# WESTSIDE CREEKS ECOSYSTEM RESTORATION

*Appendix A: Geomorphology*

# GEOMORPHOLOGY APPENDIX

## INTRODUCTION

### PURPOSE

The San Antonio River Authority (SARA) contracted with Michael Baker Jr., Inc. (Baker) in February 2012 to develop a preliminary bankfull pilot channel design and plan form for the West Side Creeks project (WSC) as part of the SARA Stream Restoration Program. The project is in support of the Ecosystem Restoration (ER) feasibility study being conducted by the US Army Corp of Engineers Fort Worth District (USACE) for WSC. The purpose of this report is to describe project objectives, provide a general overview of the WSC project reaches and corresponding watersheds, describe the methodology of the preliminary plan form design process, and summarize the assumptions of the resulting preliminary design parameter values. Preliminary cost estimates associated with the proposed in-stream structures for each WSC project reach are also provided.

### OBJECTIVES

The following objectives were outlined for WSC by USACE:

- *Objective 1* – Restore, to the extent practicable, a sustainable dynamic riverine ecosystem providing habitat for aquatic and riparian dependent migratory and native resident bird species in the WSC study area.
- *Objective 2* – Maximize, to the extent practicable, recreation benefits along WSC compatible in scope and scale of the project's ecosystem restoration objective and consistent with national, regional, and local recreation goals.

Baker incorporated the USACE objectives to develop the preliminary bankfull pilot channel design and base plan form for WSC using natural channel design (NCD) principles. NCD is an applied technique that can be employed to help restore various ecologic functions to impaired stream systems. These primary functions are categorized as hydrology, hydraulic, geomorphic, physiochemical, and biological. The restoration of hydraulic and geomorphologic functions provides a framework for restoring other related functions and ultimately determines the functional lift potential and project success.

### BASIN OVERVIEW

The WSC include approximately 14 miles of channel of the following creeks:

- San Pedro Creek (approximately 3.8 miles)
- Apache Creek (approximately 4.2 miles)
- Alazan Creek (approximately 3.3 miles)
- Martinez Creek (approximately 2.8 miles)

The WSC are generally located west to northwest of downtown San Antonio, TX except for San Pedro Creek which is located south of downtown. The WSC are nested tributaries, all predominantly flowing south or southeast and converging with one another, eventually flowing into San Pedro Creek which drains into the San Antonio River.

The WSC are all drained by highly urbanized, impervious watersheds composed primarily of medium to high density residential areas with some commercial and industrial land uses. These developed watersheds are considered to be built-out and have been so for many decades (AECOM, 2011). Drainage area and percent impervious area for the WSC project watersheds are presented in Table 1.

**Table 1.Watershed Drainage Areas and Imperviousness**

| WSC | Drainage Area (sq mi) | Impervious Area (%) |
|---|---|---|
| San Pedro Creek | 44.9 | 68 |
| Apache Creek | 40.3 | 66 |
| Alazan Creek | 17.5 | 71 |
| Martinez Creek | 7.2 | 73 |

The WSC are flood conveyance channels, typically confined by dense urban infrastructure bordering both terraces which serve as flood control boundaries. They are characterized by oversized, grass-lined trapezoidal channels with limited floodplain access, and an inadequate buffer comprised primarily by herbaceous grasses that provide no stream cover and marginal habitat value. These channels are actively maintained and have been severely manipulated and channelized several decades ago by USACE for flood conveyance. Concrete-lined channels within the WSC project area include the majority of Apache Creek and the upstream half of the San Pedro Creek project reach beginning at Camp Street, where portions of channel have been culverted beneath parking lots and roads. Hydrology within the watersheds has been historically altered by flood control structures and extensive stormwater drainage networks. The upstream project limits for Apache, and Alazan Creeks consist of flood control structures with impounded water from an Elmendorf Lake, and Woodlawn Lake respectively.

# METHODOLOGY

## EXISTING CONDITIONS

Development of design criteria and the preliminary base plan form for WSC was exclusively achieved by analysis and remote sensing of pre-existing digital data provided primarily by SARA using a combination of GIS, CAD, and Google Earth. Site visits for ground-truthing of existing data, or collection of additional field data was not scoped for this project. Data provided by SARA was compiled and inventoried. The following datasets were integral to the methodology for the WSC preliminary design process:

- Existing SARA concept plan for WSC and related GIS layers (basin delineations, hydrography, project corridor boundary)
- Current aerial photography
- Utility crossings
- 2005 contours, TINs, local survey data
- HEC-RAS models and DFIRM data

- East Salitrillo Creek mini-regional curve
- Harris County, Texas regional curve (Harris County Flood Control District, 2009)
- North Carolina regional curves (Urban and Rural Piedmont), (Harman et al., 1999)

The data listed above was used to perform a desktop review of the WSC watersheds and riparian corridor conditions, and to aid in reach delineation and preliminary design approach for the project reaches. Drainage area, land use and impervious area were calculated for each creek and cross-referenced with the WSC concept plan. The drainage areas were delineated to the downstream terminus and used in relation with regional curves to appropriately size a stable bankfull pilot channel for each WSC reach. Watershed land use and imperviousness data helped to assess the extent of urban influence on the stormwater runoff regime and the potential for channel enlargement (when sizing the design channel); larger magnitude peak discharges can occur from smaller magnitude storm events as a result of increased drainage density and conveyance efficiency (from extensive paved surfaces and stormwater infrastructure) inherent to highly developed urban areas.

Existing HEC-RAS models were analyzed for each WSC project reach using cross-sectional and longitudinal profile data. Channel geometry and alignments were reviewed to identify potential relocation opportunities within the existing riparian corridors. Culvert crossings, stormwater outfall locations, utilities and infrastructure, and areas of limited channel or floodplain confinement were identified throughout the corridor as part of a constraints analysis. Each of the four creeks were subdivided into distinct project reaches based upon changes in potential design approach dictated by a combination of the above mentioned variables, namely drainage area, modeled discharge, and available geomorphic floodplain width.

## BANKFULL VERIFICATION

The term “bankfull” discharge or dominant discharge represents a breakpoint between processes of channel formation and floodplain development. It is this channel forming flow that fills the channel to the top of its banks and at a point where the water begins to overflow onto the active floodplain (Leopold et al., 1964). This discharge, along with the range of flows that make up an annual hydrograph, governs the shape and size of the active channel. Bankfull discharge is associated with a momentary maximum flow that has an average recurrence interval range of 1.1 – 1.8 years as determined by using a flood frequency analysis (Dunne and Leopold, 1978).

The bankfull elevation or bankfull stage is typically estimated first in the field by identifying geomorphic indicators within the stream channel. These indicators usually include the top of the bank in stable riffle sections, consistent high scour marks in incised sections, and depositional bar areas. However, WSC channels have been severely manipulated and channelized for flood conveyance and geomorphic indicators are unlikely; thus field visits were precluded from this scope of work for the preliminary base plan form design.

For preliminary design plan purposes, detailed cross-section data were extracted from the HEC-RAS models and then compared with regional curve data in order to relate bankfull channel dimensions (dependent variables) such as cross-sectional area, width, mean depth, and discharge versus the drainage area (independent variable). Regional curves can be a useful tool for applying NCD methodology when estimating bankfull channel dimensions for developed and/or ungaged watersheds within the same hydro-physiographic province.

The East Salitrillo Creek mini-regional curve data were used to help compare these hydraulic geometry relationships. Baker and SARA team members originally developed the curve for a stream restoration project in Converse, TX. After identifying stable channels within the watershed, the team performed detailed cross-sectional surveys at each stable riffle identified. Using the cross-sectional dimensions and overall channel slope, bankfull discharge was estimated using Manning's equation. The team then performed site searches to identify stable USGS gage stations within the same hydro-physiographic province to estimate velocity and discharge ranges. The water surface elevations at both the cross-section and the gage station were recorded and the curve was later revised by others after incorporating the additional gage station analysis based on peak discharges.

Additionally, published Harris County TX, NC regional curve data (urban and rural piedmont), and the WSC concept plan data sets/regression curves were compared as converging lines of evidence to appropriately size the bankfull pilot channel to carry the bankfull discharge. Flows larger than bankfull were also validated to determine adequate floodplain widths necessary to transport these flows. Although evaluating regional curve data and hydrologic and hydraulic (H&H) models can be a useful comparison exercise, they do not replace the need for field calibration and verification of bankfull stage and discharge to determine design channel dimensions. Since the hydrology within this area has been historically altered by flood control structures and extensive stormwater networks, a more robust and comprehensive geomorphic field assessment and modeling analysis is recommended to effectively compare the hydrologic calculations with the bankfull discharge predicted by the regional curve for subsequent design phases.

## Evaluation of Preliminary Restoration Goals and Alternative NCD Approaches

Before proceeding with the design criteria development for WSC, preliminary restoration goals and alternative NCD approaches were evaluated to ensure fulfillment of restoration objectives outlined by USACE in Section 1.2.

To achieve these objectives, the following NCD components were considered to maximize the natural functionality of the riparian corridors for improving water quality, habitat, and recreation while minimizing flood impacts to surrounding areas:

- Create geomorphically stable conditions for the channels by determining a bankfull pilot plan form and dimension;
- Improve and restore hydrologic connections between the low flow channels and their geomorphic floodplains;
- Improve water quality by establishing native buffer vegetation for nutrient and sediment removal from stormwater runoff and by stabilizing stream banks to reduce bank erosion and sediment contribution from larger flows;
- Improve aquatic and terrestrial (reptiles, mammals, birds) riparian habitat along the corridor channels by introducing desirable native buffer vegetation; and
- Improve in-stream habitat (fish, benthic macroinvertebrates) by providing a more diverse bed form with riffles and pools, create deeper pools and areas of water re-aeration, and provide woody debris for habitat.

The first step using a NCD design approach was to define the preliminary channel alignment and determine bankfull pilot channel widths. It was imperative to review existing channel geometry and identify potential pattern relocation opportunities and lateral constraints before moving ahead to the next design phase. The low valley/channel slopes of WSC warrants the dissipation of flow energies through riffle-pool sequences in meandering stream geometry that would minimize near bank stresses by allowing higher storm flows to spread out onto the active floodplain.

However, based on stable reference reach ratios and successful past projects, meandering streams must have adequate belt-widths to function properly. For example, a new pattern or minimal channel relocation could be introduced along Martinez Creek between Fredericksburg Road and Calubera Road, but suggested design Meander Width Ratios (Wblt/Wbkf) for meandering streams (Rosgen 'C' or 'E' stream type) range from 3.5 to 8 times the riffle width, which is not feasible unless property buyouts are initiated and extensive floodplain and terrace side slope excavation is permitted. Therefore, due to urban channel confinements and lateral constraints caused by roads and utilities within the WSC riparian corridors, relocation of the existing channels to re-establish meandering stream geometry was not recommended. Such constraints can severely limit restoration success, construction feasibility, and increase project risk in terms of geomorphic stability.

Instead, an alternative NCD approach was chosen to dissipate flow energies vertically and reduce lateral bank erosion via a nested step-pool stream system. This approach utilizes in-stream structures by centering in-channel flows away from steam banks while maximizing the geomorphic floodplain through excavating bankfull benches. This is defined as a Rosgen Priority Level 3 approach and is recommended to maximize functional lift. Reconnecting and/or creating wider floodplains throughout the WSC riparian corridors will also provide better opportunities for water quality improvements (BMP's) by way of increased sediment and nutrient filtering through floodwater retainage during over bank flows, capturing and treating stormwater runoff by providing stormwater wetland complexes, installing plunge pools at outfall locations, and establishing native buffer vegetation to improve bird nesting and foraging habitat.

In addition to creating a geomorphic floodplain, restoration efforts would also consist of removing any concrete lined bed/banks and installing in-stream structures along with bioengineering methods. In-stream structures are constructed from natural materials, predominantly large rock and wood and consist of cross vanes, constructed riffles, rock vanes, and double wing deflectors which are installed to control the elevation (vertical stability) of the stream bed, provide bank protection, and improve habitat for aquatic life. Bioengineering methods or "soft armoring" measures would provide lateral (steambank) stability and help propagate native buffer vegetation. Examples of bioengineering techniques include: erosion control matting, geolifts, brush mattresses, live staking, fascines, and native vegetation transplants.

## DEVELOP DESIGN CRITERIA

After selecting the general restoration approach based on project objectives, design criteria were then developed so that channel pattern, bankfull dimensions, and representative longitudinal profiles could be determined for each reach. Developing appropriate design criteria is a critical pathway to successful planning, restoration design, and final construction implementation.

After sizing the preliminary bankfull pilot channel, floodprone area widths (width at elevation twice the bankfull maximum depth) and meander belt widths (straight-line distance from the outermost bends of the channel) were measured and compared with existing channel slopes throughout the project corridors using a combination of existing HEC-RAS longitudinal profiles and cross-sections, local survey data, 2005 contour data, and current aerial photography. This analysis validated that entrenchment ratios (ER = floodprone area width divided by the bankfull riffle width) would be within an acceptable range to support the design steam type, and minimum floodplain bench widths could be achieved for stability and constructability purposes, even with some sections only having minimal floodprone area widths due to lateral constraints.

The existing channel slopes were then used to determine pool-to-pool spacing and pool lengths by comparing reference reach parameters and design parameter ratios used for similar stream types and successful restoration designs. Once these features and facet slopes were determined, in-stream structures, such as roack cross-vanes, were placed in locations that would not interfere with existing infrastructure while meeting the design criteria requirements previously mentioned.

## SEDIMENT TRANSPORT CONSIDERATIONS

The geomorphic approach for the WSC project reaches based on natural channel design principals includes consideration of sediment transport. A geomorphically stable channel with riffle/run/ pool complexes serve several purposes including energy dissipation and providing aquatic habit. Proper dimensioning of the bankfull channel and floodprone areas, as well as pool-to-pool spacing, is critical to the maintain sediment transport capabilities of the channels so that they do no aggrade or degrade overtime.

Additionally, the proposed in-stream structures, such as cross vanes, serve several purposes including:

- creating and maintaining the scour pools (as part of the riffle/run/pool complexes);
- providing grade control at the downstream end of riffles and,
- providing bank protection by conveying flows (all flow including flood flows) towards the center of the channel.

The proposed cross-vanes structures will consist of at least two rock vanes sufficiently sized to remain in place during flood events. A detailed geomorphic assessment, including sediment transport analysis, will be conducted during the final design phase to refine the bankfull channel dimensions and pool-to-pool spacing, in-stream structure selections, and sizing of the riffle material.

## VEGETATION CONSIDERATIONS

Riparian buffer vegetation provides the necessary stabilization of slopes and stream banks to reduce erosion while increasing shade for wildlife and aesthetics, and to moderate water temperatures. Turf establishment is the first priority for site stabilization and rapid revegetation. Once the site is stabilized with turf and permanent coverage has been established, native woody (trees and shrubs) and herbaceous vegetation (grasslands and wildflowers) may be introduced within the corridor to meet the specific needs and goals of the WSC project.

Native plant species should be established throughout the bankfull pilot channel banks, geomorphic floodplain, and transitional upland areas; and plant selection must consider onsite conditions such as wetness, drought, backwater, etc. Taller canopy trees could to be planted in transitional & upland areas throughout the corridor, but should not be planted within the geomorphic floodplain, utility easements or on side slopes steeper than 3:1. The Appendix contains a typical corridor section detail for reference in illustrating the above-mentioned vegetation buffer planting considerations. Refer to the USACE H&H modeling analysis section for specific planting details and proposed vegetation densities.

Long-term buffer maintenance of the WSC riparian corridor must address safety concerns, debris removal for flood conveyance, selective cutting/pruning activities, invasive species control, and include educating workers to the sensitivity of wetland habitats that are both planted and propagated through natural colonization.

## SUMMARY OF RESULTS

Deliverables and supporting data for WSC project reaches are provided in the Appendix and include the following:

- Summary table of preliminary design criteria and parameter values;
- Typical corridor section detail;
- Preliminary workmaps illustrating the base plan form design approach;
- Preliminary plan sheets containing bankfull pilot channel alignment, typical sections, representative longitudinal profiles, and in-stream structure locations and details.

A preliminary construction cost estimate was prepared for work related to installing in-stream structures as shown on the base plan form design and typical details (see Table 2 below). Calculating rough costs for in-stream structure installation is a worthwhile exercise during the preliminary design phase for planning a project budget. Typical costs involved with installing in-stream structures include equipment, labor, and materials. It is important to emphasize that these cost estimates are to be used only as a guideline since fluctuating material prices, contractor experience, and installation procedures can heavily influence overall construction costs. Factors that affect installation costs include site accessibility for crews and heavy equipment, local labor/equipment/material rates, and the distance over which boulders must be transported. For example, installing a cross vane structure in a larger channel requires longer vane arms. This proves more costly because it requires larger boulders, additional stone, and increased installation and material haul times. For the purposes of this report, costs assumptions related to installing in-stream structures included stone materials (price per tonnage quotes from two local quarries), standard labor rates, and estimated construction time (using equipment rates) required along each WSC reach, but excluded additional channel excavation and incidental grading costs.

**Table 2. In-stream Structure Cost Estimates**

| Site | *Proposed Length (LF) | Total Structures | **Cost Estimate | Cost / LF |
|---|---|---|---|---|
| San Pedro Creek | 12,676 | 51 | $1,379,000 | $109 |
| Apache Creek | 4520 | 16 | $448,000 | $99 |
| Alazan Creek | 17,211 | 79 | $1,269,000 | $74 |
| Martinez Creek | 14,715 | 0 | $0 | $0 |
| TOTAL | 49,122 | 146 | $3,096,000 | $63 |

*Restoration/Enhancement activities include in-stream structures, bioengineering, sloping banks, floodplain excavation, streambank and riparian buffer planting.

**Cost for installing in-stream structures includes materials, labor, and construction time, but excludes additional channel excavation and grading costs.

As previously mentioned the resulting preliminary data from this study should only be used for planning purposes and are not for detailed design. A more comprehensive evaluation of design approach/criteria are necessary and should include field calibration and verification of bankfull stage, a geomorphic field assessment and survey, mapping of potential site constraints (utilities and infrastructure), and additional H&H modeling. It is expected that further design modifications would be made during the next design phase once additional information was obtained.

## REFERENCE LITERATURE


AECOM 2011. Westside Creeks Restoration Project - Conceptual Plan. Prepared for SARA.

Dunne, T., and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman Co. San Francisco, CA.

Harman, W., and R. Starr. 2011. Natural Channel Design Review Checklist. US Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD and US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Wetlands Division. Washington, D.C. EPA 843-B-12-005.

Harman, W.A., G.D. Jennings, J.M. Patterson, D.R. Clinton, L.O. Slate, A.G. Jessup, J.R. Everhart, and R.E. Smith, 1999. *Bankfull Hydraulic Geometry Relationships for North Carolina Streams*. Wildland Hydrology. AWRA Symposium Proceedings. Edited by: D.S. Olsen and J.P. Potyondy. American Water Resources Association. June 30 - July 2, 1999. Bozeman, MT.

Harris County Flood Control District (HCFCD). 2009. Fluvial Geomorphological Conditions of Harris County, Texas, prepared by AMEC Geomatrix, Inc. and Stantec.

Rosgen, D.L. 1994. A Classification of Natural Rivers. Catena 22:169-199.

Rosgen, D.L. 1997. A Geomorphological Approach to Restoration of Incised Rivers.

Rosgen, D.L. 1996. Field Survey Procedures for Characterization of River Morphology.

Rosgen, D.L. 2006. The Cross-Vane, W-Weir and J-Hook Vane Structures: Their Description, Design and Application for Stream Stabilization and River Restoration. Wildland Hydrology. Fort Collins, CO. http://www.wildlandhydrology.com/html/references_.html

Soar and Thorne. 2001. *Channel Restoration Design for Meandering Rivers.* US Army Corps of Engineers (USACE), Engineering Research and Development Center. Coastal and Hydraulics Laboratory, ERDC\CHL CR-01-1. September, 2001.

United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), 2007. Geomorphic Channel Design, Chapter 11, Part 654 Stream Restoration Design, National Engineering Handbook by the Natural Resources Conservation Service. http://www.nae.usace. army.mil/reg/RestorationStabilization/nrrbs/MAIN-MENU.pdf.

The Federal Interagency Stream Restoration Working Group (FISRWG)(15 Federal Agencies of the US gov't), 2001. Stream Corridor Restoration: Principles, Processes, and Practices. GPO Item No. 0120-A; SuDocs No A 57.6/2:EN3/PT.653 ISBN-0-934213-59-3. Adopted as Part 653 of the National Engineering Handbook, Natural Resource Conservation Service. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044574.pdf