Appendix F
Ecology Engineering Evaluation Report, Buffalo River, New York

DRAFT FINAL

Ecology Engineering Evaluation Report
Buffalo River, New York

Prepared on behalf of:

Buffalo River Great Lakes Legacy Act Project Coordination Team

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List of Tables

List of Figures

List of Appendices

ACRONYMS AND ABBREVIATIONS

%	Percent
AOC	Area of concern
BNR	Buffalo Niagara Riverkeeper
BUI	Beneficial Use Impairment
EEE Report	Ecology Engineering Evaluation Report
ENVIRON	ENVIRON International Corporation
EV	Emergent vegetation
GLLA	Great Lakes Legacy Act
GLNPO	Great Lakes National Program Office
Honeywell	Honeywell International Inc.
MACTEC	MACTEC Engineering and Consulting, Inc.
mg/L	Milligrams per liter
NYSDEC	New York State Department of Environmental Conservation
PCT	Project coordination team
RM	River mile
SAV	Submerged aquatic vegetation
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency

1 INTRODUCTION

This Ecology Engineering Evaluation Report (EEE Report) has been prepared by ENVIRON International Corporation (ENVIRON) and MACTEC Engineering and Consulting, Inc. (MACTEC) on behalf of Buffalo River GLLA Project coordination team (PCT) pursuant to the Buffalo River Great Lakes Legacy Act (GLLA) Project Agreement. It is being submitted as an addendum to the *Buffalo River Feasibility Study*. The PCT includes the United States Environmental Protection Agency (USEPA) Great Lakes National Program Office (GLNPO), the Buffalo Niagara Riverkeeper (BNR), New York State Department of Environmental Conservation (NYSDEC), United States Army Corps of Engineers (USACE), and Honeywell International Inc. (Honeywell).

The EEE report includes:

- A description of restoration practices and techniques considered for the Buffalo River (Section 2)
- Examples of how those techniques may be combined for certain general shoreline types along the river (Section 3)
- Proposed restoration alternatives for six river locations identified by the Habitat Restoration Subgroup of the PCT (Section 4)
- An evaluation of those alternatives against evaluation criteria identified by the Habitat Restoration Subgroup (Section 5)

Additional projects beyond those described herein may be included in the Buffalo River Master Plan that is currently under development by the USEPA GLNPO in consultation with the Buffalo River PCT Habitat Restoration Subgroup.

2 SELECTED RESTORATION TECHNIQUES

This section provides a range of subaquatic, bank, and riparian zone restoration techniques that will improve habitat in the Buffalo River, while also providing adequate flexibility for dealing with the wide variety of conditions found in the river. The techniques discussed below include:

- Enhancement or creation of aquatic vegetation
- Improvement of shallow water substrate
- Enhancement of bank habitat using various structures that increase the complexity of shoreline habitats
- Bank stabilization measures
- Expansion of riparian habitat

Example photographs and schematics of the restoration techniques are provided in Appendix A.

Restoration techniques that occur above the water line will require land owner acceptance prior to project implementation. It is anticipated that additional due diligence (including any necessary access negotiations with land owners) will be conducted during the design phase.

2.1 Aquatic Vegetation Enhancement

Emergent vegetation (EV) and/or submerged aquatic vegetation (SAV) beds may be created or enhanced for shallow areas with sufficient light penetration, substrate depth, substrate type, and flow characteristics, among other factors. EV and SAV beds provide substrate for invertebrate communities, as well as spawning, nursery, and cover areas for fish.

The selection of EV and SAV species depends upon several factors, including that species are:

- Indigenous to western New York
- Suitable for growth in current Buffalo River conditions (e.g., turbidity, light penetration)
- Adaptable to extremely variable water quality conditions (e.g., dissolved oxygen, temperature)

Example species for each planting zone are provided in Tables 1 and 2. These lists will be refined during the remediation design phase, based on plant stock availability and consideration of additional site-specific conditions. Plant material for stream bank restoration is available in a variety of forms (e.g., seed mix, plugs, potted materials, bare root seedlings, containerized seedlings, and bagged root balls with short saplings). It is anticipated that a combination of forms will be used. Specifications detailing the number, form, size, and placement of plant material will be presented in the final design. Vegetation planting season will depend upon the plant form used and will be coordinated with remediation activities in an effort to minimize physical disruption of the planting area. Plant spacing will follow the supplier's recommendation and standard practices and will also be included in the final design.

This technique may also include the removal of non-native invasive plants. Ultimately, the goal is to establish native vegetation that is dense enough to compete with the non-native invasive species. The methods and targeted areas for non-native invasive plant removal will be refined during the design phase. For EV specifically, the shoreline can be accessed by land or from boat depending on the site and contractor preference. The typical method for the removal of invasive EV is by wick application of approved herbicides repeated over a 2-year period until the target species are eradicated. Other methods may also be considered for the removal of invasive EV. Eradication of invasive SAV species can be conducted by planting native SAV species that will out-compete the invasive species present.

2.2 In-Stream Shallows Substrate Enhancement

Natural stream substrates are composed of a variety of materials (e.g., clay, sand, gravel, cobbles, boulders, organic matter). Substrate enhancement is the addition of natural materials to enhance targeted functions. For example, gravel may be added in selected locations to enhance in-stream shallows and fish spawning habitat, or finer grain sediment may be enhanced to provide substrate for targeted EV or SAV species. Substrate enhancement may also benefit areas with physical limitations. For example, the addition of cobble and stone along the toe of sheetpiling would provide additional habitat complexity for fish and invertebrates within the physical constraints of the system.

Not all substrates can be employed in all areas, and it may be necessary to select one substrate in favor of another. For example, a gravel substrate to enhance fish spawning habitat may be deployed at the expense of a fine grained substrate to support targeted EV or SAV. Substrate selection should be based on habitat improvement goals and should also consider natural hydrodynamic and sedimentation processes in the river, so that those processes complement and enhance the selected substrate with time.

2.3 Anchored Woody Debris

The construction of anchored woody debris or pilings can be considered in areas where in-stream habitat is limited or absent in specific reaches of the river. These structures can provide cover and structural diversity for aquatic macroinvertebrates. They would provide cover for fish to escape or rest when moving from one river segment to another, but they do not provide habitat for spawning or feeding. Anchored woody debris or piling structures are made of untreated hardwood or whole tree trunks and typically have a design life of more than 25 years. In areas where pilings already exist and provide enhanced habitat quality, the remedy and habitat restoration plan may attempt to conserve existing pilings.

2.4 Modified Lunker Boxes

The typical lunker box design has been modified in this case to create a submerged shelf that is anchored to a hardened shoreline (e.g., sheet pile wall, concrete cap) rather than to the streambank. The modified lunker box is filled with riprap, substrate, or cobble. This modified design provides shade, shelter, and habitat for fish and other biota in areas of hardened shoreline where other restoration techniques may not be suitable. The shelves could either be constructed out of natural materials (e.g., wood), wire, or metal. The final determination regarding materials would be made in the design phase. These structures will have a finite life span due to human (e.g., ship traffic) and natural forces (e.g., ice) along bulkhead walls. In general, modified lunker boxes have limited proven success and are costly to implement and maintain.

2.5 Floating Log Shelters

Floating log shelters are logs that are anchored close to the river bank or shoreline (e.g., sheet pile wall) by cables, giving them the ability to move up and down with changing surface water elevations without the risk of floating downstream. The floating logs would provide shelter and shade for fish and macroinvertebrates. However, the benefits are limited in areas with hardened shoreline due to the physical constraints (e.g., vertical banks, limited in-stream habitat). Sizing and anchoring specifications would be determined in the design phase. The life span of floating log shelters may be adversely affected by ice scour and anthropogenic impacts.

2.6 Rootwads

Rootwads are installed directly into the river banks to provide submerged or shoreline habitat. For installation, soil is cut from the banks to six feet below the water line and eight feet back from the bank at the deepest point. The tree trunks with the root balls attached are then installed so that they are emerging from the bank (Appendix A). The stumps are then anchored using large boulders or concrete debris and backfilled with removed fill material. Rootwads can extend up onto the bank where they would eventually decompose and be replaced by vegetation.

Rootwads provide maximum instream habitat for fish to feed, rest, and escape. The rootwads contain countless crevices and large amounts of surface area onto which aquatic macroinvertebrates can attach. The design life of a submerged rootwad can be greater than 25 years depending on species. Because the rootwads are installed perpendicular to the bank, this robust technique reinforces the river bank, is relatively resistant to propeller wash and wave and ice action, and can withstand woody debris accumulation.

2.7 Tree Revetments

Tree revetments are rows of interconnected trees anchored to the streambank. The trees trap sediment, provide a multitude of resting and hiding places for fish, reduce flow velocities along eroding streambanks, and assist with plant establishment. The installed tree revetment system should occupy less than 15 percent (%) of the channel’s cross sectional area at bankfull level to prevent the revetment from acting as a debris trap (FISRWG 1998). This technique has a limited life span and has the potential to be damaged by ice flows because it is anchored parallel to the streambank. Tree revetments require additional stabilization where toe scour is anticipated, and they require an anchoring system to secure them in place. Nevertheless, their ability to capture sediment and provide cover enhances conditions for native species, by creating small shallow areas for vegetation growth and spawning.

2.8 Vanes

Vanes are natural flow barriers placed completely within a waterway or set at an angle from the bank. Vanes can vary in type (e.g., simple vane, J vane, cross vane) and material (e.g., rock, log). They are typically used to redirect flows away from sensitive areas like eroding banks. Vanes can also enhance ecological habitat by creating scour pools and improving water quality through increased oxygenation. Because the Buffalo River is used for commercial and recreational boating, decisions on vane placement will be important.

2.9 Bank Shaping

Bank shaping is intended to achieve a natural angle of repose in areas that are unstable due to maintenance dredging, undercutting, or natural hydrodynamic forces. This technique assumes the ability to regrade banks into an existing riparian zone and/or to introduce fill material to reshape banks as needed. This technique is not recommended for locations with infrastructure or land use concerns or locations where waves or ice scour can degrade the banks. This approach could change the channel cross section or floodplain and could affect navigation depending on the location of the bank restoration and the availability of shoreline and space. A hydraulic model and/or floodplain analysis would need to be performed to determine where this technique is feasible and where it would not adversely affect floodplain and stormwater storage and conveyance capacity during high flow events.

Bank shaping often starts by “pulling the banks back” at the top of the slope. To achieve a material balance during construction, the excess material removed at the top will be deposited at the base of the slope in the river channel[1]. A slope of 3:1 is the optimal slope for bank stability (FISWRG 1998), though site-specific grades may vary depending on the soil material, flow conditions, and bank structure. Below the water line, a littoral bench can be cut into the bank, generally between one and three feet below the normal elevation of the river. Following regrading, a woven coir fabric may be rolled parallel to the river to provide short-term stabilization until vegetation can provide long-term stabilization by an established root mat. Following the erosion control fabric installation, the slope is planted with native grasses, shrubs, and trees.

This technique offers water quality and habitat benefits with maximum nutrient uptake, maximum overhanging vegetation, maximum root systems, and canopy structure. In the long term, this technique can match the strength and stability of riprap and similar stabilization methods. This approach provides for maximum aquatic vegetation and shoreline spawning and nursery habitat by providing riparian and submerged habitat targeted at centrarchids (bluegills), aquatic macroinvertebrates, and other aquatic species. Water quality benefits are very high for this technique. For example, gentler, stable slopes provide more suitable conditions for the growth of overhanging vegetation, which can shade the water resulting in lower temperatures and higher dissolved oxygen saturation.

[1] Material removed from the top of the slope will only be used as fill at the base of the slope if the material is deemed appropriate (i.e. physical and chemical characteristics).

2.10 Stone Toe Protection

Stone toe protection is a robust solution intended to protect critical infrastructure or land use or to resist erosional forces. It consists of riprap, typically in the 24-inch to 36-inch range, with the exact size based on external design issues such as ice or wave action and current velocities during high flow events. The rock structures can provide a firm foundation and force deflection while providing microhabitat complexity. The slope can be 2:1 or less, and material can be added to act as a substrate for vegetation. This method has the benefit of a robust treatment while providing vegetation for water quality and wildlife.

2.11 Wrapped Earth with Branch Packing

This technique uses either a woven coir blanket or geogrid to wrap around an enclosure of soil, creating reinforced earth. Branch packing is installed between the lifts, and the growth of this root system replaces the coir fabric or reinforces the geogrid with time. Slopes can be steeper than 2:1. The geogrid application is robust and can withstand waves and ice. This technique results in dense overhanging vegetation along the bank, enhancing water quality for aquatic macroinvertebrates and fish. Over time, good root development and nutrient uptake will continue to enhance bank stability.

2.12 Living Crib Wall

A living crib wall makes use of certain species of trees (e.g., black willow) that are cut into segments and used in a crib configuration (similar to a log cabin) to hold the banks together. These logs send off new shoots that become trees. This is a robust treatment when roots become established. In order for the living crib wall to serve as a longer-term measure, the logs must be placed at the correct elevation within the saturated soils so that roots can establish. A living crib wall can be up to five feet tall and almost vertical. Branch packing can be performed to increase success. The application can withstand ice and wave action and is very effective for short banks. This technique has very high value for aquatic macroinvertebrates and fish by providing submerged substrate and improves with time as the trees continue to grow.

2.13 Geocells

Geocells are structurally robust treatments that can be installed at a steep angle (e.g., 1:1 slope), but still allow for vegetation. Geocells are engineered net-shaped cell structures that are typically made of a geosynthetic fabric frame (e.g., high density polyethylene, low density polypropylene) that is filled with soil. Much like the wrapped earth technique, geocells are reinforced earth applications that are, in time, further stabilized by the root mat of applied vegetation. Vegetation does not occur as densely in this application, but it does overhang the open water. This is a fairly expensive application that is usually reserved for horizontally constrained sites.

2.14 Bank and Riparian Zone Vegetation Enhancement

In areas where banks are stable and mature trees are present, vegetation enhancement is often the preferred technique. This method includes the removal of non-native invasive plants and the installation of native grasses, shrubs, and trees. The goals are to maintain bank stability, introduce vegetative diversity, increase the successional stage, and establish canopy, understory, shrub and herbaceous layers. Vegetation enhancement also makes it difficult for non-native invasive species to become dominant. Table 3 provides example riparian vegetation species. The selection of plant species will be based on the following criteria:

- Species should be native to western New York.
- Species should be adapted to the appropriate hydrologic regime and corresponding soil conditions.
- Species should be able to root, grow rapidly, and compete with invasive species.

Wetland species will be selected based on additional recommendations provided by the Buffalo River PCT.

Plant material is available in a variety of forms, ranging from bioengineered cuttings to large saplings (FISRWG 1998). A combination of tree sizes may be used in the installation, generally targeting stocks with higher growth rates and rapid root establishment. Insertion of “live stakes” (i.e., cuttings of certain species that can successfully form roots from branch tissues) will be utilized where appropriate to enhance tree growth along the steep primary stream bank. For example, various dogwood and willow species root rapidly from cuttings and can be planted in this manner.

Revegetation plans and specifications will be developed prior to planting. The revegetation plans will identify planting zones and will include a planting schedule listing plant species, density, quantities, size, and form. Tree and shrub planting will most likely take place in the fall or spring, during the early root growth period. Transplant timing will be determined after consideration of seasonal rainfall/ice-melt variability to reduce the likelihood of washout, as flood events could occur before tree roots become established. To afford added support, trees may be placed in tubes and anchored with wooden stakes and biodegradable twine.

2.15 Expansion of Riparian Zone

In urban rivers, wide riparian buffers often are not feasible except in select locations where land use is not limiting. Where feasible, the expansion of the riparian buffers would improve water infiltration (reducing surface runoff during storm events), nutrient cycling, ecological habitat, water quality (overhanging vegetation to shade the water and increase dissolved oxygen), and would reduce erosion and sedimentation. The riparian zone can be expanded by regrading, if necessary, and planting a variety of trees (both canopy and understory species) and shrubs.

3 COMBINATIONS OF TECHNIQUES FOR GENERAL SHORELINE TYPES

The individual techniques described in Section 2 can be combined to maximize restoration value. Different shoreline types (e.g., parking lots, bulkheads, riprap, softened shoreline) may dictate a unique combination of techniques. General restoration examples for each shoreline type are provided below and summarized in the restoration techniques matrix (Table 4). These general restoration examples are intended to provide some additional information for future restoration projects that may be included in the separate Master Plan.

3.1 Commercial Parking Lot Shorelines

In areas where commercial parking lots abut the shoreline, the restoration techniques will depend on the area of the parking lot that can be obtained for use and whether or not the shoreline material can be removed. For example, if a bank height of 15 feet is assumed, 45 feet will be needed to achieve a 3:1 slope. Assuming these two factors are not limiting, a combination of EV and SAV enhancement (Section 2.1), bank shaping (Section 2.9), bank and riparian vegetation enhancement (Section 2.14), and/or riparian width enhancement (Section 2.15) can be used. Enhancement of the riparian zone would reduce the potential impact of surface runoff during storm events by increasing the potential for water infiltration, providing filtration capacity for potential contaminants, and reducing sheet flow to the river.

3.2 Bulkhead Shorelines

Where bulkheads exist, the first decision is to determine whether they continue to be required. If the bulkheads are no longer needed, then consideration may be given to removal. Bulkheads impede the back and forth flow of groundwater and river water, prevent the movement of root systems into the banks from the riparian zone, reduce bank strength, and impede much of the function of the bank. However, cost will be a major consideration for bulkhead removal. An item of concern may be the type of material behind the bulkhead, which could require partial or complete removal and special disposal depending on its physical and chemical properties. For areas where bulkheads can be removed, bank shaping (Section 2.9), stone toe protection (Section 2.10), wrapped earth and branch packing (Section 2.11), living crib wall (Section 2.12), and geocells (Section 2.13) could all be considered for bank stabilization and habitat enhancement measures. The appropriate bank technique(s) associated with the complete or partial removal of a bulkhead is determined based on site constraints and forces acting on the banks. In addition to the bank enhancements, submerged and riparian zone vegetation should also be enhanced, as appropriate (Sections 2.1 and 2.14) or expanded (Section 2.15).

If the bulkhead must remain in place, or if there is insufficient structural and geotechnical information to make a determination that the bulkhead can be removed, then a determination must be made if fill can be placed in the river on the opposite site of the bulkhead. The ability to fill will be limited by the location and depth of the authorized navigation channel and by the hydraulic capacity of the channel at each location. Flooding is a critical issue on the Buffalo River, and the addition of material will not be permitted if it impedes the flow in the river and causes an unacceptable rise in the floodplain. However, the proposed volume to be dredged from the Buffalo River would diminish the potential for flooding.

Three alternatives exist where the hydraulic capacity is limited: 1) in-stream shallow substrate enhancement (Section 2.2); 2) modified lunker boxes; (Section 2.4); or 3) floating log shelters (Section 2.5). Where there is adequate space to add to the wall, the techniques will be driven by space, physical conditions of each site, cost, and safety considerations to minimize aquatic obstructions and maintain safe navigable conditions. Special design consideration will need to be given to anchoring any given system to the wall. The shoreline applications can either be held in place with gravity which means a relatively large system that can be maintained in place, or it will need to be tied to the wall, which requires mechanical attachments, structural design issues, and an understanding of the application lifespan.

3.3 Riprap Shorelines

A considerable amount of bank along the Buffalo River is lined with riprap or concrete debris. Property owners often protect their shorelines or banks with riprap and demolition debris for both short and long term protection. From a design approach, most engineers and property owners are comfortable with riprap river bank protection because it has been observed to be reliable over long periods and it has the lowest cost per linear foot of any solution. The drawback of riprap is that it offers limited water quality and habitat benefits and vegetation often has difficulty becoming established due to poor soil contact.

Riprap (including concrete debris) can be configured in a manner that provides both robust bank stability and improved water quality and habitat using one or more of the following methods:

- Enhance any EV and/or SAV (Section 2.1)
- Reconfigure the riprap to a more gentle slope and limit its use to a few feet above the ordinary water line (Section 2.10)
- Reshape the banks above the riprap to a gentle slope (Section 2.9)
- Enhance the bank and riparian zone vegetation (Section 2.14)
- Expand the riparian zone (Section 2.15)

Employing these measures will maintain the riprap for protection, allow water to flow into the banks, allow vegetation to grow on the banks including overhanging vegetation and water contact with root zones, provide aquatic and terrestrial habitat, and improve aesthetics.

3.4 Natural/Softened Shorelines

In a few locations on the Buffalo River, the banks appear stable and have good vegetative cover. However, upon close examination, it is apparent that much of the vegetation is invasive. In some areas native vegetation is virtually absent at multiple levels (i.e., herbaceous, understory, and canopy), and the non-native vegetation provides limited or poor structural stability for the bank. EV or SAV enhancement (Section 2.1), enhancement of in-stream shallows (Section 2.2), and the establishment of a littoral bench (Section 2.9) may be possible to complement the existing naturalized shoreline. Anchored woody debris (Section 2.3), rootwads (Section 2.6), or tree revetments (Section 2.7) may be used to add in-stream habitat complexity. Bank shaping (Section 2.9), stone toe protection (Section 2.10), wrapped earth and branch packing (Section 2.11), living crib wall (Section 2.12), and geocells (Section 2.13) may be considered to provide additional bank stabilization, if necessary. Implementation of bank and riparian zone vegetation enhancement (Section 2.14) and, if possible, expansion of the riparian zone (Section 2.15) would result in a desirable and cost effective bank treatment that would provide maximum benefits.

4 POTENTIAL RESTORATION PROJECTS

The restoration techniques and combinations used for the general shoreline types serve as building blocks to create a conceptual restoration design for potential restoration locations along the Buffalo River Area of Concern (AOC). The Habitat Restoration Subgroup identified six locations in the Buffalo River and the City Ship Canal where habitat enhancement and restoration is expected to provide significant ecological enhancements to the river, and where restoration opportunities can be implemented in the short-term (Figure 1). The conceptual restoration designs for each location were determined by consensus of the PCT Habitat Restoration Subgroup during a site visit on August 12, 2009, and during subsequent meetings (Appendix B). Background, existing conditions, and the conceptual restoration alternatives for each location are provided in the following subsections, which provide background information, describe existing conditions, and propose restoration concepts for each location. The locations are identified in Figure 1 and include:

- Kelly Island
- City Ship Canal
- Ohio Street shoreline
- Katherine Street Peninsula
- Buffalo Color Peninsula shoreline
- Riverbend

4.1 Kelly Island

4.1.1 Background and Existing Conditions

Kelly Island is located at the confluence of the City Ship Canal and the Buffalo River (Figure 2). The adjacent land is owned by General Mills. The toe of Kelly Island is characterized by a sloping concrete apron that extends from the shoreline to approximately 25 feet below the water line (the extent of the concrete apron should be verified during restoration design). Heavy ship traffic and the proximity of the authorized navigation channel limit the habitat potential outside of the nearshore area.

An August 2008 survey noted a single SAV bed (SAV-3) located along the northwestern tip of Kelly Island at approximately three feet below mean low water depth (ENVIRON et al. 2009). This bed was characterized by four species: curlyleaf pondweed (*Potamogeton crispus*), American pondweed (*Potamogeton nodosus*), sago pondweed (*Potamogeton pectinatus*), and wild celery (*Vallisneria americana*). Of those, curlyleaf pondweed is an invasive species. Wild celery is considered to be high quality based on the Coefficient of Conservatism (Ohio EPA 2006).

4.1.2 Conceptual Restoration Alternatives

The Kelly Island area is a modified riprap shoreline. However, the restoration design must work around several significant design constraints. Restoration in this portion of the Buffalo River is restricted to the area below the water line, due to property ownership and the presence of the concrete apron that extends approximately 25 feet into the river[2]. Additionally, the navigation channel is authorized to within 100 feet of the shoreline, providing a narrow area for potential restoration between the navigation channel and the edge of the concrete apron. This selected restoration area is approximately 75 feet wide, 200 feet long, with a sloping depth from 0 feet to 15 feet below mean water level (569 feet above mean sea level).

Based on site limitations, restoration options at this location are restricted to the area below the waterline (Figure 2). Therefore, a combination of in-stream vegetation enhancement (Section 2.1), in-stream shallows substrate enhancement (Section 2.2), and modified lunker boxes (Section 2.4) are considered in the restoration alternatives (Table 4).

4.1.2.1 Kelly Island Alternative 1 (KS-A1)

Restoration Alternative 1 for Kelly Island (KS-A1) will incorporate restoration techniques presented in Sections 2.1 and 2.2 (in-stream vegetation and substrate enhancement). The existing slope is gradual enough to provide a stable base for vegetation restoration. Additional areas within the proposed EV bed may receive gravel/cobble to enhance available fish spawning substrate.

Two planting zones would be established based on bathymetry data and light penetration: 1) SAV beds from 2 to 10 feet water depth; and 2) EV beds from 0 to 2 feet water depth. Note that the concrete apron may extend into the EV zone, thereby limiting restoration potential. Three, non-invasive, SAV species were found at the tip of Kelly Island (sago pondweed, American pondweed, and wild celery). The presence of these species indicates their affinity to this location and their compatibility with the water quality and hydrological conditions of the area. Therefore, preferred selection of these species for early establishment of the shallow SAV bed is recommended.[3] Additional potential SAV species are presented in Table 2.

Established EV beds were not found along the tip of Kelly Island during the August 2008 vegetation survey. However, installation of approximately 0.07 acres of EV beds is proposed. During the 2008 vegetation survey, four non-invasive EV species were found within the Buffalo River AOC: pickerelweed (*Pontederia cordata*), broadleaf arrowhead (*Sagittaria latifolia*), softstem bulrush (*Scripus validus*), and broadleaf cattail (*Typha latifolia*). The presence of these species indicates their compatibility to Buffalo River water quality and hydrological conditions. Therefore, preferential selection of these species for early establishment of EV beds is recommended.

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[2] Land owner acceptance will be necessary prior to implementation of any restoration below the water line that is directly fastened to the concrete apron. It is anticipated that additional due diligence (including any necessary access negotiations with land owners) will be conducted during the design phase.

[3] During the August 2008 vegetation survey these species were found at a depth of approximately 3 feet.

4.1.2.2 Kelly Island Alternative 2 (KS-A2)

Similar to KS-A1, restoration Alternative 2 for Kelly Island (KS-A2) will incorporate in-stream vegetation and substrate enhancement techniques (Section 2.1 and 2.2). In addition, KS-A2 includes the installation of modified lunker boxes (Section 2.4) along the tip of the island and staggered into the restored SAV and EV beds. As described in Section 2.4, modified lunker boxes can be constructed out of natural materials (e.g. wood), wire, or metal and are anchored to hardened shoreline. At Kelly Island, the lunker boxes could be anchored to the already existing concrete apron. Installation of lunker boxes would provide shade, shelter, and habitat for fish and other biota.

4.2 City Ship Canal

4.2.1 Background and Existing Conditions

The Buffalo River City Ship Canal was originally constructed in the mid-1800s to provide extra moorings for ships (Ecology and Environment 2008). While the AOC includes the entire length (1.4 miles) of the City Ship Canal, relatively little information is available on the quality of aquatic and riparian habitat within the canal. The City Ship Canal habitat restoration project area is approximately 6.7 acres and includes the upstream portion of the canal that is outside of the authorized navigation channel. There are no reliable bathymetry data for most of the restoration project area (Figure 3).

With the exception of a short length of what is described as a concrete cap (Figure 4-1b of ENVIRON et al. 2009), the head of the City Ship Canal is bordered by natural shoreline with shrubby and herbaceous riparian vegetation. Some of the naturalized shoreline is scattered with debris, rubble, and scrap. Riparian vegetation does not extend beyond the top of the canal banks. Railroad beds are located within approximately 30 feet of both banks of the City Ship Canal restoration area. The concrete cap is located along the eastern side of the City Ship Canal and appears to stabilize the bank immediately adjacent to an old rail spur. Based on aerial photographs, the concrete cap is approximately 300 feet long.

In August of 2008, SAV beds within the undredged portion of the ship canal were identified and mapped. The SAV beds are identified as SAV-8 and SAV-9 (ENVIRON et al. 2009). SAV-8 is approximately 7 feet wide and extends along almost the entire length of the western shore of the undredged ship canal (approximately 1,800 feet) to cover an area of approximately 12,600 square feet. The average depth of the bed was estimated at nine feet. Six species were identified in the bed: four native species (coontail [*Ceratophyllum demersum*], Canadian waterweed [*Elodea canadensis*], sago pondweed, and wild celery) and two exotic invasive species (Eurasian watermilfoil [*Myriophyllum spicatum*] and curlyleaf pondweed). SAV-9 is approximately 6 feet wide and extends for approximately 800 feet along the southern end of the eastern shoreline to cover an area of approximately 4,800 square feet. The average depth of SAV-9 was estimated at 7 feet. Five of the six species identified in SAV-8 were also identified in SAV-9. The only species not observed in SAV-9 was Canadian waterweed. Both SAV-8 and SAV-9 have been classified as high quality SAV beds.

An EV stand was identified along the western shore of the City Ship Canal in August 2008. The stand, identified as EV-4 (ENVIRON et al. 2009), extends for approximately 2,000 feet and ends near the extent of dredging in the City Ship Canal habitat restoration area. The only species identified in the stand were purple loosestrife (*Lythrum salicaria*) and common reed (*Phragmites australis*), both common exotic invasive species.

Water level fluctuations in the City Ship Canal are driven by riverine flow and Lake Erie seiche conditions. Water levels and flow rates were monitored at the mouth of the Buffalo River for six weeks from October 2008 through November 2008 (ENVIRON et al. 2009). Water levels within the City Ship Canal are expected to be consistent with those measured at the mouth of the river. Seiche-induced water-level changes occurred over a period of approximately 14 hours. Strong seiche events resulted in three to four foot fluctuations in water levels at the mouth of the river while more common seiche events resulted in water level changes of less than one foot.

4.2.2 Conceptual Restoration Alternatives

The City Ship Canal habitat restoration area is based on the area delineated for remediation under the Preferred Remedy (Remedy Alternative 5). This includes placing a cap over the existing sediments within the restoration area in order to isolate sediment contaminants and to improve water depths for the establishment of high quality habitat. Placing a sediment cap within the already shallow head of the canal provides an opportunity to recreate valuable submerged and emergent wetland habitat (Section 2.1). The cap will include the addition of at least 12 inches of substrate. Additional substrate may be added to achieve restoration grades. The canal is an active location for recreational fishing and plans include maintaining a channel that is adequate so that small boats can continue to access the canal.

Following cap installation, restoration techniques will be used to enhance the habitat within the restoration area (Figure 3). A combination of in-stream vegetation (Section 2.1), substrate enhancement (Section 2.2), anchored woody debris (Section 2.3), rootwads (Section 2.6), bank shaping (Section 2.9), bank and riparian zone vegetation enhancement (Section 2.14), and riparian zone expansion (Section 2.15) are considered for the area. Restoration alternatives for the City Ship Canal are presented below (Table 4).

4.2.2.1 City Ship Canal Alternative 1 (CSC-A1)

Alternative 1 for the City Ship Canal (CSC-A1) will incorporate in-stream vegetation (Section 2.1), in stream shallows substrate enhancement (Section 2.2), bank shaping (Section 2.9), and bank and riparian zone vegetation enhancement (Section 2.14) techniques. Installation of the remedial sediment cap will enhance in-stream shallows and provide the public with recreational opportunities. A relatively thin cap will allow for the persistence of submerged channels in the wetland and will provide sufficient substrate for native SAV species. The deeper submerged channels will be designed and constructed to allow small recreational boats to have access to the restored wetland for angling and/or wildlife viewing.

To maximize the potential services provided by the restored EV wetland described above, restoration measures will also target the adjacent EV stand (EV-4), which currently consists of non-native invasive species. Efforts will be made to minimize both purple loosestrife and common reed and promote the growth of native species such as broadleaf cattail or softstem bulrush in EV-4 (Section 2.1). The most appropriate native species will depend on the local substrate, water quality, and flow conditions. A comprehensive list of native EV species to be considered is provided in Table 1.

Four native SAV species were found in the established SAV beds within the proposed restoration area of the City Ship Canal. These native species have rapid growth rates, prefer relatively shallow water (i.e., less than seven feet), and only require thin sediment substrate. Substrate depth is important because depths in this portion of the City Ship Canal are already relatively shallow (i.e., less than 10 feet). The presence of the four native species indicates their compatibility with the water quality and hydrological conditions of the area. Therefore, preferred selection of these species for early establishment of the shallow SAV bed is recommended. Additional potential SAV species are presented in Table 2. During the design phase, the SAV zone may be expanded to enhance recreational fishing opportunities.

Due to the available riparian zone and the ability to fill in part of the canal, creating a more gradual bank slope by regrading the perimeter of the City Ship Canal is possible. The reshaped bank slope and current riparian zone will be planted with native grasses, shrubs, and trees. As discussed in Section 2.9, bank shaping provides the highest level of water quality and habitat benefit with maximum nutrient uptake, maximum overhang vegetation, root systems, and canopy.

4.2.2.2 City Ship Canal Alternative 2 (CSC-A2)

For restoration Alternative 2 (CSC-A2), in-stream vegetation (Section 2.1), substrate enhancement (Section 2.2), bank shaping (Section 2.9), and bank and riparian zone vegetation enhancement (Section 2.14) are proposed as they are in CSC-A1. In addition to those techniques, CSC-A2 includes rootwads (Section 2.6) along the perimeter of the City Ship Canal. Installation of rootwads increases the complexity and potential habitat value of the banks by creating large surface areas for macroinvertebrates and shelter for fish.

4.2.2.3 City Ship Canal Alternative 3 (CSC–A3)

Restoration Alternative 3 for the City Ship Canal (CSC-A3) is similar to CSC-A1 with the addition of anchored woody debris (Section 2.3) within the canal. In order to enhance the subaquatic vegetation, anchored woody debris structures would be installed in targeted areas throughout the EV portion and/or along the perimeter of the SAV portion of the restoration area. The woody debris provides substrate and cover for fish and macroinvertebrates.

4.2.2.4 City Ship Canal Alternative 4 (CSC–A4)

Restoration Alternative 4 for the City Ship Canal (CSC-A4) incorporates all restoration techniques proposed above with the addition of riparian zone expansion (Section 2.15). In-stream vegetation, substrate enhancement, anchored woody debris, rootwads (staggered along the perimeter of the City Ship Canal) and bank and riparian zone vegetation enhancement will be further supported by expansion of the riparian zone. Depending upon land owner willingness, it may be possible to remove the inactive railroad line along the western bank of the canal. Native vegetation can be expanded along both banks and riparian zones.

4.3 Ohio Street Shoreline

4.3.1 Background and Existing Conditions

The Ohio Street Shoreline (formerly referred to as Dead Man's Creek) is part of the Buffalo River Urban Canoe Trail. Surrounding land ownership must be verified, but it is believed that the City of Buffalo owns a narrow strip of property on either side of the canal that can be used for river access. This remnant "canal" once connected the Buffalo River to what is now "Father Conway Park". The canal receives discharge from a nearby combined sewer outfall. Due to river hydrology, this canal collects debris, trees, and litter. While the debris does provide some submerged and nearshore habitat, the sheer volume of debris is likely to serve as an impediment to effective ecological use of the area. While providing some low quality habitat, this debris is aesthetically undesirable and also interferes with canoeing, kayaking, and crew boats that use this area for river access.

The majority of the restoration area includes naturalized shorelines. The slip is characterized by a sheetpile wall. The riparian zone in most areas is less than 5 to 10 feet. A few mature trees exist that provide some shade to the river. The majority of the area is characterized by grass that directly abuts the river. Thus, the potential ecological benefits of the riparian zone (e.g., shading, filtration, infiltration) may be enhanced in this area.

SAV and EV were limited along the Ohio Street Canal. In an August 2008 survey, only a portion of SAV-13 is present along the Ohio Street shoreline restoration area. This bed occurred at approximately three feet below the water elevation. Six species were identified in the bed: four native species (coontail, American pondweed, sago pondweed, and wild celery) and two exotic invasive species (Eurasian watermilfoil and curlyleaf pondweed).

Future uses of the adjacent downstream property may impact potential restoration of the Ohio Street shoreline. Construction is beginning for plans to build a boathouse along the northern bank of the slip. There is some disagreement about potential ownership of the slip, which may or may not limit the restoration project area. Land owner acceptance will be necessary prior to project implementation. It is anticipated that additional due diligence (including any necessary access negotiations with land owners) will be conducted during the design phase.

4.3.2 Conceptual Restoration Alternatives

The preferred remedy may impact the downstream portion of the Ohio Street shoreline restoration area (Figure 4). However, the majority of the restoration may be implemented independently of the remediation implementation. Due to the lack of habitat along this segment of the river, many of the general natural/softened shoreline technique combinations have been selected in order to provide maximum value as an ecological island.

Restoration alternatives for the Ohio Street shoreline are presented below. A combination of in-stream vegetation enhancement (Section 2.1), in-stream shallows substrate enhancement (Section 2.2), installation of a log or rock vane (Section 2.8), bank shaping (Section 2.9), stone toe protection (Section

2.10), bank and riparian zone enhancement (Section 2.14), and expansion of riparian zone (Section 2.15) techniques are considered for the area.(Table 4).

4.3.2.1 Ohio Street Shoreline Alternative 1 (OSS-A1)

Ohio Street Shoreline restoration Alternative 1 (OSS-A1) incorporates restoration techniques including in-stream vegetation enhancement (Section 2.1), substrate enhancement (Section 2.2), bank shaping (Section 2.9), stone toe protection (Section 2.10), bank and riparian vegetation enhancement (Section 2.14), and riparian zone expansion (Section 2.15). OSS-A1 focuses on expanding the riparian zone from a width of 5 to 10 feet to a width of approximately 20 feet, regrading the bank to a more gradual slope, enhancing the bank and riparian zone by removing non-native plants and installing native grasses, shrubs, and trees, and installing stone toe protection to prevent bank erosion and redirect flow. In-stream shallows will be enhanced by creating new EV beds and enhancing and expanding upon the existing SAV bed. Two planting zones will be established based on bathymetry data and light penetration: 1) SAV beds from 2 to 10 feet water depth; and 2) EV beds from 0 to 2 feet water depth. Appropriate substrate will be added that will target optimal conditions for EV and SAV species as well as enhance in-stream shallows for fish and spawning habitat.

4.3.2.2 Ohio Street Shoreline Alternative 2 (OSS-A2)

Restoration Alternative 2 for the Ohio Street shoreline (OSS-A2) is similar to the techniques presented in OSS-A1 for in-stream vegetation enhancement (Section 2.1), substrate enhancement (Section 2.2), bank shaping (Section 2.9), stone toe protection (Section 2.10), bank and riparian vegetation enhancement (Section 2.14), and riparian zone expansion (Section 2.15). However, OSS-A2 differs by the addition of a rock or log vane (Section 2.8) to redirect flow and debris from the slip. This should reduce the amount of debris that accumulates over time. In addition, the property owners of the downstream boathouse have committed to debris removal to allow boats to be put in the water at the slip. The combination of in-stream structures and debris maintenance should create conditions that will add additional ecological value to the restoration of the rest of the shoreline.

4.4 Katherine Street Peninsula

4.4.1 Background and Existing Conditions

The Katherine Street Peninsula restoration area includes approximately 1,100 feet of shoreline on the southeastern corner of the Katherine Street Peninsula. The site is opposite the turning basin at river mile (RM) 3.5. The river bank is steepest at the northern portion of the shoreline where the navigation channel is approximately 50 feet from the shore and the bank slope is estimated to approach a 2.5:1 slope. The shoreline becomes considerably shallower at the southeastern corner of the peninsula where the navigation channel is almost 150 feet from shoreline and the bank slope is estimated to be closer to a 5:1 slope. Flow rates around the site are predicted to be low relative to the areas immediately upstream and downstream due to its location opposite the wide turning basin (ENVIRON et al. 2009).

The entire shoreline is classified as natural with coarse woody debris abundant along the southern shoreline. Vegetation surveys in August of 2005 indicate that the riparian vegetation contains woody and herbaceous species (Irvine et al. 2005). Five woody species were identified including at least four native species (boxelder [*Acer negundo*], red osier dogwood [*Cornus sericea*], staghorn sumac [*Rhus typina*], and black willow [*Salix nigra*]) and one exotic invasive species (tree of heaven [*Ailanthus altissima*]). At least nine species of herbaceous plants were identified along the southeastern shoreline of the Katherine Street Peninsula, including five native species and four non-native species (Irvine et al. 2005). However, a survey of the potential restoration area in August of 2009 indicated that invasive riparian species dominated the riparian plant community along the Katherine Street Peninsula. Land use within the area immediately adjacent to the restoration area is classified as vacant (Ecology and Environment 2008).

Aquatic vegetation surveys in August 2008 indicated that an SAV bed along the northern shore of the Buffalo River extends from RM 3.5 to RM 4.5 and is present along most of the Katherine Street Peninsula habitat restoration area (ENVIRON et al. 2009). The bed (SAV-18) was estimated to be approximately 12 feet wide with an average depth 3 feet. Six species were identified within the bed; four native species (coontail, American pondweed, sago pondweed, and wild celery) and two exotic invasive species (Eurasian watermilfoil and curlyleaf pondweed).

An EV stand was identified along the southern shore of the Katherine Street Peninsula in August of 2008 (ENVIRON et al. 2009), a portion of which overlaps with the Katherine Street Peninsula restoration area. The EV stand (EV-9) extends for about 500 feet along the southern shore, adjacent to abandoned pilings. Although the stand is classified as moderate quality, it was described as only consisting of three exotic invasive species; purple loosestrife, common reed, and Japanese knotweed (*Polygonum cuspidatum*).

4.4.2 Conceptual Restoration Alternatives

Due to the differences in shoreline stability between the northern and southern portions of the restoration area, conceptual restoration alternatives are considered separately (Figures 5a and 5b). Extensive riparian soil excavation and habitat modification may be limited by potential soil contamination; to our knowledge, soils have not been tested in the Katherine Street Peninsula and should be evaluated before proceeding with upland/riparian restoration. Additionally, the nearby transmission tower may limit potential bank and riparian restoration techniques due to limited access and right of ways. Restoration techniques for this restoration area are presented in Table 4.

4.4.2.1 Katherine Street Peninsula (KSP) – Northern Shoreline

The northern half of the Katherine Street restoration area is anticipated to be impacted by the proposed remedy. In addition, water velocities and sheer stresses are locally elevated along the northern portion of the Katherine Street Peninsula restoration project area (e.g., Figure 3-42 of ENVIRON et al. 2009). This portion of the restoration project area may require some bank stabilization techniques following remediation. It is anticipated that these may include bank regrading (Section 2.9), stone toe protection (Section 2.10), wrapped earth with branch packing (Section 2.11), living crib walls (Section 2.12), and/or geocells (Section 2.13). In addition, enhancement of the bank and riparian vegetation (Section 2.14) is considered.

4.4.2.1.1 KSP (Northern Shoreline) Alternative 1 [KSP(NS)–A1]

Restoration Alternative 1 (KSP(NS)-A1) will incorporate restoration techniques presented in Sections 2.9, 2.10, and 2.14. KSP(NS)-A1 will focus on bank stabilization (Section 2.9) by regrading the bank to a more gradual slope and enhancing the bank and riparian zone (Section 2.14) by removing non-native plants and installing native gasses, shrubs, and trees. Bank shaping (Section 2.9) is intended to achieve a natural, stable bank while providing the highest level of water quality and habitat. In targeted areas, stone toe protection (Section 2.10) may be required to further armor the bank and limit erosion. Enhancing the vegetation within the bank and riparian zone will decrease sedimentation and runoff and will introduce vegetative diversity. To the greatest extent possible, the invasive species that dominate the local riparian community should be eradicated and replaced with native species (Section 2.14).

4.4.2.1.2 KSP (Northern Shoreline) Alternative 2 [KSP(NS)–A2]

Restoration Alternative 2 (KSP(NS)-A2) will incorporate the riparian vegetation enhancement (Section 2.14) technique summarized in KSP(NS)-A1. However, instead of bank regrading and stone toe protection, KSP(NS)-A2 includes the use of wrapped earth with branch packing (Section 2.11) for bank stabilization. As described in Section 2.11, this technique uses either a woven coir blanket or geogrid to wrap around an enclosure of soil, creating reinforced earth. Branch packing is installed between the lifts and the growth of this root system replaces the coir fabric or reinforces the geogrid with time. This technique is robust and can be used in areas with wave flow, ice, and steep slopes.

4.4.2.1.3 KSP (Northern Shoreline) Alternative 3 [KSP(NS)–A3]

Restoration Alternative 3 (KSP(NS)-A3) includes the riparian vegetation enhancement (Section 2.14) technique summarized in KSP(NS)-A1. However, instead of bank regrading and stone toe protection, Alternative 3 proposes to install a living crib wall (Section 2.12). As described in Section 2.12, a living crib wall holds a bank together by making use of specific species of trees that are cut into logs and placed in a crib formation within the stream bank. The logs send off shoots that become trees, because of this the living crib wall technique becomes more stable over time as the trees grow.

4.4.2.1.4 KSP (Northern Shoreline) Alternative 4 [KSP(NS)–A4]

Restoration Alternative 4 (KSP(NS)-A4) includes the riparian vegetation enhancement (Section 2.14) technique summarized in KSP(NS)-A1. However, instead of bank regrading and stone toe protection, KSP(NS)-A4 proposes geocells (Section 2.13) to stabilize the banks. As described in Section 2.13, geocells are costly but are structurally robust treatments that can be installed at a steep angle (e.g., 1:1 slope) and still allow for vegetation.

4.4.2.2 Katherine Street Peninsula (KSP) – Southern Shoreline

The river bank along the shallow areas of the southern shoreline of the Katherine Street Peninsula appear to be stable and should not require new bank stabilization measures as part of restoring aquatic habitat. Indeed, hydrodynamic modeling of flows in the Buffalo River under various flow conditions indicates that flow velocities and sheer stress along southeastern corner of the Katherine Street Peninsula (within the turning basin) are low relative to the areas immediately upstream and downstream. Therefore, this portion of the restoration area may be suitable for “softer” techniques such as vegetation enhancement of the bank (Section 2.14). Restoration alternative design for the southern shoreline of the Katherine Street Peninsula is based on natural/softened shoreline techniques. Therefore, a combination of techniques presented in Sections 2.1, 2.2, and 2.14 are considered.

4.4.2.2.1 KSP (Southern Shoreline) Alternative 1 [KSP(SS)–A1]

Restoration Alternative 1 (KSP(SS)-A1) incorporates vegetation and substrate enhancement (Section 2.1 and 2.2). EV and SAV beds were noted in the August 2008 vegetation survey conducted along the southern shoreline of Katherine Street Peninsula. Four native SAV species (coontail, American pondweed, sago pondweed, and wild celery) were found. The presence of these species indicates their affinity to this location and their compatibility with the water quality and hydrological conditions of the area. Efforts will be taken to eradicate the two invasive species there and protect, improve, and expand upon the existing bed. Additional potential SAV species are presented in Table 2.

One established EV bed was found along the southern shoreline of Katherine Street Peninsula; however, only invasive species currently exist there. Efforts will be taken to eradicate these species and replace them with non-invasive species such as pickerelweed, broadleaf arrowhead, softstem bulrush, and broadleaf cattail (four species currently found within the Buffalo River). Site-specific habitat conditions such as substrate grain size and water quality will dictate which additional native species may be best suited for integration into the existing beds.

4.4.2.2.2 KSP (Southern Shoreline) Alternative 2 [KSP(SS)–A2]

Alternative 2 (KSP(SS)-A2) incorporates the same techniques for in-stream vegetation and substrate enhancement that are used in KSP(SS)–A1. However, in KSP(SS)-A2 riparian vegetation enhancement (Section 2.14) is added to provide an additional measure of bank stabilization.

4.5 Buffalo Color Peninsula Shoreline

4.5.1 Background and Existing Conditions

The Buffalo Color Peninsula site is located on the northern bank of the Buffalo River, between RM 4.5 and 5.0. The site was remediated in 1997, including construction of a slurry wall around the entire perimeter of the site. During remedy construction, wastefill material was identified along the shoreline and outside of the slurry wall. In order to preserve the stability of the slurry wall, approximately 4,000 cubic yards of wastefill immediately adjacent to the slurry wall were left in place along a 500 foot length of the southwestern shoreline (Parsons 1998). Based on the as-built cross sections from the area, up to 10 feet of wastefill were excavated to within 30 feet of the slurry wall. The wastefill material remaining in the river was capped with a base layer of sand to stabilize sideslopes, followed by a geotextile layer and then a surface layer of shot rock and/or rip rap (Parsons 2003). Review of the habitat features of the peninsula indicates that habitat restoration measures may be appropriate for the Buffalo Color Peninsula shoreline.

The upland portion of the site has been capped and the area within the slurry wall is maintained as grass. Vegetation outside of the slurry wall is not maintained and consists of shrubs and herbaceous species. The entire shoreline is stabilized with riprap from above the waterline (approximately 575 feet elevation) for approximately 30 feet out into the river channel (to an elevation of approximately 565 feet or a water depth of approximately 7 feet). The distance from the edge of the shoreline to the nearest edge of the navigation channel ranges from 50 feet to 100 feet.

Riprap was installed along the entire shoreline of the peninsula as part of the remediation in 1997. Bank slopes in excess of 3:1 slope were considered to be unstable and were filled with sand and capped with riprap such that all bank slopes did not exceed a 3:1 slope (Parsons 1998).

In their August 2004 and 2005 vegetation surveys, Irvine et al. (2005) reported no overhanging cover along the Buffalo Color Peninsula shoreline and minimal herbaceous and aquatic plant species. However, a more recent survey by ENVIRON et al. (2009) in August 2008 indicates a greater diversity of aquatic plants present along the shoreline. Coarse woody debris and shrubby and herbaceous vegetation is present along the waterline of most of the site.

A single EV stand (EV-13) is present along the most downstream portion of the shoreline (ENVIRON et al. 2009). This bed is approximately 500 feet long, and six species were identified in the stand: two exotic invasive species (purple loosestrife and Japanese knotweed) and four native species (broadleaf arrowhead, softstem bulrush, broadleaf cattail, and pickerelweed). EV-13 is classified as a moderate quality EV stand.

The downstream half of the site is bordered by an SAV bed and a smaller SAV bed is present along the eastern shore of the site. The SAV beds are identified as SAV-19 and SAV-20 in ENVIRON et al. (2009). In August of 2008, SAV-19 was observed in approximately 4.5 feet of water and was approximately 10 feet wide. It consists of two exotic, invasive species (Eurasian watermilfoil and curlyleaf pondweed) and three native species (coontail, American pondweed, and sago pondweed). SAV-20 is approximately 200 feet long and 12 feet wide; it was observed in approximately 4 feet of water in August of 2008. It is comprised of one exotic invasive species (Eurasian watermilfoil) and three native species (coontail, American pondweed, and sago pondweed). Both beds are considered to be of moderate quality.

Surface water quality measurements taken just upstream of RM 4.5 (the downstream end of the Buffalo Color Peninsula shoreline) in September 2008 as part of the fish community assessment provided the following results: dissolved oxygen of 7.7 milligrams per liter (mg/L) and a secchi disk depth of 2.3 feet (0.7 meters). Similar measurements conducted near RM 4.75 as part of the benthic invertebrate community assessment also in September 2008 provided similar results. The dissolved oxygen concentration was 7.9 mg/L at a water temperature of 20.6°C (approximately 90% saturation). With a secchi disk depth of 6.6 feet (2 meters), water clarity was higher at the benthic invertebrate collection location. Measured water velocity in the channel at RM 4.75 in September 2008 was 0.05 feet per second.

4.5.2 Conceptual Restoration Alternatives

The Buffalo Color Peninsula shoreline is a combination of riprap and naturalized shoreline types (Figure 6). The techniques proposed are constrained by the presence of the slurry wall along the perimeter of the entire site. This slurry wall limits the possible restoration measures in the riparian areas along the Buffalo Color Peninsula shoreline. However, the presence of both EV and SAV beds along the downstream portion of the site indicates that the habitat is suitable for aquatic vegetation. Therefore, proposed restoration at this site focuses on expansion and improvement of the existing EV and SAV beds (Section 2.1) with limited bank and riparian restoration (Sections 2.14) focused on planting native species along the shoreline.

Restoration alternatives for the Buffalo Color Peninsula are presented below. A combination of in-stream vegetation enhancement (Section 2.1) and bank and riparian zone enhancement (Section 2.14) are considered for the area (Table 4).

4.5.2.1 Buffalo Color Peninsula Shoreline Alternative 1 (BCAD–A1)

Alternative 1 (BCAD-A1) includes the expansion of an EV bed to approximately 1.2 acres and the expansion of an SAV bed to approximately 2 acres. Invasive species (purple loosestrife, Japanese knotweed, Eurasian watermilfoil, and curlyleaf pondweed) will be removed to the maximum extent possible and replaced with native species (Section 2.1). Four non-invasive EV species and three non-invasive SAV species were found during the August 2008 vegetation survey. The presence of these species indicates their affinity to this location and their compatibility with the water quality and hydrological conditions of the area. Therefore, preferred selection of these species for early establishment of EV and SAV beds is recommended. Additional potential EV and SAV species to be used are presented in Tables 1 and 2.

4.5.2.2 Buffalo Color Peninsula Shoreline Alternative 2 (BCAD–A2)

Buffalo Color Peninsula Shoreline Restoration Alternative 2 (BCAD-A2) is similar to BCAD-A1 with the addition of limited bank and riparian vegetation enhancement (Section 2.14).[4] The presence of the slurry wall around the perimeter of the site limits the opportunity for restoration. However, shrubs and herbaceous species are common along the shoreline of most of the site. Therefore, it may be possible to expand and improve the riparian community by eradicating invasive species and planting native herbaceous plants that will not compromise the integrity of the slurry wall.

[4] The banks along the Buffalo Color Peninsula are assumed to be generally stable and bank stabilization measures are expected to be minimal. However, some stabilization may be considered if new substrate is required for the expansion of EV and SAV beds.

4.6 Riverbend

4.6.1 Background and Existing Conditions

The Riverbend restoration project area extends for approximately one mile along the southern bank of the Buffalo River, from approximately RM 5.75 to RM 4.75. The upland area is comprised of two parcels within the South Buffalo Brownfield Opportunity Area: the Village Farms site along the upstream half and the River Bend site along the downstream half (USI et al. 2008). The Village Farms site was historically occupied by industrial facilities prior to its remediation and was converted to a hydroponic agricultural facility in the late 1990s. The hydroponic facility was closed and demolished in 2003. The River Bend site was the location of a steel and coke-making facility that is now closed. The site was the subject of a Voluntary Cleanup Program; remedial work was completed in October 2007. Remediation at both the Village Farms and the River Bend sites largely consisted of removing storage tanks and contaminated soil. A slurry wall was installed in one portion of the Riverbend site, approximately 0.75 miles from the shoreline, to facilitate the containment and treatment of contaminated groundwater (USI et al. 2008; NYSDEC personal communication 2009). Site remediation is not known to have included the banks or sediments of the Buffalo River. Both sites are currently vacant and are owned by the City of Buffalo and the Buffalo Urban Development Corporation (USI et al. 2008).

The shoreline within the Riverbend restoration project area is variable. Along the upstream half of the project area, it is classified as stone, concrete cap, or natural (ENVIRON et al. 2009). Riparian vegetation is present along portions of this area. The shoreline along the downstream half consists of natural cover, old timber pilings, a concrete cap, and an extensive retaining structure along the most downstream portion of the site (ENVIRON et al. 2009). Little, if any, riparian vegetation is present along this downstream half of the project area.

In their evaluation of potential habitat restoration sites within the Buffalo River, Irvine et al. (2005) surveyed a portion of the Riverbend project area at RM 5.5. In August of 2004 and 2005, they identified four woody plant species along the shoreline: silver maple (*Acer saccharinum*), staghorn sumac, black willow, and the exotic invasive Siberian elm (*Ulmus pumila*). A variety of herbaceous species were also identified along the northern shoreline including the following native species: dodder (*Cuscuta gronovii*), horsetail (*Equisetum arvense*), cream avens (*Geum virginianum*), Saint Johnswort (*Hypericum perforatum*), and alfalfa (*Medicago sativa*). In addition, they identified the following two exotic herbaceous species: butter and eggs (*Linaria vulgaris*) and purple loosestrife. Finally, they also identified the exotic invasive submerged aquatic plant Eurasian watermilfoil along the northern shoreline of the project area (Irvine et al. 2005).

In their more recent survey of aquatic vegetation along the entire Buffalo River, ENVIRON et al. (2009) identified two SAV beds along the Riverbend restoration project area. A small bed located at RM 5.5 was identified as SAV-22. It was approximately 35 feet long and 8 feet wide and was approximately 3 feet deep. The only species identified in SAV-22 was wild celery. A larger bed was identified near the South Park Avenue Bridge. This bed, identified as SAV-23, was approximately 600 feet long and 8 feet wide and was also approximately 3 feet deep. Five species were identified in SAV-23, including three native species (coontail, American pondweed, and sago pondweed) and two exotic invasive species (Eurasian watermilfoil and curlyleaf pondweed). No other SAV beds were identified along the entire downstream half of the Riverbend project area. Finally, although Irvine et al. (2005) identified some EV species in their earlier survey, ENVIRON et al. (2009) did not identify EV stands anywhere along the Riverbend project area.

Water level fluctuations in the Buffalo River along the Riverbend restoration project area are driven by Lake Erie seiche conditions and upstream riverine flow. Water levels monitored for six weeks from October 2008 through November 2008 indicate that water-level changes at RM 5.5 were similar to but more pronounced than those at the mouth of the Buffalo River (ENVIRON et al. 2009). Seiche-induced water-level changes occurred over a period of approximately 14 hours. Strong seiche events resulted in four to five feet fluctuations in water levels at RM 5.5, while more common seiche events resulted in water level changes of less than a foot.

Hydraulic modeling of the Buffalo River indicates that flow velocities and sheer stress are relatively low and uniform throughout the river under normal, low-flow conditions. Under higher flow conditions, however, flow velocity and sheer stress along the upstream half of the Riverbend restoration project area are among the highest estimated throughout the lower six miles of the Buffalo River (ENVIRON et al. 2009). The relatively narrow channel and shallow depth along the Riverbend restoration project area are likely factors contributing to the greater flow velocities and sheer stress. As a result of the relatively higher flow rates and sheer stresses during high flow events, sediment along the Riverbend project area has more sand and less fines than in downstream areas, although fines are still the dominant grain size class, making up 75% of sediment collected along the Riverbend project area (ENVIRON et al. 2009).

4.6.2 Conceptual Restoration Alternatives

Restoration alternatives for the Riverbend project include a combination of the natural/softened shoreline and bulkheaded shoreline restoration techniques (Figures 7a and 7b, Table 4). Relatively little of the Riverbend restoration area is expected to be impacted by implementation of the remedy. However, the lack of aquatic vegetation along most of the Riverbend shoreline indicates that some factor(s) limit the extent of aquatic vegetation within this reach of the Buffalo River.

Under the current Brownfield development plan, a 100-foot wide green space buffer is envisioned for the entire shoreline of the Riverbend project area (USI and URS 2009) indicating that there may be some willingness on the part of the current landowner to institute restoration measures that promote the enhancement of the riparian zone in this area. Preliminary restoration alternatives, measures, and design are summarized below. Due to the differences of the downstream bulkheaded shoreline and the upstream naturalized shoreline, restoration alternatives are presented separately.

4.6.2.1 Riverbend – Upstream/Natural Shoreline

In the more naturalized portions of the Riverbend property, banks may be reshaped (Section 2.9) to provide more gradual slopes with greater flood storage and conveyance capacity as well as a littoral bench to provide in-stream shallows (Sections 2.1 and 2.2)[5]. In addition to reshaping the river bank, possible

[5] Any new development along this section of the river must abide by the 100 foot setback ordinance. The current landowner has

below surface stabilization measures include installing rootwads (Section 2.6) or tree revetments (Section 2.7). Enhancement and expansion of the riparian zone (Sections 2.14 and 2.15) are also considered for the upstream natural shoreline.

4.6.2.1.1 Riverbend – Upstream Alternative 1 (RU-A1)

The bathymetry and topography data for the area indicate that an EV zone (water depths of 0 to 2 feet) is largely absent along the entire Riverbend project area. The only exception is in the area immediately upstream of the South Park Avenue Bridge. It may be possible to create areas conducive to the establishment of EV stands by pulling back the river bank thus creating more shallow water habitat (i.e., a littoral bench) (Sections 2.1, 2.2, and 2.9). This may be the most feasible in areas where the shoreline is classified as natural or stone but may also be possible in the areas with abandoned timber pilings and old concrete caps. However, any such excavation of the river bank will require confirming that these areas are not contaminated and that past upland remediation actions have ensured that there are no ongoing sources of chemicals to these areas. Assuming that it is feasible to expand the shallow water habitat area, it may be possible to establish several stands of native EV species (Section 2.1) along portions of the Riverbend peninsula.

The limited extent of SAV beds along the Riverbend project area could be due to the lack of suitable habitat conditions in the area. The extensive retaining structure along the turning basin limits the ability to increase SAV habitat in the downstream portion of the Riverbend project area, but the relatively shallow bank slope along the shoreline of the upstream portion of the site suggest that expanding SAV beds within this reach may be feasible. However, habitat conditions such as relatively high flow velocities and sheer stress during high flow events or inappropriate shoreline substrate may limit the current extent of SAV beds in this reach. Therefore, expansion and restoration of SAV beds will require determining what factors are currently limiting their extent along the Riverbend peninsula. Assuming that the key factors are hydraulic conditions and substrate, efforts to increase shallow water aquatic habitat by pulling back the shoreline to create a littoral bench would also benefit SAV species. Potential restoration options include protecting, improving, and expanding the existing SAV beds (Section 2.1). Eradication efforts should be implemented to remove invasive species such as Eurasian watermilfoil and curlyleaf pondweed from SAV-23. The quality of the existing beds could be further improved by increasing the diversity of native species. Site-specific habitat conditions such as substrate grain size and water quality will dictate which additional native species may be best suited for integration into the existing beds. A complete list of potential native SAV species to be considered is provided in Table 2.

RU-A1 also utilizes bank and riparian zone vegetation enhancement (Section 2.14) and the expansion of the riparian zone (Section 2.15).

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expressed a willingness to cooperate with shoreline restoration/greenway implementation at this site and has also expressed a willingness to negotiate the amount of setback (i.e.: 50 feet trade off in one location, or 150 feet in another depending on its value) (Jill Jedlicka, Buffalo Niagara Riverkeeper, personal communication, 2009). Additional due diligence (including any necessary access negotiations with land owners) will be conducted during the design phase.

4.6.2.1.2 Riverbend – Upstream Alternative 2 (RU-A2)

Alternative 2 (RU-A2) is similar to RU-A1 with the addition of rootwads (Section 2.6). Rootwads will add habitat complexity for fish and macroinvertebrates.

4.6.2.1.3 Riverbend – Upstream Alternative 3 (RU-A3)

Alternative 3 (RU-A3) is similar to RU-A1 with the addition of tree revetments (Section 2.7).

4.6.2.2 Riverbend – Downstream/Bulkheaded Shoreline

In the downstream portion of the Riverbend property where bulkheads are present, restoration may include the placement of in-stream substrate immediately adjacent to the sheetpile (Section 2.2), installation of modified lunker boxes (Section 2.4), placement of floating log shelters (Section 2.5), and riparian zone expansion (Section 2.15).

4.6.2.2.1 Riverbend – Downstream Alternative 1 (RD-A1)

Restoration Alternative 1 (RD-A1) for the Riverbend area includes in-stream substrate enhancement (Section 2.2), and riparian zone expansion (Section 2.15). A variety of substrate materials will be added to the area in front of the sheet pilings in order to enhance targeted functions (i.e. fish spawning habitat). The substrate enhancement area would be limited by the proximity of the authorized navigation channel. As a result, the potential ecological benefits may be limited based on the size of the substrate enhancement area. RD-A1 will also focus on expanding the riparian zone.

4.6.2.2.2 Riverbend – Downstream Alternative 2 (RD-A2)

Restoration Alternative 2 for the Riverbend area (RD-A2) includes the installation of floating log shelters (Section 2.5) along the existing bulkheads. As discussed in Section 2.5, the floating log shelters are secured by cables, giving them the capability of movement up and down with the varying water level, without the risk of floating downstream. These kinds of shelters provide shade and habitat for fish and macroinvertebrates. RD-A2 will also focus on expanding the riparian zone (Section 2.15).

4.6.2.2.3 Riverbend – Downstream Alternative 3 (RD-A3)

Restoration Alternative 3 (RD-A3) includes the installation of modified lunker boxes (Section 2.4) along the existing bulkheads. Modified lunker boxes will be installed, and anchored to the steel pilings, creating a submerged shelf. This shelf will be filled with gravel and cobble to provide in-stream shallow habitat. RD-A3 will also focus on expanding the riparian zone (Section 2.15).

5 PROJECT EVALUATION

5.1 Criteria

To develop and evaluate potential restoration options, evaluation criteria were developed in consultation with the PCT Habitat Restoration Subgroup[6]. These evaluation criteria provide a basis for design and allow comparison of relative costs and benefits of each alternative within a project location. The evaluation criteria may also be used in the future to evaluate additional proposed restoration projects to be presented in the Master Plan.

The evaluation criteria were separated into screening criteria and scoring ranking criteria. The eight screening criteria are similar in concept to the threshold criteria of the Comprehensive Environmental Response, Compensation, and Liability Act Evaluation Criteria (40 CFR 300.430(e)(9)(iii)) in that they are required to be met for any given project alternative to be evaluated (Table 5). The scoring criteria are used to rank or prioritize between various alternatives (Table 6). All evaluation criteria are summarized below.

5.1.1 Screening Criteria

The screening criteria used to determine whether or not a restoration alternative may be appropriate for consideration include the following (Table 5)[7]:

- Complies with federal, state, tribal, and local laws, policies, and regulations: Restoration alternatives must be permitable based on existing regulations; those that are not, will not be further evaluated.
- Extent to which the proposed project alternative may be affected by actual or planned remedial or response actions: Proposed projects alternatives that are likely to be enhanced or augmented by remedial/response actions may be preferred for selection, whereas proposed project alternatives that are likely to be adversely impacted by response/remedial actions may not be preferred.
- Agency acceptance: State and federal agencies overseeing sediment remediation in Buffalo River must agree to the conceptual design of the remediation alternative for it to be evaluated under this program.
- Community acceptance: Project alternatives unlikely to be accepted by the local community will not be evaluated further under this program.
- Minimal potential effects of the project alternative on human health and safety: Project alternatives will not be considered if they may adversely impact long-term human health and safety.

[6] PCT Habitat Restoration Subgroup evaluation, as well as ENVIRON's evaluation, of the scoring criteria for each project location is presented in Appendix C.

[7] Due diligence, including property ownership and owner acceptance, is critical to project implementability. Due diligence is included in Section 5.1.2 (Scoring Criteria) and is evaluated for project locations.

- Minimal potential for adverse ecological impacts resulting from the proposed restoration activities: Project alternatives will not be considered if they may adversely impact long-term ecological services.

5.1.2 Scoring Criteria

Only those project alternatives determined to meet all of the screening criteria listed above will be evaluated according to the scoring criteria. Project alternatives are scored on a four-point interval scale (possible score of 1, 4, 7, or 10 for each criterion). The scoring criteria include the following (Table 6):

- Proximity to site: Project alternatives occurring within closest proximity to the area impacted by remediation will be given the highest value (10). Values will decrease (to a value of 1) with increasing distance from the remediation area. For example, an alternative within the remedy footprint would receive a higher score than an alternative that is outside the AOC, but within the watershed.
- Maximizing preferred services from natural resources: Project alternatives will be scored based on the degree to which the proposed alternative targets beneficial use impairments (BUIs). For example, an alternative that would target five BUIs would have a higher score than an alternative that targets one BUI.
- Public use: Project alternatives will be scored based on the extent to which the alternatives are likely to provide significant value to the public. Those that enhance public use (e.g., access, observation opportunities, aesthetics) will receive higher scores (10), while those where public use is not deemed as great or is unclear will receive lower scores. For example, an alternative that improves recreational fishing and wildlife observation would score higher than an alternative that did not add human uses.
- Use of established, successful methods: Project alternatives will be scored based on the likelihood of success of the alternative. Use of methods that have documented success will score higher than novel, undocumented methods. For example, an alternative that proposed bank stabilization and/or installation of rootwads will score higher than an alternative that uses less established methods (i.e., tree revetments have a limited life span and the potential to be damaged by ice flows).
- Scope of benefits: Project alternatives will be scored based on the size of the alternative and the level of services expected to be provided when the alternative reaches full function. Project alternatives providing the greatest benefits will receive the highest scores. For example, project alternatives that restore larger areas of habitat will score higher than those restoring smaller areas.
- Addition of benefits: Project alternatives to restore natural resources that will experience natural restoration within a reasonable period of time in the absence of active restoration efforts may not be preferred as part of this restoration planning effort. Project alternatives will be scored based on the level of services expected to be provided relative to current services provided. Those alternatives with the greatest level of services increase will receive the highest scores. For example, an alternative that improves habitat from low to high quality would score higher than an alternative that improves habitat from moderate to high quality.
- Maximizing time over which benefits accrue: Project alternatives will be scored based on the projected life-span of the alternative and the time required for each alternative to achieve full function. Project alternatives providing benefits for the longest period of time (e.g., longer life-span, sustainable alternatives) will receive the highest scores. For example, an alternative that regrades the

bank and is sustainable for decades would score higher than an engineered structure which has a finite lifespan.

- Due diligence: Project alternatives will be scored based on the current land use, property ownership, parcel availability, and owner acceptance. Property owner permission is critical to project implementability. Those alternatives with available property and willing owners will be scored higher than those with unclear property availability or ownership. For example, alternatives for which limited information is available will receive lower scores because they require additional due diligence research during the design phase.
- Measurability of success: Project alternatives will be scored based on whether or not easily measured metrics can be developed to closely track the performance of the alternative over time. Project alternatives where measurable metrics can be easily developed will receive the highest scores. Measurable metrics may include: vegetation cover, water quality (e.g., dissolved oxygen, turbidity), bank erosion, sedimentation, vegetative diversity (native vs. invasive), macroinvertebrate abundance, and establishment of fish habitat.
- Cost effectiveness: Alternatives will be based on the total cost of the project alternative. For example, alternatives with relatively low costs will receive the highest scores (10 or 7) and alternatives with high costs will receive a 1 or a 4.

5.2 Evaluation and Preferred Conceptual Restoration Projects

This section presents descriptions of the evaluation and selection of the preferred restoration alternative at each of the six potential restoration locations presented in Section 4. The preferred project alternatives were those that passed the screening criteria (Table 5) and scored the highest among the various alternatives for each project location based on the scoring criteria (Table 6)[8].

5.2.1 Kelly Island

Of the two restoration alternatives evaluated for Kelly Island, KS-A2 met all of the screening criteria necessary to be considered as a restoration alternative (Table 5). KS-A2 differs from KS-A1 by its use of modified lunker boxes. These modified lunker boxes provide shade, shelter, and habitat for fish and other biota. KS-A2 also scored higher than KS-A1 based on selected scoring criteria (Table 6). KS-A2 is chosen over KS-A1 due to its greater use to the public, the scope of benefits, and the measurability of success. Therefore, KS-A2 is the preferred restoration alternative for Kelly Island (Figure 8).

5.2.2 City Ship Canal

CSC-A4 is chosen as the preferred restoration alternative for the City Ship Canal because it scored the highest among the four restoration alternatives proposed for the location (Figure 9). As mentioned in Section 4.2, restoration alternative CSC-A4 incorporates all restoration techniques proposed in CSC-A1,

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[8] Table 6 presents the mode scores for each criterion for each alternative. The mode score was calculated from survey's completed by the PCT. Final selection of the preferred restoration alternative for all project locations was agreed upon by the PCT on October 29th, 2009.

CSC-A2, and CSC-A3 with the addition of riparian zone expansion. If adjacent land is not available upon further due diligence, then the riparian zone expansion may be limited or not possible. Specifically, CSC-A4 scored highest due to:

- Maximizing preferred services from natural resources: CSC-A4 scored higher than other alternatives due to its higher potential for establishing fish and wildlife habitat (habitat creation and water quality improvement).

- Public use: Similar to the criteria above, CSC-A4 scored higher than other alternatives due to its potential for establishing fish and wildlife habitat and, therefore, recreational fishing and wildlife observation opportunities for the general public.

- Use of established, successful methods: All of the alternatives proposed for the City Ship Canal use well-established methods. However, CSC-A2 and CSC-A4 received higher scores because they incorporate rootwads for additional bank stabilization. As discussed in Section 2.5, the use of rootwads has been shown to be a robust treatment. Rootwads can be applied to reinforce the river bank, and have been shown to be resist to propeller wash and wave and ice action and can withstand woody debris accumulation. Rootwads have a design life of greater than 25 years.

- Addition of ecological benefits: CSC-A4 incorporates more restoration techniques than other proposed alternatives for this location, including the combination of in-stream vegetation and substrate enhancement, anchored woody debris, rootwads, bank shaping, bank and riparian zone vegetation enhancement, and riparian zone expansion, and therefore provides more ecological benefits.

- Maximizing time over which benefits accrue: CSC-A4 scored higher than CSC-A1 and CSC-A3 due to its use of both rootwads and bank shaping (two techniques that have demonstrated higher life span and therefore maximize the time over which the benefits accrue). As discussed in Section 2.5, rootwads have a design life of greater than 25 years.

5.2.3 Ohio Street Shoreline

Of the two restoration alternatives proposed for the Ohio Street Shoreline, OSS-A2 is chosen as the preferred alternative (Figure 10). OSS-A2 differs from OSS-A1 in its use of a vane to redirect flow and increase oxygenation along the shoreline; all other proposed restoration techniques are the same for each alternative (in-stream vegetation and substrate enhancement, bank shaping, stone toe protection, bank and riparian zone vegetation enhancement, and riparian zone expansion). Both OSS-A1 and OSS-A2 passed the screening criteria presented in Table 5. However, OSS-A2 received a higher score based on the scoring criteria presented above and in Table 6. Specifically, OSS-A2 scored highest due to:

- Maximizing preferred services from natural resources: The use of a vane redirects flow along the shoreline and therefore helps decrease debris accumulation (decreasing degradation of aesthetics). Not only does the vane redirect flow but it also has the potential to increase oxygenation, therefore improving water quality for fish populations.

- Public use: OSS-A2 scored higher than OSS-A1 due to its use of the vane. Installment of a vane will improve aesthetics and enhance potential recreational fishing habitat for the general public by improving water quality.

- Addition of ecological benefits: A vane can potentially increases oxygenation along the shoreline, increasing water quality and therefore ecological habitat.

5.2.4 Katherine Street Peninsula

5.2.4.1 Katherine Street Peninsula – Northern Shoreline

A combination of KSP(NS)-A1 and KSP(NS)-A3 is chosen as the preferred restoration alternative for the northern shoreline of the Katherine Street Peninsula (Figure 11a). All restoration alternatives for the Katherine Street Peninsula (northern and southern shoreline) passed the screening criteria presented in Table 5. All restoration alternatives proposed for the northern shoreline incorporate bank and riparian zone vegetation enhancement. KSP(NS)-A1 differs from the other restoration alternatives by its use of bank shaping and stone toe protection and KSP(NS)-A3 differs by its use of a living crib wall (Table 6). A combination of KSP(NS)-A1 and KSP(NS)-A3 for the preferred alternative was decided on by the PCT. Therefore, the bank stabilization techniques along the northern shoreline will include a combination of bank shaping and stone toe protection as well as localize installation of a living crib wall[9]. KSP(NS)-A1 and KSP(NS)-A3 are chosen as the preferred restoration alternatives because they scored the highest among the four alternatives according to the scoring criteria presented in Table 6. Specifically, KSP(NS)-A1 and KSP(NS)-A3 scored highest due to:

- Use of established, successful methods: The bank stabilization techniques proposed in KSP(NS)-A1 and KSP(NS)-A3 are used more frequently than the bank stabilization techniques proposed in KSP(NS)-A2 and KSP(NS)-A4. For this reason, the likelihood of success of the combination of these alternatives is higher than other alternatives proposed for this location.

- Addition of ecological benefits: KSP(NS)-A1 and KSP(NS)-A3 scored the same for this criterion. KSP(NS)-A2 proposed the use of wrapped earth with branch packing and KSP(NS)-A4 proposes installation of geocells. Although the wrapped earth technique and geocells are robust treatments, bank vegetation does not occur as densely as it would with the bank shaping technique. Higher values for aquatic macroinvertebrates and fish habitat are achieved by installing a living crib wall. (Sections 2.9 and 2.12).

- Cost: KSP(NS)-A1 and KSP(NS)-A3 received the same cost scoring, however they received higher scores than KSP(NS)-A4. Geocells, a component of KSP(NS)-A4, have the highest installation cost of all other bank stabilization techniques proposed for this project location.

[9] The length and specific location of the living crib wall will be determined during the restoration design phase.

5.2.4.2 Katherine Street Peninsula – Southern Shoreline

Of the two restoration alternatives proposed for the southern shoreline of the Katherine Street Peninsula, KSP(SS)-A2 is chosen as the preferred alternative (Figure 11b). The alternatives differ because KSP(SS)-A2 incorporates bank and riparian zone vegetation enhancement whereas KSP(SS)-A1 does not. Both restoration alternatives passed the screening criteria presented in Table 5. KSP(SS)-A2 is chosen as the preferred alternative because it scored highest among the two proposed alternatives. Specifically, KSP(SS)-A2 scored highest due to:

- Maximizing preferred services from natural resources: KSP(SS)-A2 scored higher than KSP(SS)-A1 due to its higher potential for establishing wildlife habitat due to bank and riparian zone vegetation enhancement.

- Public use: KSP(SS)-A2 scored higher than KSP(SS)-A1 due to its potential for recreational opportunities based on the observation of wildlife.

- Use of established, successful methods: KSP(SS)-A2 differs from KSP(SS)-A1 in its use of a vegetation enhancement technique (bank and riparian zone vegetation enhancement). For this reason, the likelihood of success of KSP(SS)-A2 is higher than all KSP(SS)-A1.

- Addition of ecological benefits: KSP(SS)-A2 scored higher than KSP(SS)-A1 due its use of bank and riparian zone vegetation enhancement, which can improve nutrient uptake, overhanging vegetation, root system development, and canopy structure. Therefore, KSP(SS)-A2 provides a higher level of service than KSP(SS)-A1 (proposed in-stream vegetation and substrate enhancement only).

- Maximizing time over which benefits accrue: KSP(SS)-A2 scored higher than KSP(SS)-A1 due to its use of bank and riparian zone vegetation enhancement.

- Measurability of success: KSP(SS)-A2 scored higher than KSP(SS)-A1 for this criterion due to the number of metrics available to measure development over time. The success of the techniques used in KSP(SS)-A2 (in-stream vegetation and substrate enhancement, and bank and riparian zone vegetation enhancement) can be measured by metrics such as: vegetation cover, water quality (e.g., dissolved oxygen, turbidity), bank erosion, sedimentation, vegetative diversity (native vs. invasive), macroinvertebrate abundance, and establishment of fish habitat. The KSP(SS)-A1 success criteria are more limited.

5.2.5 Buffalo Color Peninsula Shoreline

Of the two restoration alternatives proposed for the Buffalo Color Peninsula shoreline, BCAD-A2 is chosen as the preferred alternative (Figure 12). BCAD-A2 differs from BCAD-A1 by the proposed enhancement of bank and riparian zone vegetation. Both alternatives passed the screening criteria presented in Table 5. However, BCAD-A2 received a higher score based on the scoring criteria presented above and in Table 6. Specifically, BCAD-A2 scored highest due to:

- Maximizing preferred services from natural resources: BCAD-A2 scored higher than BCAD-A1 due to its higher potential for establishing wildlife habitat due to bank and riparian zone vegetation enhancement.

- Public use: BCAD-A2 scored higher than BCAD-A1 due to its potential to provide public opportunities for wildlife observation.

- Addition of ecological benefits: BCAD-A2 scored higher than BCAD-A1 due its use of bank and riparian zone vegetation enhancement. The goals of bank and riparian zone vegetation enhancement are to maintain bank stability, introduce vegetative diversity, and to achieve sufficient canopy, understory, and shrub and herbaceous layers. Therefore, BCAD-A2 provides a higher level of service than BCAD-A1 (in-stream vegetation enhancement only).

- Maximizing time over which benefits accrue: BCAD-A2 scored higher than BCAD-A1due to its use of bank and riparian zone vegetation enhancement. A goal of vegetation enhancement (in addition to the goals discussed above) is to increase the successional stage of the bank and riparian zone. The bank enhancement becomes more robust over time and maximizes the time over which the benefits accrue.

- Measurability of success: BCAD-A2 scored higher than BCAD-A1 for this criterion due to the number of metrics available to measure development over time. The success of the techniques used in BCAD-A2 (in-stream vegetation enhancement and bank and riparian zone vegetation enhancement) can be measured by metrics such as: vegetation cover, water quality (e.g., dissolved oxygen, turbidity), bank erosion, sedimentation, vegetative diversity (native vs. invasive species establishment), macroinvertebrate abundance, and establishment of fish habitat. BCAD-A1 had more limited success criteria.

5.2.6 Riverbend Area

5.2.6.1 Riverbend Area – Upstream/Natural Shoreline

RU-A2 is chosen as the preferred restoration Alternative for the upstream/natural shoreline of the Riverbend Area (Figure 13a). All alternatives for the Riverbend Area (downstream and upstream) passed the screening criteria presented in Section 5.1.1 and Table 5. All three restoration alternatives for the upstream/natural shoreline of the Riverbend Area incorporate in-stream vegetation and substrate enhancement, bank shaping, bank and riparian zone vegetation enhancement, and riparian zone expansion. RU-A2 differs from the other alternatives by its use of rootwads (RU-A1 does not include any additional bank stabilization techniques, where as RU-A3 incorporates tree revetments instead of rootwads). RU-A2 is chosen because it scored highest among the three restoration alternative proposed for the location (Table 6). Specifically, RU-A2 scored highest due to:

- Maximizing preferred services from natural resources: Both RU-A2 and RU-A3 scored higher than RU-A1 because they each provide a technique in addition to the RU-A1 techniques. Additional restoration enhancements provide additional ecological benefits.

- Public use: RU-A2 and RU-A3 scored higher than RU-A1 due to their potential for establishing fish habitat and therefore recreational fishing habitat for the general public.

- Use of established, successful methods with a high probability of success: RU-A2 scored higher on this criterion because the use of rootwads is an established bank stabilization technique that reinforces the river bank, is resistant to propeller wash, wave and ice action, and can withstand woody debris accumulation. RU-A1 and RU-A3 score lower for this criterion because RU-A1 is limited to bank reshaping and RU-A3 uses tree revetments, which are not as robust as rootwads.

- Addition of ecological benefits: Both RU-A2 and RU-A3 scored higher than RU-A1 because they each provide a technique in addition to the RU-A1 techniques. Both rootwads and tree revetments are expected to provide benefits such as improved habitat for fish and macroinvertebrates, a reduction in flow velocities along eroding streambanks, and the promotion of plant establishment.

- Maximizing time over which benefits accrue: RU-A2 scored higher than RU-A1 and RU-A3 due to its use of rootwads (a technique that has demonstrated higher life span and therefore maximizes the time over which the benefits accrue). As discussed in Section 2.5, rootwads have a design life of greater than 25 years.

5.2.6.2 Riverbend Area – Downstream/Bulkheaded Shoreline

RD-A1 is chosen as the preferred restoration alternative for the downstream/bulkheaded shoreline of the Riverbend Area (Figure 13b). As mentioned above, all alternatives for the Riverbend Area (downstream and upstream) passed the screening criteria presented in Section 5.1.1 and Table 5. All three restoration alternatives for the downstream/bulkheaded shoreline of the Riverbend Area incorporate riparian zone expansion. RD-A1 uses in-stream substrate enhancement rather than floating log shelters (RD-A2) or modified lunker boxes (RD-A3). RD-A1 is chosen because it scored highest among the three restoration alternatives proposed for the location (Table 6). Specifically, RD-A1 scored highest due to:

- Use of established, successful methods: In-stream substrate enhancement (used in RD-A1) is a common technique for enhancing aquatic habitat for fish and invertebrates and scored higher for this criterion than the significantly less frequently used alternatives of using floating log shelters (RD-A2) or modified lunker boxes (RD-A3).

- Maximizing time over which benefits accrue: Floating log shelters and modified lunker boxes are expected to have a finite lifespan due to human and natural forces along the bulkhead. In-stream substrate enhancement (RD-A1) does not rely on attaching any structures to the bulkhead wall and is not subject to degradation; therefore it scores higher than the other two alternatives for this criterion.

- Due diligence: As mentioned above, RD-A1 uses in-stream substrate enhancement rather than floating log shelters (RD-A2) or modified lunker boxes (RD-A3). Because installation of floating log shelters or modified lunker boxes would require additional due diligence research, RD-A1 received a higher score for this criterion.

6 SUMMARY AND CONCLUSIONS

The PCT evaluated multiple potential restoration alternatives and selected a single restoration alternative as the recommended restoration approach for each location. These include:

- Kelly Island Alternative 2 (KS-A2)
- City Ship Canal Alternative 4 (CSC-A4)
- Ohio Street Shoreline Alternative 2 (OSS-A2)
- Katherine Street Peninsula Northern Shoreline Alternative 1 (KSP(NS)-A1) with a Katherine Street Peninsula Northern Shoreline Alternative 3 (KSP(NS)-A3) demonstration project
- Katherine Street Peninsula Southern Shoreline Alternative 2 (KSP(SS)-A2)
- Buffalo Color Peninsula Shoreline Alternative 2 (BCAD-2)
- Riverbend Upstream Alternative 2 (RU-A2)
- Riverbend Downstream Alternative 1 (RD-A1)

These recommended restoration projects are in agreement with the initial conceptual recommendations from the PCT Habitat Restoration Subgroup (Appendix B). Additional discussions during the project negotiation phase will determine which, if any, projects should proceed to the design phase for implementation following the Buffalo River remediation. Projects that are not pursued at this time may be incorporated into the Master Plan for future consideration.

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Tables

Table 1
Example Species List for Emergent Vegetation Restoration
Buffalo River, NY

Scientific Name	Common Name	Preferred Water Depth (ft)	Planting Suggestions	Buffalo River	Reference
Acorus calamus	Sweet flag	0-0.5	1-3 ft apart		NYSDEC General Standard Planting Recommendations, May 12, 2009
Alisma palntago-aquatica	Water plantain		clusters at irregular intervals		NYSDEC General Standard Planting Recommendations, May 12, 2009, Lower Passaic River Restoration Project, 2008
Andropogon sp	Sedge sp.	0.5-1.5			NYSDEC General Standard Planting Recommendations, May 12, 2009
Asclepias incarnata	Swamp milkweed		clusters at irregular intervals near wooded edge		NYSDEC General Standard Planting Recommendations, May 12, 2009, Lower Passaic River Restoration Project, 2008
Calamagrostis canadensis	blue joint grass	0.5-1.5			NYSDEC General Standard Planting Recommendations, May 12, 2009
Carex lurida	shallow sedge				Lower Passaic River Restoration Project, 2008
Carex scoparia	broom sedge				Lower Passaic River Restoration Project, 2008
Carex vulpinoidea	Fox sedge				Lower Passaic River Restoration Project, 2008
Cornus amomum	Silky dogwood				Prioritizing Wetland Restoration Potential in the Tributaries of the Cuyahoga River AOC 2008.
Cyperus esculentus	nutsedge		1-3 ft apart		NYSDEC General Standard Planting Recommendations, May 12, 2009
Cyperus strigosus	Strawcolored flatsedge				Lower Passaic River Restoration Project, 2008
Eleocharis palustris	Common spikerush				Lower Passaic River Restoration Project, 2008
Glyceria striata	Fowl mannagrass				Lower Passaic River Restoration Project, 2008
Iris versicolor	Blue flag iris	0-0.5	0.5-1.5 ft apart		NYSDEC General Standard Planting Recommendations, May 12, 2009, Lower Passaic River Restoration Project, 2008
Juncus effuses	soft rush				Lower Passaic River Restoration Project, 2008
Juncus tenuis	Poverty rush				Lower Passaic River Restoration Project, 2008
Leersia oryzoides	Rice cutgrass				Prioritizing Wetland Restoration Potential in the Tributaries of the Cuyahoga River AOC 2008.
Nuphar lutea	Yellow pond-lily				Lower Passaic River Restoration Project, 2008
Onoclea sensibilis	Sensitive fern				Prioritizing Wetland Restoration Potential in the Tributaries of the Cuyahoga River AOC 2008.
Peltandra virginica	Green arrow arum	0-6"			Lower Passaic River Restoration Project, 2008: http://www.pondsplantsandmore.com/Arrow_Arum_Peltandra_virginica_Marginal_Bog_p/pmh%20arrow%20arum.htm
Polygonum arifolium	Halberd-leaved tearthumb				Lower Passaic River Restoration Project, 2008
Polygonum hydropiperoides	swamp smartweed				Lower Passaic River Restoration Project, 2008
Polygonum sagitatum	arrow-leaved tearthumb				Lower Passaic River Restoration Project, 2008
Pontederia cordata	pickerelweed			☑	ENVIRON 2009 - Buffalo River SRIR, Lower Passaic River Restoration Project, 2008

Table 1
Example Species List for Emergent Vegetation Restoration
Buffalo River, NY

Scientific Name	Common Name	Preferred Water Depth (ft)	Planting Suggestions	Buffalo River	Reference
Potentilla potens	Marsh cinquefoil	0-0.5			NYSDEC General Standard Planting Recommendations, May 12, 2009
Rhamnus frangula	European buckthorn				Prioritizing Wetland Restoration Potential in the Tributaries of the Cuyahoga River AOC 2008.
Rumex verticillatus	Swamp dock				Lower Passaic River Restoration Project, 2008
Sagittaria latifolia	broadleaf arrowhead	0-2	clusters at irregular intervals	☑	ENVIRON 2009 - Buffalo River SRIR, NYSDEC General Standard Planting Recommendations, May 12, 2009, Lower Passaic River Restoration Project, 2008
Sagittaria rigida	Deep duck potato	0.5-2	clusters at irregular intervals		NYSDEC General Standard Planting Recommendations, May 12, 2009
Scirpus acutus	Hardstem bulrush				Lower Passaic River Restoration Project, 2008
Scirpus americanus	Chairmakers bulrush				Lower Passaic River Restoration Project, 2008
Scirpus atrovirens	Green bulrush				Lower Passaic River Restoration Project, 2008
Scirpus cyperinus	woolgrass				Lower Passaic River Restoration Project, 2008
Zizania aquatica	Annual wildrice	<15 cm to 1.6 m			Lower Passaic River Restoration Project, 2008;http://www.rook.org/earl/bwca/nature/grass/WIP/zizania.html

cm: centimeter
ft: feet
m: meter

Table 2
Example Species List for Submerged Aquatic Vegetation Restoration
Buffalo River, NY

Scientific Name	Common Name	Preferred Water Depth (ft)	Planting Suggestions	Buffalo River	Reference
Ceratophyllum demersum	Coontail			☑	ENVIRON 2009 - Buffalo River SRIR
Elodea canadensis	Canadian waterweed			☑	ENVIRON 2009 - Buffalo River SRIR
Justicia americana	American waterwillow			☑	ENVIRON 2009 - Buffalo River SRIR
Nymphea odorata	Pond lily	5	3-4 in a cluster	-	NYSDEC General Standard Planting Recommendations, May 12, 2009
Polygonium sp.	Smartweed species	2-4	spacing 2-4 feet apart	-	NYSDEC General Standard Planting Recommendations, May 12, 2009
Potamogeton crispus	Curlyleaf pondweed			☑	ENVIRON 2009 - Buffalo River SRIR
Potamogeton filiformis Pers.	Fine leaf pondweed			☑	Irvine et al 2005
Potamogeton nodosus	American pondweed	3	2-4 ft apart	☑	ENVIRON 2009 - Buffalo River SRIR, NYSDEC General Standard Planting Recommendations, May 12, 2009
Potamogeton pectinatus	Sago pondweed			☑	ENVIRON 2009 - Buffalo River SRIR
Potamogeton perfoliatus	Claspingleaf pondweed	3	2-4 ft apart	-	NYSDEC General Standard Planting Recommendations, May 12, 2009
Potamogeton sp.	i.e. Sago pondweed, sheather pondweed, variable pondweed, etc	3-6		-	NYSDEC General Standard Planting Recommendations, May 12, 2009
Scirpus subterminalis	Water bulrush	3		-	NYSDEC General Standard Planting Recommendations, May 12, 2009
Vallisneria americana	Wild celery	5	2-4 ft apart	☑	ENVIRON 2009 - Buffalo River SRIR, NYSDEC General Standard Planting Recommendations, May 12, 2009, Irvine et al 2005

Table 3
Example Species List for Riparian Vegetation Restoration
Buffalo River, NY

Scientific Name	Common Name	Buffalo River	Reference
Acer negundo L.	Ashleaf maple/Box elder	☑	Irvine et al 2005; Ohio Stream Management Guide Restoring Streambanks with vegetation Guide No 7; Lower Olentangy River Ecosystem Restoration Project July 2009
Acer rubrum	red maple		Lower Passaic River Restoration Project, 2008
Acer saccharinum L.	Silver maple	☑	Irvine et al 2005; Lower Olentangy River Ecosystem Restoration Project 2009
Alnus rugosa	Speckled alder		Lower Passaic River Restoration Project, 2008
Amorpha fruticosa	Desert false indigo		Lower Passaic River Restoration Project, 2008
Aster spp.	Asters		Prioritizing Wetland Restoration Potential in the Tributaries of the Cuyahoga River AOC 2008.
Bidens coronata	Crownerds beggarticks		Lower Passaic River Restoration Project, 2008
Carex spp.	Wetland sedges		Prioritizing Wetland Restoration Potential in the Tributaries of the Cuyahoga River AOC 2008.
Cephalanthus occidentalis	Common buttonbush		Lower Passaic River Restoration Project, 2008
Circaea lutetiana L.	Enchanter's nightshade	☑	Irvine et al 2005
Cirsium arvense (L.) Scop.	Canada thistle	☑	Irvine et al 2005
Cornus amomum	Silky dogwood		Lower Passaic River Restoration Project, 2008
Cornus sericea L.	Red osier dogwood	☑	Irvine et al 2005; Ohio Stream Management Guide Restoring Streambanks with vegetation Guide no 7
Cuscuta gronovii Willd.	Dodder	☑	Irvine et al 2005
Dichanthelium clandestinum	Deertongue		Lower Passaic River Restoration Project, 2008
Elymus canadensis L.	Wild rye	☑	Irvine et al 2005
Elymus virginicus	Virginia wildrye		Lower Passaic River Restoration Project, 2008
Equisetum arvense L.	Horsetail	☑	Irvine et al 2005
Eupatorium maculatum L.	Joepyeweed	☑	Irvine et al 2005
Eupatorium perfoliatum L.	Joepyeweed	☑	Irvine et al 2005
Eupatorium purpureum L.	Joepyeweed	☑	Irvine et al 2005
Euthamia graminifolia	Grass-leaved goldenrod		Lower Passaic River Restoration Project, 2008
Fraxinus pensylvanica Marshall	Green ash	☑	Irvine et al 2005, Lower Passaic River Restoration Project, 2008; Ohio Stream Management Guide Restoring Streambanks with vegetation Guide no 7.; Prioritizing Wetland Restoration Potential in the Tributaries of Cuyahoga River AOC 2008
Galeopsis tetrahit L.	Hempnettle	☑	Irvine et al 2005
Geum virginianum L.	Cream avens	☑	Irvine et al 2005
Glyceria striata	fowl manna grass		Prioritizing Wetland Restoration Potential in the Tributaries of the Cuyahoga River AOC 2008.
Helianthus tuberosus L.	Jerusalem artichoke	☑	Irvine et al 2005
Hibiscus moscheutos	Swamp hibiscus		Lower Passaic River Restoration Project, 2008
Hypericum perforatum L.	St. Johnswort	☑	Irvine et al 2005
Ilex glabra	Inkberry		Lower Passaic River Restoration Project, 2008
Impatiens capensis Meerb.	Jewelweed	☑	Irvine et al 2005
Liquidambar styraciflua	Sweetgum		Lower Passaic River Restoration Project, 2008
Maclura pomifera	Osage-orange		Lower Olentangy River Ecosystem Restoration Project 2009

Table 3
Example Species List for Riparian Vegetation Restoration
Buffalo River, NY

Scientific Name	Common Name	Buffalo River	Reference
Pontederia cordata L.	Pickerelweed	☑	Irvine et al 2005
Populus deltoides Marshall	Eastern cottonwood/sycamore	☑	Irvine et al 2005; Ohio Stream Management Guide Restoring Streambanks with vegetation Guide no 7
Potentilla reptans L.	Creeping cinquefoil	☑	Irvine et al 2005
Rhus typhina L.	Staghorn sumac	☑	Irvine et al 2005
Robinia fertilis	Bristly locust		Ohio Stream Management Guide Restoring Streambanks with Vegetation Guide no 7;
Salix alba	White willow		Ohio Stream Management Guide Restoring Streambanks with Vegetation Guide no 7;
Salix cottet	Bankers willow		Ohio Stream Management Guide Restoring Streambanks with Vegetation Guide no 7;
Salix interio	Sandbar willow		Ohio Stream Management Guide Restoring Streambanks with Vegetation Guide no 7;
Salix nigra Marshall	Black willow	☑	Irvine et al 2005, Lower Passaic River Restoration Project, 2008; Ohio Stream Management Guide Restoring Streambanks with Vegetation Guide 7; Lower Olentangy River Ecosystem Restoration Project 2009
Salix purpurea	Streamco willow		Ohio Stream Management Guide Restoring Streambanks with Vegetation Guide no 7;
Sambucus canadenisis	American black elderberry		Lower Passaic River Restoration Project, 2008
Scrophularia marilandica L.	Carpenter's square	☑	Irvine et al 2005
Solanum dulcamara L.	Climbing nightshade	☑	Irvine et al 2005
Solanum nigrum L. B	lack nightshade	☑	Irvine et al 2005
Solidago gigantea Ait.	Giant goldenrod	☑	Irvine et al 2005
Spiraea latifolia	Meadowsweet		Lower Passaic River Restoration Project, 2008
Ulmus americana	American elm		Prioritizing Wetland Restoration Potential in the Tributaries of the Cuyahoga River AOC 2008.
Verbena urticifolia L.	White vervain	☑	Irvine et al 2005
Vergbena hastata	Blue vervain		Lower Passaic River Restoration Project, 2008
Vernonia noveboracensis	New York ironweed		Lower Passaic River Restoration Project, 2008
Viburnum recognitum	northern arrow-wood		Prioritizing Wetland Restoration Potential in the Tributaries of the Cuyahoga River AOC 2008.
Viburnum dentatum	Southern arrowwood		Lower Passaic River Restoration Project, 2008
Viburnum lentago	Nannyberry		Lower Passaic River Restoration Project, 2008
Vitis riparia Michx.	Riverbank grape	☑	Irvine et al 2005

Table 4
Restoration Techniques Matrix
Buffalo River, NY

	Aquatic Vegetation Enhancement	In-Stream Shallows Substrate Enhancement	Anchored Woody Debris	Modified Lunker Boxes	Floating Log Shelters	Rootwads	Tree Revetments	Vanes	Bank Shaping	Stone Toe Protection	Wrapped Earth with Branch Packing	Living Crib Wall	Geocells	Bank and Riparian Zone Vegetation Enhancement	Expansion of Riparian zone
General Project Shoreline Types:															
Parking lot	x								x					x	x
Bulkhead	x	x		x	x				x	x	x	x	x	x	x
Riprap	x								x	x				x	x
Natural / Softened	x	x	x			x	x		x	x	x	x	x	x	x
Potential Restoration Project[1]:															
Kelly Island															
Alternative 1 (KS-A1)	x	x													
Alternative 2 (KS-A2)	x	x		x											
City Ship Canal															
Alternative 1 (CSC-A1)	x	x							x					x	
Alternative 2 (CSC-A2)	x	x				x			x					x	
Alternative 3 (CSC-A3)	x	x	x						x					x	
Alternative 4 (CSC-A4)	x	x	x			x			x					x	x
Ohio St. Shoreline															
Alternative 1 (OSS-A1)	x	x							x	x				x	x
Alternative 2 (OSS-A2)	x	x						x	x	x				x	x

Table 4
Restoration Techniques Matrix
Buffalo River, NY

	Aquatic Vegetation Enhancement	In-Stream Shallows Substrate Enhancement	Anchored Woody Debris	Modified Lunker Boxes	Floating Log Shelters	Rootwads	Tree Revetments	Vanes	Bank Shaping	Stone Toe Protection	Wrapped Earth with Branch Packing	Living Crib Wall	Geocells	Bank and Riparian Zone Vegetation Enhancement	Expansion of Riparian zone
Katherine St. Peninsula															
Northern Shore (NS)															
Alternative 1 [KSP(NS)–A1]									x	x				x	
Alternative 2 [KSP(NS)–A2]											x			x	
Alternative 3 [KSP(NS)–A3]												x		x	
Alternative 4 [KSP(NS)–A4]													x	x	
Southern Shore (SS)															
Alternative 1 [KSP(SS)–A1]	x	x													
Alternative 2 [KSP(SS)–A2]	x	x												x	
Buffalo Color Peninsula Shoreline															
Alternative 1 (BCAD–A1)	x														
Alternative 2 (BCAD–A2)	x													x	x

Table 4
Restoration Techniques Matrix
Buffalo River, NY

	Aquatic Vegetation Enhancement	In-Stream Shallows Substrate Enhancement	Anchored Woody Debris	Modified Lunker Boxes	Floating Log Shelters	Rootwads	Tree Revetments	Vanes	Bank Shaping	Stone Toe Protection	Wrapped Earth with Branch Packing	Living Crib Wall	Geocells	Bank and Riparian Zone Vegetation Enhancement	Expansion of Riparian zone
Riverbend															
Upstream/Natural Shoreline															
Alternative 1 (RU-A1)	x	x							x					x	x
Alternative 2 (RU-A2)	x	x				x			x					x	x
Alternative 3 (RD-A3)				x											x

[1] Land owner acceptance of these potential projects has not been resolved, but will be critical to project implementability and success. It is anticipated that additional due diligence (including any necessary negotiations with land owners) will be conducted during the design phase.

Table 5
Evaluation with Screening Criteria
Buffalo River, NY

Project ID #	Project Name	Complies with laws, policies, regulations (i.e., permittable)	Effected by remedial/response actions	State, Agency, and/or Tribal (Trustee) acceptance	Community acceptance	Human Health and Safety (minimal potential for adverse effects)	Ecological Effects (minimal potential for adverse effects)	Result
KS-A1	Kelly Island - Alternative 1	P	P	P	P	P	P	Pass
KS-A2	Kelly Island - Alternative 2	P	P	P	P	P	P	Pass
CSC-A1	City Ship Canal - Alternative 1	P	P	P	P	P	P	Pass
CSC-A2	City Ship Canal - Alternative 2	P	P	P	P	P	P	Pass
CSC-A3	City Ship Canal - Alternative 3	P	P	P	P	P	P	Pass
CSC-A4	City Ship Canal - Alternative 4	P	P	P	P	P	P	Pass
OSS-A1	Ohio Street Shoreline - Alternative 1	P	P	P	P	P	P	Pass
OSS-A2	Ohio Street Shoreline - Alternative 2	P	P	P	P	P	P	Pass
KSP(NS)-A1	Katherine Street Peninsula (Northern Shoreline) - Alternative 1	P	P	P	P	P	P	Pass
KSP(NS)-A2	Katherine Street Peninsula (Northern Shoreline) - Alternative 2	P	P	P	P	P	P	Pass
KSP(NS)-A3	Katherine Street Peninsula (Northern Shoreline) - Alternative 3	P	P	P	P	P	P	Pass
KSP(NS)-A4	Katherine Street Peninsula (Northern Shoreline) - Alternative 4	P	P	P	P	P	P	Pass
KSP(SS)-A1	Katherine Street Peninsula (Southern Shoreline) - Alternative 1	P	P	P	P	P	P	Pass
KSP(SS)-A2	Katherine Street Peninsula (Southern Shoreline) - Alternative 2	P	P	P	P	P	P	Pass
BCAD-A1	Buffalo Color Peninsula Shoreline - Alternative 1	P	P	P	P	P	P	Pass
BCAD-A2	Buffalo Color Peninsula Shoreline - Alternative 2	P	P	P	P	P	P	Pass
RU-A1	Riverbend Upstream - Alternative 1	P	P	P	P	P	P	Pass
RU-A2	Riverbend Upstream - Alternative 2	P	P	P	P	P	P	Pass
RU-A3	Riverbend Upstream - Alternative 3	P	P	P	P	P	P	Pass
RD-A1	Riverbend Downstream - Alternative 1	P	P	P	P	P	P	Pass
RD-A2	Riverbend Downstream - Alternative 2	P	P	P	P	P	P	Pass
RD-A3	Riverbend Downstream - Alternative 3	P	P	P	P	P	P	Pass

Table 6
Evaluation with Scoring Criteria [a]
Buffalo River, NY

ID #	Project Name	Description/Techniques Proposed	Proximity to Remedy 5 [b]	Maximizes the Preferred Services from Natural Resources	Public Use	Use of Established, Successful Methods	Scope of Benefits	Addition of Ecological Benefits	Maximizes Time Over Which Benefits Accrue	Due Diligence[c]	Measurability of Success	Cost[d]	Total Score
KS-A1	Kelly Island - Alternative 1	Sections 2.1, 2.2	10	4	1,4	7	4	4	4	4,7	4	10	52-58
KS-A2	Kelly Island - Alternative 2	Sections 2.1, 2.2, 2.4	10	4	1,7	4	7	4	4	4,7	7	10	**55-64**
CSC-A1	City Ship Canal - Alternative 1	Sections 2.1, 2.2, 2.9, 2.14	10	4,7	7	7	7	4	10	7	4	1	61-64
CSC-A2	City Ship Canal - Alternative 2	Sections 2.1, 2.2, 2.6, 2.9, 2.14	10	7	7	10	7	7	10	7	4,7,10	1	70-76
CSC-A3	City Ship Canal - Alternative 3	Sections 2.1, 2.2, 2.3, 2.9, 2.14	10	7	7	7	7	10	7	7	4,7,10	1	67-73
CSC-A4	City Ship Canal - Alternative 4	Sections 2.1, 2.2, 2.3, 2.6, 2.9, 2.14, 2.15	10	10	10	10	10	10	10	1,7,10	10	1	**82-91**
OSS-A1	Ohio Street Shoreline - Alternative 1	Sections 2.1, 2.2, 2.9, 2.10, 2.14, 2.15	4	4	7	4,7	4,7	4	7	7	7	10	58-64
OSS-A2	Ohio Street Shoreline - Alternative 2	Sections 2.1, 2.2, 2.8, 2.9, 2.10, 2.14, 2.15	4	7	7	7	10	10	7	7	10	10	**79**
KSP(NS)-A1[e]	Katherine Street Peninsula (Northern Shoreline) - Alternative 1	Sections 2.9, 2.10, 2.14	10	4	4	7	4	7	7	4	7	10	**64**
KSP(NS)-A2	Katherine Street Peninsula (Northern Shoreline) - Alternative 2	Sections 2.11, 2.14	10	4,7	4	4	4	4,7	4	4	4,7	10	52-61
KSP(NS)-A3[e]	Katherine Street Peninsula (Northern Shoreline) - Alternative 3	Sections 2.12, 2.14	10	7	4	7	4,7	7	4	4	7	10	**64-67**
KSP(NS)-A4	Katherine Street Peninsula (Northern Shoreline) - Alternative 4	Sections 2.13, 2.14	10	4	4	4	4	4	4	4	7	4	49
KSP(SS)-A1	Katherine Street Peninsula (Southern Shoreline) - Alternative 1	Sections 2.1, 2.2	7	7	4	4,7	4	4	4	7	4	10	55-58
KSP(SS)A2	Katherine Street Peninsula (Southern Shoreline) - Alternative 2	Sections 2.1, 2.2, 2.14	7	7	4	7	7	7	7	4	7	10	**67**
BCAD-A1	Buffalo Color Peninsula Shoreline - Alternative 1	Section 2.1	4	1	1	7	4	4	4,7	10	4	10	49-52
BCAD-A2	Buffalo Color Peninsula Shoreline - Alternative 2	Sections 2.1, 2.14, 2.15	4	4	4	7	7	4	7	4,10	7	7	**55-61**
RU-A1	Riverbend Upstream - Alternative 1	Sections 2.1, 2.2, 2.9, 2.14, 2.15	4	4	4	7	4	4	4,10	4	4,7	1	40-49
RU-A2	Riverbend Upstream - Alternative 2	Sections 2.1, 2.2, 2.6, 2.9, 2.14, 2.15	4	7	7	7	7,10	10	7	4,10	7	1	**61-70**
RU-A3	Riverbend Upstream - Alternative 3	Sections 2.1, 2.2, 2.7, 2.9, 2.14, 2.15	4	7	7	7	7,10	10	4,7	7,10	7	1	61-70

Table 6
Evaluation with Scoring Criteria [a]
Buffalo River, NY

ID #	Project Name	Description/Techniques Proposed	Proximity to Remedy 5 [b]	Maximizes the Preferred Services from Natural Resources	Public Use	Use of Established, Successful Methods	Scope of Benefits	Addition of Ecological Benefits	Maximizes Time Over Which Benefits Accrue	Due Diligence[c]	Measurability of Success	Cost[d]	Total Score
RD-A1	Riverbend Downstream - Alternative 1	Sections 2.2, 2.15	4,10	4	4	4,7,10	4	7	10	4,7,10	4	7	**52-70**
RD-A2	Riverbend Downstream - Alternative 2	Sections 2.5, 2.15	4,10	4,7	4	4	7	7	7	4,7,10	7	10	58-73
RD-A3	Riverbend Downstream - Alternative 3	Sections 2.4, 2.15	4,10	4	4	4	7	7	4	4,7,10	7	4	49-61

Notes:

Total scores in bold denote the preferred restoration alternative. [f]

a Criterion scoring represents the mode value assigned by the Project Coordination Team (PCT). See Appendix C for individual scoring.

b Scoring based on percent area within Remedy 5: 1=0-25%, 4=25-50%, 7=50-75%, 10=75-100%.

c Land owner acceptance of these potential projects has not been resolved, but will be critical to project implementability and success. It is anticipated that additional due diligence (including any necessary negotiations with land owners) will be conducted during the design phase.

d Cost scoring based on the following:1> $1 million, 4= $1 million-$500,000, 7= $500,000-$250,000, 10<$250,000.

e The preferred alternative for Katherine Street Peninsula (Northern Shoreline) will be a combination of KSP(NS)-A1 and KSP(NS)-A3.

f Preferred restoration alternatives were agreed upon by the PCT.