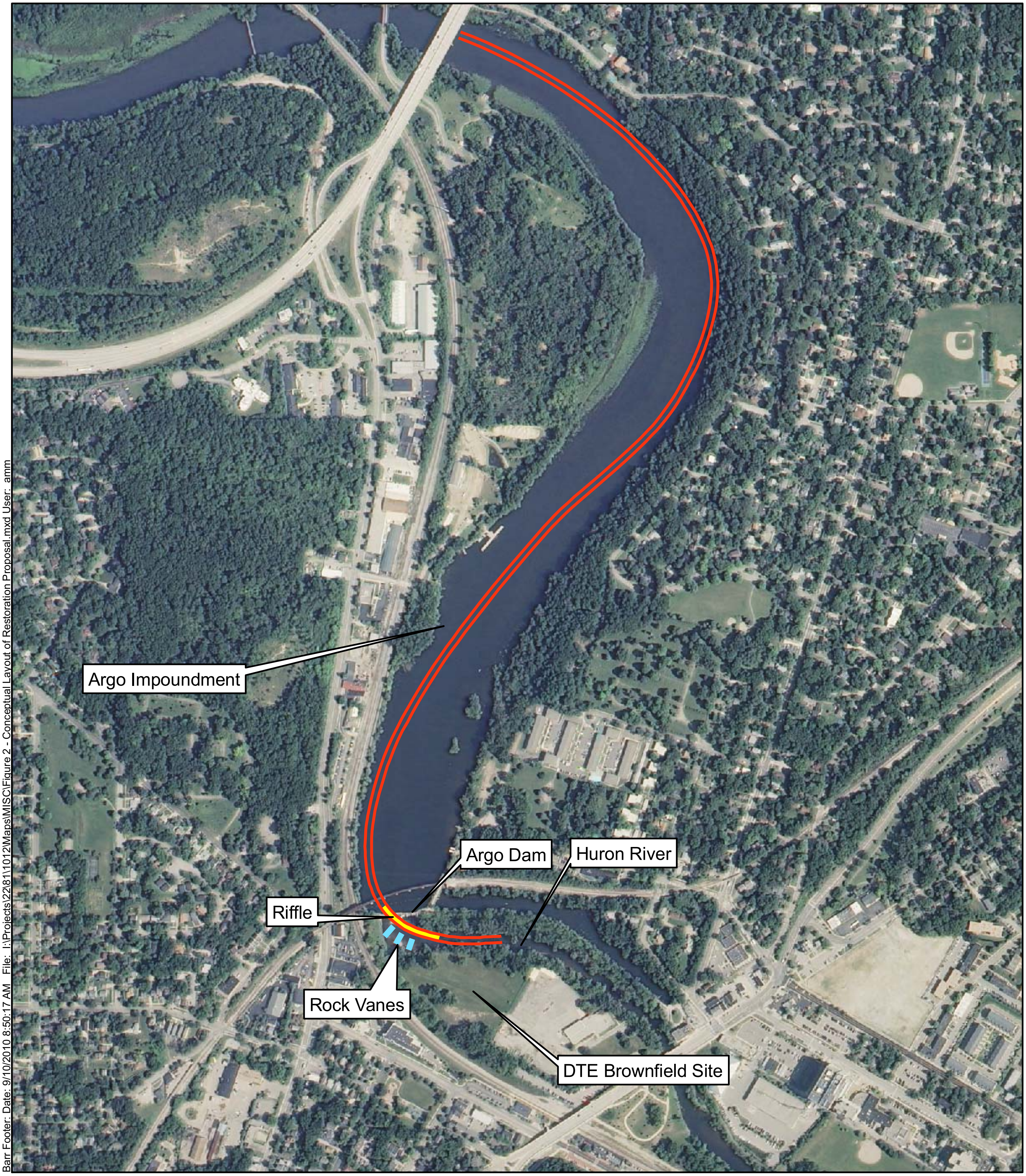


Figure 1 – Section view of Huron River downstream and upstream of Argo Dam.



Barr Footer: Date: 9/10/2010 8:50:17 AM File: I:\Projects\22\81\1012\Maps\MISC\Figure 2 - Conceptual Layout of Restoration Proposal.mxd User: amm

Excavated Channel

Riffle

Rock Vanes

0 325 650 1,300 Feet

0 100 200 400 Meters

N

Figure 2

Conceptual Layout of Restoration Proposal
Erosion Potential of the Huron River
Downstream of Argo Dam Following
a Dam Removal