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**US Army Corps**
**of Engineers**
Kansas City District
*You Matter – We Care*

# Blue River Channel Modifications
# Brush Creek to $53^{rd}$ Street

# Jackson County, Missouri

# Design Documentation Report
## Prefinal Submittal
## Channel Modifications and Environmental Enhancements
## Excluding Waterline and Sanitary Sewer Relocations

# August 2008

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## 1.0 ACCOMPANYING AND PREVIOUSLY SUBMITTED DOCUMENTS

This Design Documentation Report is submitted with Prefinal Plans and Specifications for channel modifications and environmental enhancements. Design features detailed in those documents are described in detail within this report.

Design documents for this design-build project are completed and submitted for review in a series. Below is a summary of the documents that have been submitted prior to this prefinal submittal of the Plans, Specifications, and Design Document Report for channel modifications and environmental enhancements.

| Version | Date | Submitted Items |
|---|---|---|
| Final | 04-01-08 | Land Disturbance Plans |
| Final | 04-01-08 | Design Verification Report |
| Final | 04-16-08 | Refines Environmental Enhancement Report |
| 65% | 06-02-08 | Water Main Relocation; Plans, Specifications, and Design Documentation Report |
| Prefinal | 06-12-08 | Sanitary Sewer Relocation; Plans, Specifications, and Design Documentation Report |
| Preliminary | 07-22-08 | Geotechnical Report |
| Prefinal | 08-05-08 | Water Main Relocation; Plans, Specifications, and Design Documentation Report |
| Final | 08-05-08 | Sanitary Sewer Relocation; Plans, Specifications, and Design Documentation Report |
| Prefinal | 08-22-08 | Channel Modifications, Blue River Stations 86+00 to 122+89.16; Plans, Specifications, and Design Documentation Report |
| Prefinal | 08-22-08 | Environmental Enhancements, Blue River Stations 86+00 to 122+89.16; Plans, Specifications, and Design Documentation Report |

# 2.0 PROJECT DESCRIPTION

## 2.1 Project Site

### 2.1.1 Project Background

Blue River drains a watershed that extends from southern Johnson County in Kansas into Missouri and flows into the Missouri River in Kansas City, Jackson County, Missouri. Major tributaries to the Blue River include Indian Creek and Brush Creek, both of which extend from Johnson County, Kansas, to join with Blue River in Kansas City, Missouri.

Major flooding along the Blue River Valley has been recorded as early as 1928. After continuing flooding along the river, local authorities requested that the US Army Corps of Engineers began studying the basin after the major flood of 1961. Based on the results of that study, the Corps developed recommendations to mitigate flooding in the watershed. In 1970, Congress authorized a flood control effort along the Blue River.

The original authorized project proposed a control system that would include reservoirs in the upper reaches of the watershed and rechannelization through the downstream reaches of the river. Due to a lack of local support for upstream reservoirs, the project includes only downstream channel modification. The rechannelization project would provide an estimated level of 30-year storm event. Although not contained within the channel, the flooding elevations of larger-volume flows would be significantly reduced as well. Local authorities agreed to move forward with the downstream channel modifications. Kansas City, Missouri entered into a Local Cooperation Agreement with the Corps of Engineers in 1983 and construction began.

The channel modification project was subdivided into a series of reaches extending from the confluence of the Blue River with the Missouri River upstream to approximately 63rd Street. Downstream reaches up to Brush Creek have been constructed. The reach covered in this report (from Brush Creek to 53rd Street) will be followed by subsequent projects extending modifications to a grade control proposed to be constructed north of 63rd Street. The channel generally follows the alignment and template established in the *Blue River Channel Modification, Design Memorandum No. 4, Stage III Features, Volume 1*, dated July 1991. Modifications to the ultimate channel alignment were made at the upstream end of the reach, from stations 86+00 through 90+00, to provide a transition to the existing channel. The channel upstream of station 90+00 would be realigned as part of the channel modifications for the next upstream reach of the project.

The contract for this project has been awarded as a design-build delivery method to ESI Contracting Corporation. The design subconsultants to ESI include HDR, Inc. for channel modificatioin design and environmental enhancements; Norton & Schmidt for structural engineering; and Gary Van Riessen for geotechnical engineering. Supplemental field surveys are provided by Kaw Valley Engineering.

The design-build approach involves the contractor and designers in all stages of design and constructing, allowing more effective coordination between design documents and construction methods than is typically possible through the more common design-bid-build process.

The objectives of this project include design and construction of Blue River channel modifications; an upstream channel transition and temporary drop structure; modifications to existing storm sewer outlets; relocation of a waterline and a sanitary sewer both owned by Kansas City, Missouri; removal of solid waste from the channel banks; and environmental enhancements. The scope-of-work for this project is provided as an attachment in Appendix A.

## 2.2 Authorization

### 2.2.1 Directives

The Blue River Channel Modification Project was authorized by Congress on 31 December 1970 under the Flood Control Act of 1970 (P.L. 91-611, 91st Congress, 2nd Session). The City of Kansas City, Missouri entered into a Local Cooperation Agreement (LCA) for the project with the US Army Corps of Engineers on September 8th, 1983.

The project generally conforms to the alignment and template established in Design Memorandum No. 4 for the Blue River Flood Protection Project. Proposed alignments and templates have been modified to conform to existing conditions.

# 3.0 PERTINENT DATA

## 3.1 Purpose

The purpose of the project is to provide flood damage reduction in the Blue River Valley between the mouth and 63rd Street. The Contractor shall design and construct an upstream channel transition from the existing channel to the proposed channel section (approximately Station 86+00 to approximately Station 90+00) including a temporary drop structure (approximately Station 86+00). The exact upstream tie-in point and drop structure location will be determined by the design of the transition. The Contractor shall coordinate and provide for the maintenance of the existing channel flow capacity throughout the construction period. The Contractor shall muck out the existing channel prior to permanently filling those areas. Designated fill areas shall be used for temporary or permanent disposal of material.

## 3.2 Physical Features

Channel modifications downstream of Brush Creek have been completed under eight previous design and construction contracts to the Corps of Engineers.

Within the project reach covered by this report, a short section of the existing channel immediately north of the Blue Parkway Bridge has been relocated to the final alignment. This work was completed under a separate contract to relocate utilities that cross the channel near Blue Parkway Bridge. The utility corridor project was completed in 2005.

The remaining existing channel consists of banks overgrown with trees and shrubs, with steep, nearly vertical banks descending fifteen to thirty feet to the normal flow channel. Because of the steepness of these banks, they contain limited vegetation growth. In many locations solid and construction waste materials are partially protruding from the channel banks, from the elevations of the normal flow channel up the height of the bank.

Blue Parkway Bridge is being replaced under a construction contract to Kansas City, Missouri. It is anticipated that major construction activities on the proposed bridge will be complete before the modified channel is built under the bridge. The scope of this project requires coordination between the channel design-build contractor and the bridge contractor.

After the completion of the channel modifications through this reach, the City intends to construct a new bridge to carry Colorado Avenue. This bridge will connect the industrial park on the west side of the downstream end of the reach to the proposed location of Hardesty Avenue. The future Hardesty Avenue will follow the east bank to Blue Parkway. The bridge crossing will be located approximately 200-feet from the end of this project reach.

### 3.3 Controlling Conditions

The Corps of Engineers provided the following criteria to be used for the design of the proposed channel modification project.

> The following considerations are to guide the design of a temporary transition structure connecting the existing Blue River channel to the upstream end of the proposed channel modifications. The Contractor shall produce a design of his choosing subject to the following criteria; complete calculations supporting the selected design are to be submitted to the Kansas City District, U.S. Army Corps of Engineers in accordance with the submittal guidance in the Summary of Work Specification.
>
> The transition reach shall extend from the existing Blue River channel at the point offset from Station 86+00 (±50 ft) of the proposed channel to Station 90+00 (±50 ft) of the proposed channel.
>
> Channel and channel protection design shall be consistent with U.S. Army Corps of Engineers guidance, including EM 1110-2-1601 and appropriate reference to Hydraulic Design Criteria (700) Special Problems. Project requirements not specifically addressed by Corps of Engineers guidance shall be designed using acknowledged, documented procedures approved by the Kansas City District, USACE.
>
> The maximum lateral change in flow line entering or exiting the transition shall be 6 degrees, and any curvature within the transition shall have a radius of 1,000 feet or greater.
>
> The transition shall be designed to obtain a water-surface profile that is as straight as practical. Flows leaving the transition shall be subcritical and without excessive turbulence so that downstream channel erosion is minimized.
>
> The design should cause minimum energy losses consistent with economy of construction. Specifically, the energy grade losses through the transition shall be less than 4.0 ft for flows up to 13,000 cfs, and less than 2.5 ft for flows of 26,000 cfs and greater.
>
> The materials used for construction of the rock transition shall be selected to maintain stable channel sides and bed for flows up to 44,500 cfs.
>
> The transition shall include a grade control structure designed to arrest the potential

upstream progression of channel incision.

The grade control shall include rock sized to maintain stability and prevent excessive scour for flows up to and including 44,500 cfs.

The grade control structure shall include a steel sheetpile cutoff wall designed for stability up to 44,500 cfs.

The upstream end of the transition shall incorporate measures designed to prevent failure by flanking.

The riprap gutter outlet entering the transition reach at Station 88+04 shall be straight and shall join the flowline of the reconstructed channel perpendicularly or no greater than 15 degrees angled downstream.

The original scope of work identified that appropriate armoring should be provided for 200 feet upstream of the transition structure to prevent excessive erosion for flows up to 44,500 cfs. This criteria was removed from the project by direction from the Corps of Engineers.

## 3.4 Previously Obtained Data

During the Request-for-Proposal stage of this project, the Corps of Engineers provided design drawings developed to a nominal 65% level and specifications that included contract requirements and design criteria. Data used to develop those drawings and specifications were provided by the Corps of Engineers after the notice-to-proceed was issued. Additional guidance documentation was provided through links to websites containing relevant project history and technical design guidance manuals.

### 3.4.1 Hydrologic and Hydraulic Models and Data

HEC-RAS models for the Blue River were provided by the Corps of Engineers. These models were adjusted to reflect modifications to the original design assumptions based on final design considerations reflected in the Prefinal Construction Drawings and Specifications that accompany this report.

### 3.4.2 Conceptual Plans and Design Specifications

Plans and specifications for channel modifications were previously prepared to a nominal 65% level and provided to the design-build team. Environmental enhancement concepts were developed and designed by the design-build team with basic criteria provided prior to award. The waterline and sanitary sewer relocations were identified in the nominal 65% plans and specifications, but were considered to be conceptual. These two utility relocations were developed from the conceptual level by the design-build team.

### 3.4.3 Utility Relocations

Utility record drawings were provided by Kansas City, Missouri. Additional field data was collected by the surveyor for the design-build team. Potholing operations were completed to verify subsurface utility locations during development of the prefinal plans and specifications for utilities.

During review of waterline and sanitary sewer line construction documents, it was identified that there may be inconsistencies between the design-build specifications and the requirements of Kansas City, Missouri. This is an outstanding issue that will be reviewed as design progresses.

3.4.4 Survey Data

Base mapping used to develop the 65% plans was provided as part of the design data provided to the design-build team at the beginning of the project. Base mapping was spot-checked by field surveys completed between March and June of 2008.

## 3.5 Geotechnical Site Investigations

Geotechnical investigations were completed by the Corps of Engineers and the data were provided with other design document records at the beginning of this project. A summary and the results of additional geotechnical investigations and analyses have been previously submitted in the Preliminary Geotechnical Report.

## 3.6 Property Acquisitions and Adjacent Properties

Land surrounding the project site is well developed with both residential and industrial areas. Kansas City, Missouri acquired property for the construction, staging areas, and excess-fill disposal sites required for this project. The property limits for those areas were provided to the design-build team at the beginning of this project. Legal descriptions of the easements were obtained from County records and checked against the project limits provided.

In general there is a 20-foot wide permanent right-of-way measured from the channel top of bank and an additional 20-foot wide temporary construction easement outside the permanent right-of-way. Kansas City, Missouri, acquired property for the construction of the project which includes purchase-in-fee of entire parcels, partial acquisitions, permanent easements and temporary easements. Approximately eighty-two parcels are impacted by the proposed project.

# 4.0 REFERENCES

The project shall follow all applicable U.S. Government and City of Kansas City, Missouri, standards for design and preparation of plans, specifications and other supporting documents. The project shall comply with the applicable USACE Engineer Regulations and Engineer Manuals. Any variances to the applicable design criteria will be documented and pre-approved in writing by the Contracting Officer or Contracting Officers Representative (COR).

## 4.1 USACE Standards (Engineering Regulations and Manuals)

To the extent applicable, the project complies with the following USACE Engineer Manuals. The following standards from the U.S. Department of the Army, Corps of Engineers are available at http://www.usace.army.mil/publications/.

| | |
|---|---|
| EM 1110-1-1002 | (1990) Survey Markers and Monumentations |
| EM 1110-1-1804 | (2001) Engineering and Design - Geotechnical Investigation |

| | |
|---|---|
| EM 1110-1-1904 | (1990) Settlement Analysis |
| EM 1110-1-1905 | (1992) Bearing Capacity of Soils |
| EM 1110-1-2908 | (1994) Rock foundations |
| EM 1110-2-1205 | (1989) Environmental Engineering and Local Flood Control Channels |
| EM 1110-2-1413 | (1987) Hydrologic Analysis of Interior Areas |
| EM 1110-2-1415 | (1993) Hydrologic Frequency Analysis |
| EM 1110-2-1416 | (1993) River Hydraulics |
| EM 1110-2-1417 | (1994) Flood Run-off Analysis |
| EM 1110-2-1418 | (1994) Channel Stability Assessment For Flood Control Projects |
| EM 1110-2-1601 | (1994) Hydraulic Design of Flood Control Channel Change 1 ENG 4794-R |
| EM 1110-2-1610 | (1975) Hydraulic Design of Lock Culvert Valves |
| EM 1110-2-1902 | (2003) Slope Stability |
| EM 1110-2-1906 | (1970) Laboratory Soils Lab Testing |
| EM 1110-2-2104 | (2003) Strength Design for Reinforced Concrete Hydraulic Structures |
| EM 1110-2-2302 | (1990) Engineering Design – Construction with Large Stone |
| EM 1110-2-2502 | (1989) Retaining and Flood Walls |
| EM 1110-2-2504 | (1994) Design of Sheetpile Walls |
| EM 1110-2-2902 | (1997) Conduits, Culverts, and Pipes Change 1 1998 |
| EM 1110-3-136 | (1984) Drainage and Erosion Control |
| EM 385-1-1 | (2003) Safety -- Safety and Health Requirements |
| EI 02C202 | (1995) Subsurface Drainage |
| ECB 2005-10 | (2005) Scheduling Requirements for Testing of Mechanical Systems in Construction |
| ASTM D 3740 | (2004a) Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction |
| ASTM E 329 | (2005b) Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction |
| ER 1110-1-12 | (1994) Quality Management |
| ER 1-1-11 | (1995) Progress, Schedules, and Network Analysis Systems |
| ER 1110-1-8155 | (2003) Engineering and Design Specifications |
| TM 5-818-7 | (1983) Foundations in Expansive Soils |

| | |
|---|---|
| TM 5-820-4 | (1983) Drainage for Areas Other Than Airfields |
| TM 5-830-32 | (1987) Dust Control for Roads, Airfields and Adjacent Areas |
| TM 5-818-5 | (1983) Dewatering and Groundwater Control (Incl C1) |

## 4.2 Other Pertinent References


Derrick, D.L., 2008. Presentation entitled "Kansas City District Talk", at USACE District Kansas City, MO.

Doll, B.A., G.L. Grabow, K.R. Hall, J. Halley, W.A. Harman, G.D. Jennings and D.E. Wise, 2003, "Stream Restoration: A Natural Channel Design".

Fischenich, J.C, and Seal, R. (1999). "Boulder clusters," *EMRRP Technical Notes Collection* (EDRC TN-EMRRP-SR-11), U.S. Army Engineer Research and Development Center, Vicksburg, MS., http://www.wes.army.mil/el/emrrp

Kansas City, Missouri Water Services Department, "Standards and Specifications for Water Main Extensions and Relocations".

Kansas City Metro Chapter, American Public Works Association, "Standard Specifications and Design Criteria", as revised and adopted by the City of Kansas City, MO.

Handbook. NC Stream Restoration Institute, NC State University.

HDR, Inc., April 2008, "Refined Conceptual Mitigation and Enhancement Plan; Blue River Channel Modifications Project; Brush Creek to 53rd Street, USACE Kansas City District, and the City of Kansas City, Missouri".

Mid-America Regional Council/American Public Works Association. 2007. "Manual of Best Management Practices for Stormwater Quality", (draft edition).

Rosgen David L., P.H., Ph. D.. 2006. "Cross Vane, W-weir, and J-hook Vane Structures – Description, Design and Application for Stream Stabilization and River Restoration". Wildland Hydrology Inc. Fort Collins, CO.

Sylte, T.L., and Fischenich, J.C. (2000). "Rootwad Composites For Streambank Stabilization And Habitat Enhancement," *EMRRP Technical Notes Collection* (EDRC TN-EMRRP-SR-21), U.S. Army Engineer Research and Development Center, Vicksburg, MS., http://www.wes.army.mil/el/emrrp

US Army Corps of Engineers. 2007. "Blue River Channel Modifications; Brush Creek to 53rd Street, Jackson Country, Missouri, Construction Specifications".

US Army Corps of Engineers. 1991. "Blue River Channel Modification Design Memorandum No. 4 Stage III Features, Volume 1".

US Army Corps of Engineers. 2003. "Blue River Site Investigation Report for Potential Excavation of Solid Waste Brush Creek to 59th St. For Brush Creek to 63rd St. Reach".

US Army Corps of Engineers. 1987. "Hydraulic Design Criteria (700) Special Problems" (Revised 1970), http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=Publications;9

US Army Corps of Engineers. 2004. "Interim Operations & Maintenance Manual for the Blue River".

US Army Corps of Engineers. 2008. “Part III Characteristics and Indicators of Hydrophytic Vegetation, Hydric Soils, and Wetland Hydrology”, http//www.wetlands.com

# 5.0 ENGINEERING STUDIES, INVESTIGATIONS AND DESIGN

## 5.1 Channel Design

### 5.1.1 Determination of Final Location and Resulting Site Plan for Specific Features

The proposed channel baseline alignment reflects the baseline alignment used in the Revised General Design Memorandum – Phase II, dated May 1979. The proposed alignment of the modified channel contains two zones, a transition zone between approximate channel stations 86+00 and 90+00 and a modified channel from channel station 90+00 to channel station 122+89.16.

### 5.1.2 Refinements to Project Hydrology

An existing conditions HEC-RAS hydraulic model for Blue River was provided by USACE, Kansas City District. The existing conditions peak discharges were unaltered during the proposed conditions hydraulic analysis.

### 5.1.3 Hydraulic Design Features

The proposed design slope of the channel is 0.00055 ft/ft. Two unnamed tributaries discharge in to the Blue River within the project limits at approximate channel stations 90+65 (right bank) and 101+70 (right bank).

Six gutters are designed to carry storm water runoff into the proposed channel. Approximate discharge locations of the gutters are at station 88+04 (left bank), 90+65 (right bank), 93+00 (left bank), 104+60 (left bank), 107+00 (left bank) and 107+72 (right bank).

The typical cross-section of the modified channel is a benched trapezoid with a 24-foot wide bottom; a lower 3-to-1 side-slope for a horizontal distance of 12 feet; a 70-to-1 side-slope for a horizontal distance of 23 feet (referred to as the “lower bench”); a middle level 3-to-1 side-slope for a horizontal distance of 29 feet; a 10-to-1 side-slope for a horizontal distance of 30 feet (referred to as the “upper bench”); and an upper 3-to-1 side-slope for a horizontal distance of 45-feet. Fill in adjacent overbank areas creates additional banking in some locations.

A temporary grade control structure is proposed at the modified channel station of 86+00 at the upstream end of the transition from the modified channel to the existing natural channel. The function of this structure will be to arrest the potential scour from propagating upstream of the modified channel. The proposed grade control structure is design as a sheet pile wall and with riprap placed on the upstream and downstream faces of the wall.

#### 5.1.3.1 *Flow Characteristics*

During normal flow conditions, water depth within the modified channel is approximately 4 feet and is contained between the lower benches. During a 2-year event, the water depth is approximately 20-feet. Analysis indicates that the design discharge of 38,000 cfs through the modified channel reach is contained within the modified channel. Flows greater than the design charge overtop channel banks.

#### 5.1.3.2 *Discharge Capabilities*

The proposed modified channel is designed to carry a 30-Year discharge of approximately 38,000 cfs at the project location with some freeboard.

### 5.1.4 Design Water Surfaces, Profiles, Data and Plots Hydraulic Model Results

The existing conditions HEC-RAS hydraulic model for Blue River provided by USACE, Kansas City District has the following plans:

Plan: Scenario 2 Existing Channel Work Nov2006:

This plan reflects the channel hydraulic conditions existing as of 2006 with constructed modified channel alignment and cross-sections from the confluence of Blue River with Missouri River to the confluence of Brush Creek with Blue River. Upstream of Brush Creek the channel cross-sections reflect the existing channel. The model analyzes the effect of Blue Parkway Bridge on channel hydraulics. The future Colorado Avenue Bridge is not included in the model.

Plan: Scenario 7 Add BCto53rd Channel:

This plan reflects the hydraulic conditions with a constructed (modified) channel alignment and cross-sections from the confluence of Blue River with Missouri River to the upstream end (53$^{rd}$ Street) of the current construction project location. Upstream of 53$^{rd}$ Street the channel cross-sections reflect the existing channel. Blue Parkway Bridge is included in the model. The future Colorado Avenue Bridge is not included in the model.

In the HEC-RAS model provided by USACE for proposed conditions, the overbank and channel reach lengths in the current project area did not match with that of proposed modified channel alignment design. The reach lengths, cross-sections and roughness coefficients were modified in coordination with environmental enhancement concepts to reflect the modified channel characteristics at the enhancement locations. The discharges analyzed include 2-, 5-, 10-, 20-, 50-, 100-, 200- and 500-year flood events. In addition to these discharges the design discharge of 38,000 cfs through the current project location was also analyzed.

The water surface elevations under the proposed conditions are lower than the existing conditions water surface elevations for all analyzed flood events. Detailed output of the HEC RAS models is listed in Appendix B.

### 5.1.5 Dredged Materials

Excess excavated materials from project site will be spoiled to the designated fill areas as shown in the plan sheets and may include additional sites provided by the Corps of Engineers or Kansas City, Missouri. Some excess fill will be disposed of at a location provided by the Contractor and reviewed by the Corps of Engineers. Solid waste is removed from the site and disposed of at a sanitary landfill in accordance with state law. Kansas City, Missouri will provide for disposal of part of the waste tires found within the project limits.

#### 5.1.5.1 *Locations of the Disposal Areas*

Three disposal sites were initially identified for excess material taken from the project site. During project development, one of these sites was identified as needing select fill for the future Colorado Avenue Bridge project and therefore the site would not receive excess material from this project. An additional site has been identified as having potential capacity used during an earlier channel modification project on Blue River. Additional excavated material is available to another project (Dodson Levees) and the remainder will be taken to a disposal site provided by the Contractor. Details of specific disposal areas are listed below.

Fill Area B is located on the right (generally east) bank of the transition channel between approximate stations 88+30 and 90+20. The east end of this fill area will have an elevation of 764-foot and sloping towards the channel with the west end elevation of 762-foot.

Fill Area C is located on the left (generally west) bank of the existing channel between future modified channel stations of 59+00 and 73+20. The proposed elevations of the fill area range from 765-foot to 750-foot, sloping towards the left bank of the channel. Part of this site was used as a disposal area for a previously constructed reach of the Blue River channel modifications project.

Fill Area D is located on the right (generally south) bank of the modified channel between approximate stations 119+00 and 121+60. The south end of this fill area will have an elevation of 761-foot and sloping towards the channel. This fill area will serve as the southern bridge abutment for the future construction of the Colorado Avenue Bridge. After project initiation, it was determined that the fill at this site would need to be controlled as part of the bridge construction. Use of this fill site area was removed from the scope-of-work for this project.

Fill Area E-2 is located downstream of the project limits along the Blue River. This site was used as a disposal site for a previously constructed channel modification reach of the Blue River. The site has additional capacity and has been proposed as a location to receive some of the material previously planned to go to Fill Area C.

## 5.2 In-Stream Structure Design

A variety of in-stream structures is included in the environmental enhancements portion of the design. Although some of these types of structures are commonly used for channel stabilization, the structures' function in this project is to provide terrestrial- and aquatic-habitat diversification. These structures are discussed in greater detail in the Environmental Enhancement paragraphs of this report.

## 5.3 Temporary Grade Control Structure Design

### 5.3.1 Determination of Final Location and Resulting Site Plan for Specific Features

A temporary grade control structure is proposed at an approximate modified channel station of 86+00 at the upstream end of the transition from the modified channel to the existing natural channel to arrest the potential upstream progression of channel incision that may result from high velocities due to the transition. Both the approach channel upstream and the modified channel downstream of the structure are straight sections resulting in relatively uniform hydraulic conditions through the structure at all times. The grade control structure will consist of sheet piles and rock. The channel bottom and a portion of the banks will be armored using rock riprap both upstream and downstream of the grade control structure.

### 5.3.2 Hydraulic Design Features

The intent of grade control measures is to hold the bed in place and to reduce velocities and erosive energy. In-stream grade control structures establish fixed elevations in the streambed which assists in long term stability and development of the anticipated stream equilibrium slope and limit the maximum potential degradation. The design concept is to install structures that will produce cumulative rises in the streambed greater than the documented degradation. 50-year peak flow for the channel along with other channel characteristics including channel slope, sediment characteristics, and roughness coefficients is used in determining the design features of the proposed grade control structure.

#### 5.3.2.1 *Channel Characteristics*

Stage data from USGS stream gage (No. 06893500) located on Blue River at E. 95th Street, Kansas City, Missouri was analyzed to determine whether the Blue River is exhibiting degradational or aggradational bed tendencies. The stage and discharge data plotted (See Appendices) between 1990 and 2007 indicate an increasing linear trend for the stream bed elevation. Hence it can be concluded that Blue River exhibited an aggradational condition from 1990 to 2007, the limit of available data at this gage.

High overbank ground elevations in the left bank of the existing topography in the vicinity of the grade control structure produce a natural constriction of the flow under existing conditions. In order to improve hydraulic conditions and minimize turbulence in the area, high overbank elevations will be reduced by excavating the natural constriction to result in more uniform floodplain geometrics.

Given the improved hydraulic conditions and the aggradational history of the channel, a single grade control structure (steel sheet pile) with rock armoring is proposed at the upstream end of the project (station 86+00) to minimize potential scour from propagating upstream of the modified channel.

#### 5.3.2.2 *Vertical Embedment*

It is critical to ensure that the embedment of the steel sheet pile extends below the maximum potential scour depth and provides adequate depth for structural stability. One of the important parameters in determining the embedment depth of the grade control structure is the determination of the anticipated drop (Net Drop) at the structure. “Net drop” is defined as the difference in elevation between the natural streambed slope and the predicted long term stable channel slope (final equilibrium slope). “Net drop” was calculated at the proposed location of the grade control structure using different methodologies with the worst case scenario used to design the vertical embedment depth. The primary factors affecting the final equilibrium slope upstream of a structure include the sediment inflow, channel characteristics (slope, width, depth, roughness, etc), and hydraulic effects of the structure.

Net drop at the proposed grade control structure was calculated using different equilibrium slopes including the proposed downstream channel slope (design slope), existing upstream channel bed slope, and the potential channel equilibrium slopes derived using various empirical equations presented in Hydrologic Engineering Circular No. 20. Net drop was also computed using the existing steel sheet piling cutoff wall located in the vicinity of Stanley Palmer Engineering Center on Coal Mine Road as the fixed point. Detailed bed scour calculations are presented in the Appendices.

Based on bed scour calculations, potential scour depth is estimated to be approximately 4 feet at station 86+00, using the existing grade control structure in the vicinity of Stanley Palmer Engineering Center on Coal Mine Road as the fixed point.

Using the scour depth calculation results and based on field experience on previous projects on Blue River in the vicinity, it is recommended to drive sheet pile to depth of 12 feet measured from the stream bed.

##### 5.3.2.3 *Lateral Embedment*

Using USACE guidelines (EM 1110-2-1601) a lateral embedment of 25 feet on either side of the stream banks is proposed at station 86+00.

##### 5.3.2.4 *Armoring*

The primary method of armoring used for this channel reach is riprap. To provide greater efficiency in placing operations, a single riprap size is used where ever possible. In addition to riprap armoring, erosion control blankets will be used on upper slopes in select locations. The locations will be determined as construction progresses. Armoring using rock riprap will be used at the following locations.

- Approximately 8 feet upstream of the temporary grade control structure
- Approximately 70 feet downstream of the temporary grade control structure.
- Approximately 60 feet into both left and right over banks (on either side of the channel bottom).
- Approximately 6 feet below the channel invert at the temporary grade control structure.

Sizes of the riprap were calculated using the riprap computer program “Channel Pro”, used for open channel flow as per the guidance from USACE – Kansas City District. Detailed riprap sizing calculations and results are presented in the Appendices.

#### 5.3.3 Structural and Geotechnical Design Features

##### 5.3.3.1 *Vertical Embedment*

Proposed sheet pile extends 2 feet above the channel invert to provide protection for the top 2 feet of rock fill in the vicinity of the sheet pile. The proposed vertical embedment of 12 feet below the channel invert is determined to be more than adequate to develop the proper embedment length of the sheet piling to resist the applied loading cases. Detailed structural calculations are presented in the Appendices.

##### 5.3.3.2 *Lateral Embedment*

Structural analysis results presented in the Appendices show that the proposed lateral embedment of 25 feet on either side of the stream banks is adequate.

#### 5.3.4 Stability Analysis

##### 5.3.4.1 *Structural Stability*

Structural stability calculations presented in the Appendices show that the proposed steel sheet piling (PZC 13) is determined to be sufficiently stable for the applied loading cases. Best engineering judgment is used in applying loading cases as there are no available USACE criteria.

###### *5.3.4.1.1 Applied Loads and Load Factors*

The following test cases are used in determining the structural strength of the proposed sheet pile.

Case 1: Low Flow: A differential pressure equivalent to 2 feet of water head is used as the first test case.

Case 2: Intermediate Flow/Partial Pool: A differential pressure derived from scour of 2 feet of rock is applied on the downstream side of sheet pile and hydro-dynamic/water flow pressures are applied on upstream side of the sheetpile.

Case 3: Maximum Flood Condition: Similar to Case 2, but with reduced magnitude of pressures due to water flow applied on the sheet pile.

Case 4: Post Flood and Post Scour: Similar to Case 1, but differential pressure equivalent to 2 feet of water head and 2 feet of rock is applied on the sheet pile.

The following load factors are used in the analysis:

Active/passive earth pressure coefficients based on a minimum angle of internal friction of 35 degrees and 20 degrees for rock and soil, respectively.

Hydro-dynamic water flow velocities of 11 feet per second and 7 feet per second are assumed for Cases 2 and 3 respectively.

*5.3.4.1.2 Material Strengths*

The proposed sheet pile (PZC 13 -50 KSI steel sheet pile) has a section modulus of 24.2 cubic inches per foot and a maximum bending stress of 629 pounds per square inch (PSI). In lieu of a Z section, a flat sheet piling section could have been used (like a PS 27.5) with a section modulus of 1.9 inches cubed per foot but it is more economical to use a PZC at 21.7 pounds per square foot in lieu of a PS 27.5 at 27.5 pounds per square foot.

5.3.5 Geotechnical Evaluation and Calculations

Boring D-390, located at Station 86+03.88 (60' L), was reviewed as a part of the geotechnical assessment for the temporary grade control structure. The ground conditions identified by this boring indicate that it is possible to drive the sheet pile to the proposed embedment depth of 12 feet (Elevation 716+/-). Boring D-290 indicated the presence of shale bedrock at an approximate elevation of 710.0+/. To that end, the minimum vertical embedment depth of steel sheet piles is 12 feet unless shale bedrock is encountered at the time of installation.

5.3.6 Operation, Maintenance, Replacement and Rehabilitation Requirements

The study area will be operated and maintained in accordance with the previously developed plan titled "Interim Operation and Maintenance Manual, Blue River Channel Modification Flood Control Project, 9th Street to Brush Creek", May 2004 by USACE – Kansas City District.

5.3.7 Value Engineering

Periodic communication between the design-build contractor and the design engineering team will be established to refine the proposed design as per the field observations. Constant communication between the contractor and the design team not only ensures the proposed design meets the necessary requirements but also minimizes the construction cost.

## 5.4 Riprap Gutter Design

### 5.4.1 Final Location and Resulting Site Plan for Specific Features

Six riprap gutters are proposed for the conveyance of flow from pipes, stormwater BMP (best management practices) areas, swales and tributaries into the proposed channel at River Stations 88+04 (channel transition station), 90+65, 93+00, 104+60, 107+00, and 107+72. The riprap gutters were analyzed using HEC-RAS software, version 3.1.3, as developed by the United States Army Corps of Engineers. The design of rock riprap was conducted using USACE approved "Channel Pro" software program with pertinent data from HEC RAS 3.1.3 hydraulic models for individual gutters. Results from the "Channel Pro" are presented in the Appendices.

### 5.4.2 Refinements to Project Hydrology

All gutters, with an exception of the gutter at Sta. 90+65, will convey flows from storm sewer outlets into the modified Blue River channel. The contributing pipe size for each gutter is listed in Table 5-1 below. Manning's equation was used to calculate flow from the pipes and full pipe flow capacity was assumed. As invert elevations were not readily available for a majority of the pipes, a general slope of 0.01 and 0.02 feet/feet was assumed.

Riprap gutters at Stations 93+00 and 107+00 will also collect overland flow from adjacent drainage areas as well as discharge from BMP areas. To allow for a more accurate flow estimate, it was assumed that storm water BMP areas do not provide detention benefits. This assumption was made to adequately size the rock riprap gutters to reflect the variable nature of stormwater BMP areas based on growing conditions. The rational method was used to determine 10-year inflow rates for drainage areas (see environmental enhancements). The total flow used for these two gutters was the summation of pipe flow and flow from adjacent drainage areas.

A small tributary contributes flow for the gutter at Station 90+65. Ten-year flow values for future developed conditions were retrieved from a SWMM model provided by HNTB used for the development of a Watershed Master Plan.

**Table 5-1**

| RipRap Gutter Station | Pipe Size (in) | Roughness coefficient | $R_h$ (assuming full flow) (ft) | Pipe Slope (ft/ft) | Pipe Velocity (fps) | Pipe Flow (cfs) | Additional Drainage | Flow (10-year) (cfs) | Total Flow (cfs) |
|---|---|---|---|---|---|---|---|---|---|
| 88+04 | 36 | 0.022 | 0.75 | 0.02 | 7.91 | 55.89 | N/A | N/A | 55.9 |
| 90+65 | -- | -- | -- | -- | -- | -- | Tributary | 185 | 185.0 |
| 93+00 | 10 | 0.022 | 0.21 | 0.02 | 3.37 | 1.84 | BMP | 42.2 | 44.0 |
| 104+60 | 18 | 0.022 | 0.38 | 0.02 | 4.98 | 8.80 | N/A | N/A | 8.8 |
| 107+00 | 18 | 0.022 | 0.31 | 0.02 | 4.41 | 5.41 | BMP | 29.3 | 34.7 |
| 107+72 | 15 | 0.022 | 0.31 | 0.02 | 4.41 | 5.41 | N/A | N/A | 5.4 |

### 5.4.3 Hydraulic Design Features

Sta. 88+04 A grassed swale conveys water approximately 140 feet from a 36-inch pipe. Beyond the inlet the gutter extends approximately 67 feet along the channel bank and outlets where the invert of the gutter matches the channel. The riprap gutter is lined with 3-foot thick 36-inch rock riprap with 6-inch (min.) crushed rock bedding. The gutter has a bottom width of 5 feet and depth of 2 feet with 2-to-1 side-slopes.

Sta. 90+65 A grassed swale conveys flow from a tributary to the entrance of the riprap gutter. The gutter extends approximately 59 feet along the channel bank and outlets onto the 1-to-70 side slope of the main channel. The riprap gutter is lined with 3-foot thick 36-inch rock riprap with 6-inch crushed rock bedding and has a bottom width of 10 feet and depth of 2 feet with 2-to-1 side-slopes. Rock riprap protection is provided on the channel bank between the riprap gutter outlet and the 15-foot wide rock riprap on the 1-to-70 side-slope.

Sta. 93+00 A grassed swale conveys flow from surface runoff to the inlet of the riprap gutter. Beyond the 15-foot inlet the gutter extends approximately 29 feet to the top of bank of Blue River Channel, then approximately 98 feet along the channel bank and on the 1-to-70 side slope. A 2-foot deep and 15-foot wide bottom width native-vegetation swale with 2-to-1 side slopes drains into the gutter between the inlet and the top of bank of Blue River Channel. The riprap gutter is lined with 3-foot thick 36-inch rock riprap with 6-inch crushed rock bedding and has a bottom width of 5 feet and depth of 2 feet with 2-to-1 side slopes. Rock riprap protection is provided on the channel bank between the riprap gutter outlet and the 15-foot wide rock riprap on the 1-to-70 side slope.

Sta. 104+60 A grassed swale conveys flow from an 18-inch RCP to the entrance of the riprap gutter. Beyond the 15-foot inlet the gutter extends approximately 98 feet along the channel bank and on the 1-to-70 side slope. The riprap gutter is lined with 3-foot thick 36-inch rock riprap with 6-inch crushed rock bedding and has a bottom width of 5 feet and depth of 2 feet with 2-to-1 side slopes.

Sta. 107+00 The riprap gutter at this location extends about 50-foot from the top of bank of the Blue River Channel, with the 15-foot long entrance located under the outlet of an 18-inch RCP pipe outlet. The entrance of the gutter is approximately 3-foot below the storm sewer pipe outlet. The gutter extends approximately 98-foot along the channel bank and outlets on the 1-to-70 side slope. A 2-foot deep and 15-foot wide bottom width swale with 2-to-1 side slopes drains into the gutter from "Area 1" between the inlet and the top of bank of Blue River Channel. The riprap gutter is lined with 3-foot thick 36-inch rock riprap with 6-inch crushed rock bedding and has a bottom width of 5 feet and depth of 2 feet with 2-to-1 side slopes.

Sta. 107+72 The riprap gutter at this location conveys flow from a 15-inch flared concrete end section. The inlet of the rock riprap gutter is located at the outlet of the flared concrete end section and the gutter extends approximately 75 feet along the channel bank and outlets on the 1-to-70 side slope. The riprap gutter is lined with 3-foot thick 36-inch rock riprap with 6-inch crushed rock bedding and has a bottom width of 5-foot and depth of 2-foot with 2-to-1 side slopes.

#### 5.4.3.1 *Flow Characteristics*

The rock riprap gutters were individually hydraulically modeled using HEC RAS 3.1.3. As the rock riprap gutters will not have a smooth plain surface due to the presence of large riprap. The estimated flow depth is less than 1-foot, with a roughness coefficient of 0.06 used for both the bottom width and the banks of the riprap gutters. Multiple interpolated cross-sections were used between breaks-in-grade to more accurately model and analyze the flow regime change on different riprap gutter invert slopes.

#### 5.4.3.2 *Discharge Capabilities*

All rock riprap gutters are designed to contain total flows listed the Appendices.

### 5.4.4 Design Water Surfaces, Profiles, Data and Plots of Hydraulic Model Results

Refer to the Appendices for water surface profiles and other hydraulic model results.

## 5.5 Environmental Enhancement Plan

### 5.5.1 Determination of Final Locations and Resulting Site Plans for Specific Features

As part of the Blue River Channel Modifications (BRCM) project, Brush Creek to 53rd Street Project, various environmental mitigation and enhancement design and construction are proposed as “green solutions”. Green solutions, as provided in the final design of this project, fall within three categories, which include in-stream aquatic habitat, more native vegetation (less rock armoring), and sustainable water quality benefits. Mitigation and enhancement features are proposed throughout the 3,700 feet of channel widening and realignment.

After project award, HDR submitted the “Refined Conceptual Mitigation and Enhancement Plan” in April 2008 that described key elements to help create and restore lost functions and diverse habitats that are compatible with the flood protection project's purpose. The goals presented in this report were; to use green solutions; accomplishes sustainable long term water quality benefits; consider future plans for trail development; and help meet minimum mitigation commitments made by the USACE. Further concept design was conducted to produce a 35% plan set. A 95% “Environmental Enhancement Plan” set submittal was subsequently prepared and described below.

The 95% plans described below and shown on attached design sheets, were designed using a natural systems approach containing both physical and biological design features for in-channel and adjacent areas and habitats. The features are described starting with in-channel work, then transition upwards and outwards away from the river channel into water quality best management practice (BMP) features and terrestrial habitat creation and preservation areas. The in-channel structures and live pole staking locations listed below are approximate, and subject to change or require substitutions, if construction conditions become unfavorable.

Mitigation and enhancement features for this project are defined and understood as follows:

Mitigation is defined as USACE required native grassland planting commitments made to the United States Fish and Wildlife Service (USFWS) for the approved Environmental Impact Statement (EIS).

Environmental Enhancement Areas 1 and 2, called out in the USACE-provided design bid plans as mitigation areas, are contract-required enhancements.

In addition to USACE-provided areas, multiple other locations throughout the project include various in-channel structures and native plantings enhancements, which provide habitat and diversity. The location and details of the structures and plantings discussed below can be found in the plans for Environmental Enhancements that accompany this report.

The selection and placement of the in-channel structures discussed below (see Prefinal Environmental Enhancement Plans) are based on such factors as stability during high flows; constructability; creating habitat diversity in terms of cover, flow, depth variation, and adaptive "green" material reuse. The structures discussed in this section are meant to enhance the environmental aspects of the Blue River Channel Project and are not included for the purpose of providing additional channel stability.

*Rootwads* - Rootwads will be placed along the sides of the channel to provide habitat diversity and cover in the near bank areas of the channel. Rootwads consist of tree trunks with the roots still attached (Sylte & Fischenich, 2000, and Derrick, 2008). The tree trunks will be anchored into the bank by rock riprap and backfill, then placed at approximately 45 degree angles pointing into the flow. The vertical placement of the structure submerges at least 1/3 the depth of the rootball into normal base flow conditions is a key criteria. Rootwads will provide a variable flow habitat, which may be used for the hatching and rearing of young fish populations, organic debris accumulation, and for resting and feeding areas for other aquatic life. The partially submerged rootwads will also provide a surface break in the stream which in-turn provides a more oxygenated environment, as well as shade for the surrounding environment.

*Lunker Logs* - Lunker logs will be placed parallel to flow along the channel edges near the interface of the lower 1:3 side slope and the channel bottom. Lunker logs consist of 6 to 18 inch diameter logs with the tree crown or roots still intact that are inserted into a reinforced concrete pipe (RCP). The crown or root is intended to have about 1.5 times the diameter of the RCP diameter. The purpose of the lunker log is to provide fish cover, while the RCP anchors the lunker log in the channel and provides cover.

*Locked Logs* - Locked log structures will be placed on the outsides of bends on the low 1:3 channel slope. The structure will consist of logs anchored into the bank by rock riprap and backfill. The logs will be placed together in a side by side manner, inserted at an approximate 45 degree angle in the direction of flow approximately 1-2 feet above the channel bottom (Derrick, 2008).

*Newbury Structures* - Newbury structures or riffles (aka Engineered Rock Riffles), are cross-stream rock structures that create upstream and downstream pooling of water in the channel (Derrick, 2008). The function of the structure is to direct water toward the center of the channel, aerate water, and serve as grade-control. Newbury riffles were chosen for this project based on their environmental benefits, ease of construction, and their use of rock which can be obtained locally. Newbury riffles enhance habitat variability through four basic mechanisms; aeration of the normal flow as it passes over the sloping rock surface; variations in normal flow velocities; creation of variable interstitial spaces within the riprap structure; variation in slower-water pool depth created upstream of the structure.

*Boulder Clusters* - Boulder clusters consist of three large rocks placed together in the channel bottom. (Fischenich & Seal, 2000) and (Doll, B.A., et al. 2003). The boulder clusters will be placed within the middle two quarters of the channel, and spacing between rocks will be a minimum of two feet. The rocks will be placed in a triangular cluster with one lead rock upstream and two downstream rocks. These structures will restrict and divide flow forming scour pools and eddies around the edges of the boulders promoting aquatic habitat diversity and shelter within the center of the channel.

Native vegetation will be used throughout the project area for the creation of terrestrial habitats and water quality BMPs to meet both mitigation requirements and provide additional enhancements. This will be accomplished through several planting types within the site boundaries; hydrophytic vegetation, trees, shrubs, plugs, grasses, and forbs (wildflowers). Species adapted to regional conditions were selected. Along with re-vegetation of the project area, a preservation area has been identified at a location where impacts to existing riparian forest habitat can be avoided. The use of riprap was minimized to the extent practical in vegetated areas. A species list and details for each planting area can be found in the prefinal plans and specifications that accompany this report.

Native herbaceous hydrophytic and upland grasslands/forbs are the primary vegetation community proposed on the slopes and benches of the channel and over bank areas. Herbaceous vegetation does not restrict the flow conveyance of the design. These areas will be created by seeding. The lower 1:70 bench of the flood protection channel will be excluded from seeding (or planting) based on past siltation accumulation problems on this bench in previously constructed segments of the BRCM project. Past seeding this area was smothered by silt deposition, thus not allowing germination (Refined Conceptual Mitigation and Enhancement Plan, 2008).

*1:70 Bench plantings and opportunistic growth* - Live staked willows (Doll, B.A., et al. 2003) will be planted in select locations on the lower 1:70 bench adjacent to the channel 1:3 slope. These trees are staked at a 30-45 degree angle. They will shade water after leaf out and as they grow out and over the baseflow channel, plus serve as seed source for revegetating the lower 1:70 bench with tree cover. Leaf litter generated by the willows will also provide organic substrate accumulations within the channel that would provide food and shelter to various macro invertebrate populations. The design approach for most of this bench is to allow sediments to accumulate within the voids of proposed rock riprap bank stabilization from high flow events over the course of years and allow more seeding and natural revegetation to occur, including tree growth. Observations from previously constructed segments of the BRCM project (as early back as 2002) have shown remarkable vegetation growth occurring within rock and non-rock protected areas. Willow and cottonwood tree growth has been observed on this bench that is estimated to be between 4 – 6 years old. Project hydraulic modeling indicates design flow conveyance capacity can still be maintained, while allowing this bench to grow into trees and not be cut or maintained; therefore, providing much needed shading and wooded riparian habitat along the river margin critical to riverine ecosystem function.

*Hydrophytic plantings* - Hydrophytic plants are grasses, rushes, sedges, and forbs adapted to periodic wet and dry conditions (USACE Wetlands, 2008). Hydrophytic plantings will be installed on the middle 1:3 slopes and the 1:10 lower slopes, which are more susceptible to frequent high flow event inundation. These slopes will be seeded to hydrophytic adapted native grasses and forbs. The wetland swale in Area 1 will also be planted with native hydrophytic grasses, sedges and forbs.

*Upland plantings* - These are dryer upper slope areas planted to native upland adapted grasses and forbs. Native grasses and forbs will be planted on the 1:3 upper slopes and the 1:10 top of bank.

*Native vegetation swale and wetland plantings* – The native vegetation swale BMP areas will be planted with a selection of both hydrophytic and upland grass and forb species to allow for varied hydrologic conditions. Area 1 wetland swale will be planted with deep cell wetland plant plugs to establish hydrophytic vegetation.

*Tree and shrub plantings* – Both Area 1 and Area 2, called out in USACE-provided design bid plans, will be planted with various native tree and shrub species along with upland plantings. Tree and shrub plantings for Area 2 were specifically selected for their importance to birds and aesthetic presence.

Stormwater BMPs are proposed as enhancement features in three portions of the project to provide water quality benefits, aesthetic values, and habitat and species diversity. The proposed BMPs are consistent with Kansas City's Wet Weather Solutions Program goals and comments received from the Blue River Stakeholders Meeting held February 7, 2008 (Refined Conceptual Mitigation and Enhancement Plan, 2008). The stormwater BMP selection process was based on the Manual of Best Management Practices for Stormwater Quality (2007) developed by Mid-America Regional Council (MARC) and the American Public Works Association (APWA) and is dependent on such factors as drainage area, slope, space constraints, and location relative to the right of way boundary and channel. Use of the MARC/APWA BMP Manual for this project is not a contract or regulatory requirement, but rather, a useful tool for BMP planning, selection, and design.

Each BMP is assigned a value rating (VR) based on four criteria: water quality value, reduction of runoff volume, reduction of temperature, and oils and floatables. BMPs are evaluated on these criteria to provide a measure of overall water quality protection. A higher VR indicates an increased water quality treatment efficiency and overall water quality improvement. BMPs were selected to provide the highest level of water quality treatment where feasible.

Two types of BMPs were ultimately selected for use in this project. These include a wetland swale and three native vegetation swales. Wetland swales are defined as "broad, shallow, natural, or constructed channels with a dense stand of native vegetation covering the side slopes and emergent vegetation covering the channel bottom". Wetland swales improve water quality, reduce runoff volume and the potential for erosion, and increase habitat diversity, while providing an aesthetically pleasing BMP feature along the river bank. These swales are highly effective at removing sediment, oil and grease, and organics, and have an overall VR of 6.5. Native vegetation swales are defined as "broad, shallow, natural, or constructed channels with a dense native grass stand covering the side slopes and channel bottom". Native vegetation swales also improve water quality and reduce runoff volume and potential for erosion. These swales are most effective at removing sediment and have a VR of 4.0.

Per the MARC/APWA BMP Manual, wetland swales should collect runoff from a drainage area no larger than five acres. Outlet structures should be designed to release the WQv in 40 hours and water depths should not exceed 18 inches for the water quality storm. Longitudinal slopes should be no greater than two percent with side slopes at a 3:1 (H:V) ratio or flatter.

Native vegetation swales can treat runoff from drainage areas up to five acres. The design for native vegetation swales is based on flow rates for the water quality storm, 1% and 10% frequency storms. The velocity for the 50% event should not exceed four feet per second and the depth of water should not surpass four inches for the water quality event. Side slopes should not exceed a 3:1 horizontal to vertical (H:V) ratio and longitudinal slopes should range between 1.0-2.5% without the use of check dams.

The Small Storm Hydrology Method (MARC/APWA BMP Manual) was used to estimate the volume required to contain the water quality event, referred to as the water quality volume. This calculation is required for BMPs designed to contain the water quality event, such as wetland swales. The variables in this calculation include precipitation, volumetric runoff coefficient, and drainage area. Precipitation is provided in the MARC/APWA BMP Manual as 1.37 inches for the Kansas City Metropolitan area. NRCS rainfall data for Johnson County was used for larger storm events. The volumetric runoff coefficients were provided in the MARC/APWA BMP Manual for various cover types, including roofs, parking lots, streets, and soils. Drainage areas for each BMP were drawn from existing and proposed 1-foot contours. All drainage areas contributing flows to BMPs fall below the five acre threshold. All calculations and supporting data are provided in the Appendices.

Peak flow was estimated using the Rational Method for the Water Quality, 2-year, 10-year, and 100-year storm events. Variables involved in this calculation include a dimensionless coefficient, runoff coefficient, and rainfall intensity. Per APWA 5600, the dimensionless coefficient (K), which accounts for antecedent precipitation, is 1.0 for the 10-year and more frequent design storms and 1.25 for the 100-year storm event. The runoff coefficient accounts for percent impervious of the drainage area. Intensity calculations were based on a time of concentration of 5 minutes. The intensity was given as 1.9 inches per hour per the MARC/APWA BMP Manual. Intensity calculations for larger storm events were based on equations in Table 5602-2 in APWA 5600 and are provided in the Appendices.

Manning's equation was used to determine approximate velocities in each BMP area. Variables required for Manning's equation include Manning's n coefficient, hydraulic radius, and slope. A Manning's coefficient of 0.03 was used for a clean, straight channel. The hydraulic radius is the ratio of total cross-sectional area to wetted perimeter. The hydraulic radius was calculated assuming that the BMPs were flowing at full capacity. The longitudinal slope was determined by dividing the change in elevation by the length of the flow path. The velocity calculations are shown in the Appendices. All BMPs have velocities less than four feet per second when flowing at full capacity.

*Area 1* - Area 1 is required by the USACE's Request for Proposal (RFP) and is located on the west bank of Blue River, between Blue Parkway Bridge and the proposed Colorado Avenue Bridge. This area is located entirely within Kansas City property between Sta. 107+00 and Sta. 114+80 and consists of a combination of BMP features, including a wetland swale and native vegetation swale. Runoff will be collected and contained in the wetland swale during the water quality event for optimum water treatment and sedimentation. The water quality volume will be depleted through processes including infiltration, plant uptake, transpiration, and evaporation. During less frequent storm events, runoff will fill the wetland swale and flow through a rock weir into the native vegetation swale. Outflow from the system will be conveyed into Blue River via the riprap gutter at Sta. 107+00.

The contributing drainage area for the wetland swale is 3.9 acres, resulting in a water quality volume of 0.36 acre-feet. The wetland swale will reach a depth of approximately four feet during the water quality storm, fully containing the entire event. Side slopes of the wetland swale are 4:1 (H:V). Velocities can reach an estimated 2.5 fps when flowing at full capacity. During events greater than the water quality storm, runoff will flow through a trapezoidal weir, capable of handlings flows up to 50 cubic feet per second. Runoff will then be conveyed though the native vegetation swale, which can reach velocities of 3.6 feet per second when flowing full. An additional 2.2 acres of drainage will flow into the native vegetation swale. Side slopes of the swale range from 4:1 to 10:1 (H:V), with a longitudinal slope of 0.75%.

*Native Vegetation Swale – Left Bank* - A native vegetation swale is proposed on the west bank of Blue River between Sta. 93+00 and Sta. 98+40. Usable land in this area for enhancements is restricted due to location of the permanent right of way and top of bank. Runoff from surrounding areas will be conveyed through the swale into the riprap gutter at Sta. 93+00 and into the Blue River.

The drainage area for the swale is approximately 2.4 acres. Side slopes of the native vegetation swale are 2:1 and 3:1 (H:V) due to elevation and space constraints. The longitudinal slope is approximately 1.0%. Velocities can reach 3.4 feet per second at full capacity.

*Native Vegetation Swale – Right Bank* - A third native vegetation swale is proposed on the east bank of Blue River between Sta. 95+20 and Sta. 99+00. The swale will be constructed for gradual conveyance of runoff into a side tributary, located approximately at Sta.101+70.

This native vegetation swale collects runoff from a small drainage area of approximately 0.7 acres. Side slopes are 4:1 (H:V), with an average longitudinal slope of 1.0%. Velocities reach 3.1 feet per second at full capacity and outlet into the side tributary, with riprap protection against erosion.

### 5.5.2 Refinements to Project Hydrology

The in-channel structures designed neither enhances nor detracts from project hydrology. The native various planting areas will anchor the soil, increase infiltration, and reduce erosion and stream siltation. Considering past land use practices in the project area, such as unregulated fill and solid waste disposal, and high concentration of impervious surface development, this project provides a great opportunity to enhance hydrology. It capitalizes on better use of available land and water resources, in a more eco-friendly way, within the design constraints of a flood control channel. The project maximizes the amount of green space available, while limiting gray infrastructure (i.e. concrete and riprap) to the minimum necessary to provide for designed flood control purposes.

### 5.5.3 Hydraulic Design Features

The in-channel structures are designed to create variability in water depth, velocity, and channel bed features, all to enhance aquatic habitat features. The Newbury riffles will provide variations in water velocity, depth, and current, and will redirect stream flow towards the center of the channel. The boulder clusters will cause variations in the stream flow, and promote localized scour and deposition. Hydrophytic and upland vegetation will cause minimal resistance to water flow and encourage water filtration and sediment deposition. The wetland and native vegetation swales will slow overland flow from storm events, improve water quality, and reduce stream siltation. HEC RAS hydraulic modeling indicates that the Newbury riffle structures, live pole stakes, and as shown in the environmental enhancement plan set sheets, will not result in any significant rise in water surface elevation in the foreseeable future, nor will allowing the 1:70 bench slope adjacent to the channel to naturally re-vegetate to tree cover.

5.5.4 Geotechnical Evaluation and Calculations

The mitigation and environmental enhancements referenced in 5.5.1 neither enhances nor detracts from the geotechnical stability of the project.

5.5.5 Source and Adequacy of Construction Material

Native materials are used extensively in the project. Rootwads and logs for the lunker log structures and the locked logs structures will be obtained on-site utilizing trees that were required to be cleared. Rock for the in-stream boulder clusters and the Newbury riffle structures will be obtained from a local quarry less than five miles from the project. All plantings for the live staking of trees as well as the hydrophytic, upland, swales, wetland grasses and forbs will consist of native species from locally grown sources that are ecologically adapted to more local growing conditions.

5.5.6 Operation, Maintenance, Replacement and Rehabilitation Requirements

No operation, maintenance, replacement, or rehabilitation will be required for the planned in-channel structures. The design of in-channel structures containing recycled forest wood materials maximizes the useful life of the wood in these structures. The design considers, and provides for, minimizing the affect weather and water on wood over time. Degradation and loss of wooden material will eventually occur.

No operation, maintenance, replacement, or rehabilitation will be required for the live staked trees on the 1:70 lower benches. Tree removal must not occur on 1:70 lower benches. The failure or loss of part of the live staked trees will not impact their useful life. As sediment deposits start filling voids in rock fill used on this bench, seed from willow and cottonwood will germinate on sediment accumulations on this bench. Seedling formation will occur rapidly and sapling response could be as little as three to five years post-construction. Willows and cottonwood are especially adapt at re-vegetating bare floodplain/floodway soil near water as evidenced from field observations in the vicinity of the project area of the constructed flood control channel.

The hydrophytic, swale, and upland grasslands will require annual mowing outside of grassland bird nesting season. It’s important that several annual mowing cycles be performed during the first three growing seasons to reduce invasive and noxious weed competition. For a more complete description of the methods required to care for grasses see the Interim Operation and Maintenance Manual for the Blue River (2004). Any undesirable species should be removed by means of chemical or mechanical methods. Undesirable species may include species that are invasive or exotic. Undesirable species are rapid colonizers that may limit the growth of other desirable native species. Some undesirable species known to occur in the area of the project that should be removed include honeysuckle (*Lonicera* sp.), osage orange (*Maclura pomifera*), buckbrush (*Symphoricarpos orbiculatus*) bristly greenbrier (*Smilax tamnoides*), and garlic mustard (*Alliaria petiolata*). The removal of these species and others should be done in accordance with herbicide application guidelines in conjunction with state and EPA herbicide policy, or by other approved means such as mechanical, biological or manual removal.

Forested areas, including the preservation area, will require the removal of any undesirable tree and shrub consisting of select removal using chipping, cutting and/or EPA approved herbicides. The preservation areas will be protected from clearing, grubbing and construction activities.

The long term success of all vegetated areas will be dependent in part, upon following the Interim Operations & Maintenance Manual for the Blue River (2004). General maintenance and management measures will vary from year to year and should include mowing or prescribed burning (only as deemed safe by KCMO and local laws), and the application of EPA approved herbicides (in non-swale areas).

5.5.7 Value Engineering

The rootwads, lunker logs, locked logs, and Newbury riffle structures will require no upkeep thus reducing costs. Logs for the rootwads, lunker logs, and locked log structures are obtained on-site reducing costs. All rock for the boulder clusters and the Newbury riffles are from a quarry less than five miles from the project site saving transportation costs. All plantings are native reducing maintenance costs and providing valuable habitat benefits.

## 5.6 Access Roads

Project criteria require the design and construction of maintenance roads to access left and right banks of Blue River for the length of the project. In general, the access roads designed for this project follow along the top-of-bank and outside of the modified channel. Following this alignment avoids steep grades and the need for significant vertical elevation changes.

Road connections have been designed along the left bank to connect along existing City rights-of-way to existing public roads. Downstream of approximately Station 102+00, existing public roads fulfill this requirement along the left bank from Blue Parkway Bridge to the downstream end of the project.

Kansas City provided trail alignment design plans that follow the top-of-bank along the right bank of the project. In general, the access road follows the alignment developed for the trail. The access road is designed to connect to the public road system along existing City rights-of-way.

It is anticipated that the access roads will have little vehicular traffic on them. The roads have been designed to have six-inches of crushed stone placed on top of a compacted subgrade.

## 5.7 Land Disturbance

Land Disturbance plans were previously completed. These plans show erosion control methods and placement to be used for clearing upper-bank areas. The plans are detailed to follow Kansas City, Missouri standard requirements and were reviewed and accepted by Kansas City, Missouri. Land Disturbance plans supplement the Stormwater Protection Plan (SWPP) submitted to the Corps of Engineers and Kansas City by ESI Contracting Corporation.

# 6.0 CONSTRUCTION SCHEDULE

The construction schedule has previously been submitted to the Corps of Engineers by ESI Contracting Corporation and is periodically updated as work progresses. It is not repeated in this submittal of the Design Documentation Report.

## 7.0 INDEPENDENT TECHNICAL REVIEW DOCUMENTATION

Technical review processes for the design professional and the contractor have been previously submitted and reviewed by the Corps of Engineers. Prior to submittal to the Corps of Engineers, the design professional completes quality control reviews. After internal review, design documents are provided to the construction contractor and other design subconsultants for review. Review comments are responded to and incorporated into design documents for submission to the Corps of Engineers.

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