ABSTRACT

BUILDING A LABYRINTH IN THE BRAZOS RIVER

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The Lake Brazos Dam plays a vital role in downtown Waco, Texas. Sadly since 1970, extended periods of below-normal lake levels diminished the area’s appeal. Completed as a gated spillway, the dam posed maintenance and operational problems for the City, making the reservoir unreliable. Over the years, the City looked at options to address problems with the gated spillway. Ultimately, the City chose a labyrinth weir to replace the dam.

Building a labyrinth weir in the Brazos River presented unique challenges, particularly because the 3,000-foot long weir was constructed within the existing dam’s footprint to reduce costs and to accommodate regulatory requirements. The construction was performed in phases to accommodate river flows. Cofferdams protected work areas and maintained a full reservoir during construction. Hydraulic performance led to strict tolerances for wall profile and finish. The labyrinth weir is almost complete and the City can look forward to a reliable reservoir.

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INTRODUCTION

The Lake Brazos Dam plays a vital role in enhancing the quality of life in downtown Waco, Texas. Sadly, since 1970, extended periods of below-normal levels due to problems related with the gated spillway diminished the area’s appeal. Maintenance and operational problems made the reservoir unreliable. Over the years, the City looked at options to address problems with the gated spillway. Ultimately, the City chose a labyrinth weir to replace the dam.

The purpose of the Lake Brazos Dam Replacement Project was to improve the reliability of the reservoir and to reduce operational and maintenance costs. The selection of the labyrinth weir was based on well-established project goals, careful planning, and innovative design. The unique challenges of building a labyrinth weir in the Brazos River included utilizing the existing dam’s footprint, phasing construction to accommodate river flows, protecting work while maintaining a full reservoir during construction, and the adherence to strict tolerances for wall profile and finish.

HISTORY OF LAKE BRAZOS DAM PROJECT

Construction of the original Lake Brazos Dam was completed in 1970. It consisted of a gated spillway and a concrete-lined earthen embankment. A drum gate system was used to adjust the weir crest elevation for flow conditions in order to maintain a constant reservoir elevation. The City of Waco experienced frequent problems with the drum gate system and the ability to maintain a desired reservoir level.

Continuing problems with the drum gate system and the inability to maintain a desired reservoir level led to dam modifications in 1985. The changes consisted of gate modifications, stilling basin extension, and constructing a low flow outlet works. The drum gates were transformed into leaf gates operated by hydraulic cylinders and an automatic reservoir level sensing system. However, soon after the modifications were completed, the City experienced performance problems with the hydraulic gate system.

The Lake Brazos Dam has led to significant growth along the Brazos River. Baylor University has expanded along the eastern shoreline of the river. The City of Waco has also made many improvements along the river, including miles of riverwalk and parkway improvements that include landscaping, lighting, and boat docks. There has also been much private development on the river banks, including lakeside and floating restaurants.

The numerous improvements to the dam were fully dependent on maintaining a reliable and near constant reservoir level. Dissatisfaction with previous projects and a strong desire to expand business and amenities along the river led to a series of feasibility studies to replace the dam. Previous studies by Freese and Nichols, Inc. in 1992 and The U.S. Army Corps of Engineers in 2000 examined the
feasibility of replacing the dam with a fixed-weir structure to eliminate the gates entirely. The fixed-weir solution gained support in Waco because it would eliminate the gates and associated maintenance costs. The USACE studies recommended a labyrinth weir. The estimated construction costs exceeded $30 million due to river diversions and building a new dam downstream of the existing site. The feasibility studies also required emptying the lake for an extended period during construction. Building a new dam also involved significant environmental impact and permitting activities. The initial high estimates and environmental requirements pushed the City to look for alternatives that would make the project more feasible. The City of Waco remained interested in the labyrinth weir concept, so it continued to study the concept further with the assistance of Freese and Nichols, Inc.

A design team led by Freese and Nichols, Inc. looked at innovative ways to provide a solution to the Lake Brazos Dam problems at a reasonable cost. The primary project goals were:

- Reduce construction and maintenance costs;
- Maintain the historical normal pool upstream impoundment;
- Maintain the existing regulatory (FEMA) 100-year upstream flood plain,
- Limit nuisance inundation of the riverwalk for river flows up to the 2-year flood event;
- Minimize disruptions to lake levels during construction to reduce the impact on the central business community;
- Provide an aesthetically pleasing and low maintenance structure.

Key decisions made during the planning phase in keeping with the project goals were:

- Replace the existing structure with a labyrinth weir, as recommended by the U.S. Army Corps of Engineers in 2000, to accommodate the hydraulic challenges of the site;
- Use the existing dam as the foundation of the labyrinth weir to reduce construction cost and environmental impacts;
- Adopt a multi-phase construction plan, in which one half of the dam is built while the other half is maintained and operational; thus reducing construction cost further by eliminating diversion of the river. The multi-phase approach also provided means to maintain normal reservoir levels during construction.

**HYDRAULIC CHALLENGES**

The Lake Brazos Dam site presented challenging hydraulic conditions for properly assessing the labyrinth weir performance:

- A rapidly rising tailwater level created a submergence condition for floods larger than the 10-year flood event,
- The configuration of the labyrinth weir had to remain within the existing footprint of the dam to avoid the need for extensive river channel modifications and environmental permitting and mitigation,
The configuration of the labyrinth weir had to provide optimal capacity at low heads while maintaining satisfactory performance at large heads.

The advantage of a labyrinth weir over a straight weir is that it increases the discharge capacity for the same channel width by increasing the weir centerline length. The hydraulic benefit of a labyrinth weir decrease as the upstream reservoir level rises significantly above the design head. For a large head, cross flows from adjacent weir walls mix, thus reducing weir efficiency. The weir efficiency progressively decreases with increasing head to the point where the discharge over a labyrinth weir approaches the discharge over a linear broad-crested weir.

**Hydrologic and Hydraulic Studies**

An extensive program of hydrologic and hydraulic studies to assess the hydraulic design and construction of the new spillway included:

- Developing a refined hydraulic model of the Brazos River through Waco.
- Physical modeling the performance of the labyrinth weir, including conditions during construction.

A mathematical hydraulic river model was developed to estimate the tailwater levels below Lake Brazos Dam and to determine the impact of the labyrinth weir on upstream water levels. Tailwater levels are important at this site because the hydraulic efficiency of the labyrinth weir is affected by submergence effects.

The physical model testing was performed at the Utah Water Research Laboratories (UWRL) at Utah State University. Physical model testing included sectional and full-width models for both the existing and the proposed structures. Fourteen sectional models were evaluated, including three linear weir models, ten labyrinth weir models, and one model of the existing gated spillway. Figure 1 shows the final sectional model. Two full width models were used to evaluate the existing dam and the labyrinth weir.

The physical model study assisted in the design of:

- Suitable crest shape and labyrinth dimensions (Figure 1 and 2);
- Sequence of construction effects on river flows;
- Effect of temporary cofferdams (Figure 3);
- Upstream channel configurations (Figure 4 and 5);
- Downstream channel configurations (Figure 6).

The physical models proved very beneficial in assessing the project approach and provided important information in the behavior of the labyrinth weir during the construction phase.
Figure 1: Labyrinth weir sectional model

Figure 2: Labyrinth weir full-width model

Figure 3: Temporary bulkhead on right labyrinth simulating phase construction

Figure 4: Scour development during left labyrinth simulating phase construction

Figure 5: Upstream channel improvement testing.

Figure 6: Downstream riprap testing.
CONSTRUCTION PHASE

The Lake Brazos Dam Replacement Project involved the construction of a significant concrete structure in the Brazos River. The construction contract was awarded to Archer Western Contractors, Ltd. with a bid of $15,936,324 and construction began in January 2006. The labyrinth weir construction reused a significant portion of the existing dam and followed the guidelines established in the design phase. The weir was constructed in phases to allow for the diversion of the river. The left half of the labyrinth weir was constructed while the existing gates remained in operation. The right half of the labyrinth weir was then constructed while the river passed over the completed left labyrinth weir.

Site Description

The existing Lake Brazos Dam was founded on alluvium, overlying bedrock commonly referred to in the central Texas area as the Taylor Marl Formation. The existing dam consisted of six main sections as shown in Figure 7.

The right non-overflow section was constructed as part of the original dam and houses the operating equipment for the leaf gates. This section consists of a concrete wall set on a large concrete footing. The gated spillway (See Figure 8) was built in 1970 and extended in 1985. The original gated spillway is a large concrete slab resting in the alluvium and it is surrounded by continuous sheetpile.
Two 117’ leaf gates were used to control river levels and flow. The basin extension is a slab founded on rolled compacted concrete overlaying the Taylor Formation.

The concrete-armored overflow embankment section was 317 feet long and consisted of a concrete shell covering a sandy-clay compacted fill. The core of the embankment was composed of compacted impervious clay core and a sheetpile cutoff. Rock riprap protected the downstream area of the embankment. The upstream levee is located immediately left of the overflow embankment and was formed during the original construction of the dam by excavating into the original left riverbank to divert the water during construction. The non-overflow embankment section is to the right of the upstream levee. The embankment is made of sandy-clay compacted fill with a core made of impervious clay and sheetpile.

As part of care of water during the 1985 modifications project, a diversion channel was built to bypass river flows around the non-overflow embankment. The diversion channel was later modified into a permanent low flow outlet works. The left outlet works consists of a 16’ x 14’-6” rectangular concrete tunnel. Three 120” diameter butterfly valves at the downstream end of the tunnel regulate the flows.

**Left Labyrinth Weir Construction**

Construction on the Lake Brazos Dam began with the left labyrinth weir. While the left labyrinth weir was being built, river flows continued to pass through the existing gated spillway. To facilitate the construction of the left labyrinth weir, the construction contract included an extended lake lowering for the first four months of the project so the cofferdams could be built. The Lake Brazos was lowered by opening the existing spillway leaf gates and the three butterfly valves in the left outlet works. The lake lowering extended until April 8, 2006 and maintained headwater levels below elevation at 364 ft-msl. After this date, gates were raised and butterfly valves were closed so the Lake Brazos could be filled to
elevation 376 ft-msl in preparation for the summer season. Table 1 provides a summary of activities performed during the construction of the left labyrinth weir.

Table 1: Summary of left labyrinth weir construction activities for the construction period between January 2006 to October 2006

<table>
<thead>
<tr>
<th>Initial Lake Lowering (Four Months)</th>
<th>Lake Brazos Full (five months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site grading for construction equipment access</td>
<td>Construction of labyrinth weir drilled piers</td>
</tr>
<tr>
<td>Demolition of the overflow embankment</td>
<td>Placement of labyrinth weir concrete platform</td>
</tr>
<tr>
<td>Upstream channel improvements</td>
<td>Placement of labyrinth weir walls</td>
</tr>
<tr>
<td>Installation of permanent and temporary sheetpile</td>
<td>Construction of permanent access driveway</td>
</tr>
<tr>
<td>Installation of temporary cofferdam tie-backs</td>
<td>Placement of concrete downstream impact slab</td>
</tr>
<tr>
<td>Installation of upstream training wall permanent tie-backs</td>
<td>Installation of downstream rock riprap</td>
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</tbody>
</table>

The removal of the overflow embankment was performed with conventional excavation equipment and included concrete demolition and embankment material removal. The demolition of the overflow embankment occurred simultaneously with excavation and grading of the upstream channel. The contractor initially limited the embankment demolition to elevation 368 ft-msl to provide a working surface for the sheetpiling equipment. Once the upstream section of the sheetpile and cofferdams were significantly complete, the contractor completed the demolition and excavation upstream and downstream of the cofferdam.

Figure 10: Overflow embankment demolition and upstream excavation - February 2006

The upstream channel improvements consisted of grading the river channel and modifying the upstream levee. The excavation of the upstream river channel proceeded simultaneously with the overflow embankment demolition (Figure 10). The upstream levee modifications included construction of a sheetpile training wall and riprap installation. The upstream training wall, upstream sheetpile
cutoff, and other permanent sheetpile sections of the project were installed during this phase. The upstream training wall was supported by tie-back anchors connected to buried sections of sheetpile installed in the upstream levee. Training wall supports were installed without the benefit of a cofferdam around the work and relied on the river levels being below 363.5 ft-msl so equipment could get to the area.

The potential scour problem identified during the physical modeling of the dam construction phases led to a scour protection pad for the construction phase as part of the upstream channel improvements (Figures 11 and 12). The scour protection pad consisted of a reinforced concrete upstream impact slab surrounded by sheetpile. The pad was built just upstream of the left labyrinth platform.

![Figure 11: Upstream impact slab](image)

![Figure 12: Upstream impact slab](image)

The foundation for the left labyrinth weir platform consisted of concrete drilled piers and sheetpile. The permanent sheetpile (Figures 13 and 14) provides vertical support, serving as a permanent upstream seepage cutoff, and provides downstream scour protection. The permanent upstream cut-off was made with PZ-35 and PZC-18 sheetpile sections. The PZ-35 sheetpile section was used in areas in direct contact with upstream water levels and backfill above elevation 368 ft-msl. To reduce cost, the contract documents allowed the extension of the permanent upstream sheetpile in these areas above the platform elevation to serve as the upstream cofferdam system. The Contractor chose to extend the temporary section of sheetpile immediately in contact with lake water from elevation 363.5 ft-msl to 378.5 ft-msl. The Contractor used soil drilled anchors as temporary supports for the upstream cofferdam system. The permanent downstream cut-off was made with PZC-18 sheetpile. The downstream sheetpile was not used as a cofferdam since the existing downstream fill was graded to elevation 368 ft-msl to serve as the downstream cofferdam. Sheetpile installation was performed through the alluvium with a vibratory hydraulic hammer. After the sheetpile reached the Taylor Formation, it was pushed 2 feet into the bedrock with a hydraulic piston hammer.
Lateral and vertical support for the labyrinth platform is provided by the drilled piers. The labyrinth weir foundation has ninety five (95) drilled piers (Figures 14 and 15). The piers are 42” in diameter and extend from the bottom of the labyrinth weir platform at elevation 360.5 ft-msl to a minimum of 12 feet into the Taylor formation at elevation 325 ft-msl. Steel casing driven by a vibratory hammer was used to facilitate the pier construction. Construction of the piers began while some of the downstream sheetpile was still being driven and was concluded in less than two months.

Once the foundation piers were complete, work began in the construction of the labyrinth platform and foundation drains. The drain system consisted of slotted PVC pipe embedded in a sand envelope running along the upstream and downstream sheetpile with transverse interconnecting lines. The foundation drain system and platform area was overlaid with cement treated base for protection during platform rebar and concrete placement. The platform’s overall dimensions are approximately 308’x90’ with a thickness of 3 to 4 feet (Figure 16). The
platform concrete was placed in four large sections. Due to the amount of concrete required, pump trucks were used to facilitate and expedite placement.

![Figure 16: Labyrinth platform construction - June 2006](image)

A significant amount of effort during design was given to the height, thickness, and shape of the wall crest since hydraulic performance was demonstrated to depend on these factors. The crest shape in the physical models was designed to provide a high discharge coefficient at low flows. Therefore, construction tolerances on wall finish and elevations were very tight (±1/4”). Construction on the labyrinth weir walls began soon after the first section of platform slab was complete (Figures 17 and 20). The straight sections of wall were formed and poured first. Subsequent labyrinth walls were poured in alternating sequence to accommodate concrete curing and form use. The corners of the cycles, called apexes, were poured after the two adjacent walls were complete (Figures 21 and 22). Reusable steel forms provided allowed for special care to the wall crest finish. The elevation of wall sections were checked prior to the crest form installation. The crest forms were built to be removed within hours of concrete placement so the crest shape could be checked and the concrete could be finished.

As the labyrinth walls were built, downstream impact slabs and an access driveway was also constructed in sections (Figure 23). The driveway provides access to the left labyrinth platform from the right abutment. The access driveway was included to provide means access to the labyrinth downstream area to remove debris that could accumulate on the labyrinth weir following a flood. Construction in this phase was limited to the driveway immediately downstream of the left labyrinth (Figure 25).
Figure 17: Labyrinth wall crest forms (test pour)

Figure 18: Typical labyrinth wall reinforcement

Figure 19: Labyrinth Weir Construction

Figure 20: Labyrinth crest finishing

Figure 21: Apex reinforcement and formwork installation

Figure 22: Apex concrete placement
The downstream impact slab size and configuration resulted from the physical model testing. The impact slab helps to dissipate the water energy as the flow drops 8.5 feet from the labyrinth platform at elevation 363.5 ft-msl into the river channel at elevation 355 ft-msl. The downstream impact slab is 15 feet wide, extending the length of the labyrinth platform area (Figures 24 and 27).

To further mitigate downstream scour potential during labyrinth discharges as the right labyrinth was being built, a layer of riprap was placed downstream of the impact slab. The riprap layer was added because the downstream area is subject to increased water turbulence and hydrodynamic forces when only the left labyrinth is operational. The riprap provided additional scour protection to the left labyrinth downstream area during the construction phase.
The left labyrinth weir was substantially complete by late September 2006, which was 3 months ahead of another scheduled lake lowering in January 2007. Therefore, the City approved an earlier intermediate lake lowering to complete the left labyrinth weir and to begin work on the right labyrinth weir. The lake was lowered between October 2 and 14 2006. During the intermediate lake lowering, the temporary sections of upstream sheetpile at the left labyrinth weir were removed (Figures 28 and 29). Also, the riprap downstream of the impact slab was completed. The first spill over the left labyrinth weir occurred on October 31 2006.
Right Labyrinth Weir Construction

Construction on the right labyrinth weir began once the left labyrinth weir was substantially complete (See Figure 30). While the right labyrinth weir was being built, river flows were diverted over the left labyrinth weir. Construction of the right labyrinth weir required the following activities:

Table 2: Summary of right labyrinth weir construction activities for the construction period between October 2006 to July 2007

<table>
<thead>
<tr>
<th>Intermediate Lake Lowering (two weeks)</th>
<th>Lake Brazos Full (ten months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site grading for construction equipment access</td>
<td>Placement of labyrinth weir slabs</td>
</tr>
<tr>
<td>Demolition of the spillway baffle blocks and endsill</td>
<td>Placement of labyrinth weir walls</td>
</tr>
<tr>
<td>Modifications to existing gates to serve as temporary cofferdam</td>
<td>Construction of permanent access driveway</td>
</tr>
<tr>
<td>-</td>
<td>Demolition of existing left training wall</td>
</tr>
</tbody>
</table>

A temporary access road on the right abutment provided access to the right labyrinth area. This temporary road follows the same alignment of the permanent road for access to the labyrinth weir.

During the October lake lowering, modifications to the existing gates were made so they could serve as an upstream cofferdam. The modifications included an extension (Figure 31) to control wave action and supports (Figure 32) on every hydraulic cylinder to prevent a sudden failure. The contractor chose not to install a downstream cofferdam since the existing endsill provided some level of protection from river flows. A metal bulkhead was also installed between the existing left training wall and the closest left labyrinth upstream apex to keep the area between the left training wall and the closest labyrinth weir wall dry. The
bulkhead was added so some demolition of the existing left training wall could be performed while the lake was still full.

![Figure 31: Gate extension installation](image1)

![Figure 32: Gate cylinder supports](image2)

Initial preparation work on the existing stilling basin included existing baffle block and end sill demolition. Once the basin was cleared, work began in the construction of the right labyrinth slabs (Figures 33 and 34). The right labyrinth weir was designed so it could rest directly on the section of stilling basin over the rolled compacted concrete (RCC) installed in 1985. The use of this section of the basin eliminated the need for an expensive foundation system for the right half of the labyrinth. To save concrete cost, the slab/wall connection was designed so most of the slabs did not extend upstream of the labyrinth weir. Slab construction was performed in an alternating sequence for crack control.

![Figure 33: Right labyrinth slab formwork installation](image3)

![Figure 34: Slab and wall formwork installation](image4)

Construction on the labyrinth weir walls began soon after some of the slab sections were complete. Construction methods used on the right labyrinth weir walls were similar to the left labyrinth. The straight sections of wall were formed and poured first, followed by the apexes (Figure 36). The crest forms were
removed within hours after placement, so the concrete could be finished to the specified tolerances (Figure 35).

An access driveway for this phase was built directly on the RCC immediately downstream of the existing stilling basin. The construction of the driveway was coordinated with labyrinth slabs and walls so the driveway area could then be used as a work surface. A right abutment driveway connects to the right labyrinth driveway. The abutment driveway rests partially on the existing RCC and four foundation piers embedded in the Taylor Formation. The driveways connect to the driveway built for the left labyrinth to provide means to remove debris from the labyrinth weir after flood events (Figure 37).

As the right labyrinth weir was constructed, some demolition of the existing left training wall was performed (Figure 38). The demolition on this wall was performed by sawcutting and removing sections of the existing wall.
During construction of the right labyrinth weir, changes were made to the right labyrinth to accommodate further hydraulic improvements to the dam. These changes were paid from underruns on some of the bid quantities and from allowances included in the contract for change orders.

Outlet Works Modifications and Improvements

During the construction of the right labyrinth, the City of Waco decided to make two changes to the project: Replace the damaged trashrack at the existing left outlet works and build a new right outlet works. These changes were incorporated into the project in December 2006.

The existing trashrack on the entrance to the left outlet works tunnel had several missing panels, causing debris to enter the structure and damaging the seals on the butterfly valves. To address this problem, a new trashrack was designed and built to prevent debris from entering the structure. Handrail was also installed around the perimeter of the structure to replace old and corroded handrail.

The labyrinth weir replaces the gated spillway, so the ability to lower the lake was limited to the capacity of the existing left outlet works. Through the years, the City of Waco used the leaf gates to lower the lake level early in the year for dam maintenance. The periods of lake lowering are also used by residents upstream of the dam to repair docks and river banks. To maintain this lake lowering ability, an additional outlet structure was built next to the right labyrinth weir. The new outlet works consists of a single 10’x10’ sluice gate. The right outlet works required the demolition of the existing right training wall (Figure 39) and modifications to the length of the right labyrinth weir to provide the space required for the outlet structure. The right outlet works slab rests on the existing stilling basin and three new foundations piers embedded into the Taylor Formation (Figure 40). The right outlet works construction began in December 2006 (Figure 41) once most of the work on the right labyrinth weir walls neared completion (Figures 42 and 43).
As work proceeded in the right labyrinth weir and right outlet works, the river’s low flow conditions experienced during most of the project due to a Statewide
drought changed significantly. Heavy rains and high river flows first hit the project on March 20, 2006. High river flows and continuous rain persisted on the Brazos River through July 2006.

Managing the river

The labyrinth weir construction was performed under both advantageous river conditions due to a drought and adverse river conditions due to severe weather and flooding. During construction in 2006 and the first quarter of 2007, the State of Texas experienced a severe drought. This led to little flow in the river, which facilitated the construction of the left labyrinth weir and most of the right labyrinth weir (Figure 44).

Except for some days with rain and below freezing temperatures, construction few interruptions. However, conditions changed dramatically starting in late March. Severe rains increased flows in the Brazos River from 4,000 cfs to 34,400 cfs within 12 hours. Since then, continuous rain has filled upstream reservoirs and Brazos River flows at the site have been high due to flood control releases (Figure
45). River flows have exceeded 20,000 cfs at least 40 days from late March to the end of July. The labyrinth weir withstood the flooding but work on the project has been interrupted. The City of Waco and the Contractor are currently waiting for the high flows to pass so that the last 5% of work can be completed and the full labyrinth weir can be put into service.

CONCLUSIONS

An innovative approach to the challenges presented by the Lake Brazos Dam combined reuse of the existing dam site with an unconventional spillway configuration, yielding substantial reduction in estimated time and cost of construction. Physical modeling was a key design tool to assess a complicated structure on a challenging site. Design studies demonstrated that the existing gated spillway could be replaced with a labyrinth weir and assisted in understanding complications associated with the construction.

The 3,000-foot long labyrinth weir was constructed within the footprint of the existing dam to accommodate regulatory requirements and to reduce cost by reusing the existing foundation. The construction was performed in phases to manage normal river flows and potential flooding and to eliminate costly river diversions. Sections of the permanent sheetpile cut-off and the existing gates were used as cofferdams to protect work areas and maintain a full reservoir during construction. Strict tolerances for wall height, crest profiles and concrete finish were required to satisfy special requirements for hydraulic performance and aesthetics. The project also included demolition, extensive foundation work, riprap installation and a significant amount of concrete placement, all within the limits of the existing dam. The labyrinth weir construction was performed under both advantageous river conditions due to a drought and adverse river conditions due to severe weather and flooding. During construction in 2007, flooding on the Brazos River flooding provided the first test of the labyrinth weir, and it performed successfully.

As the project nears completion, the City can look forward to improved reliability of Lake Brazos Dam. The labyrinth weir has eliminated the leaf gate maintenance problems, and allows residents and visitors to enjoy the beauty and recreational opportunities along the Brazos River as it flows through Waco, Texas.