RECLAMATION
Managing Water in the West

CONCLUDING APPRAISAL REPORT
Conveyance System Expansion

FORT COBB DIVISION, Washita Basin Project
Oklahoma

U.S. Department of the Interior
Bureau of Reclamation
Oklahoma-Texas Area Office
Austin, Texas

December 2006

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Mission Statements

The mission of the *Department of the Interior* is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the *Bureau of Reclamation* is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Executive Summary

Fort Cobb Reservoir, part of the U.S. Bureau of Reclamation's Washita Basin Project in central Oklahoma, provides water to the City of Anadarko, Western Farmers Electric Cooperative, the Public Service Company of Oklahoma, and the City of Chickasha. This project is operated and maintained by the Fort Cobb Reservoir Master Conservancy District (District). All but the City of Chickasha are served by the Federally owned Anadarko Aqueduct. The City of Chickasha is served by the privately constructed Chickasha Aqueduct.

Over the past several years, the District has begun to experience difficulty in delivering sufficient water through the Anadarko Aqueduct to meet the peak demands of its service population due to physical limitations of the pipeline. Projected increases in the future demand of these customers are expected to intensify this problem.

The purpose of this appraisal study was to evaluate alternatives that would expand the capacity of the District's conveyance system. All of the alternatives include the construction of a new aqueduct but vary in system configuration (i.e., the number of pipelines used), pipeline alignment (i.e., gravity-flow or pumping), and system capacity (i.e., the total annual delivery capacity). With regard to system capacity, four scenarios were evaluated that would enable the District to deliver different amounts of water on a peak day basis, including:

- The calculated *100-year firm yield* of Fort Cobb Reservoir (13,300 acre-feet per year);
- The total *current contract obligation* of the District (15,300 acre-feet per year);
- The present *water right appropriation* to the District by the State of Oklahoma (18,000 acre-feet per year); and
- The *projected 2040 demand* of the District's present municipal and industrial customers (21,500 acre-feet per year).

In all, a total of 16 alternatives were developed and evaluated as to estimated construction and operation costs. The most economically attractive alternative appears to be the construction of a new pipeline from Fort Cobb Reservoir to Anadarko to supplement the existing Anadarko and Chickasha Aqueducts. The alignment of this new pipeline would not be gravity-flow but would require construction of a pumping plant below Fort Cobb Dam.

However, three of the four system capacity scenarios evaluated for this alternative would require the importation of additional water supplies; i.e., the total amount of water to be delivered would exceed the firm yield of Fort Cobb Reservoir. The potential source(s) of such additional water supplies have not yet been identified, and such a task was beyond the scope of the present study. Until it is clear that viable options exist to supplement the existing water supply, selection of a preferred conveyance system alternative is premature. **Therefore, it is recommended that none of the conveyance system expansion alternatives evaluated in this report be investigated in a feasibility study at this time.**

The District could consider initiating an appraisal level investigation of potential alternatives to augment the water supply of Fort Cobb Reservoir. If a viable source of supplemental water can be identified, both investigations (conveyance system expansion and water augmentation) could then be folded together and the feasibility of a combined water supply/distribution project determined.

Introduction

AUTHORITY

This study is authorized under the Reclamation Act of June 17, 1902, (32 Stat. 388, 43 U.S.C. 391) and the Reclamation Project Act of 1939. Construction of the Washita Basin Project, which includes Fort Cobb Reservoir and the Anadarko Aqueduct, was authorized by Congress in 1956 under the Washita Basin Project Act (P.L. 84-419).

Recreation at Fort Cobb Reservoir.

PURPOSE

The purpose of this appraisal study is to evaluate alternatives that would expand the capacity of the Fort Cobb Reservoir Master Conservancy District's (District) conveyance system. These alternatives would enable the District to deliver different amounts of water on a peak day basis, including:

- The calculated *100-year firm yield* of Fort Cobb Reservoir (13,300 acre-feet);
- The total *current contract obligation* of the District (15,300 acre-feet);
- The present *water right appropriation* to the District by the State of Oklahoma (18,000 acre-feet); and
- The *projected 2040 demand* of the District's present municipal and industrial customers (21,500 acre-feet).

The information and analysis presented in this Concluding Report were based on existing data, and the level of detail used to scope and evaluate potential alternatives was conceptual in nature.

THE WASHITA BASIN PROJECT

The Washita Basin Project is a water supply project constructed by the U.S. Bureau of Reclamation (Reclamation). It is comprised of two divisions (Foss and Fort Cobb), both of which are located in the Washita River basin of southwestern Oklahoma.

The project lies within Oklahoma Congressional Districts 3 (R-Frank Lucas) and 4 (R-Tom Cole). Senators Jim Inhofe (R) and Tom Coburn (R) represent the State of Oklahoma in the U.S. Senate.

Foss Division

The Foss Division includes Foss Dam and Reservoir and the Foss Aqueduct. This division provides municipal and industrial water to the communities of Clinton, Bessie, Cordell and Hobart. Foss Dam is located on the Washita River about 95 miles west of Oklahoma City, Oklahoma.

Fort Cobb Division

The Fort Cobb Division, which is the subject of the present study, includes Fort Cobb Reservoir and the Anadarko Aqueduct. Reclamation completed construction of these two project features in 1959 and 1961, respectively. Fort Cobb Dam is located on Cobb Creek about 5 miles upstream of where the creek joins the Washita River in Caddo County, about 55 miles west of Norman, Oklahoma. The District operates and maintains the facilities of Fort Cobb Dam and the 20.9-mile long, gravity-flow Anadarko Aqueduct.

Fort Cobb Dam and Reservoir.

The Fort Cobb Division was originally designed to provide municipal and industrial water to the communities of Anadarko and Chickasha, and water for irrigation of about 9,000 acres of land. However, during project development and the first few years of operation, changes were made in the sponsorship of the project. The community of Chickasha ultimately withdrew its participation in the project, while the town of Fort Cobb and Western Farmers Electric Cooperative (WFEC) were included, the latter to secure a cooling water supply for an electricity generation plant located in Anadarko. Today, Fort Cobb Reservoir provides water to the City of Anadarko, WFEC, the Public Service Company of Oklahoma (PSO), and the City of Chickasha[1]. Although irrigation was an originally envisioned benefit of the Fort Cobb Division, this component was never developed.

[1] Water to the City of Chickasha is delivered through the privately-constructed Chickasha Aqueduct. This pipeline is not part of the Federal Washita Basin Project, and is owned, operated and maintained by the City.

Other authorized purposes for Fort Cobb Dam and Reservoir include flood control, conservation of fish and wildlife resources, and enhancement of recreational opportunities. Fishing and hunting opportunities at Fort Cobb Reservoir are managed by the Oklahoma Department of Wildlife Conservation, and recreational facilities are managed by the Oklahoma Tourism and Recreation Department. Fort Cobb Lake State Park is a 1,900-acre park on the shores of Fort Cobb Reservoir featuring 5 camping areas with 985 campsites and a community building. Recreational amenities include a swimming beach, boating, water skiing, playgrounds, a nature center, golf course, and gift shop.

Boat dock at Fort Cobb Reservoir.

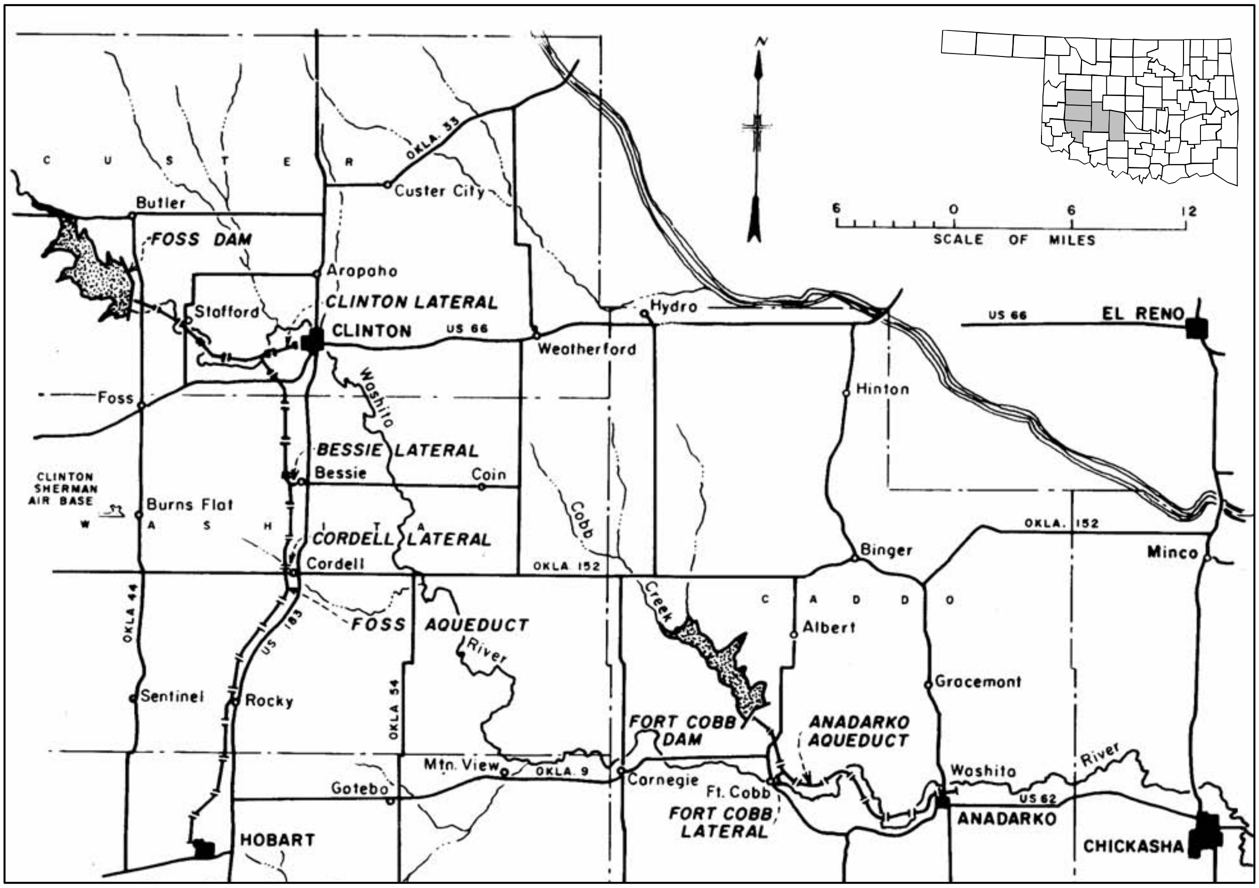


FIGURE 1: The Washita Basin Project, including both the Foss and Fort Cobb Divisions.

PRIOR STUDIES

Numerous water resources studies have been conducted in the region over the years. Reports particularly applicable to this study include:

- Definite Plan Report (Revised), Volume I, General Plan Fort Cobb Division, Washita Basin Project, Oklahoma, Bureau of Reclamation, 1960. This revised report provides the engineering and economic basis from which the project was authorized and constructed.

- Fort Cobb Division, Washita Basin Project. Water Supply Study Appraisal Report, Bureau of Reclamation, 1984. This study investigated alternatives to increase the hydrological yield of Fort Cobb Reservoir and increase water delivery capacity.

- Fort Cobb Division, Washita Basin Project, Oklahoma. Water Supply Study Appraisal Report, Bureau of Reclamation, 1994. This study investigated increasing the conservation pool level and the delivery capacity of the aqueduct system at Fort Cobb Reservoir.

Problems and Opportunities

RESOURCES AND CONSTRAINTS

Surface Water Resources

The Cobb Creek watershed is a relatively small but productive basin (approximately 327 square miles in surface area). Fort Cobb Reservoir had an original storage volume of 80,087 acre-feet at the conservation pool elevation of 1,342.0 feet above mean sea level (msl). Of this amount, 15,000 acre-feet of storage was reserved for sediment during the project life (Bureau of Reclamation 1960). Although the City of Chickasha owns a small reservoir located about 13 miles to the northwest (Lake Chickasha), poor water quality restricts its use as a municipal water supply. Therefore, both the communities of Anadarko and Chickasha are dependant on surface water from Fort Cobb Reservoir to meet their water supply needs.

Fort Cobb Reservoir serves as the water supply for the cities of Anadarko and Chickasha, Oklahoma.

Firm Yield, Water Rights and Supply Contracts

In general, the amount of water available in a reservoir tends to decrease over time due to the effects of sedimentation. Silt suspended in the river water column settles out in the slower moving lake water. Over time, accumulated sediments reduce the volume capacity of the reservoir, decreasing the amount of water that can be stored and released. Reclamation considers the effects of sedimentation when projecting the amount of available water that a new reservoir can provide and usually defines this in terms of the *100-year firm yield*. The 100-year firm yield is the maximum amount of water the reservoir is capable of providing during the drought of record after 100 years of sedimentation. In the case of Fort Cobb Reservoir, this projected condition is expected to be realized in 2059.

During planning of the Washita Basin Project, Reclamation projected that the 100-year firm yield of Fort Cobb Reservoir would be 13,300 acre-feet per year (Bureau of Reclamation 1960). This amount included 8,964 acre-feet for municipal and industrial uses and 4,336 acre-feet for irrigation. Because the irrigation component never developed, this agricultural portion of the water allocation was eventually converted to municipal and industrial uses. However, until the 100-year sediment condition occurs, it is possible for the reservoir to provide an *interim firm yield* greater than 13,300 acre-feet per year.

In 1979, the District requested that Reclamation conduct an operational study of Fort Cobb Reservoir to estimate what the firm yield would be in 1985 (or about 26 years into the project life). The analysis resulted in an interim firm yield estimate of 18,000 acre-feet per year (Bureau of Reclamation 1980). This amount then became the basis for the current water right permit (No. 51-128) issued by the State of Oklahoma to the District.

At present, the District has executed water supply contracts to provide a total of 15,214 acre-feet per year to its customers. Of this amount, 8,964 acre-feet are contracted to Anadarko[2] and WFEC on a long term basis, and 6,250 acre-feet are contracted to Chickasha on a limited term (10-year) basis[3].

[2] The water needs of PSO are met from Anadarko's contracted amount.

[3] The City of Chickasha's contract with the District expires in 2011 and includes an option to renew.

Existing Conveyance Systems

Anadarko Aqueduct

Water deliveries from Fort Cobb Reservoir are made through two pipelines; the Anadarko and Chickasha Aqueducts. The Anadarko Aqueduct was constructed as part of the Washita Basin Project and is operated and maintained by the District. This aqueduct is a gravity-flow pre-cast, reinforced concrete pressure pipeline that begins just below Fort Cobb Dam and terminates at the Anadarko bifurcation structure on the west side of the City of Anadarko. At the bifurcation, three separate diversions are made. The first is a 250-foot pipeline (Anadarko Lateral) to the Anadarko water treatment plant, the second is a 2-mile pipeline that continues east to the WFEC power generating plant, and the third a 25-foot long pipeline to a one million gallon, concrete storage tank. Deliveries to PSO are made from a private pipeline connecting the Anadarko Aqueduct to a holding pond.

Anadarko Aqueduct inside Fort Cobb Dam.

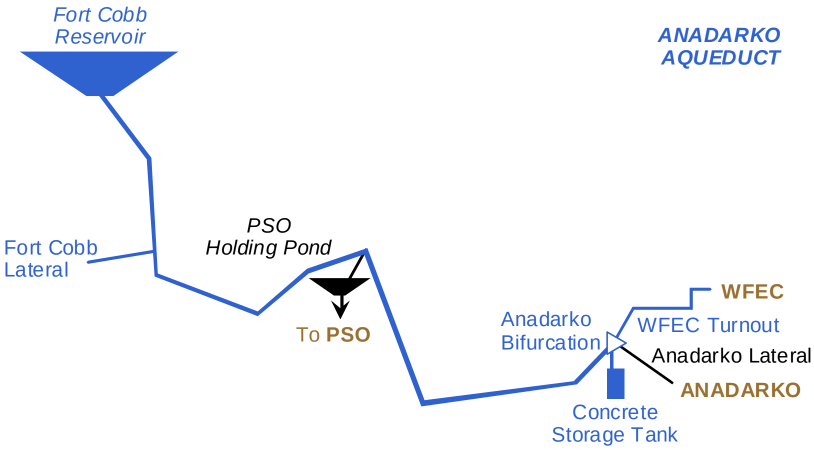


FIGURE 2: Schematic diagram of the Anadarko Aqueduct. Components of the Federal Washita Basin Project are indicated in **blue**, non-Federal components in **black**, and existing customers in **brown**. Not to scale.

The Anadarko Aqueduct was sized to deliver the original municipal and industrial allocation of the reservoir yield (8,964 acre-feet per year). This amount did not include the 4,336 acre-feet per year irrigation allocation, which was subsequently converted to municipal and industrial use. Accordingly, the maximum design capacity of the Anadarko Aqueduct is 16 cubic feet per second (cfs) from Fort Cobb Dam to the Fort Cobb Lateral[4] turnout, and 14 cfs from the Fort Cobb Lateral turnout to the Anadarko bifurcation (Bureau of Reclamation 1962). From the bifurcation, existing pipeline capacities allow Anadarko to receive a maximum of 8.4 cfs and WFEC 5.6 cfs.

[4] The Fort Cobb Lateral, which has a maximum capacity of 2 cfs, is operational but has never been used.

Chickasha Aqueduct

The Chickasha Aqueduct delivers water to the City of Chickasha. This private conveyance system is a pressurized 24-inch transite (asbestos cement) pipeline that includes a separate intake and pumping plant at Fort Cobb Reservoir, an aqueduct that transports raw water to the City of Chickasha, and a connection to the Chickasha holding pond, which is a small regulating reservoir located on a hill directly north of Anadarko. The City of Chickasha re-sells some water to several small towns and one rural water district. The maximum design capacity of the Chickasha Aqueduct is just over 11 cfs (Shelton 2006).

The City of Chickasha's pumping plant on Fort Cobb Reservoir at the beginning of the Chickasha Aqueduct.

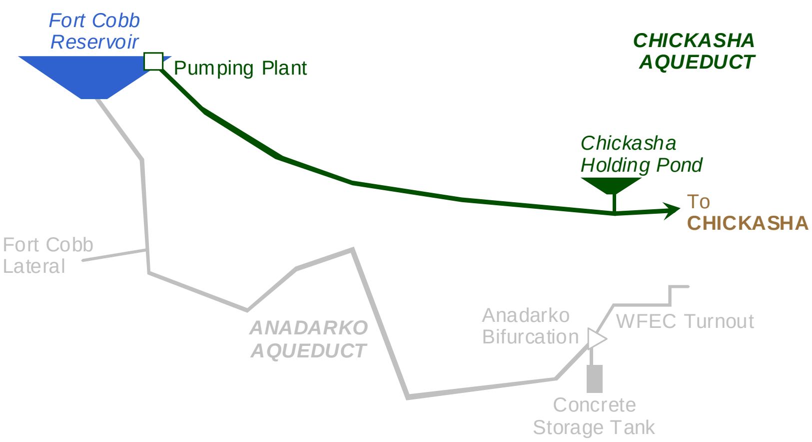


FIGURE 3: Schematic diagram of the Chickasha Aqueduct. Components of the Chickasha Aqueduct are indicated in **green**, those of the Federal Washita Basin Project in **blue** and existing customers in **brown**. Not to scale.

Overview of Economic Conditions

Based on a review of regional social and economic data (Bureau of Reclamation 2004), the economy of the study area can be characterized as having relatively low income, average to high unemployment (high in Caddo County), relatively low wages, and a large percentage of manufacturing jobs. The retail and services sectors also appear to be important to the study area.

There has been very little population growth in Caddo County. However, Grady County appears to be growing fairly consistently at a 0.5 percent to 1.0 percent annual rate.

In general, the economy of the region appears to be growing at a rate that is somewhat slower than for all of Oklahoma as a whole, and the population and demographic trends indicate limited slow growth will probably continue into the future.

EXISTING CONDITIONS

Over the past several years, the District has begun to experience difficulty in delivering sufficient water through the Anadarko Aqueduct to meet the peak demands of its service population (Opitz 2005). Although this total demand has not yet exceeded the amount contracted to these entities, the actual total deliveries requested by Anadarko, WFEC and PSO during the summer months have begun to approach the physical limitations of the existing pipeline.

EXPECTED FUTURE CONDITIONS

Recent trends of increasing municipal and industrial demands from Fort Cobb Reservoir also indicate that the Anadarko Aqueduct is insufficient to meet future demand. An analysis of the present and future water demands for each customer of Fort Cobb Reservoir (Anadarko, WFEC, PSO, and Chickasha[5]) projects that the total demand will be almost 21,500 acre-feet by the year 2040.

[5] The City of Chickasha requested that their future water needs be taken into consideration during this planning effort. This request was approved by the District's Board of Directors.

TABLE 1: Tabular summary of annual average historic (*italics*) and projected future water use for municipal and industrial customers of Fort Cobb Reservoir, Oklahoma. Data reported in acre-feet per year.

Year	Anadarko Aqueduct				Chickasha Aqueduct		TOTAL
	Anadarko	WFEC	PSO	Subtotal	High-use	Low-use	
1996-2004	*1,587*	*1,713*	*2,080*	***5,380***	***4,730***		***10,110***
2000	1,550	2,600	2,070	**6,220**	**4,740**	4,740	**10,960**
2010	1,800	3,200	2,550	**7,550**	**5,480**	5,070	**13,030**
2020	2,000	3,930	3,130	**9,060**	**6,270**	5,460	**15,330**
2030	2,050	4,840	3,850	**10,740**	**7,060**	5,860	**17,800**
2040	2,100	5,950	4,740	**12,790**	**8,660**	6,260	**21,450**

Water use projections for Anadarko, WFEC and PSO were derived from Oklahoma Water Resources Board (1995) data for the Southwest Region[6]. The increases in future water use shown for PSO and WFEC reflect the State of Oklahoma's projections for the anticipated construction of new power plant or enlargements of existing plants. Projections for Chickasha were derived from estimates made by the City of Chickasha, which included both high-use and low-use scenarios (City of Chickasha 2003). The total projected water demand includes the high-use scenario for Chickasha. With either projection, there could be opportunities to reduce overall water demand by implementing conservation measures. However, such measures are beyond the scope of this appraisal investigation.

[6] Municipal and industrial water demand projections were made in cooperation with the U.S. Army Corps of Engineers using the Institute for Water Resources Municipal and Industrial Needs forecasting model. Agricultural water projections were estimated in cooperation with Reclamation and based upon recent irrigation and livestock watering trends and assumptions of future scenarios in agricultural water demands. Water needed for power generation was forecasted according to the best available information on the future plans of Oklahoma's power generating companies.

These projections may be represented graphically:

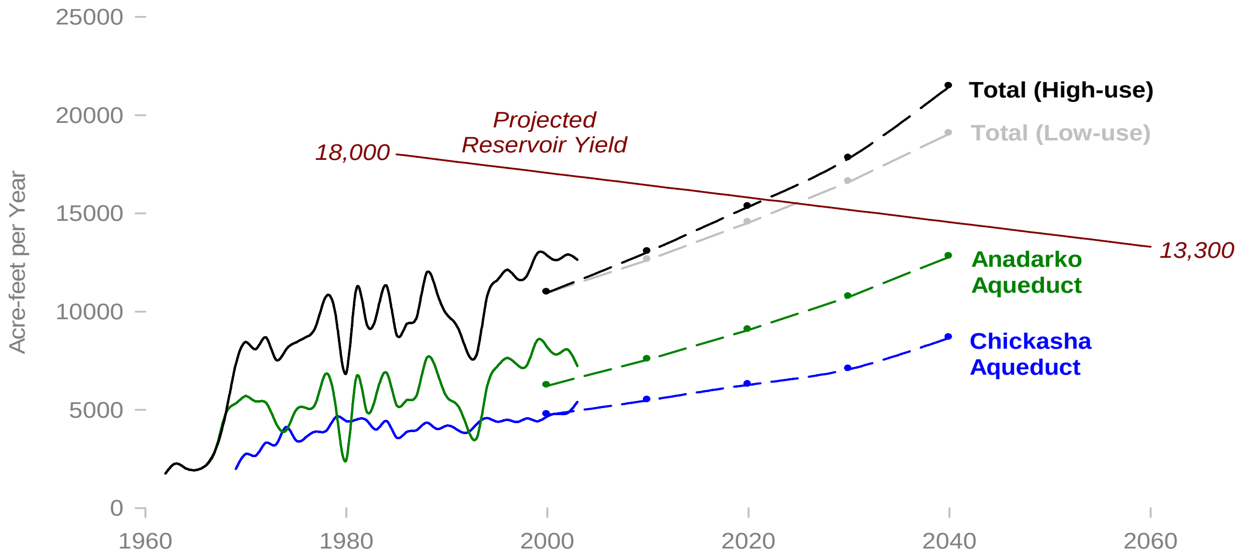


FIGURE 4: Graphical summary of historic (solid) and projected (dashed) water demand of current Fort Cobb Reservoir customers. The Total Low-use projection is shown for comparison. Also shown is the estimated future reservoir storage capacity of Fort Cobb Reservoir, Oklahoma. Upon inspection, it appears that importation of additional water supplies sometime after the early 2020's could be necessary in order to meet the total demand.

Given the District's developing challenge in meeting the current peak demands of the customers of the Anadarko Aqueduct, increasing municipal and industrial demand in the future will only intensify the situation.

NEED FOR ACTION

Fort Cobb Dam and Reservoir is a Federal water supply project operated and maintained by the District. Because conversion of the project's irrigation water allocation to municipal and industrial uses occurred subsequent to project construction, the existing Anadarko Aqueduct was not designed with sufficient capacity to deliver the current full yield of Fort Cobb Reservoir on a peak demand basis. As a result, in recent years, total demand by District customers is approaching the physical limitations of the existing pipeline. Therefore, there is a need to evaluate construction of a new aqueduct to replace or supplement existing conveyance pipelines from Fort Cobb Reservoir.

FEDERAL INTEREST

A Federal interest exists in addressing the identified water supply need of the customers of Fort Cobb Reservoir. Through original project authorization in 1956, Reclamation was directed by Congress to construct and operate the Washita Basin Project, Fort Cobb Division, for the purposes of providing a municipal and industrial water supply. Since its construction, this project has continued to provide the specified project benefits under the management and operation provided by the District.

PUBLIC INVOLVEMENT

Because this assessment primarily addressed pipeline sizes and alignments, there were no public involvement activities associated with this appraisal level investigation.

Alternatives

PLAN FORMULATION

Each of the alternatives evaluated in this Concluding Report includes the construction of a new aqueduct from Fort Cobb Reservoir. The different variables considered in developing the alternatives include:

- *Configuration* of the entire delivery system (i.e., the total number of pipelines that would be used to deliver water from Fort Cobb Reservoir to its customers). At present, there are two operational aqueducts from Fort Cobb Reservoir; Anadarko and Chickasha.

- *Alignment* of the proposed new pipeline (i.e., dictating either gravity-flow or pumping as the primary means of water delivery).

- *Capacity* of the entire delivery system (i.e., the combined volume of water that could be delivered by all pipelines from the reservoir).

System Configuration

Two scenarios for the overall configuration of the proposed delivery system were considered, each including the construction of a new pipeline from Fort Cobb Reservoir.

Two ipeline System (2) A new aqueduct would be constructed to effectively replace the Chickasha Aqueduct and be used in tandem with the Anadarko Aqueduct. Therefore, only two pipelines would comprise the overall delivery system from the reservoir, the existing Anadarko Aqueduct and the proposed new aqueduct.

Three Pipeline System (3) A new aqueduct would be constructed as a supplement to the Anadarko Aqueduct. The Chickasha Aqueduct would remain in service. Therefore, three pipelines would comprise the overall delivery system from the reservoir, the existing Anadarko Aqueduct, the existing Chickasha Aqueduct, and the proposed new aqueduct.

A one pipeline scenario, where a single new aqueduct would be constructed to replace both existing aqueducts, was considered early in the planning process but ultimately rejected as a viable alternative. The relatively good condition and low operating cost of the existing

Anadarko Aqueduct rendered any alternative to replace it ineffective based solely on cost.

Pipeline Alignment

Two scenarios for the potential alignment for the new aqueduct were considered, each resulting in different implications for conveyance system operation and maintenance.

Gravity-Flow (Grav) The Gravity-flow alignment includes construction of a new, 21.8-mile long pipeline essentially parallel to the existing Anadarko Aqueduct. The system would be designed as a full static pressure system with air valves in place of pipe stands. The sleeve valve and outlet works at the dam would be modified to accommodate the increased delivery requirements. Several stream crossings would be required for this alignment.

This pipeline alignment would consist of three reaches, the first two of which would be gravity-flow. Reach 1 would be 17.1 miles extending from Fort Cobb Dam to the Anadarko bifurcation structure. A pressure reducing valve would be required before the water enters the Anadarko bifurcation structure to regulate pressure. Reach 2 would continue 2.7 miles from the bifurcation structure almost to the WFEC power plant where a new pumping plant would be constructed. Reach 3 would consist of a 2.0-mile pipeline extending from the new pumping plant to the Chickasha holding pond.

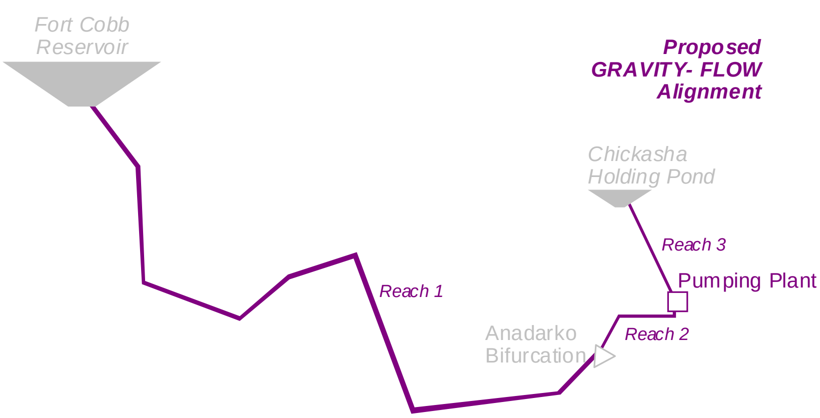


FIGURE 5: Schematic diagram of the proposed Gravity-flow aqueduct alignment. Not to scale.

Either reinforced concrete pipe (RCP) or high density polyethylene (HDPE) plastic pipe could be used on the first two (low head) reaches from the dam to the new pumping plant. HDPE plastic pipe could be used for the short, high pressure reach from the pumping plant to the Chickasha holding pond (Reach 3).

Pumping (Pump) The Pumping alignment includes construction of a new pumping plant below Fort Cobb Dam and a new, 16.2-mile long pipeline located a few miles north of the Washita River. Similar to the Gravity-flow alignment, this alignment would also require the sleeve valve and outlet works at Fort Cobb Dam be modified to accommodate the increased delivery requirements. However, the Pumping alignment is approximately 5.6 miles shorter and has fewer stream crossings.

The Pumping alignment would also include three reaches. Reach 1 would be 12.9 miles long and extend from the new pumping plant, along the existing Anadarko Aqueduct alignment just after the Highway 146 crossing, then overland in a southeasterly direction to the existing section line road. The aqueduct would then continue east along this road to a new storage tank[7]. Reach 2 would continue 0.3 miles from the new storage tank east to Highway 281, then turn southward and end at a turnout for the Chickasha holding pond. Reach 3 would extend 3.0 miles from the Chickasha holding pond turnout to the Anadarko bifurcation structure.

[7] A storage tank would be required for the Pumping alignment to provide control for the pumps and to provide short term storage if the power supply to the pumps were interrupted. The tank would be sized to hold 2.3 million gallons with a 140 foot diameter and 20 foot tank height. This size would provide approximately 4 hours of storage under the 2040 average daily demand.

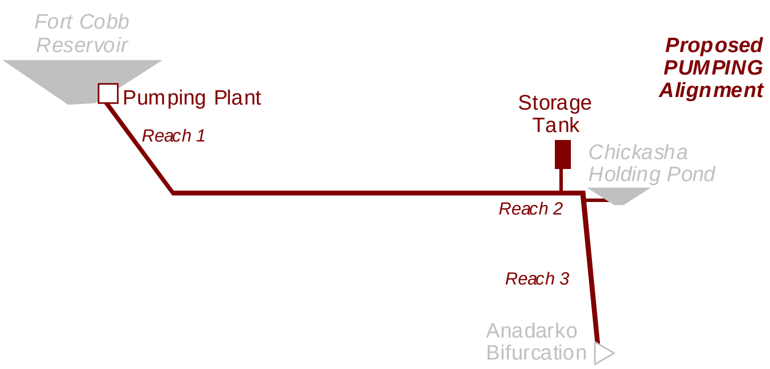


FIGURE 6: Schematic diagram of the proposed Pumping aqueduct alignment. Not to scale.

Either polyvinyl chloride (PVC) or HDPE plastic pipe could be considered as pipe options for this alignment.

Profiles for the two potential alignments are shown in Exhibit A.

System Capacity

Four scenarios for the overall capacity of the delivery system were considered, each representing a different total water demand to be supplied through the combination of aqueducts from Fort Cobb Reservoir under each scenario.

100-Year Firm Yield ($^{13.3}$) The overall delivery system would be sized to deliver the projected 100-year firm yield estimate for Fort Cobb Reservoir (13,300 acre-feet per year) on a peak day demand basis.

Current Contract Obligation ($^{15.3}$) The overall delivery system would be sized to deliver the District's total present contracted water supply (15,300 acre-feet per year) on a peak day demand basis.

Water Right Appropriation ($^{18.0}$) The overall delivery system would be sized to deliver the total amount permitted to the District by the State of Oklahoma (18,000 acre-feet per year) on a peak day demand basis.

Projected 2040 Demand ($^{21.5}$) The overall delivery system would be sized to deliver the total projected demand for all present water supply customers of Fort Cobb Reservoir (21,500 acre-feet per year) on a peak day demand basis.

It is recognized that deliveries from Fort Cobb Dam in excess of the 100-year firm yield amount (13,300 acre-feet per year) would eventually require the importation of additional water. Identifying the source(s) of additional water is beyond the scope of this appraisal study. However, scenarios that anticipate deliveries greater than the 100-year firm yield are included in this investigation to allow consideration of future needs in infrastructure planning.

Summary

There were two different scenarios evaluated for system configuration, two for pipeline alignment, and four for system capacity. This array of scenarios resulted in a total of sixteen possible alternatives that were evaluated. For the purposes of this report, each alternative was identified by abbreviation. For example,

Alternative *2-Grav*$^{13.3}$ represents a two pipeline (2) gravity-flow (Grav) conveyance system with the capacity to convey the 100-year firm yield of Fort Cobb Reservoir of 13,300 acre-feet per year ($^{13.3}$) on a peak day demand basis.

Similarly,

Alternative *3-Pump*$^{21.5}$ represents a three pipeline (3) pumping (Pump) conveyance system with the capacity to deliver the total projected 2040 demand of existing Fort Cobb Reservoir customers of 21,500 acre-feet per year ($^{21.5}$) on a peak day demand basis.

DESIGN ASSUMPTIONS

Calculating Peak Flow Demands and Pipe Sizing

As previously discussed, the 100-year firm yield of Fort Cobb Reservoir is 13,300 acre-feet per year. The smallest sized conveyance system capable of delivering this amount would require a capacity of 18.4 cfs and need to operate at full capacity all day, each day, for an entire year. However, municipal and industrial water conveyance systems rarely operate at full capacity for extended periods of time. This is because the demand for water fluctuates on a seasonal basis, with larger demands usually occurring in the warmer months of the year. This period of increased need is known as the *peak* demand, the value of which can be calculated on a monthly, daily or even hourly basis. Average use from Fort Cobb Reservoir exhibits a similar pattern, as shown below:

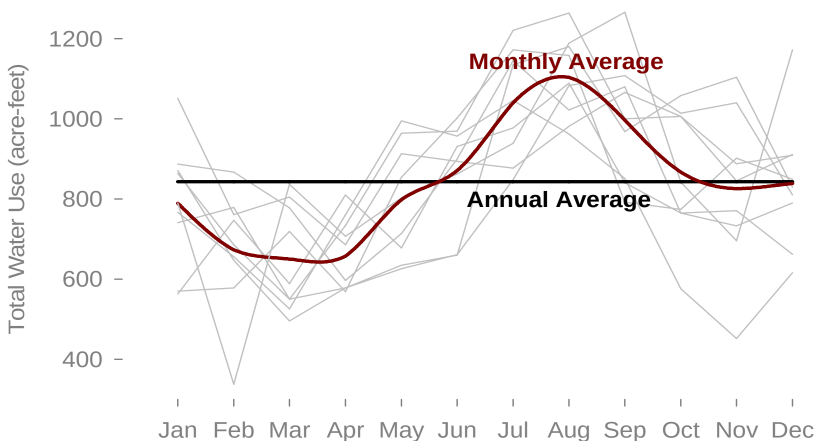


FIGURE 7: Summary of total water use from Fort Cobb Reservoir. Grey lines indicate total monthly usage by year from 1996 to 2004. The annual peak in monthly average demand during the summer months is evident. Source: Bureau of Reclamation (2005b).

For most communities, the maximum daily (*peak day*) demand is about 180 percent of the annual daily average (Linsley et al. 1992). Therefore, for each of the four system capacity scenarios, the annual demand for each customer was determined proportionally from the annual total. From these estimates, the peak day demands for each customer were calculated, as presented below:

TABLE 2: Summary of calculated peak flow delivery rates for each system capacity scenario. Customers of the Anadarko Aqueduct indicated in **blue** and Chickasha Aqueduct in **green**.

Scenarios for Total Conveyance System Capacity		Annual Volume (acre-ft)	Calculated Peak Day Delivery Rate (cfs)					
			Anadarko Aqueduct				Chickasha Aqueduct	TOTAL
			Anadarko	WFEC	PSO	Subtotal		
13.3	100-Year Firm Yield	13,300	5.2	6.8	5.6	**17.6**	**15.4**	**33.0**
15.3	Current Contract Obligation	15,300	6.0	7.8	6.4	**20.2**	**17.8**	**38.0**
18.0	Water Right Appropriation	18,000	7.1	9.3	7.6	**24.0**	**21.1**	**45.0**
21.5	Projected 2040 Demand	21,500	8.3	10.9	9.0	**28.2**	**24.8**	**53.0**

Once the peak day demands were known, hydraulic calculations (Bureau of Reclamation 2005a) were performed to determine the appropriate pipeline size for each reach of each alternative, as presented below:

TABLE 3: Summary of proposed pipe diameters for each reach of the new aqueduct. Data reported in inches.

Alternative	Reach 1	Reach 2	Reach 3
2-Grav$^{13.3}$	36	36	30
3-Grav$^{13.3}$	30	30	16
2-Pump$^{13.3}$	36	24	16
3-Pump$^{13.3}$	30	18	16
2-Grav$^{15.3}$	42	36	30
3-Grav$^{15.3}$	30	30	18
2-Pump$^{15.3}$	42	30	18
3-Pump$^{15.3}$	30	24	18
2-Grav$^{18.0}$	42	36	36
3-Grav$^{18.0}$	36	36	24
2-Pump$^{18.0}$	42	30	20
3-Pump$^{18.0}$	36	24	20
2-Grav$^{21.5}$	48	42	36
3-Grav$^{21.5}$	42	42	30
2-Pump$^{21.5}$	48	36	24
3-Pump$^{21.5}$	42	30	24

Pipeline Construction

At several places where the existing Anadarko Aqueduct crosses streams, extensive erosion during floods has resulted in destabilization of the stream bank. In these areas, where the construction technique used to install the original aqueduct was trenching, riprap has been added to stabilize these crossings.

Riprap stabilizes the stream bank where the existing Anadarko Aqueduct crosses under the Washita River.

In order to reduce this maintenance issue with the new aqueduct, as well as to minimize environmental damage to riparian habitat during construction, the river crossings in each alternative were assumed to be accomplished by directional drilling offset from the river bank.

Other assumptions relating to the new pipeline in each alternative include the use of HDPE plastic pipe for all reaches and in-line sectionalizing valves spaced every 3 miles to allow for dewatering of individual pipeline sections for maintenance. Costs for corrosion monitoring and cathodic protection of the pipelines were not included because the anticipated pipe material used in construction would be plastic.

Pumping Plants

Pumping plants would be required for both the Gravity-flow and Pumping alignments. The pumps for the Gravity-flow alternatives would move water from the Anadarko bifurcation to the Chickasha holding pond and be vertical turbine type pumps located in a sump beneath the pumping plant. The pumps for the Pumping alignment alternatives would be the horizontal split case type located below Fort Cobb Dam. All pumping plants were designed assuming they would be unattended facilities.

System Controls

The control system for each alternative would be a Supervisory Control and Data Acquisition (SCADA) system, which is a collection of field instrumentation, communications equipment, and hardware and software systems for monitoring and controlling the system behavior. Such a system would be used to automate the new aqueduct and pumping system based on pressure, flow, tank water levels, and pump controller information.

ENVIRONMENTAL CONSIDERATIONS

Appraisal level environmental analysis seeks to identify major issues affecting the implementation of proposed alternatives. The comparisons are relative and are not intended to offer a detailed analysis of environmental resources associated with a particular alternative. The preparation of actual compliance documents in satisfaction of the National Environmental Policy Act and other similar laws is typically conducted during the feasibility study. This includes fulfilling the necessary consultations with Federal and state resource agencies for any activities affecting sensitive natural and cultural resources.

Overview of Resources in the Study Area

The project area lies within the Washita River Basin and contains numerous ephemeral and perennial streams, including Cobb Creek, Dry Creek, Lost Creek, Two Hatchet Creek, and Deep Creek. Forested areas are rare and confined primarily to riparian corridors along streambeds. Typical tree species include willow, cottonwood, elm, post oak, and hickory. Upland areas are composed primarily of agricultural land and consist of wheat, soybean, milo, corn, peanuts, cotton, and open fields. Native prairie grasses are almost nonexistent and consist of a few patches of bluestem, Indian grass, and switchgrass. Other open areas are dominated by non-native species like burmuda.

The project area also lies within the central flyway for migratory birds and is used extensively as winter or breeding habitat. Fort Cobb Reservoir, as well as nearby streams within the project area, contain numerous common fish species, including bass, walleye, white crappie, sunfish, catfish, sand shiner, and gizzard shad. These areas also support a variety of macroinvertebrates and amphibians. Mammals consist of white-tailed deer, cottontail, coyote, bobcat, beaver, jackrabbit and raccoon.

Potential Impacts

Impacts to the environmental and cultural resources would primarily depend on the *alignment* of the new aqueduct, with differences in system configuration and capacity variations having negligible effects. This is because the impacts associated with existing pipelines are minimal, and different system capacities require small variations in pipeline sizes, which in turn, yield minimal environmental impact differences among alternatives. Both the Gravity-flow and Pumping alignments would likely result in minor environmental impacts overall.

Construction Activities

Construction related impacts would occur from pipeline and pump station installation, as well as right-of-way clearing. Alignments would attempt to follow existing roads or other maintained corridors in order to minimize disturbance. Most of the upland habitat within the project area is previously disturbed and cultivated for agricultural production. Native vegetation, as well as trees and shrubs, are uncommon and primarily limited to riparian corridors along stream channels.

Both alignments would cross waters of the United States under jurisdiction of the U.S. Army Corps of Engineers. Directional drilling of stream crossings, however, would reduce riparian habitat loss and erosion problems, while minimizing the need for Section 404 permits. The Pumping alignment crosses fewer jurisdictional waters and is more than five miles shorter than the pipeline proposed under the Gravity-flow alignment, resulting in relatively less disturbance to riverine, riparian, and upland habitat. The Pumping alignment's shorter length would also likely incur less cost associated with conducting surveys within the alignment right-of-ways for cultural resources.

Other Federal laws and regulations would require that measures be taken to avoid take of migratory birds, threatened or endangered species, and other wildlife during construction. No threatened or endangered species critical habitat is designated within the project area of either alignment. Three Federally listed bird species are in the project area and could potentially be affected by construction activities, but adverse impacts are not anticipated under either alignment.

Operation and Maintenance Activities

Facility operation and maintenance activities would include pump stations and pipelines. No environmental impacts are anticipated from the operation of the proposed pumping plants, and pipeline right-of-way maintenance would result in the suppression of woody vegetation by regular mowing activities.

Maintained right-of-way of the Anadarko Aqueduct. A rip-rap protected stream crossing is in the foreground.

None of the alternatives evaluated would impose different operating conditions on Fort Cobb Reservoir than what currently exist. It is assumed, for the purposes of this study, that any alternative with a system capacity of greater than the 100-year firm yield of 13,300 acre-feet per year would require imported water. It is anticipated that such water would be 'passed through' the reservoir (i.e., immediately released into the municipal and industrial pipeline distribution system and not used to stabilize the level of Fort Cobb Reservoir). This would result in essentially equivalent future reservoir operations for both with- and without-action scenarios.

ESTIMATED PROJECT COSTS

As a preliminary means of evaluating possible alternatives, conceptual level cost estimates were developed. These estimates should be considered cursory in nature and are intended only for comparing alternatives relative to one another. Development of these estimates does not imply support by Reclamation for project authorization or any specific language in an appropriation bill.

The following cost estimates were developed based on preliminary design data prepared by Reclamation's Technical Service Center (Bureau of Reclamation 2004) adjusted to reflect updated pipeline alignments and using unit prices presented in RS Means Heavy Construction Cost Data. All estimates reflect a January 2005 cost basis.

Estimated Total Capital Costs

The initial capital costs for each alternative include construction and non-contract expenses. Construction cost estimates were developed by the Bureau of Reclamation (2005a) and include 5 percent for mobilization, 15 percent for unlisted items, and 25 percent for contingencies. Non-contract costs were estimated at 30 percent of the construction cost and account for activities such as planning, design, right-of-way acquisition, environmental compliance, and construction management.

Estimated Annual Operation, Maintenance, Replacement and Energy Costs

The annual operation, maintenance, replacement and energy (OMR&E) costs for each alternative were developed by the Bureau of Reclamation (2005a) and include estimates for pipelines and pumping plants. Estimated OMR&E costs for pipelines were based on the actual average cost of maintaining the existing Anadarko and Chickasha Aqueducts[8]. Estimated OMR&E costs for the pumping plants were based on analyses of records of 174 existing electric and hydro-powered pumping plants assuming the maximum pump discharge and the peak pumping rate (Bureau of Reclamation 1965).

[8] Maintenance costs for the existing Chickasha pipeline were assumed to be 50 percent higher than for the existing Anadarko Aqueduct due to the type of pipeline material (asbestos-cement) used for construction.

Estimates of power costs (Bureau of Reclamation 2005a) included two components: rate charge and demand charge. First, the cost of power was based on the rate charged per kilowatt hour of usage[9]. Second, the demand charge was based on kilowatt usage per month. The energy charge (cents/kWh) for the first 200 kWh per horsepower was $0.0731, and for all power above this level for the year was $0.0431.

[8] The power rate information was obtained from the Caddo Electric Cooperative Inc., for both industrial and business service. Industrial service power rate was for lighting and heating and was not used.

Cost Summary

A summary of the estimated project cost for each alternative is presented in the following table and graph:

TABLE 4: Tabular summary of estimated project costs. Estimated total capital costs include expenses for the new aqueduct. Estimated annual OMR&E costs include such expenses for all pipelines (Federal and non-Federal) in the conveyance system under each alternative.

Alternative	**Estimated Total Capital Costs**	**Estimated Annual Operation, Maintenance, Replacement and Energy Costs**			
		Power	Pipelines	Pumping Plants	**Total Annual OMR&E**
2-Grav$^{13.3}$	**38,000,000**	100,000	130,000	70,000	**300,000**
3-Grav$^{13.3}$	**30,000,000**	110,000	190,000	100,000	**400,000**
2-Pump$^{13.3}$	**26,000,000**	110,000	110,000	70,000	**290,000**
3-Pump$^{13.3}$	**20,000,000**	135,000	175,000	110,000	**420,000**
2-Grav$^{15.3}$	**42,000,000**	120,000	140,000	70,000	**330,000**
3-Grav$^{15.3}$	**30,000,000**	125,000	200,000	105,000	**430,000**
2-Pump$^{15.3}$	**30,000,000**	135,000	120,000	75,000	**330,000**
3-Pump$^{15.3}$	**22,000,000**	160,000	180,000	120,000	**460,000**
2-Grav$^{18.0}$	**45,000,000**	140,000	155,000	75,000	**370,000**
3-Grav$^{18.0}$	**36,000,000**	145,000	210,000	115,000	**470,000**
2-Pump$^{18.0}$	**31,000,000**	170,000	130,000	90,000	**390,000**
3-Pump$^{18.0}$	**25,000,000**	200,000	200,000	130,000	**530,000**
2-Grav$^{21.5}$	**52,000,000**	165,000	170,000	85,000	**420,000**
3-Grav$^{21.5}$	**46,000,000**	170,000	230,000	120,000	**520,000**
2-Pump$^{21.5}$	**38,000,000**	220,000	150,000	100,000	**470,000**
3-Pump$^{21.5}$	**30,000,000**	250,000	205,000	145,000	**600,000**

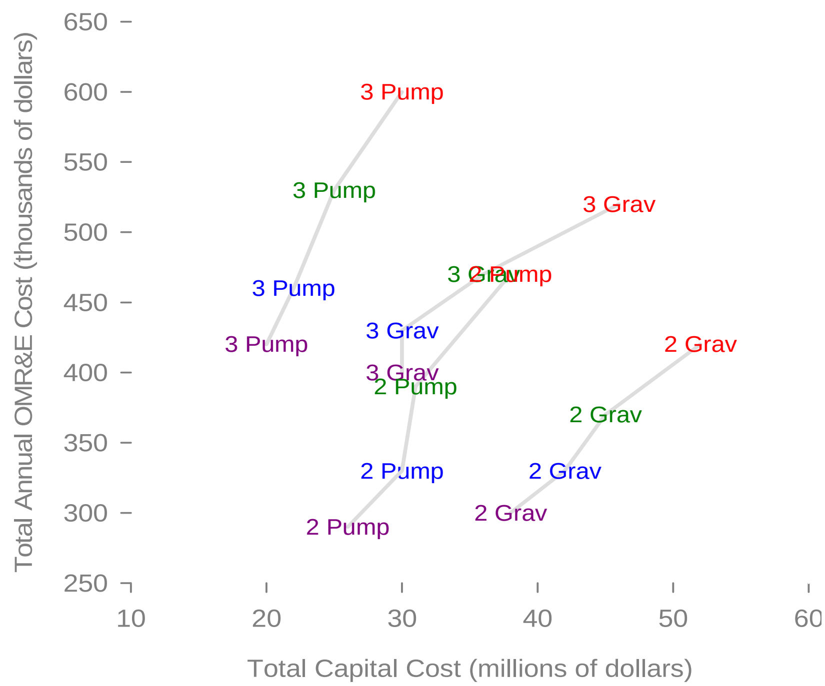


FIGURE 8: Graphical summary of estimated project costs, including total capital and annual OMR&E. Color indicates the design capacity of the overall delivery system:

Purple - 13,300 acre-ft/yr
Blue - 15,300 acre-ft/yr
Green - 18,000 acre-ft/yr
Red - 21,500 acre-ft/yr

To facilitate a better comparison of the life-cycle costs for each alternative, the *present value* of the OMR&E cost was calculated for each alternative assuming a 40-year service life for the project, 6 percent discount rate, and 4 percent rate of inflation. The present value total costs for each alternative were then derived by adding the present value OMR&E costs with the total capital costs, as presented below:

TABLE 5: Tabular summary of total life-cycle project costs. Data reported in millions of dollars.

Alternative	Total Capital Cost	Present Value 40 Years of OMR&E	**Present Value Total Cost**
2-Grav$^{13.3}$	38.0	8.5	**46.5**
3-Grav$^{13.3}$	30.0	11.5	**41.5**
2-Pump$^{13.3}$	26.0	8.0	**34.0**
3-Pump$^{13.3}$	20.0	12.0	**32.0**
2-Grav$^{15.3}$	42.0	9.5	**51.5**
3-Grav$^{15.3}$	30.0	12.0	**42.0**
2-Pump$^{15.3}$	30.0	9.5	**39.5**
3-Pump$^{15.3}$	22.0	13.0	**35.0**
2-Grav$^{18.0}$	45.0	10.5	**55.5**
3-Grav$^{18.0}$	36.0	13.5	**49.5**
2-Pump$^{18.0}$	31.0	11.0	**42.0**
3-Pump$^{18.0}$	25.0	15.0	**40.0**
2-Grav$^{21.5}$	52.0	12.0	**64.0**
3-Grav$^{21.5}$	46.5	15.5	**61.5**
2-Pump$^{21.5}$	38.5	13.5	**51.5**
3-Pump$^{21.5}$	30.5	17.5	**47.5**

When presented graphically, it appears that the most economically attractive alternative over the projected 40-year project life for all four flow scenarios evaluated is the three pipeline, Pumping alignment (3-Pump^{X}).

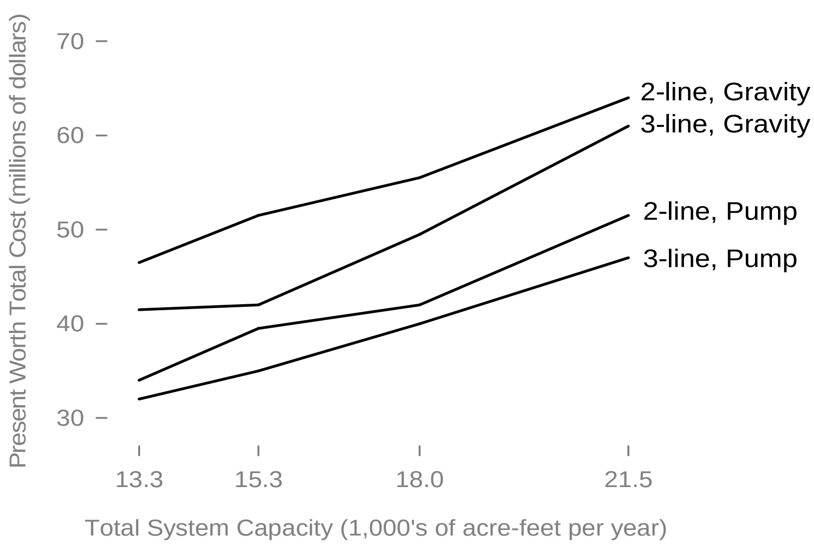


FIGURE 9: Graphical summary of total life-cycle project costs for each alternative.

Alternative 3-Pump[X] is represented schematically as follows:

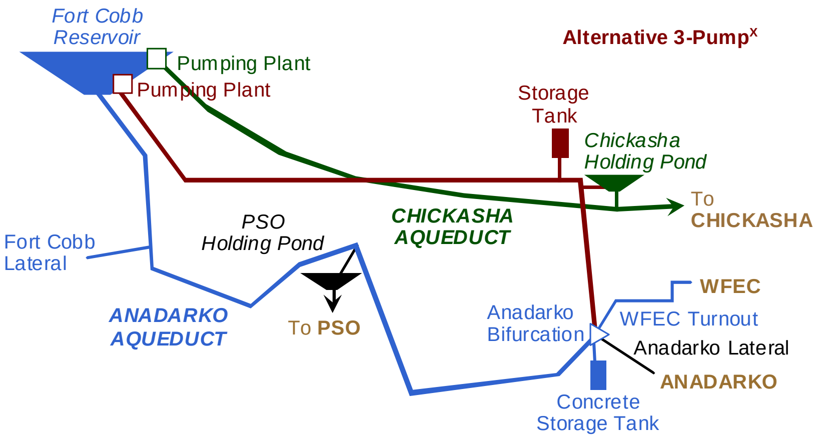


FIGURE 10: Schematic diagram of Alternative 3-Pump[X]. In summary, a new aqueduct and pumping plant (**red**) would be constructed to supplement the Anadarko Aqueduct (**blue**) with the assumption that the Chickasha Aqueduct (**green**) would remain in operation. This alternative was the most economically favorable alternative under each system capacity scenario evaluated.

Findings

A need exists to expand the capacity of the District's conveyance system since, in recent years, the District has experienced difficulty in meeting peak-day demands. The original Anadarko Aqueduct was designed and constructed prior to the conversion of the irrigation water right to municipal use, and in recent years, the District has experienced difficulty in meeting peak day demands.

River outlet works, Fort Cobb Dam.

Several alternatives for expanding the capacity of the existing conveyance system appear viable. The most economically attractive alternative appears to be *Alternative 3-Pump^X*, which would include the construction of a new pipeline from Fort Cobb Reservoir to Anadarko to supplement the existing Anadarko and Chickasha Aqueducts. The alignment of this new pipeline would not be gravity-flow but would require construction of a pumping plant below Fort Cobb Dam. However, three of the four system capacity scenarios evaluated for this alternative would require the importation of additional water supplies. These scenarios include conveying enough water on a peak day basis to meet the current contract obligation of the District (15,300 acre-feet per year), provide the full water right appropriation to the District (18,000 acre-feet per year), or supply the total projected 2040 demand of the District's current customers (21,500 acre-feet per year).

RECOMMENDATION

The potential source(s) of such additional water supplies have not yet been identified, and such a task was beyond the scope of the present study. Until it is clear that viable options exist to supplement the existing water supply, selection of a preferred conveyance system alternative is premature. **Therefore, it is recommended that none of the conveyance system expansion alternatives evaluated in this report be investigated in a feasibility study at this time.**

The District could consider initiating an appraisal level investigation of potential alternatives to augment the water supply of Fort Cobb Reservoir. If a viable source of supplemental water can be identified, both investigations (conveyance system expansion and water augmentation) could then be folded together and the feasibility of a combined water supply/distribution project determined.

References

Bureau of Reclamation. 1960. (Revised) Definite Plan Report, Washita Basin Project, Oklahoma: Volume I, General Plan and Fort Cobb Division (Except Irrigation Features). Bureau of Reclamation, Amarillo, Texas.

Bureau of Reclamation. 1962. Designer's Operating Criteria, Anadarko Aqueduct, Fort Cobb Division, Washita Basin Project, Oklahoma. Bureau of Reclamation, Office of Design and Construction, Denver, Colorado.

Bureau of Reclamation. 1965. Guidelines for Estimating Pumping Plant Operation and Maintenance Costs. John Eyer, U.S. Bureau of Reclamation, Denver, Colorado.

Bureau of Reclamation. 1980. Memorandum from Reclamation to Oklahoma Water Resources Board, Oklahoma City, Oklahoma, dated December 5, 1980.

Bureau of Reclamation. 2001. Fort Cobb Dam; Comprehensive Facility Review. Washita Basin Project, Oklahoma. Great Plains Region. US Department of the Interior. Bureau of Reclamation, Technical Service Center, Denver, CO October 2001. 200 pgs.

Bureau of Reclamation. 2004. Washita Basin Project, Oklahoma, Fort Cobb Division, Appraisal Report. U.S. Bureau of Reclamation, Oklahoma-Texas Area Office, Austin, Texas.

Bureau of Reclamation. 2005a. *Pipeline Appraisal Study Cost Estimate and Design Assumptions, Fort Cobb Division, Washita Basin Project, Oklahoma.* Memorandum from Leon Esparza, Supervisory Program Coordinator, to Area Manager, Austin, Texas, dated December 22, 2005.

Bureau of Reclamation. 2005b. *Pipeline Appraisal Study Peak Flow Analysis, Fort Cobb Division, Washita Basin Project, Oklahoma.* Memorandum from James Allard, Acting Supervisory Program Coordinator, to Area Manager, Austin, Texas, dated September 26, 2005.

City of Chickasha. 2003. Letter to Fort Cobb Master Conservancy District dated September 17, 2003. City of Chickasha, Oklahoma.

Linsley, Ray, Joeseph Franzini, David Freyberg, and George Tchobanoglous, 1992. Water Resources Engineering, Fourth Edition. Irwin/McGraw-Hill, New York.

Oklahoma Water Resources Board. 1976. Report on Application and Monitoring Program for Fort Cobb Reservoir, FY-76. March. Publication No. 68. 65 pgs.

Oklahoma Water Resources Board. 1995. Update of the Oklahoma Comprehensive Water Plan. Oklahoma Department of Water Resources, Oklahoma City, Oklahoma.

Opitz, Quintin. 2005. Personal Communication, August 11, 2005.
Mr. Opitz is the Superintendent of the Fort Cobb Master Conservancy District.

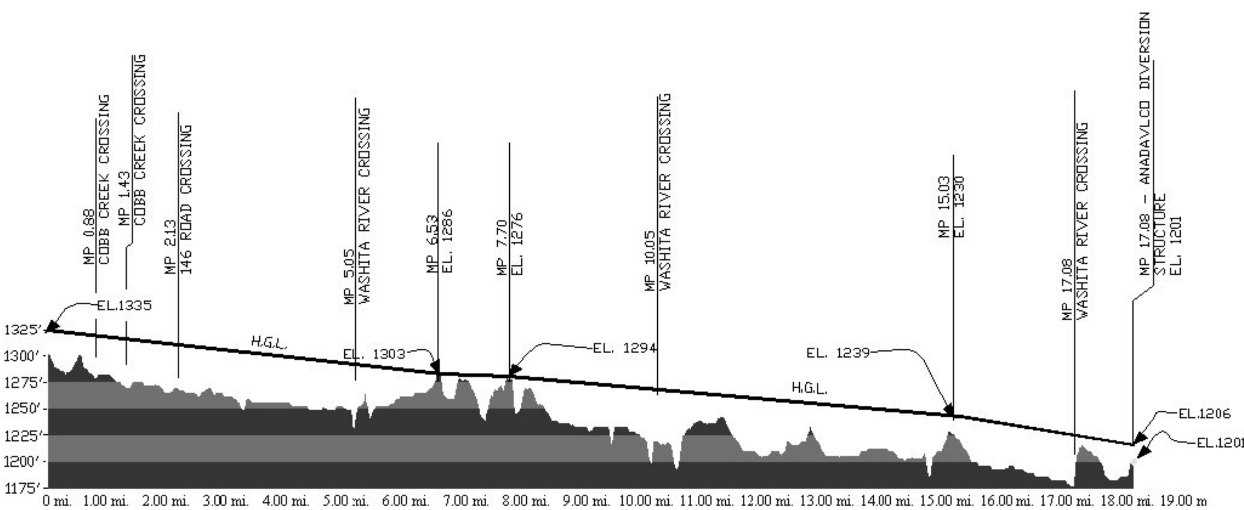
Shelton, Larry. 2006. Personal Communication, January 4, 2006.
Mr. Shelton is the City Manager of the City of Chickasha.

EXHIBIT A: Alignment Profiles

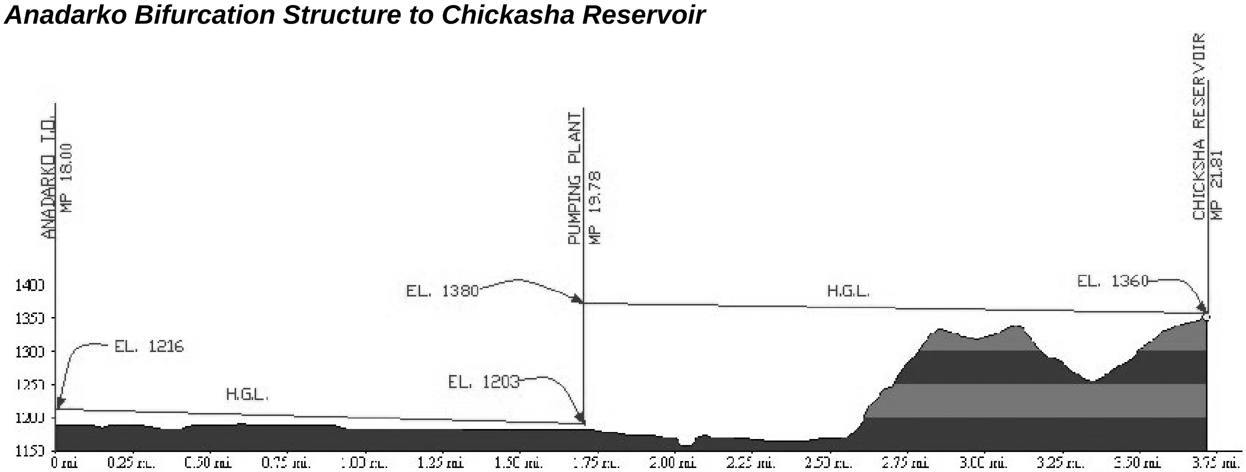
Pipe size was determined by laying out the general plans and profiles for the alternatives using the National Geographic Topographic Software (TOPO!). The plans and profiles were then used to determine the pipe lengths and elevation differences for each reach. The Hazen-Williams equation was used to compute the loss due to friction in the pipe. As a guideline, design velocities of approximately 5 feet per second were used. The pipe size for each reach and each alternative was calculated from the acceptable amount of loss based on the pipeline profiles (Bureau of Reclamation 2005a).

Gravity-Flow Alignment

Fort Cobb Dam to Anadarko Bifurcation Structure



Anadarko Bifurcation Structure to Chickasha Reservoir



Pumping Alignment

Fort Cobb Reservoir Pumping Plant to Anadarko Bifurcation Structure