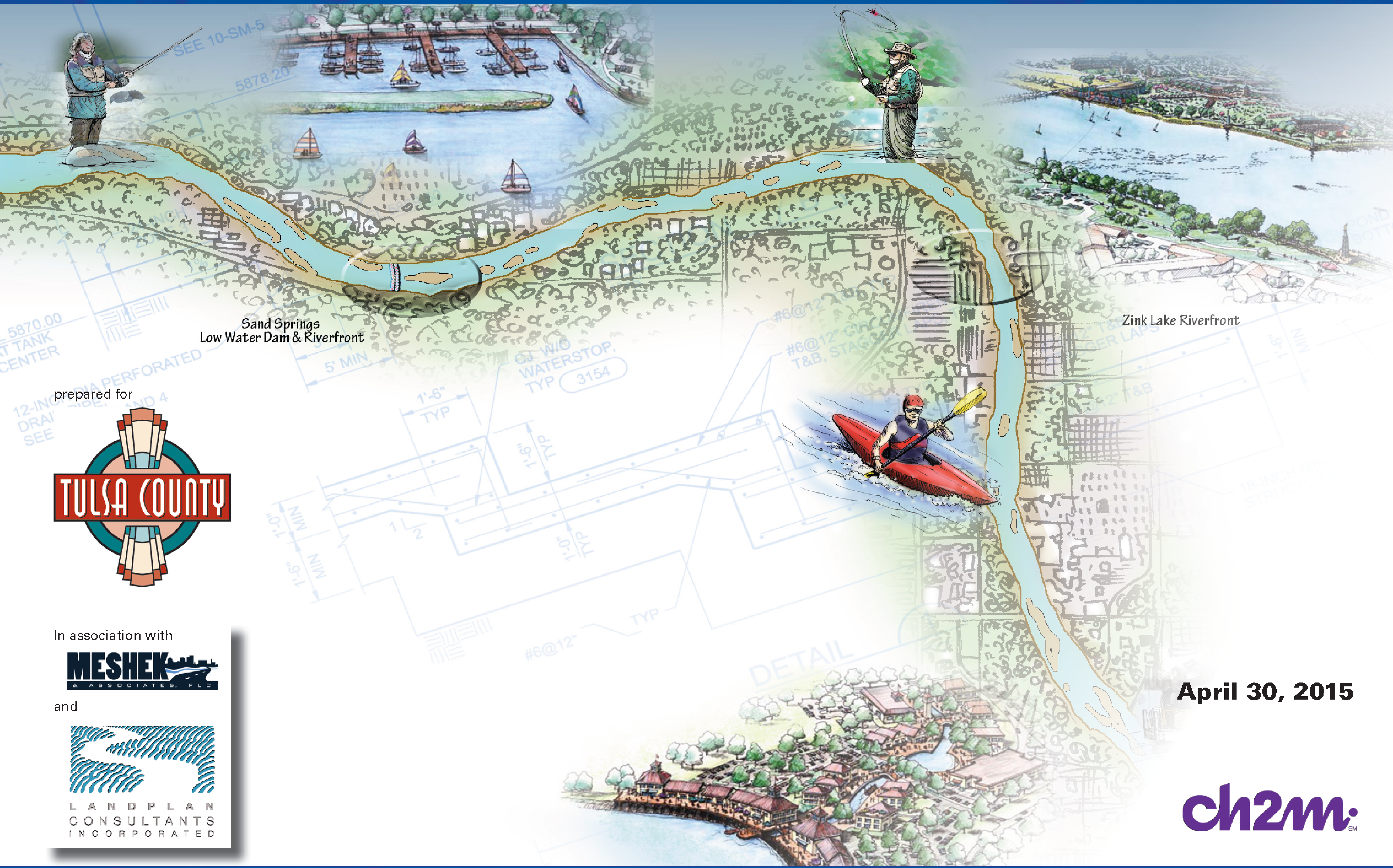
Arkansas River Low Water Dams and Public Access/Recreational Improvements

Schematic Design and Cost Estimates



prepared for

TULSA COUNTY

In association with

MESHEK & ASSOCIATES, PLC

and

LANDPLAN CONSULTANTS INCORPORATED

April 30, 2015

ch2m

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Acronyms/Abbreviations

AACE	Association for the Advancement of Cost Engineering
ADA	Americans with Disabilities Act
cfs	cubic feet/second
CLOMR	Conditional Letter of Map Revision
CWA	Clean Water Act
EA	Environmental Assessment
EIS	Environmental Impact Statement
FEMA	Federal Emergency Management Agency
NEPA	National Environmental Policy Act
O&M	operation and maintenance
PPMP	Preliminary Project Management Plan
RHA	Rivers and Harbors Act
SWPA	Southwest Power Administration
USACE	US. Army Corps of Engineers

Executive Summary

Purpose and Scope

This document summarizes the results of the schematic design process and defines the multiple project components that have been envisioned as a result of previous reports and studies related to developing the Arkansas River as a community resource for Tulsa County. This definition of project components was used to develop cost estimates for the related improvements and associated requirements for implementation. The underlying purpose of this effort is to provide the Arkansas River Infrastructure Task Force with cost estimates for the prospective projects for use in evaluating the potential funding sources needed for implementation.

Summary of Individual Project Facilities

The concepts included in this schematic design report were initially conceived during previous planning studies conducted from 2004 through 2009. The concepts were vetted through both community meetings with public input and involvement and consultation with multiple federal and state agencies relative to environmental and permitting requirements. The 2009 Preliminary Project Management Plan was the most recent study containing the conceptual basis for the potential improvements. This document can be found at the following Tulsa County web site: www.riverprojectstulsa.info

During the development of this schematic design, many of the concepts and design functions were discussed and reviewed, with consensus sought from the Engineering Working Group. This group, established by the Arkansas River Infrastructure Task Force, comprises technical representatives from each of the participating communities and Tulsa County, as well as other local technical resources. The group met every other week starting in November 2014 during development of the project work scope and throughout January through April 2015 during the development of the schematic design and cost estimate preparation. Members of the Engineering Work Group included the following representatives:

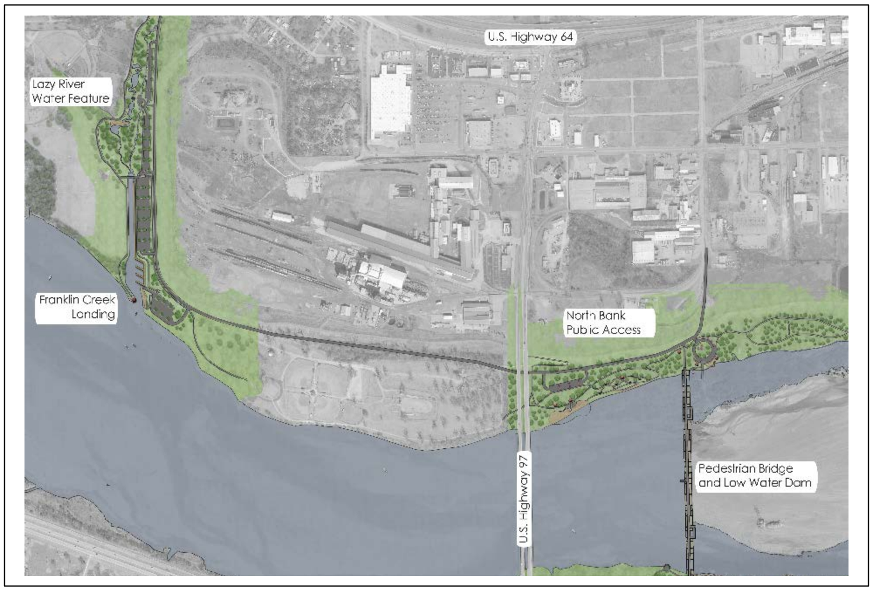
- Jared Cottle/Bixby
- Derek Campbell/Sand Springs
- Robert Carr/Jenks
- Paul Zachary/Tulsa
- Tom Rains/Tulsa County
- Rich Brierre/INCOG
- Lars Ostervold/CH2M HILL
- Stuart Solomon/PSO – Chairman
- Bob Jack/Manhattan Construction
- Bill Smith/River Parks
- Gaylon Pinc/Project Manager (PMg)
- Kirby Crowe/PMg
- Murry Fleming/CH2M HILL

In addition to these regularly scheduled Engineering Working Group meetings, the schematic design team conducted two meetings with each of the four individual participating communities to review and confirm the concepts for public access and recreational improvements specifically related to their communities. These meetings served to clarify the goals and tailor the scope based on each community's input and incorporated public interests into the project improvements. Summaries of the four proposed projects are discussed in the following section. In-depth discussions of these projects follow this Executive Summary.

1. Sand Springs

Dam/Pedestrian Bridge

Sand Springs is the first project location on the Arkansas River downstream of the Keystone Dam. The proposed dam is located downstream of Highway 97. The planned gate operation at Sand Springs is unique in that the lake level and volume will provide the ability to release enough water to maintain minimum flow conditions during the weekends when there are generally no flow releases from the hydropower generation unit at the Keystone Dam, as well as serving to equalize daily flow fluctuations. This flow augmentation and "flow smoothing" capability will be accomplished by allowing the water level upstream of the dam to drop as much as 3 feet to enhance downstream flow conditions.



The dam and related improvements are summarized below and are shown in the drawings and montages included in the appendices. The dam will have a crest elevation of 638.5 feet, resulting in a lake level at the dam of approximately 10 feet. This lake level will extend upstream to the base of Keystone Dam. The dam is 1,900 feet in length with a total gate area of 8,192 square feet, or approximately 43 percent of the dam face area. In addition, the dam will support a bridge structure for pedestrian use as well as for the performance of some maintenance functions. The bridge will include several seating, fishing, and overlook areas to enhance recreational opportunities.

Public Access/Recreational Improvements

A new road connecting with Main Street is planned from the north dam abutment, passing over the levee to provide vehicle access, allowing the public to access the area on the north bank. The road will also be extended to the west to connect with the City Park access road near the Case Community Center. Areas on both the north and south banks of the river at the dam will provide parking and trail connections for access to the bridge. In addition, other planned facilities will provide access to the river downstream of the dam.

A boat landing and launch area is planned at the entrance to Franklin Creek within River City Park on the north bank. Additionally, a lazy river water park-type feature will be developed to the area east of the soccer and ball fields to allow water tubing activities during summer months through the use of pumped water from the Arkansas River.

Bank Stabilization

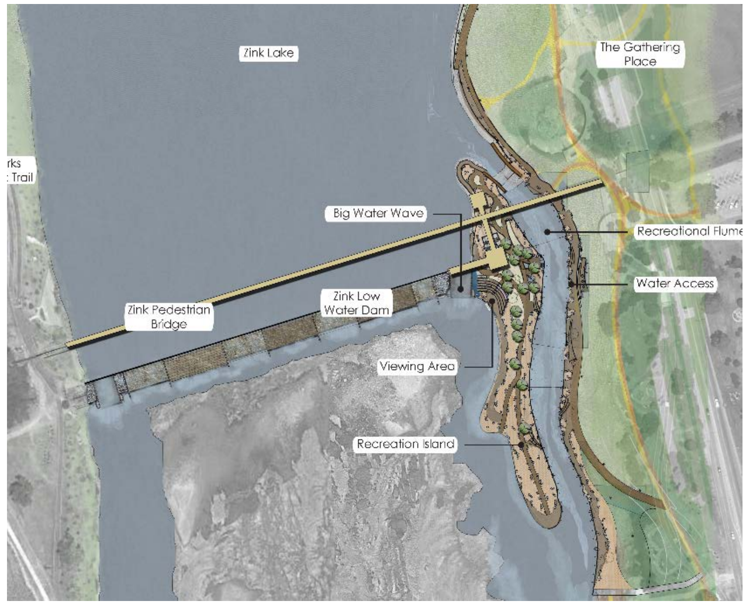
Stabilization of the bank toe is proposed in several areas to mitigate existing erosion and to protect against potential future erosion. Bank areas that will be affected by development of the dam and associated facilities will be stabilized as part of the project.

Compensatory Mitigation

To meet Clean Water Act Section 404 Compensatory mitigation requirements, several areas along the banks will be planted to create riparian habitat as well as wetland habitats in the upper reaches of the lake pool. In addition, islands will be created to provide nesting habitat for the least tern, federally listed as an endangered species.

2. Tulsa Zink

Dam



Improvements to the Zink Dam have been previously developed and shown in the 2012 preliminary design documents. The project will increase the height of Zink dam and will include the installation of additional gates. The Zink project improvements will need to be modified to accommodate the changes in alignment of the east bank that are occurring as a result of ongoing A Gathering Place For Tulsa (Gathering Place) improvements. The project also includes the construction of a narrow island within the river resulting in a channel along the east bank to create a recreational flume for kayaks.

The existing Zink dam was initially constructed in 1982 and is 7 feet in height and 1,030 feet in length. The proposed modifications include raising its height by 3 feet to a total of 10 feet and modifying the existing gate structures and including additional new gates, for a total gate area of 5,564 square feet or approximately 54 percent of the dam face area. Improvements to the existing Zink pedestrian bridge structure are planned as part of the double-decking project and as part of a separate ongoing sales tax project. An allowance of $10 million has been included in the cost estimate to supplement funding of the Zink Bridge.

Public Access/Recreational Improvements

The project includes modifications within the river channel itself involving construction of an island area adjacent and parallel to the east bank. The space between the east bank and island will be approximately 900 feet in length and will form a channel through which water can be diverted for recreational kayaking. Additionally, two of the dam gates will be specially designed to create hydraulic conditions to provide additional kayaking recreational opportunities.

Bank Stabilization

Stabilization of the bank toe is proposed in several areas to arrest existing erosion and to protect against potential future erosion. Bank areas that will be affected by development of the dam and associated facilities will be stabilized as part of the project.

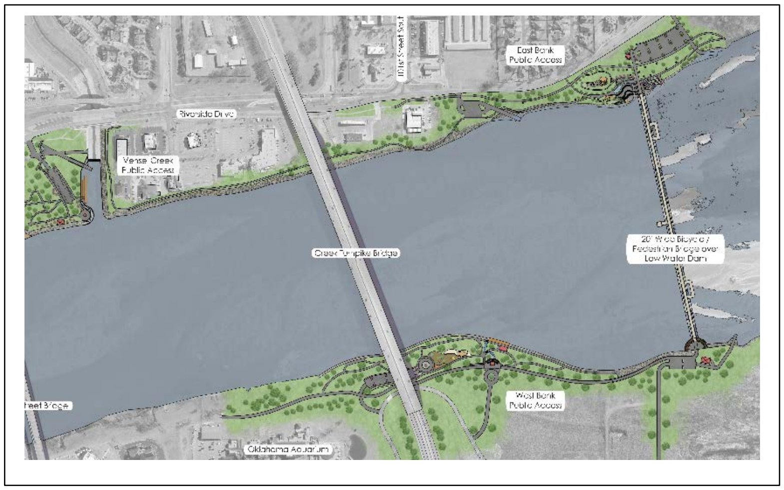
Compensatory Mitigation/Preservation

To meet Clean Water Act Section 404 Compensatory mitigation requirements, possible mitigation alternatives include planting areas along the banks to create riparian habitat, planting wetland habitats in the upper reaches of the lake pool, and constructing fish habitat within Zink Lake. In addition, islands will be created downstream of Zink Dam to provide nesting habitat for the least tern, federally listed as an endangered species.

3. South Tulsa/Jenks

Dam/Pedestrian Bridge

The South Tulsa/Jenks dam location is downstream of the Creek Turnpike bridges and will have a crest elevation of 597.5 feet, resulting in a lake level at the dam of 7 feet. The dam is 1,850 feet in length with a total gate area of 5,688 square feet or approximately 44 percent of the total dam face area. In addition, the dam will provide support for the pedestrian bridge structure and aid in the performance of some maintenance functions. The bridge will include several seating, fishing, and overlook areas to enhance recreational opportunities.



Public Access/Recreational Improvements

Riverside Parkway will provide vehicle access to the dam and bridge on the east bank. Vehicles will access the west bank area from a new access road planned on the south side of the Creek Turnpike that connects to Aquarium Drive in Jenks by passing underneath the Creek Turnpike Bridge. Areas on each bank of the river at the dam will provide parking, access to the bridge, future connections to the River Parks trail system and park, and overlook areas for the public. A boat ramp on the west bank will provide emergency access to the river downstream of the dam.

A boat launch dock area is planned on the east bank at Vensel Creek for public access, as well as a boat ramp between the dam and the Creek Turnpike. The Vensel Creek boat landing area could serve as a rental area for kayaks or other non-motorized vehicles, as well as provide an off-channel protected area for the overnight docking of water taxis, should the need occur.

Bank Stabilization

Stabilization of the bank toe is proposed in several areas to arrest existing erosion and to protect against potential future erosion. Bank areas that will be affected by development of the dam and associated facilities will be stabilized as part of the project.

Compensatory Mitigation/Preservation

To meet Clean Water Act Section 404 Compensatory mitigation requirements, several areas along the banks will be planted to create riparian habitat as well as wetland habitats in the upper reaches of the lake pool. In addition, an island will be created to provide permanent nesting habitat for the least tern, federally listed as an endangered species.

4. Bixby

Dam

The Bixby Dam location is the farthest downstream of any of the four dam locations. The planned dam height will result in a lake level at the dam of 4 feet and will result in a pool length of approximately 2 miles extending upstream from near the old Bixby Bridge alignment near south Mingo Road to the Fry Ditch Creek drainage channel on the north bank.

The dam will have a crest elevation of 583.5 feet, resulting in a lake depth at the dam of approximately 4 feet. The dam is 2,784 feet in length with a total gate area of 1,000 square feet, or approximately 9 percent of the total dam area. No bridge across the dam structure is planned.

Public Access/ Recreational Improvements

Vehicle access to the dam is provided on the north and south banks. Areas on each bank of the river at the dam will provide parking and access to the river. In addition, other planned facilities will provide access to the river downstream of the dam and at the Memorial Drive Bridge.

Bank Stabilization

Stabilization of the bank toe is proposed in several areas to mitigate existing erosion and to protect against potential future erosion. Bank areas that will be affected by development of the dam and associated facilities will be stabilized as part of the project.

Compensatory Mitigation/Preservation

To meet Clean Water Act Section 404 Compensatory mitigation requirements, several areas along the banks will be planted to create riparian habitat as well as wetland habitats in the upper reaches of the lake pool. In addition, an island will be created to provide permanent nesting habitat for the least tern, federally listed as an endangered species.

Project Cost Opinions

Costs estimates were developed based upon the dam / bridge design drawings, layout drawings of the public access and recreational improvements, and other supporting information contained in this report. The completed cost estimate is contained in the appendices documenting the assumptions and basis for the cost estimate. Tables ES-1 and ES-2 provide summaries of total costs, as well as operation, maintenance, and replacement costs per project.

TABLE ES-1
Total Project Costs

Project Summary of Total Project Costs (x1,000)						
Location	**Dam/Bridge**	**Public Access/ Recreation**	**Bank Stabilization/ Outfalls**	**Compensatory Mitigation / Preservation**	**Permitting**	**Total**
Sand Springs	65,230	32,487	3,876	5,225	1,051	107,869
Zink	38,442	18,799	927	1,718	354	60,240
South Tulsa/Jenks	47,240	29,597	1,797	844	422	79,900
Bixby	45,735	18,648	1,767	813	1,038	68,001
					Total	$316,010

TABLE ES-2
Operation and Maintenance Costs

	Dam/ Gates	Public Access/ Recreational	Total
Yearly Operation and Maintenance Costs			
Yearly O&M	$520,000	$1,018,000	$1,538,000

TABLE ES-3
Periodic Capital Replacement and Maintenance Costs

Yearly Sinking Fund Contribution	
Gate Rubber Bladders /30 years	$293,000
Sediment Removal / 5 years	$284,000
Gate Epoxy Coating / 20 years	$9,000
Compressor Air System/20 years	$26,000
Least Tern Island Replenishment/7 years	$13,000
Buoy Replacement	$14,000
Initial 5-year Mitigation Monitoring	$160,000
Yearly Sinking Fund	$799,000

Common Project Elements

Overview

The proposed dam and public access improvements will enhance portions of the Arkansas River corridor for the enjoyment of citizens and the public at large by creating new ways to experience the river. This goal has been the focus of many studies conducted since the 2005 Arkansas River Corridor Master Plan was adopted and is the subject of numerous community discussions. The schematic design discussed in this report was developed so that reliable cost estimates could be prepared and used as the basis for community leaders to make funding decisions.

The proposed dam and public access improvements involve the construction of three new low water dams and the modification of the existing Zink Dam. These improvements will result in four individual lakes between the Keystone Dam and the Tulsa/Wagoner county line. Within the overall river distance of 43 miles, the four lakes will occupy 17.4 miles. The remaining 25.6 miles of river length will remain similar to their current “braided river” state with water levels fluctuating in response to water releases from Keystone Dam. The four individual lakes and their corresponding river profiles are shown in Figures 1 and 2, respectively.

It is important to understand that Arkansas River flow depends on the release schedule from Keystone Dam and that proposed low water dams will serve to create a series of shallow lakes; they do not store or create flow in the river, nor do they provide any type of flood protection. The only exception is that the upper dam at Sand Springs will have the capability to release 3 feet of its 10-foot total depth when the Southwestern Power Administration (SWPA) is not generating power or when the U.S. Army Corps of Engineers (USACE) does not make a low flow spillway release. As a result, the gate operation at Sand Springs is interconnected with, and provides a benefit to, the river and the three downstream dams by providing some minimum river flow for enhancing water quality and flow in the river and through the lakes during limited periods of no flow. Additionally, during daily fluctuations in river flow due to power generation releases, dam gate operation at Sand Springs will have the capability to some extent to “smooth” the river flow rate throughout the day.

FIGURE 1

Locations of the Four Dams and Lakes

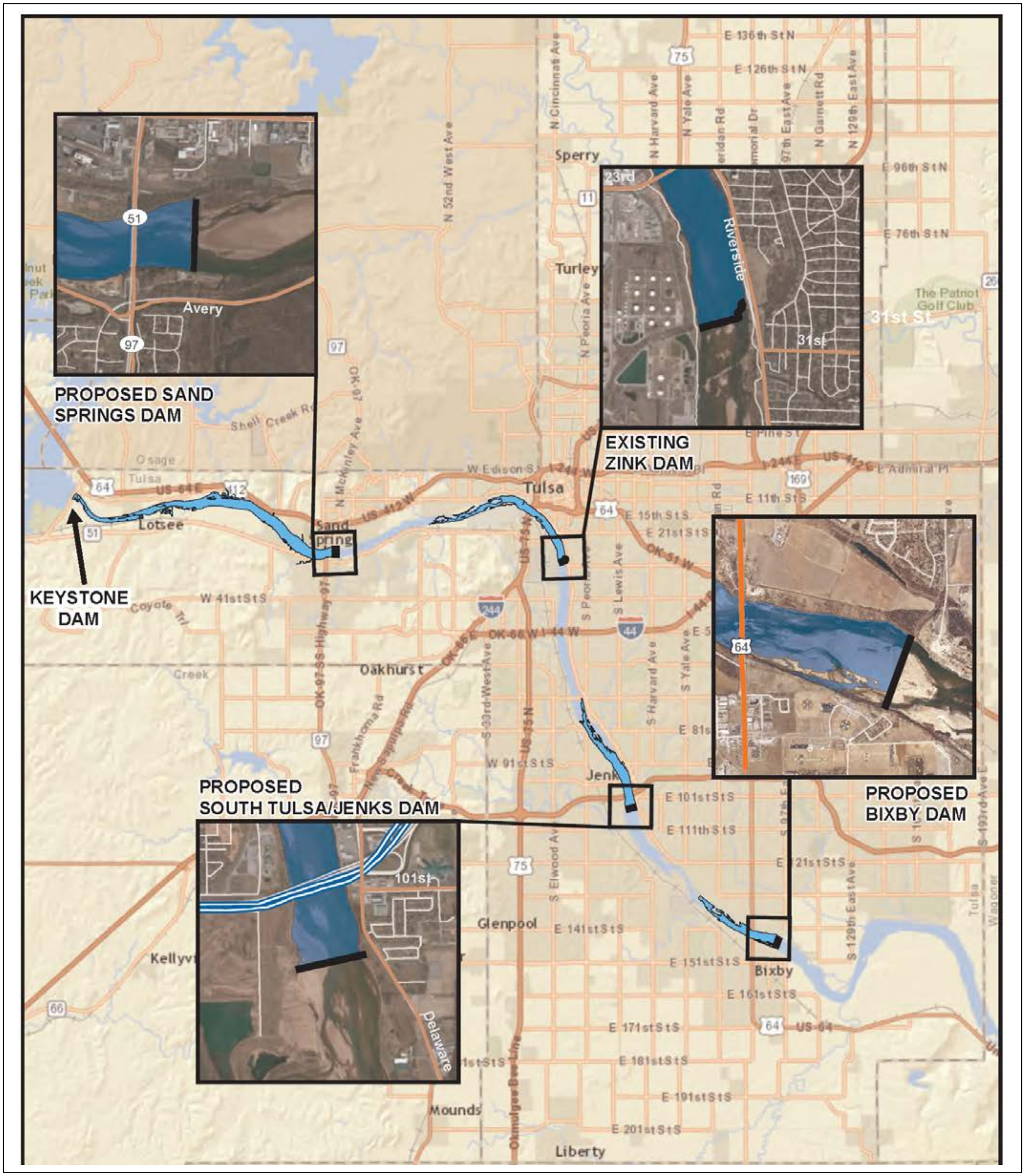


FIGURE 2
River Profiles of the Four Lakes

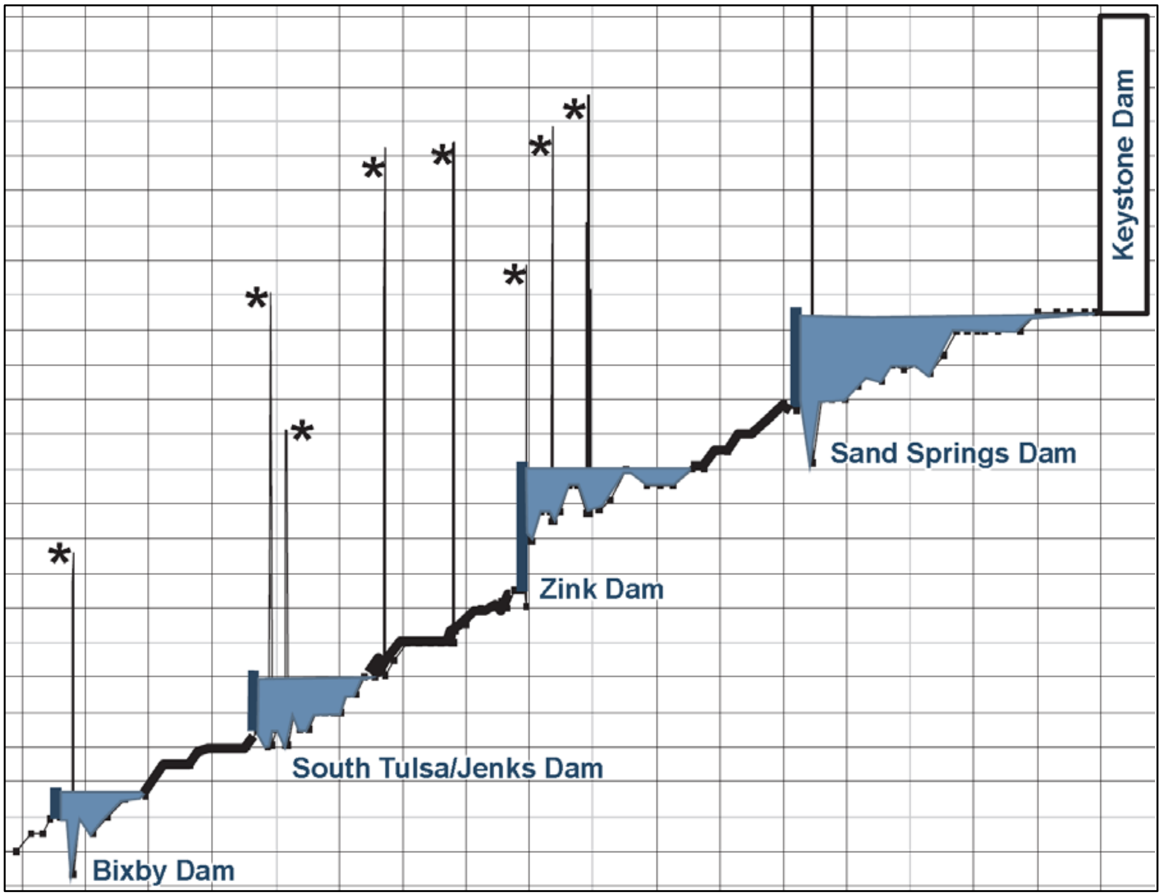


Table 1 provides the estimated flows and their duration based upon the release of 3 feet of depth, representing a stored volume of approximately 142,379,000 cubic feet (19 million gallons) from the Sand Springs Dam.

TABLE 1
Estimated Minimum Flows and Release Durations

Release Rate (cubic feet per second)	Duration of Release (days)
550	3.0
660	2.5
825	2.0
1,000	1.65

Each of the four dams associated with this project differs in size, amenities, and specific adjacent facilities. However, the technical aspects of these facilities share a common basis of design, which is included in the schematic design development and resulting cost estimate for each site. To avoid duplication, the common design elements shared between the dam sites are discussed in this section. These design elements include the following:

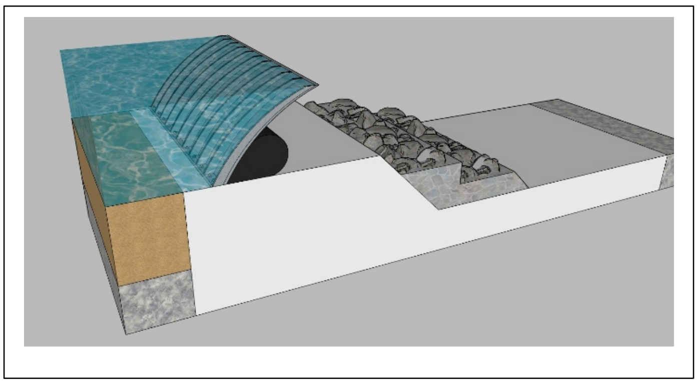
- Hydraulic roller mitigation during low to moderate flow conditions

- Pedestrian bridges (Sand Springs and South Tulsa/Jenks sites)
- Hydrology and hydraulic evaluations for confirmation of no adverse impact
- Riverbank stabilization/restoration
- Compensatory mitigation
- Public access improvements
- Recreational improvements
- Permitting
- Cost estimates

A discussion and summary of each of these common elements is provided below.

Dams

The proposed dams at Sand Springs and South Tulsa/Jenks span the Arkansas River and have similar overall geometry. Both dams have three different cross-sections: a fixed crest section, a 3-foot crest gate section, and a full-height gate section. The full-height gate section is 10 feet high at Sand Springs and 7 feet high at South Tulsa/ Jenks. The Bixby dam has a very different alignment to accommodate constraints where the dam abutment will tie into each riverbank. The Zink Dam will be raised in height and cross-section modified similar to that of the three new dams. The overall geometry of each section is driven primarily by geotechnical and hydraulic requirements. The proposed dam sections will be constructed of mass concrete founded upon the underlying shale bedrock and extending up to the design crest (or sill) elevation at each section to meet crest elevation and sediment management requirements.



The geology at the three dams generally consists of sandy alluvial overburden, which is underlain by shale bedrock. The overburden thickness varies at each dam site. The overburden material is loose, erodible, and relatively highly permeable and not suitable for supporting the proposed dam structure. It is recommended that the overburden be stripped and the dam be founded upon competent shale bedrock. The mass concrete of the dam structures will require minimal reinforcement and will incorporate a stepped downstream face to mitigate formation of a hydraulic roller for the range of design flows. A hydraulic roller is the hydraulic condition below a dam caused by the vertical drop in water surface that creates dangerous conditions.

The geometry of the stepped face is hydraulically determined; however, these steps have relatively low structural demands and could be constructed of mass concrete, grouted riprap, anchored stone blocks, or other material with density similar to concrete.

Each proposed dam section must be stable under the geologic, geotechnical, structural, and hydraulic loadings anticipated at each site. Results of geotechnical evaluations for these conditions are provided in the appendices. Preliminary geotechnical stability analyses indicate that pre-stressed permanent ground anchors will be required to resist sliding forces imparted by critical design loadings.

The proposed dams at Sand Springs and South Tulsa/Jenks will incorporate integral columns to support a pedestrian bridge across the river. These columns will be structurally connected to diaphragm walls that separate the various sections at each dam (fixed crest, crest gate, and full-height gate).

Two-dimensional stability evaluations were performed for the three cross-sections at each dam (fixed crest, crest gate, and full-height gate). Abutment configurations and dam end-walls have not been designed at this time; however future detailed abutment designs will need to consider seepage, scour, and stability needs at these locations within the floodway.

Geotechnical Dam Design

CH2M HILL reviewed available geotechnical reports and published geologic literature to estimate geotechnical properties for schematic design of the proposed project features. Overall geologic context for the dam locations was obtained by reviewing available geologic mapping data prepared by the U.S. Geological Survey and the Oklahoma Geologic Survey.

At the existing Zink Dam, the available information includes the boring logs from the original investigations for the dam, and a 2012 report prepared by Terracon for preliminary design of the planned modifications. At the proposed Sand Springs and South Tulsa/Jenks locations, a report prepared by Stantec (2008) includes subsurface data for geotechnical explorations performed on the riverbanks and within the river channel. At the seawall feature planned for the west abutment of the South Tulsa/Jenks Dam, a report prepared by Kleinfelder (2008) defines subsurface conditions along the proposed alignment. At the proposed Bixby Dam, a 2009 report prepared by Terracon for an unrelated project provides subsurface information at the riverbank approximately 300 feet from the proposed alignment.

The schematic design team also reviewed numerous other historical reports and data for other nearby projects such as roadway bridges and pipelines near the project. Although these historical reports contain useful data confirmation of general subsurface conditions within the river corridor, the projects and facilities they describe are generally located too far from the proposed dam locations to be of specific use the project. The subjects of the historical reports are often located more than 1,000 feet away from the proposed structures. Additionally, the subsurface information published in these reports is generally not specific to design of dams.

The available subsurface data provides a broad overview of subsurface conditions at the proposed project features; additional data will be needed for future designs. The available subsurface data indicate relatively similar subsurface conditions at Sand Springs, South Tulsa/Jenks, and Bixby Dam. Typical subsurface conditions are interbedded alluvial silt, clay, and sand overburden overlying shale bedrock. In some locations residual clay soils are found overlying the shale. The proposed seawall at South Tulsa/Jenks is also underlain by sandy alluvium overburden and shale bedrock. The existing Zink Dam is founded upon sandstone bedrock, which overlies shale bedrock at depth. At all dams, the alluvium overburden was found to be very loose to medium dense. Thin discontinuous layers of very soft to soft lean to fat clay were also encountered within the alluvium. Groundwater elevations along the riverbanks were not reported.

Typically, shale bedrock was encountered at depths ranging from 5 to 10 feet below the ground surface within the river bottom, to between 20 and 30 feet along the riverbanks, although the overburden thicknesses vary at each site. Many of the existing boreholes described in the available geotechnical reports were not surveyed at the time of drilling, complicating interpretation of the bedrock elevation at each site. The term, *shale*, generally describes several mapped geologic units that vary along the river corridor and include, from upstream to downstream, the Nelly Bly formation, the Coffeyville formation, the Memorial formation, the Seminole formation, the Nowata formation, the Wewoka formation, and the Senora formation—all of which are shale bedrock. Where encountered, in the literature, the shale is generally described as gray, thinly bedded, and highly weathered in zones (independent of depth below surface).

The shale bedrock is expected to provide suitable foundation conditions for the proposed dams. It is recommended at that the alluvial overburden materials and any residual clay soils be stripped from the bedrock surface at each new dam site. The dam foundation elevations selected at each site include excavation of the uppermost weathered portions of the shale to expose relatively less-weathered material suitable for foundation support—approximately 4 feet. The rock excavation also provides a buffer against the possible undulation of the bedrock surface, which may be possible according to available subsurface information. Excavation of this material also provides increased scour resistance if the soft shale erodes below the downstream toe. Revision of the recommended foundation elevation, either upward or downward, should be anticipated following review of subsurface information collected for detailed dam design.

The prepared shale foundation will provide suitable bearing capacity and resistance to structure settlement. Although future site-specific geotechnical investigations will confirm this, the literature suggests that the local shale units are generally massive and of low permeability. As such, under-seepage through the shale foundation or through rock joints is assumed to be acceptable so long as a tight contact is achieved between the structure and the foundation. This contact will be achieved in part by concrete turndowns, which are recommended below both the upstream and downstream ends of the structure foundation. These turndowns should extend 3 feet below the dam bottom elevation. The downstream turndown also to resist scour forces below the dam.

Preliminary evaluations were conducted for the proposed dam cross-sections under the critical design load cases as established by the USACE. The details of the geotechnical evaluations are described in the geotechnical appendix. These evaluations indicate that the new dam structures shown in the drawings are stable under anticipated static, flood, and seismic loading cases. The sliding forces developed by large net hydrostatic and sediment loadings on the upstream face of the dam structures will require installation of pre-stressed ground anchors to meet required factors of safety for structure stability. The geotechnical appendix provides the anchor forces for each structure.

Additional geotechnical data are needed for further design efforts for the proposed three new dams. Site-specific field borings, samples, and laboratory test data will be necessary for future design tasks to confirm several key items, including:

- Confirm elevation of bedrock along the alignment
- Confirm bedrock variation with depth to confirm selection of dam foundation elevation
- Complete detailed video and manual logging of the shale to identify bedding and potential seepage pathways
- Estimate shear strength of the shale bedrock
- Estimate interface strength between concrete and shale bedrock
- Investigate shale durability, including potential for slaking
- Investigate soil conditions at the abutments, retaining walls, and floodwalls, including assessment of permeability, density/consistency, compressibility, and strength

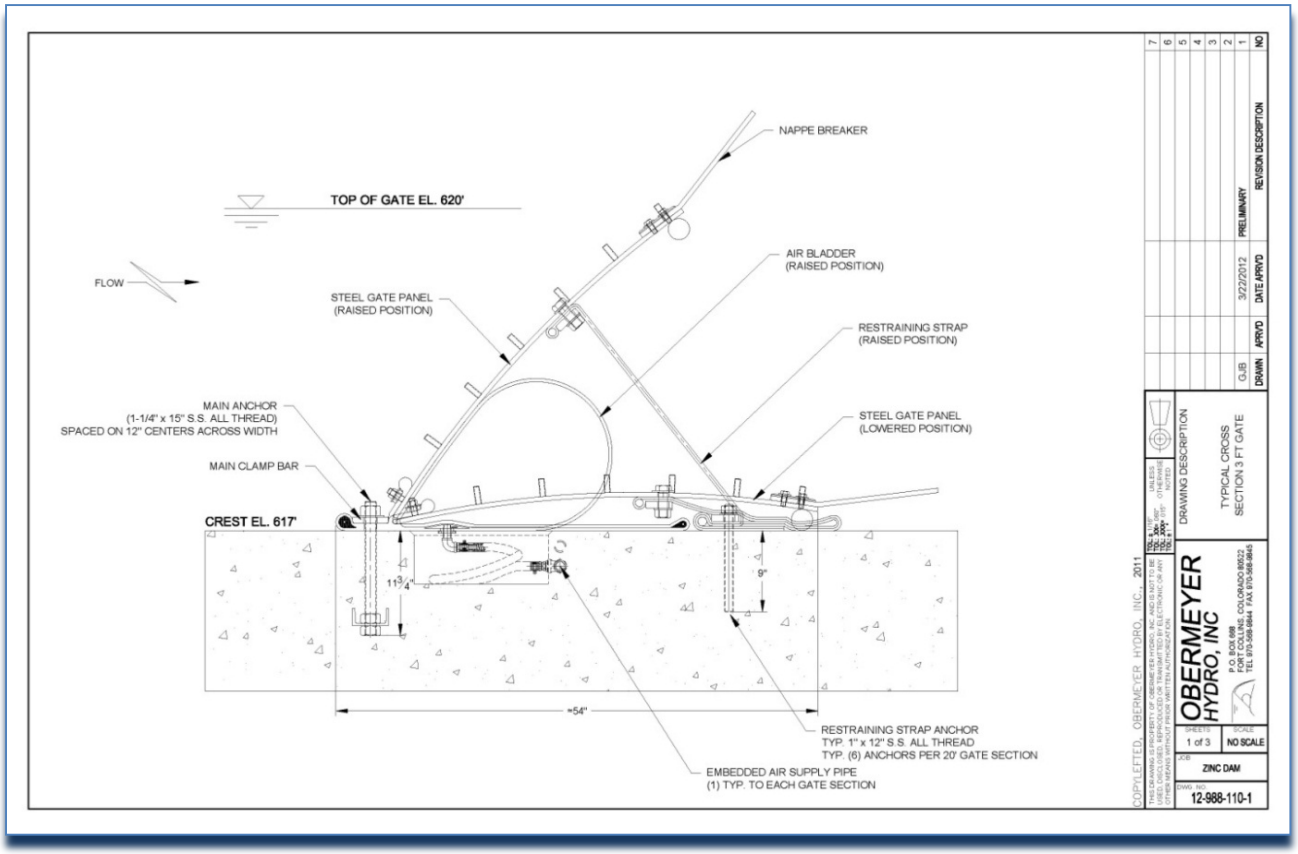
Gate Selection

The Zink Dam preliminary design determined that the Obermeyer Hydro, Inc. gate was the most cost-effective type of gate. It is suited for multiple project purposes and the wide range of hydraulic conditions that will be encountered on the Arkansas River. The Obermeyer gates are made in the U.S. and are specifically designed for durability and ease of operation without the need for a superstructure to control gate operation.

A similar alternative gate for this type of application would be an inflatable rubber dam (without the steel gate leaf); however, these structures don’t provide the hydraulic control available with the Obermeyer Hydro, Inc. gate and the largest manufacturer of this gate no longer produces it. Another alternative is the hydraulically operated Bascule gate, similar to those currently installed in Zink Dam. However, due to previous experience with these types of gates with hydraulic operating systems and their associated maintenance requirements, they were not considered for use. Figure 3 shows a detailed cross-section of the air bladder operated gate proposed for in each of the dams.

FIGURE 3

Cross-Section of Obermeyer Hydro, Inc. Air Bladder Gate



Gate Layout and Operational Control

Total gate areas for each of the three new dams were based upon the initial HEC-RAS modeling done as a part of the 2009 Preliminary Project Management Plan (PPMP). A specific gate layout was developed for each dam using both full-height and crest gates to provide for the operational level control, allow sediment passage, and address the Federal Emergency Management Agency's (FEMA's) floodway requirements. The total gate area was divided between full-height and crest gates. These gate lengths, along with the fixed dam crest length and pier widths, made up the overall dam length. Table 2 summarizes the gate types and overall dam length in feet for each of the dams.

TABLE 2

Summary of Gate Height and Length by Project

Location	Lake Depth at Dam	Full-Height Gate Length	Crest Gate Length	Fixed Crest and Pier Length	Total Dam Length
Sand Springs	10	608	704	588	1,900
Zink	10	432	400	197	1,100
South Tulsa/ Jenks	7	600	560	690	1,850
Bixby	4	250	0	2,584	2,784

* Length of dam connection via the recreational flume not included

Crest Gates

The crest gates consist of 3-foot-high bladder operated gates that are located along the length of the dams at elevations above the bottom, or sill, of the dam structure. Because of their size, these gates can be easily operated to minimize change in lake levels as power generation flow variations are experienced in the river flow.

Full-Height Gates

Full-height gates will provide additional hydraulic capacity, beyond that of the crest gates, needed to address FEMA's objectives when flood flow releases are experienced from Keystone Dam. Full-height gates also extend to the bottom of the dam sill and when fully open or in the down position, will maximize the sediment passage downstream at each of the dams, and will provide for fish egg passage as is anticipated for the Bixby and South Tulsa/Jenks locations.

Fixed Crest Dam Sections

A portion of each dam will be non-gated, or fixed-crest. The fixed crest portion will be 6 inches above the gate tips. This elevation difference will direct flow through the gated section and minimize adverse hydraulic conditions downstream of the full-height gated sections. This 6-inch depth also provides response time as the gates begin to open to maintain lake level. The fixed crest dam sections next to each bank are anticipated to be 1.2 inches lower than the gate elevations so that water initially flows over these fixed dam sections, creating a wetted surface next to the bank and providing an aesthetic water cascade, while discouraging the public from accessing the dam's downstream face.

Lake Level Control

Each of the lakes will have a level sensing instrument(s) to monitor and control water levels by varying the gate positions in accordance with the river flow. Lake levels will be controlled by initially opening crest gates and then opening full-height gates. Typically, as the river flow increases and lake level begins to rise, the control system will lower a section of crest gates, allowing release of water. If the lake level continues to rise, additional crest gate sections will open sequentially, until the level is stabilized. When all of the crest gates are fully open, and if the river flow continues to increase, a full-height gate section will open. If the river flow continues to increase and the level continues to rise, another full-height gate section will be lowered. Crest gate operation will accommodate river flow conditions that fall within the capacity of a full-height gate section. This sequence of gate operation will continue as the river flow continues to increase until all gates are fully down. With all gates down, the dam will essentially have no impact on the river's capacity and resulting hydraulic elevation. The sequence of gates closing (raising up) will be the reverse of the opening sequence, as flow in the river decreases, and as the river level begins to recede.

Under daily river flow conditions when there are no flood releases from Keystone Dam, the typical flows are the result of releases from SWPA's two power generation units, each discharging approximately 6,000 cubic feet/second (cfs). This typical 6,000–12,000 cfs flow range can be accommodated by the crest gates at both the Sand Springs and South Tulsa/Jenks locations. At Zink Dam, the crest gates will accommodate up to approximately 6,800 cfs and then the full-height gate capacity will be required for higher flows. At the Bixby location, opening all of the 4-foot gates will provide about 6,300 cfs; flows in excess will pass over the entire length of the dam.

Additional information on this can be found in the Hydrology and Hydraulics section.

A signal from lake level instruments, installed in stilling wells in each of the lakes to dampen the influence of wave action on the lake surface, will control the gates. The level signal will be processed according to the control logic in a programmable logic controller that will control operation of the dam gates through a compressor air system for operation of air bladders. Bladder inflation and deflation ultimately close and open the various gate sections. The system will automatically control and manage gate position, monitor and control the gates and compressors, and monitor and control the reservoir lake level. The gate operation will not allow a flow of more than 6 inches over a gate.

This will eliminate a retentive downstream wave or hydraulic roller and associated safety hazards. A local signal at each dam will provide notification as desired as any gate lowering operation begins to accommodate an increase in river flow.

Earlier environmental studies identified upstream fish migration and downstream egg passage as important for any dam downstream of the existing Zink Dam. Initially, the schematic design team proposed that a type of "fish ladder" be integrated into the South Tulsa/Jenks Dam. However, through discussion with the federal and state agencies, the team determined that a fish ladder would be marginally effective for upstream passage due the fish species present. As a result, the team determined that it would be more effective to operate the dams with the gates in the down position during the spawning season when the river flow will allow fish passage upstream as well as provide for egg passage downstream. This requirement for fish passage is also anticipated at the Bixby location. During the fish spawning season, March through May, gate operation at the South Tulsa/Jenks and Bixby dams will be coordinated with the actual river flow conditions and will be lowered during periods of flow that are advantageous for fish and egg passage. During these times and flow conditions, the lake levels will be lowered to accommodate this environmental condition. Also, during periods of higher flows, sediment passage downstream can also be enhanced with the gates in the full-down position at all of the dam locations. An operations plan will be developed in the future to coordinate dam operations with the USACE.

Risk Considerations

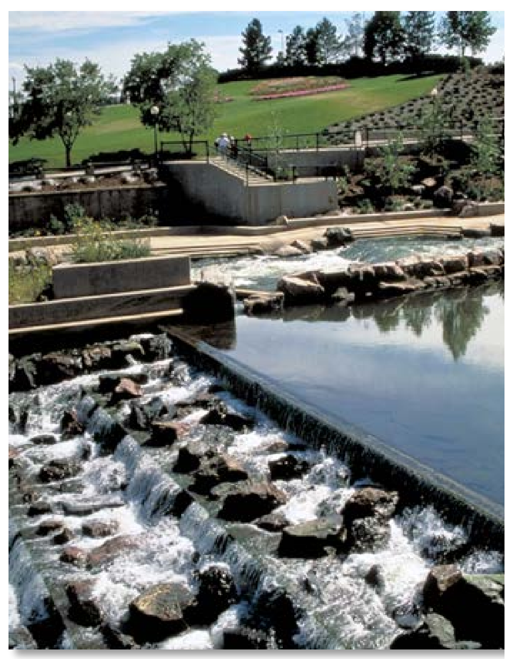
Floodplain/Floodway

FEMA's goal is directed at hydraulic conditions before and after modifications within a river channel. The goal is to avoid causing the water surface to rise above the elevation of the current regulatory 100-year flood event to ensure no adverse, cumulative impact. The designs for all of the dams provide additional gates to mitigate the floodway impacts of the dams. Each of the dams has been subjected to a rigorous hydraulic analysis to determine what impacts might result from its construction. Further detail is included in the Hydrology and Hydraulics section.

Modified Hazard Reduction Implementation

One of the stated primary goals of the project is to reduce hazards at the existing Zink Dam and to avoid the creation of hydraulic rollers at the other three new dam locations. The proposed design concept at fixed crest and crest gate locations will be to construct the downstream face of the dam with a series of steps that disrupt the formation of hazardous hydraulic roller conditions. The gate operational plan (described in the Gate Layout and Operational Control section) will prevent flow over the top of any full-height gate greater than 6 inches during non-flood release conditions. The purpose of the full-height gates is to allow sediment to pass downstream and to provide the hydraulic open area to meet the FEMA goal.

FIGURE 4
Rock Step Dam on the South Platte River, Denver



There is no intent to allow individuals to pass over the dam or through gate openings for recreational purposes. To support this intent, the design includes the installation of signage, warning system, and cabled buoys upstream of the dams to warn the public of potential dangers.

Drowning Risk

Nearly all low-head diversion dams are a potential safety risk due to overly retentive hydraulics or hydraulic rollers that can typically form downstream. In this reach of the Arkansas River, drownings have been recorded at both the Sand Springs re-regulation dam before it was removed, and at the existing Zink Dam. A major component of the hydraulic design of the new low water dams and the modification to the Zink Dam is to reduce the occurrence of overly retentive hydraulics or roller conditions that create dangerous conditions. At a certain river flow, the conditions become such that being on the river poses a risk for a recreational user as well as a potential rescue team, should it become necessary. In advance of the river flow reaching 40,000 cfs, it would be reasonable to close the river to recreational users because it is the upper deign limit of mitigating overly retentive hydraulic conditions. In addition, it is recommended that a public safety plan be developed that includes public information, warning signs, and specific rescue plans.

Hazard Mitigation

The schematic design concepts greatly reduce spillway hazards by mitigating the formation of overly retentive hydraulics, or hydraulic rollers.

Physical hydraulic roller mitigation improvements primarily consist of constructing a series of steps on the downstream side the dam. The preliminary design of the hydraulic roller mitigation incorporates 6-foot-wide by 2-foot-high steps, based on "Hydraulic Design of Stepped Spillways and Downstream Energy Dissipators" [Chanson, H. (2001), Dam Engineering, Vol. 11, No. 4 pp. 205-242].

Several precedents exist for the anti-roller step design, including Confluence Park in Denver (Figure 4), and Yorkville Dam in Illinois (Figure 5).

FIGURE 5
Yorkville Dam on the Fox River, Illinois

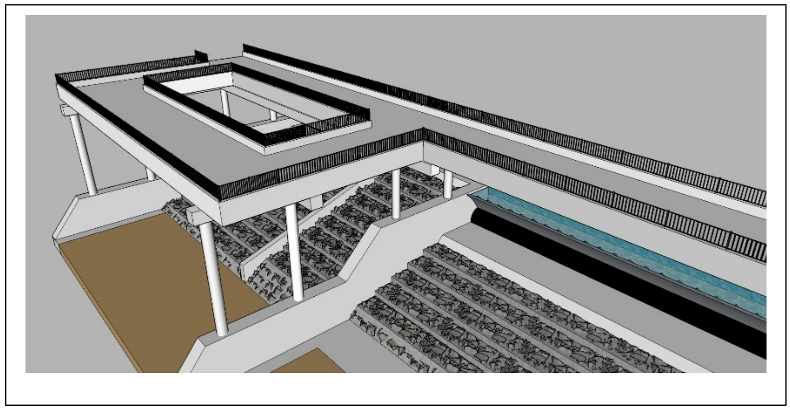
Dam Break Analysis

The proposed low water dams create relatively shallow lakes; for a low concrete dam founded on rock, it is highly unlikely that a large breach would develop. As a result, a dam break analysis would not be effective and is not recommended. However, with a scenario such as complete and instantaneous failure of all the pneumatic bladders for the new Obermeyer gates there would likely be a short-term surge downstream, but this is a large river channel where a flow increase from 10,000 cfs to 50,000 cfs would not pose much surge and it would be contained within the existing river channel.

Pedestrian Bridges

Pedestrian bridges have been included for the Sand Springs and South Tulsa/Jenks Dam locations. Given the Bixby Dam location, configuration, and local preferences, a pedestrian bridge was not a part of the project components and therefore is not included. Modifications and rehabilitation of Zink Dam pedestrian bridge are part of an ongoing and previously funded project related to the double-decking of the pedestrian bridge. A budget allowance for this work is included in the cost estimate for the Zink Dam improvements. The primary function of the two new pedestrian bridges is to provide for pedestrian and bicycle traffic connecting both banks of the river. These bridges will provide a 20-foot width for pedestrian and bicycle users, which would match the current width of the River Parks trail system. Additionally, there will be several areas along the bridge with expanded width and extended areas for seating, overlooks, and fishing. The work on Zink Dam pedestrian bridge will provide the primary functions of the new bridges, but will use existing pedestrian bridge structural elements and dimensions. Bicycle traffic will be addressed by double-decking the bridge.

Much debate and consideration took place relating to the new pedestrian bridge's design that would provide access for dam/gate maintenance tasks and potential debris removal. Providing for this capability required that the bridge structure be designed to carry the wheel loads associated with a portable crane, as well as the possible live load associated with pedestrian crowds that could gather on the bridge. The resulting vehicle loadings to perform such maintenance tasks would require that the bridge structure be capable of supporting the wheel loading in excess of a 20-ton vehicle. This loading has a significant impact on the bridge structural design and the construction costs. Since the maintenance requirements on the dam and gates are infrequent and can be accomplished during river low-flow periods, the schematic design determined that dam and gate maintenance could be effectively accomplished by access from the streambed and without a bridge structure above.

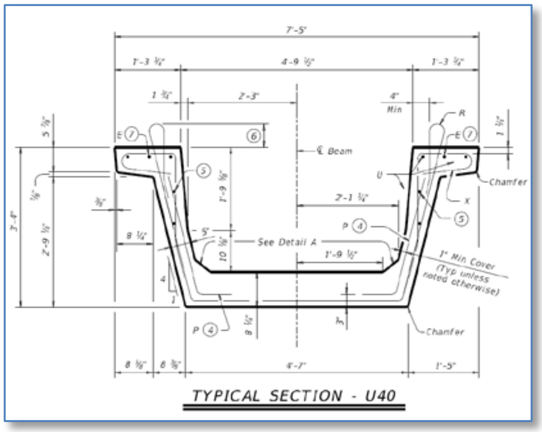


The team considered both 50-foot and 100-foot bridge spans. The 100-foot span design is more feasible using a 1-ton vehicle loading requirement. This consideration, along with the desire to have fewer bridge piers and their associated hydraulic impacts, resulted in the selection of 100-foot spans. Additionally, the bottom clearance or "low chord" of the bridges will be set at the elevation equal to the elevation produced by the USACE levee design flow (350,000 cfs). The primary benefit of this elevation is that it also mitigates any negative impacts on the river hydraulic capacity and results in the new pedestrian bridges surface being approximately 23 to 24 feet above the lake surface.

The proposed new bridge cross-section is anticipated to be constructed of two pre-stressed, 100-foot concrete girders with a concrete deck spanning across the two girders. A typical pre-stressed concrete girder is shown in Figure 6. Additional options to meet the 100-foot span structural support will evaluated during the design process to confirm that the most cost-effective construction solution is implemented.

FIGURE 6

Typical Concrete Bridge Girder



Hydrology and Hydraulic Evaluations

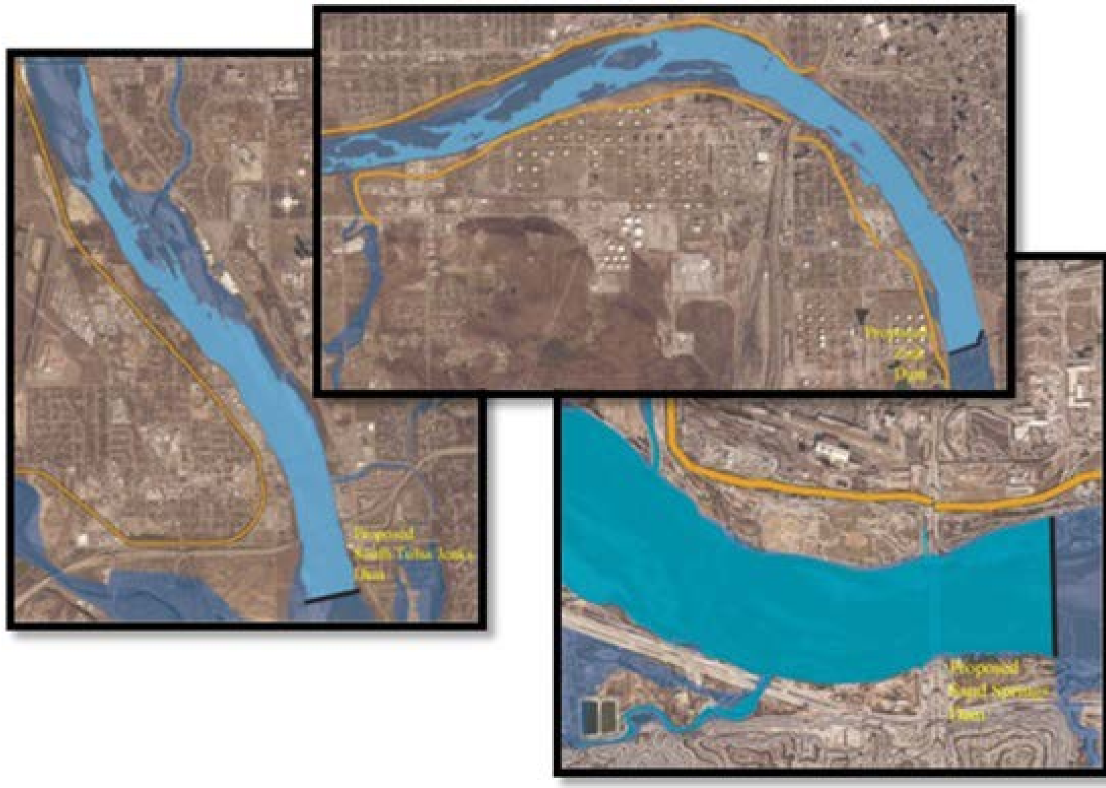
Each of the dam locations and associated public access/recreational improvements was identified during development of the 2009 PPMP, which included an initial assessment, through hydraulic modeling, of any impacts to the river hydraulic capacity, including the required gate area openings.

The hydraulic model has since been updated, including the addition of a detailed topographic survey for the Sand Springs and South Tulsa/Jenks locations. A revised existing conditions model was updated using the newly acquired topography. The gate configurations have been further defined and also were updated in this model, and pedestrian bridges were added; the 2009 PPMP did not include pedestrian bridges at these two locations.

The dam and bridge configurations are modeled with inline structures for the dams and gates and immediately downstream of the pedestrian bridge. The primary purpose of this modeling is to analyze the FEMA flow rates as well as the USACE levee design flow and determine if the addition of the structures have an adverse impact on the surrounding properties. The goal of the modeling is to obtain a no rise condition for each of the dams. If that cannot be achieved in a feasible manner, the team will analyze the increase in elevation to determine any adverse impacts. If there are no adverse impacts, then the proper permitting process would follow for each of the regulatory agencies, including the local jurisdictions, FEMA, and USACE.

For the local jurisdictions that have a no rise criterion, a formal variance request would be submitted. This would go through the review process after the design and modeling were submitted. For FEMA, a

FIGURE 7
Proposed Inundation Pools and FEMA Floodplains



Conditional Letter of Map Revision (CLOMR) application would be completed and submitted. Typically, if no structures are impacted and the levee freeboards during the 1 percent annual chance event are not impacted, the CLOMR applications are approved. For USACE permitting, a Section 404 review would be completed prior to construction.

As Figure 7 shows, the proposed inundation pools (lighter blue) and the FEMA 1 percent annual chance (100-year) floodplains (dark blue) do not touch the levees (tan). Therefore, the new pools and any of the slight increases in the 1 percent annual chance elevations will not have any impacts to levee performance.

Public Access/Recreational Facilities

The four dam locations and resulting lakes will create new opportunities for public recreational use. Accordingly, the schematic design team developed opportunities for public access to the dams, lakes, and river, as well as recreational improvements, as essential project components. These concepts were initially developed during previous river planning studies and formalized through public meetings and agency review during development of the 2009 PPMP. These concepts were then more specifically defined and developed with involvement by each local community during this project. Improvements include multi-use bike/pedestrian trails, nature trails, overlooks, water access such as docks and boat launches, restrooms, picnic shelters, playgrounds, water features, fishing areas, parking, and other related elements. Specific facilities envisioned and included in the cost estimate are identified in each of the project location descriptions.

The Infrastructure Task Force, along with individual communities, will determine how these public access and recreational improvements are included in the projects, according to the available funding.

Overall Design Criteria

Top priorities for design of public access and recreation facilities for each of the four project locations focuses on safety for the recreational users, creating an inviting outdoor space for the public to enjoy, and construction of facilities to withstand the periodic flooding events within the river corridor. Past flooding events have caused substantial damage to existing facilities due to the destructive force that up to 300,000 cubic feet per second flows can create. In addition, low-cost maintenance is desired to enable the responsible entities to properly maintain the facilities to provide the level of service the public will desire.

Bank Stabilization

The existing riverbank areas along the Arkansas River vary in condition, from stable to highly unstable, relative to erosion potential. As a part of this project, the schematic design team assessed the riverbank within the new lake areas and estimated costs to alleviate further bank erosion. The team assessed stream bank erosion potential by identifying and classifying the typical conditions along the existing stream banks. Bank failure mechanics can be complex, but generally speaking, the geometry of the bank, the geotechnical properties of the bank material, and the bank stratigraphy are particularly important. Existing bank geometry and surface conditions are two primary indicators of future erosion potential with or without the dams. However, bank conditions in newly formed lake areas could be adversely affected if more frequent and or rapid dewatering of saturated cohesive soils occurs, or the newly created pools would expose banks to potential wave action that had previously not existed.

Compressive geotechnical field studies and analyses of over 25 miles of riverbank were not practical for the scope of this effort but will be performed as part of the future design effort. For purposes of developing a quantity-based estimate, an emphasis was placed on the reviewing bank geometry and existing conditions of the bank surface, such as whether or not existing revetment materials (riprap, concrete rubble, etc.) are presently located on the bank. Given the significantly large spatial extent of riverbank along the pools, the team conducted a desktop assessment to quantify the existing bank geometry and identify existing bank surface conditions along the pools. The following data sources were used for the desktop assessment:

FIGURE 8
East Riverbank – South Tulsa/Jenks

- Digital elevation model generated from a LiDAR survey conducted in 2008
- High-quality aerial imagery depicting 2014 conditions
- Low-altitude helicopter Immersive media video of the riverbanks flown in 2009

The team evaluated the digital elevation data and aerial images and assigned an elevation to both the top and bottom (or toe) of the riverbank at multiple locations that characterized hundreds of reaches of riverbank based on bank slopes and heights, and changes in bank slopes and heights. Bank slopes were assessed using two different toe locations:

(1) The inflection point or grade change between the bank face and the river bed
(2) The intersection of the bank and the equivalent elevation of the top of the dam associated with a given pool

Because the later approach is slightly more conservative, yielding steeper bank slopes, it was used for the basis of the bank stability cost estimate. Bank slopes were calculated at approximately 530 cross-sections over approximately 25.4 miles of riverbank at the four locations.

A hierarchy of screening criteria was used in the desktop assessment to identify and exclude reaches of riverbank for which bank-stability treatment was not recommended. Riverbanks subject to pool depths of less than 1 foot were eliminated from further consideration since the amount of inundation is assumed to have a negligible effect on bank stability. Similarly, riverbanks with heights of less than 5 feet were eliminated from further consideration because it was assumed that the consequences of erosion were negligible. Bank slopes flatter than a 2:1 slope were eliminated from further consideration since the angle of repose for sandy soils is typically 1.9:1 or steeper. Bank reaches were eliminated from consideration for treatment in the following sequence:

- Pool depths of less than 1 foot
- Bank slopes flatter than a 2-horizontal:1-vertical
- Bank heights of less than 5 feet
- Areas that are adequately riprapped

For all four pools combined, approximately 5 miles of riverbank remained candidate bank areas for stabilization following the screening process (Table 3). These riverbank areas were then further evaluated, visually, through the use of aerial mapping and low-altitude helicopter Immersive Media video. Reviewing the imagery allowed the team to refine or modify interpretation of the calculated bank geometry data and initial riprap identification. It also served to identify particular bank areas where field verification of the bank slope or surface conditions was necessary. Bank reaches that were observed to be disturbed and or heavily modified due to active industrial operations were excluded from treatment consideration. It is assumed such reaches will continue to be altered, modified, and or stabilized as required by the industrial operators.

Field visits to select locations were conducted to confirm the desktop assessment of the riverbank conditions. These site visits confirmed that the underlying cause of existing bank failures was directly related to the absence or lack of stream bank "toe" protection in the majority of locations. Some areas of bank erosion were caused by surface overflow conditions and had no connection to the creation of the proposed lakes. The site visits also served as an opportunity to associate one of the three bank stabilization treatment options with the bank stabilization needs as observed in the field. Each of the project location sections in this report includes the recommended bank stabilization approach for the bank conditions, along with estimated costs.

TABLE 3
Bank Stabilization Data Summary and Recommended Areas for Stabilization by Project

Summary of Bank Stabilization Evaluation (all values in linear feet)			
Location	**Total Bank Length**	**Eliminated Through Screening Criteria**	**Candidate for Stabilization**
Sand Springs	53,385	42,567	10,818
Tulsa Zink	30,844	28,457	2,387
South Tulsa/ Jenks	33,365	26,924	6,441
Bixby	16,566	9,594	6,972
Total	134,160	107,542	26,618

It became clear through viewing the riverbank areas documented by Immersive Media video and in conducting the site visits that the primary cause of existing bank failures is the absence of bank toe protection. Therefore, all of the bank treatment options considered were chosen to provide toe protection under varying bank situations; these are shown in the bank stabilization drawing in the appendices. These dimensions are considered typical for these treatment types and are used for the purpose of computing material quantities for cost estimating purposes. A variety of stable stone (and concrete rubble) sizes were observed in the field. The median axis of several individual stones were measured at two different sites where stable riprap revetments were observed. An average (n = 15) median diameter (D50) of 10 inches was observed along the toe of the east bank just south of 71st Street (Figure 9); an average (n = 15) D50 of 18 inches was assumed for the basis of bank stabilization volume calculations.

Based upon the bank stabilization desktop assessment, the bank treatment options, and dimensions of rock coverage, rock quantities were calculated to develop the cost estimate for bank stabilization. The quantities for each of the four locations are summarized in the Table 4.

TABLE 4
Bank Stabilization Material Volumes by Project

Rock Quantity Estimates	Total	Sand Springs	Zink	South Tulsa/ Jenks	Bixby
Total Length (feet)	134,160	53,385	30,844	33,365	16,566
Treatment 1, Length (feet)	15,907	7,719	1,616	2,774	3,798
Treatment 1, Volume (cubic yards)	67,645	34,857	5,912	11,397	15,477
Treatment 2, Length (feet)	10,711	3,099	771	3,667	3,174
Treatment 2, Volume (cubic yards)	23,931	9,977	779	8,254	4,921
Total Treatment, Length (feet)	26,618	10,818	2,387	6,441	6,972
Total Treatment, Volume (cubic yards)	91,576	44,834	6,692	19,652	20,398

Compensatory Mitigation/Preservation

The proposed construction of the low water dams and resulting lake impoundments will result in the need for compensatory mitigation to offset the unavoidable impacts to federal jurisdictional wetlands, surface waters, and protected wildlife species. The specific mitigation requirements will not be known until preparation of permits for each of the individual projects, including the Section 404 permit, and until the regulatory agency review and approval process has occurred. To develop budgets that represent potential costs for mitigation (implementation rather than planning, permitting, or design), estimates were developed based upon projects that have occurred as part of the 2009 PPMP and other more recent project experience within the banks of the Arkansas River requiring Section 404 permitting and associated mitigation activities. Recent project experience with the Tulsa District USACE has provided insight regarding regulatory agency expectations, mitigation strategies, and implementation level of effort and cost.

The proposed low water dam projects provide the opportunity to improve and restore Arkansas River ecological functions throughout the project corridor from the Keystone Dam south to Bixby. Habitats such as surface waters, marshes, riverbanks, and riparian buffers have the opportunity to be stabilized or improved through the principle project components and provide associated mitigation benefits. The intended result would be to provide improved ecological functions for wildlife and water quality within the reach of the river adjacent to the urban Tulsa environment.

Description of Potential Impacts

In order to develop requirements for mitigation, an estimate of the potential impacts to habitats used by protected wildlife species and jurisdictional areas was needed. A more formal quantification of potential impacts will occur as part of future permitting efforts through continued agency coordination, field assessments, environmental studies, and surveys. A desktop assessment was performed to develop rough projections to base needed mitigation efforts and associated costs. Potential impacts from the project components identified for this assessment include:

- Filling of wetlands and riverine sand bar habitat from the construction footprint of the dam (that is, the structural components)
- Inundation of wetlands and riverine sand bar habitats from the created lake pools
- Loss of least tern nesting habitats from the dam construction and lake pool inundation

These impacts were estimated based upon the following parameters:

- Dam footprints (acres)
- Lake pool footprints (acres)
- National Wetlands Inventory (NWI) mapped aquatic habitats (acres)

The existing Tulsa Zink low water dam is proposed to be elevated, subsequently creating a larger lake pool area. The construction activity will result in an increased dam footprint of 1.0 acre, which will require the placement of fill material that will permanently impact wetland and riverine sand bar habitats within the expanded footprint. The new lake pool areal extent will increase by approximately 900 acres.

Using geographic information system (GIS) tools, the preliminary dam design drawings and projected lake pool inundation areas were overlain with National Wetland Inventory (NWI) coverages downloaded from the U.S. Fish and Wildlife Service website. The estimated acres of each impact type are presented in Table 5.

TABLE 5
Estimated Acres of Each Impact Type

Location	Wetlands (acres)		Riverine Sand Bars (acres)	
	Dam Footprint	Lake Pool	Dam Footprint	Lake Pool
Sand Springs	0.7	68.5	2.1	972.2
Tulsa Zink	0.0	20.9	1.0	281.3
South Tulsa/Jenks	0.0	6.0	1.9	563.1
Bixby	0.0	4.2	2.7	347.9
Total	0.7	99.6	7.7	2164.5

The placement of fill material for the construction of the low water dams will result in the permanent loss of habitats within the associated dam structural footprint. However, wetland and riverine sand bar habitat occurring within the footprint of the created lake pools will be converted from the existing aquatic resource to a more frequently flooded or open water aquatic resource that itself has ecological functions and benefits. The difference in the loss of existing functional values and those gained by the creation of the lake pools will be enumerated during the permitting process through use of an accepted functional assessment evaluation. This approach was presented to the USACE Tulsa District's regulatory staff and agreed upon as acceptable during a March 2015 pre-application meeting for the South Tulsa/Jenks low water dam project. The specific method to be used for the functional assessment of the pre- and post-project aquatic resources has not been agreed to at the time of this cost estimate. The result of the functional assessment evaluation is anticipated to be a reduction in the mitigation needed to compensate impacts to aquatic resources from the inundation of the lake pools. For the purposes of this cost estimate, the change in function of the aquatic resources is represented as a reduction in the mitigation to impact ratios and is further discussed below.

Potential Mitigation Strategies

The goal for the development of mitigation strategies is to fully compensate the unavoidable impacts from the proposed projects, while seeking opportunities to provide an overall improvement to the Arkansas River corridor in the vicinity of the projects. Proposed compensatory mitigation strategies presented for this cost estimation follow guidance provided in the *USACE and EPA document Compensatory Mitigation for Losses of Aquatic Resources, Final Rule* (2008) and USACE Tulsa District's *Aquatic Resource Mitigation and Monitoring Guidelines* (2004). USACE guidelines define the strategies as follows:

Restoration – the reestablishment of aquatic resource characteristics and functions at a site where they have ceased to exist or exist in a substantially degraded state.

Enhancement – an activity conducted in existing aquatic resources that increases or improves one or more aquatic functions or characteristics.

Creation – the establishment of an aquatic resource where one did not formerly exist.

***Preservation** – the conservation or dedication of ecologically important existing aquatic resources in perpetuity through the implementation of appropriate legal and physical mechanisms to prevent its destruction or degradation in the future.*

Preliminary mitigation activities identified for this cost estimation include opportunities for each of the four compensatory mitigation strategies described above. For the unavoidable losses of wetlands, mitigation will likely include the enhancement to wetland areas outside of the lake pools, creation of lake-fringe wetlands, and preservation of existing wetland habitats outside of the lake pools. Enhancement activities would likely include the removal of invasive/nuisance plant species along with the planting of native species. Wetland creation would likely take place at the upstream shorelines of the permanent lake pools by planting native wetland plant species where water levels are commonly shallow.

For the unavoidable losses of riverine sand bar habitats, mitigation will likely include the enhancement and preservation of sand bars outside of the lake pools. Enhancement activities would likely include the removal of invasive/nuisance plant species. Riverine sand bar potential habitat preservation would be accomplished through legal instruments. Mitigation for impacts to Arkansas River sand bar habitats will also likely include riparian buffer habitat restoration and preservation. Riparian buffer habitat restoration would include planting of banks and riparian corridors above the high bank of the river with native vegetation species. Preservation of existing riparian buffers would be through legal instruments.

Least tern habitat can be more reasonably projected for the three new dams because of consultations during the 2009 PPMP, the Zink Section 404 permitting process, and recent experience on the Section 404 permit for the Muscogee (Creek) Nation and the resulting requirements. Based on this experience, each of the three new dams will also include the construction of a new island that provides 2 acres of new least tern habitat above the elevation of the SWPA power generation flow of 12,000 cfs. The islands will be constructed based upon the design criteria presented in the least tern island design document in 2003 by the Bio-systems & Agricultural Engineering Department, Oklahoma State University. At lower non-generating flows of 1,000 cfs and corresponding lower water levels, the islands will be approximately 5 acres in size. Construction of these islands are included in the project cost estimates and periodic sand replenishment that will be required to maintain the islands for the life of the project.

Other potential mitigation strategies that have been identified that offer benefits to the Arkansas River corridor near the proposed projects include restoration of existing degraded streams that are tributaries to the Arkansas River. The 2009 Ecosystem Restoration Plan by the USACE identified the areas around both Polecat and Prattville Creeks as possible restoration opportunities. Since that report was prepared, extensive work has already been accomplished at the mouth of Prattville Creek by Public Service Company of Oklahoma consisting of riprap protection for a power line tower that included both the river channel and Prattville Creek areas. Rock bendway weirs were also installed along the Arkansas Riverbank near the tower. Additionally, the proposed South Tulsa/ Jenks dam location near Polecat Creek was moved approximately 0.3 mile upstream due to improved hydraulic conditions. Both of these occurrences change the basis for previously recommended restoration opportunities at these sites, but opportunities for some mitigation are still considered to be available in these two areas.

Potential Mitigation Requirements

The USACE District's Mitigation Guideline document provides ratios used for calculating the amount of compensatory mitigation needed to offset impacts. These ratios vary by type of habitat being impacted, type of mitigation proposed, proximity of mitigation area to impact area, and lag time until mitigative effect is realized. For the purpose of this cost estimate, the following assumptions were made regarding mitigation strategies and associated ratios:

- All mitigative strategies will be "in-kind," meaning the aquatic resource provided through mitigation will match the aquatic resource impacted.
- All mitigative strategies will be "onsite," meaning within the Arkansas River and within proximity of the project.
- Impacts to wetland and riverine sand bar habitats from the placement of fill within the dam footprint would be permanent and mitigated at a ratio of 1.5:1 (mitigation: impact).
- The accepted functional analysis tool will reduce mitigation ratios for wetland habitats converted to open water habitats from the inundation of the lake pool. These impacts to wetlands would be mitigated at a ratio of 1:1 (mitigation: impact).
- Riverine sand bar habitats being inundated by the created lake pools will not be considered an impact. These habitats are regularly inundated by daily and seasonal Arkansas River flows as dictated by releases from the Keystone Dam. The primary ecological function they serve is to provide nesting habitat for least terns. This function will be fully compensated for by the creation of the least tern nesting islands. The open water resource that will result from the creation of the lake pools will provide stable habitat for fish, waterfowl, wading birds, amphibians, and insects; will provide more stable hydrology for riparian vegetation; and will have a greater ecological function value than the existing intermittently inundated riverine sand bars. Therefore, no mitigation will be required for the conversion of the riverine sand bars to open water habitats.

Table 6 summarizes the results of the desktop assessment to identify the estimated mitigation requirements. A total of 100.7 acres of wetland habitat mitigation and 11.7 acres of riverine sand bar mitigation need to be implemented among the strategies identified within the Arkansas River to compensate for unavoidable impacts from the projects. In addition, four least tern nesting islands ranging in size from 2 to 5 acres, depending on the river stage, will be constructed.

TABLE 6
Mitigation Requirements

	Wetlands (acres)		Riverine Sand Bars (acres)	Least Tern Nesting Habitat (acres)
Location	**Dam Footprint (1.5:1)**	**Lake Pool (1:1)**	**Dam Footprint (1.5:1)**	
Sand Springs	1.1	68.5	3.2	2 - 5
Tulsa Zink	0.0	20.9	1.5	
South Tulsa/ Jenks	0.0	6.0	2.9	2 - 5
Bixby	0.0	4.2	4.1	2 - 5
Total	100.7		11.7	6 – 15

Note: Numbers shown reflect the impacts multiplied by the associated mitigation ratio.

Estimated Mitigation Cost

The estimated cost for mitigation activities associated with the low water dam projects is based on related project experience within Tulsa County and average unit costs (cost/acre) available through online information. Mitigation costs vary by strategy and associated effort to ensure success of the mitigation.

The strategies used to reach the compensatory mitigation goals will ultimately be determined during the permitting process for each of the projects. The use of a particular mitigation strategy and its contribution to the overall mitigation needs will depend on factors such as relative value to the overall Arkansas River Master Plan (eco-restoration), sustainability, external benefits (aesthetics and public recreation), and cost. In accordance with the Tulsa District's Mitigation Guidelines document, up to 50 percent of the overall mitigation needs can be achieved through preservation of existing habitats. Preservation represents a sustainable, low-cost strategy that could prove effective, depending primarily on the availability of city and state parcels within and adjacent to the river. Private landowners willing to dedicate their land to preservation for the purpose of mitigation are another potential source, although assessing the number and acreage, if any, of such candidates has not been performed at this point.

Table 7 provides a range of costs associated with various mitigation strategies from related project experience and from available online resources. Sources of information include government agencies and private economic institutes. The cost information was typically presented as range and average values since mitigation costs vary by strategy and geographic location. Various strategies were included in each of the sources that presented a range of values. Cost source information included general localities such as the northeastern and southeastern United States and more specific localities such as individual states. The costs typically included pre-construction and post-construction work such as site assessments and monitoring. The unit cost for information sources compiled was limited to cost per acre to make relative comparisons.

TABLE 7
Summary of Mitigation Cost Sources

Mitigation Strategy	Unit	Costs			Source	Notes
		Average	Maximum	Minimum		
General	acre	$38,275	$77,900	$18,000	Baca et al.	Mostly southeastern U.S.
Riparian	acre	-	$63,000	$36,000	Ecosystem Marketplace 2015	North Carolina
General	acre	$54,000	-	-	NCHRP 2002	EPA Study of northeastern DOT projects
General	acre	-	$50,000	$10,000	USEPA 2015	Maryland Counties
Riparian Restoration	acre	$54,000	-	-	River Spirit Casino Expansion Project	Approved mitigation strategy for the Arkansas River
Least Tern Nesting Island	Island	$90,000	-	-	River Spirit Casino Expansion Project	Approved mitigation strategy for the Arkansas River

From these available sources of generalized mitigation costs, an average cost of mitigation per acre within the United States is approximately $45,255. The cost of least tern nesting island construction is $90,000 per island. Table 8 shows estimated mitigation costs for the low water dam projects based on calculated impacts as previously described. The total impacts that would require mitigation are estimated to be 112 acres (100.7 acres of wetlands plus 11.7 acres of riverine sand bars [Table 6]). Preservation of existing Arkansas River resources is assumed to be the primary (up to 50 percent of the mitigation need) mitigation strategy to be implemented. Preservations costs are estimated at approximately $3,000 per acre and assumed to have no land acquisition costs. The costs associated with preservation are assumed to include the cost of the legal instrument (conservation easement, deed restriction) implementation. The mitigation cost per acre is shown as a range around the average to accommodate for future dollars. The costs included for mitigation in the overall project cost estimate summary were based upon the costing method above. However, a contingency of 100 percent was added to account for how the regulatory requirements may be interpreted, as well the potential costs for needed right-of-way or land purchase that may be necessary.

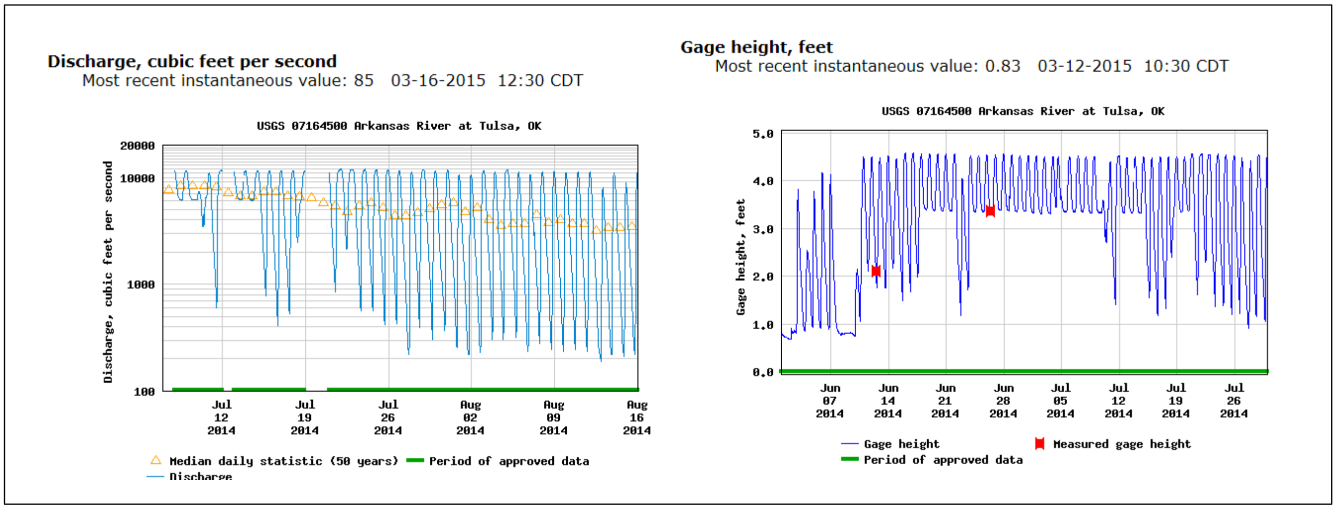
TABLE 8
Summary of Mitigation Cost Estimates by Project

Mitigation Strategy	Unit	Unit Cost	Estimation of Mitigation Costs: Sand Springs Mitigation Need (ac)	Sand Springs Cost	Tulsa Zink Mitigation Need (ac)	Tulsa Zink Cost	South Tulsa Jenks Mitigation Need (ac)	South Tulsa Jenks Cost	Bixby Mitigation Need (ac)	Bixby Cost	Total
Preservation	acre	$3,000	36.4	$109,200	11.2	$33,600	4.5	$13,500	4.2	$12,600	$168,900
General	acre	$45,000	36.4	$1,638,000	11.2	$504,000	4.5	$202,500	4.2	$189,000	$2,533,500
Least Tern Nesting Island	Island	$90,000	2-5	$90,000	2-5	$90,000	2-5	$90,000	2-5	$90,000	$360,000
Total				$1,837,200		$627,600		$306,000		$291,600	$3,062,400

Outfall Infrastructure

The three new dams and the increased height of Zink Dam will create lake pools and immerse areas of the riverbank that previously were not continuously immersed. However, much of these bank areas have been immersed on a daily basis for years due to the cyclic nature of flows resulting from hydropower releases from the SWPA station at Keystone Dam. For example, the 11th Street Arkansas River gauge shows the daily flow ranges during summer generation schedule with the corresponding river fluctuations ranging from 1 to 4.5 feet (Figure 9).

FIGURE 9
Daily Flow Ranges and Depths of Arkansas River



During release periods of flood flow from Keystone Dam, much more of the riverbank is immersed including numerous storm sewer outfalls that discharge into the river. As a part of this project, the team identified and classified outfalls into the Arkansas River into three groupings: (1) those with inverts below the new pool elevations, (2) those with inverts within 2 feet of the new pool elevations, and (3) those with invert elevation greater than 2 feet above the new pool. Table 9 shows that there were 159 outfalls identified within the four pools along with the breakdown between the three groups and between the four pool areas. A complete listing of all the outfalls, their locations, and invert elevations is included in the appendices.

TABLE 9
Outfall Summary

Invert Elevation	Sand Springs	Zink	South Tulsa/Jenks	Bixby	Total
Below the Pool	3	9	5	1	18
Within 2 feet of the pool	3	14	6	0	23
Greater than 2 feet above the pool	14	60	40	4	118
Total					**159**

The three outfall classifications shown in Table 9 helped to assess if and what infrastructure improvements might be needed to remedy existing problems resulting from the increased water level created by the proposed dams and to support the continued function of these outfall structures. Any support or protection improvements needed for these outfalls were identified and included in the estimated costs for each of the four project locations. Documentation of existing outfalls with invert elevations below or within 2 feet of the lake surface and example modifications needed for support of these existing structures are included in the appendices.

Of all the outfalls identified, 14 were shown to be in need of additional support and/or protection relative to the water levels created by the proposed dam projects. Sand Springs and Bixby had one outfall each while Zink and South Tulsa/Jenks had eight and four outfalls, respectively, that needed attention. Any existing or potential outfall problems were the result of insufficient bank protection that resulted in bank erosion, the underlying cause for settlement and resulting problems. Therefore, the recommended remedy to correct the deficiency was to repair and supplement riprap to provide a stable riverbank for outfall support and to prevent the erosion and under mining of the outfall. The cost for repairing and supplementing riprap was estimated at an average of $35,000 per outfall and is shown as a line item in the overall cost estimate summary.

Land Acquisition

The 2009 PPMP identified each of the dam locations and associated public access/recreational improvements. Land ownership and access are required for the dam abutments on each of the riverbanks as well as the area needed for public access and recreational improvements. As a part of this project, these land areas were identified consisting of land ownership that includes city/municipal, foundations, and private. Affected land parcels were identified along with current ownership determined from public records. This information, in the form of parcel maps, was provided to Tulsa County, which then provided assistance in determining the potential land acquisition costs, if any, associated with acquiring the needed parcels to construct and operate the planned facilities. These projected land acquisition costs totaled $9.1 million and have been incorporated into the overall project cost estimate with the associated dam or public access improvement.

Permitting

Permitting and environmental evaluations are an integral component of the work needed to implement the Arkansas River projects and improvements. Given the differing staging and progression of improvements to the Zink Dam and addition of low water dams at Sand Springs, Bixby, and South Tulsa/Jenks, environmental permitting requirements are at various levels of completion. The Zink low water dam has received a Section 404 permit but the original application will need to be modified to incorporate the addition of the Gathering Place. The Sand Springs and Bixby Section 404 permit applications and environmental assessments have not been initiated. The South Tulsa/Jenks low water dam Section 404 permit is currently being developed under an ongoing project. The overall permitting strategy will build on permitting and evaluations that have been initiated or completed and will extend the relevant information to other projects and locations.

For example, information assembled during preparation of the PPMPs for Sand Springs, Zink, South Tulsa/Jenks (2010), and Bixby (2014) and as a result of follow-up work, will be used to support permitting and the Environmental Assessments (EA). Similarly, the EA prepared for the Zink Dam retrofit will be used as a starting point to meet National Environmental Policy Act (NEPA) requirements associated with Section 404 permit modification as a result of the Gathering Place Project that is currently underway and the required Zink Dam retrofit design revisions. This material is expected to provide relevant information for the EAs needed for other low water dams and associated permitting. In addition, an area-wide Environmental Impact Statement (EIS) for Sand Springs, Bixby and South Tulsa/Jenks will provide a comprehensive analysis of the entire corridor. The information developed for the EIS will be used to develop the follow-on tiered EAs that will be needed to support the Section 404 permit applications needed for the Sand Springs and Bixby projects.

Table 10 summarizes permit requirements associated with each of the low water dam sites and summarizes which have been completed, which will be prepared under a separate contract, and which are addressed within this scope of work. The following subsections describe the permitting requirements and associated costs by site.

TABLE 10
Permitting and Environmental Approval Activities Required

Task		Sand Springs	Bixby	Zink	South Tulsa/Jenks
Clean Water Act (CWA) Section 404/401 Permitting, Operation and Maintenance (O&M) Plans, and Mitigation Plans		Yes	Yes	Yes—Revision to Existing Application	Yes—Only O&M plans
Rivers and Harbors Act (RHA)—Section 408 Review		Yes	Yes	Yes	Yes
FEMA CLOMR		Yes	Yes	*To be completed under separate contract*	Yes
NEPA Environmental Assessment	Independent EA	No	No	*Completed under separate contract*	No
	Area-wide EIS	*N/A*	*N/A*	No	*Yes*
	EA Tiered from Area-wide EIS	Yes	Yes	No	No

The Area-wide EIS will include all the projects and will be used to support the future Tiered EAs for Sand Springs and Bixby.

Sand Springs

Permitting and environmental requirements for Sand Springs will include:

- Section 404/401 CWA permits, including agency coordination (four meetings with USACE; Oklahoma Department of Environmental Quality and U.S. Fish and Wildlife Service participation as appropriate), preparation of a wetland/stream mitigation (30 percent design) and monitoring plan, separate O&M plans for channel geometry and bank maintenance and for least tern islands.

The estimated budget includes:

- Permit application submittal
- Section 408 RHA review, with agency coordination meetings with USACE Geotechnical Design and Dam Safety Sections, and coordination with regional levee district
- FEMA Conditional and Final Letter of Map Revision and supporting documentation
- An EA Tiered from the area-wide EIS to be prepared for the entire corridor
- Cultural resources assessment and State Historic Preservation Office coordination have been or will be completed under separate contracts

Bixby

Permitting and environmental requirements for the Bixby low water dam should be comparable to the Sand Springs low water dam.

Zink

- Modified and revised Section 404/401 CWA permits to incorporate Gathering Place designs, including agency coordination (one interagency review team meeting and one additional coordination meeting), modified wetland/stream mitigation (30 percent design) and monitoring plan, separate O&M plans for channel geometry and bank maintenance, and for least tern islands. The O&M plans will be modified from those prepared for other low water dams. The estimated budget includes submittal of the permit application.
- Section 408 RHA review, with agency coordination meetings with USACE Geotechnical Design and Dam Safety Sections, and coordination with regional levee district.

South Tulsa/Jenks

- Separate O&M plans for channel geometry and bank maintenance and for least tern islands to support previously authorized Section 404/401 CWA permits
- Section 408 RHA review, with agency coordination meetings with USACE Geotechnical Design and Dam
- Safety Sections and coordination with regional levee district
- FEMA Conditional and Final Letter of map revision and supporting documentation
- NEPA requirements will be addressed through in the overall EIS to be prepared as part of the Section 404 permitting for the South Tulsa/Jenks project. The overall area-wide EIS will address the entire corridor including Sand Springs, Zink, South Tulsa/Jenks, and Bixby project areas. The EIS will result in the Section 404 permit for South Tulsa/Jenks and support the future Tiered EAs for Sand Springs and Bixby.

TABLE 11
Estimated Permitting and Environmental Approval Costs

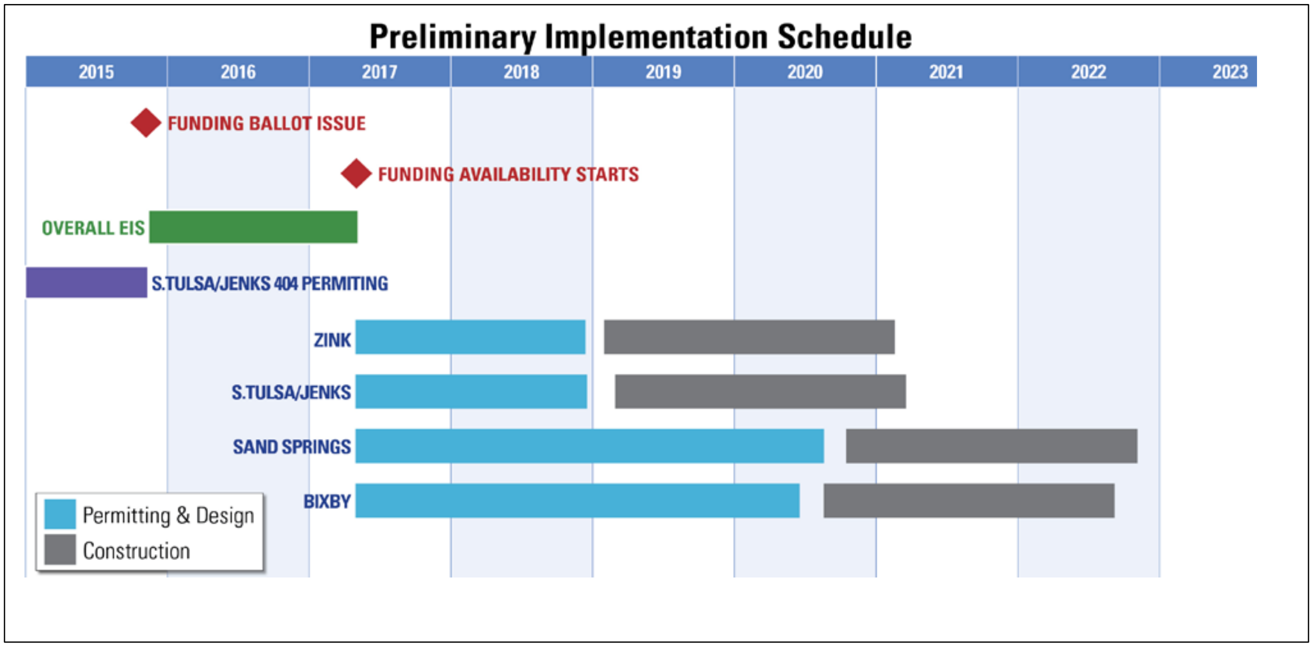
Task		Sand Springs	Bixby	Zink	South Tulsa/ Jenks
CWA Section 404/401 Permitting, O&M Plans, and Mitigation Plans		$283,000	$283,000	$89,000	$80,000 (O&M only)
RHA—Section 408 Review		$43,000	$43,000	$43,000	$43,000
FEMA CLOMR		$58,000	$58,000	*Funded*	$58,000
NEPA	Tiered EA	$229,000	$229,000	—-	—-
	Overall Project EIS	**$500,000**			

Implementation Schedule

Project implementation is dependent on many factors, including funding availability and receiving the required approvals and permits. A preliminary schedule is shown in Figure 10 and is based upon assumptions regarding the key dates for timing of major tasks and duration necessary for their completion. Tasks durations for permitting, design, and construction are based upon previous experience; however, factors such as funding availability and the review and approval processes for both the design and regulatory approvals typically have a major impact on a projects implementation schedule. Similarly, the actual construction duration of any project can be significantly affected by how the project is packaged, the number of projects, weather conditions and the actual contractors that are involved. Working in the river has increased risks that typical construction projects do not have. When the projects are bid will impact the actual construction costs due to the construction cost escalation that will occur between the date of the cost estimate and the actual time of bid advertisement and construction. A more detailed schedule showing the individual tasks associated with permitting, design, and overall construction is included in the appendices.

To have a basis for the development of the estimated costs, the preliminary schedule in Figure 10, showing specific construction dates for each of the projects, was used as the basis to account for cost escalation. This preliminary schedule assumed that each project location would be a stand-alone construction project and would have a duration of 24 months and that the projects would be sequenced as shown. There are many possible schedules and sequencing of the individual projects and the schedule used has no particular advantage or preference over a different schedule. As the Task Force identifies the source of project funding and potentially adjusts the project sequence, the construction start point for each of the projects can be modified to simulate the impact of the different schedule assumptions on cost escalation and the overall project costs.

FIGURE 10
Schedule



Construction Cost Estimate

The design concepts for the dams and related public access/recreational improvements presented in the 2009 PPMP were the basis for schematic design presented in the report. This design effort provides additional project definition and design criteria to allow preparation of drawings that provide the basis for the cost estimate. This cost estimate is directly linked to the drawings presented, as well as the descriptions, design criteria, and stated assumptions. Any modification to any of these would require an adjustment in the cost estimates. In addition to the estimated costs of construction, the team has identified other items necessary for the actual implementation, such as costs associated with land acquisition, permitting, engineering design, administrative/legal, and escalation. Financing costs are based upon the type and source of project financing and are not included in the estimate provided.

Basis and Assumptions

The schematic design team prepared cost estimates based upon the infrastructure and improvements shown on the drawings and illustrative concepts and layouts. An estimated cost for each project component was developed from estimated unit quantities and then incorporated into an aggregated cost for each of the components. Several assumptions have also been made to provide the basis for preparation of the estimate. These assumptions include the following:

- Construction at the four locations is anticipated to occur over a phased timeframe and cost escalation has been included accordingly.
- Sales tax for materials incorporated into the project has not been included since these are publicly funded municipal projects.
- Project will be implemented using a traditional design-bid-build approach.
- A project owner’s reserve of 5 percent for scope changes has been included.
- Cost contingencies are include based on industry guidelines / standards based on completeness of the work effort.
- For specific site assumptions, see the cost estimating information in the appendices.

Overall Project Summary Cost Estimate

Based upon the project schematic and the basis and assumptions presented in this report, the overall project estimated costs are summarized in Table 12.

TABLE 12
Overall Project Cost Estimates

Description	Sand Springs	Zink	South Tulsa / Jenks	Bixby	Total
Low Water Dams / Bridges	$45,940,000	$28,200,000	$34,700,000	$32,620,000	$141,460,000
Public Access					
Sand Springs					
North Bank Public Access	$6,630,000				$6,630,000
South Bank Public Access	$3,470,000				$3,470,000
Franklin Creek Landing Public Access	$10,260,000				$10,260,000
Franklin Creek Landing Lazy River	$2,520,000				$2,520,000
Zink					
Big Water Recreation Feature		$3,080,000			$3,080,000
East Bank		$1,230,000			$1,230,000
Island		$6,030,000			$6,030,000
Recreational Flume / Cut Off Wall		$3,450,000			$3,450,000
South Tulsa / Jenks					
West Bank Public Access			$8,170,000		$8,170,000
East Bank Public Access			$9,350,000		$9,350,000
Vensel Creek Public Access			$4,220,000		$4,220,000
Bixby					
North Bank Public Access				$5,100,000	$5,100,000
South Bank Public Access				$3,620,000	$3,620,000
Memorial Public Access				$1,910,000	$1,910,000
Memorial to Dam Trail				$1,750,000	$1,750,000
Irving North Park Access				$920,000	$920,000
Bank Stabilization	$2,690,000	$400,000	$1,180,000	$1,220,000	$5,490,000
Outfall Protection	$40,000	$280,000	$140,000	$40,000	$500,000

TABLE 12
Overall Project Cost Estimates

Description	Sand Springs	Zink	South Tulsa / Jenks	Bixby	Total
Mitigation	$3,680,000	$1,260,000	$620,000	$580,000	$6,140,000
Total Construction Cost (2015)	**$75,230,000**	**$43,930,000**	**$58,380,000**	**$47,760,000**	**$225,300,000**
Permitting	$610,000	$130,000	$180,000	$610,000	$1,530,000
Overall EIS	$130,000	$130,000	$130,000	$130,000	$520,000
Subtotal Project Costs	**$75,970,000**	**$44,190,000**	**$58,690,000**	**$48,500,000**	**$227,350,000**
Escalation					
Anticipated Midpoint of Construction	October-21	February-20	April-20	July-21	
Years of Escalation	6.48	4.80	4.98	6.23	
Escalation per Year	3.00%	3.00%	3.00%	3.00%	
Escalation Factor	19.45%	14.40%	14.94%	18.69%	
Total Escalation	$14,780,000	$6,360,000	$8,770,000	$9,060,000	$38,970,000
Subtotal Project Costs	**$90,750,000**	**$50,550,000**	**$67,460,000**	**$57,560,000**	**$266,320,000**
Owner's Reserve for Scope Changes (%)	5.00%	5.00%	5.00%	5.00%	
Total Owner's Reserve for Scope Changes	$4,540,000	$2,530,000	$3,370,000	$2,880,000	$13,320,000
Subtotal Project Costs	**$95,290,000**	**$53,080,000**	**$70,830,000**	**$60,440,000**	**$279,640,000**
Total Engineering	$10,670,000	$6,100,000	$7,650,000	$6,350,000	$30,770,000
Total Admin. / Legal	$1,910,000	$1,060,000	$1,420,000	$1,210,000	$5,600,000
Total Capital Costs	**$107,870,000**	**$60,240,000**	**$79,900,000**	**$68,000,000**	**$316,010,000**

The purpose and sizing of many project components are interrelated and therefore do not represent independent components that can be modified or omitted without having some impact on the cost of the other project components. The detailed cost estimate showing estimated quantities and unit costs is provided in the appendices. The estimate was prepared independently; local construction experts were then consulted to validate the construction cost experience in the Tulsa area.

Estimate Accuracy

The estimate was prepared using standard cost estimating principles and practices in accordance with the guidelines of the Association for the Advancement of Cost Engineering (AACE) International for a Class 3 authorization/control estimate. Material costs were developed using standard costs, except for the dam gate equipment costs, which were based on manufacturers' quotations. Costs have been adjusted for Tulsa local area pricing and validated by local construction firms.

A Class 3 Estimate is defined by AACE International as an estimate prepared to form the basis for the project authorization and or funding. A schematic design of engineering represents a 10 to 15 percent complete design, and would comprise facility layout drawings essentially completing process and facility equipment lists. This estimate becomes the project control or project budget estimate until more detailed estimates are completed. Examples of methods used would be a high degree of detailed unit cost and quantity takeoffs for major processes. Factoring and or scale-up factors can be used for less significant or support areas of the project. This type of estimate requires a great deal of time to prepare, where actual facilities have been designed. The expected accuracy ranges for this class of estimate are -15 percent on the low range side and +20 percent on the high range side.

The cost estimates shown in this report have been prepared from the information available at the time of the estimate to guide project evaluation and implementation. The final project costs and resulting feasibility will depend on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, continuity of personnel and engineering, and other variable factors. Therefore, the final project costs will vary from the estimate presented here.

Operation and Maintenance Cost

This section provides information on the associated operational and maintenance related requirements of the project facilities described in this report. In addition to maintaining the physical assets, a focused and intentional effort will be essential to maximize benefits to the public by maintaining the intended uses of the projects for the longer term.

The description of the associated operational and maintenance activities is intended to capture the project components that will have an associated cost for operation and maintenance, along with an identification of needed functions and associated costs. Many of the cost assumptions are based upon the management structure and the number of the facilities that are covered. It is recommended that O&M requirements be specifically developed upon the completion of the final design and based upon the ownership / operational responsibilities that are adopted. Accounting for longer-term capital replacement costs also needs to be anticipated and included. This approach will provide for the development of a sustainable plan for adequately funding the O&M costs and will assure the long-term sustainability of this project investment for the citizens of Tulsa County.

Structures and facilities identified as part of the dam and public access improvements will require operational activities as well as routine preventative and corrective maintenance tasks. These O&M needs range from daily cleaning of the public access areas to monitoring of the dam gate system operation, etc. Longer-term capital replacement and maintenance needs include items such as removal of sediment, replacement of gate air bladders, and repair and replacement of the protective coating on the steel gates. These activities need to be anticipated and funding set aside to assure that the facilities are fulfilling their intended purpose and the public assets are protected. The following paragraphs describe the anticipated O&M / capital replacement items, along with estimated annual costs.

Dam and Gate Operation

The dam gates will normally be operated through an automated control system that will modulate the gate positions. The operational status of gate control systems will be monitored remotely, including video signal, alarms, and gate status, so that the dam and gate conditions can be monitored remotely.

Seasonal gate operation protocols will include conditions for sediment movement, egg passage, and flow conditions in excess of normal flows from hydropower generation. Flows below 12,000 cfs will be handled by crest gates, while flows above 12,000 cfs will require the progressive opening of full-height gates. Gate operation will be controlled by the automated control system based upon maintaining a target lake level. The automated control system can be overridden at any time and the operation of gates manually selected. This mode of operation will be preferred during high-river flow conditions to open specific full-height gates for the purpose of selective sediment sluicing from different areas within each lake. The specific gate operation will be determined and optimized over the initial years of operation through adaptive management to the varying flow conditions from Keystone Dam. Full-height gate operation at South

Tulsa / Jenks and Bixby will also be specifically performed to accommodate egg passage downstream and fish migration upstream during the spring spawning season.

Staffing for the overall management of the dams should be in place during the final design and construction phase to provide coordination for the new facilities during the initial planning and startup. This level of participation during the initial project phases will provide insights on how to best perform the long-term O&M responsibilities. Some of the O&M duties and responsibilities could be handled by actual employees or on a contract basis, depending on the preferences of the owing entity.

Mechanical and Control Equipment

A small control building will be located at each dam, housing the mechanical systems such as air compressors, air dryers/filters and gate control systems, and will require regular inspection and maintenance. Operational status can be monitored remotely and critical items alarmed as needed. Generally, mechanical items will need to be checked and inspected on a weekly basis and serviced monthly or bi-monthly, depending on operational run times. Parts replacement will also be necessary based upon manufacturers' recommendations.

Gate Maintenance and Panel Repair/Replacement

All gate elements should be inspected after a flood event, and at least once per year. The main anchor bolts on the 10-foot gate sections will require inspection after the first year of operation and less frequently thereafter. The Keystone Dam has the capability to minimize releases during certain times, allowing significant maintenance tasks to be scheduled in advance. Additionally, coffer dams constructed from sediment within the lakes will be able to direct flows so that certain maintenance functions can be performed and so that bulkheads can be placed in position by access from either the upstream or downstream riverbed.

Gate panels are available in either ceramic impregnated epoxy coated steel or stainless steel. The durability of the epoxy coating depends on factors such as sun exposure and the amount of abrasive materials (sediment) in the river water. Longer durations of sun exposure, and larger amounts of abrasive materials will shorten the coating life. The coated steel panels are expected to require re-coating approximately every 20 years. However, according to Obermeyer Hydro, Inc., some coated gates have been in service for as long as 30 to 35 years before re-coating was needed. Re-coating will require each gate section to be taken out of service, and the gates removed.

Stainless steel panels have an expected life of 50+ years, with minimal maintenance requirements. However, initial costs for stainless steel panels may be three to four times the cost of coated steel panels, but could be included as a bid alternate to the epoxy-coated steel gates.

Bladder Repair/Replacement

Air bladders have an expected life of 30 years. Should a bladder be punctured or abraded, patching techniques similar to those used to repair tires are available. Some patching materials have a limited shelf life; therefore, the manufacturer does not recommend that they be procured in advance. However, patching materials can be readily found locally.

Sediment and Debris Removal

Sediment accumulation within the lakes and debris removal from around the dam and gates will occur and should be anticipated. The timing and extent of associated sediment maintenance tasks is difficult to predict but some insight can be gained through the experience over the years at Zink Dam. The movement of sediment down the river has been slowly declining since Keystone Dam was constructed, since it captures much of the sediment that was previously transported by the Arkansas and Cimarron Rivers.

Debris, such as trees, may pose a threat of damage or interfere with dam gate operation. Historically, Zink lake maintenance crews have dealt with debris when river levels allowed access by vehicle across the river bed. In some years there has been no effort required while other years with more frequent and higher flows have required more debris removal. The approach normally taken involves cutting the tree/vegetation material into smaller components and allowing the material to pass without damaging the gates. It will be essential to proactively prevent any large debris from blocking gate operation and causing the associated potential damage.

A summary of the periodic O&M/capital replacement items related to the dam and lake areas, along with the estimated costs, is shown in Table 13. The resulting yearly O&M costs total $520,000, which includes a 25 percent contingency. The yearly total sinking fund contribution for periodic capital replacement and maintenance is $799,000. All costs are presented in 2015 dollars and will need to be escalated accordingly for future inflation.

TABLE 13
Dam/Gate Operation and Maintenance Cost Summary

Annual Operations and Maintenance Requirements	
Oversight and Management	Oversight of the O&M of the four dams would involve a supervisor/manager, field maintenance person, and clerical. Associated yearly salary and benefits are estimated at $232,000. Office space at $7,500/year and maintenance vehicle / miscellaneous tools and supplies costs estimated at $12,000/year = $252,000/year.
Debris Removal	The need for debris removal will vary from year to year and may be contracted on a case-by-case basis. On the average it is projected that $40,000/year be set aside ($10,000/dam/year) to cover this maintenance need over the long term.
Power	Power for dam access area lighting is estimated $200/year plus $900/year for dam gate controls / air compressor operation = $4,400/year for all locations.
Riprap Maintenance	Expected ongoing repair and maintenance to bank riprap areas = $120,000 yearly.
Periodic Capital Replacement / Maintenance Requirements	
Sediment Removal	Five-year frequency of removing sediment/sand from each of the lake areas. Each of the lake areas is initially cleaned as part of the dam construction projects. Thereafter, assume that sediment accumulation to a depth of 2 feet is removed from an area of 1,800 feet (river width) by 500 feet (upstream) = 67,000 cubic yards every 5 years at a cost of $5/cubic yard for a total of $335,000/dam, or a total of $1.3 million every 5 years.
Buoy Maintenance	Assume maintenance and recurring replacement costs of $30,000/location = $120,000 every 10 years.
Bladder Replacement	Gate bladder life is expected to be 30 years. As such, $5.7 million will be needed to fund bladder replacements every 30 years.
Gate Coating Replacement	Steel gates are furnished by the manufacturer with a durable epoxy coating that is projected last 20–25 years, depending on service conditions. The cost for cleaning and recoating the dam gates is estimated at $125,000 and funding should anticipate those costs every 20 years.
Air Compressor Systems	Maintenance on air compressors, dryers and filters - $16,000/year and replace equipment every 20 years at a cost of $385,000 for all four locations.
Initial Mitigation Permit Monitoring	Monitor and report the condition and viability of the implemented mitigation methods. Field evaluating, documentation, regulatory reporting for the first 5 years of the project. Costs estimated at $200,000 per location over a 5-year period, or $40,000 per year per location for a total of $160,000 per year for the first 5 years.

Public Access Operational/Maintenance Needs

The public access and recreational improvements will have very different O&M requirements from those required by the dam and associated infrastructure. These maintenance needs will be similar in nature to those of public park areas, including lawn and landscaped areas, litter pickup and removal, bathroom cleaning and security, and related utility costs. To capture these types of O&M costs, discussions were held with River Parks Authority staff members, given their local operational experience with similar type facilities. Those costs are shown in Table 14 and are based upon a single contracting entity performing the services at six separate River Parks Authority locations/facilities. Based upon the criteria and assumptions shown in Table 14, the projected O&M expense for the all of the public access facilities at the four locations is show to be approximately $1,018,000 per year, including a 25 percent contingency. All costs are presented in 2015 dollars and will need to be escalated accordingly for future inflation.

TABLE 14
Public Access and Recreational Areas O&M Cost Summary

Annual Operation and Maintenance for Public Access and Recreational Areas	
Restroom Service	$2,800/year per restroom – $36,400 total.
Water and Sewer	$480/year per restroom for water and sewer – $3,840 total. During drought/high heat conditions - $2,000/week for hand watering.
Grass Mowing	Use $760/acre for mowing every 7 days during the growing season, times 58 acres for a yearly total of $44,000.
Power	Each area provided with park lighting at $150/year per location = $1,500/year.
Maintenance	Maintenance of area with splash pad, play areas, seasonal plantings, bed care, etc. Therefore, assume that they will have a similar cost of maintenance and use $50,000/year for 6 of the 10 public access areas – $300,000/year.
Vandalism/Water Leaks	Assume $3,000/year/restroom, or $24,000/year for the total of eight restrooms.
Security	Assume each entity will provide for this service as desired – no cost included.
General Cleanup/Trash	Assume one full-time employee at $45,000/year at each of the four locations to perform the daily cleanup work at all the public access facilities. Total for all locations is $180,000/year.
Lazy River Operation	Operational oversight at 0.5 full-time employee 4 months of the year, $19,000/year, plus pumping power cost for operating 12 weeks/year/9 hours /day, 6 days per week, $3,500/year = total of $12,500/year.
Zink Recreational Features	Operational oversight of the recreational flume and the Big Water Gates. Staff at 0.5 full-time employee at $30/hour = $31,200 plus benefits = $ 56,000/year.
Park Patrol/Security	Assume each local community will provide for this if desired.
Oversight and Management	Assume contract hire two full-time employees at $12/hour for clerical and $30/hour for supervisor/manager with benefits – $157,000/year.
Exclusions	Operational/maintenance items not specifically accounted for include liability insurance, event coordination, seasonal decorations and lighting and snow removal.

Sand Springs Dam

Dam/Gates/Pedestrian Bridge

The proposed dam will be constructed of mass concrete founded upon the underlying shale bedrock and extending up to the fixed crest at elevation 638.50. The dam will incorporate a stepped downstream face to prevent formation of hydraulic rollers for the design flows. The geometry of the stepped face is hydraulically determined to prevent the formation of hydraulic rollers; however, these steps have relatively low structural demands and could be constructed of mass concrete, grouted riprap, anchored stone blocks, or other material with density similar to concrete, based on cost or aesthetic preferences.

The 1,900-foot-long dam will include 10-foot-tall, full-height gates and 3-foot-tall crest gates. The tip of the gates will be set at elevation 638.0, which is 6 inches lower than the fixed crest gates, to concentrate flows through the gates. Table 15 summarizes these gates.

TABLE 15
Sand Springs Dam Gates

Gate Width (feet)	Gate Height (feet)	Gate Type	Quantity
48	3	Crest	12
64	3	Crest	2
48	10	Full	10
64	10	Full	2

The pedestrian bridge will be constructed of pre-stressed concrete girders and a concrete deck spanning across the two girders. The bridge will be supported from reinforced concrete columns founded on abutment walls located approximately every 100 feet. In addition to supporting the pedestrian bridge, the abutment walls will separate the changes in the various cross-sections of the dam (fixed crest, crest gates, and full-height gates). The bridge will be constructed of precast concrete girders and will include the following features:

- Typical bridge section has a 20-foot clear width
- The bridge will be designed for pedestrian loading and a 1-ton pickup truck for maintenance needs
- Some sections will be wider to allow for seating and shade areas
- Fishing piers will extend upstream and downstream of the dam
- Guardrail will allow for viewing through the railing

Geotechnical

Subsurface Data

Stantec advanced three boreholes along the proposed Sand Springs dam alignment in 2008. Foundation data sheets from the Highway 97 structure, located roughly 1,500 feet upstream, include boring logs showing subsurface materials encountered in 1974. The locations of the previous investigations are shown in the appendices.

The relevant geologic maps from the Oklahoma Geologic Survey are Wekiwa (Stanley, 2010), Sand Springs (Chang and Stanley, 2010), and Saluda North (Chang and Stanley, 2011). Geologic mapping suggests that the shale bedrock that underlies the site is part of the Nelly Bly Formation on the southern end of the project location and part of the Coffeyville Formation on the northern end of the project.

The 2008 Stantec report indicates that one borehole was advanced at each riverbank near potential abutment locations, and one borehole was advanced near the center of the river channel. The borings were advanced between 50.5 and 75.0 feet below ground surface. The boring near the north (left) abutment consisted of silty sand overlying shale bedrock; the boring near the south (right) abutment consisted of sandy silt and silty sand overlying shale bedrock. The boring in the riverbed encountered sandy alluvial materials overlying a thin layer (less than 2 feet thick) of sandstone overlying shale bedrock to the maximum depth penetrated. The Highway 97 investigations indicate sandy overburden overlying shale bedrock beneath the existing bridge. Available laboratory testing available from the Stantec borings included index testing in the soil samples (Atterberg limits and grain size analyses) and unconfined compression tests in collected rock cores.

No ground survey was performed during the Stantec investigation. Due to the natural variation and migration of sandbars within the river channel, the ground surface elevation and the corresponding bedrock elevation, within the river channel at the time of drilling, are difficult to ascertain. The 2008 Stantec geotechnical report and the available subsurface profile for the existing Highway 97 bridge support that the bedrock surface exhibits relatively little undulation across the river corridor. The top of bedrock elevation was estimated to be 615 feet at the abutments and

618 feet in the river bed based on the Stantec boreholes. The upper few feet of the bedrock are highly weathered. A foundation elevation of 611 feet is recommended for conceptual design of the dam.

Hydrology/Hydraulics

The Sand Springs Dam's previous model was modified to include both the full-height and crest gates, as well as the proposed pedestrian bridge. Once all of the proposed improvements were input, the model showed a slight increase in water surface elevations. Several alternatives were analyzed to try to reduce or eliminate the increased water surface. Several different gate configurations were used, as well as additional grading on the banks and channel. However, these changes did not produce much change in the proposed water surface. Some bank excavation on the north bank is included in the final scenario. The excavation includes the lower tiered bank on the north for approximately 2,000 feet downstream of the dam. Table 16 shows the results of the current analysis.

TABLE 16
Results of Current Hydrology/Hydraulics Analysis

	1% Chance (100-year) 205,000 cfs	0.2% Chance (500-year) 490,000 cfs	USACE Levee Design 350,000 cfs
Existing	649.02	662.85	657.36
Proposed	649.15	663.13	657.43

The pool elevation is 638.00 with a sill elevation of 628. An approximate flowrate of 50,000 cfs is required before the dam in inundated with all gates open. The crest gates have a sill elevation of 635. This elevation would be inundated at approximately 25,000 cfs. The proposed dam height would create an impoundment up to the Keystone Dam. The general elevation of the top of levee near the dam site is approximately 662, providing approximately 4 feet of freeboard in the levee design event. With the additional rise, the 100-year storm event does not come in contact with the levee and the levee design flow would have an increase of 0.07 feet.

FEMA and the City of Sand Springs do have a no-rise policy; therefore, additional analyses will be performed during final design to eliminate these increases. If they cannot be eliminated, coordination with the regulatory agencies will be needed to obtain their concurrence on the project. Since the rise is minimal and the 1 percent annual chance floodplain is contained within the river and no structures are impacted, a Conditional Letter of Map Revision should be granted by FEMA. This will require the local jurisdiction to consider a variance to their criteria. No adverse impact will have to be shown along the river, as well as on the Franklin Creek tributary, for the variance to be considered. At this point in the modeling, it appears that any impacts would be negligible.

Public Access/Recreational Improvements

Overall

The Sand Springs low water lake provides boating and fishing recreational opportunities. At the full height elevation of 638, the upper reach of the lake will extend to the base of Keystone Dam. For this reason, Sand Springs River City Park will become a regional recreational destination.

The majority of the public access and recreational improvements for the Sand Springs low water lake are on the north shore near River City Park. Improvements near Franklin Creek will include boat launch areas for motorized and non-motorized boats, docks, a lazy river recreation water feature, improvements to Franklin Creek, multi-use bicycle pedestrian trails, new landscaped areas, and expanded parking.

The north bank area provides access to the pedestrian bridge as well as the lake and downstream areas. Traffic access to the dam and the north bank will be provided by extending Main Street south over the levee to the park. Multi-use trails connecting picnic shelters, fishing areas, concrete landings at the water's edge, an interactive water feature, and restroom facilities will enhance the public's recreational opportunities. All facilities provided will be Americans with Disabilities Act (ADA) accessible.

The water level at the Sand Springs low water lake will vary up to 3 feet to supplement river flow rates for improved water quality in the river and for improved recreational opportunities in the downstream lakes. With this normal water surface variation, boat ramps, landings, channel depth, and rock fishing areas will accommodate this fluctuation in water surface elevation.

The south bank area primarily provides access to the dam bridge trail, with a lake overlook, restroom, shelter, dam operations building and a series of nature trails east of Prattville Creek. Access to this area will be provided with a paved road with access to both the north and southbound lanes of Highway 97 Bridge.

Franklin Creek Public Access

The Franklin Creek public access area includes many recreational facilities for various users. All of the existing soccer and baseball areas will remain, including a new concession/restroom building and splash pad area currently being constructed. The proposed lazy river water feature is close to the splash pad and will use the existing concession/restroom for visitors tubing down the lazy river. The water for the lazy river will be pumped from the Arkansas River or from a connection to a pipeline from Shell Lake when excess is available, and will outflow back into the Arkansas River. The lazy river will have the appearance of a boulder lined stream with large slow-flowing pools that periodically merge into fast-moving channels. The lazy river will include a boulder vantage point for onlookers, while a 20-foot- wide concrete trail will provide easy access back to the top of the lazy river. Nearly 200 parking spaces will be added along River City Park Road to support these and other sports/recreation facilities. Visitors coming from the parking lot will cross over a pedestrian bridge where they can see users of the lazy river.

Franklin Creek will be improved by stabilizing its banks to prevent erosion. Where Franklin Creek and the lazy river outflow converge, there will be a 3–4-foot waterfall. Below the waterfall, Franklin Creek will become a channel with a dock area and boat ramp for boat access to the lake. Larger boat trailer parking areas will be included and will double for normal vehicle 18-foot spaces during non-boating seasons. An accessible trail leading to a concrete landing near the parking area will welcome users with smaller non-motorized boats such as kayaks, canoes, paddle boards, and sail boards. An iconic light house on the west side of the channel will enhance the look of Franklin Channel.

Franklin Channel will be approximately 50 feet wide, with battered stone walls on either side. Gangway access on the west side will allow visitors to access the water's edge on the floating dock running the length of the channel. A new foot bridge over Franklin Creek will provide easy access from a large parking area to the existing soccer fields west of Franklin Creek. Concrete trails will run along the length of the channel to offer walking and hiking opportunities. In addition, the riverbanks will be stabilized to protect the public access features.

North Bank Public Access

The extension of Main Street south and the connection to River City Park Road will provide easy access to the north bank facilities. Having a through road within the park will also increase access and security for park users. On the lake side of the dam, a parking lot area will support recreational activities, as well as eight family picnic shelters and three large group shelters. Shoreline fishing areas will provide easy access to the water for fishermen. Central to the area is a concrete landing for non-motorized boats to launch; this landing will also include an interactive water feature. A restroom will be located near the north end of the dam in a central location for ease of access.

Numerous nature-oriented outdoor facilities will be located below the dam and a parking lot will provide ample access for users. The entire shoreline below the dam will be accessible for fishing. East of the parking will be a series of nature trails for those whom want to experience native flora and fauna. These trails will also be used by fishermen wanting a more isolated fishing experience. An emergency access ramp is located downstream of the dam.

South Bank Public Access

The south side of the dam does not contain provisions for public access to the lake due to the steepness of the banks. The south bank area will be accessed from the Highway 97 bridge, with an access road to a new parking lot. Facilities will include a lake overlook shaded with an arbor, a group picnic shelter, and a restroom. A nature trail, constructed of crushed granite, will cross Prattville Creek and extend downstream. The operations and compressor building controlling the dam gates will be housed near the parking lot on the south side of the dam.

Bank Stabilization/Restoration

Bank stabilization and restoration assumptions for the Sand Springs location are included and summarized in the Common Project Elements section.

Compensatory Mitigation/Preservation

Compensatory mitigation assumptions for the Sand Springs location are included and summarized in the Common Project Elements section.

Land Acquisition

The schematic design team identified potentially impacted land parcels based upon the proposed public access and recreational improvements and the Sand Springs Dam location, as shown in the drawings. A total of 21 parcels were identified, along with their ownership. Based upon this information, it does not appear that there would be any costs associated for land acquisition required for any of the project improvements at Sand Springs.

Permitting

Permitting requirements and assumptions for the Sand Springs location are included and summarized in the Common Project Elements section.

Zink Dam

Overview

The 1,100-foot-long dam will include 10-foot–tall, full-height gates and 3-foot tall crest gates. The tip of the gates will be set at elevation 619.5, which is 6 inches lower than the fixed crest gate to concentrate flows through the gates. Table 17 provides a summary of the gates.

TABLE 17
Zink Dam Gates

Gate Width	Gate Height	Gate Type	Number
20	3	Crest	20
48	10	Full	7
48	8	Wave Shaper	1
48	10	Wave Shaper	1
20	4	Wave Shaper	2

Dam/Gates/Recreational Flume

The existing Zink Dam will be modified to: (1) raise the dam height by 3 feet for elevation 617 to 620, (2) replace existing gates and install additional gates to provide a total gate area of 5,864 square feet, (3) modify the downstream face of the dam to mitigate dangerous hydraulic roller conditions, and (4) construct an island parallel to the east bank to form a 900-foot-long channel, or flume, for recreational purposes. In addition, two of the gates installed in the dam will have a specialized design to create a “big water” wave conditions similar to the Tulsa Wave on the west bank just downstream of the dam.

In 2012, the preliminary design was completed for the Zink Dam and recreational flume project. The design details and project description are not repeated in this document. However, several modifications will be required to the preliminary design as a result of modifications to the east bank area that are being made as part of A Gathering Place for Tulsa project. These modifications include the creation of a “bench” area along the east bank that provides for flume access and safety. As a result, the island will need to be moved further away from the bank to provide space for the actual flume. This will also result in moving one of the big water gates and adding another 16-foot-length of full-height gate to compensate for the loss of three crest gate sections. The team made red-lined markups on a couple of the Zink preliminary design report drawings; these markups are included for reference. The cost estimates for the preliminary design have been modified according to the above changes and as shown on the red-lined markups.

The hydraulic design of the flume and the Section 404-required river HEC-RAS hydraulic analysis will need to be revised as a result of the changes when the Zink Dam and recreational flume project is authorized.

Bank Stabilization/Restoration

Bank stabilization and restoration assumptions for the Tulsa Zink location are included and summarized in the Common Project Elements section.

Compensatory Mitigation/Preservation

Compensatory mitigation assumptions for the Tulsa Zink location are included and summarized in the Common Project Elements section.

Permitting

Permitting requirements and assumptions for the Tulsa Zink location are included and summarized in the Common Project Elements section.

South Tulsa/Jenks

Dam/Gates/Pedestrian Bridge

The proposed dam will be constructed of mass concrete founded upon the underlying shale bedrock and extending up to the fixed crest at elevation 597.50. The dam will incorporate a stepped downstream face to prevent formation of hydraulic rollers for the design flows. The geometry of the stepped face is hydraulically designed to prevent the formation of hydraulic rollers; however, these steps have relatively low structural demands and could be constructed of mass concrete, grouted riprap, anchored stone blocks, or other material with density similar to concrete, based on cost or aesthetic preferences.

The 1,850-foot-long dam will include 7-foot-tall, full-height gates and 3-foot-tall crest gates. The top of the gates will be set at elevation 597.0, which is 6 inches lower than the fixed crest gate to concentrate flows through the gates. Table 18 provides a summary of the gates.

TABLE 18
South Tulsa/Jenks Gates

Gate Width (feet)	Gate Height (feet)	Gate Type	Quantity
32	3	Crest	2
40	3	Crest	2
48	3	Crest	12
48	7	Full	8
60	7	Full	2

The pedestrian bridge will be constructed of pre-stressed concrete girders and a concrete deck spanning across the two girders. The bridge will be supported from reinforced concrete columns founded on abutment walls located approximately every 100 feet. In addition to supporting the pedestrian bridge, the abutment walls will separate the changes in the various cross-sections of the dam (fixed crest, crest gates, and full-height gates). The bridge will be constructed of precast concrete girders and will include the following features:

- Typical bridge section has a 20-foot clear width
- The bridge will be designed for pedestrian loading and a 1-ton pickup truck for maintenance needs

- Some sections will be wider to allow for seating and shade areas
- Fishing piers extending upstream and downstream of the dam
- Guardrail will allow for viewing through the railing

Geotechnical

Subsurface Data

The existing information published by Stantec (2008) and Kleinfelder (2008) applies to the proposed South Tulsa/ Jenks dam and seawall projects, respectively. The available 2008 Stantec boreholes were advanced roughly 1,000 feet downstream of the current dam alignment, so the subsurface conditions along the dam alignment are not precisely known. Some subsurface data is also available from an investigation performed by Terracon at the Creek Turnpike, approximately 2,000 feet upstream of the dam location. The relevant geologic map from the Oklahoma Geological Survey is for the Jenks location (Stanley and Chang, 2012). The geologic mapping suggests that the shale bedrock is part of the Memorial and/or the Nowata formations. The locations of the previous investigations are shown in the appendices.

The Stantec investigation shows sandy alluvium overlying shale bedrock at the proposed alignment. The Kleinfelder borings along the seawall alignment indicated sandy alluvium with clay overlying shale along the seawall location. The Terracon report for the Creek Turnpike widening included the foundation data sheet boring logs for the original Oklahoma Department of Transportation borings. It was noted that all of the investigations for the Creek Turnpike Bridge showed interbedded silt and sand alluvium with minor amounts of clay overlying shale at the abutments; in the riverbed, sand was reported to directly overlie the shale.

The Stantec report included laboratory index test results for the soil samples (Atterberg limits and grain size analyses) and unconfined compression tests in collected rock cores. The Kleinfelder and Terracon data provide grain size analysis results for select soil samples, and Texas Cone Penetration testing in rock. This testing provides an indication of strength, but does not provide a direct strength measurement or interpretation of rock mass properties for seepage control or interface strength. The testing does provide a useful indication of the variation in density with depth.

The existing investigations, particularly at the Creek Turnpike, support that the bedrock surface elevation is roughly uniform across the proposed dam site. Bedrock elevations are estimated at 584 feet along the proposed dam location. The previous information indicates that the upper few feet of the bedrock may be weathered and will require over-excavation for the proposed dam. As a result, a dam foundation elevation of 580 feet is recommended for the dam; this elevation may be revised (upward or downward) pending review of future geotechnical explorations at this site conducted prior to further design.

Jenks Floodwall

At the west abutment of the proposed South Tulsa/Jenks dam, a public access area will be developed and will extend from roughly the Creek Turnpike downstream to the proposed South Tulsa/Jenks dam. The area will consist of a number of tiered retaining walls, with the upper tier at elevation 612 feet. Near the dam abutment, the park will be consolidated to the top of a single large retaining wall (floodwall) that overlooks the river and provides user access to the pedestrian bridge over the dam. The 100-year flood elevation is 612 feet; the park is expected to be inundated during flood events greater than the 100-year event. Depending on the flood velocities during high water events, erosion protection measures may be necessary for the park surfacing. Relatively low velocities can be reinforced with geosynthetic turf reinforcement; velocities less than 6 feet per second can resist erosion with maintained grass.

The Jenks Floodwall is a significant wall structure with a top elevation of 612 feet and a bedrock elevation of 584 feet—a total grade differential of approximately 28 feet. Note that the anticipated sediment level in the river extends above the bedrock elevation; however, this sandy material has the potential to scour to the bedrock and cannot be relied upon for wall design. Although several wall types are feasible at this location, considering the available subsurface data and the conceptual level park design, it is preliminarily recommended that a tied-back soldier-pile-and-lagging wall will provide a robust solution for this location well suited for the nature of the project. Sheet piles are not recommended for the large floodwall due to the large quantity of steel required and anticipated difficulty achieving embedment into the shale bedrock.

A mechanically stabilized earth wall would be feasible at this location, but would require mass excavation of native soil down to bedrock, disposal of the soil material, prolonged dewatering efforts, and large quantities of imported backfill material. Reinforced concrete walls or concrete gravity walls are also feasible, but would require large quantities of concrete and formwork labor to construct, in addition to the excavation required.

A soldier pile and lagging wall, if implemented, can be constructed top-down from the existing grade by first drilling through the overburden and into the shale bedrock along the wall alignment. Preliminarily, rock socket embedment of 15–20 feet into shale should be considered until sufficient subsurface data can be collected to support advanced evaluation of lateral earth pressures. Steel H-pile sections are then placed into the holes and the rock sockets concreted in place; above the bedrock, the holes are backfilled around the pile with lean concrete. Once the soldier piles are installed, excavation can begin on the riverward side of the wall to form the approach channel upstream of the dam and the outlet channel on the downstream side of the dam.

The top-down excavation will require placement of timber or concrete lagging members between the soldier piles to retain the native soil. Waler beams and tieback anchors will be installed at prescribed intervals as the excavation proceeds. The sizing and number of anchors will depend on the soils present and the loads imparted by the park amenities, but for planning purposes it should be assumed that three rows of anchors are installed in the face of the wall. Note that in locations where 8 to 10 feet of fill is necessary to bring the west park up to the desired elevation, deadman anchors could be installed in the backfill. Due to the displacement required to develop passive resistance behind deadman anchors, the tolerable movements of the wall at these locations should be reviewed.

Excavation and tieback installation should proceed to the bedrock elevation. Once the wall is excavated and tied back down to the top of bedrock, permanent reinforced concrete facing can be applied to the wall to prevent backfill migration out of the wall and to provide desired architectural details. It is recommended that the lagging and concrete facing be placed down to the depth of potential scour of the shale bedrock—preliminarily estimated to be elevation 580 feet (4 feet of embedment). Drainage provisions should be included in the wall facing to prevent building up hydrostatic pressures behind the wall.

The soldier pile and lagging wall enables re-use adequate resistance to scour and due to the height of the wall, the abutments of the South Tulsa/Jenks dam are significantly embedded into the existing riverbanks.

Hydrology/Hydraulics

The previous South Tulsa/Jenks Dam model was modified to include both the full-height and crest gates, as well as the proposed pedestrian bridge. The west bank of the river is shown to be filled in to an elevation above the 1986 flood levels, to accommodate future development. Once all of the proposed improvements were input, the model showed a slight increase in water surface elevations. Table 19 shows the results of the current analysis.

TABLE 19
Current South Tulsa/Jenks Analysis

	1% Chance (100-year) 205,000 cfs	0.2% Chance (500-year) 490,000 cfs	USACE Levee Design 350,000 cfs
Existing	611.29	621.23	617.38
Proposed	611.62	622.70	617.76

The South Tulsa/Jenks low water dam is proposed to have a pool elevation at 597 feet with a sill elevation of 590 feet. The pool elevation of 638 feet will be 3.5 miles long and approximately 443 acres. The dam will become inundated at an approximate flow rate of 25,000 cfs. The crest gates will have a sill elevation of 594 feet. This elevation will be inundated by approximately 8,000 cfs. This dam location does not include a levee; however, the Jenks levee is approximately 4,500 feet upstream and next to the river near the 96th Street Bridge.

Due to the increases in the base flood elevations, the regulatory agencies will be engaged during the review process to determine if there are adverse impacts to the area. Within this reach, the 1 percent annual chance floodplain is also contained within the channel. There are no structures that would be impacted by the increases in water surface and the base flood elevation does not touch the toe of the levee. A Conditional Letter of Map Revision will be required prior to construction of the dam.

During final design, the team will evaluate additional alternatives to reduce and/or eliminate the rise in water surface.

Public Access/Recreational Improvements

Overall

The South Tulsa/Jenks low water dam impoundment will extend beyond the Muscogee (Creek) Nation Casino almost to 71st Street, creating a 3.5-mile lake. Recent development has revitalized the riverfront with commercial and retail activity along both sides of the river. The Oklahoma Aquarium attracts visitors to the area along on the west bank between the 91st Street and Turnpike Arkansas River bridges. Public access development on both sides of the river includes boat docks, ramps, landing areas, water features, playgrounds, splash pads, multi-use trails, climbing walls, overlooks, restrooms, and a pedestrian bridge which will link Jenks and Tulsa. All facilities will be ADA accessible.

Trails will include a new River Parks trail from Vensel Creek along the east bank of the lake to the low water dam. In addition, the River Parks trail will be extended from 101st Street to the low water dam along Riverside Parkway. The bicycle/pedestrian trail bridge will extend across the Arkansas River over the dam connecting South Tulsa to Jenks. On the west bank in Jenks, a new trail will connect the dam overlook, the public access recreation area, the Oklahoma Aquarium, and the existing trail south to 81st Street through the Riverwalk Crossing commercial district.

Jenks West Bank Access

The Jenks west bank access areas will consist of two development areas. On the south end near the dam, 40 new parking spaces will provide access to trail users, sightseers, and fishermen. At the terminus of the dam on the west bank, an overlook with a shaded plaza extending out over the dam will provide a location for viewing lake and river activities. This area will also include the dam operations/maintenance building, which will supply the compressed air to inflate the dam bladders. This building and the downstream river emergency access ramp will be located south of the dam and away from the general public.

The second development area north of the dam overlook will provide a lakeside recreation area in Jenks. Facilities will include a playground and splash pad, shelters, boat dock landing, concrete landing/boat launch, a cascading water feature, and a shaded overlook and restroom facilities. These areas will be handicap accessible and connected with a series of walking trails. Fishing opportunities will be provided along the water’s edge.

Tulsa Vensel Creek Access

The Vensel Creek public access area will merge with the existing 96th Street trailhead/park. The Vensel Creek improvements will provide public access to the river in two locations. The first is a concrete landing and launch near the 96th Street Bridge, which is accessed via a 10-foot concrete trail from the park area. This landing will allow park users to access the lake shoreline and enjoy various water activities. The second water access point is in Vensel Channel, which will be widened and deepened to allow for the use of small watercraft. A series of gangways and a floating dock will provide an accessible route down to the water’s edge. Small watercraft can be carried down the emergency ramp or the gangway, depending on the size. The focal point of Vensel Creek will be the lighthouse and plaza on the north side of the channel opening. This area will also include a large group shelter overlooking the lake and a series of interconnected ADA accessible trails.

Tulsa East Bank Public Access

The Tulsa east bank public access consists of three distinct areas. The north end of the development will include a public boat ramp with trailer parking and additional vehicular parking for trail and lake access. Multi-use trails in this area will extend along the lake edge and along Riverside Parkway, making a connection to the existing River Parks trail.

Just north of the dam, the second development area will offer numerous recreational opportunities. North of the parking lot is “the hill,” an 18-foot-tall earthen structure accessed by a trail for views of the lake. The hill will include small shade shelters and bench swings facing the lake, and will serve as a sledding hill after winter snowfalls. Below the hill at the plaza level, an interactive fountain with jets will activate the plaza area and send water cascading toward the lake. A series of seats/steps will create amphitheater seating with the lake as the backdrop. An ADA accessible walkway will lead visitors past the rock climbing wall and the double concrete hill slide to the stage at the base of the amphitheater seating. Next to the main parking lot, a trail will provide access to the River Parks trail and the 20-foot-wide bicycle/pedestrian trail bridge located above the dam structure.

The third development area located immediately downstream of the dam will provide access for shoreline fishing. Concrete landings near the riverbank will provide access to the water's edge for fishing in the back current of the river. The top of the bank near the parking lot will include shelters for fishermen and other users. An emergency access ramp will be located downstream of the fishing area.

Bank Stabilization/Restoration

Bank stabilization and restoration assumptions for the South Tulsa/Jenks location are included and summarized in the Common Project Elements section.

Compensatory Mitigation/Preservation

Compensatory mitigation assumptions for the South Tulsa/Jenks location are included and summarized in the Common Project Elements section.

Land Acquisition

Potentially impacted land parcels were identified based upon the proposed public access and recreational improvements associated with South Tulsa/Jenks as shown in the drawings. Land valuations were determined based upon these parcels along with land ownerships. A total of 11 parcels were identified where the dam abutment and/or public access areas are proposed. Based upon this information, the needed land has been identified and the cost estimates to acquire the affected parcels have been estimated by other parties and included in the cost estimate for the individual items.

Permitting

Permitting requirements and assumptions for the South Tulsa/Jenks location are included and summarized in the Common Project Elements section.

Bixby

Dam/Gates

The proposed dam will be constructed of mass concrete founded upon the underlying shale bedrock and extending up to the fixed crest at elevation 583.50 with a total overall length of 2,784 feet. The dam will incorporate a stepped downstream face to prevent formation of hydraulic rollers for the design flows. The geometry of the stepped face is hydraulically determined to prevent the formation of hydraulic rollers; however, these steps have relatively low structural demands and could be constructed of mass concrete, grouted riprap, anchored stone blocks, or other material with density similar to concrete based on cost or aesthetic preferences.

The dam will include 4-foot-tall, full-height gates. The tip of the gates will be set at elevation 583.0, which is 6 inches lower than the fixed crest gate to concentrate flows through the gates. Table 20 provides a summary of the gates.

TABLE 20
Bixby Gates

Gate Width (feet)	Gate Height (feet)	Gate Type	Quantity
50	4	Full	5

Geotechnical

Terracon (2009) performed a geotechnical exploration near the proposed Bixby Dam site for an unrelated project. Terracon advanced one borehole on the east bank (B-5) and one on the west bank (B-1) of the river. Both of these boreholes were located approximately 300 feet downstream of the proposed dam. Generally, soil conditions observed in these boreholes identified alluvial soils above elevation 572 feet, consisting of silt, clayey sand, poorly graded and well graded sand. The thickness of the alluvium varies across the river at this location.

Boreholes B-1 and B-5 encountered a roughly 4-foot-thick layer of shaley lean clay beneath the alluvium before transitioning to a soft to moderately hard shale at elevation 571 feet. The clay layer is assumed to be residual soil derived from the weathering of the underlying parent shale bedrock. Due to the active scouring forces in the river channel, it is conservatively assumed that this residual clay soil is not present beneath the channel, similar to the conditions noted in the boreholes at South Tulsa/Jenks. The locations of these boreholes are shown in the appendices.

With no data in the river channel, it was assumed that the elevation of the top of shale is uniform across the river channel. The relevant geologic maps for Bixby (Chang and Stanley, 2009) and Leonard (Stanley, 2008) indicate that the shale layer comprises the upper layer of the Nowata and/or the Wewoka Formation. This formation consists of an upper shale layer, interbedded limestone and shale layer, and a lower shale layer, and has an overall thickness of approximately 400 feet.

Hydrology/Hydraulics

The Bixby Dam's previous model was modified to include multiple full-height gates. This dam will not have a pedestrian bridge due to its unique alignment. The arched portions of the dam were coded into the model using ground points. The rest of the dam was coded with an inline structure and gates. The existing sand bar downstream of the dam, in the middle of the river, is shown as excavated in the proposed model. Once all of the proposed improvements were input, the model showed a slight decrease in water surface elevations. Table 21 shows the results of the current analysis.

TABLE 21
Bixby Dam Model Analysis

	1% Chance (100-year) 205,000 cfs	**0.2% Chance (500-year) 490,000 cfs**	**USACE Levee Design 350,000 cfs**
Existing	600.75	607.83	605.88
Proposed	600.37	607.56	605.31

The proposed pool elevation of 583 will create a pool approximately 1.9 miles upstream. The top of dam will be inundated at approximately 12,000 cfs.

Public Access/Recreational Improvements

Overall

The Bixby low water lake extends 1.9 miles to provide recreational activities for the City of Bixby. Memorial Drive Bridge crosses the lake to provide water views. Access to the water's edge is continuous from the dam to Memorial Drive on the south bank of the lake along a 10-foot-wide concrete trail. On the north bank, public water access adjacent to the dam offers numerous water opportunities, including a boat ramp/launch, a concrete landing at the water's edge, and access to the river flowing below the dam. All facilities will be ADA accessible.

Memorial Drive Public Access

A Memorial Drive public access location will provide easy access to the lake at a site on either the north or the south bank of the Arkansas River, along the west side of the roadway. A new parking lot will provide 70 spaces at the access location. Conceptually, this area has been shown on the south side of the river and includes a proposal for not only a parking lot, but also a dog park, which will allow users to walk their dogs. In addition to the dog park, a restroom, shelter, and trail access have been included. North of the parking lot is a boat launch and concrete landing for non-motorized boats such as kayaks, canoes, sailboards, and water boards. This area will connect to the dam to existing and new trails. The lower trail, a 10-foot-wide concrete trail, will extend along the shoreline to the dam. The existing upper trail will be widened to a 20-foot-wide multi-use trail to meet the demand along this segment of the river.

South Bank Public Access

The south bank public access is a passive recreation area in the midst of Bentley Park. A "dancing" interactive fountain will welcome visitors as they head into the park from the parking lot. An overlook bridge will extends north over the dam structure to provide views of the lake and the dam. The historic Bixby Bridge will be highlighted with educational signage on the overlook, emphasizing the views to the remnant structural piles from the original bridge that are still visible in the river today. A large turf area just east of the parking lot will provide opportunities for passive recreation, such as kite flying, Frisbees, and other activities that do not require a traditional field. A series of concrete seatwalls will be provided as the trail slopes toward the river. The seatwalls will be illuminated at night to enhance access. A 10-foot-wide concrete path will lead to water's edge to the east, eventually connecting to the Memorial Drive access area. An emergency access ramp will extend down to the water on the east end of the park, providing access to the downstream side of the dam.

North Bank Public Access

The north bank public access area will be accessible from a new road extending east from the Washington Irving Park location at Memorial Drive. Improvements to Highway 64/ South Memorial Drive near Washington Irving Park will allow traffic to enter and exit the highway with greater ease. The north bank public access area is next to the north end of the low water dam. Above the dam, a large semi-circular overlook will highlight the views of the lake and the water flowing over the dam. The south end of the overlook will provide access for fishermen while the north end of the overlook will include shade structures. The upper level of the site will include picnic shelters for large and small groups offering views of the lake. A non-traditional play area, sand volleyball court, and a restroom facility will be connected to the west end of the park with ample parking for visitors. The steep bank on the west end will have a terraced hill with artificial turf slopes and concrete terraces. Visitors will be able to view the lake from under the shaded arbor at the top of the bank or from the turf slopes heading down the slope. A cascading waterfall feature will flow down the slope ending at the concrete landing/launch area for small watercraft. An emergency boat ramp will be located on the east side of the dam following the newly improved Haikey Creek channel. Boaters will have trailer/boat ramp access to the lake via the west side of the public access area.

Bank Stabilization/Restoration

Bank stabilization and restoration assumptions for the Bixby location are included and summarized in the Common Project Elements section.

Compensatory Mitigation/Preservation

Compensatory mitigation assumptions for the Bixby location are included and summarized in the Common Project Elements section.

Land Acquisition

Potentially impacted land parcels were identified based upon the proposed public access and recreational improvements associated with Bixby as shown in the drawings. Land valuations were determined based upon these parcels along with land ownerships. A total of 8 parcels were identified that are likely to be involved with the proposed dam location, along with the public access areas and the estimated land values included in the cost estimates.

Permitting

Permitting requirements and assumptions for the Bixby location are included and summarized in the Common Project Elements section.

Appendices