VISION 2025
ARKANSAS RIVER CORRIDOR

ECOSYSTEM RESTORATION PLAN

IN CONJUNCTION WITH
PROPOSED LOW WATER DAMS

FOR
TULSA COUNTY, OKLAHOMA
13 FEBRUARY 2009

US Army Corps of Engineers

TULSA COUNTY

TVA

TABLE OF CONTENTS

RESTORATION PLAN
For the
Arkansas River Corridor Project
Ecosystem Restoration Study in Conjunction with Future Low Water Dam Requirements

Problems and Opportunities

Problems. The construction of Keystone Dam was complete in 1964. The dam has successfully reduced the negative impacts of flooding along the Arkansas River in Tulsa County. However, changes have occurred to the natural flow regime of the river. These changes, in combination with land use changes in the watershed, have altered the river corridor ecosystem. For example, Keystone Lake significantly reduces the amount of sediment that maintains downstream island habitat for the endangered Interior Least Tern. Also, frequent and extreme river fluctuations from hydropower operations, consisting of high flows followed by low flows, have a drying effect on the aquatic habitat.

The impacted geomorphology has resulted in streambank erosion problems at various locations and the destruction of riverine wetlands and oxbow habitats that were once important fish nurseries and feeding/resting areas to migrant waterfowl. The destruction of these habitats has decreased the species diversity and overall productivity of the remaining downstream habitat. Other watershed concerns include pathogens, pesticides, and organics from urban, municipal, commercial, and agriculture runoff that affect the water quality.

The cumulative effects of these impacts have adversely affected the native fish populations. Following the construction of Keystone Lake, game fish that are more tolerant of the altered aquatic ecosystem were introduced in an attempt to offset the reduction to the native riverine fishery. The river now has a viable population of striped bass, paddlefish, sand bass, largemouth bass, channel catfish, sauger, and sunfish.

In addition to the Interior Least Tern, other endangered and threatened species that utilize the Arkansas River Corridor are the Bald Eagle and Piping Plover. The

Corridor is also heavily utilized by migratory waterfowl, resident shorebirds, and neotropical migrants.

Opportunities. The communities in Tulsa County approved a 0.6-penny, 13-year tax to support Vision 2025 for community enrichment of the Greater Tulsa Area. A portion of the sales tax is devoted to improvements associated with the Arkansas River Corridor. The Greater Tulsa Area communities recognize that the Corridor is an important natural resource that could be developed to stimulate immense private investment and greatly improve the quality of life for current and future generations. The Indian Nations Council of Government directed the development of the Arkansas River Corridor Master Plan/Phase 1 Vision Plan, completed in August 2004. The plan was general in nature and scale, but established a framework in which future planning and design work would be accomplished. The Corps of Engineers and the Indian Nations Council of Governments finalized a Phase-2 Master Plan and Pre-Reconnaissance Study in October 2005 under the Planning Assistance to States program for the 42-mile Corridor. See Map 1, from the Master Plan. The objectives of the plan are to recommend potential environmental and economic planning initiatives. A Letter of Agreement was signed by Tulsa County, the Oklahoma Water Resources Board, and the Corps of Engineers for this Ecosystem Restoration Study, in Conjunction with Future Low Water Dam Requirements.

Habitat Inventory and Improvement

Inventory. The Tulsa County portion of the Arkansas River Corridor has experienced significant degradation due to past riverine alterations and encroachment from urban and industrial development. The Corps contracted with Cherokee CRC, Inc. of Tulsa to inventory the existing environmental data for the following parameters. See Appendix B.

1. Faunal and Floral Inventory
2. Fish Community Structure and Composition Assessment
3. Aquatic Macroinvertebrate Structure and Composition
4. Water Quality and Habitat Evaluation
5. Cultural Resource Evaluation

The purpose of the study is to document the baseline environmental data as early as possible in the proposed development of two low-water dams and subsequent river-lakes. The two dam locations are in the Sand Springs and South Tulsa/Jenks areas. The data will be used to establish direct and indirect impacts for future development and ecosystem restoration. However, the study will encompass the entire Corridor, from the Keystone Dam to the Tulsa/Wagoner County line, to provide cumulative information for the Department of the Army regulatory permits and future environmental documents.

The Tennessee Valley Authority (TVA) assessed the river hydrology and ecosystem to recommend seasonal dams that will allow continued spawning of native game and non-game fish species, including minnow species that provide forage for the Interior Least Tern. See Appendix A.

Improvements. A total watershed approach to the Corridor is being used by the sponsor to manage the river's best land use practices between competing economic and environmental interests. Stakeholders are concerned that the Corridor will be subject to serious degradation if environmental concerns are not addressed and zoning and environmental regulatory restrictions are not established early in the development. For example, all development will need to be to the 100-year flood pool elevation. Where possible, water flow and streambank rehabilitation will use bio-remediation construction methods.

This Restoration Plan will only address those developments proposed in the Sand Springs and South Tulsa/Jenks river-lakes portions of the Phase-2 Master Plan and Pre-Reconnaissance Study. The Keystone Dam and the Tulsa County urbanization will limit restoring most natural functions back into the severely disturbed ecosystem. The expectation of restoring the corridor to a *pre-urbanization* or *reference* braided prairie river system is not realistic or feasible. Therefore, restoration will in reality be limited to the extent the ecosystem can be rehabilitated and stabilized. Rehabilitation will require a design approach integrating multi-uses by analyzing the existing conditions and developing designs that will satisfy the conceived short-term and long-term goals of Tulsa County.

Information provided in this plan will be used by Tulsa County to submit an application for the Department of the Army Regulatory Permit. Other portions of the river are being developed by individual landowners, and additional development proposals have been proposed by other interests since the completion of the Master Plan. Those projects will be addressed in future NEPA documents as they apply for their necessary Regulatory Permits.

Map 1 ~ From the Master Plan

ARKANSAS RIVER CORRIDOR OVERVIEW **FIGURE 1.1-1**

ARKANSAS RIVER MASTER PLAN AND PRE-RECONNAISSANCE STUDY C.H. GUERNSEY | EDAW | ALABACK DESIGN OCTOBER 2005

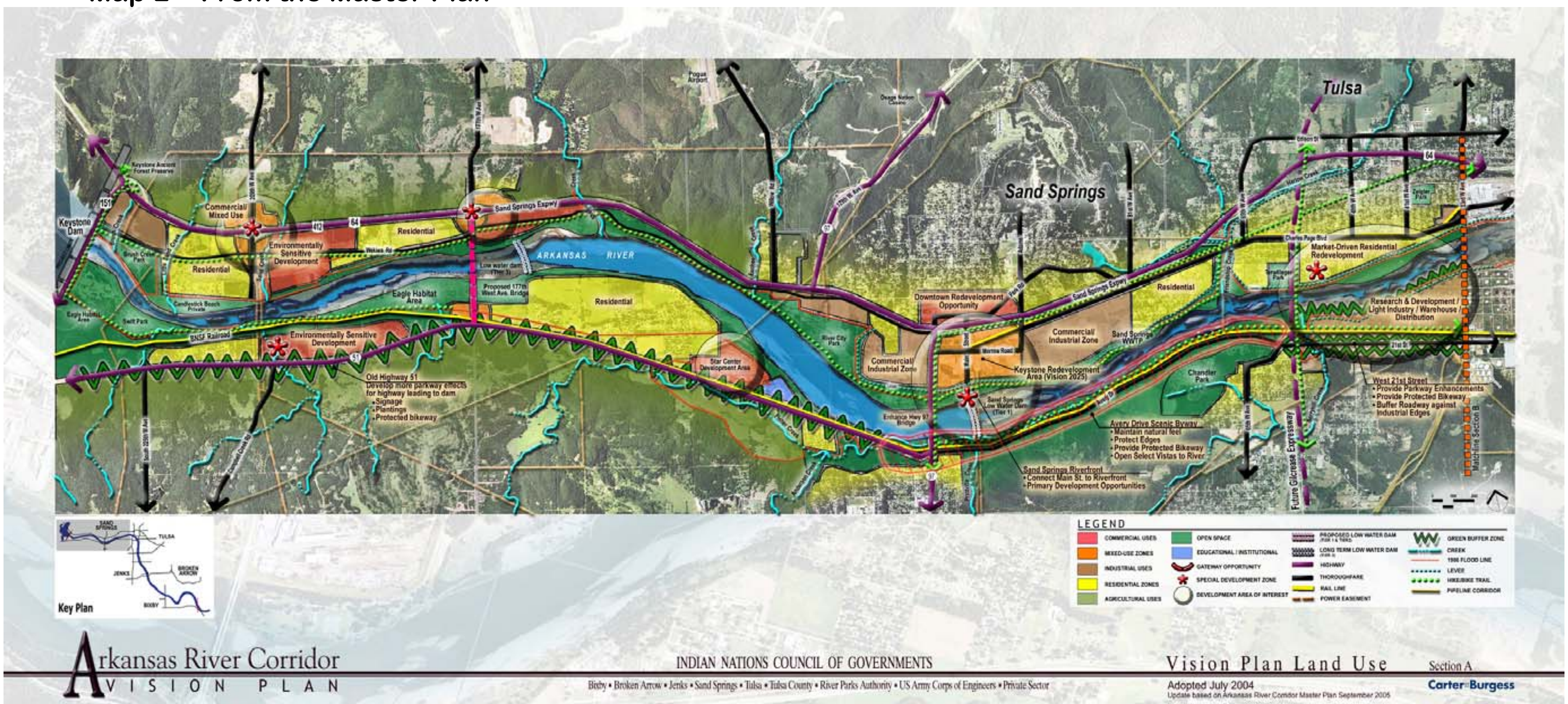
Proposed Plans – Sand Springs

<u>Low-Water Dam and River/Lake.</u> The proposed location for the Sand Springs dam is downstream of the State Highway 97 Bridge, directly south of Main Street. The Master Plan proposes a seven feet high dam that will create a lake upstream for approximately 4.8 miles. This location will allow ready access and viewing from the Highway 97 Bridge, the River City Park area, and a proposed new development at the levee. The dam will impound water beyond the River City Park area, which will be enhanced and expanded to the east. Development of the riverside area will extend from Highway 97, three quarters of a mile to the east on both the north and south sides of the river. See Map 2.

<u>Riverfront Development.</u> A primary development goal is to provide a riverfront destination for retail and commercial services, and to improve the appearance of the City. The proposed low water dam and riverfront development will also provide recreational opportunities and aesthetic improvements to the area. Specific improvements proposed in the Master Plan are as follows. See Map 3.

1. The proposed dam would include a pedestrian bridge with fishing piers.
2. The wooded areas along both the north and south banks of the river would provide an opportunity for hiking and nature trails.
3. A boat ramp is proposed on the south bank below the dam for public use, fish harvesting, and emergency access.
4. A boat ramp and marina would provide for local boating and fishing access on the lake. The proposed area would be recessed from the flow of the river in a constructed cove on the north bank, downstream from the Highway 97 Bridge.
5. The continued operation of a sand and gravel operation that is located on the south side of the river, and west of the Highway 97 Bridge.
6. Development of the riverside area would greatly increase public use. As a result, more trash will be brought into the area. Trash is already scattered throughout the area, mostly washed in from upstream locations during high flow.
7. A parking lot is proposed in the wooded area above the north riverbank, downstream of the marina. The area is heavily wooded, with several large mature trees. Access would be from Main Street over the levee. All the proposed development is in the floodplain.

Map 2 ~ From the Master Plan



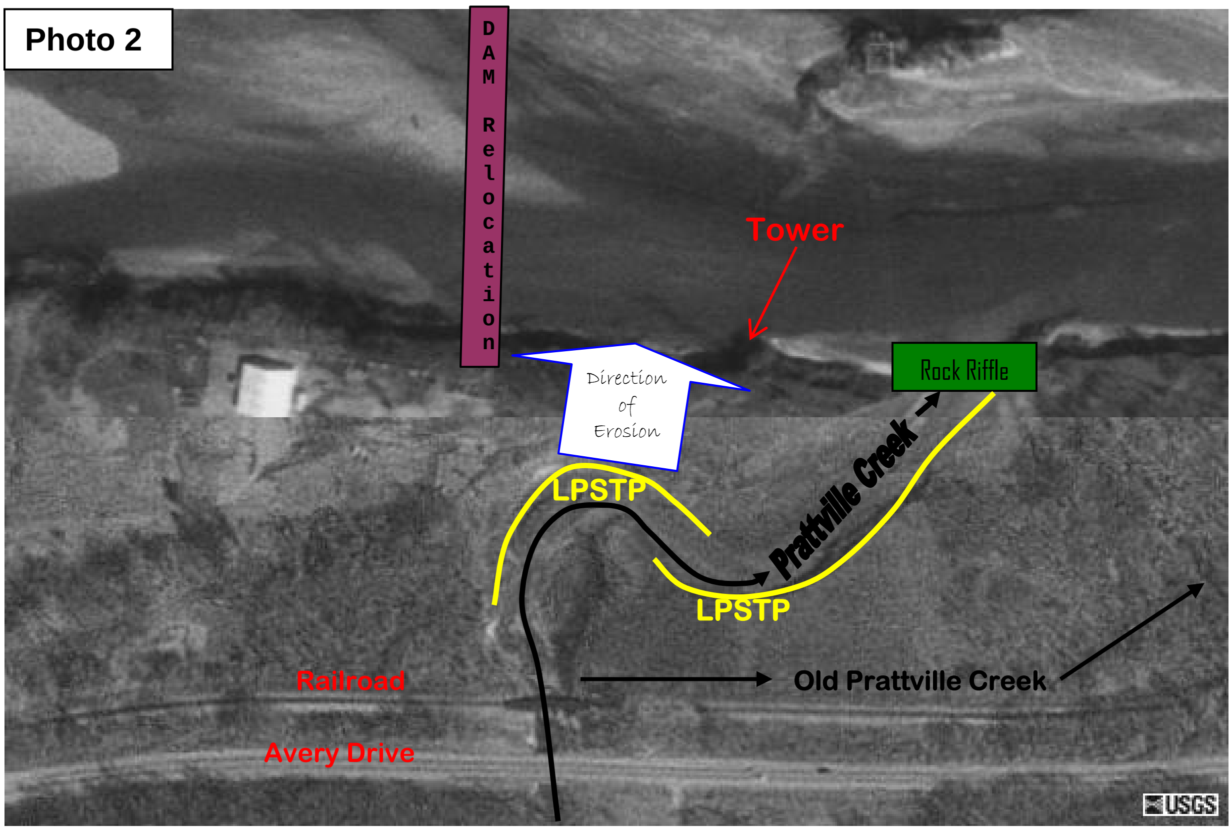
Map 3 ~ From the Master Plan

Restoration Recommendations – Sand Springs

Low-Water Dam and River/Lake. The key to the riverside development is the seasonal dam. The TVA has recommended an adjustable dam design that will allow for either a river system or a lake system. The dam can be lowered to allow the river system to flow freely during the spring spawning season of the local fishery, typically January through March. After the spawning months the dam can be raised to create a lake system. See the attached report from TVA. An eleven feet high dam is recommended, which will create a lake reaching upstream for approximately five miles, to the Shell Creek area. The upper three feet of the lake would be released daily at a rate of 400-1000 cfs through the low-flow valves to maintain the water quality of the river downstream, and to provide a daily water flow for activities in the Tulsa and Jenks areas. Although the lake will reduce erosion to the embankments for most of the year, measures will be needed for bank protection when the dam is down. The exposed shoreline will be void of vegetation, at a time of the year when the river flows are the highest. High risk areas are discussed below, with some recommended bio-technical erosion control methods. Alternative methods may be used if they are known to be as effective.

The proposed location for the dam on the south shoreline could be compromised by erosion from Prattville Creek, which is cutting into the 20-feet high embankment from the south. See Photo 1. Bank stabilization would be needed along Prattville Creek above the proposed pedestrian bridge to prevent the creek from eroding into the lake upstream of the dam. The threat to the dam should be avoided by moving the south end of the dam far enough up stream to not be impacted by Prattville Creek flows and erosion. A distance of approximately 150 feet should suffice. See Photo 2.

Riverfront Development. Several conceptual restoration features were identified in the Master Plan using a balanced ecosystem approach to increase public use of the river while protecting and enhancing its riparian features. See Map 2. Protection of the riparian corridor to the intent of the Master Plan will require a concerted effort by city officials and land owners to use aesthetically pleasing and ecological construction methods. The Oklahoma Department of Environmental Quality Rule OKR10, Stormwater Rules, require protection of the riparian habitat in this section of the Arkansas River. The following recommendations correlate to the above listed proposed plans.



1. A pedestrian/bicycle bridge and fishing piers are proposed to cross the river over the dam. Access over the river will provide excellent viewing and fishing access. The bridge should be designed into the construction of the dam and blend in with the local aesthetics.

Sand and gravel should settle below the dam structure when it is open to river flows. These islands will provide additional nesting habitat for Interior Least Terns.

During the river months, when the dam is down, eagles will be able to utilize the river as they do now. When the dam is up and the lake is impounded, eagles will use the lake for feeding. Eagles will concentrate more in the tailwater to feed on fish that accumulate below the dam.

2. Development of the north bank and south bank nature trails and overlooks will require removal of some underbrush and immature trees. See Photo 3. To preserve the riparian habitat, all mature trees should be avoided and all immature trees that are removed should be replaced 5:1. The replacement trees can be planted in the open spaces in the immediate area. Sycamore, or other tall growing tree species, should be planted along the shoreline to provide for future Bald Eagle habitat. The overlooks next to the riverbank will need stabilization to protect them. Vegetated Rip-Rap may be most suitable. See Figure 1.


Photo 3

Development of the south bank nature trail will include construction of a pedestrian bridge across Prattville Creek that is approximately 20-feet deep and 125-feet across. The immediate embankments will need to be stabilized to protect the bridge. The Longitudinal Peaked Stone Toe Protection (LPSTP) method is recommended. See Figure 2.

The mouth of Prattville Creek will need to be stabilized to prevent continued erosion below the Avery Road Bridge and the creek embankments to the river. A high-tension power line tower is on the 22-feet high riverbank just upstream of the mouth of the creek. See Photo 4. If left uncontrolled, erosion will cut through the peninsula (30-35 feet), creating a more direct route into the river.

A Rock Riffle (see Figure 3) should be placed across the mouth of the creek to elevation 640. See Photo 2. This will create a pool to the bottom of the Avery Street culvert. Flows can then return to the old Prattville Creek drainage into the Arkansas River approximately 1.25-miles downstream. Approximately three acres of the existing creek will be converted to a wetland habitat. The Rock Riffle can be used for high-flow relief. The nature trail could be placed on top of the Rock Riffle, or the pedestrian bridge could be constructed over it. The north embankment of the creek and the embankment on the east side of the creek-mouth should be stabilized by using the LPSTP method.


Photo 4

The steep south riverbank, from the Highway 97 Bridge to the mouth of Prattville Creek, should be stabilized by installing LPSTP's and Reverse Bendway Weirs (see Figure 4), or similar biotechnological methods.

3. Placement of a boat ramp on the south bank to access the river below the dam would require construction of an access road approximately 700-feet beyond the existing road through the FFA/4H facilities. The ramp will require considerable earth disturbance to properly slope the ramp off the 20-feet high bank. The ramp should be relocated between Highway 97 and the FFA/4H facilities, where the bank is lower and more room is available for parking. The FFA/4H facilities should be relocated offsite.

4. The marina should be moved upstream of Highway 97 and incorporated more into the River Parks activities. Moving the marina would also reduce the need for boats to navigate through the Highway 97 bridge piers and the probability of boats inadvertently passing over the dam during generation at Keystone Dam. Boat traffic can use the existing River City Park boat ramp, therefore, the proposed marina ramp will not be needed east of the Highway 97 Bridge. The marina dock should be accessible from a land based marina office on top of the 18-feet high riverbank. All the existing mature trees should be avoided. Construction of a jetty to protect the dock will likely promote sedimentation

around the dock. The dock could be securely anchored by cables to allow flows and sediments to pass under the dock.

Sufficient room is available for the construction of the marina parking lot without removal of any mature trees. Construction plans should incorporate existing trees into their design. Rain Gardens and French Drains should be used for the parking lot runoff.

5. The existing sand and gravel operation can be used to remove sedimentation in the lake to maintain its depth. The proposed island should be moved downstream of the dam to prevent harassment from boating traffic and public access. The upstream end of the island should be protected by a sufficient rock Chevron to prevent the island from being washed away, and allow sedimentation downstream of the rock to maintain the island. The rock elevation should be such that high flows will cover the island. Higher flows will scour vegetation from, and deposit new sand on, the top of the island. The high flow elevation will need to be coordinated with the Corps of Engineers and Fish and Wildlife Service.

6. City trash containers will be provided for the public. Community participation will be used to help keep the area clean.

7. The north riverbank should be developed to protect the naturalized area where the marina was proposed. The area can be used for expansion of the nature trails without disturbing the area to a large extent. Additional features for public use and education could be developed. All construction should avoid disturbance to the existing mature trees. See Photo 5. The parking lot should be built around the trees,

Photo 5

incorporating them into the design. Rain Gardens and French Drains should be used for the parking lot runoff.

A Watchable Wetland could be incorporated into the river area downstream from Main Street. Construction of Reverse Bendway Weirs along the north riverbank would stabilize the shoreline and mudflats, while supporting the wetland features. The wetlands should be linked to the nature trails for access by hikers and bird watchers. Schools could use the area for educational purposes.

Proposed Plans – South Tulsa/Jenks

Low-Water Dam and River/Lake. The proposed location of the Jenks/South Tulsa Dam in the Master Plan is approximately 1,800-feet downstream of the Creek Turnpike. The Master Plan proposes an 8-feet high dam that will create a lake upstream for approximately 2.9 miles. See Map 4 from the Master Plan.

Riverfront Development. The primary focus for future development of the Jenks/South Tulsa riverfront is the creation of a retail and entertainment district on both sides of the river. Specific site activities proposed in the Master Plan are as follows. See Map 5 from the Master Plan.

1. A public park area is proposed immediately upstream of the east end of the dam. The riverbank is approximately 20-feet high, and approximately 140-feet to Delaware Avenue. There are a few small to mid-size trees in the area.

2. The shoreline above the park, to the Creek Turnpike, is a potential retail area. A Kum-n-Go convenience store was constructed in 2006 next to the turnpike bridge. The 20-feet high riverbank is approximately 30-feet from the store.

3. Upstream of the Creek Turnpike, to Vensel Creek, is an additional commercial development area. The riverbank along this shoreline is approximately 30-feet high. Rock and concrete debris have been placed over the entire area. Native vegetation has voluntarily revegetated the embankment.

4.   Vensel Creek is a major man-made drainage for the local residential watershed. Before construction, Vensel Creek drained into the river further downstream. The mouth of the drainage has been concrete-lined for a distance of approximately 640-feet upstream. The lower 420-feet has been undermined by the river and collapsed. See Photo 6.   The adjoining concrete-lined creek banks are also eroding into the creek. See Photo 7.

Photo 6

A pedestrian bridge is proposed over the mouth of Vensel Creek, adjacent to the river. Also, an Overlook structure is proposed on top of the embankment in the park. An existing boat ramp for emergency use enters the north side of the creek just west of the Riverside Drive Bridge. Boat access to the river may be possible when the dam is up, and the lake backs up into the mouth of Vensel Creek.

Photo 7

5.   The existing Habitat Restoration and Bald Eagle Preserve above the 96th Street Bridge will continue to be protected.

6.   Construction of an island is proposed on the lake for use by Interior Least Terns. The island would be placed between the Jenks River Walk and the Eagle Preserve. It would be visible from the river walk for public viewing,

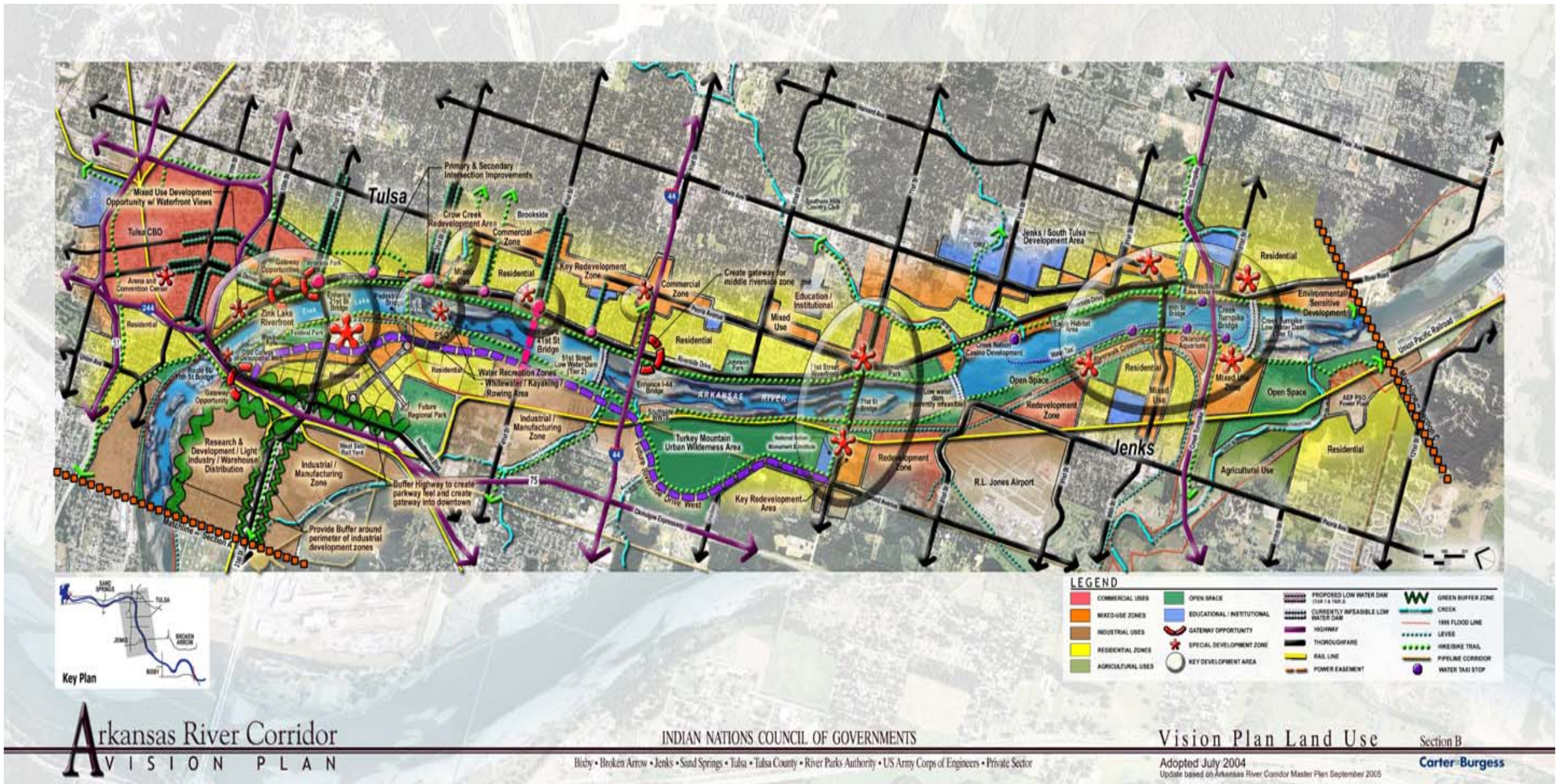
which would also provide shoreline surveillance for protection of the terns.

7. The potential Jenks Riverfront and Retail Development may be built on the west shoreline approximately 600-feet upstream from the dam, overlooking the lake. A canal is proposed in the Master Plan that would be cut from the river, through the riverfront, to an estimated 48-acre shallow lake area approximately 2,000-feet to the northwest. Multi-Use Development would be developed along the canal, with a large parking lot to the north. Several large mature Sycamore trees, assorted hardwoods, and grasses dominate the flora near the river. However, the canal will pass through pasture land with scattered mature pecan trees where the lake would be. The shallow lake would provide a nursery area for small fish and minnows, which would provide a feeding area for the terns during their nesting season.

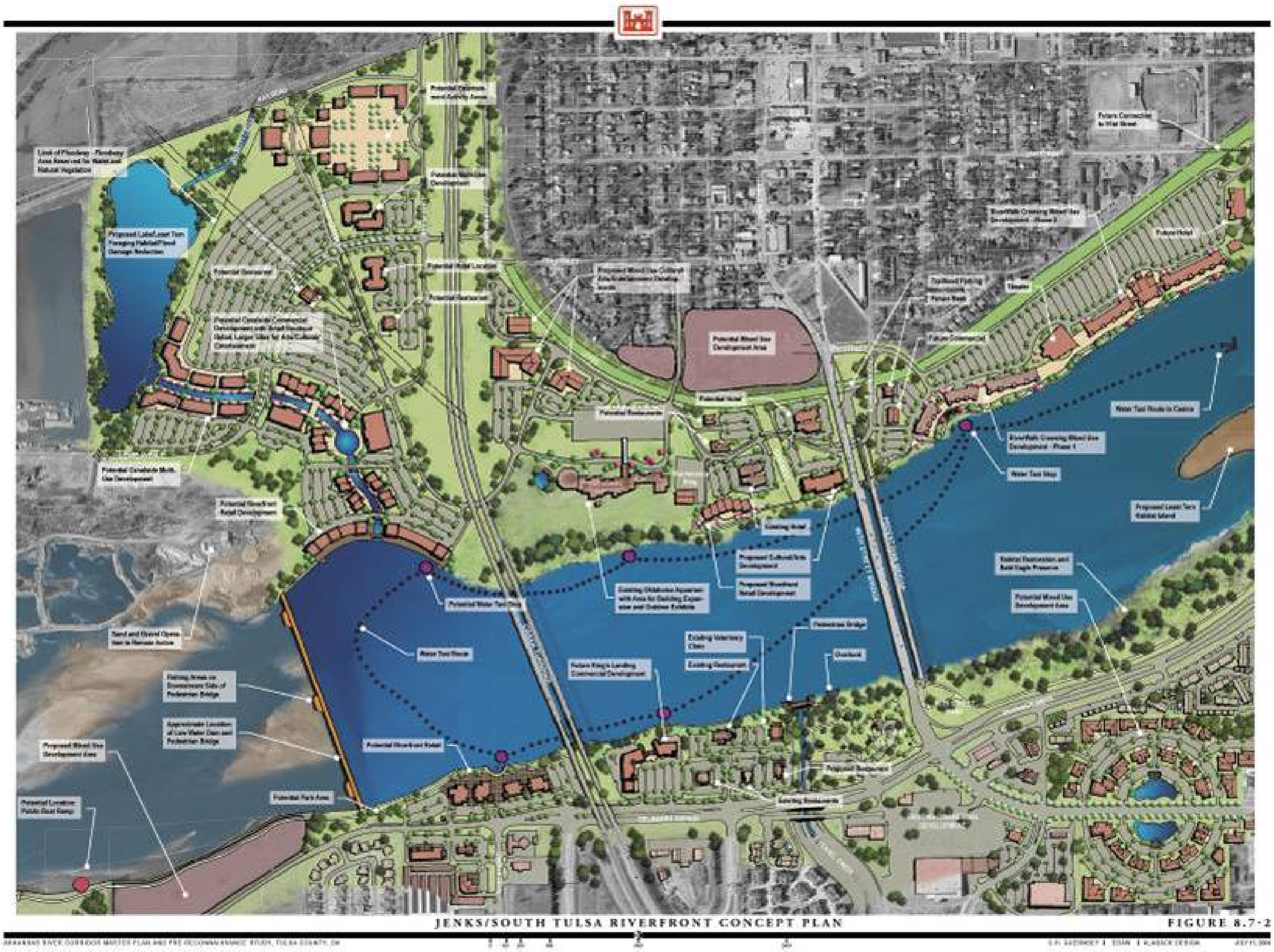
8. The west side of the river between the Creek Turnpike and the 96th Street Bridge has already been developed to some extent. However, an additional Riverfront Retail and Cultural Arts area is proposed near the existing hotel. The Oklahoma Aquarium may expand their building in the future, and/or they may construct a riverside Outdoor Exhibit.

9. A commercial Jenks River Walk has been developed above the 96th Street Bridge. Expansion of the Jenks River Walk to the north is proposed and construction of a major parking lot has begun.

Map 4 ~ From the Master Plan



Map 5 ~ From the Master Plan



Restoration Recommendations – South Tulsa/Jenks

Low-Water Dam and River/Lake. The key to the riverside development is the seasonal dam. The TVA has recommended an adjustable dam design that will allow for either a river system or a lake system. The dam can be lowered to allow the river system to flow freely during the spawning season of the local fishery, typically January through March. After the spawning season the dam can be raised to create a lake system.

The Cities of Tulsa and Jenks plan to locate the eight-feet high dam approximately 1,700 feet further downstream than identified in the Master Plan, placing it approximately 3,500 feet downstream of the Creek Turnpike. The reach of the lake upstream should remain approximately 2.9-miles. This location will still allow ready access and viewing from the Creek Turnpike Bridge, 96th Street Bridge, and the 96th Street Pedestrian Bridge. Public access to the lake will be available at the Oklahoma Aquarium, the Jenks/South Tulsa Riverfront areas, and the 96th Street Park. The existing bike/running trail that runs along the east side of the river will remain; as will the Bald Eagle Preserve on the east side of the river, above 96th Street.


Photo 8

The proposed location of the east end of the dam will tie into an embankment that is approximately 20-feet high. See Photo 8. The proposed location at the west end of the dam is a former commercial sand plant. The soil composition is sand for several hundred feet inland from the shoreline. See Photo 9. This will pose a challenge to the engineering design. Measures will need to be taken to insure that lake water will not seep through the sand around the west end of the dam. Subterranean erosion, or piping, could jeopardize the integrity of the structure and lake, as well as the proposed commercial development of Jenks.

The shoreline from the dam to the Creek Turnpike will need to be engineered to hold the lake water by placement of an impervious soil or other type of hard-surface barrier.

Photo 9

Riverfront Development. Several conceptual restoration features were identified in the Master Plan using a balanced ecosystem approach to increase public use of the river while protecting and enhancing its riparian features. Much of the area has already been, or is being, commercially developed. Protection of the riparian corridor to the intent of the Master Plan will require a concerted effort by county officials, businesses, and landowners to use aesthetically pleasing and ecological construction methods. The following recommendations correlate to the above listed proposed plans.

1. Bank stabilization will be needed to protect the east end of the dam and potential park area. The Soil-Choked Riprap technique is recommended. See Figure 5. The riprap should extend from the dam upstream to the existing riprap near the Kum-n-Go, being approximately 2,300 feet. Public access to the dam and water will require a walkway down the engineered embankment. Some of the existing trees can be preserved, but additional landscape vegetation should be incorporated into the park design, using native vegetation as much as possible. The existing Riverside Pedestrian/Bike trail should be extended to the dam.

2. The rock and concrete debris application on the riverbank below the commercial development, upstream of the Creek Turnpike, appears to have stabilized the embankment. The businesses have planted a few trees on the top of the bank, and native vegetation has volunteered through much of the rock and concrete debris. See Photo 10. No immediate controls are needed at this time, but native shrubs should be planted on the slope of the embankment and native trees on the top.


Photo 10

Extension of the Riverside Pedestrian/Bike trail is proposed on top of the embankment.

3. The mouth of Vensel Creek will need to be refurbished to restore and control future erosion. Although the lake will reduce erosion on the shoreline, measures will be needed for bank protection when the dam is down. Removal of the failed concrete will allow replacement of aesthetically pleasing biotechnics for erosion control. The side slopes will need to be reshaped and Vegetated Rip-Rap should be placed on both sides of the creek from the remaining concrete drainage to the river. Rip-Rap should be placed below the concrete drainage at a 10:1 slope to stabilize the concrete drainage. Sediment will fill in around the rip-rap so that the slope may also be used for boat launching from the existing emergency boat ramp, depending on the lake level.


Photo 11

The proposed Pedestrian Bridge and Overlook should be constructed of materials that will blend in with the local aesthetics. The elevation of the bridge will need to be above the floodplain. The toe of the embankment from the 96th Street Bridge to the Creek Turnpike can be protected by Bendway Weirs. See Figure 4. This will keep the flow of the river away from the embankment. See Photo 11. The elevation of the Bendway Weirs should be equivalent to the river elevation during high flows. The high flow elevation will need to be coordinated with the Corps of Engineers before construction begins. The 25-feet high embankment below the Overlook and park should be stabilized with Vegetated Rip-Rap. Salvaged trees and logs can be anchored into the dams and at the bottom of the Vegetated Rip-Rap to provide fish habitat.

4. All future development must avoid direct and indirect disturbance to the Eagle Preserve. An inventory should be made of the existing mature trees, and plans developed for their replacement in the future. Existing younger hardwoods may need to be directly managed to assist in successful maturation.

5. Placement of the island in the lake would subject the terns to harassment if boating is allowed on the lake. Measures would need to be taken to avoid human disturbance to the terns. Also, the island would require considerably more fill to bring the top of the island and Chevron to an appropriate height above the water.

The island should be placed further upstream, beyond the upper reach of the lake, and/or downstream of the dam. The upstream end of the island should be protected by a sufficient rock Chevron to withstand river flows. The layout and elevation of the rock should be such that river flows will pass around and over it to allow sedimentation to deposit downstream of the rock to maintain the island. Higher flows will scour vegetation from, and deposit new sand on, the top of the island. The location and high flow elevation will need to be coordinated with the Corps of Engineers and Fish and Wildlife Service.

6. Jenks has decided to not include the canal in their development. They have already begun development south of the Creek Turnpike by removing all the existing trees and features to within 200-feet of Polecat Creek. The tree line was left to block the view of the Public Service Company of Oklahoma power plant south of Polecat Creek. This remaining vegetative buffer zone should be protected to provide soil stability along the riparian corridor of Polecat Creek. In addition to the more pleasing aesthetic view for the development patrons, hiking trails and fishing access could be incorporated into the natural area with minimal impact. Re-vegetation of the development should use non-invasive species, with the use of native species as much as possible.

The existing 48-acre pond is scheduled to be expanded to 73-acres with a maximum depth of 10-feet. It will provide detention for the development and overflow for Polecat Creek. The pond will be stocked with fish and made available for public fishing. A portion of the lake should be shallow enough for terns to see and feed on minnows. The spillway will be below the river/lake dam. A Vegetated Rock Riffle, or similar biotechnical control, could be used to control the overflow into the river.

An eight to nine acre detention pond will be constructed north of the existing pond and just east of the railroad tracks. It will be seven to eight feet deep and drain into the larger pond.

Surface runoff from the development will need to be controlled to reduce shoreline erosion. Rain-Gardens could be designed into the landscape to reduce surface runoff as much as possible. These gardens would reduce the amount of hard structure drainages and enhance the aesthetics.

7. The west shoreline between the Creek Turnpike and the 96th Street Bridge is heavily vegetated and stable. Construction of the proposed development should avoid disturbance of the riverbank.

8. A large parking lot is under construction upstream of the Jenks River Walk. However, the 13-feet high riverbank is being severely eroded by surface flows around the parking lot. See Photo 12. The integrity of the parking lots new drainage structures are in jeopardy.


Photo 12

The embankment below the River Walk is also eroding and portions of the foot trail have collapsed. Erosion control for the runoff is needed as soon as possible. The embankment can be sloped, filling the eroded areas, and an LPSTP constructed from 91st Street to the Jenks River Walk. The elevation of the top of the LPSTP will need to be coordinated with the Corps of Engineers before construction. Reverse Bendway Weirs, or other similar biotechnical controls, should be installed along the toe of the embankment to divert the river flow away from the shoreline. The River Walk foot trail can be routed on top of the LPSTP. Low-growing native plants should be planted upslope of the trail to the top of the embankment.

Summary

Many opportunities were identified in the Phase 2 Master Plan and Pre-Reconnaissance Study for urban development, reuse, aesthetic enhancement, and infrastructure improvement. However, the development of those opportunities could greatly increase pressures on the natural resources if poorly planned. To assure that the ecosystem of the corridor is protected and enhanced to the fullest extent possible, zoning restrictions and requirements should be implemented as soon as possible.

To the extent of this plan, those activities proposed for the river-lakes should incorporate biotechnical bank stabilization techniques to the fullest extent possible. The existing river system has minimal shoreline cover, so the riprap along the shorelines and embankments will provide substantially more aquatic habitat, especially when the lakes are in place. However, to enhance the ecosystem and the aesthetics of the river-lakes, the recommended biotechnics should be used.

Native plants and materials should be used to the fullest extent possible for habitat enhancement and construction. Care must be taken to avoid the use of invasive species.

Construction of the dams, bridges, overlooks, etc. should use designs and materials to blend in with the local environment. TVA has provided design techniques to eliminate safety hazards in the tailwater below the dams. These techniques should be included into the designs of the dam. Engineering and operation of the dams will need to consider potential impacts from vandalism, sedimentation, debris, Zebra Mussels, and historic flow regimes.

Construction of the tern islands will need to be designed so that they will be high enough to provide sufficient tern habitat, yet low enough to be scoured by high flows every two or three years. Coordination of the design, elevation, and location will need to include all the appropriate stakeholders.

Development of a river flow regime to accommodate the needs and goals of the river-lakes will require considerable coordination among the stakeholders. A Memorandum of Agreement should be developed by the stakeholders to clarify water flow needs, goals, procedures, and responsibilities.

This plan is conceptual and limited to recommendations for ecosystem considerations for the development and construction of the Sand Springs and South Tulsa/Jenks River-Lakes. This restoration plan and the attached baseline environmental study (see Appendix B) will be used to apply for the necessary Corps of Engineers regulatory permits. Future environmental studies and documentation will be needed for compliance with the National Environmental Policy Act to address the impacts of all the activities described in the Master Plan.

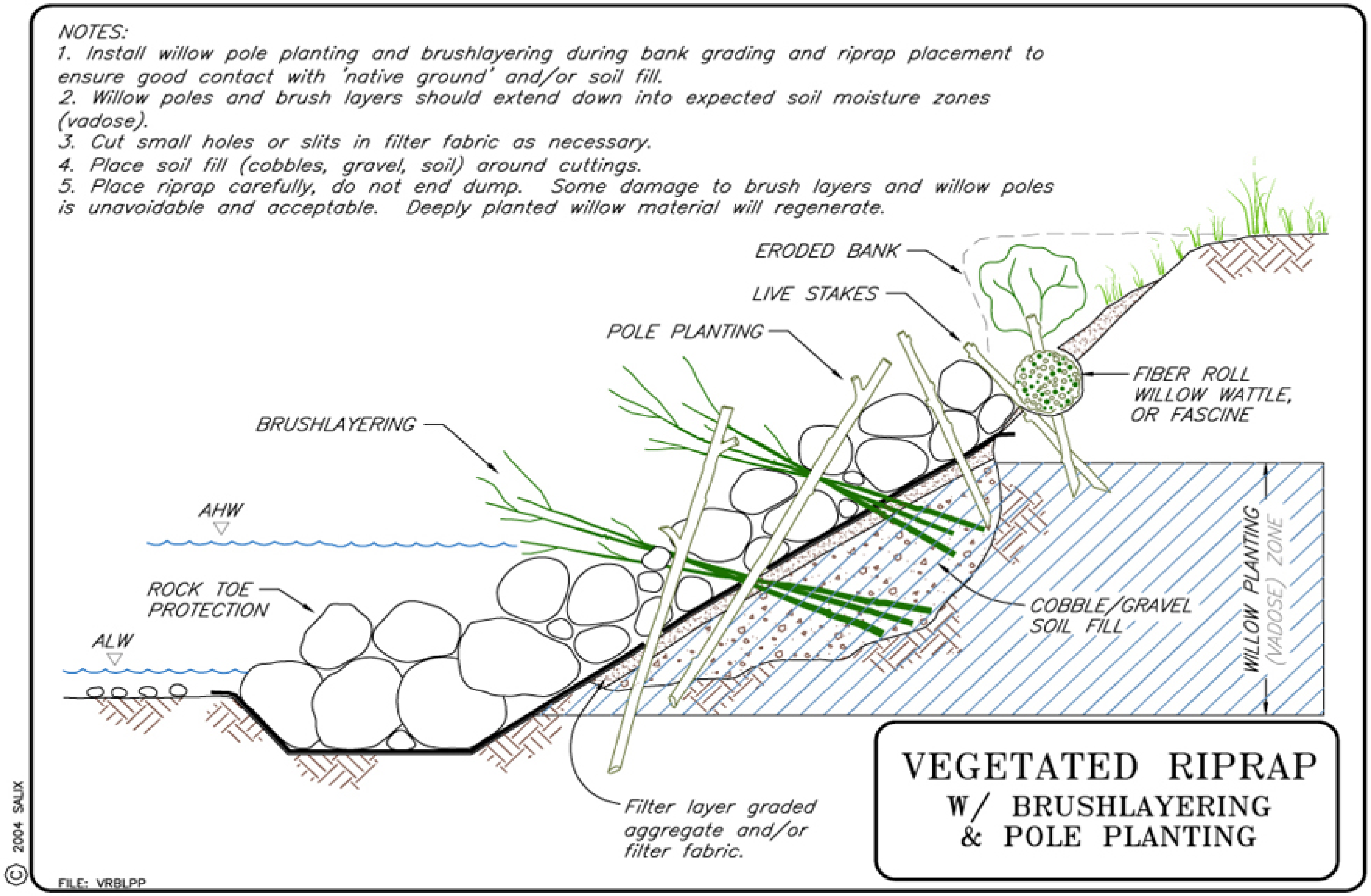
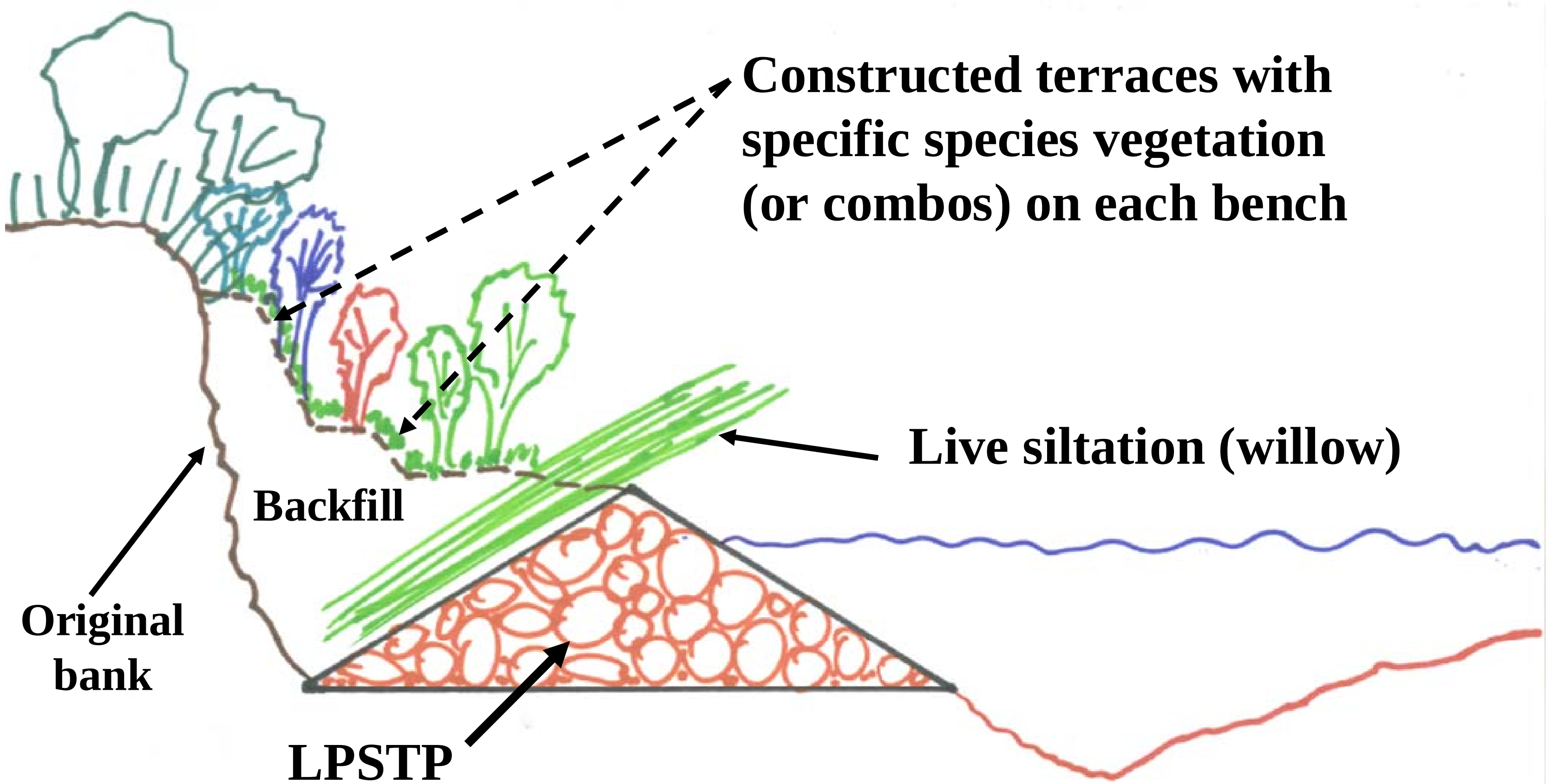

NOTES:
1. Install willow pole planting and brushlayering during bank grading and riprap placement to ensure good contact with 'native ground' and/or soil fill.
2. Willow poles and brush layers should extend down into expected soil moisture zones (vadose).
3. Cut small holes or slits in filter fabric as necessary.
4. Place soil fill (cobbles, gravel, soil) around cuttings.
5. Place riprap carefully, do not end dump. Some damage to brush layers and willow poles is unavoidable and acceptable. Deeply planted willow material will regenerate.
ERODED BANK
LIVE STAKES
POLE PLANTING
FIBER ROLL WILLOW WATTLE, OR FASCINE
BRUSHLAYERING
AHW
ROCK TOE PROTECTION
ALW
COBBLE/GRAVEL SOIL FILL
WILLOW PLANTING (VADOSE) ZONE
Filter layer graded aggregate and/or filter fabric.
VEGETATED RIPRAP
W/ BRUSHLAYERING & POLE PLANTING
© 2004 SALIX
FILE: VRBLPP

Figure 1.



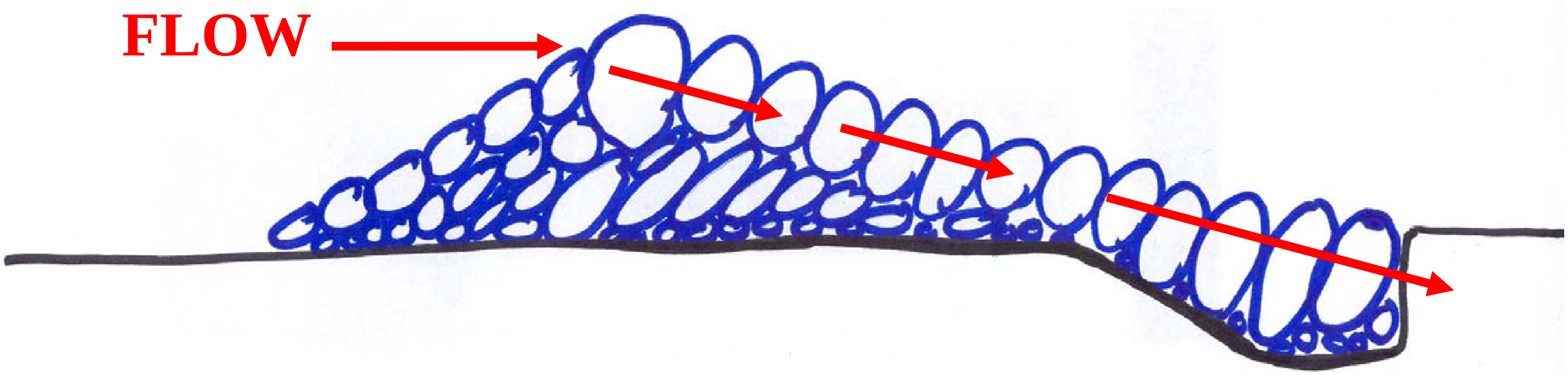
Longitudinal Peaked Stone Toe Protection (LPSTP)

Constructed of a well-graded, self-adjusting, self-filtering stone (no filter fabric underlayment)

Figure 2.

AN ENGINEERED ROCKED RIFFLE WITH WEIGHTED TOE

Stones on crest, the downstream face, & toe all set in compression



Weighted toe can be designed to help stop the headward migration of a knickpoint {headcut}

Figure 3.

BENDWAY WEIRS

typical design, angled upstream, outside embankment

(derivations include Reverse or J-Curve Bendway Weirs)

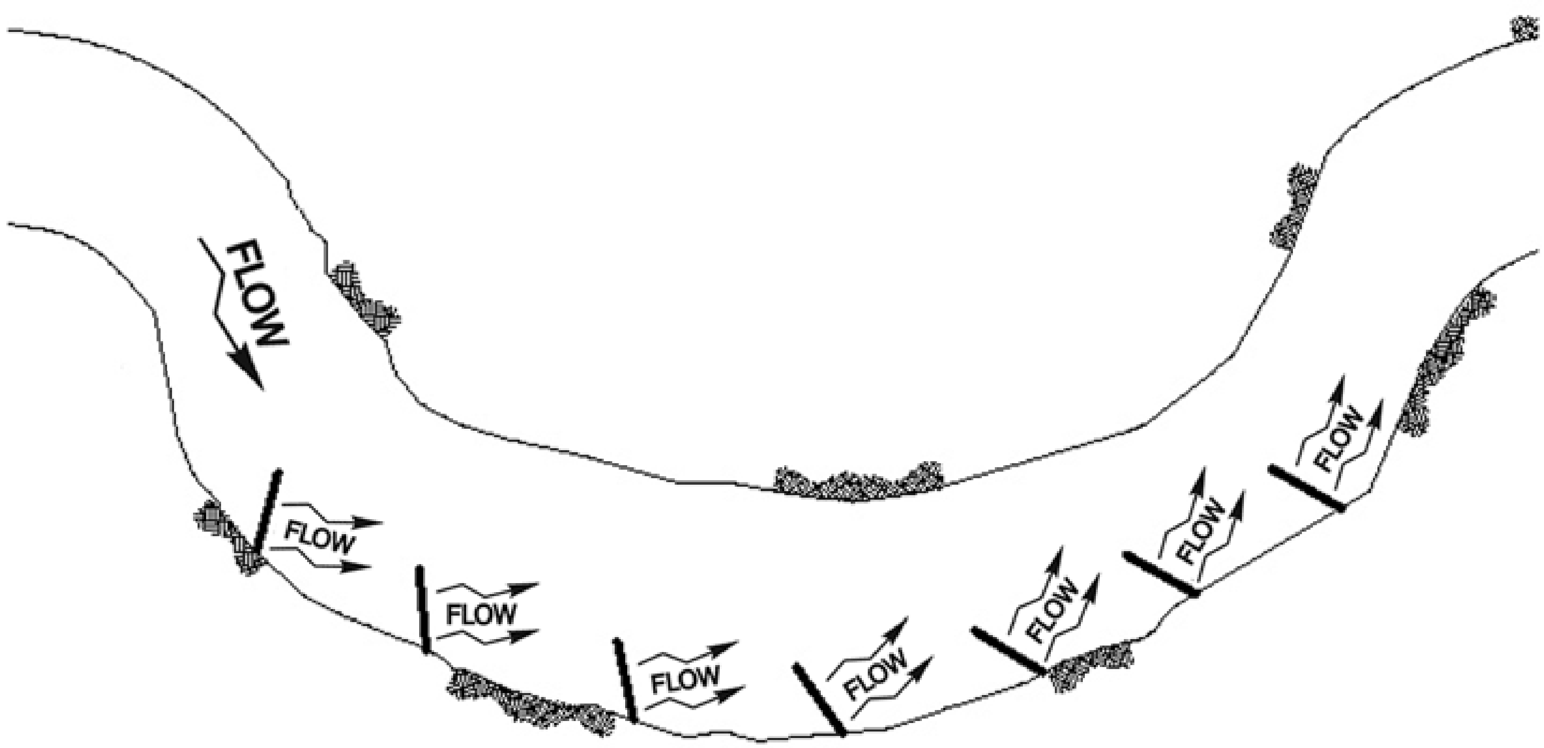
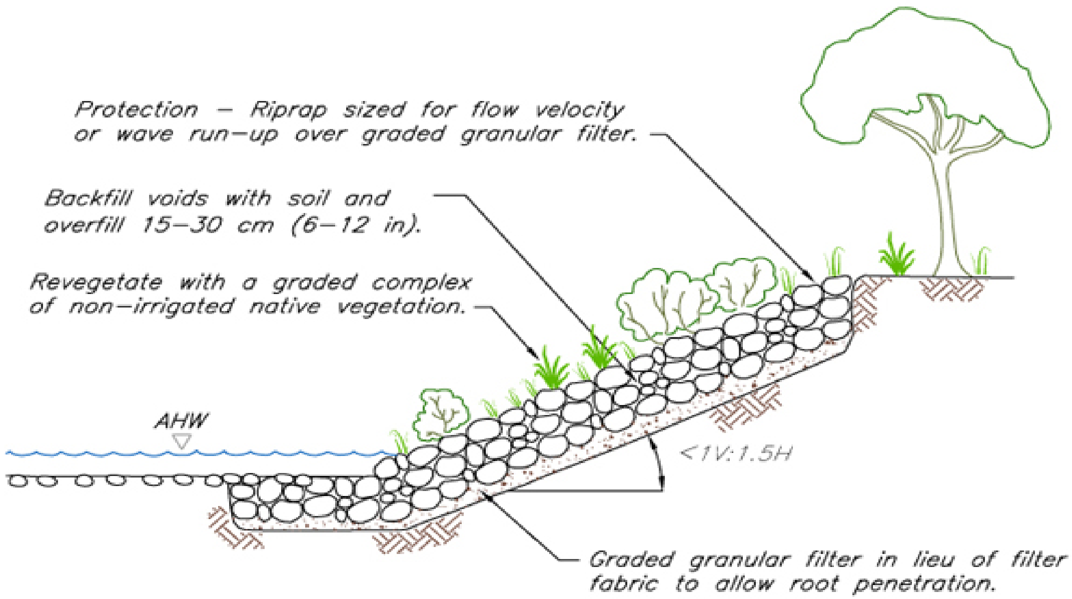


Figure 4.



NOTES: *CLASS 2 PERMEABLE MATERIAL*

Permeable material for blankets or other subdrainage purposes shall consist of hard, durable, clean sand, gravel or crushed stone and shall be free from organic material, clay balls, or other deleterious substances.

Class 2 permeable material shall have a Durability Index of not less than 40 and a Sand Equivalent value of not less than 75.

SIEVE SIZES	PERCENTAGE PASSING
1–Inch	100
3/4–Inch	90–100
3/8–Inch	40–100
No. 4	25–40
No. 8	18–33
No. 30	5–15
No. 50	0–7
No. 200	0–3

RIPRAP
W/ SOIL AND GRASS
OR GROUND COVER

FILE: RRSG

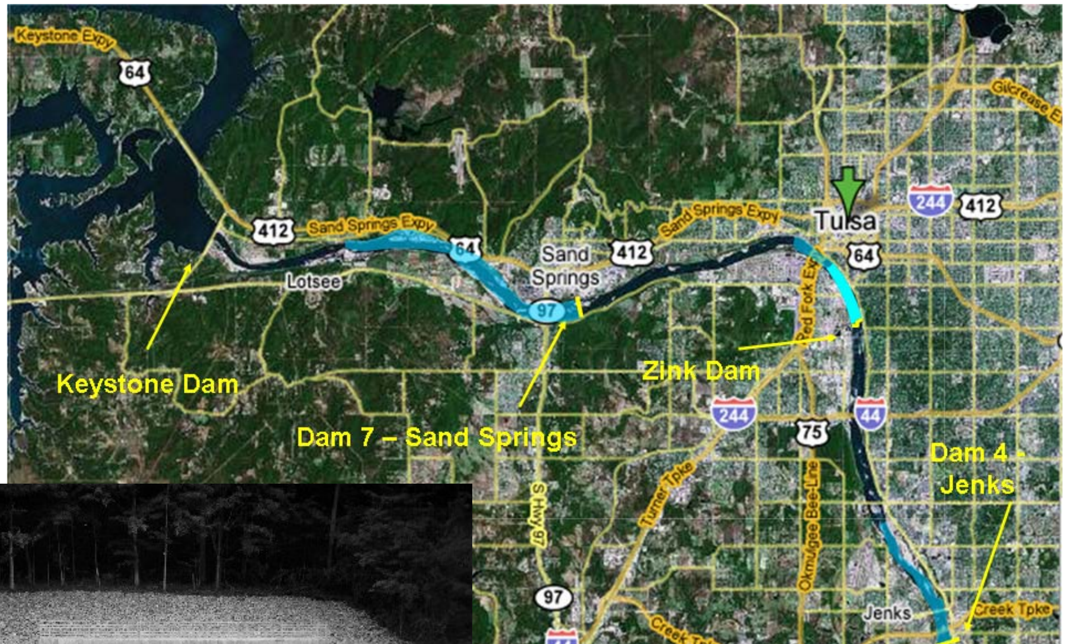
Figure 5.

APPENDIX A

TENNESSEE VALLEY AUTHORITY
Vision for the Arkansas River Corridor
Tulsa County

TENNESSEE VALLEY AUTHORITY
River System Operations & Environment

Vision for the Arkansas River Corridor at Tulsa



Prepared by:
William D. Proctor
Coleman Hoskins
Colleen Montgomery
Ronald Pasch

Knoxville, Tennessee
March 2008

TABLE OF CONTENTS

Page No.

Vision for the Arkansas River Corridor at Tulsa

INTRODUCTION

In October 2006, personnel from the Tennessee Valley Authority (TVA) met with representatives from the Corps of Engineers and local officials in Tulsa, Oklahoma. TVA representatives were invited to discuss concerns and issues related to installing weirs (low-head dams) in the portion of the Arkansas River flowing through the Tulsa metro area as part of Tulsa's Vision 2025 plan. TVA was consulted due to past experience in weir designs with an emphasis on river safety for recreational users and enhancement of the aquatic environment below the weirs. Over a three-day period, meetings, discussions, and site visits were conducted to define areas of concern and to attempt to formulate some preliminary concepts for future discussion. This report is to document the identified issues and preliminary findings to assess the feasibility of constructing weirs on the Arkansas River.

INTEGRATED RIVER SYSTEM FROM KEYSTONE DAM TO JENKS

To achieve all of the desired objectives for the Tulsa weir project and ensure the greatest benefits for the majority of the people, an integrated river system approach is essential. The ability to control flows through a system of coordinated hydraulic structures is necessary so that the river system can provide for multiple benefits. To achieve the benefits, which include habitat enhancement and protection, economic and recreational opportunities, while still meeting floodplain development restrictions, requires thoughtful design and carefully coordinated operation. An integrated system approach offers a solution to the many conflicting interests inherent in attempting to control even a portion of a river system. Ultimately, the success of the river system depends on both appropriate design and construction of the structures, as well as their prudent operation and maintenance.

Key Issues

- Designing an Integrated River System to optimize river operations.
- Extending the Zink Dam pool farther upstream by raising the crest elevation.
- Protecting least tern nesting areas by eliminating land bridging that occurs when the channel is mostly dry.
- Providing consistent riverine habitat for smaller non-migrating fish species; e.g., shiners, minnows, darters, and silversides are more important than their passage past low head dams.
- Complying with Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) and other floodplain regulations.
- Passing striped bass, sauger, shovelnose sturgeon, and paddlefish at the correct time of year to allow upstream migration, spawning, and downstream egg transport.
- Passing the heavy sand loads through the weirs must be included.
- Minimizing impacts on smaller fish species utilized as food for least terns.
- Building a weir considering the sandy nature of the channel and soil in the floodplain.
- Providing hydropower from the projects
- Improving Aquatic Habitat Related to Weir Construction

Discussion

Integrated River System

The Tulsa low-head dams (or weirs) would create a system of lakes that would be operated in an integrated manner to provide a wide range of benefits through the Arkansas River tailwater below Keystone Dam. The integrated system will include three weirs: at Sand Springs, at Jenks, and at the existing John Zink Dam, located in-between the two proposed weirs.

The benefits of these river lakes would include beautification of the water front, recreational opportunities for boaters, and additional protection of the nesting islands for least terns. In addition, minimum flows provided from the Sand Springs Weir would increase the foraging areas for the least terns, provide consistent habitat for aquatic species in the river, as well as provide flow to operate a new whitewater course at Zink Dam and possible future whitewater courses below Sand Springs and Jenks Weirs.

Operation of the system would rely on some of the daily generation from Keystone Dam being captured by the Sand Springs Weir, which will have a pool about five miles in length and a depth ranging from 9 to 11 feet at the structure. During Keystone’s non generation periods, the top two feet of the Sand Springs pool would be used to provide a continuous minimum flow to the downstream channel, helping to achieve the public’s desire for “water in the river” throughout the corridor. These flows would be provided by gradually releasing water through the Sand Springs Weir to maintain a consistent minimum flow.

The other two weirs, which are farther downstream, would be operated at a fixed pool elevation. The continuous minimum flow provided by reregulation releases from Sand Springs Weir could allow 400 to 1000 cfs of flow to continuously travel down the river channel, as long as their pool is refilled by Keystone Dam releases once a day. To be consistent throughout the document, plots are shown with a release rate of 600 cfs.

An additional proposal is to increase the height of Zink Dam by 2 feet (or even 3 feet) to essentially double the length of the pool. The crest of the existing dam could be retrofitted with 2-foot tall flap gates to accomplish this. These gates could be lowered in the event of a flood and should provide no additional obstruction to flood flow than the existing condition.

The following figure illustrates the extent and approximate location of the proposed weir pools, as well as the additional pool area that could be gained by raising the height of Zink Dam.

Figure 1. Conceptual Plan View of Tulsa Area Showing Existing and Proposed Weir Pools and Keystone Dam

The river bed drops approximately 35 feet between the Sand Springs and Jenks weir locations. The steepest part of this reach is between Zink Dam and the upper end of the Jenks weir pool. This area would have the opportunity for whitewater recreation with a continuous release of 400 - 1000 cfs and the construction of an artificial whitewater course. In addition, the existing whitewater attraction below Zink Dam may possibly be enhanced even further as a result with multiple areas of the tailwater that could be used for whitewater.

Figure 2 shows a profile view of the streambed with the three full weir pools and with a reregulation flow through the river channel. The figure also shows the change in size of the available weir pool from raising the height of Sand Springs Dam by 3 feet, and highlights the fluctuating top 2 feet of pool area in the Sand Springs weir pool, with a total depth of up to 11 feet when the weir pool is completely full.

A flow rate of 600 cfs is presented in Figure 2 because it was one of the design flows already present in the HEC-RAS model provided by Tulsa USACE (labeled as “Water Quality”) and it was also within the possible range of flows that could be provided by Sand Springs Dam. At the small scale of the profile in Figure 2, 600, 800, or 1000 cfs would look virtually the same.

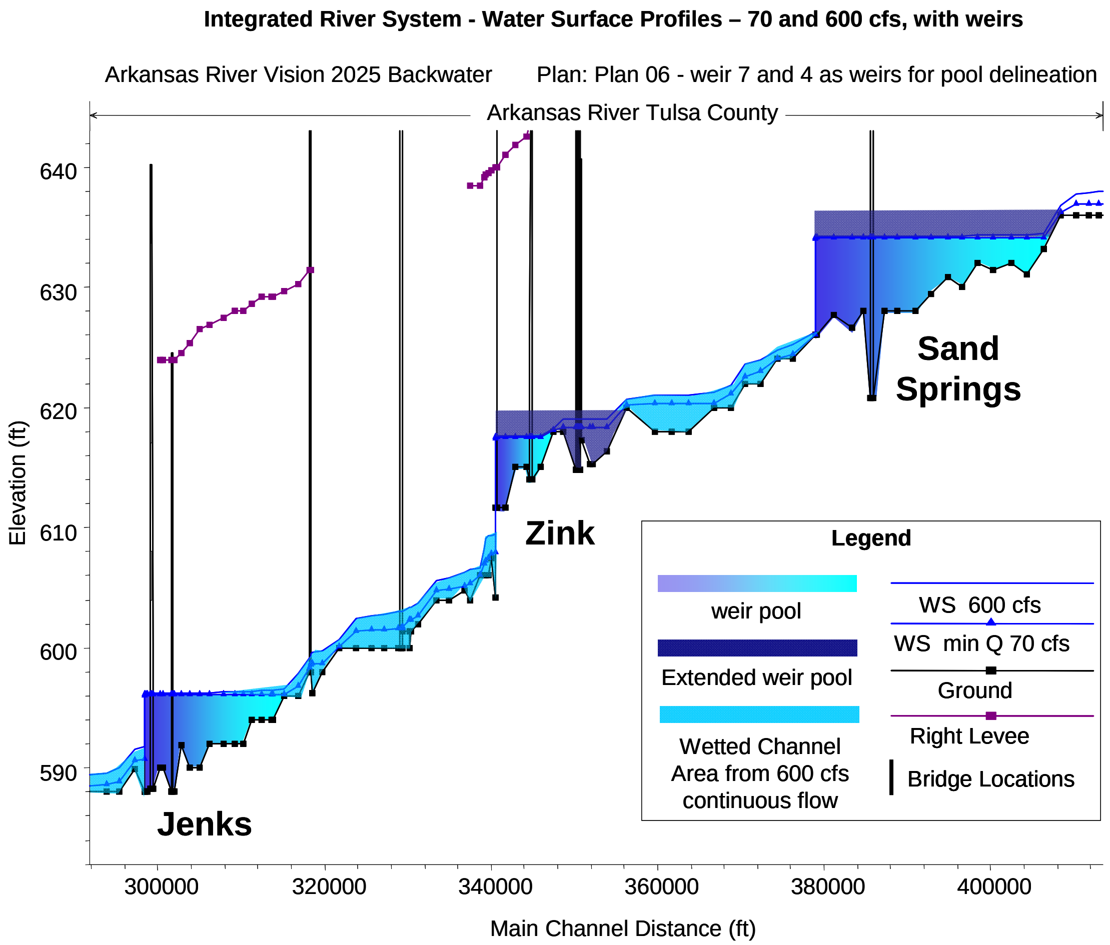


Figure 2. Water Surface Profile View Showing Weirs and integrated River System Concept

Protection of Least Tern Nesting Areas and Food Supply

A continuous flow in the river would also help provide protection for the least tern by reducing the amount of land bridging to the mid-channel islands through the river. Because least terns build their nests on the ground, they are susceptible to predation from carnivorous mammals that traverse the dry channel. A continuous flow in the channel would cut off many of these pathways and help isolate the least tern nesting areas on the islands from these predators. In addition, minimum flows, by increasing the aquatic habitat through the riverine portions of the river, should provide additional foraging opportunities for the least terns in the riverine reaches between the weir pools.

FEMA NFIP Compliance

Another key factor in the design or modification of structures such as the weirs, which are located within the 100-year floodplain, is that they would have no impact on the FEMA 100-yr flood and 100-year floodway elevations of the Arkansas River as stipulated by the FEMA NFIP. The city of Tulsa and Tulsa County both participate in the NFIP (FEMA, 2007). For an 8-foot high weir at each location to cause no increase in the 100-year flood elevations would require an opening about 650 feet wide through the weir in the central portion of the channel during these large floods. This will be accomplished by installing gate segments in each weir in the middle portion of the channel where flood flow conveyance is the greatest. According to the Tulsa District, flood events are most likely to occur in the spring, from March to May, or during the fall. Additional discussion centered around adding even more gates, but this would increase the costs for the weir.

Flow Enhancement for Migrating Fish Species

The primary fish species of concern to the state are striped bass, sauger, shovelnose sturgeon, and paddlefish. Spawning migration for these fish species occurs during the spring (March to May). It is proposed to lower the center sections of the weirs during the spring flooding/fish spawning migration season to (1) allow flood flows to pass downstream without impacting the 100-yr floodway elevations, (2) allow transport of sand loads downstream through the weirs and help avoid the need for dredging of the weir pools, and (3) allow passage of key migratory fish species upstream through the weir.

It is also important that riverine habitat is maintained through the spawning season to allow larvae and eggs of these key species to pass downstream. Striper eggs, spawning, and fry all require a steady flow of fresh water, and there must be a steady current flowing over several miles. The eggs of striped bass are semi-buoyant and are carried downstream by a flowing river. Without adequate water velocity the eggs would sink to the bottom, be smothered in sediment, and die. Early larval stages of all four species are typically swept downstream from spawning habitat (higher current velocity) to nursery habitat (lower current velocity). Furthermore, if the river lakes were kept full during this period, these eggs would likely drop out of the flow, be buried, and suffocate in the sandy bottoms of the weir pools.

In addition, several other fish species, ranging from channel catfish to river shiner, would also use the weir openings for upstream and downstream migration. The primary season for migration for these fish species is during the spring (March to May). It is proposed to lower the center sections of the weirs (essentially eliminating the river lakes) during all or part of the spring flooding and the fish migration seasons (March to May). The exact duration of lowering the weir dams can be varied to achieve the optimum balance of all the objectives as determined by the asset owners and stakeholders. The rate at which these weir pool elevations would be lowered can be also varied to avoid stranding any aquatic species within the drawdown pool.

Habitat for Small Non-Migrating Fish Species

A minimum flow is also necessary to maintain habitat for aquatic species along the riverine reaches throughout the year. After installation of weirs below several TVA projects, diversity and abundance of both macro invertebrate and fish assemblages increased dramatically downstream with improvements to aquatic habitat and adequate concentrations of dissolved oxygen. Results of biological monitoring in the Clinch River downstream of the weir below TVA's Norris Dam demonstrated the relative importance of improved minimum flows to aquatic biota, where the macro invertebrate abundance increased by 300 percent. (Bendnarek, 2002)

Fish Passage through the Weirs

Numerous fish passage designs were evaluated to allow fish passage upstream over or around the weirs. But even if fish passage upstream was provided for, biologists expressed more concern about the eggs hatching. Because the striped bass eggs rely on being carried downstream by the river currents to prevent them from being buried or caught in a stagnant pool, the opinion of biologists was that weir pools would hinder the progress of the hatching eggs. This would decrease the hatching rate for striped bass and limit the amount of fry that could be harvested downstream of the Zink and Jenks weirs. Given this concern and the hatching characteristics of the other species of concern, it was concluded that free river flow during the spawning seasons would be the best way to provide fish passage and hatching habitat for the fish eggs. Therefore, fish passage would be provided by opening up the weirs for several months of the year during the flood control and spawning period. This also allows sand to pass through the weir as well, to prevent excessive accumulation in the pool areas. Differing methods of constructing fish passage/weir openings are outlined below.

Methods to Open up the Weirs

Inflatable Rubber Dam

One attractive option to create a large gate in the weir structure was the Bridgestone Rubber Dam (see Figure 3).

Figure 3. Schematic of Bridgestone Inflatable Dam

The inflatable dam concept allowed a large portion of the channel to be completely opened up for fish spawning runs, or to restore the river channel to essentially pre-weir conditions and not increase 100-year flood elevations as required by FEMA. The inflatable dam technology has been in existence for about 50 years.

Obermeyer Gate

The pneumatically operated spillway gate manufactured by Obermeyer Hydro Inc. is a much more recent innovation than a stand-alone inflatable rubber dam. This technology utilizes a combination of metal flap-gates and multiple small inflatable bladders to adjust the elevation of the gates as shown in Figure 4. The metal gate protects the inflatable bladders from debris, provides a much more predictable water surface elevation and discharge rate, and also provides a cover for the bladders when they are deflated.

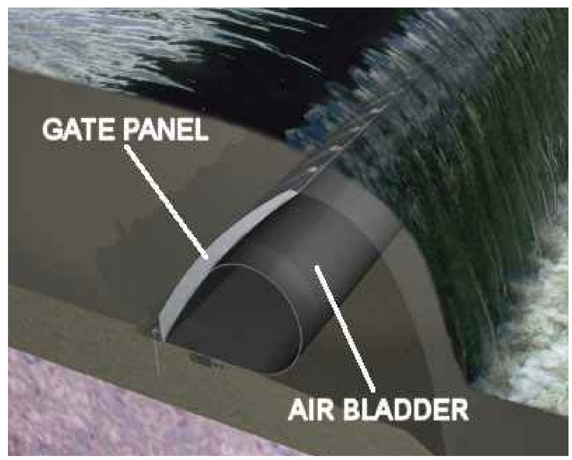


Figure 4. Schematic of Water Flow Over Obermeyer Gate and Air Bladders

Obermeyer gates are typically manufactured in 10-foot segments and each segment is controlled by its own small air bladder. Air bladders can be connected to controls individually or in banks of multiple bladders to achieve virtually any desired gate operation scenario. The bladders are constructed of several laminated layers of material, and are UV and puncture resistant.

This technology has been in use for about fifteen years and gates with heights of up to approximately 5.5 m (18 ft) have been installed. Up to now, most Obermeyer spillway gates have been installed in the United States; but, with contracts in India, Peru, and Germany under way, it is likely that its use will become as global as that of the inflatable rubber dam within a very short period (Obermeyer, 2006).

Mechanical Gates

Conventional mechanical gates similar to the ones currently installed at John Zink Dam could also be used. This would require many additional abutments (as compared to the other two technologies) to support the mechanical gates and to hoist the motors or drives used to raise and lower the gates. This would increase the expense of the project and probably would have higher operation/maintenance costs.

Fusegates

Fusegates are a tipping-bucket-type gate design, where the gate falls down at preset water elevations to allow the excess flow to pass. The system owes its versatility to the simple design and to the various configurations that can be set up to address specific operational needs, which may include safety, storage capacity, and the flood recurrence interval linked to the first fusegate tip-over, and complete tip-over of all gates for the ultimate design flood.

Hydroplus, the designer of this type of gate, has recently developed a new system: folding fusegates. As opposed to the normal type of fusegate, folding fusegates do not overturn in the event of flooding. The gates stay in place and fold away, allowing discharge to flow over the crest. Post flooding, the folding fusegates are raised up to their initial position. According to Hydroplus, the implementation of a fusegate solution requires an investment that is normally significantly lower than that of conventional systems (mechanical gates, inflatable dams, and similar solutions). In addition, lifecycle maintenance costs for fusegates are reported to be five to ten times lower than that of alternative systems. The systems are made of very large, heavy gate units constructed of steel or concrete. They are nearly impossible to vandalize, other than perhaps by spray-painting. Figure 5 shows a typical tipping Fusegate installation at McClure Dam in New Mexico, and how the tipping fusegate system works (Hydroplus, 2006).

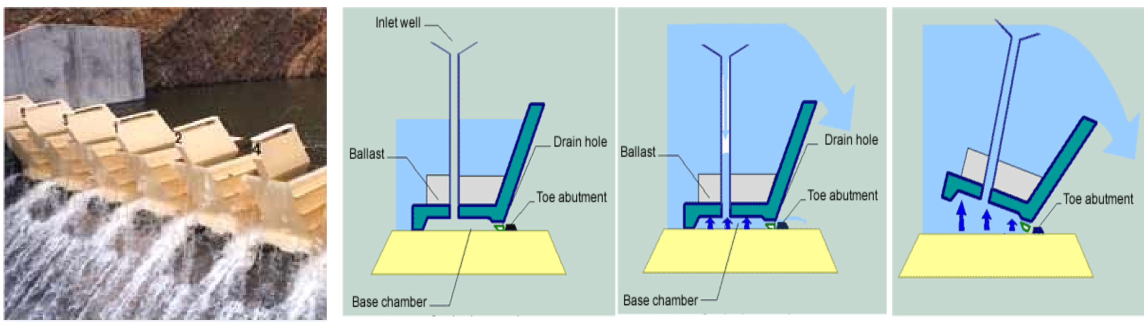


Figure 5. Fusegate Installation and Operation Diagrams

Fusegates would be an alternative to raise the height of Zink Dam, as well as for the open section of the Jenks weir. Advantages of this system include that they appear to be reliable and resistant to damage from vandalism, other than spray-painting; and there is no instrumentation to install or worry about actuating, as they are actuated by buoyant forces. Disadvantages of the system are that, when tipped the gates are heavy and may require some heavy equipment to reposition them; and they are rather unsightly, but are an alternative worth considering, nonetheless.

Each of these alternatives can be investigated. The River Parks Authority has emphasized that resistance to vandalism and ease of maintenance will be very important design considerations. Each of the proposed alternatives can be examined in light of these concerns during the final design process. At present time, however, the preferred concept is the Obermeyer gate system and its usage will be assumed through the remainder of the report.

Hydropower

Hydropower production at the proposed dams would be for low head (less than 8 feet) - high flow (800 cfs) conditions. The maximum power achievable would be about 330 kilowatts (kw) assuming 100% efficiency. There have been recent improvements of the development of the use of small hydro systems for low heads with prices estimated at between $2000 and $2500 per kilowatt of capacity (ABS Alaskan). With any installed hydro units requiring long shafts to keep the generator and other parts of the system out of the water during flood events, this could escalate the costs to $4,000 per kilowatt and a rough net project cost of $800,000 per dam for the small hydro units. Given a value of $0.05 per kilowatt, the payback period would be on the order of 10 years. Some of the adverse impacts would be on aeration of the releases when required and damage to fish migrating downstream.

Aquatic Habitats

TVA constructed weirs below Norris, South Holston, and Chatuge dams to sustain minimum flows between generating pulses by slowly releasing water stored by the weirs after periodic refill from upstream dams. Hence, the primary function of these weirs is downstream flow augmentation with habitat alteration in the weir pool being only incidental. South Holston and Chatuge weirs were also designed as aeration structures. The greater flow below these projects resulted in a permanent 10 to 20 percent increase in wetted area, which in turn has been one of the reasons for significant improvements in aquatic biota. Higher dissolved oxygen (DO) concentrations in these tailwaters achieved by several methods, including labyrinth and infuser weirs at South Holston and Chatuge projects, have also been important to aquatic biota. Another benefit of these weirs has been a reduction in temperature variation in rivers below the projects between generating pulses. Continuous discharge form the weir pools between generating pulses prevents water temperature from rising significantly thus reducing thermal shock experienced by biota. Although effects of thermal shock on aquatic biota were not quantified at TVA projects, reductions in daily temperature variations undoubtedly reduced stress to which these animals were subjected.

After installation of weirs below TVA projects, diversity and abundance of both macroinvertebrate and fish assemblages increased downstream of the weirs. Results of biological monitoring in the Clinch River downstream of the Norris weir demonstrates the relative importance of improved minimum flows to aquatic biota. At the Norris project, aeration of turbine discharges preceded construction of the reregulation weir. Aquatic biota responded positively to enhanced DO levels only at sampling stations furthest downstream from the weir. Higher minimum flows produced by operation of the weir, however, led to some increases in diversity at all sampling stations. Effects of habitat improvements on aquatic biota were limited because of water temperature regimes in all tailwaters where weirs were constructed. These projects have deep hypolimnetic discharges with water temperatures cold enough to sustain year-round trout fisheries. Consequently, these cold discharges prevent reestablishment of many native fish and macroinvertebrate species in immediate tailwater reaches.

TVA has not monitored aquatic biota in weir pools, but some improvements in diversity and abundance have undoubtedly occurred because of increases in wetted area and greater stability of shoreline habitat. Cold hypolimnetic discharges, however, preclude reestablishment of most native fish and macroinvertebrate species. Additionally, assemblages of fish and macroinvertebrates should differ upstream and downstream of the weirs depending on minimum depth of the weir pool. If the weir pool is almost completely drained between turbine pulses (e.g., Norris project), habitat in the impounded area would resemble somewhat that downstream of the weir, and biota, particularly macroinvertebrates, should be more similar. However, if the pool remains at weir crest depth (e.g., South Holston and Chatuge projects), habitat will be fairly dissimilar from that downstream of the weir between turbine pulses with significantly greater depth and lower water velocity. Fish and macroinvertebrate assemblages in these deeper pools will be different from those found in flowing water because the habitat resembles that of larger impoundments.

Fish assemblages in these weir pools are affected no only by cold-water discharges but by lack of fish passage facilities at the weirs. Fish assemblages are augmented, however, by recruitment or native and introduced species from the upstream reservoir. Fish resident in these reservoirs are entrained in turbine discharges, especially during winter when the reservoirs are drawn down and temperatures more uniform in the water column. Large numbers of catfish, walleye, and sunfish species were observed in the Chatuge weir pool when it was drawn down for turbine maintenance work. These fish were undoubtedly entrained from the reservoir in turbine discharges.

Cold-water sport fisheries have improved tremendously in response to changes in habitat downstream of the weirs. Quality and quantity of catchable trout in all tailwaters have led to tremendous increases in fishing pressure and catch. For example, fishing pressure more than doubled below South Holston weir in six years of monitoring. These fisheries are sustained by stocking hatchery-reared trout, however, carryover from year to year of stocked trout and some natural reproduction are important contributors to the quality of these fisheries. The weirs not only improve habitat for trout, they provide minimum flows desirable for wade fishing, which greatly enhances the experience for anglers.

Diversity of the fish assemblage would be maximized in river reach where weir installations have been proposed if there were significant free flowing sections downstream of the weirs. The weir pools will provide significant improvement in habitat for several fish species because of increased wetted area, depth, and shoreline habitat stability. Recreationally, important species such as the black basses, sunfish, catfish and others preferring lentic (still water) conditions will respond positively to increases in depth and wetted area. However, many fish species native to our rivers require flowing water for at least part of their lives and are typically not found in deep pools.

SAND SPRINGS DAM

Key Issue

- Adjusting the height of the weir to meet all of the operational objectives.
- Providing continuous releases to the downtown river reach through Jenks and beyond.
- Preventing erosion in the top portion of the weir pool that will be used for reregulation of Keystone Dam releases.
- Providing a safe recreational venue at this location.
- Constructing the weir in the best location.
- Providing for passage of the heavy sand loads.
- Avoiding the badly eroded area near the 4H hog farm.
- Setting weir foundations and abutments given the sandy nature of the soil.
- Minimizing any other issues such as impacts on tributary streams or changes in ground water conditions.
- Providing a pedestrian bridge over the river at this location.

Discussion

Description of the Weir

In the original design concept of the Sand Springs weir, the 1400-foot long structure would consist of two 350-foot fixed-elevation, stepped crib weir segments on each end, with a 700-foot adjustable section in the middle, and an 8-foot weir height. However, TVA proposes to make the weir taller, and if that occurs, the center gated section would need to be wider and the stepped sections on the end would be correspondingly shorter. For an 11-foot height, the gated adjustable section would need to be 925 feet wide, and if the weir was designed at a 10-foot height the gated section would need to be 850 feet wide. The additional width of the gated section is required for the taller weir heights to comply with FEMA NFIP regulations during the 100-year flood event. The weir will also cause no rise in the 1986 flood elevations, which the city of Tulsa also uses for regulatory purposes. The 1986 flood was at a recurrence interval between 100 and 500 years. In addition, the impacts of the increase in pool elevations would need to be evaluated on the surrounding area.

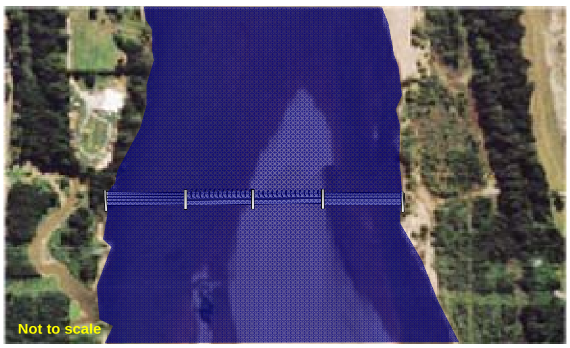


Figure 6a. Conceptual of Sand Springs Weir Passing Flood Flows

Figure 6b. Conceptual of Sand Springs Weir Passing Reregulating Flows

During normal Keystone turbine generation (12,000 cfs) and in flood operations, flows would pass over the stepped crib sections of the weir and the gate sections (Figure 6a). During larger flood operations, or to pass sand that has accumulated on the upstream side of the weir, part or all of the center section of the weir would be lowered and flow would still pass over the entire length of the weir. During reregulation releases, the stepped side sections of the weir would become dry and water would pass over the gated sections in the center or through pipes through the weir, maintaining a downstream minimum flow.

Instead of mechanically operated gates, it is proposed to install OBERMEYER pneumatically operated spillway gates (www.Obermeyerhydro.com). According to Obermeyer Hydro, its spillway gate system is most simply described as "*a row of steel gate panels supported on their downstream side by inflatable air bladders. By controlling the pressure in the bladders, the pond elevation maintained by the gates can be infinitely adjusted within the system control range (full inflation to full deflation) and accurately maintained at user-selected set-points*," (www.obermeyerhydro.com/info.htm). Some of the many advantages of this system are that bank side or remote control of the spillway gates is easily accomplished by controlling the air bladders, the air bladders are small and therefore easier to control, they are protected on the upstream side by the steel gate panels, can be hidden on the downstream side by a constant flow of water over the top of the gates, and are hidden when the gates are completely dropped.

When water is passing over the gate sections, the nappe is aerated by nappe breakers installed on the tops of the weir gates (Figure 7). The water curtain flowing over the gates will be designed to be thin enough to be safe for recreation in the downstream river channel.

Weir Height

The original proposal was for the weir to be 8 feet tall; however, in reviewing the extent of the weir pool and the shallow water depth near the upstream end of the pool, increasing the height of the weir by one foot would help provide protection to the least tern nesting islands in that part of the channel.

Additionally, because the streambed at the upper extent of the pool slopes upward fairly steeply just upstream of the weir pool, a further increase of two feet to the weir height would not increase the pool length by any significant amount, but it would provide a significant amount of storage to provide a continuous release to the downstream channel. Therefore, it is proposed to extend the weir height by a total of three feet, one foot for additional protection to the bird habitat, and the top two feet of the pool to hold enough volume to draw down gradually and provide the target continuous minimum flow to the downstream channel. Based on the available storage volume in the top 2 feet (5 miles x 2 feet deep x 1300 ft wide) which equals about 1575 acre-feet, 800 cfs could be continuously provided for 24 hours from this volume. If the Keystone Dam leakage and local inflows are also accounted for, the amount of flow provided to the downstream channel would be closer to 900 to 1000 cfs. This pool volume could be refilled by about 1.6 hours of two-unit generation from Keystone Dam each day.

Figure 7. An Obermeyer Gate installation Showing Steel Panels, Air Bladders and Stabilizers

If the Keystone Dam hydro units were not operated during the weekend, with an 11-foot weir height, the gates on Sand Springs Dam could be adjusted to release about 400 cfs instead of 800, which would draw the pool down about 3 feet in the 3-day period from Friday to Monday, allowing river-based and weir pool-based recreational activities to continue.

The continuous release over the gates at Sand Springs should keep that part of the channel immediately downstream of the gates relatively free of sand, so that when the gates are completely lowered for a flood or fish passage event, there should be no accumulated sediment debris to prevent them from being lowered.

It may be desirable to armor the shoreline with riprap or other protective materials in key places along the Sand Springs weir pool to prevent erosion from the fluctuating pool level, and for aesthetic impacts.

Recreation

The continuous release from Sand Springs, besides providing aquatic habitat improvements and least tern protection, could also provide flow for the proposed whitewater course at Zink Dam and possibly even future whitewater courses at the other two weir sites. NOTE: TVA provides a very heavily utilized whitewater rafting run below Ocoee 2 Dam with 1400 cfs. Thus, minimum flows of even half that amount could provide sufficient flow for a very good kayak course,

Figure 8. TVA Norris Weir's Stepped Weir Deck

if sufficient drop height is available. In addition, if sufficient funding is available, a bridge could be built above or near the weir structure to allow pedestrian traffic to move freely across the river.

Hydraulic Roller

Preventing the development of hydraulic rollers under normal operating conditions is also a critical part of the proposed projects. TVA conducted extensive testing to ensure that its weir installations did not create unsafe hydraulic rollers. For the Tulsa weirs, such as Sand Springs, the overflow section of the weir would be constructed similarly to the Norris weir (Figure 8) to help eliminate any potential for dangerous hydraulic roller conditions. The Norris weir breaks up the water flow using a two-fold approach of stair stepping down the elevation of the water, and also having a porous weir surface which diverts some of the flow downward through and out of the weir, eliminating the roller. The timber crib weirs are usually formed using pressure treated timbers, but a method using concrete sections could be investigated as well.

For the Obermeyer gated section of the weir, there would be a free overfall of water in a classic aerated nappe during minimum flow operations. TVA research in laboratory flumes and field installations of recirculation produced by free overfall nappes has indicated that a weir overflow of 1.2 cfs/ft is generally safe for a child with some swimming skills and wearing a life jacket, and does not produce a strong enough roller to entrain a healthy child under these conditions. Overflow of 1.5 cfs/ft was very negotiable for a healthy adult, but 2 cfs/ft was trickier and the test subject became winded after several cycles of entering and exiting the recirculation zone at these flows. It was easier to exit the recirculation area when the water was shallow enough for the subject to get their feet on the ground, and trickier if just swimming was involved (Hauser, 1991). The 800 cfs over a 700-foot Obermeyer gate section is equivalent to 1.15 cfs/ft. This is less than the 1.5 cfs/ft target for an adult test subject and less than the 1.2 cfs/ft that appeared to be safe for a child in a life jacket and even less for a wider weir gated section. If the discharge were 1000 cfs instead of 800, the discharge per foot over the gated section would be 1.4 cfs/ft, which is still below the 1.5 cfs/ft that the adult TVA subject found negotiable. During turbine generation, the gates could respond to the rise in pool elevation and adjust to maintain the same pool height over the gates to provide the same safe flow rate.

Location

The current preference is to locate the weir just downstream of the Highway 97 bridge near the 4-H hog farm. This location could create problems for construction of the Sand Springs Weir as at the right abutment there exists a 30’ deep bank cut from a small inflowing stream. To deal with this issue, the weir location would need to be adjusted or the small stream rerouted along with the construction of a more extensive weir abutment.

Pool Drawdown for Fish Passage

Unlike the downstream dams (Zink and Jenks), Sand Springs would not necessarily be lowered on the same schedule as the other weirs for fish passage upstream because it will be providing the minimum flows for the river. However, the Sand Springs pool would need to be dropped during part of the year to allow passing of floods and to allow passing of the heavy sand loads downstream. Barring floods, the movable portions of the Sand Springs weir would be lowered only to keep sand from accumulating on the upstream side of the weir (maybe January through early March). The goal is for this open-gate free-flow period to be shorter than the downstream weir pools’ open gate periods as part of the trade-off for providing the continuous flow. Drawdown at this weir, when it occurs, would be accomplished by having a gated section in the middle of the weir open to allow for sand/flood passage downstream (as shown above in Figure 6).

Foundation and Abutment Issues

Available soils information indicates that deep, rapidly permeable soils are located along the embankments in the general area identified as desirable for construction of both the proposed Sand Springs and Jenks weirs. Soils of this type are certainly a concern for weir construction and will increase the cost of weir installation. While various methods are available to address this situation, construction costs can escalate very rapidly. Final site selection must consider all aspects of the installation including foundation concerns, which may be the overriding consideration. Thorough soils investigations must be performed to determine the best course of action. This issue is one of the primary constraints for weirs on the Arkansas River and will need to be investigated further in the design process.

Other Issues

During future engineering analysis, the impacts that increased pool elevations might have on inflowing tributary streams would need to be investigated. In addition, the stream banks would need to be analyzed to assess the effects of higher pool elevations on ground water flows and stream bank stability.

ZINK DAM

Key Issues

- Modifying Zink Dam to eliminate the hydraulic roller.
- Enhancing recreation by adding a whitewater course downstream of dam.
- Providing extra height at Zink Dam to double the length of the weir pool for rowing, and possibly provide additional drop for an improved kayak course.
- Passing striped bass, sauger, shovelnose sturgeon, and paddlefish at the correct time of year to allow upstream migration, spawning, and downstream egg transport.
- Replacing or modifying the existing bascule gates as some or all of them may need extensive maintenance.
- Adding additional gates to help pass the heavy sand loads

Discussion

Hydraulic Roller

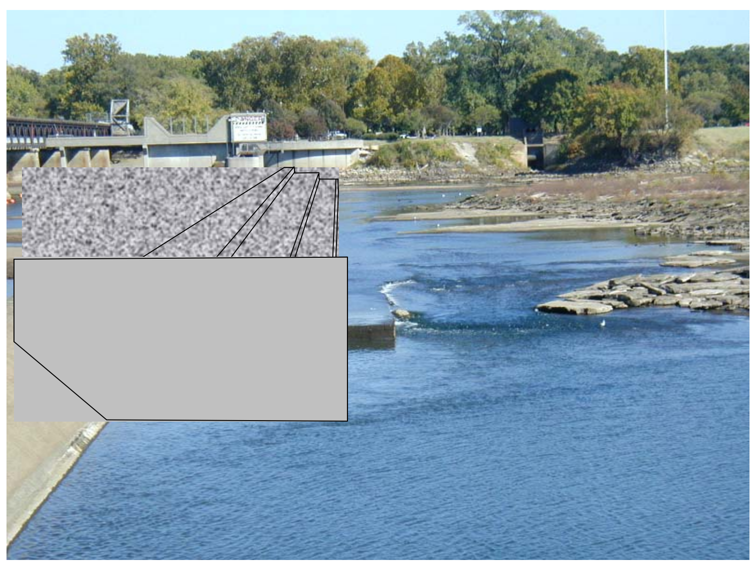


Figure 9. Conceptual of Zink Dam Retrofit with Stepped Weir to Eliminate the Hydraulic Roller

Ensuring elimination of the hydraulic rollers that have been produced by flow over the ogee-style spillway sections on this dam is a critical part of the proposed project. This is of increased importance now, due to the proposed kayak/whitewater course which could place people near the existing hydraulic roller. For Zink

Dam, a stepped crib weir filled with rock would be added to the downstream face of the weir and might possibly fit on the existing spillway apron (see Figure 9). The overflow section of the weir would be constructed similarly to the TVA Norris weir (Figure 8) to help eliminate any potential for dangerous hydraulic roller conditions. Both the porosity and the stepped design of the Norris weir work toward breaking up the water flow and diverting it downward through and out of the weir, which eliminates the roller.

Enhancing Recreation in Zink Dam Pool

The pool created by Zink Dam is relatively short, as it is a little over 2 miles in length, but broken into two pools by a shoal area about 1.2 miles up upstream of Zink Dam. If the height of Zink Dam is increased by 2 or 3 feet using Obermeyer gates (Figure 10b) or similar feature, the extended pool created by this height increase would drown the shoal and merge the two pool areas, allowing for additional recreational opportunities for rowers and other low-draft watercraft as shown in Figure 10a. The future cost estimate will include the option of using two-foot high Obermeyer gates to raise the height of Zink Dam.

Recreation in Zink Dam Tailwater

The minimum flow from Sand Springs Dam could provide sufficient continuous flow (400 to 1000 cfs) to allow for operation of a whitewater course at Zink Dam. To further enhance the whitewater course, an increase in the Zink Dam elevations would provide even more headwater elevation to drive the whitewater course and to provide additional depth and pool length for rowing skulls at Zink Lake. This dam elevation increase could be accomplished by using 2-ft or 3-ft tall Obermeyer gates (www.obermeyerhydro.com). These gates would normally remain in the fully raised position, allowing higher pool elevations; but during floods, the gates could be signaled to be dropped, reducing the weir crest elevations back to the present height and providing

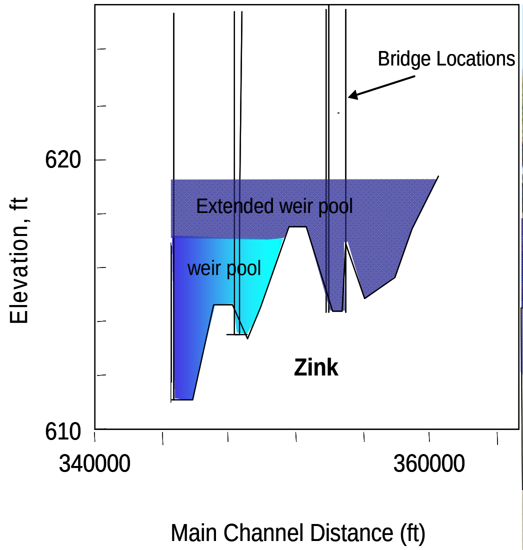


Figure 10a. Extension of Zink Dam Pool by Raising Crest Elevation Two Feet

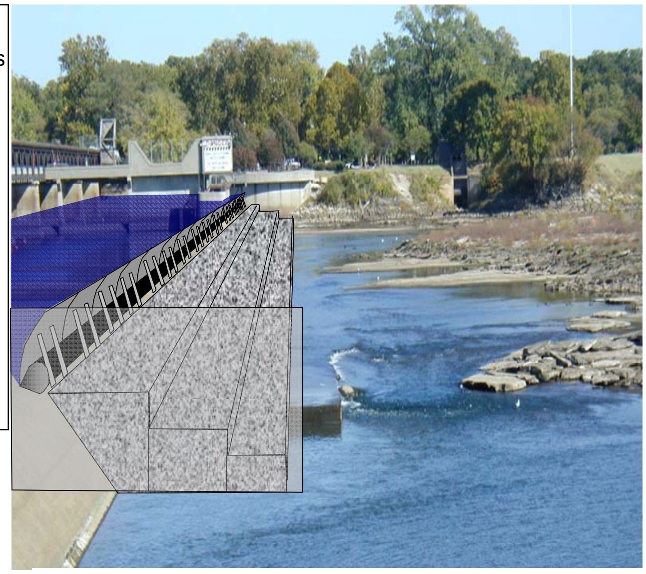


Figure 10b. Conceptual Sketch of Zink Dam with Stepped Deck and Obermeyer Gate Retrofits

no additional obstruction to the flood flows to be in compliance with FEMA regulations. The design of the stepped weir below Zink Dam would need to consider the impact that these flap gates would have on the hydraulic roller to ensure that the roller hazards are minimized under both crest gates open and crest gates closed operating conditions.

Pool Drawdown

During the flood, sand passage, and fish migration seasons, the pool at Zink Dam will be dropped to produce essentially riverine conditions from Sand Springs Dam all the way through Jenks Dam. This would probably be in effect periodically from March through May. This would occur by lowering the crest gates and opening the other mechanical gates that are presently installed along the weir, allowing flood flows and sand to pass downstream. There would need to be sufficient openings through the weir and minimum flows would need to be set to provide the required velocity regimes to encourage the passage of the four targeted fish species.

Bascule Gate Condition

The bascule gates in Zink Dam are in need of maintenance. There are three bascule gates installed in Zink Dam. One is on the west end of the long, straight spillway section, and the other two are on the east end of that same section. Each gate is 50 feet wide, 5 feet tall, and operated with hydraulic lines. Their base elevation when lowered is 612.0 feet (as shown in Figure 11) and they lay flat on the spillway apron when lowered.

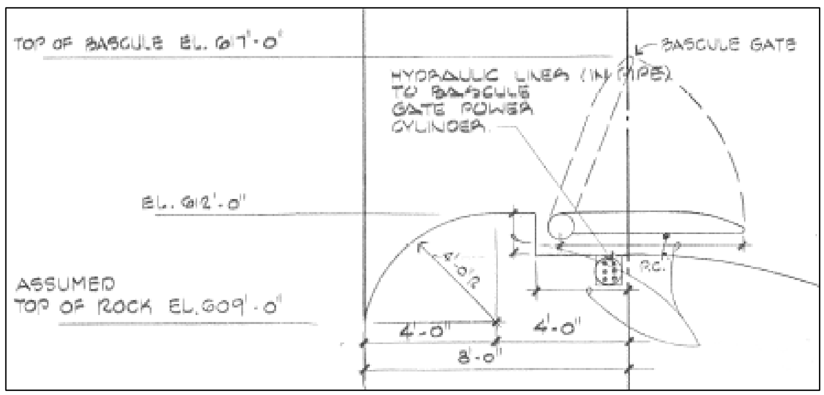


Figure 11. Diagram of Bascule Gate

Because these gates are only installed at each end of the spillway, there is significant sand accumulation behind the long ogee sectiondam. Additional gates may need to be added to the center of the weir to help ensure passage of the heavy sand loads associated with the Arkansas River.

The channel invert is approximately elevation 610, while the current gates lower to about elevation 612. To ensure passage of the fish upstream and over the barrier, sufficient flows through the gates would be necessary for the fish to pass over the sills and through the gates. Another alternative is to increase the downstream rating curve elevations to enable the fish to pass over the Zink Dam sills.

JENKS DAM

Key Issues

- Constructing the Jenks weir between the existing bridge and sand mining operations.
- Providing a safe recreational venue at this location.
- Providing a pedestrian bridge over the river channel at this location.
- Providing for passage of the heavy sand loads
- Passing striped bass, sauger, shovelnose sturgeon, and paddlefish at the correct time of year to allow upstream migration, spawning, and downstream egg transport (especially important at this location).
- Designing and building a weir considering the sandy nature of the channel and soil in the floodplain
- Designing the weir abutments to avoid water circumventing or piping in the sandy soil.

Discussion

Project Description

Construction would be similar to the Sand Springs weir. The 1400-ft long Jenks weir would consist of two 350-ft stepped crib weirs on each end with a 700-ft adjustable section in the middle. During normal turbine operations (less than 13,000 cfs *for example*) flows would pass over the stepped crib sections of the weir and the gates in the raised position. During larger flood operations or to pass sand that has accumulated on the upstream side of the weir, part or all of the center section of the weir would be lowered. Instead of mechanically operated gates for the center section of the weir, it is proposed to install OBERMEYER pneumatically operated spillway gates (www.Obermeyerhydro.com) as previously described in this report.

Recreation

Primary recreation uses at Jenks would be encouraged by waterfront development along the river lake. In the future, a whitewater course could be added below this project if usage for whitewater courses is sufficiently high at Zink and Sands Springs. In addition, as with the Sand Springs project, if sufficient funding is available, a bridge could be built above or near the weir structure to allow pedestrian traffic to move freely across the river and could possibly be integrated into the weir structure.

Hydraulic Roller

Ensuring elimination of the potential for hydraulic rollers is also a critical aspect of this installation as well. As with the Sand Springs weir, the end sections will be constructed similarly to the TVA Norris Dam Reregulation Weir (Figure 8) to help eliminate any potential for dangerous hydraulic roller conditions. The Norris weir breaks up the water flow by both stepping down the elevation of the water along with having a porous weir surface, which diverts some of the flow down through and out of the weir, which eliminates the roller. The central section would be an Obermeyer gate, which is safe on the downstream side when the water curtain passing over it is thin (flows less than 1.5 cfs/foot), as under typical recreational flow conditions. The area below the Obermeyer gate is the section of greatest concern, but the overflow is in the range of $1.15\ cfs/ft$ for the 800 cfs discharge rate, which according to TVA experience, appears to be safe for healthy adults and children wearing life jackets (TVA, 1991).

Location

Due to other variables, the Jenks weir needs to be located just downstream of the Creek Turnpike Bridge and upstream of the sand quarry operations. A major concern and

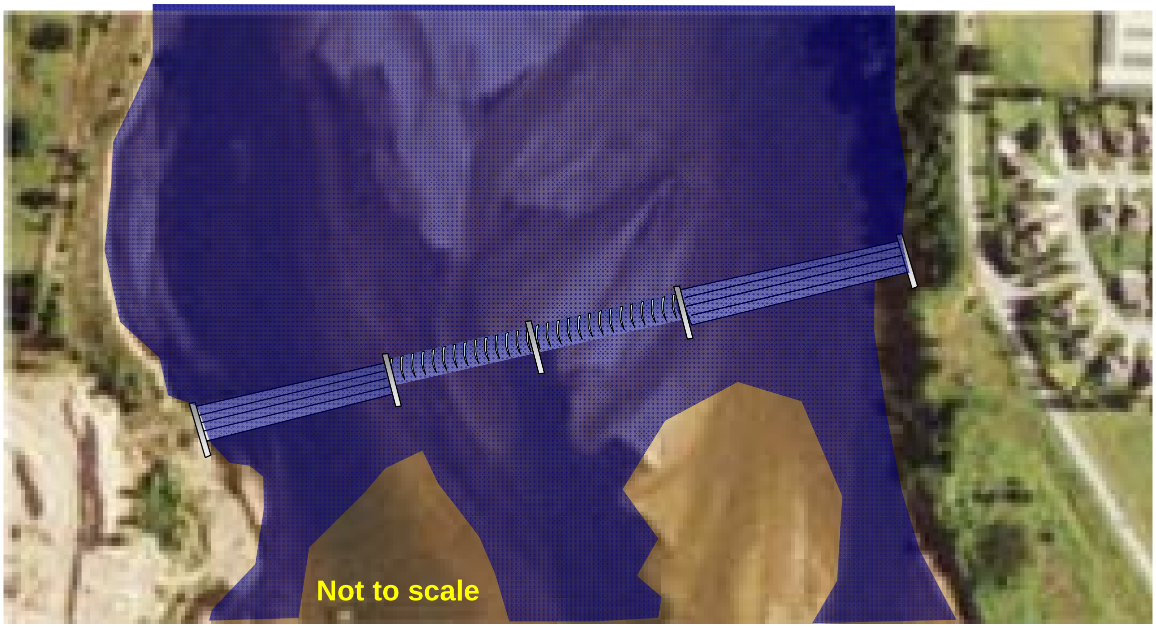


Figure 12. Visualization of Jenks Weir with Obermeyer Gate Sections and stepped Weir Sections Under Reregulation Flow Conditions

potential variable in the construction costs is the sandy composition of the river banks which could require extensive preparation to ensure that piping does not occur around or under the weir structure. Further analysis has indicated that the rock below the sand at Jenks may be very suspect as well.

Pool Drawdown

During the flood, sand passage, and fish migration seasons, the pool at Jenks Dam will be dropped to where the river is essentially a river without weirs from the Sand Springs Dam all the way through Jenks Dam. This would probably be in effect from March to May. Drawdown would be accomplished by dropping all or part of the gated section in the middle of the weir. This open period would allow for sand/flood passage downstream, as well as migratory fish species to pass upstream through the weir (see Figure 12).

CONCLUSIONS

The proposed integrated river system outlined in this document offers many advantages to the Tulsa area, such as shoreline beautification, recreational opportunities, and improved habitat for native species. It also offers numerous challenges, such as integrating an aesthetically pleasing structure with a design that is structurally sound, and it addresses issues such as FEMA NFIP guidelines and recreational safety issues along with addressing the structural concerns of the construction in a sandy river channel.

One consideration is the numerous benefits that can be gained from making the Sand Springs weir 11 feet tall instead of the originally proposed 8 feet. The extra height will allow up to 800 cfs continuous flow to be provided from weir pool storage to the downstream channel even though Keystone Dam is only operated for a short time each day. The continuous flow will provide the aforementioned habitat and recreational benefits, and will also serve to protect the gated portion of the structures from vandalism.

Of the three projects studied, rehabilitation and raising the height of Zink Dam appears to be the most feasible. Most of the foundation work and supporting infrastructure are already in place. Only a relatively small increase in elevation is required and this would be taken care of by the installation of additional gates.

Construction of a new dam at Sand Springs appears to be feasible. Available boring information indicates hard shale lies approximately 15 feet below the existing river bottom. Some grouting is considered likely even in hard shale but may tend to be minimal. The cost for construction may be somewhat reduced by lowering the height of the Obermeyer Gates and shortening their length. Even a slight reduction in gate height coupled with an appropriate reduction in length will provide substantial cost savings.

Construction of a new dam at Jenks is more problematical. Foundation conditions currently appear to be undesirable. Available borings indicate that hard shale is not available even in depths greater than 20 feet. Installation of a lower dam will result in lower costs but much of this advantage may be lost to the need for extensive grouting and it still could be problematical due to foundation problems. Additional concerns were raised about Jenks/South Tulsa weir with the need to quantify the effects on water quality of the cities waste loadings flowing into the weir pool. These concerns could be addressed by using a tailwater model to study any water quality concerns.

RECOMMENDATIONS

From an engineering standpoint, rehabilitation and increasing the height of Zink Dam appears to be the most feasible of the three projects. Zink Dam needs rehabilitation to continue to work properly and to improve public safety. Construction of a new dam at Sand Springs also appears to be feasible from an engineering standpoint. Hard shale foundation material lies a reasonable distance below the river bed, but it would still require significant foundation work and looking for a better site both upstream and downstream would be advisable. Construction of a new dam at Jenks / South Tulsa also needs more study. Foundation conditions currently appear to be undesirable. Available borings indicate weathered shale may extend to relatively large depths.

To better evaluate the feasibility of building a dam at Jenks / South Tulsa rock borings should be drilled along the center line of the proposed dam. These borings should be advanced through the weathered shale to hard shale to better define foundation conditions, not only in the immediate target area of the weir, but upstream and downstream as well to see if there is better rock in the vicinity.   This should also be done for the Sand Springs weir site as well to better quantify the exact requirements for the weirs’ foundation.

REFERENCES

ABS Alaskan @ http://www.absak.com/tech/turbines.pdf

Bendnarek, Angela T., “Dams and Decision-Making: Socioeconomic and Ecological Considerations,” Dissertation in Biology, Presented to the Faculties of the University of Pennsylvania, 2002.

Bridgestone Rubber Dams, http://www.bridgestone.co.jp/english/diversified/rubberdam/design.html

FEMA NFIP Community Status,: http://www.fema.gov/fema/csb.shtm, 2007.

Fusegates, http://www.hydroplus.com/hydroplus.nsf/web/fusegates.htm

Hauser, G. E., “Full-Scale Physical Modeling of Plunge Pool Hydraulics Downstream of a Vertical Weir,” TVA, May 1991.

Hydroventuri, at http://www.hydroventuri.com/news.php

Obermeyer Gates, http://www.obermeyerhydro.com/

Tempe, Arizona inflatable dams, http://www.tempe.gov/lake/LakeHistory/dams.htm

Appendix A.

River dams study challenged by: MICHAEL OVERALL World Staff Writer 9/10/2007
A federal biologist says the Corps of Engineers' report used a faulty assumption.

The Arkansas River might not bring enough water to Tulsa to support additional low-water dams without harming the environment, U.S. Fish and Wildlife Service officials say. The agency is questioning an environmental impact study by the Army Corps of Engineers in advance of the Oct. 9 vote on taxes to support proposed river projects. But a consultant who worked with the corps on its first report on the projects says they won't harm wildlife.

"I'm convinced, in my professional opinion," said Gaylon Pinc, a consultant who is working with Tulsa County and the Corps of Engineers on the environmental part of the master plan, "that the net effect will be an improvement to the river and to the habitat." A spokesman for the corps said it hadn't started the process that could result in a permit for the projects, and until it does, he can't say whether possible environmental problems can be overcome.

Pinc's report to the corps found no reason to oppose a key part of the proposal -- constructing low-water dams near Jenks and Sand Springs in addition to altering the dam near 31st Street and Riverside Drive.

A Fish and Wildlife biologist, Kevin Stubbs, said the corps' analysis assumed an unrealistically high average flow of water in the river. Partly because of the natural flow of the river, and partly because of electric power generation at Keystone Dam, the amount of water in the Arkansas tends to fluctuate a great deal from day to day, even from hour to hour, Stubbs said.

"It tends to be all or nothing," said Stubbs, a member of an advisory committee for the proposed river developments in Tulsa. "You have a lot of water or hardly any water. Statistically, the average will be somewhere in the middle, but in reality you never see the average." Without enough water coming downstream, pollutants could build up behind the dams, possibly creating a fetid and murky pool, Stubbs said. And the amount of dissolved oxygen could drop, too -- essentially suffocating fish in the river.

"Averages don't mean anything to a fish," Stubbs said. "If you have eight hours of low flow followed by two hours of high flow, if you're a fish you're still dead. The two good hours won't bring you back." The corps' environmental impact study used a standard called "7Q2," a complicated method of predicting the lowest average flow of water that a river would be expected to have over an extended period.

The problem, Stubbs said, is that the Arkansas routinely falls below its 7Q2 level. In fact, during last year's drought, the river fell below 7Q2 on all but three days during a three-month stretch, records from the U.S. Geological Survey show. Instead of using the 7Q2 standard, the Fish and Wildlife Service wants the corps to study what impact the dams would have on water quality during drought conditions, with 2006 used as a benchmark.

"You can make an argument that last year was an extreme situation and it won't happen again," Stubbs said. "Well, it won't happen every year, but it is sure to happen again, sooner or later.

"And you have to account for extremes like that when you plan a project like this." Tulsa's existing low-water dam, which creates Zink Lake south of the 21st Street bridge, has been shown to reduce fish populations for miles downstream, according to a report from the Oklahoma Department of Wildlife Conservation. Pollution, nonetheless, hasn't been a major issue in Zink Lake. The proposed low-water dams, however, would create larger pools of water and would come one after the other along the river's course, creating a cumulative effect, Stubbs said.

More important, Zink Lake is upstream from Tulsa's sewage treatment plant, but Jenks is downstream, Stubbs noted. "You're going to be pooling water at precisely the point where you want to dilute this discharge," he said. "What happens when you have 10 or 12 hours -- or even 10 or 12 days -- without a significant amount of fresh water coming into that pool?"

Tulsa County voters will decide Oct. 9 whether to approve a $282 million plan to build the two low-water dams and renovate Zink Lake. The projects would be financed by an additional 0.4 percent sales tax. Those revenues would be added to a $117 million pledge by the George Kaiser Family Foundation to develop attractions along the river.

Proponents acknowledge that Tulsa will endure periods of drought, during which the low-water dams will likely not be able to keep the river high. Especially on weekends, when Keystone Dam tends to release less water as it reduces power generation, water levels may drop, said Pinc, the corps' consultant.

"The vast majority of time, we're going to have a good, steady flow of high water," Pinc said. "As for the extremes of nature, there's no way to avoid them. We'll simply have to suffer through them, like we suffer through them now." Ken Levit, the executive director of the Kaiser Foundation, referred environmental impact questions to Pinc. Pinc promised that officials would work with the federal wildlife agency to minimize the environmental impact as they design the low-water dams and the supporting infrastructure.

Wildlife habitat can either be protected or "replaced" by restoring similar habitats elsewhere along the river, he said. The Oklahoma Department of Wildlife Conservation, however, predicted a net loss of habitat, especially for native species of fish, in a report prepared for the corps' environmental impact study.

The low-water dams would destroy about 10 miles of "prairie river habitat," said Brent Gordon, a fisheries biologist who prepared the report for the state agency. And the water level will fluctuate too much to replace the river habitat with a sustainable lake habitat, Gordon said. "What you end up with is neither," he said. "People think that if you want fish, all you need is water. But that's not true. It's not even close to true." Neither the federal Wildlife Service nor the state Wildlife Conservation Department could block construction of the low-water dams.

But under the federal Clean Water Act and the Endangered Species Act, the Corps of Engineers must consult both agencies before it can issue a permit for the construction. Edward Engelke, a spokesman for the corps, said the process that could lead to a permit for the projects would also involve consulting historical groups and conducting public hearings.

That process hasn't started, so it would be premature to address the river projects specifically, he said. Hypothetically, if a project could harm an endangered species such as the least terns that nest in the Arkansas River in the Tulsa area, it might not receive a permit, Engelke said.

However, such impacts often can be mitigated or the project changed in modest ways to allow it to proceed, he said. When the Creek Turnpike was planned, problems that a bridge over the Arkansas River would have produced for least terns led to design changes that allowed the project to advance without hurting the birds, he said.

Federal authorities define the “7Q2 standard” as “the lowest average stream flow for seven consecutive days with a recurrence interval of two years, as statistically determined from historical data.”

Possible remedies have own troubles
Tulsa could find ways to ensure a steady flow of water in the Arkansas River to prevent the buildup of pollutants behind low-water dams, including these strategies suggested by U.S. Fish and Wildlife Service officials. But each potential solution comes with at least one drawback:

Strategy: Use a relatively large low-water dam near Sand Springs to “store water,” releasing it when needed to maintain a steady flow to smaller low-water dams downstream. The proposed river project does include a larger dam near Sand Springs for this purpose, but the Wildlife Service believes that the dam might need to be even larger.

Drawback: A larger dam would be more expensive to build, and it’s not clear whether any low-water dam could store enough water to sustain the flow through an extended drought.

Strategy: Adjust the release of water from Keystone Lake to ensure an adequate flow to Tulsa.

Drawback: Keystone Lake would have more trouble maintaining its own level, possibly affecting recreation and power generation.

Strategy: Periodically open gates in the low-water dams to allow pollutants to wash downstream and become diluted.

Drawback: The river’s level would drop while the gates are open, and it’s not clear how often — or for how long — the gates would need to be open.

RESPONSE

Continuous minimum flows are needed in tailwaters of tributary dams to reduce dry channel conditions between generating periods. The targeted reach is the immediate tailwater between the dam and significant downstream sources of local inflow. The need for continuous flow in this reach is distinguished from other system needs, far downstream from the dam that may be adequately met with daily or weekly average minimum releases. Habitat benefits from higher minimum flows include more wetted channel area to support benthic organisms; improved attraction water for fish spawning runs (increased minimum velocity); continuous flushing of deep natural pools between riffle locations that might otherwise be subject to low dissolved oxygen (DO) due to excessive residence times between turbine generating periods; and to some extent reduced thermal shock at the onset of hydro generation. Continuous minimum flows below tributary projects also benefit water supply, assimilative capacity/water quality, thermal compliance and safety at power plants, and navigation.

Comments from the Oklahoma Department of Wildlife Conservation are correct in predicting a loss of prairie river habitat as a result of the pools formed by the low head dams. They are also correct in stating that the prairie river habitat would not be replaced by “sustainable lake habitat.” Pools formed by the low head dams would not be permanent because parts of the dams would be lowered during fish spawning season to allow passage of migrating fish. Also, at high river flows, these shallow pools would not resemble lake habitat. However, the series of three low head dams could be operated to re-regulate the hydro generation pulses from Keystone Dam to provide enhanced riverine habitat in those stretches not impacted by the low-head dam pools. Such habitat would probably more closely resemble large prairie-river habitat than exists now. The question is would enhancements to riverine habitat offset losses due to existence of the low-water dam pools? A hydrodynamic and water quality model of the affected part of the Arkansas River would address these and other uncertainties.

APPENDIX B

See Accompanying
FINAL REPORTS OF ENVIRONMENTAL DATA
TASKS 1,2,3,4 and 5
For The
Arkansas River Corridor Project
Tulsa County, Oklahoma