ARKANSAS RIVER CORRIDOR

Appendix J: Hydraulics and Hydrology

ARKANSAS RIVER CORRIDOR, TULSA COUNTY, OKLAHOMA

Introduction

The Arkansas River is a water resource serving numerous nationally significant purposes. The river has historically served as a nationally significant resource for aquatic and terrestrial habitat of the nation's wildlife that live, breed, and migrate through the Arkansas River ecosystem. This includes federally endangered Interior Least Tern (Least Tern, *Sterna antillarum*), a nationally significant resource, and two federally threatened bird species, the Piping Plover (*Charadrius melodus*) and the Red Knot (*Calidris canutus rufa*) as well as a plethora of native species and migratory waterfowl that support a healthy and functional riverine ecosystem. Keystone Lake and its dam located along the Arkansas River also play vital roles in supporting the continued provision of many of those multi-purposes. In particular, the lake and dam provide flood risk management benefits, contribute to the eleven reservoir system operation of the McClellan-Kerr Arkansas River Navigation System, provide clean and efficient power through the associated hydropower plant, and provide a source of water for municipal and industrial uses. However, construction, operation, and maintenance of the Keystone Dam, lake, associated hydropower operations and other multi-purposes have significantly degraded the riverine ecosystem structure, function, and dynamic processes below Keystone Dam on the Arkansas River within Tulsa County, Oklahoma.

Stage of Planning Process

This is a feasibility study. A planning Charette was conducted in October 2013, and an Alternatives Milestone Meeting was completed in September 2015. The study is in the Alternative Formulation and Analysis Phase. Utilizing a reasonable level of detail, the PDT has analyzed, compared, and evaluated the array of alternatives to identify a Tentatively Selected Plan for consideration by the Vertical Team.

Study Authority

The Arkansas River Corridor study is authorized in the Water Resources Development Act (WRDA) of 2007, Section 3132.

> Section 3132. Arkansas River Corridor.
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> (a) IN GENERAL. – The Secretary is authorized to participate in the ecosystem restoration, recreation, and flood damage reduction components of the Arkansas River Corridor Master Plan dated October 2005. The Secretary shall coordinate with appropriate representatives in the vicinity of Tulsa, Oklahoma, including representatives of Tulsa County and surrounding communities and the Indian Nations Council of Governments.
> (b) AUTHORIZATION OF APPROPRIATIONS. – There is authorized to be appropriated $50,000,000 to carry out this section.

Non-Federal Sponsor

Tulsa County is the non-federal sponsor for the Arkansas River Corridor feasibility study.
An amended feasibility cost-sharing agreement was executed in May 2015.

Purpose

This study is in response to the Section 3132 authorization of the 2007 WRDA. The purpose of this study is to evaluate the aquatic ecosystem restoration components of the October 2005 Arkansas River Corridor Master Plan (ARC Master Plan) and determine if there is a Federal Interest that aligns with the Corps of Engineers ecosystem restoration mission.

HYDRAULIC ANALYSIS

The goal of hydraulic analysis for this study was to develop a model using USACE Hydrologic Engineering Center – River Analysis System (HEC-RAS) that would provide the necessary hydraulic information to be used to evaluate the wildlife benefits associated with the project. These benefits are developed based on several factors related to the flow in the Arkansas River. HEC-RAS provides detailed flow information at predetermined locations, which allows for a comparison of the wildlife benefits for each of the scenarios considered.

Four models were developed to evaluate the benefits of the project. The model scenarios include existing conditions, future without project (includes other local projects being implemented within the study area), future with project at the location of the previous structure, and future with the project located downstream of the Highway 97 bridge.

The existing conditions model establishes the current conditions along the Arkansas River and provides a baseline to compute benefits associated with the project. The future without project model establishes the conditions that will exist following the implementation of ongoing Arkansas River projects downstream of the structure being studied. There are two potential locations being considered for the project structure, so a model was developed for the two locations. The two future with project models include a pool structure downstream of Keystone Dam that will hold back a portion of the hydropower releases. Once the hydropower release is completed, the pool structures will slowly release the impounded water.

Terrain Data

Knowing that the model needed to operate at low flow conditions in the Arkansas River, a well-defined terrain dataset was needed to closely represent the river channel. The proximity of the project to a major metropolitan area was critical for this phase of the model development. The City of Tulsa and the Indian Nation Council of Governments (INCOG) had commissioned the gathering of terrain data for Tulsa County. This information was available for use for this project. The data provided was a topographic map of contours on a two-foot interval. The contours were processed into a terrain raster using ArcGIS.

HEC-RAS Model Development

The Tulsa District had previously developed a HEC-RAS model that was used as the base model for this project. This model was developed as a part of the Arkansas River Corps Water Management System (CWMS) effort, and had been calibrated. One of the challenges for HEC-RAS models is modeling very low flows in very wide channels. The current flow regime in the Arkansas River is very low flows (minimal releases from Keystone Dam), or high flows resulting from hydropower or flood control releases from Keystone Dam.

Cross-sections

Stream and valley cross-section data were developed from the detailed topographic mapping discussed in "Hydrologic Analysis". Environmental Systems Research Institute (ESRI) ArcMap software was used to develop the three-dimensional terrain modeling.

USACE HEC-GeoRAS software was used to accomplish the following steps:

- Develop stream stationing along the Arkansas River channel.
- Develop preliminary measurements for channel and overbank reach lengths between cross-sections.
- Identify preliminary channel bank stations at each cross-section.
- Extract the cross-section data points (elevation versus section station).
- Populate each of the associated input data fields within the HEC-RAS models.

Locations and Layout Considerations

The locations for cross-sections were identified to capture the critical hydraulic features within the study reach.

- Cross-sections were spaced as necessary to model significant hydraulic features such as bridges, low water crossings, dams, or to capture expected flow change locations.
- Inline structures were used to model the low-water dams included in the system.
- Locations of tributaries that contribute to the study streams were also considered for choosing the appropriate cross-section locations.

Structures

Railroad and roadway bridges were incorporated within the HEC-RAS models in the study. The low-water dams were included as inline structures. The low-water dam impounding Zink Lake (current and proposed modification configuration) is included in the model, as well as the downstream proposed low-water dam near Jenks, Oklahoma. The Sand Springs pool structure was included at the appropriate location for the two models of future with project conditions.

Manning's Roughness Coefficients

Manning's *n* values were estimated based on the land use. Manning's *n* values varied horizontally for each cross-section, thus capturing the variation in land use along the cross-section. The flows modeled for this project are within the channel banks of the Arkansas River, so the in-channel Manning's *n* values were the critical values for this project.

Water Surface Elevations

A steady flow model was utilized to develop the water surface profiles for specified flows of interest for the ecological studies included in the project. An unsteady flow model was developed to simulate releases from Keystone Dam for the period of available record. RAS Mapper was used to prepare inundation maps for the various flows that were modeled to provide visual reference of the areas inundated.

Structure/Road Crossings

Existing bridges were included in the hydraulic models to incorporate their effect on water surface profiles.

Levees

There are several levee systems along the Arkansas River downstream of Keystone Dam. These levees protect industrial and residential areas along the river. These areas were included in the HEC-RAS model for the project.

Ineffective Flow Areas

To define the appropriate limits for the areas of effective flow, ineffective flow areas were designated around structures according to the HEC-RAS modeling standards. Ineffective flow was also designated for that portion of cross-sections where flow was not effectively conveyed downstream.

Model Calibration

The CWMS Hydraulic model was calibrated using stage information at stream gages during high-flow events.

Water Surface Profiles

Water surface profiles were developed for flow rates of 50, 100, 200, 300, 400, 500, 750, 1,000, 6,000, 12,000, 15,000, and 25,000 cfs. These flow rates were modeled using a steady flow simulation.

Floodplain Delineation

Water surface delineation was completed in HEC-RAS using the RAS Mapper tool. Inundation areas were prepared as needed for the desired flow rates.

Impacts of Flood Releases

Model scenarios were run to determine the potential impact to the levee system downstream of Keystone Dam. A flow rate of 205,000 cfs is the peak flow associated with the 100-year frequency event. This peak flow rate was utilized in the HEC-RAS model to determine the water surface changes near the upstream end of the levee system for this event. Based on the conceptual design, the location of the project structure at the original location results in a minimal change in the 100-year frequency event water surface, while the location of the project structure downstream of the Highway 97 bridge resulted in a water surface increase of approximately 0.2 feet. These results are similar to published studies developed for the Arkansas River Corridor Study associated with the Master Plan. Final project configuration and operations will need to be evaluated to ensure project impacts are acceptable.

Future with Project Hydraulic Analysis

The future with project conditions hydraulic models were developed by including an inline structure to represent the proposed pool structure. The pool structure was modeled based on a preliminary design, and was operated to release approximately 1,000 cfs during times when hydropower releases did not provide flow over the top of the structure. No model parameters were changed except those needed for inclusion of the pool structure.

Future Model Utilization

The existing CWMS model was used as the base model for this project. Additional improvements were completed as a part of this project. The model developed for this project will move forward as the master model for the Arkansas River corridor through the project area.