



**US Army Corps
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Buffalo District
BUILDING STRONG®

CUYAHOGA RIVER RESTORATION - BOSTON MILLS NORTH

STANDARD PERMIT PRECONSTRUCTION NOTIFICATION



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May 2023

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1 Introduction and Background

1.2 Project Authority

This project is funded through the United States Environmental Protection Agency's (USEPA) Great Lakes Restoration Initiative (GLRI) Program under the authority of the Economy Act (31 U.S.C. 1535) for USEPA by the United States Army Corps of Engineers (USACE). This authorizes the USACE to provide goods and services to the USEPA in order to meet requirements under the GLRI program.

1.2 Project Purpose

The purpose of this project is to help restore the degraded structure and function of the subject reach of the Cuyahoga River system, using modern stream ecosystem restoration design principles.

1.3 Project Need

Accelerated channel erosion observed over the last 40 years and associated habitat degradation has been observed throughout the Cuyahoga River National Park (CVNP). A comprehensive diagnostic analysis of the causes of this degradation concluded that the root cause is increased river flows coupled with other anthropogenic impacts to the river channel and riparian zone. Specifically, both stream discharge and stream channel slope have increased due to direct and indirect anthropogenic stressors, resulting in a disequilibrium with channel and floodplain. This manifests as accelerated lateral channel erosion.

1.4 Project Objectives

The primary objective is to restore dynamic equilibrium to a reach of the Cuyahoga River within the CVNP by reestablishing an equilibrium between the river system's erosive forces and its resistance to such forces. Equilibrium in this case is defined as a balance between slope and flow and would translate into greater channel stability.

Secondary objectives, which follow from the primary objective, include:

- Reduce the accelerated lateral channel erosion
- Restore hydraulic processes to provide resilience within the river system
- Enhance autogenic recovery of riparian forest and associated river functions (e.g., large woody debris recruitment and storage)

1.5 Public Need

Public need means an activity or project that provides important tangible and intangible gains to society, that satisfies the expressed or observed needs of the public where accrued benefits significantly outweigh reasonably foreseeable detriments.

The channel lengthening project is funded by the USEPA and the National Park Service (NPS). The mission of the US EPA is to “protect human health and the environment.” The mission of the NPS is “to preserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations.” The goals and objectives of both agencies aim to benefit the whole of the American public. This project has been funded by the USEPA and has been determined to be aligned with its mission.

The project meets a *demonstrated* public need because the Boston Mills reach of the Cuyahoga River is a defined and agreed-upon project on the “management action list” for the Cuyahoga Area of Concern (AOC), which was also approved by the interagency and public stakeholder AOC Advisory Committee. The channel lengthening project expressly advances the goals of the AOC Program and the goals of the Clean Water Act. The project’s goal is to help restore the stream system functions, which are integrated with floodplain wetland functions. The channel lengthening project is *necessary* because this restoration approach is the only viable alternative that targets the root cause of the system’s degradation and is grounded in modern stream restoration principles.

The root cause of the river system’s degradation is not erosion itself but rather the increased flows that cause *excessive* erosion. In essence, the Cuyahoga River is attempting to lengthen itself by eroding its banks to accommodate the increased flows within the watershed. This lengthening is manifesting as lateral erosion at a rate of about 14 feet per year within the study reach. This excessive erosion degrades fish and macroinvertebrate habitat within and downstream of the project reach. In addition, the disturbed conditions created by excessive erosion along channel banks provides prime habitat for invasive species such as Japanese knotweed (*Reynoutria japonica*), which thrive on enhanced disturbance regimes. In the absence of the channel lengthening project, the Cuyahoga River channel would continue to erode laterally as it attempts to regain equilibrium on its own. By implementing the proposed changes to the hydraulic geometry of the river, it is being assisted to accomplish what would naturally take well over 100 years (if ever) to achieve. As the channel is brought closer to equilibrium, the residual lengthening rate would be expected to decrease proportionally. This means that, even if the channel length is brought to within 45 percent of the length needed to achieve equilibrium, erosion within the system will still be reduced proportionally because it is closer to equilibrium.

The basis for this project is landscape-level ecological restoration. The “accrued benefits” (restored river system) significantly outweigh the “reasonably foreseeable detriments” (conversion of wetland and tributary habitat to riverine habitat).

1.6 Ecological Restoration Approach

This project has implemented a process-based approach to restoration and is anchored to an empirical understanding of the processes that have been degraded. This approach attempts to restore the baseline functions of the riverine ecosystem rather than apply structural restoration actions (e.g., hard-armoring riverbanks).

A heuristic lens to conceptualize this framework is the USEPA’s (2012) stream functions pyramid, which operationalizes stream functions in a hierarchical structure (Figure 1). The two forcing factors of geology and climate underlie the base functions of the pyramid. Hydrology

(Tier 1), then supports the higher tier functions in sequence — hydraulics (Tier 2), geomorphology (Tier 3), physicochemical (Tier 4), and biological (Tier 5).



Figure 1: USEPA Stream Functions Pyramid

1.7 Design Principles

This project has employed a geomorphically-principled, process-based design to river restoration.

Four guiding principles put forth by Hawley (2018) correspond to the approach this project has taken:

1. Target the root cause of habitat and ecosystem change
 - Our diagnostic analyses have identified and targeted the root cause of observed degradation.
2. Tailor restoration actions to local potential
 - Targeting the root cause can be accomplished by reestablishing the channel to its historic, pre-modification location and slope.
3. Match the scale of restoration to the scale of the problem
 - This project identified the scale of disequilibrium and aims to take restorative action at that scale.
4. Be explicit about expected outcomes
 - By targeting the root cause, this restoration is understood to restore base functions of the stream system, affording system resilience and the ability for higher tier functions to recover holistically over time.

2 Existing Conditions

2.1 Project Area

The CVNP encompasses about 33,000 acres in the Cuyahoga River Valley between the metropolitan areas of Cleveland and Akron, Ohio. The CNVP lies within Cuyahoga and Summit counties and is located within 15 municipalities.

The Boston Mills project reach spans from Vaughn Road downstream to just south of Boston Mills (Figure 2, inset). The Boston Mills reach is the focus of this project.

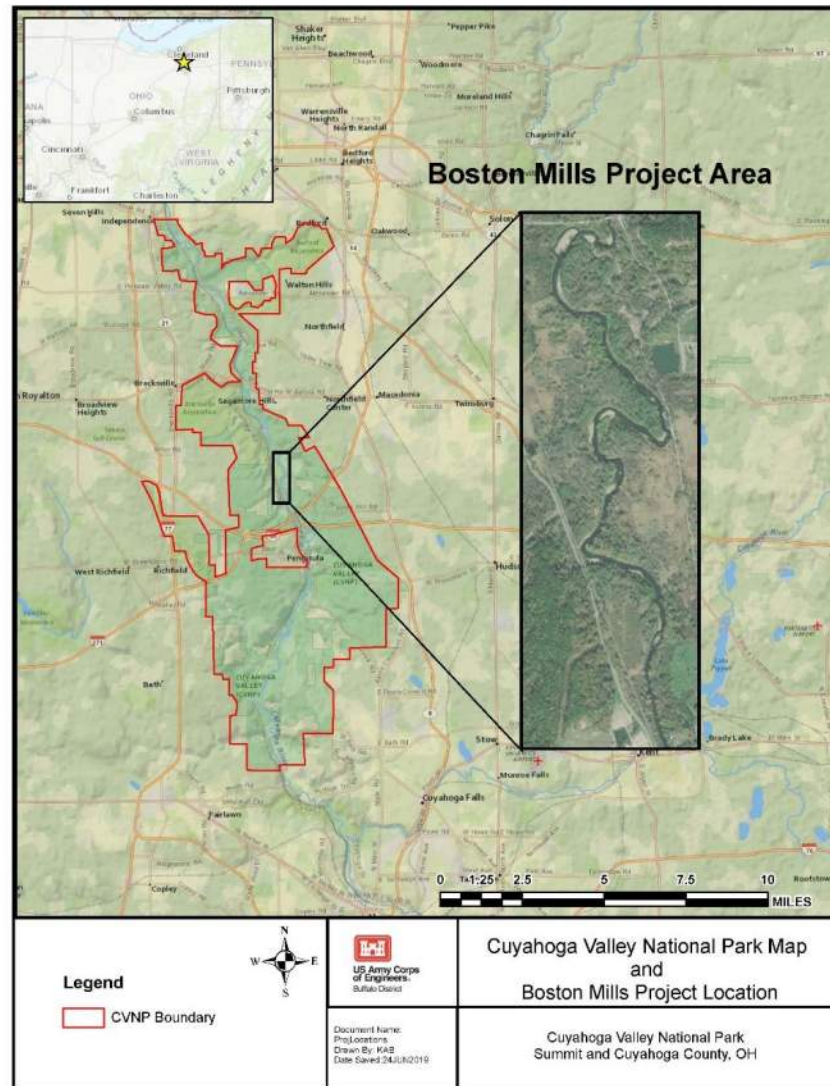


Figure 2: Map of the Cuyahoga Valley National Park boundary and the Boston Mills project area

2.2 Channel Erosion

Excessive channel erosion and bank instability along the Cuyahoga River was qualitatively assessed through several site visits to the CVNP. All observed reaches showed a considerable amount of erosion. In most cases the typical bank condition is characterized by vertical or near-vertical banks with bare, exposed soil (Figure 3).

Bank instability can be attributed to several factors within the watershed. One of the largest drivers is the increase of impervious surfaces in the watershed which results in increased peak runoff and an increase of overland flow in a watershed. These changes in a watershed's hydrology lead to increased flows in the streams and rivers. An increase in flow leads to a change in channel geometry as the river tries to deepen, widen, and lengthen to accommodate the increased flow. These changes happen through erosion in locations determined by the river.



Figure 3: Example bank erosion along Cuyahoga River

2.3 Trends in Flow

To understand the change in flows experienced by this section of the Cuyahoga River over time, flow frequency analysis on annual peak flows was performed for two time periods: 1922-1975 and 1976-2019 (Table 1). There has been a 34 percent increase in the two year flow event, which is the typical channel-forming flow event.

Table 1. Flow Frequencies for Cuyahoga River at Independence

	Year – 1922 to 1975	Year – 1976 to 2018	
Percent Chance Exceedance	Computed Curve Flow (cfs)	Computed Curve Flow (cfs)	Percent Increase (%)
0.2	22049.5	27699.2	25.6
0.5	19748.6	24975.2	26.5
1	18044.1	22945	27.2
2	16361.1	20928.8	27.9
5	14145.6	18255.4	29.1
10	12447.4	16189	30.1
20	10680.1	14020.2	31.3
50	8010	10700.2	33.6
80	6048.8	8219.3	35.9
90	5237.1	7178.9	37.1
95	4656.1	6428.1	38.1
99	3747	5241.8	39.9

2.4 Channel Length Trend

To determine if the Cuyahoga River project reach has lengthened in response to the increased flows, channel centerlines were delineated from aerial imagery from 1937-2017. Between 1960 and 1970, the plot shows a loss of 1,800 feet in length (Figure 4). This loss can be attributed to a deliberate (e.g., man-made) cutoff of an oxbow just upstream of Vaughn Road. Between 1970 and 2017, the overall rate of lengthening for the design reach has been about 14 feet per year in response to increased flows. Increased flows have contributed to greater sediment transport capacity and increased erosion rates along the project reach. Over time, the slope of the stream is changing to adjust to the new flow regime by eroding channel bends to make it longer.

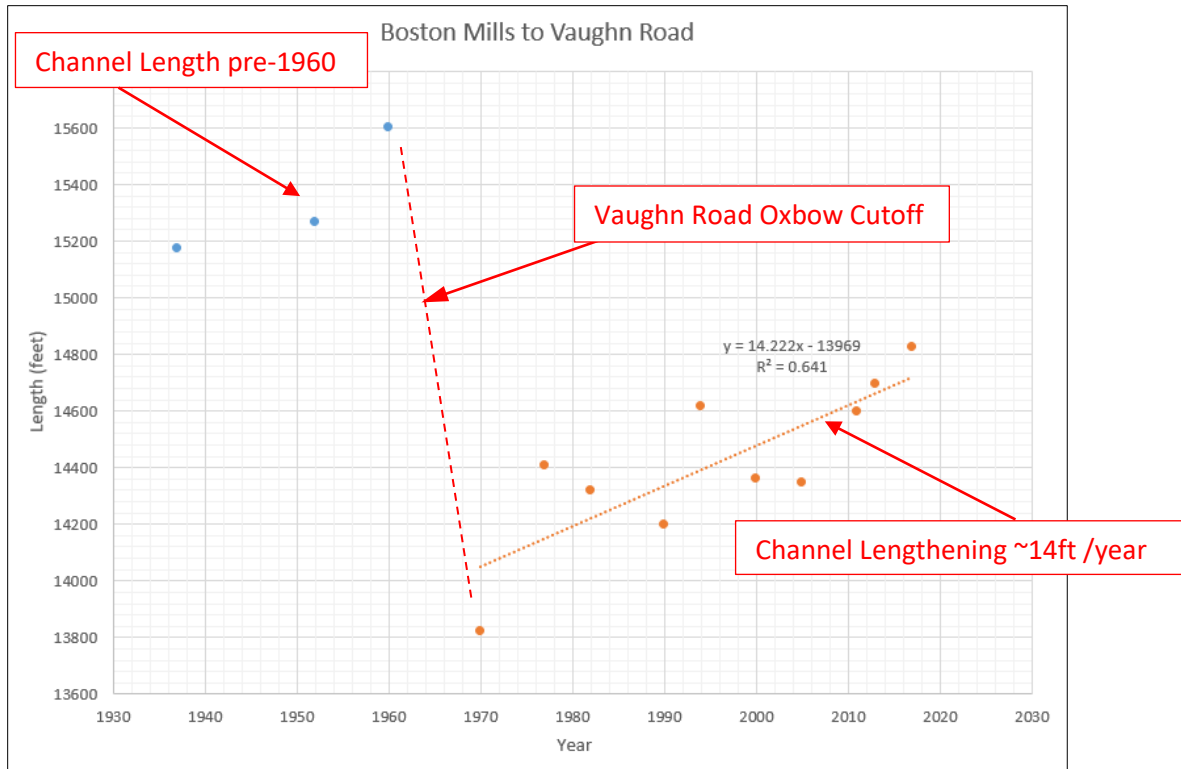


Figure 4: Change in Cuyahoga River length over time (Boston Mills to Vaughn Rd)

3 Environmental Resources

3.1 Streams and Wetlands

A wetland delineation was conducted within the Boston Mills project area between May 18 and May 22, 2020. See Appendix A for the Wetland Delineation Summary Report.

4 Alternative Plans

A total of three alternatives were developed as part of this proposed restoration project. The alternatives are as follows and are described in further detail below:

1. Alternative 1 – Six Bends
2. Alternative 2 – Two Bends (Bend #2 and Bend #6)
3. Alternative 3 – One Bend (Bend #6)

4.1 Alternative 1: Construct Six Meander Bends and Backwater Wetlands

Alternative 1 would consist of lengthening the river channel at six locations along a 2.4 mile stretch of the Cuyahoga River between Boston Mills and Vaughn Road (Figure 5). By constructing six new meander bends, the Cuyahoga River channel would lengthen by about 2,800 linear feet, which is 100 percent of the length needed to restore the channel to dynamic equilibrium.

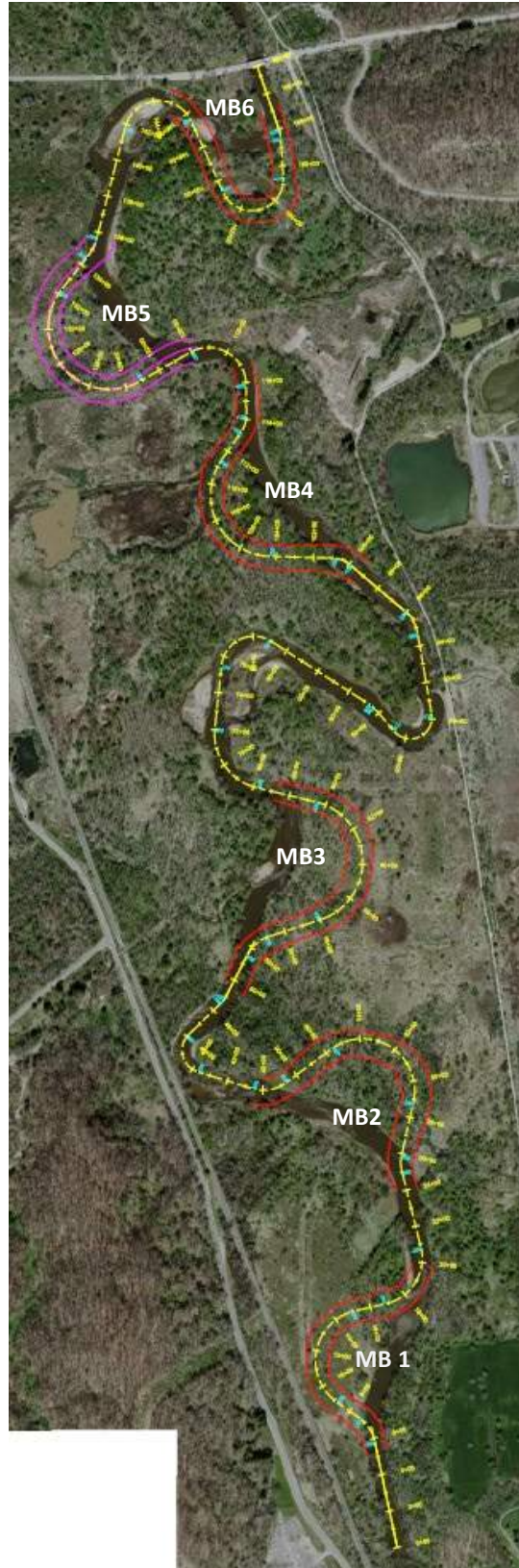


Figure 5: Proposed meander bend (MB) locations within the design reach

The project would excavate new channel reaches (meander bends) at each of the six locations, and the existing channels at Meander Bend 2, 3, 4, and 5 would be converted to approximately 2.0 acres of backwater wetlands each. The new channels would be designed to stabilize planform and add structural habitat complexity to the channel bed. Vegetation planting along the new channel reaches would include live stakes and seeding with container trees and shrubs along the tops of banks. The project would be phased to keep the excavated channels disconnected from the main stem for two years allowing the new vegetation to establish before being exposed to flow.

4.1.1 Permanent Impacts to Waters of the U.S. (WoUS)

The impacts to aquatic resources are captured in Table 2. A total of 31.4 acres of impact are associated with this alternative. Approximately 23.8 acres of this permanent impact would be characterized as wetland loss. This permanent impact is characterized as conversion from one resource type to another, or conversion from palustrine habitat to lower riverine habitat. These impacted wetland areas would cease to function as wetlands and would function as a lotic aquatic habitat.

Approximately 7.6 acres of this permanent impact is characterized as fill: placing fill material in WoUS to construct the river plugs.

A total of 3,220 linear feet of tributary would be permanently impacted as a result of the construction of six new meander bends.

Table 2: Impacts to aquatic resulting from the construction of Alternative 1

Alternative 1 Impacts			
Type of Impact	Resource	Impact Acres	Impact Linear Foot
Bend 1			
Fill: River plug	Cuyahoga River	1.35	-
Total		1.35	
Bend 2			
Fill: River plug	Cuyahoga River	1.39	-
Wetland impact	PEM/PSS/PFO	6.15	-
Stream impact	Stanford Run Unnamed trib. 3	-	1,157 603
Total		7.54	1,760
Bend 3			
Fill: River plug	Cuyahoga River	1.98	-
Wetland impact	PSS/PFO	2.93	-
Stream impact	-	-	-
Total		4.91	
Bend 4			
Fill: River plug	Cuyahoga River	1.35	-

Wetland impact	PFO	5.38	-
Stream impact	Unnamed trib.	-	692
Total		6.73	692
Bend 5			
Fill: River plug	Cuyahoga River	1.25	-
Wetland impact	PFO	4.63	-
Stream impact	-	-	-
Total		5.88	-
Bend 6			
Fill: River plug	Cuyahoga River	1.67	-
Wetland impact	PSS/PFO	4.7	-
Stream impact	Brandywine Crk.	-	768
Total		6.37	768
Total River Fill		7.6	
Total Wetland Loss		23.79	
Total Stream Loss		3,220	

4.2 Alternative 2: Construct Two New Meander Bends

Alternative 2 would consist of lengthening the river channel at two locations along a 2.4 mile stretch of the Cuyahoga River between Boston Mills and Vaughn Road (Figure 6). By constructing two new meander bends, the Cuyahoga River channel would lengthen by about 2,800 linear feet, which is 100 percent of the length needed to restore the channel to dynamic equilibrium.

As with Alternative 1, the project would excavate new channel reaches (meander bends) at two locations, and the existing channel at Meander Bend 2 would be converted to about 2.0 acres of backwater wetland. These two locations were chosen because these two bend locations would offer the greatest increase in Cuyahoga River channel length. In addition, constructing the most upstream and downstream bends would offer the greatest spatial footprint of the ecological benefits because the channel reach between the bends would benefit from the reduced flows and erosional forces.

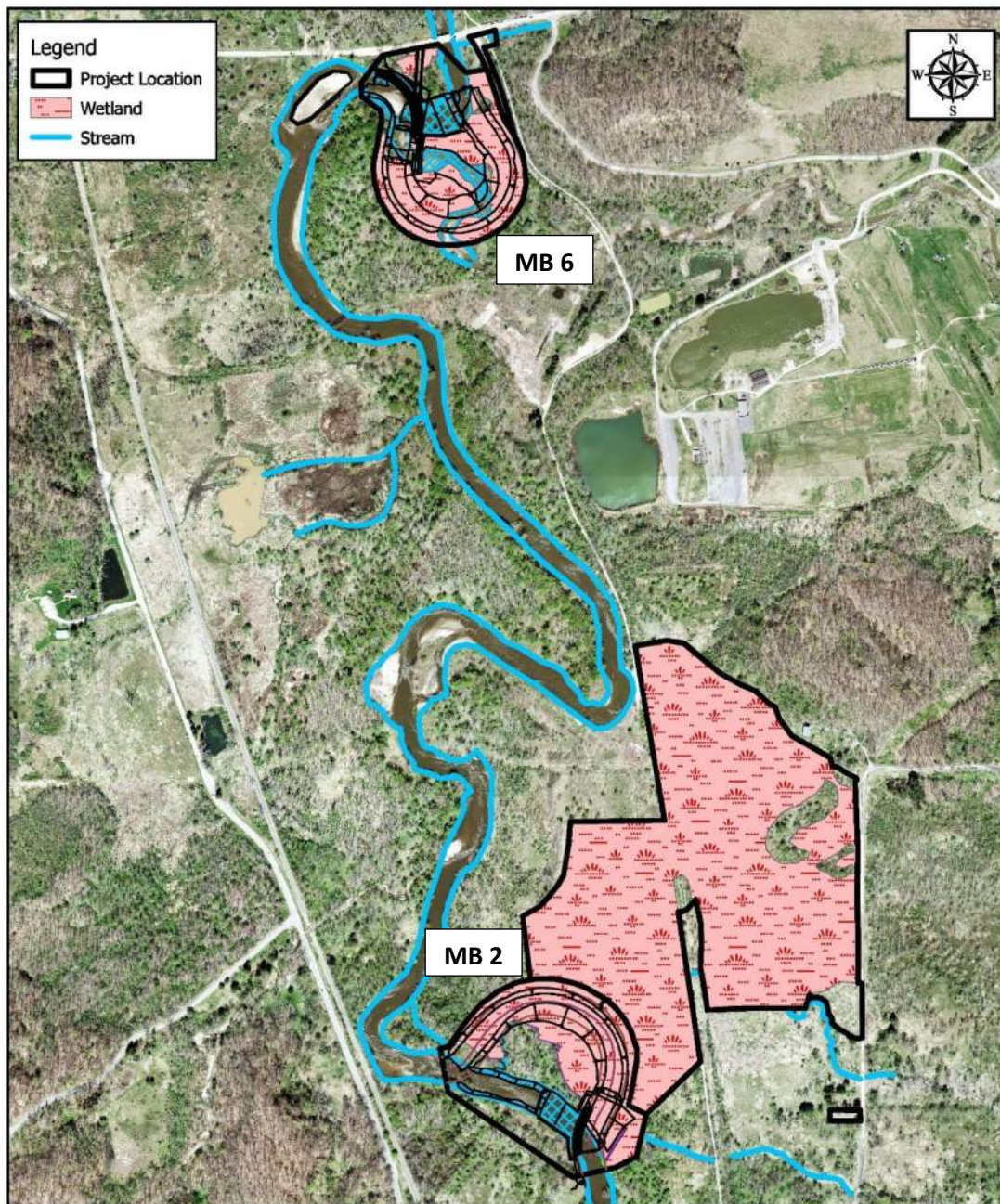


Figure 6: Alternative 2 meander bend locations

4.2.1 Permanent Impacts to WoUS

Alternative 2 would result in considerably fewer impacts to aquatic resources than Alternative 1.

Meander Bend 2 is associated with Stanford Run, which is a perennial tributary to the Cuyahoga River. Bend 2 would pass through Palustrine emergent, scrub/shrub, and forested wetlands, as well as the lower reach of Stanford Run, and second unnamed tributary to the Cuyahoga River.

Meander Bend 6 is associated with the former Cuyahoga River channel that has converted to Palustrine emergent habitat. Meander Bend 6 would also pass through Palustrine forested

wetlands associated with the floodplain. This meander bend would also pass through the lower reach of Brandywine Creek that occupies a portion of the former Cuyahoga River channel.

The impacts to aquatic resources are captured in Table 3. A total of 13.9 acres of impact are associated with this alternative. A total of 10.8 acres of wetland would be permanently impacted by the creation of two new meander bends. This permanent impact is characterized as conversion from one resource type to another, or conversion from palustrine habitat type to lower riverine habitat type. These impacted wetland areas would cease to function as wetlands and would function as a lotic aquatic habitat.

Approximately 3.06 acres of this permanent impact is characterized as fill: placing fill material in WoUS to construct the river plugs.

A total of 2,528 linear feet of tributary would be permanently impacted as a result of the construction of two new meander bends.

Table 3: Impacts to WoUS associated with Alternative 2

Alternative 2 Impacts			
Type of Impact	Resource	Impact Acres	Impact Linear Foot
Bend 2			
Fill: River plug	Cuyahoga River	1.39	-
Wetland impact	PEM/PSS/PFO	6.15	-
Stream impact	Stanford Run Unnamed trib. 3	-	1,157 603
Total		7.54	1,760
Bend 6			
Fill: River plug	Cuyahoga River	1.67	-
Wetland impact	PSS/PFO	4.7	-
Stream impact	Brandywine Crk.	-	768
Total		6.37	768
Total River Fill		3.06	
Total Wetland Loss		10.85	
Total Stream Loss		2,528	

4.3 Alternative 3: Construct One New Meander Bend

Alternative 3 would consist of lengthening the river channel at one location along the Cuyahoga River within the CVNP (Figure 7). By constructing one new meander bend, the Cuyahoga River channel would lengthen by about 1,250 linear feet, which is about 45 percent of the length needed to restore the channel to dynamic equilibrium.

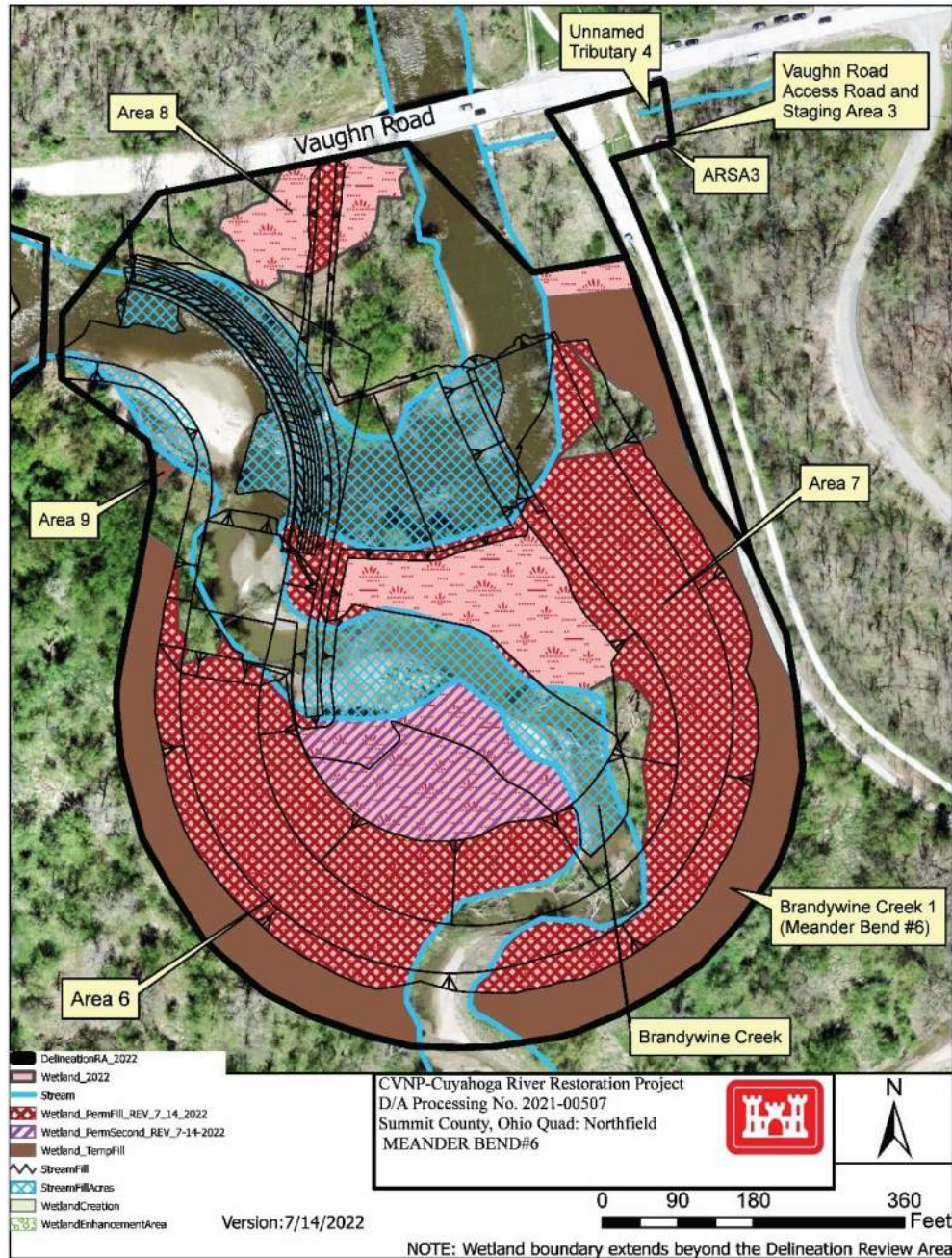


Figure 7: Alternative 3, Meander Bend 6 location and impacts

As with Alternatives 1 and 2, the project would excavate a new meander bend but only at one location. Meander Bend 6 was chosen because this is the location of the Vaughn Road cutoff that took place in the 1960s and resulted in a substantial loss of Cuyahoga River channel (Figure 8). This alternative would restore the Cuyahoga River in this location to its condition prior to the man-made cutoff event.

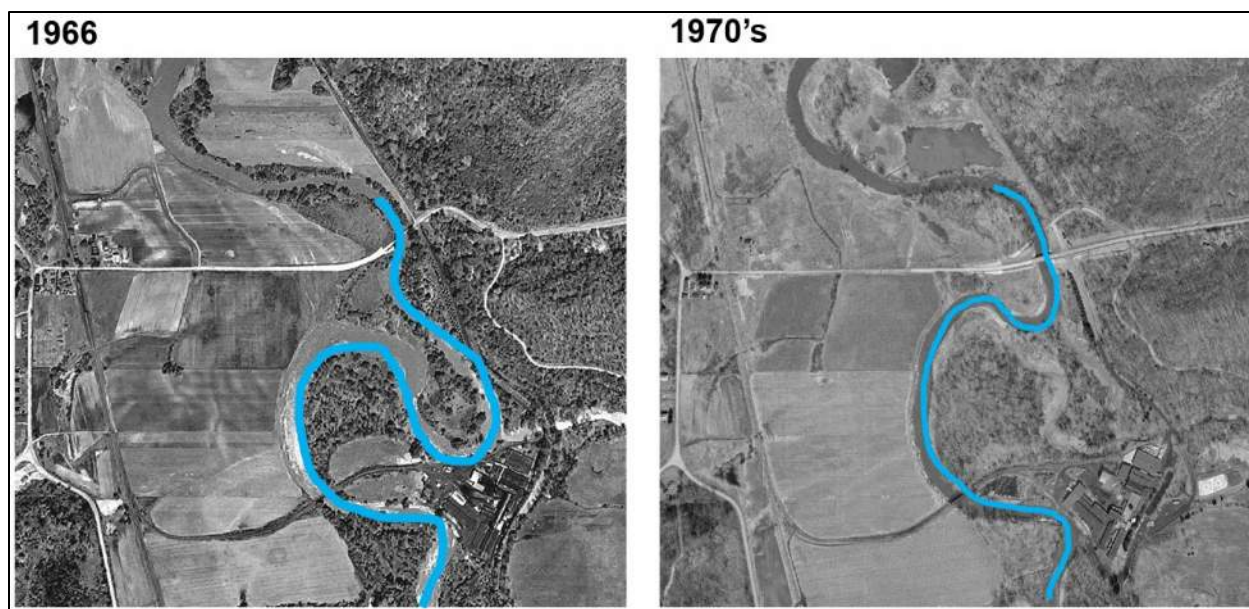


Figure 8: Cuyahoga River channel before and after the Vaughn Road Bridge repair work

4.3.1 Permanent Impacts to WoUS

The impacts to aquatic resources are captured in Table 4. A total of 6.37 acres of impact are associated with this alternative. Approximately 4.7 acres of this permanent impact would be characterized as wetland loss. This permanent impact is characterized as conversion from one resource type to another, or conversion from palustrine habitat type to lower riverine habitat type. The impacted wetlands would occur to the former river channel that has since converted to Palustrine emergent wetland. Also, the stretch of Brandywine Creek that now occupies the former channel would be impacted.

Approximately 1.67 acres of this permanent impact is characterized as fill: placing fill material in WoUS to construct the river plug.

A total of 768 linear feet of tributary would be permanently impacted as a result of the construction of the new meander bend.

Table 4: Wetland and stream impacts associated with Alternative 3

Alternative 3 Impacts			
Type of Impact	Resource	Impact Acres	Impact Linear Foot
Bend 6			
Fill: River plug	Cuyahoga River	1.67	-
Wetland impact	PSS/PFO	4.7	-
Stream impact	Brandywine Crk.	-	768
Total		6.37	768
Total River Fill		1.67	
Total Wetland Loss		4.7	
Total Stream Loss		768	

5 Description of the Selected Plan

5.1 Channel Lengthening at Meander Bend 6

The recommended alternative is Alternative 3: Construct one New Meander Bend. Channel lengthening is the only alternative, of the suite of restoration measures that were initially explored, that meets all of the project objectives and is the only restoration approach that addresses the root cause of instability within the Cuyahoga River, while minimizing impacts to wetlands and streams to the greatest extent practicable. This alternative would restore this reach of the Cuyahoga River to its configuration before the Vaughn Road Bridge cutoff event.

The project would excavate a new meander bend. The new section of added channel length will be excavated to have a top width of 180-185 feet, a depth of approximately 10 feet, and side slopes of 3H:1V or flatter. Riffle and pool structures would be designed within the meander bend to function in accordance with the watershed hydrology to be stable over time and providing cover for aquatic macroinvertebrates and fish species. Based upon coring data presented in the geotechnical evaluation, the bottom of the new meander bends would be in a stratigraphic layer of fluvial bed material similar to the existing riverbed composition and suitable to receive the flows of the Cuyahoga River. Large boulders and coarse gradations of stone would be sorted and reused to construct the in-channel riffle-pool sequences.

The project would be phased to keep the excavated channels disconnected from the main stem for two years, thereby allowing the new vegetation to establish and aid in stabilizing the new channel before being exposed to flow (Figure 9). In year three, the existing river channel would be “plugged” with a structure composed of a combination of a stone base and coir fabric wrapped soil. The “plug” would also be vegetated with live stakes and shrubs on the front face of the slope and rooted whips between the layers of coir fabric wrapped soil. Some of the trees cleared for excavation of the channel would be reused as large woody debris within the new channel by incorporating them into the side slopes of the new channel and plug to aid in streambank stabilization and promote habitat complexity.

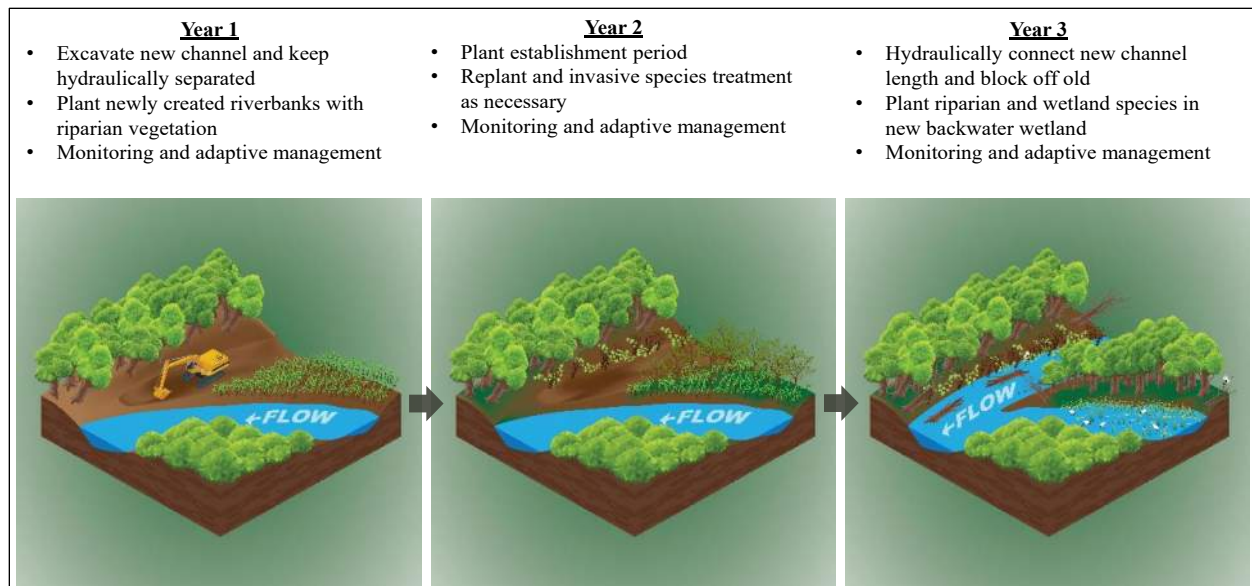


Figure 9: Design and sequencing of the new meander bends

In addition to reusing the cleared woody debris for the applications above, habitat piles composed of small trees, bushes, and limbs would be constructed in the vicinity of the new meander bend. A wide variety of wildlife use woody piles for shelter, as dens or nesting spots, to escape predators, and to forage. Ideally, the habitat piles would be placed within 100 feet of the river to provide habitat to the greatest diversity of species.

This alternative requires extensive excavation and management of the spoils from the new meander bends. Approximately 70,000 CY of soils would be excavated to create the new river channel. While a proportion of that material would be reused on-site to construct the water diversion plug, most of the material would be transported offsite via dump truck or potentially using the Cuyahoga River Scenic Railroad. The soils would be disposed of at the Haydite Mine site (Figure 10). The Haydite mine, located in Independence, OH, approximately 10-15 miles north of the project reach on the west bank of the Cuyahoga River, has recently ceased operations and is in the process of being donated to the NPS. It is currently being managed by West Creek Conservancy who has indicated interest in receiving the material to aid in restoration of the site. The material would be used to fill in the mine and regrade the topography to restore the landscape of the site. The Cuyahoga River Scenic Railroad could provide a direct transportation route from the channel lengthening location to the Haydite mine.

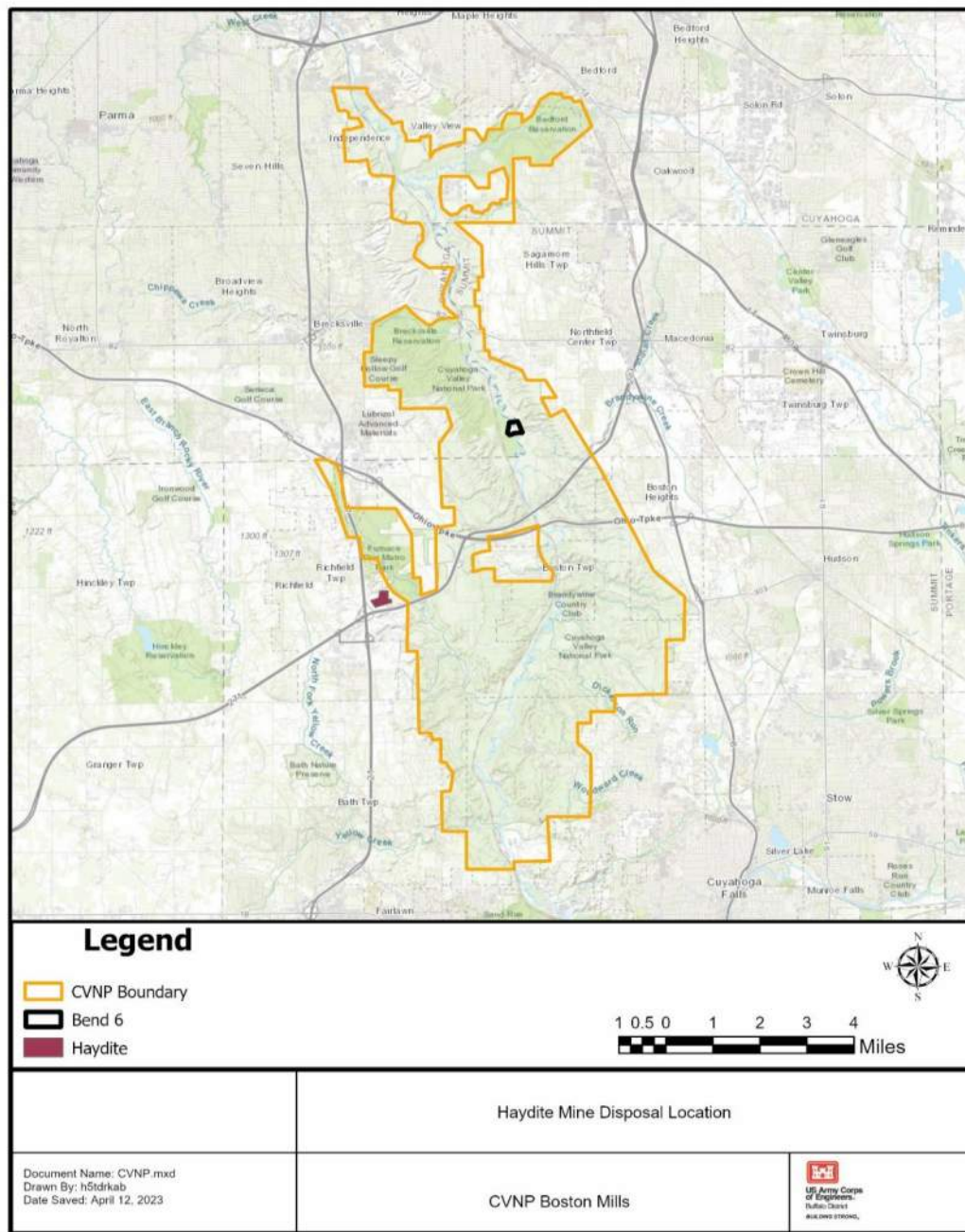


Figure 10: Haydite Mine disposal location

5.2 Channel Lengthening Reach of Benefits

The purpose of the channel lengthening project is to reduce the channel slope in the project reach, thereby bringing the project reach into equilibrium with the increased flows caused by development of impervious surfaces. This reduction in slope, along with the additional conveyance created, will reduce excessive bank erosion occurring and stabilize other associated

restoration work (e.g., aquatic habitat improvements, invasive species management, and restoring native riparian vegetation) along the Cuyahoga River.

As a result of constructing Bend 6, channel lengthening calculations were determined to benefit approximately 7,900 feet (Figure 11). The structural impacts to the river within this reach would be riverbanks transitioning from bare and near vertical with excessive loss of trees and other vegetation to riverbank erosion, to stable banks with slopes on the order of 1.5:1 to 2:1, with active and continuous vegetative growth. The bed channel elevation is expected to adjust to match the equilibrium slope, in response to the river segment's new length, with the largest adjustment to the channel bed being on the downstream end, tapering to no adjustment on the upstream end of the reach.

This reach of channel benefits was also evaluated using HEC-RAS model results for velocity, stream power, energy, and shear stress. These results show benefits extending about 7,900 feet upstream from Bend 6. However, the greatest benefits based on these metrics would occur closest to Bend 6, with the net benefits decreasing with increased distance upstream.

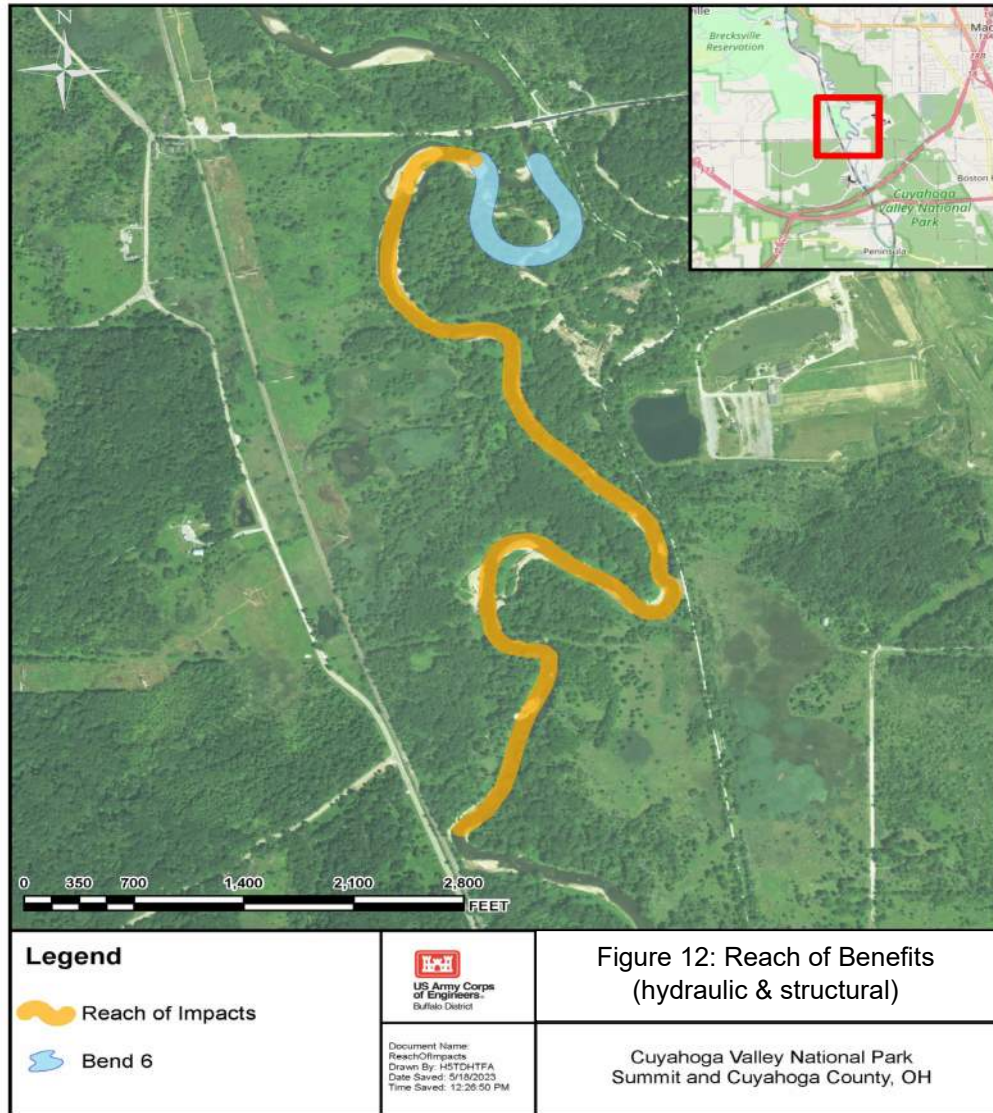


Figure 11: Channel Lengthening reach of expected benefits

A yearly monitoring plan for the expected reach of impacts is outlined below:

1. Annual cross section surveys done at the two locations identified on Figure 12. This would be done by the USACE Survey Team on an annual basis from 20 feet outside the top of bank and along the cross section to 20 feet into the other bank floodplain.
2. Installing bank pins at the two cross section location identified on Figure 12. Top of bank pins would be installed on both sides of the channel and measurements would be taken two times a year.

3. Measure velocity at the old railroad bridge at the location shown on Figure 12. This would be measured using The USGS Type AA current meter or similar.

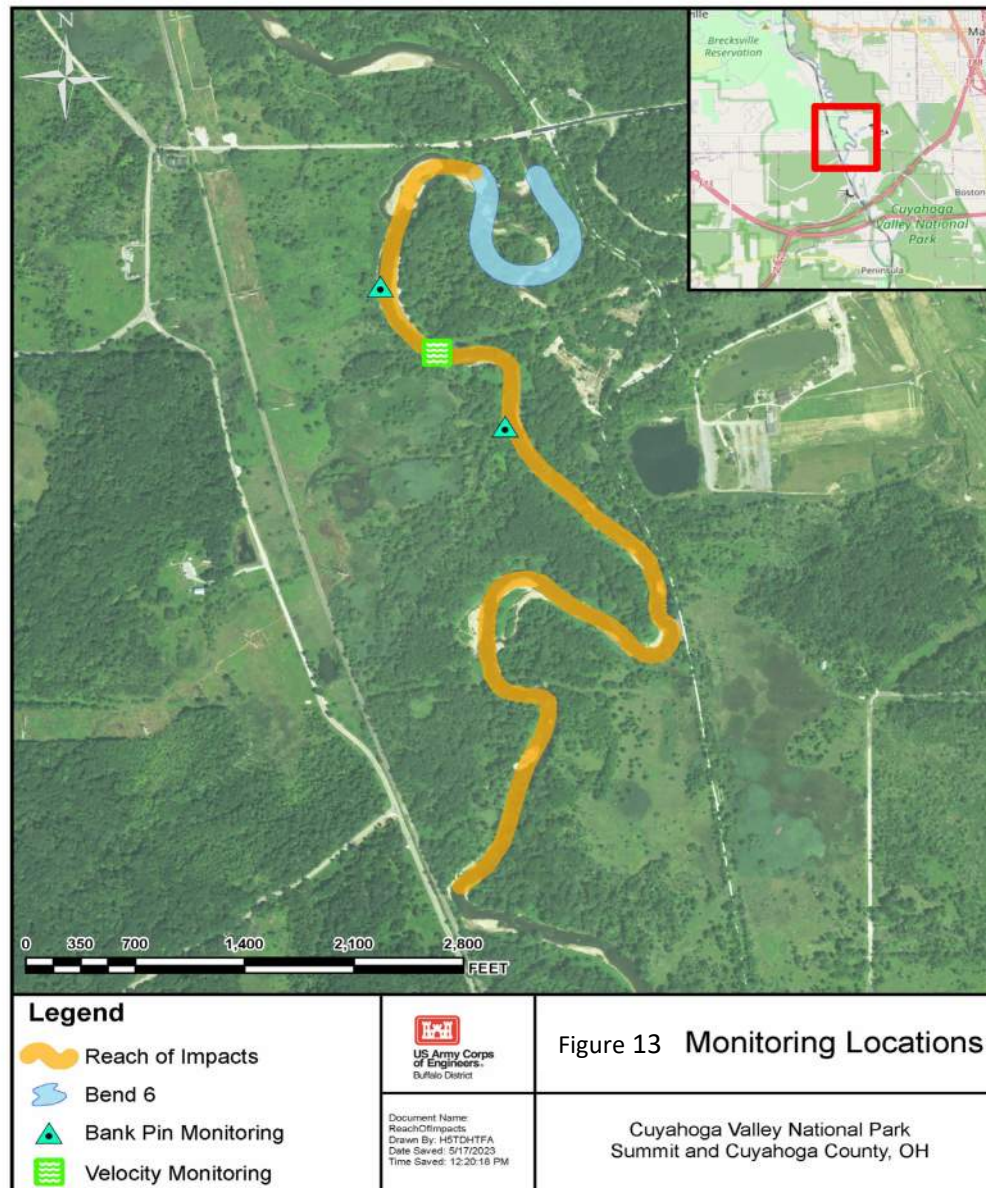


Figure 12: Monitoring locations for the channel lengthening project

5.3 Impacts to Waters of the U.S.

A total of 4.7 acres of wetland would be permanently impacted by the creation of new river channel and would cease to function as wetlands. These wetland areas would now function as a lotic/riverine aquatic system. In addition, about 800 linear feet of Brandywine Creek would be permanently impacted by the creation of the new river channel. This impacted section of

Brandywine Creek would be converted from a lower riverine habitat to the mainstem of the Cuyahoga River.

6 Mitigation

Compensatory mitigation is required to offset the loss of Category 3 wetlands and about 800 linear feet of Brandywine Creek, which is a perennial tributary to the Cuyahoga River. The compensatory mitigation proposal will take place at the Brandywine Golf Course, located in Peninsula, Ohio (Figure 13). The mitigation proposal is explained in the following sections.



Figure 13: Compensatory mitigation location at Brandywine Golf Course

6.1 Compensatory Mitigation Location and Existing Conditions

The Brandywine Golf Course, now owned by the National Park Service, was constructed in the 1960s during a time in American history when the importance of small streams was not recognized and development usually resulted in burying or channelizing many small tributaries. Two such tributaries at the Brandywine Golf Course, Haskell Run and Ritchie Run, flow through the property from east to west before converging and then flowing directly into the Cuyahoga River (Figure 14). Both tributaries are characterized as upper perennial riverine systems which have been modified and degraded by the construction and operation of the Brandywine Golf Course. This CMP focuses on restoring the Ritchie Run tributary.



Figure 14: Location of tributaries Haskell Run and Ritchie Run on the Brandywine Golf Course property

To develop the golf course, about 90 percent of the Ritchie Run stream channel was buried in a culvert. Fill material was then brought in to construct a fairway over the former stream channel. This fill was used to raise, grade, and flatten the Ritchie Run valley. Figure 15 shows Ritchie Run flowing into the buried culvert with about three feet of fill material above the culvert. This fill material forms the fairway. This buried condition continues unbroken for about 3,500 linear feet until the culvert empties into an inline ornamental pond (Figure 14). Ritchie Run then confluences with Haskell Run before emptying into the Cuyahoga River. Figure 16 shows the reference condition of Ritchie Run just upstream of the buried section, which is a meandering channel with access to a sedge/grass meadow floodplain and an open forest riparian corridor.



Figure 15: Ritchie Run flowing into buried culvert

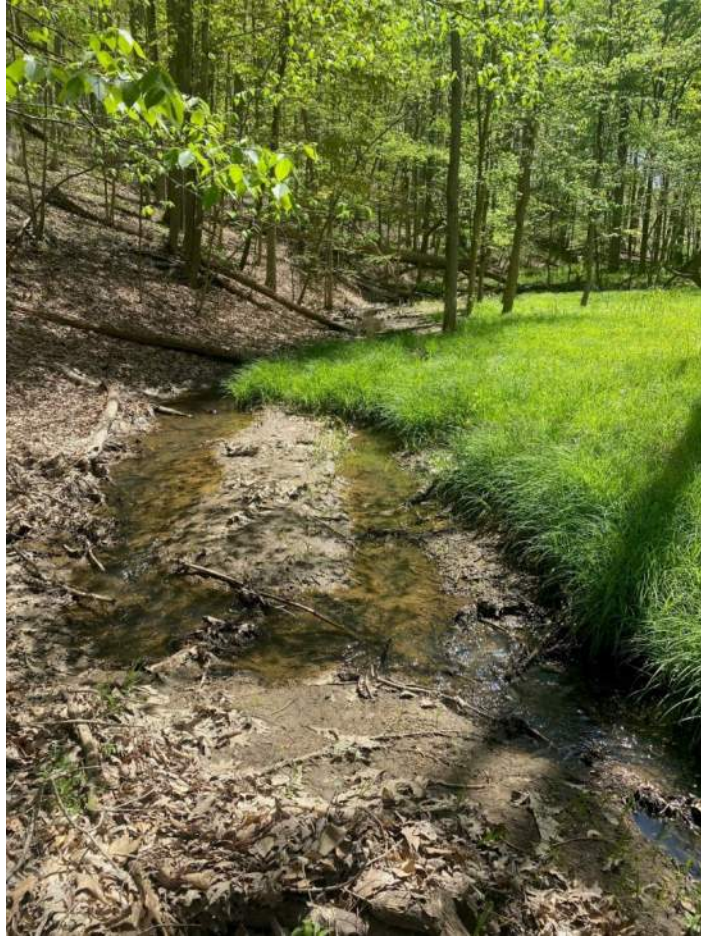


Figure 16: Upstream reference conditions at Ritchie Run

6.2 Compensatory Mitigation Plan

The CMP at the former Brandywine Golf Club would involve restoring about 3,500 linear feet of stream channel and about 15-20 acres of forested riparian wetland (Figure 17). The stream restoration component of the CMP would be to daylight the entire buried channel of Ritchie Run. The fill material used to construct the fairway would also be excavated down to an elevation sufficient to support riparian and floodplain wetlands. The daylighted section of Ritchie Run would be constructed to follow, as closely as possible, its historic alignment prior to construction of the golf course. The new channel would also be designed to match the upstream reference conditions shown in Figure 16 constructed as a two-stage channel with a floodplain bench and instream habitat structures using large woody debris.



Figure 17: Conceptual mitigation proposal at Ritchie Run, on Brandywine Golf Course

The entire excavated floodplain wetland would be planted with tree species typically found within the CVNP, including sycamore (*Platanus occidentalis*), cottonwood (*Populus deltoides*), boxelder (*Acer negundo*), maple (*Acer spp.*), and oak (*Quercus spp.*). A comprehensive planting plan would be developed for the riparian wetland that includes seeding, installation of herbaceous plugs, lower story shrubs, and native grasses and sedges. All plantings would be native species typically found within the CVNP. In addition, the restoration work plan would include invasive species management and herbivore management measures.

7 Planting and Invasive Species Management Plan

The goals of the planting and invasive species management plans are to restore the riparian vegetation communities that exist along the current river channel, and to create a functional riparian community along the created river channels. Figure 18 shows the general layout of the riparian zone planting plan that would be followed for vegetation establishment. The establishment of a variety of robust vegetation communities and the enhancement of existing vegetation communities is very important to success of the channel lengthening alternative and would serve several purposes, including water quality protection and enhancement, wildlife habitat creation and movement corridors, bank stabilization, detrital input into the waterbody,

and invasive species control. For full details of the Planting and Invasive Species Management Plan refer to Appendix B.

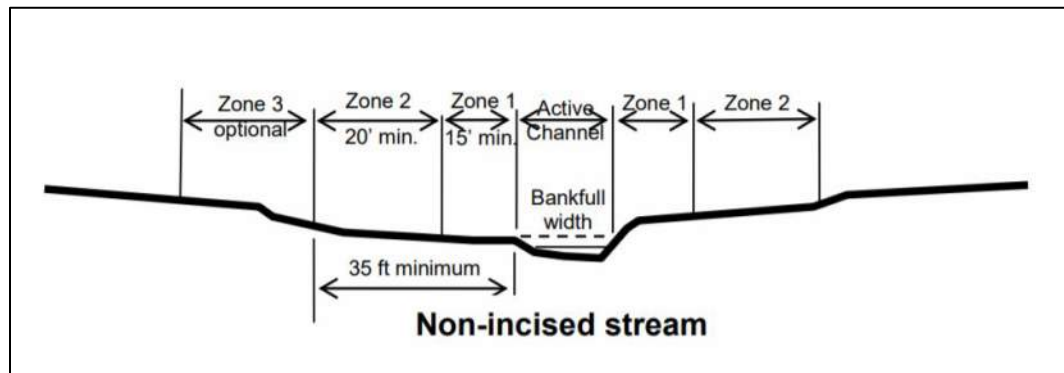


Figure 18: Typical cross section of a riparian planting plan

Invasive species are prevalent in the CVNP. Invasive species propagules are constantly being supplied from upstream sources; therefore, it is unrealistic to assume complete eradication of any particular invasive species. It is important to manage invasive species populations for a duration of time sufficient to allow the native plantings to effectively compete with the invasive species. A four-year invasive species management protocol is recommended for the most pervasive invasive species found in the project area; Japanese knotweed (*Reynoutria japonica*), and reed canary grass (*Phalaris arundinacea*).

Integrated Vegetation Management (IVM) would be used to manage the Japanese knotweed population throughout the project area. IVM is an approach to managing vegetation that achieves the desired outcome using the plants biology to identify effective, safe, and efficient methods of control. IVM uses well-timed mechanical and chemical controls treatments to release the natural response of native vegetation. The goal of IVM is to establish native vegetation which provides a barrier to re-infestation by Japanese knotweed. A dense barrier of native vegetation, maintained by monitoring and spot-treatment of exotics, blocks further infestation by invasive plant colonization. IVM for this project uses three general methods of control: physical, chemical, and interspecific competition. Figure 19 provides a general management calendar for how the Japanese knotweed will be treated for this project. Refer to Appendix B for full details of the Invasive Species Management Plan.

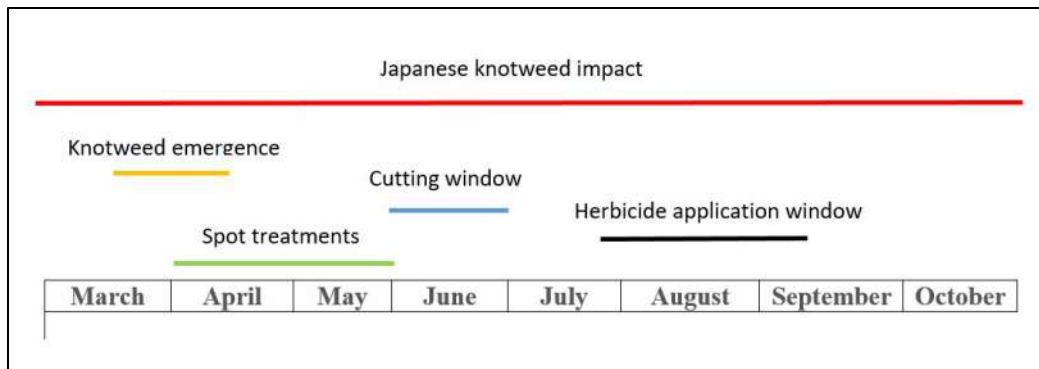


Figure 19: Knotweed management calendar, based on its growth pattern and response to management actions

8 Monitoring and Adaptive Management Plan

The purpose of monitoring and adaptive management plan is to provide data that can suggest mid-course corrections that should be implemented to better realize the project's objectives. The river restoration monitoring objectives are to assess the physical stability of the restored channel, vegetation establishment, and habitat improvements. The site should be monitored bi-annually for a period of at least five years after restoration activities are complete. At the end of each year, data collected as described below shall be used to identify any issues regarding vegetation recruitment, adequate hydrology, invasive species control, and recommend maintenance. It is estimated that proposed monitoring can be accomplished for \$10,000 – \$15,000 per year.

The methods used for monitoring include the establishment of fixed photo points, physical habitat assessments, biological assessments, and vegetation assessments. At the constructed bend, the following appropriate standardized protocols shall be used to assess performance, including the following:

- Physical habitat assessments:
 1. Qualitative Habitat Assessment Index (QHEI)
 2. Modified Bank Erosion Hazard Index (BEHI)
 3. Ohio Rapid Assessment Method (ORAM) for wetlands
 4. Large Woody Debris Index
 5. Channel Catfish HSI
- Biological assessments (aquatic life usage):
 1. Fish Index of Biotic Integrity (FIBI)
 2. Invertebrate Community Index (ICI)
 3. Floristic Quality Assessment Index (FQAI)
- Customized assessments based on project goals:
 1. Coverage of riparian vegetation within restoration reach
 2. Presence and coverage of plant species installed during restoration
 3. Presence and coverage of invasive plant species
 4. Visual assessments of floodplain connectivity

Refer to Appendix B for full details of the Monitoring and Adaptive Management Plan.

8.1 Performance Standards and Adaptive Management

The overall goal of the project is to contribute to BUI removal within the CVNP and downstream reaches by reducing the erosion rate and restoring equilibrium to the project reach. The following performance standards will measure the project's success:

Performance Standard #1: The following QHEI sub metric scores should show increases as outlined in Table 5 by the end of the third year following construction activities.

Table 5: QHEI sub-metric scores to show increases at the end of three years

QHEI Sub-metric (Optm score)	Existing	Attainable	Δ Increase
Substrate (20 pt)	13	14	1 pt
Instream cover (20 pt)	11	20	9 pt
Channel morphology (20 pt)	12	15	3 pt
Bank erosion & riparian zone (10 pt)	8	9	1 pt
Pool/current (12 pt)	10	12	2 pt
Riffle/run (8 pt)	3	5	2 pt
Gradient (10 pt)	10	10	-

Performance Standard #2: Measurable increases in the Fish IBI and ICI scores (conducted by OEPA) throughout the project reach three years after construction activities have been completed.

Performance Standard #3: BEHI scores must show an increase of at least five points by the end of the second year following construction activities.

Performance Standard #4: Riparian vegetation communities must exhibit at least 80 percent native species composition by the end of the third growing season following construction activities.

Performance Standard #5: No more than 10 percent cumulative areal cover of the riparian zone may be vegetated with the following species: reed canary grass, common reed, European buckthorn, glossy buckthorn, or Japanese knotweed.

Performance Standard #6: Measurable increase in the Channel Catfish HSI score throughout the project reach two years after construction activities have been completed.

The following adaptive management measures will be considered if the performance standards are not achieved:

Adaptive Management Measure #1: If the desired hydrology is not achieved by the end of the first growing season following construction, elevations should be adjusted by excavation of soil, grading, or placement of fill.

Adaptive Management Measure #2: If the fish and macro-invertebrate abundance and diversity do not increase as indicated by Fish IBI and ICI scores, measures should be implemented to further enhance habitat quality within the project reach.

Adaptive Management Measure #3: If the above invasive species vegetation thresholds are exceeded (i.e., not met) at the end of any monitoring year, corrective measures should be implemented to preclude the growth of the above listed species within the restoration area. Corrective measures include additional herbicide applications to invasive species, increased mechanical treatment (e.g., cutting or hand-pulling) and/or additional plantings to compete with invasive species.

Adaptive Management Measure #4: If the desired vegetation is not achieved at the end of any monitoring season following construction, additional plantings or seeding should take place.