Phase II Report on Hydrology, Hydraulics, and Low Water Dams

Arkansas River Corridor
Tulsa, OK

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Submitted To:
U. S. Army Corps of Engineers
Tulsa District

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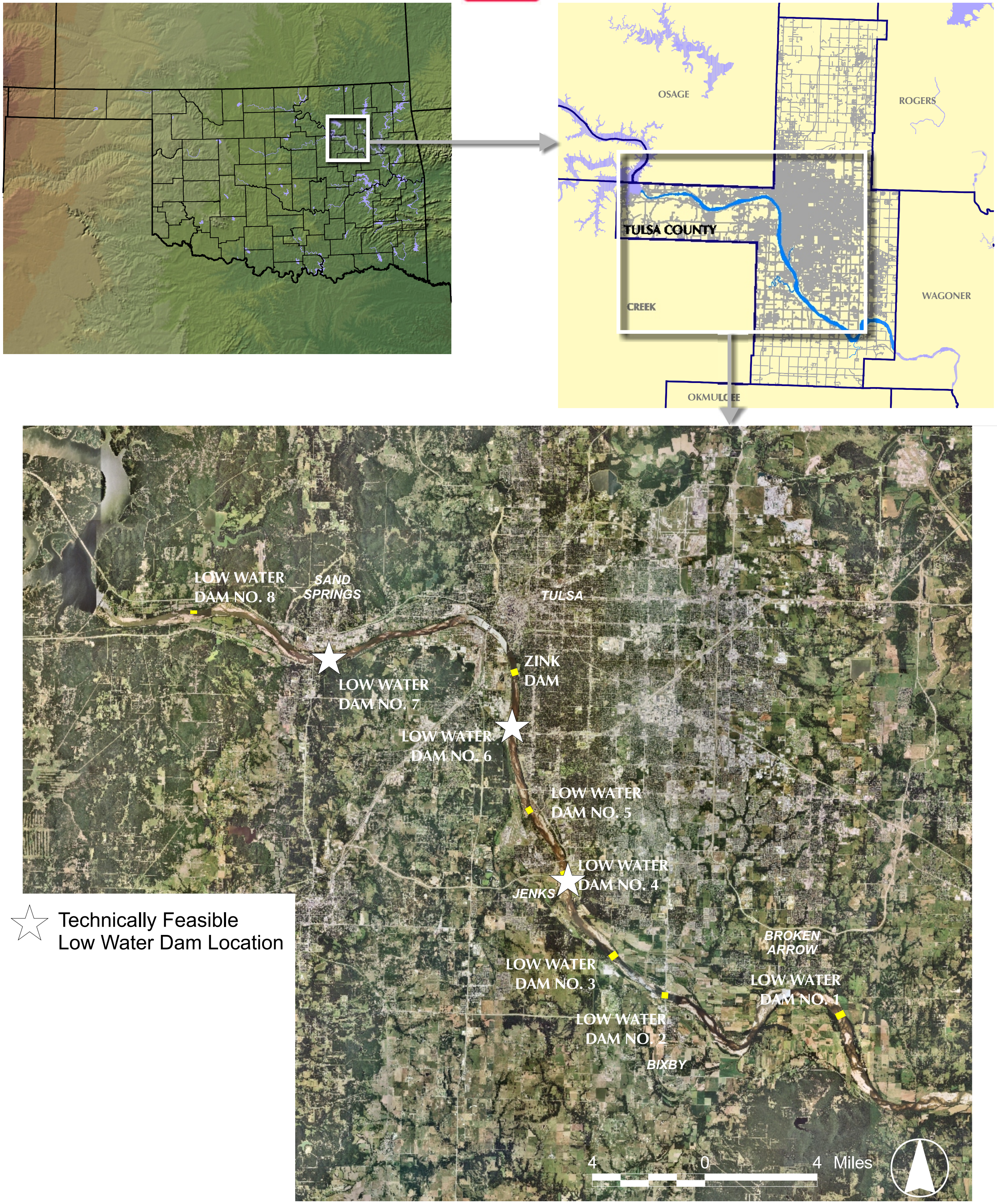
1.0 BACKGROUND/REQUIREMENTS

Aerial photographs provided by the Indian Nation Council Of Governments (INCOG) and the Phase I Vision Plan prepared by Carter & Burgess were reviewed for the purpose of evaluating the various locations for future low water dams on the Arkansas River between Keystone Dam and the Tulsa/Wagoner County line southeast of Broken Arrow, Oklahoma. This information was used in conjunction with data obtained through Project team meetings, agency consultation, technical evaluations, and preliminary environmental information collected for the Phase II Master Plan and Pre-Reconnaissance Study. GUERNSEY Team member HISINC, L.L.C. performed the hydrologic and hydraulic analyses for the Phase II study. Figure 1 provides a Site Location Map for the Arkansas River Corridor. This figure depicts the proposed low water dam locations from the Phase I Vision Plan and identifies the technically feasible dam locations identified in this Hydrology and Hydraulics Analysis Report (H/H Report).

The purpose the H/H Report is to:

- convey the results of the detailed engineering evaluations of each of the low water dams identified in Phase I
- discuss the development sequencing of the low water dams that were evaluated,
- classify the low water dams based on their technical and economic feasibility, and
- identify those low water dams that are recommended for further detailed analysis and consideration in the continuing phases of Vision 2025.

FIGURE 1 – SITE LOCATION MAP



SITE LOCATION MAP FIGURE 1

2.0 GENERAL SUMMARY OF HYDROLOGY AND HYDRAULICS

The U.S. Army Corps of Engineers, Tulsa District (Tulsa District) completed the updating of the Hydrologic Engineering Centers, River Analysis System (HEC RAS) hydraulic – backwater elevations and floodplain limits – model for the Arkansas River in late December 2004 and the Corps' "Super" hydrology/flows model in early January 2005. This data will be used in the new Arkansas River backwater model that will be the basis for a Letter of Map Revision (LOMR) to the Federal Emergency Management Agency (FEMA) on behalf of Tulsa County sometime in 2005. The previous backwater model was developed in 1977 as part of the initial FEMA Flood Insurance Study (FIS) and had not been thoroughly reviewed since that time. The new backwater model is based on new cross sections derived from 2002 aerial topography, on-site field survey cross sections, and Arkansas River sedimentation range data. The cross section locations in the new model are different than the original model; however, the bridge locations and river mile designations are very similar. Similarly, the Tulsa District has updated the existing "Super" hydrology model and re-evaluated the hydraulic spillway capacity of Keystone Dam. A detailed review of the new model has not been performed as part of this study. However, based on discussions with the Tulsa District's modelers there is very little change in the water surface elevations from the 1977 model, and floodplain limits are being revised primarily based on the new more detailed topographic mapping.

The Tulsa District indicates that the new hydrology shows the originally accepted 170,000 cubic feet per second (cfs) for the Base Flood flow, commonly accepted to be the 100-Year event, will be raised to 205,000 cfs. However, the Arkansas River has been degraded and eroded over the past 25 years leading to increased channel storage. The increased channel storage allows the River to handle a larger flow without a noticeable increase in water surface elevation.

A copy of the April 2001 Flood Emergency Plan for Keystone Lake was provided by the Tulsa District for this H/H Report. This document addresses the flooding limits on the Arkansas River for the maximum spillway discharge, 940,000 cfs, and the flooding limits in the event of a dam breach. The previously identified maximum historical inflow to Keystone Lake was 344,000 cfs during the October 1986 flood. The maximum recorded flow at the United States Geological Survey (USGS) Tulsa gage was 301,800 cfs from this same flooding event.

Floodplain mapping for the new Arkansas River backwater model is currently in process at the Tulsa District. As stated, this new mapping will be submitted to FEMA for modification of the existing FEMA Flood Insurance Rate Maps (FIRM) which will be issued after the new hydrology study, new backwater modeling, and proposed changes to the FEMA FIRM floodplain limits have been accepted by FEMA. This will establish the new floodplain boundaries for the Arkansas River between Keystone Dam and the Tulsa/Wagoner County Line. When complete, these boundaries will provide the basis for preparing maps to illustrate the elevations of the Base Flood flow or 100-year event, as well as flood elevations for the maximum release rate from Keystone Dam that can be maintained by the current levee system along the Arkansas River Corridor.

3.0 LOW WATER DAM LOCATIONS

The following is a summary of the proposed locations presented in the Phase I Vision Plan, and the potential relocation of some existing low water dams including the rationale behind the proposed relocations. The potential locations are presented beginning at the Tulsa/Wagoner County line and proceeding upstream to Keystone Dam.

3.1 LOW WATER DAM NO. 1, CITY OF BROKEN ARROW

The proposed location of this low water dam is between the extension of 145th East Avenue and 161st East Avenue, located downstream of a future nature park and upstream of the existing City of Broken Arrow wastewater treatment plant. There are currently no bridges crossing the Arkansas River at these locations, but there is a long range plan for a bridge extending East 161st Street South to connect with South 193rd East Avenue downstream of this low water dam location.

The Phase I Vision Plan proposes the expansion of recreational sports complexes in the Indian Springs area. The low potential for commercial, residential, and recreational development in this area suggests that a low water dam would be a long range consideration.

3.2 LOW WATER DAM NO. 2, CITY OF BIXBY

This proposed low water dam location is downstream of Memorial Road Bridge. The existing bridge provides easy access for construction of the dam, while the river lake created by the dam would enhance visual aesthetics from the Bridge. The Memorial Road Bridge would also provide ready access to development around the low water dam location. There are two existing sand and gravel operations at the bridge location that could be incorporated into the operation and maintenance of the new river lake.

The City of Bixby has no current economic development plans adjacent to the Arkansas River, though there are several private subdivisions being developed on both the north and south side of the Arkansas River at the current time, along with some small private commercial developments. This location has high volume traffic loads and the existing City Park on the north side of the Arkansas River has been recently renovated with the addition of an amphitheatre. The reasonable potential for commercial, residential, and recreational development in this area makes a low water dam feasible within a 5 to 15-year timeframe.

3.3 LOW WATER DAM NO. 3, JENKS/SOUTH TULSA – YALE AVENUE BRIDGE

This proposed low water dam location is southeast of the future privately-funded Yale Avenue Bridge southeast of the City of Jenks. Once constructed, this bridge would provide access for construction of the dam, while the river lake created by the dam would enhance the view from the Bridge. The Bridge would also provide ready access to development around the low water dam and associated river lake. The Public Service Company of Oklahoma (PSO) Riverside Station, an electrical generating station, is upstream of this location and the impoundment would provide a more constant water supply for PSO's station. There is also an existing sand and gravel operation opposite the PSO Riverside Station that could be incorporated into the operation and maintenance of the new river lake. There is a future park and residential development proposed south of East 121st Street South. The proposed Yale Avenue Bridge will be a privately owned toll bridge and financing for this project is currently in progress. There is good potential for commercial, residential, and recreational development due to the planned construction of the Yale Avenue Bridge at this location.

3.4 LOW WATER DAM NO. 4, JENKS/SOUTH TULSA – 96TH STREET AND CREEK TURNPIKE BRIDGES

This proposed low water dam location is downstream of the 96th Street and Creek Turnpike Bridges and upstream of the Polecat Creek Confluence. The existing bridges would provide visual and vehicular access to the low water dam and river lake area from both the east-bound and west-bound traffic. A low water dam and river lake would enhance the new Oklahoma Aquarium, the Riverwalk Crossing Area, and the proposed Creek Nation Development with an attractive water feature. There is an existing sand and gravel operation downstream of this location on the west bank of the River that could be incorporated into the operation and maintenance of the new river lake. There is extensive commercial, recreational, and residential development in this area and a low water dam would likely result in short range economic benefits.

3.5 LOW WATER DAM NO. 5, CITY OF TULSA – UPSTREAM OF 81ST STREET

This site is shown on the Phase I Vision Plan to be located upstream of 81st Street and upstream of the confluence with Joe Creek. There is a potential for short range economic benefits of a low water dam in this location; however, the City of Tulsa Southside Wastewater Treatment Plant on the downstream side of Interstate 44 (I-44) would discharge its wastewater treatment plant effluent directly into the river lake created by Low Water Dam No. 5.

3.6 LOW WATER DAM NO. 6, CITY OF TULSA – UPSTREAM OF I-44

This dam, as shown on the Phase I Vision Plan, is to be located upstream of the I-44 Bridge. There are currently plans and right-of-way acquisitions for widening Skelly Drive which will change in the River corridor characteristics.

The location of the Southside Wastewater Treatment Plant likely makes relocating this low water dam from its Phase I Vision Plan location infeasible. The treatment plant effluent needs to discharge downstream of a low water dam to minimize the water quality impacts to the pool. A low water dam at this location has the potential to impact the existing kayaking activities at the existing PSO rock dam by raising the tailwater level of the existing "riffle" and reducing the "whitewater" effect. The height of the new dam may need to be lower in this location to avoid these impacts. The potential for commercial, residential, and recreational development exists at this location.

The River Parks Low Water Dam and Zink Lake at 21st Street are next in sequence traveling upstream from Low Water Dam No. 6.

3.7 LOW WATER DAM NO. 7, SAND SPRINGS – MAIN STREET

The site for this low water dam in the Phase I Vision Plan is downstream of the Highway 97 Bridge near the Main Street extension. The existing bridge would allow ready access to the dam. The dam and the river lake could be seen both from the existing bridge and the existing park. The dam would also impound water at the Sand Springs River City Park which is proposed to be enhanced, along with the area to the north of River City Park into the Main Street area of Sand Springs. Also there is an existing Sand Springs Gravel/Mohawk Materials Sand and Gravel operation on the upstream side of the Highway 97 Bridge that could benefit commercially from sand and gravel maintenance operations for the proposed low water dam, since the available volume of sand and gravel is diminishing in this reach of the Arkansas River. This area of the Arkansas River is being strategically addressed for commercial and recreational development and the presence of a low water dam downstream of the Highway 97 Bridge supports this strategy.

3.8 LOW WATER DAM NO. 8, SAND SPRINGS – 177TH WEST AVENUE

This low water dam as shown on the Phase I Vision Plan would be located downstream of a future 177th West Avenue bridge as well as the existing bald eagle habitat area and extension of the River City Park. This area currently exhibits a low potential for commercial, residential, and recreational development in the short- and mid-range timeframe; thus a low water dam in this area is likely a long range consideration.

4.0 HYDRAULIC BACKWATER EVALUATIONS

The following is a summary of the hydraulic backwater evaluations performed during the H/H Report for the low water dams proposed for future study under the Vision 2025 planning. The low water dams have been categorized, based upon technical and economic feasibility, as:

- Tier 1 – short range development, less than 5 years,
- Tier 2 – mid-range development, 5-15 years,
- Tier 3 – long range development, greater than 15 years, or
- Infeasible based on technical, economic, or environmental impacts.

In addition, other comments on potential enhancements along the reach of the River will be noted.

Low water dams number 1 and number 8 have been categorized as Tier 3 and were not analyzed further in this H/H Report.

Copies of the HEC RAS backwater model output data for both the U.S. Army Corps of Engineers' base model dated December 2004 and the proposed Project model prepared as a part of this H/H Report are included in Section 4.8. In addition, a backwater summary table has been developed to compare the water surface elevations, energy grade elevations, channel velocities, flow area, and top width for the 100-Year, 1986 historic flood event, and the levee design flows provided by the Corps of Engineers. A copy of the HEC RAS models on CD is being provided to the U.S. Army Corps of Engineers for their use in review of the proposed modeling that has been performed as part of this Phase II evaluation.

In each case, the proposed Project model elevations are equal to, or less than the existing Corps of Engineers' base model elevations, thus surmising the hydraulic design of the proposed low water dams are acceptable and meet all of the hydraulic criteria presented earlier in the H/H Report.

4.1 GENERAL CONCEPT PLAN

The general concept plan for each low water dam is to provide multiple sets of bascule gates across the entire crest of each low water dam. With this concept, the possibility of storing significant sediments, sands, and gravels on the upstream side of the each low water dam is reduced. Each gate or set of gates would require a hydraulic operator at each end of each gate. These hydraulic operators would be housed in "towers" adjacent to each gate or fixed ogee weirs along the crest of the dam. The "towers" would also provide structural support for the pedestrian/maintenance walkway proposed for construction above each of the low water dams. The pedestrian/maintenance walkways would also connect the east and west banks of the Arkansas River for easy access to recreational, commercial, and residential locations.

The main structure of each low water dam will be a reinforced concrete ogee spillway section with a fixed crest elevation. This structure provides the support for the gates and provides uncontrolled spillway capacity to pass Arkansas River flows. It is proposed to create a hydraulically efficient pier nose and tail at each "tower" location.

As with the original Zink Lake Dam, the operational concept is proposed to maintain a fixed pool level between 0 cfs flow and approximately 10,000 cfs flow. A hydraulic operator will cause the gates to open or close based on signals from an upstream level controller. Above some yet to be determined flow rate, the bascule gates are fully opened on the bottom of the Arkansas River, allowing Arkansas River flows to pass both through the entire gate opening and over the fixed ogee weir. The bascule gates will begin to close once the flows decrease to some yet to be determined rate. The hydraulic operators on the bascule gates are set to a "fully open" fail safe operation in the event of loss of hydraulic pressure or mechanical failure to assure that each low water dam would not cause an upstream flooding impact in the event of a mechanical failure. Each gate should be operated periodically to assure that it is functional.

Each low water dam is required to be hydraulically designed to pass the Base Flood flow, currently understood to be the 100-Year flood event, without causing a rise in the upstream water surface elevation, in accordance with FEMA, the City of Tulsa, the U.S. Army Corps of Engineers, and Tulsa County floodplain management criteria. Each low water dam that was hydraulically evaluated in this study meets these criteria within current standards of hydraulic design. ***The elevations and assumed dam heights to achieve these results are subject to change when further detailed studies are performed. For each low water dam location, it will be necessary to consider more detailed field survey data, geologic stratum, land ownership, and economic development opportunities on the banks of the Arkansas River.*** For each low water dam a hydraulic concept design was created and input into the HEC RAS backwater analysis.

At the end of this section is a Summary Table that presents the new Corps of Engineers' Backwater model results and compares them with those generated having the low water dams included in the model.

4.2 LOW WATER DAM NO. 2, CITY OF BIXBY

Low Water Dam No. 2 is proposed to be located downstream of Memorial Road Bridge at River Station 267496.2 in the new Corps of Engineers' HEC RAS backwater model.

This low water dam is proposed to have three sets of bascule gates across the crest of the dam. These could either be sets of four 45-foot long gates, or sets of two 100-foot long gates. For the hydraulic modeling in this study, sets of four 45-foot long gates were considered since there will be more "towers" required thus creating more obstruction in the Arkansas River floodplain. The proposed bottom of each gate is at Elev. 576.0 based on the best available data from the INCOG aerial topography and the new Corps of Engineers' HEC RAS backwater model. The fixed ogee crest is proposed to be at Elev. 583.0 thus creating a 7-foot deep pool at the upstream face of the low water dam. This is the maximum height of dam that can be created at this location, based on the information available, without causing a rise in the water surface elevation. The recreational river lake that is created will reach to approximately River Sta. 279420 or 2.2 river miles upstream to approximately 5,000 feet downstream of Low Water Dam No. 3. This location would be feasible from an engineering and economic perspective; however, negative water quality effects would be associated with this dam. Water quality issues are further discussed in Section 7.0 of this report.

Based on the negative water quality impacts associated with Low Water Dam No. 2, it has been categorized as infeasible at this time.

4.3 LOW WATER DAM NO. 3, JENKS/SOUTH TULSA – YALE AVENUE BRIDGE

Low Water Dam No. 3 is proposed to be located downstream of the proposed privately-funded Yale Avenue Bridge southeast of the City of Jenks at River Station 284396.7 in the new Corps of Engineers' HEC RAS backwater model.

This low water dam is proposed to have five sets of bascule gates across the crest of the dam. These could either be sets of four 45-foot long gates, or sets of two 100-foot long gates. For the hydraulic modeling in this study, sets of four 45-foot long gates were considered since there will be more "towers" required thus creating more obstruction in the Arkansas River floodplain. The proposed bottom of each gate is at Elev. 586.0 based on the best available data from the INCOG aerial topography and the new Corps of Engineers' HEC RAS backwater model. The fixed ogee crest is proposed to be at Elev. 592.5 thus creating a 6.5-foot deep pool at the upstream face of the low water dam. This is the maximum height of dam that can be created at this location, based on the information available, without causing a rise in the water surface elevation. This low water dam has more gates due to the width of the Arkansas River at this location. The final location would be dependent on the location and modification of the Arkansas River banks after the proposed Yale Avenue Bridge is located and constructed. The recreational river lake would reach to approximately River Sta. 300184.8 or 3 river miles upstream to the downstream side of Low Water Dam No. 4. This location would be feasible from an engineering and economic perspective;

however, negative water quality effects would be associated with this dam. Water quality issues are further discussed in Section 7.0 of this report.

Based on the negative water quality impacts associated with Low Water Dam No. 3, it has been categorized as infeasible at this time.

4.4 LOW WATER DAM NO. 4, JENKS/SOUTH TULSA – 96TH STREET AND CREEK TURNPIKE BRIDGES

Low Water Dam No. 4 is proposed to be located downstream of the 96th Street and Creek Turnpike Bridges and upstream of the Polecat Creek Confluence at River Station 298448.8 in the new Corps of Engineers' HEC RAS backwater model.

This low water dam is proposed to have three sets of bascule gates across the crest of the dam. These could either be sets of four 45-foot long gates, or sets of two 100-foot long gates. For the hydraulic modeling in this study, sets of four 45-foot long gates were considered since there will be more "towers" required thus creating more obstruction in the Arkansas River floodplain. The proposed bottom of each gate is at Elev. 588.0 based on the best available data from the INCOG aerial topography and the new Corps of Engineers' HEC RAS backwater model. The fixed ogee crest is proposed to be at Elev. 596.0 thus creating an 8-foot deep pool at the upstream face of the low water dam. This is the maximum height of dam that can be created at this location, based on the information available, without causing a rise in the water surface elevation. The recreational river lake that is created will reach to approximately River Sta. 313999.4 or 2.9 river miles upstream to approximately 3,100 feet downstream of the 71st Street Bridge over the Arkansas River and downstream of the effluent discharge location from the City of Tulsa Southside Wastewater Treatment Plant.

This low water dam location is classified as a Tier 1 dam location based on technical feasibility and potential economic benefits. ***This low water dam site is proposed as one of the conceptual plan locations for low water dams in the Phase II Master Plan.***

4.5 LOW WATER DAM NO. 5, CITY OF TULSA – UPSTREAM OF 81ST STREET

Low Water Dam No. 5 is proposed to be located upstream of the Joe Creek Confluence near 81st Street at River Station 312552.2 in the new Corps of Engineers' HEC RAS backwater model.

This low water dam was modeled with three sets of bascule gates across the crest of the dam. The hydraulic modeling included both sets of four 45-foot long gates, and sets of two 100-foot long gates. The proposed bottom of each gate was at Elev. 594.0 based on the best available data from the INCOG aerial topography and the new Corps of Engineers' HEC RAS backwater model. The fixed ogee crest was initially set at Elev. 600.5 thus creating a 6.5-foot deep pool at the upstream face of the low water dam.

Multiple trials of dam configurations were evaluated with none meeting the "no-rise criteria" established for installation of a low water dam. Each trial run reduced the dam height by 0.5 feet until the final runs were set with a dam height of 3.0 feet which is considered non-economic. The downstream Low Water Dam No. 4 creates a river lake that causes a backwater effect through most of the proposed pool that would be created by Low Water Dam No. 5 and "tails out" downstream of the 71st Street Bridge.

Based on the hydraulic modeling and negative water quality effects, detailed in Section 7.0, Low Water Dam No. 3 is categorized infeasible.

4.6 LOW WATER DAM NO. 6, CITY OF TULSA – UPSTREAM OF I-44

Low Water Dam No. 6 is proposed to be located upstream of the I-44 Bridge and upstream of the Cherry Creek confluence at River Station 329092.8 in the new Corps of Engineers' HEC RAS backwater model.

This low water dam is proposed to have three sets of bascule gates across the crest of the dam. These could either be sets of four 45-foot long gates, or sets of two 100-foot long gates. For the hydraulic modeling in this study, sets of four 45-foot long gates were considered since there will be more "towers" required thus creating more obstruction in the Arkansas River floodplain. The proposed bottom of each gate is at Elev. 600.0 based on the best available data from the INCOG aerial topography and the new Corps of Engineers' HEC RAS backwater model. The fixed ogee crest is proposed to be at Elev. 608.0 thus creating an 8-foot deep pool at the upstream face of the low water dam. This is the maximum height of dam that can be created at this location, based on the information available, without causing a rise in the water surface elevation. The recreational river lake that is created will reach to approximately River Sta. 339414.4 or 1.9 river miles upstream to a point between the existing PSO rock dam and the downstream side of the existing Zink Lake Low Water Dam. A dam at this location and at this height will affect the existing kayaking activity on the west bank of the Arkansas River by increasing the tailwater elevation of the white water area and reducing the hydraulic head that creates the white water effect. A shorter dam could be used at this location to avoid impacts to the kayaking area; however, a smaller river lake would result from this change.

Based the proposed level and timeframe of development, Low Water Dam No. 6 is categorized as Tier 2, for mid-range, 5 to 15 year, consideration.

4.7 LOW WATER DAM NO. 7, SAND SPRINGS – MAIN STREET

Low Water Dam No. 7 is proposed to be located downstream of the Highway 97 Bridge near the Main Street extension at River Station 377829 in the new Corps of Engineers' HEC RAS backwater model.

This low water dam is proposed to have three sets of bascule gates across the crest of the dam. These could either be sets of four 45-foot long gates, or sets of two 100-foot long gates. For the hydraulic modeling in this study, sets of four 45-foot long gates were considered since there will be more "towers" required thus creating more obstruction in the Arkansas River floodplain. The proposed bottom of each gate is at Elev. 626.0 based on the best available data from the INCOG aerial topography and the new Corps of Engineers' HEC RAS backwater model. The fixed ogee crest is proposed to be at Elev. 633.0 thus creating a 7-foot deep pool at the upstream face of the low water dam. This is the maximum height of dam that can be created at this location, based on the information available, without causing a rise in the water surface elevation. The recreational river lake that is created will reach to approximately River Sta. 403112.2 or 4.8 river miles upstream to a point near the Shell Creek confluence with the Arkansas River.

This low water dam location is classified as a Tier 1 dam location based on technical feasibility and potential economic benefits. ***This low water dam site is proposed as one of the conceptual plan locations for low water dams in the Phase II Master Plan.***

4.8 HEC RAS BACKWATER COMPUTER RUN SUMMARIES

This section presents the summary printouts from the HEC RAS Backwater Modeling. There are two sets of HEC RAS computer printout summaries for each modeling plan.

Plan 01 is the Tulsa District's Base Model that was provided to the Project Team in December 2004 which represents the newly created Arkansas River model that will be used for the FEMA Letter of Map Revision of the currently effective Flood Insurance Rate Maps for Tulsa County. One set of summary printouts presents only the 100-Year, 1986 Flood event and the Levee Design Flows. The second set of summary printouts presents the 10-Year, 50-Year, 100-Year, 500-Year 1986 Flood event, Water Quality Flows provided to INCOG, and the Levee Design Flows.

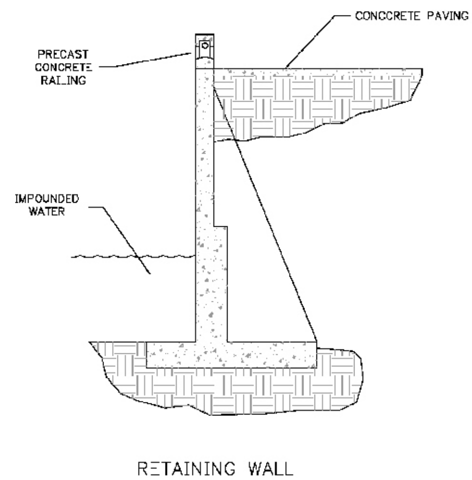
Plan 02 is the Tulsa District's Base Model that has been modified to add cross sections and low water dams at each of the locations described in the preceding sections. One set of summary printouts presents only the 100-Year, 1986 Flood event and the Levee Design Flows. The second set of summary printouts presents the 10-Year, 50-Year, 100-Year, 500-Year 1986 Flood event, Water Quality Flows provided to INCOG, and the Levee Design Flows.

A Summary Table has also been created for the each of the following flood events: Base/100-Year Flood, 1986 Flood Event, and the Levee Design Flow. Data from each of the HEC RAS Plans 01 and 02 were input into these Summary Tables to provide a ready comparison of the change in water surface elevation, energy grade elevation, channel velocity, flow area, and top width of the floodwaters between the Base Corps Model and the Proposed Low Water Dam Model.

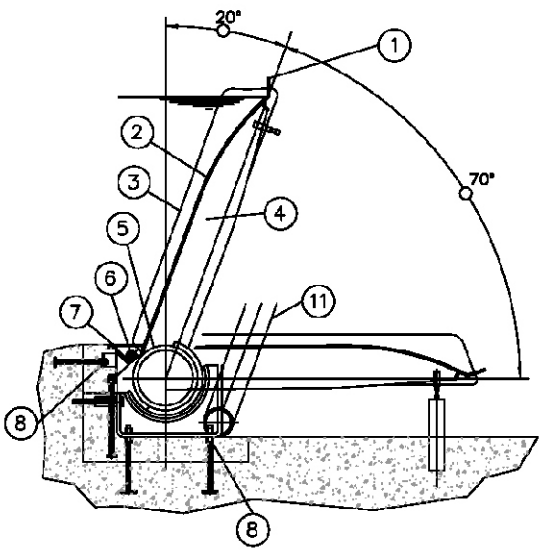
Figure 2 shows a typical low water dam representative of those being recommended for further detailed analysis.

Figure 3 shows the Arkansas River profile including the proposed low water dams and associated river lakes.

FIGURE 2 - TYPICAL CROSS SECTION OF A LOW WATER DAM

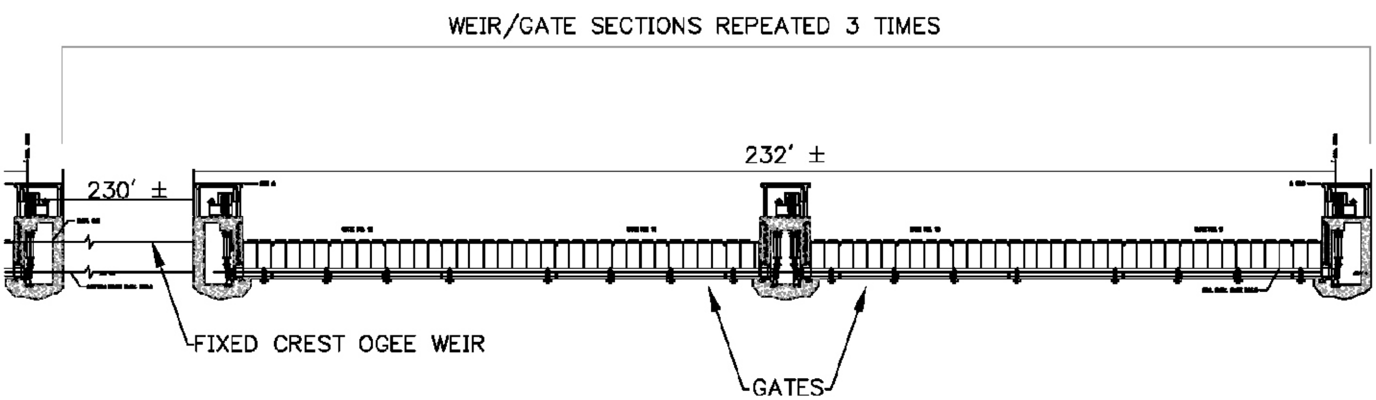


RETAININGWALL CONCEPT



1. NAPP BREAKER
2. UPSTREAM SKIN PLATE
3. END PLATE
4. GATE RIB
5. TORQUE TUBE
6. LONGITUDINAL RUBBER SEAL
7. SEAL COVER PLATE
8. SILL BEAM
9. ANCHOR BOLT
10. INTERMEDIATE BEARING
11. AIR ADMISSION PIPE
12. PACKING BOX
13. FIELD JOINT RIB
14. CYLINDER OPERATOR
15. LEVER
16. MAIN BEARING

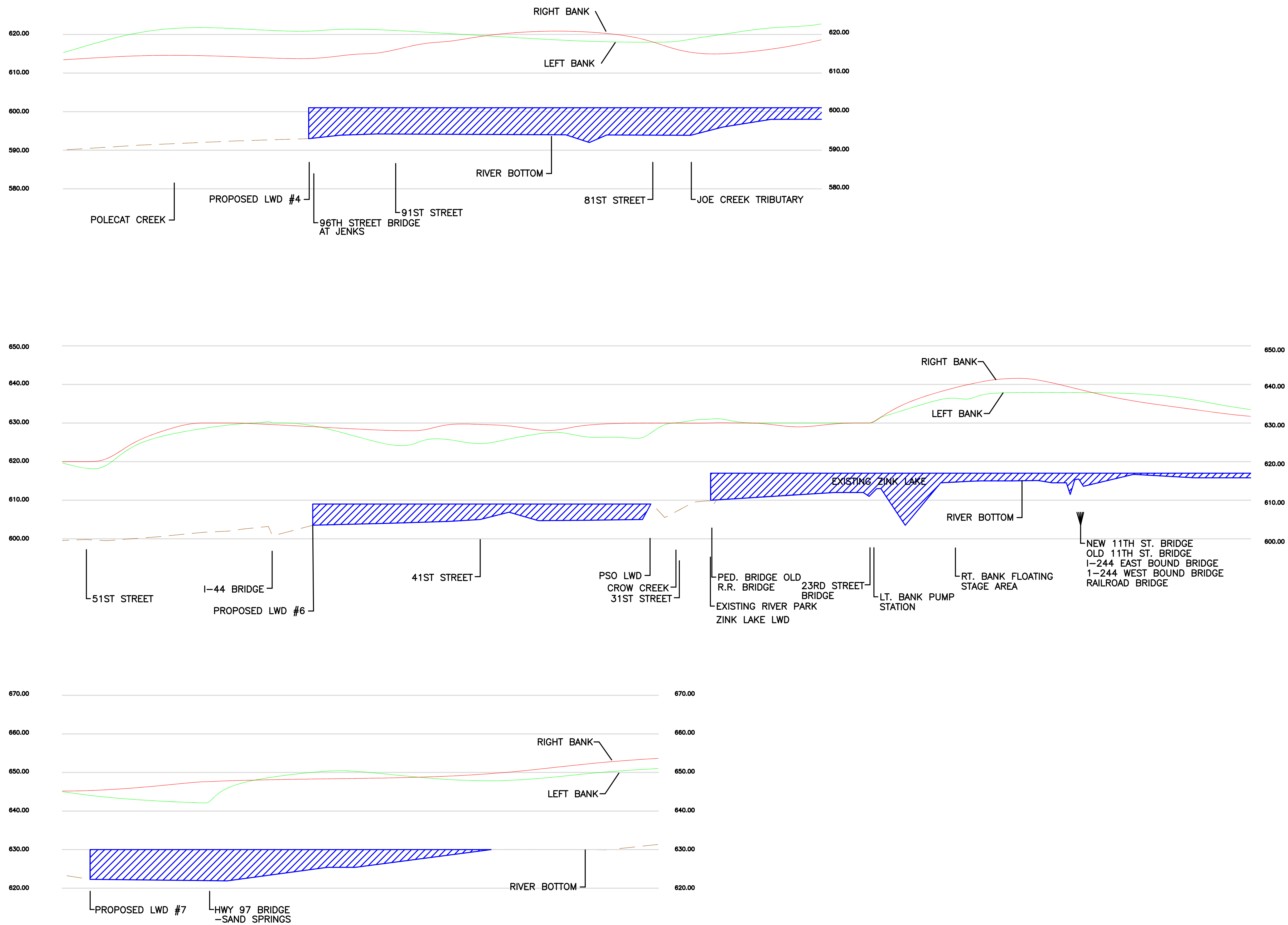
GATE CONCEPT



TYPICAL CROSS SECTION

FIGURE 2

FIGURE 3 – ARKANSAS RIVER PROFILE



RIVER PROFILE FOR TECHNICALLY FEASIBLE DAMS

FIGURE 3

FIGURE 4 – PROPOSED CONCEPT FOR PEDISTRIAN/MAINTENANCE BRIDGE OVER THE TOP OF THE LOW WATER DAM.

5.0 ESTIMATES OF PROBABLE DEVELOPMENT COSTS

5.1 INITIAL CAPITAL COSTS OF LOW WATER DAMS

An estimate of the initial capital costs of a typical low water dam with three sets of bascule gates was created for this report. To develop these costs not only were the initial construction costs considered, but also the design engineering, construction management, and legal and administrative costs. The costs for the pedestrian/maintenance bridge were developed by the Project Team and are included as a separate category from the low water dam costs. Financing costs are not included at this time.

Specific quotations were obtained from a manufacturer of the bascule gates that are proposed to be utilized for the typical low water dam. A preliminary design of the reinforced concrete fixed ogee section of the dam was prepared to estimate the concrete quantities and rock excavation quantities. An allocation, based on the original design of the Zink Lake Low Water Dam was made for the electrical and mechanical portions of the typical low water dam, considering that there will be additional sets of gates across the entire crest of the low water dam.

The cost summary sheets for the typical low water dam are included at the end of this section as Figures 5, and 6. Figure 7 shows the cost estimate for rehabilitation of Zink Dam. Detailed cost sheets are available upon written request.

5.2 MAINTENANCE OF LOW WATER DAMS

One of the major criticisms of the existing low water dam that creates Zink Lake is the issue of sedimentation. During the original design, extensive investigations were made concerning options for maintaining Zink Lake. Due to lack of initial capital funding, the number of bascule gates were reduced from the original design which reduced the capability to pass suspended sand during high flow events. Again, due to reduced maintenance funding capability, an undersized dredge was purchased by the River Parks Authority which was not able to perform adequately and was eventually eliminated from use.

It is recommended that as a part of the development of any additional low water dams an initial escrow account be established that will provide perpetual financial resources for proper maintenance of the existing and any new river lakes that are created. Adequate equipment, permitting, manpower, etc. needs to be established to maintain the new river lakes.

In addition, for some of the low water dams in locations where there are existing sand and gravel operations, a concept has been considered for collection and transfer of sand and gravel to the banks of the Arkansas River that will minimize maintenance dredging operations for the dam operators, and with the support of the sand and gravel operators, could reduce the collection costs of the existing sand and gravel operations. A meeting was held with the sand and gravel operation owners on the Arkansas River during this Phase II study. Based on extensive discussions of various maintenance concepts, and the currently diminishing volume of sand and gravel that is being transported downstream by the higher frequency flooding events, it was generally concluded that any type of mechanical or hydraulic sand collection system built into the new low water dams would not be economical. Instead, the sand and gravel operators would consider periodically dredging the pools upstream of each low water dam on an approximate five year cycle. The sand and gravel operators requested the opportunity to review the quality of the sand and gravel in Zink Lake and evaluate the approximate quantities. With this information, and if a "staging" area is made available by the River Parks Authority for storage handling and truck loading in the immediate area, the sand and gravel operators would consider removing the sand and gravel buildup at little or no cost to River Parks Authority or other governing agency, and would sell the sand and gravel to cover their costs of performing the maintenance dredging.

Another issue raised by the staff of the River Parks Authority is the accessibility for maintenance of the gates and hydraulic equipment. It is proposed in the future low water dams to create a pedestrian walkway/maintenance access bridge over the operating towers in each of the gate bays along the low water dam. A preliminary concept is shown on Figure 4. These towers would provide the structural support for the pedestrian walkway/maintenance access bridge and would allow maintenance vehicles to drive onto the bridge to perform periodic maintenance of the hydraulic equipment used to operate the gates.

An alternate to the periodic sand and gravel removal is the additional of another set of gates in the center of the existing Zink Lake Dam. This option is similar to the original design concept prepared in 1977. This would require dewatering of the existing Zink Lake for approximately 3 months, the removal of a section of the existing low water dam, construction of two towers to support the new hydraulic gate operators, installation of the new gate sections, and construction of an electrical and hydraulic duct bank in the rock ledge either upstream or downstream of the existing dam sill to connect to the existing hydraulic system. Upgrading of the control system would also be required to interconnect the new gate sections.

Discussions were raised about the use of an upstream siltation basin as a possible solution to the existing sedimentation issue. The main problem with this concept is the approach velocities from the existing rock sill upstream of the I-244 Bridge to the downstream side of the new 11th Street Bridge. There is an eroded section near all of the bridge piers that is over 12 feet deep due to the high velocities, therefore an upstream sedimentation basin is not applicable in this reach of the Arkansas River.

FIGURES 5, 6, and 7 - COST SUMMARY SHEET

Arkansas River Corridor Phase 2 Master Plan Study
Estimate of Probable Construction Costs - Typical Low Water Dam - 4 Gate Sections

Summary of Costs
(Based on 2005 Dollar Value)

Item	Description	Estimated Costs	Estimated Costs
1	Excavation and Backfill	$ 47,630	$ 48,000
2	Concrete	4,260,000	4,260,000
3	Bascule & Sluice Gates with Controls	6,600,000	6,600,000
4	Water Diversion & Control	77,000	77,000
5	Slope Protection (Temporary & Permanent)	90,000	90,000
6	Architectural Amenities	25,000	25,000
7	Miscellaneous Work to Complete	554,982	555,000
8	Contractor Mobilization and Demobilization	12,500	13,000
	Subtotal	$ 11,667,112	$ 11,668,000
	Continguencies (15%)	1,750,067	1,750,500
	Construction Cost	$ 13,417,178	$ 13,418,500
	General Construction Costs & Site Administration (8%)	1,073,374	1,073,500
	Contractor Insurance and Bonds	174,901	175,000
	Contractor Overhead & Profit (10%)	1,449,055	1,450,000
	Engineering, Legal, & Adminstrative (10%)	1,341,718	1,342,000
	Total Project Costs	$ 17,456,227	$ 17,459,000

Note: Values Rounded Up for Presentation

Arkansas River Corridor Phase 2 Master Plan Study
Estimate of Probable Construction Costs - Typical Low Water Dam - 5 Gate Sections

Summary of Costs
(Based on 2005 Dollar Value)

Item	Description	Estimated Costs	Estimated Costs
1	Excavation and Backfill	$ 47,630	$ 48,000
2	Concrete	3,195,000	3,195,000
3	Bascule & Sluice Gates with Controls	8,800,000	8,800,000
4	Water Diversion & Control	77,000	77,000
5	Slope Protection (Temporary & Permanent)	90,000	90,000
6	Architectural Amenities	25,000	25,000
7	Miscellaneous Work to Complete	611,732	555,000
8	Contractor Mobilization and Demobilization	12,500	13,000
	Subtotal	$ 12,858,862	$ 12,803,000
	Continguencies (15%)	1,928,829	1,750,500
	Construction Cost	$ 14,787,691	$ 14,553,500
	General Construction Costs & Site Administration (8%)	1,183,015	1,073,500
	Contractor Insurance and Bonds	192,766	175,000
	Contractor Overhead & Profit (10%)	1,597,071	1,450,000
	Engineering, Legal, & Adminstrative (10%)	1,478,769	1,342,000
	Total Project Costs	$ 19,239,312	$ 18,594,000

Note: Values Rounded Up for Presentation

Arkansas River Corridor Phase 2 Master Plan Study
Estimate of Probable Construction Costs - Add Gate Section to Zink Dam

Summary of Costs
(Based on 2005 Dollar Value)

Item	Description	Estimated Costs	Estimated Costs
1	Excavation and Backfill	$ 5,810	$ 5,800
2	Concrete	75,000	75,000
3	Bascule & Sluice Gates with Controls	1,100,000	1,100,000
4	Water Diversion & Control	38,500	38,500
5	Slope Protection (Temporary & Permanent)	11,500	11,500
6	Architectural Amenities	8,000	8,000
7	Miscellaneous Work to Complete	61,941	62,000
8	Contractor Mobilization and Demobilization	12,500	12,500
	Subtotal	$ 1,313,251	$ 1,313,300
	Continguencies (15%)	196,988	197,000
	Construction Cost	$ 1,510,238	$ 1,510,300
	General Construction Costs & Site Administration (8%)	120,819	121,000
	Contractor Insurance and Bonds	19,687	175,000
	Contractor Overhead & Profit (10%)	163,106	151,000
	Engineering, Legal, & Adminstrative (10%)	151,024	151,000
	Total Project Costs	$ 1,964,874	$ 2,108,300

Note: Values Rounded Up for Presentation

6.0 OTHER CONSIDERATIONS FOR RIVER DEVELOPMENT

6.1 PSO ROCK DAM

The old rock dam just south of the existing low water dam could be rebuilt or "cleaned up" as the diversion for the water intake on the west bank of the River. It would not be feasible to create a new concrete low water dam there, and it would detract from the existing historical significance of the existing rock diversion dam. However, both sides of the River in this area need to be improved and the rock dam maintained for aesthetics. This is also an area that is currently used for kayaking, and this reach of the River could possibly be extended to further fulfill this purpose.

6.2 POTENTIAL ISLAND

At 161st West Avenue, approximately 13 miles upstream of the Highway 97 Bridge Crossing, there is an area in the existing riverbed that has a large sand bar. This can be seen from Highway 412 heading west and from Highway 51 heading east. This would be a good location for a new natural habitat island with trees, etc. like the Smith Islands at the River Parks' Zink Lake. It would have to be evaluated in the backwater model, but there is no other development in the area and an island could provide a wildlife sanctuary area.

6.3 OTHER TYPES OF LOW WATER DAMS

One issue that has been raised during various discussions is alternative types of low water dams such as inflatable dams. There are many benefits with the inflatable type dam; however, there is always one major impediment – vandalism. Though the major manufacturers of the rubber bladders that create the inflatable dam have examined many different types of fabrics, there has been no solution to penetration by rifle bullets, knives, or arrows from high power bows. Municipalities, rural water districts, etc. that currently have these types of dams, whether in an urban area or in a remote rural area, generally concur that the maintenance costs associated with the vandalism and the interruption of operation of the dams are major issues. Several owners have removed the inflatable dams and replaced them with alternate steel type gates to avoid loss of water. Other weir types may be feasible upon further analysis.

6.4 HYDROPOWER EVALUATION

The Tulsa District requested the consideration of hydropower at each of the proposed low water dams. Hydropower provides a renewable/green energy source utilizing the natural river flows in the Arkansas River combined with the hydraulic power head developed with the creation of the low water dams. In the early 1980's, a report was prepared for the U.S.

Department of Energy to evaluate "high flow", "low head" turbine-generator technology for applications such as the Arkansas River. At that time, every known manufacturer of turbines or generators was contacted to evaluate the available technology. Though there were types of equipment commercially available, the economic evaluation of such applications was not feasible from an initial capital investment or a maintenance and operation perspective.

During this study, the remaining viable turbine manufacturers in the world were contacted to determine the status of this older technology. Each manufacturer responded that the "high flow", "low head" technology did not develop after the initial concept in the early to mid 1980's and that such projects were determined at that time, and still today, not to be economically feasible.

6.5 AQUATIC LIFE ISSUES

There has been discussion concerning the potential for fish passage around/over the proposed low water dams. Other issues have been raised regarding the preservation of existing fisheries in the River. Information concerning the migration and spawning periods of the various species of fish will be developed and this information will be compared with the historical flows in the Arkansas River. The initial evaluations determined that the migrations generally occur during historic higher flow periods when there is sufficient depth of water over the low water dams and the tailwater elevations are higher, thus there is no significant differential between the upstream pool elevation and the downstream tailwater elevation. Thus, during periods of high flows, there is sufficient depth of water flow over each of the low water dams to allow fish passage without restriction. During periods of low flows, there may not be sufficient water depths to pass fish and therefore mitigation measures may be required in the design of future low water dams, and possible remediation of the existing low water dam at Zink Lake.

6.6 WATER QUALITY EVALUATONS

INCOG performed an update of the water quality model for the Arkansas River as part of the Vision 2025 planning process. The Guernsey Team supported this modeling effort by coordinating the new Corps of Engineers' hydraulic backwater model with the INCOG water quality model to develop compatible cross section locations between the two models. Then INCOG used the preliminary conceptual design data for the proposed low water dams to evaluate the water quality impact at the various dam locations evaluated to determine any change in water quality in the pool areas as a result of the possible installation of the low water dams. A copy of the INCOG Water Quality Evaluation report is presented herewith.

7.0 INCOG WATER QUALITY REPORT

The INCOG Water Quality Report presented in this section was prepared as a part of the evaluation of the Arkansas River to determine the impact on the dissolved oxygen with the addition of certain low water dams.

The two Tier 1 low water dams – Dam No. 4 south of 96th Street Bridge in Jenks/South Tulsa area and Dam No. 7 east of Highway 91 in Sand Springs – did not exhibited unacceptable dissolved oxygen levels. Dam No. 6, upstream of I-44, is classified as a Tier 2 dam and does not present unacceptable dissolved oxygen levels. The Tier 3 dams, Dam No. 1 and Dam No. 8, were not included in this analysis. Low Water Dam Nos. 2 and 3 were demonstrated to create unacceptable dissolved oxygen levels and are, therefore, considered infeasible at this time.

INCOG REPORT ON DISSOLVED OXYGEN MODELING
OF SEVERAL PROPOSED DAM LOCATIONS ON THE ARKANSAS RIVER
Prepared May 2005

INCOG has evaluated the potential impacts on dissolved oxygen in the Arkansas River due to the potential for locating several proposed new low water dams (LWDs) in Tulsa County as part of Phase 2 of the Arkansas River Corridor Master Plan. Eight potential locations for new LWDs were identified in the Phase 1 Vision Plan, and these were the subject of INCOG's water quality evaluation. The upper-most and lower-most potential dam locations (Dams #8 and #1, respectively) were determined to be inappropriate for this evaluation due to their location and anticipated timing for implementation, and were not studied as part of this water quality evaluation. Since Zink Lake already exists, it too was modeled.

INCOG's previous dissolved oxygen modeling of this portion of the Arkansas River has been approved by the Oklahoma Department of Environmental Quality (ODEQ) and EPA Region VI and used to set wasteload allocations for all dischargers within the corridor for oxygen demanding substances, where appropriate. INCOG has used the one dimensional, steady state model, QUALTX, developed by EPA Region VI. For this study, INCOG used a Windows version of this model, called LAQUAL, which was developed by the author of QUALTX under contract with the Louisiana DEQ.

Within the past two years, the US Army Corps of Engineers performed numerous cross sections and flow measurements along this corridor to re-evaluate and update channel hydraulics. Bill Smith, P.E., Hydropower International Services, performed hydraulic modeling using the Corps data to calibrate his model, HEC-RAS. INCOG used the HEC-RAS hydraulic outputs for widths, depths and velocities of the various river reaches to set the same hydraulic conditions in LAQUAL. Since the two models input hydraulics features differently, INCOG used an Excel spreadsheet to allow adjustments of LAQUAL's hydraulic coefficients and exponents to match, as closely as possible, the HEC-RAS hydraulics under two flow conditions.

INCOG also re-set the lengths of the model reaches and computational elements used in the previous model to accommodate any future adjustments of locations of one or more dams. Heights of each dam were calculated by subtracting the difference in upstream and downstream thalweg (deepest part of a stream) elevations and adding the water depth at the upstream "end of pool" location as predicted by HEC-RAS. Each pool was divided into three model reaches with successive increases in depth to accommodate channel slope. That is, each dam's pool will be shallower upstream than at the dam, so this was taken into account in the models.

The summer temperature of 29 °C was calculated by INCOG in a 1997 modeling report based upon USGS continuous monitoring data at the 11th Street bridge gage. This value continues to be accepted by ODEQ and EPA for use in setting permit limits for dischargers in the study corridor.

Three seasons (summer, winter and spring) were used as required by the ODEQ and as stipulated in the Oklahoma Continuing Planning Process (CPP) document that guides how dissolved oxygen modeling should be performed. Seasonal upstream (headwater) base flows for the Arkansas River were based upon the most recent data available from the US Geological Survey (USGS) as required by ODEQ. The "regulated" seasonal base flows (flow calculations based upon the period of record reflecting operation of Keystone Lake) were obtained from "Statistical Summaries of Streamflow in Oklahoma through 1999" (USGS, 2002). These are 896 cfs, 938 cfs and 2,850 cfs for summer, winter and spring, respectively. All discharger loads and flows were input into the model based upon Oklahoma's current 208 Water Quality Management Plan (208 Plan) wasteloads allocated for each discharger.

Several different modeling scenarios were selected to reflect increasing installation of LWDs. These are reflected in the attached Table 1 of dissolved oxygen modeling results. The dam numbers correspond to the assigned numbers used elsewhere in this report. Table 1 includes the "target DO" for each model run. This represents a minimum dissolved oxygen (DO) concentration in milligrams per liter (mg/L) that must be maintained in all modeling results as specified by the ODEQ and the CPP. The seasonal target DOs are higher than the seasonal dissolved oxygen water quality standards as a conservative assumption.

Results of this study indicated that construction of the two highest priority dams (#7 by Highway 97 in Sand Springs and #4 near the Creek Turnpike bridge in the South Tulsa/Jenks area) will not cause a drop in dissolved oxygen below the target DOs nor the water quality standards for all three seasons. Also, Dam #6 (upstream of the I-44 bridge in Tulsa) did not exhibit water quality impacts below regulated levels for any season. The most restrictive season is summer owing to the lowest headwater (upstream) flow and the highest temperatures (29 °C).

Problems with summer dissolved oxygen arise for Dams # 3 (proposed Yale bridge area) and #2 (Bixby area) even without Dam #5 (downstream of Tulsa's Southside wastewater treatment plant) in place. If Dam #5 is added into the model, then summer dissolved oxygen in the model reaches in the Dam #5 pool and downstream of Dam #5 is below the summer target DO. This is likely due to: 1) significant pooling from multiple dams (#5, #4, #3 and #2) which slows velocities and increases depth which in turn reduces instream reaeration of the water; and 2) the Tulsa Southside discharge, along with planned 7 MGD discharges from Sapulpa directly into the Arkansas River as well as 7 MGD into Polecat Creek, exert an oxygen demand in the pools that exceeds the River's assimilative capacity.

TABLE 1: ARKANSAS RIVER DISSOLVED OXYGEN MINIMUMS WITHIN EACH DAM POOL

SCENARIO	SEASON	MODEL NAME	TARGET DO (1)(2)	MINIMUM DO (2)	MODEL REACH	DO PROFILE DESCRIPTION
Zink Lake (Z) only	Summer	ARZsu	5.0	5.78	13	In Zink Lake pool by dam
"	Spring	ARZsp	6.0	7.40	13	In Zink Lake pool by dam
"	Winter	ARZwi	6.0	8.21	13	In Zink Lake pool by dam
Dams #7 & #4 w/Z	Summer	AR7Z4su	5.0	5.35 6.83 5.08	7 20 24	In Dam #7 pool by dam In Zink Lake pool by dam In Dam #4 pool by dam
"	Spring	AR7Z4sp	6.0	6.88 7.48 7.14	7 20 24	In Dam #7 pool by dam In Zink Lake pool by dam In Dam #4 pool by dam
"	Winter	AR7Z4wi	6.0	7.74 8.68 7.49	7 20 24	In Dam #7 pool by dam In Zink Lake pool by dam In Dam #4 pool by dam
All dams but #5 w/Z	Summer	AR7Z6432su	5.0	5.35 6.09 5.72 5.07 4.28 3.42	7 13 17 24 27 31	In Dam #7 pool by dam In Zink Lake pool by dam In Dam #6 pool by dam In Dam #4 pool by dam In Dam #3 pool by dam In Dam #2 pool by dam
"	Spring	AR7Z6432sp	6.0	6.88 7.35 7.20 7.07 6.79 6.41	7 13 17 24 27 31	In Dam #7 pool by dam In Zink Lake pool by dam In Dam #6 pool by dam In Dam #4 pool by dam In Dam #3 pool by dam In Dam #2 pool by dam

SCENARIO	SEASON	MODEL NAME	TARGET DO (1)(2)	MINIMUM DO (2)	MODEL REACH	DO PROFILE DESCRIPTION
"	Winter	AR7Z6432wi	6.0	7.74	7	In Dam #7 pool by dam
				8.35	13	In Zink Lake pool by dam
				7.97	17	In Dam #6 pool by dam
				7.43	24	In Dam #4 pool by dam
				6.66	27	In Dam #3 pool by dam
				5.80	31	In Dam #2 pool by dam
All dams w/Z	Summer	AR7Z65432su	5.0	5.35	7	In Dam #7 pool by dam
				6.09	13	In Zink Lake pool by dam
				5.72	17	In Dam #6 pool by dam
				3.60	20	In Dam #5 pool by dam
				3.86	24	In Dam #4 pool by dam
				4.07	27	In Dam #3 pool by dam
				3.63	31	In Dam #2 pool by dam
"	Spring	AR7Z65432sp	6.0	7.05	7	In Dam #7 pool by dam
				7.37	13	In Zink Lake pool by dam
				7.22	17	In Dam #6 pool by dam
				6.63	20	In Dam #5 pool by dam
				6.56	24	In Dam #4 pool by dam
				6.53	27	In Dam #3 pool by dam
				6.23	31	In Dam #2 pool by dam
"	Winter	AR7Z65432wi	6.0	7.74	7	In Dam #7 pool by dam
				8.35	13	In Zink Lake pool by dam
				7.97	17	In Dam #6 pool by dam
				6.24	20	In Dam #5 pool by dam
				6.26	24	In Dam #4 pool by dam
				6.23	27	In Dam #3 pool by dam
				5.77	31	In Dam #2 pool by dam

(1) Represents the dissolved oxygen minimum "target" set by ODEQ in the Oklahoma Continuing Planning Process (CPP) document which must be shown to be maintained in the models.
(2) All dissolved oxygen concentrations are in milligrams per liter (mg/L).

8.0 RECOMMENDATIONS

8.1 RECOMMENDATIONS FOR NEXT PHASE STUDY

Based on the hydraulic evaluations performed to date, the following recommendations are made for the next phase of study:

1. Specific site locations be established in the field for the two proposed low water dams classified as Tier 1.
2. Field surveys be performed in the reach of each location to provide detailed topographic information concerning the locations, including sufficient area upstream and downstream of the proposed axis of the low water dam to adjust the location as necessary.
3. Preliminary geotechnical explorations be made with the general area of the proposed low water dams to establish the foundation conditions for each Tier 1 low water dam.
4. Detailed conceptual plans be developed for each Tier 1 low water dam. With this data, the hydraulic backwater analyses should be updated to finalize the maximum height of each dam.
5. The cost estimate be updated using the detailed conceptual plans.
6. The feasibility of each Tier 1 low water dam be determined, considering all factors of commercial and economic development, maintenance, etc.