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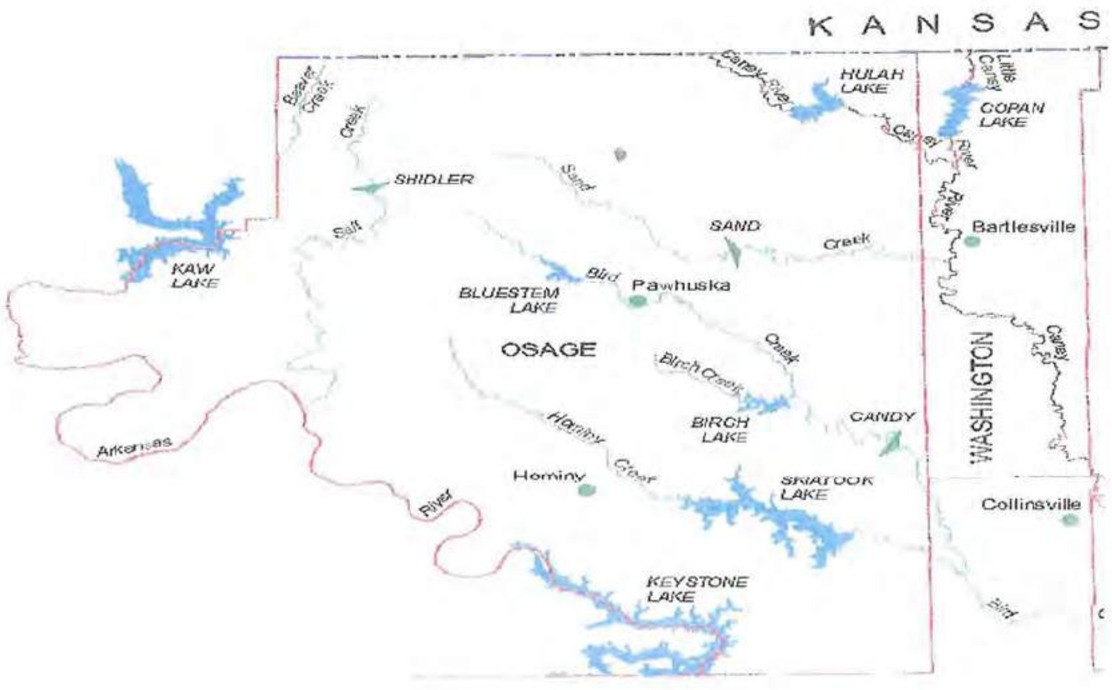
# BARTLESVILLE WATER SUPPLY AND CONVEYANCE STUDY

# PLANNING ASSISTANCE TO STATES PROGRAM




U.S. Army Corps of Engineers
December 2007

# BARTLESVILLE WATER SUPPLY AND CONVEYANCE STUDY

## PLANNING ASSISTANCE TO STATES PROGRAM

Prepared For
The Oklahoma Water Resources Board
and
The City of Bartlesville, Oklahoma

By

U.S. Army Corps of Engineers
Tulsa District
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## BARTLESVILLE WATER SUPPLY STUDY

## EXECUTIVE SUMMARY

The Bartlesville Water Supply Study evaluated alternatives for future water supply for the City of Bartlesville and most of Washington County, Oklahoma. This study was conducted by the Corps of Engineers in partnership with the City of Bartlesville and the Oklahoma Water Resources Board (OWRB) under the Planning Assistance to States Program, Section 22 of the Water Resources Development Act of 1974, as amended.

The study area includes the City of Bartlesville, Oklahoma, and the communities and rural water districts it currently serves, essentially all of Washington County, Oklahoma. The city currently utilizes Hulah Lake as its primary water supply source. The city remains concerned about the dependability of Hulah Lake. The severe drought of 2001-2002 has caused the city to evaluate the dependability of having only one primary source of water supply, Hulah Lake, in the Caney River basin. In addition, the city believes that recent industrial growth and population increases indicate a growth potential that is not necessarily reflected in the historic trends for the city and Washington County.

Phase I of this study evaluated the current and projected water demand of the study area in relationship to the existing water supply through the study period of 2005 to 2055. Phase I found that water demand could exceed the current supply as early as 2015 and that demand for water could exceed supply by 10.45 million gallons per day (mgd) by year 2055. At that time the projected demand is expected to be 14.8 mgd. Based on the available existing water supply the estimated net water needs are 10.45 mgd, which is the basis for screening alternatives for additional water supply.

Phase II of the study focused on three primary alternatives: (1) reallocation of flood control storage at Copan and Hulah Lakes to water supply; (2) non-Federal development of Sand Lake, a proposed reservoir on Sand Creek in Osage County, Oklahoma; (3) use of Kaw Lake water supply storage and development of a pipeline to the city's Hudson Lake. The study also evaluated measures to preserve and protect Hulah and Copan Lakes.

The study evaluated the use of water quality storage reallocated as a result of the 2006 Reallocation Report and found that use of the reallocated water quality storage could defer the city's water supply problems by as much as 30 years (from 2015 to about 2045), but does not completely solve their long term needs through the entire study period.

The study evaluated several options for reallocation of storage at Hulah and Copan Lakes from flood control to water supply. The study evaluated both the quantity of storage that could be made available, the projected yield associated with that storage, and also did a brief evaluation of the potential impacts to the flood control operations of the two lakes, both of which reduce flooding in the city of Bartlesville and along the Caney River. The alternatives evaluated reallocation of between 1 percent and 10 percent of the flood control storage at the two lakes, which resulted in water supply yields estimated from about 9 mgd to about 25 mgd. The impact to the areas downstream of the lakes was assessed and the study found that reduction of the flood control storage at the lakes was not significantly different between the alternatives. The additional total flood damages lost downstream ranged from about $176,000 to $222,000 over the 50 year study period, with average annual damages increasing by $9,000 to $12,000. The study also assessed impacts to the areas upstream of the Lakes Hulah and Copan Dams; the impacts were primarily to recreational facilities and cultural and natural resources. The study found that the costs for mitigation and replacement of loss of habitat and facilities were about $600,000 to $8.6 million.

The study also evaluated the costs associated with construction of Sand Lake, a potential non-Federal water supply lake on Sand Creek in Osage County, Oklahoma. The study found that construction of Sand Lake could provide sufficient water supply to meet long term needs for the city of Bartlesville in combination with the city's existing Lake Hulah contracts. The study analyzed the costs associated with construction of Sand Lake and found that these costs are about $86.0 million.. The costs associated with potential environmental and cultural impacts of constructing the dam and pipeline and costs to address mineral rights as a result of construction of the dam were not evaluated, but could be significant.

The study also evaluated use of storage at Kaw Lake and the costs associated with construction of a pipeline from Kaw Lake to Hudson Lake. The study found that sufficient water supply storage is available at Kaw Lake to meet long term needs for the City of Bartlesville. However, the cost for storage at Kaw Lake and pipeline water conveyance costs is estimated at $105.0 million. The costs associated with environmental or cultural impacts of construction of the pipeline were not addressed.

The study also addressed opportunities to protect and extend the lives of Hulah and Copan Lakes by managing the areas upstream of the reservoir to limit sediment and nutrient loading in the lakes. The study found both sediment and nutrient loading were on-going at the historic rate.

Based on these study findings, the most economical method for the city to provide for its future water supply demands is to utilize the existing sources of water supply at Hulah and Copan Lakes with flood pool reallocation when the storage is required.

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# BARTLESVILLE, OKLAHOMA
# WATER SUPPLY ALTERNATIVES

## 1. INTRODUCTION

The U.S. Army Corps of Engineers (COE), Tulsa District, conducted this study for the Oklahoma Water Resources Board and the City of Bartlesville, Oklahoma, under the authority of Section 22 of the Water Resources Development Act of 1974, the Planning Assistance to States (PAS) Program. The study explores alternatives for supplying water for the population of Bartlesville and Washington County. Based on current projections, the city's existing water supply sources will not meet water supply demands through year 2055 for the City of Bartlesville and the area for which the city supplies water. The City currently gets 100% of their water supply from Hulah Lake, a Corps of Engineers Lake on the Caney River in Oklahoma.

Based on previously expressed needs by the City of Bartlesville, the U.S. Army Corps of Engineers evaluated alternatives to reallocate storage at Hulah Lake and at Copan Lake, also a Corps reservoir in the Caney River basin, in a report dated April 2006. The recommended alternatives would provide an additional 7.2 million gallons per day (mgd) from Hulah Lake and an additional 5.54 mgd from Copan Lake. The report states that this reallocation would provide the City of Bartlesville sufficient water supply through year 2035.

At the time the reallocation report was submitted for approval, Bartlesville officials became concerned that population projections used in the reallocation report may have been underestimated. Population growth has increased the last few years with the influx of new and expanding businesses; that growth is not captured in historic trends used for the reallocation report and was not considered during the reallocation study period. This PAS study is in response to the potential revised higher demand for water. A longer study period through year 2055 was also evaluated. The goal of the study is to provide information to the City of Bartlesville in order that they can make important strategic decisions regarding a dependable, cost efficient high quality water supply for the 21st century for citizens of Bartlesville and Washington County, Oklahoma.

The study included gathering existing water system information, evaluating existing facilities, formulating alternatives in cooperation with the Bartlesville Water Resource committee, and based on the future needs that were supplied by Mike Hall, the Water Utilities director for the City of Bartlesville. The study also included a preliminary analysis of potential environmental and cultural resources issues, flood benefits lost and related implementation costs for each water supply alternative being considered.

## 2. STUDY AUTHORITY

The U.S. Army Corps of Engineers, Tulsa District, (Corps) conducted the study for the Oklahoma Water Resources Board and the City of Bartlesville, Oklahoma, under authority of Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251), also known as the Planning Assistance to States Program. This authority establishes cooperative assistance to states for preparation of comprehensive water plans.

Section 319 of the Water Resources Development Act of 1990 (Public Law 101-640) provides authority for cost sharing of the Planning Assistance to States Program. The cost-sharing ration for this study is 50% Federal and 50% non-Federal. A Letter Agreement between the COE, Tulsa District and the City of Bartlesville, Oklahoma, was signed on April 7th, 2006. The Letter Agreement is included as Appendix 1.

## 3. PURPOSE & SCOPE

This study was conducted to identify long term water supply solutions for the City of Bartlesville, Oklahoma. This study is a two-part study. Phase I evaluated water demand through year 2055 for Bartlesville and Washington County. Phase II, initiated after future water supply demand was identified, evaluated water supply alternatives to meet the identified demand. Primary water supply alternatives considered include Kaw Reservoir, a previously authorized Federal reservoir site located in Osage County (Sand Lake), and flood control reallocation alternatives at Hulah and Copan lakes.

Bartlesville is proactively planning for long term availability of its water supply. The city is currently using water from Hulah Lake, which is its sole source of available water. City officials are concerned that Hulah may be insufficient as a sole water supply source and they are also concerned about Hulah Lake dependability. Hulah Lake was built in 1951 and provides a relatively inexpensive source of water to Bartlesville. However, sediment inflows continue to reduce available water supply storage both now and in the future. The 2006 Hulah and Copan reallocation report identified water supply options that Bartlesville could execute, but city officials are concerned that those options may not provide a sufficient water supply yield beyond year 2035. The city is exploring other water supply alternatives in the event that Hulah Lake as it exists today will be insufficient as the sole water supply source for its future.,.

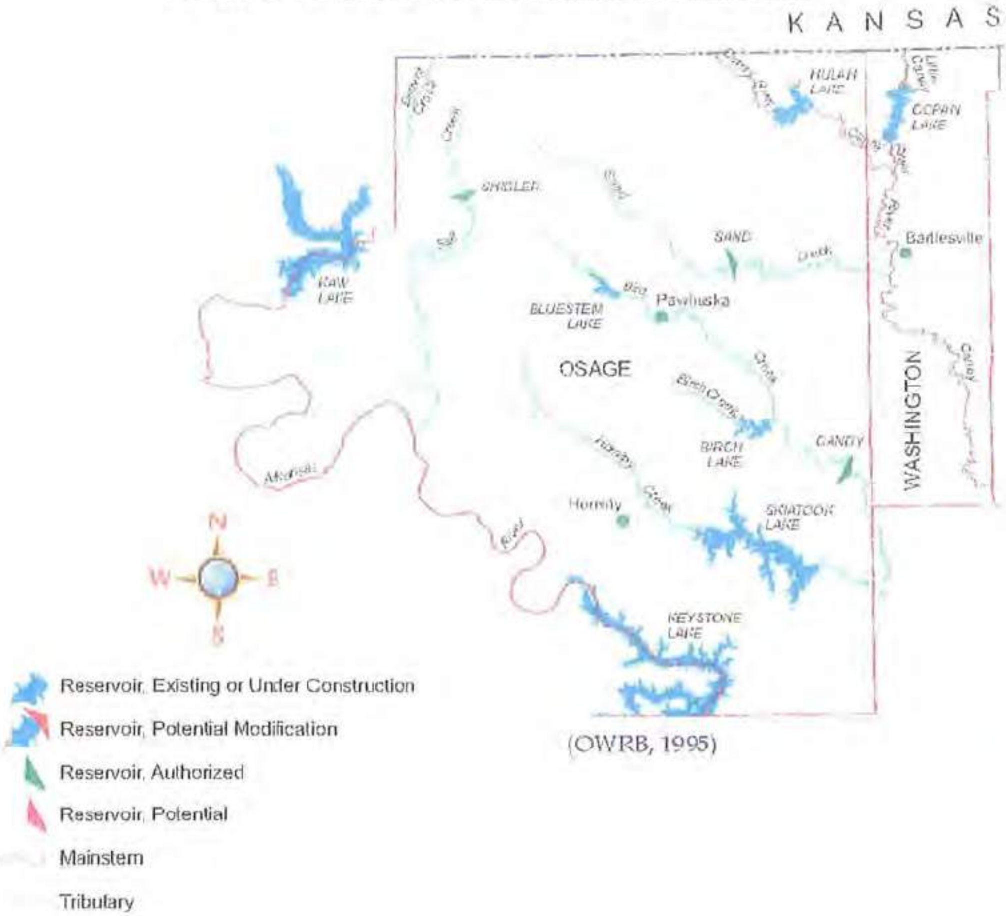
## 4. PROJECT LOCATION AND DESCRIPTION

The study area includes the City of Bartlesville, Washington County, and Osage County in Northeast Oklahoma. The City of Bartlesville lies in about the middle of the Caney River watershed. The Caney River, approximately 155 miles in length, rises in Elk County, Kansas, and flows in a southerly and southeasterly direction to enter the Verdigris River at river mile 78.3 in Rogers County, Oklahoma. The basin contains 2,111 square miles of drainage area, and has a channel capacity estimated to be 11,000 cfs at the mouth of the stream.

The major tributaries of the Caney River are Caney and Sand Creeks. Caney Creek, which is about 60 miles long and has a drainage area of 516 square miles, flows into the Caney River at river mile 80.5 at a point about 10 miles north of Bartlesville, Oklahoma. The channel capacity of the creek is about 5,000 cfs. Sand Creek flows into the Caney River at river mile 63.7 about 3 miles south of Bartlesville. The creek is approximately 50 miles long, with a drainage area of 240 square miles and a channel capacity of 5,500 cfs.

The study area is shown in Figure 1.

FIGURE 1 CANEY RIVER AREA WATERSHED




There have been three previously authorized Corps lakes in the Caney River Basin in Oklahoma; Hulah, Copan, and Sand Lakes. Hulah and Copan have been constructed and are in operation. Sand Lake was not constructed and was deauthorized in 1999. Hulah Lake is located on the Caney River at river mile 96.2 and controls 732 square miles of drainage area. Copan Lake is located at river mile 7.4 on the Little Caney River and controls 505 square miles of drainage area. The previously authorized Sand Lake site is located at river mile 10.1 on Sand Creek and would control approximately 187 square miles of drainage area.

## 5. PRIOR STUDIES AND REPORTS

Previous congressionally authorized studies pertinent to the Bartlesville Water Supply and Conveyance study are:

a. Caney River Basin, Verdigris River and Tributaries, Kansas and Oklahoma, Reconnaissance Report, September 1984. This study was designed and conducted to identify priority water resource problems in the basin and to conduct preliminary evaluations of alternatives to determine if economically feasible projects appeared to be available. This study identified water supply needs of Bartlesville as the major water resource problem in the basin.

b. Survey Report on Verdigris River and Tributaries, Oklahoma and Kansas, December 1961. Included in this report were design memorandum guidelines for Sand Lake authorization and also a summary of cost and quantity estimates. This report provided preliminary cost estimates for Federal construction of Sand Lake.

c. Hulah and Copan Lakes, Oklahoma Water Supply Reallocation Report and Water Supply Agreements and Final Environmental Assessment (EA), April 26, 2006. The Hulah Copan reallocation report reallocated water quality to water supply storage at Hulah and Copan Lakes. The April 2006 reallocation report identified an additional yield of 6.4 mgd which could be obtained from water quality storage through year 2035 from both reservoirs. The 2006 reallocation study relied on information obtained from a TetraTech, FHC report "Cost of Alternative Water Supply Sources dated August 2004. This report looked at the Cost of Alternative Water Supply Sources from Federal, State and NRCS lakes throughout Northeast and North Central Oklahoma.

d. Wholesale Water Treatment and Conveyance Study Kaw Lake Area, Oklahoma, June 2002. The study initiated data collection for three alternate plans that would provide a regional wholesale water treatment and conveyance system serving 30 communities and rural water systems in 13 counties of northern and central Oklahoma.

## 6. BACKGROUND

Since the early 1940's previous Bartlesville and State officials worked with the Corps of Engineers to build Hulah Lake as a federal water resource project that has provided numerous benefits to north central Oklahoma and the Bartlesville and Washington County Communities. Construction of Hulah Lake in 1951 provided a new source of water but it also provided flood reduction to the Bartlesville community that was greatly needed. Flood reduction benefits from Hulah greatly reduced downstream flooding within the Bartlesville community.

Shortly after Hulah was completed, in 1957, Bartlesville signed a water supply storage contract for 15,400 acre-feet (9.6 mgd) . Hulah Lake has provided Bartlesville with a reliable inexpensive dependable water supply yield for many years. Smaller water supply storage agreements were also signed in 1970 for 2,200 acre-feet (1.4 mgd) and 1980 for 2,100 acre-feet (1.3 mgd). Hulah Lake is Bartlesville's current sole water supply source.

In 1962, additional planning was started for future reservoirs to be built in north central Oklahoma. Sand Lake and Copan Lake were both authorized and studied for possible future construction. Copan Lake was built and became operational in 1983 and has the project purposes of flood control, water supply, water quality, recreation, and fish and wildlife. Copan provides additional flood protection to Bartlesville. Sand Lake was never built and was deauthorized in 1999.

Recently, Bartlesville's water treatment system has seen an expansion of its service area to a large percentage of communities surrounding Washington County. In 2001-2002, the region experienced a short but severe drought in the upper Caney River watershed which impacted

Hulah Lake. The 2001 drought created a question about available long term water supply especially during drought conditions. Bartlesville, the primary supplier in the area, was strained even more as surrounding communities, forced to meet more stringent water quality standards, increasingly relied on the city for water supply.

Shortly after the 2001 drought, a reallocation study was initiated to evaluate the impacts of reallocation from water quality and flood control storage to water supply at Hulah and Copan reservoirs. The reallocation report was submitted to Corps higher authority for approval in April 2006. The reallocation report identified an opportunity to reallocate from water quality storage to water supply storage and which would yield an additional 6.4 mgd. The report was approved in September of 2007 and can now be implemented by the City of Bartlesville, if the city so desires.

In 2005, Bartlesville officials requested an additional water supply evaluation through the PAS program. The city requested that the study evaluate water supply demand through 2055 and further review potential water supply alternatives. The PAS study, included two phases: Phase I analyzed the future water supply demand for Bartlesville and Washington County. Phase II then analyzed potential supply alternatives based on the identified demand.

## 7. STUDY SCOPE

Phase I of this study examined future water supply and water demand for the next fifty years (through 2055), and compared them to existing sources to determine Bartlesville's Net Water Needs. A collaborative effort with the City of Bartlesville was used to select the appropriate population and demand projections and, there from, the Net Water Needs before the second phase of the study. Demographic and economic variables, such as population, employment by industry, housing density, and median household income were used as a basis for projecting future water needs.

Phase II evaluated water supply yield projections for existing reservoirs and other water supply alternatives through 2055, and evaluated sediment conservation measures that could preserve existing water supply storage. Primary water supply alternatives being considered include Kaw Reservoir, previously authorized Sand Lake in Osage County, and Flood Pool reallocation alternatives at Hulah and Copan. Environmental impacts, regulatory compliance, loss of existing flood protection, availability of sufficient water supply sources to meet projected demand, and the effect that river basin size has on the dependable yield were other planning constraints that were considered. Land and legal issues for private and federal funding for new water supply reservoir alternatives was also a major constraint. Phase II also looked at potential conservation measures that addressed upstream sedimentation at Hulah and Copan Lakes and a sensitivity analysis of the future Bartlesville's existing water supply. Reliability of the water source is also an important factor to the community as well.

## 8. PHASE I – NET NEEDS ANALYSIS

### a. Phase I

(1) Introduction Phase I of the two-phase study effort was completed in March 2007. This first phase determined future net water needs for the City of Bartlesville and the surrounding communities, rural water systems, and other areas to which the City provides water. The first phase includes an estimate of future demand for water based on different population growth scenarios Washington County could experience from 2005 to 2055, with year 2005 representing the base year. The City of Bartlesville expects population growth in the city and in Washington County to occur at a much faster rate than historic growth rates indicate. Population forecast scenarios were made for the City of Bartlesville, two rural water districts the City supplies, and Washington County. The City supplies water to approximately 99% of the residents in Washington County. Since nearly all of the water demands in Washington County are supplied by the City of Bartlesville, forecasts used for the purpose of this report are based on Washington County data.

(2) Water Demand. Estimates of the quantities of water needed in the future require the use of appropriate econometric models. These models are used to project future water use that is statistically consistent with long-term water supply planning. In order to forecast Municipal & Industrial (M&I) water demand Institute for Water Resources-Municipal and Industrial Needs (IWR-MAIN) Water Demand Management Suite, a Windows based PC software package, was used to translate existing population, housing, and employment into estimates of existing water demands for the 2005 base year. Actual water use data for year 2005 for the City of Bartlesville and included rural water districts in Washington County and the City of Dewey. Some of the included rural water districts may overlap into neighboring counties.

(3) Projection Scenarios. Three water demand scenarios were presented to the Water Resource Committee of Bartlesville. The Baseline Projection Scenario is based on historical growth and weather pattern trends experienced in the study area. Due to the fact that the population of Washington County has not increased significantly over the past ten years, the baseline water demand forecasts have not deviated from the base year by a substantial amount. The baseline projection is based on a 2055 population of 53,000 in Washington County.

The City of Bartlesville provided information on actual water use for the base year 2005. This information was disaggregated into different sectors of water use such as residential, municipal, industrial, commercial, water districts, and public schools. In addition, the City also provided information on population and housing projections from years 2000-2050. This data was then used to develop a high growth scenario for the water system that Bartlesville supplies. The City developed these growth projections based on the current level and pace of development. The water demand forecast for the high growth projection was based on a 2055 population of 73,000 and developed by the Tulsa District using the IWR-MAIN forecast system. The Oklahoma Department of Commerce (ODC) provided the demographic data of population estimates as the basis for employment and housing projections. Other sources of information include, the U.S. Department of Labor, the U.S. Census, and the Oklahoma State Climate Center, and the National Weather Service.

A third projection, called the mid projection, was interpolated from the baseline and high projections. Water demand forecasts for the mid projection population were not evaluated using IWR-MAIN but are derived as an average of the baseline and high-growth projections.

(4) Methodology. The method that was selected for forecasting residential water demand uses median household income, persons per household, housing density, marginal price of water, maximum temperature, and precipitation, to adjust per unit usage rates for residential information, but not for non-residential variables. For the non-residential sector, a model for water demand was customized using values for intercept terms, model variables, and associated coefficients and elasticities. The base year per unit water use rate is calculated from the base year water use and the number of counting units for the sub-sector. This calculated rate of use is then adjusted by the relationship between sub-sector water use and those explanatory variable selected for the sub-sector, which are selected by the user and may change over time. Year-to-year changes in water use are explained by the change in the selected explanatory variables and the counting units. Counting units derived from population projections, are the driver variables, such as employee counts, housing units, acres, etc., associated with each sub-sector.

(5) Peak Demand. Another output IWR-Main can forecast is peak water demand. Peak use for a community can vary month to month depending mainly on temperature and rainfall. Typically record peak use will occur in the hottest summer months, because this is a period where water demand significantly increases as homeowners are watering their lawns and gardens more frequently and precipitation rates are low. The system peak use may be specified in gallons per day, thousand gallons per day, or million gallons per day. The user must select the month in which the base system peak occurs and enter the peak use value. For this study, the City of Bartlesville supplied the peak use in million gallons per day which occurred in the month of July.

(6) Results. On March 1, 2007, the City agreed to proceed with the water demand projections based on the mid and high population growth projections ranging from 63,000 to 73,000 by 2055, which equates to water demand in 2055 being 12.8 to 14.8 million gallons per day (mgd). Due to the uncertainty of both demand and supply 50 years in the future, a range of net needs was determined to estimate future water supply needs.

b. **Existing Water Supply**

(1) Introduction. Hulah and Copan Lakes provide the majority of the water supply to Washington County. Bartlesville obtains its water from Hulah Lake, which is then pumped to city-owned Hudson Lake prior to treatment. During periods of insufficient supply from Hulah Lake and Hudson Lake, water can be pumped from the Caney River under emergency conditions. An additional 2.0 mgd from Copan Lake is utilized by the Copan Public Works Authority in Washington County.

(2) Hulah Lake. Hulah Lake construction started in May 1946, and was completed in February 1951 for flood control, water supply, low flow regulation, and conservation purposes. Embankment closure began in February 1950 and was completed in June 1950.

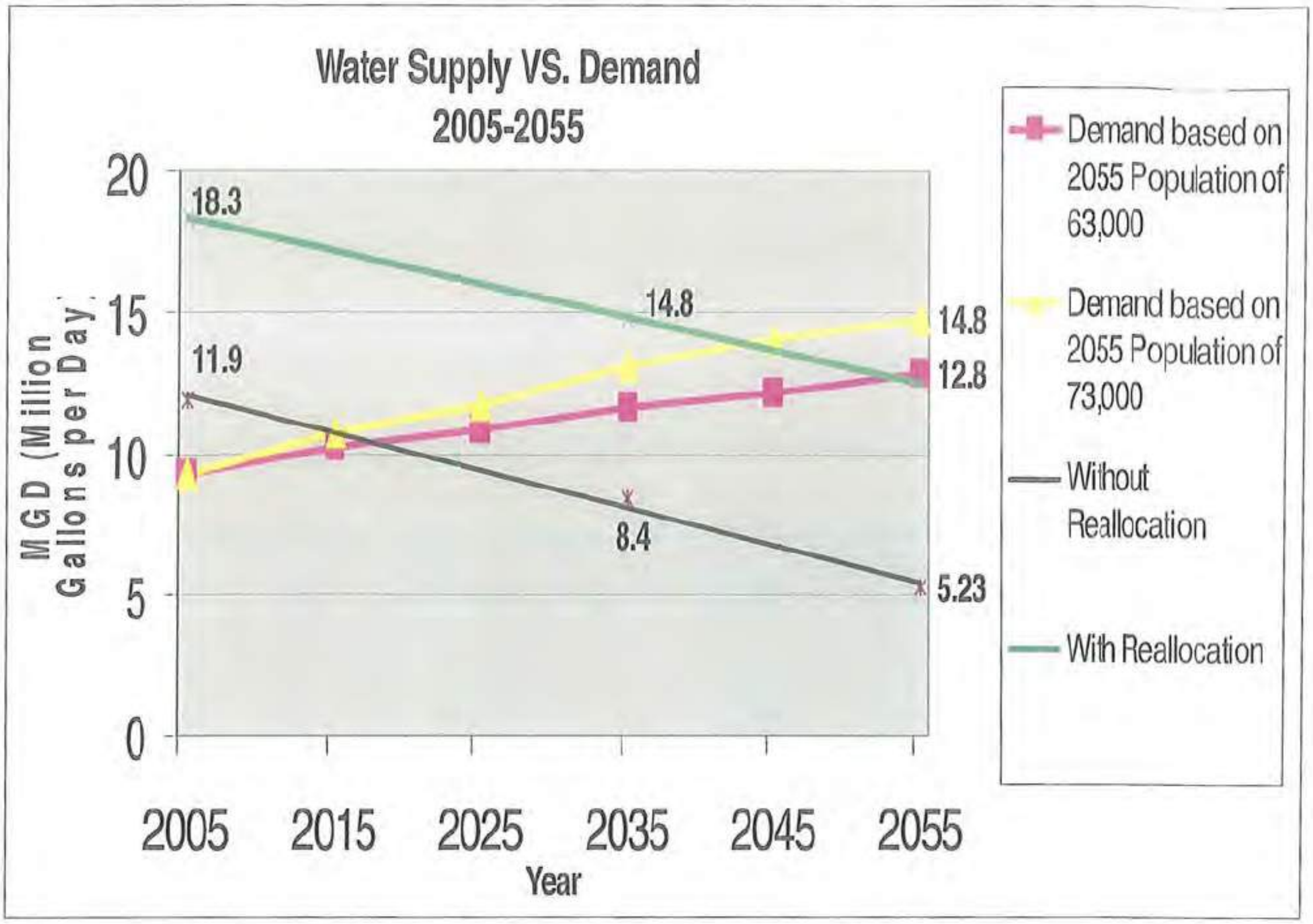
Impoundment of the conservation pool began on September 23, 1951, and was completed on September 24, 1951. The project was placed in full flood control operation in September 1951. Hulah Lake currently has 19,800 acre-feet of original water supply storage , all of which is under contract, which yields 6.4 million gallons per day (mgd) through year 2035.

(3) Copan Lake. Copan Lake construction began in November 1972, and the project was placed in useful operation in April 1983. Copan Lake provides flood control benefits to Bartlesville and is a second close water supply alternative that Bartlesville is considering. The water supply yield of Copan Lake is 7,500 acre-feet with a 3.0 mgd yield. Copan currently has one (1) million gallons per day (mgd) of available water supply not currently under contract.

(4) Dependable Yield. The Corps 2006 Hulah and Copan Reallocation study evaluated both the current (2005) and long term (2035) dependable yield of the two Lakes, including the impacts of sedimentation on available reservoir storage. The evaluation indicated that the City of Bartlesville has 6.4 mgd of dependable yield from Hulah Lake through year 2035 using historical data for the 50 year drought of record and the latest 2002 sediment survey for Hulah Lake. That data was utilized to project the dependable yield of Hulah Lake through 2055 assuming no measurable reduction in the rate of sediment deposition, and the analysis indicated that the dependable yield at Hulah Lake is projected to decline from 6.4 mgd in year 2035 to 4.35 mgd by year 2055. The same evaluation was done for Copan Lake and the findings indicated 0.97 mgd which is available through 2035 will decline to 0.88 mgd by year 2055. Based on that evaluation, a total of 7.35 mgd is currently available from Copan and Hulah lakes through 2035. The analysis indicated that a total available water supply yield from Hulah and Copan Lakes is 5.23 mgd in year 2055.

The 2006 Reallocation Report identified 1,230 acre-feet of additional storage in Hulah Lake and 12,490 acre-feet of additional storage in Copan Lake that is available for water supply purposes. The Hulah Lake yield is currently estimated to be 6.4 mgd and the Copan Lake yield is estimated to be 0.97 mgd. If the city elects to utilize both of their existing water supply contracts, the currently available water supply storage from Copan Lake, and the reallocated storage available from Hulah and Copan Lakes, the current yield would be 12.74 mgd in 2035. That yield is further projected to decline to 6.85 mgd by 2055. Figure 2 shows a graphical representation of the supply versus demand data discussed above for the demand based on population projections of 63,000 (mid) and 73,000 (high) and supply based on with and without the 2006 recommended reallocation.

Figure 2
WASHINGTON COUNTY
Supply versus Demand
(With and Without 2006 Reallocation)




c. **Net Water Needs**

Net water needs for Washington County are based on existing water supply for the City of Bartlesville from Hulah Lake and the water supply from. Copan Lake used by the Copan Public Works Authority. Based on the projections developed for this report, it appears that water demand will exceed available supply in about 2015 for both the mid and high population projections if the city does not utilize the reallocated storage at Hulah and Copan Lakes. If the city dues utilize that storage, projections indicate that the city will have sufficient water supply through 2050 for the mid projection and through 2045 for the high projection. Based on a population projection of 73,000 (high) and the existing water supply storage without the 2006 reallocation, the water demand will be 14.8 mgd and the supply from Hulah Lake will be 4.35 mgd. The net need utilized for the identification and formulation of alternatives in the second phase of this study is, therefore, 10.45 mgd.

## 9. PHASE II WATER SUPPLY ALTERNATIVE ANALYSIS

a. **Phase II Water Supply Lakes Evaluated.** Phase I identified a maximum net need of 10.45 mgd in 2055 for the study area. Although that net need represents the total Washington County need, including the City of Copan's supply and demand, it is reasonable and conservative to select 10.45 mgd as the net need for the city of Bartlesville and its service area. After evaluating the available alternatives and their potential to meet that need, the study team and the Bartlesville water resource committee members identified Hulah, Copan, Kaw and Sand Lakes as water supply alternatives to be studied in Phase II. A summary of each alternative reservoir's features including a comparison of each hydrologic basin characteristics is described below.

(1) Hulah Reservoir. Hulah Reservoir construction started in May 1946, and was completed in February 1951 for flood control, water supply, low flow regulation, and conservation purposes. Embankment closure began in February 1950 and was completed in June 1950. Impoundment of the conservation pool began on September 23, 1951, and was completed on September 24, 1951. The project was placed in full flood control operation in September 1951.

Table 1 outlines pertinent data for Hulah Lake. Lake data is based on the latest 2002 sedimentation survey.

*Table 1. Hulah Lake Data*

| *Feature* | Elevation (feet) | Area (acres) | Capacity (acre-feet) | Equivalent Runoff[1] (inches) |
|---|---|---|---|---|
| ***Top of Dam*** | 779.5 | - | - | - |
| ***Top of Flood Control Pool*** | 765 | 13,000 | 289,000 | 7.40 |
| ***Flood Control Storage*** | 733.0-765.0 | - | 257,900 | 6.61 |
| ***Spillway Crest*** | 740.0 | 5,160 | 61,400 | 1.57 |
| ***Top of Conservation Pool*** | 733.0 | 3,120 | 22,565[2] | 0.80 |
| ***Conservation Storage*** | 710.0-733.0 | - | 22,553 | 0.80 |
| ***Top of Inactive Pool*** | 710.0 | 0 | 12 | - |

***[1] From a 732-square-mile drainage area above the dam site.***

***[2] Includes 16,600 acre-feet for water supply, 5,953 acre-feet for water quality control, and 12 acre-feet for sediment reserve.***

(2) Copan Reservoir. Copan reservoir construction began in November 1972, and the project was placed in useful operation in April 1983. Copan Reservoir provides flood control benefits to Bartlesville and is a second close water supply alternative that Bartlesville is considering. Copan currently has one million gallons per day (mgd) of available water supply and a reallocation of water quality storage to water supply was recommended by the Tulsa District and approved by the United States Army Corps of Engineers Headquarters (USACEHQ) in September 2007.

Table 2 displays pertinent data for Copan Reservoir.

| *Table 2. Copan Lake Data* | | | | |
|---|---|---|---|---|
| ***Feature*** | Elevation (feet) | Area (acres) | Capacity (acre-feet) | Equivalent Runoff[1] (inches) |
| ***Top of Dam*** | 745.0 | | | |
| ***Maximum Pool*** | 739.1 | 17,850 | 338,200 | 12.57 |
| ***Top of Flood control Pool*** | 732.0 | 13,380 | 227,700 | 8.45 |
| ***Flood Control Storage*** | 710.0-732.0 | | 184,300 | 6.84 |
| ***Top of Conservation Pool*** | 710.0 | 4,449 | 34,634 | 1.61 |
| ***Conservation Storage*** | 687.5-710.0 | | 33,887[2] | 1.59 |
| ***Spillway Crest*** | 696.5 | 1,080 | 4,700 | 0.17 |
| ***Top of Inactive Pool*** | 687.5 | 110 | 747 | 0.02 |
| [1] ***Drainage area is 505 square miles.*** | | | | |
| [2] ***Includes 7,500 acre-feet for water supply (3.0 mgd yield), 26,100 acre-feet for water quality control (16 mgd yield), and 9,200 acre-feet for sediment based on 1983 survey..(In year 2002, useable storage=34,634acre-feet less 747 acre-feet)*** | | | | |

(3) Kaw Reservoir. Kaw Reservoir is located on the Arkansas River at river mile 653.7, about 8 miles east of Ponca City in Kay County, Oklahoma. Kaw Reservoir is about 45 miles from Lake Hudson. Its purpose is flood control, water supply, water quality, hydropower, recreation, and fish and wildlife. Construction began in June 1966 and the project was place into operation in May 1977. Based on a 1986 sedimentation survey, the conservation storage is estimated at 330,180 acre-feet. Flood control storage is 867,310 acre-feet. The power and conservation storage has a capacity of 383,480 acre-feet, and includes 171,200 acre-feet for water supply (167 mgd yield), 31,800 acre-feet for water quality control (39 mgd yield), and 140,500 acre-feet for sediment reserve. Table 8 below outlines Kaw Lake Data.

| *Table 3. Kaw Lake Data* | | | | |
|---|---|---|---|---|
| ***Feature*** | Elevation (feet) | Area (acres) | Capacity (acre-feet) | Equivalent Runoff[1] (inches) |
| ***Top of Dam*** | 1065.5 | - | - | - |
| ***Top of Flood Control Pool*** | 1044.5 | 39,650 | 1,327,160 | 3.74 |
| ***Flood Control Storage*** | 1010.0-1044.5 | - | 920,610 | 2.45 |
| ***Spillway Crest*** | 997.5 | 11,070 | 234,167 | 0.66 |
| ***Top of Conservation Pool*** | 1010.0 | 16,750 | 406,540 | 1.15 |
| ***Conservation Storage*** | 978.0-1010.0 | - | 330,180 | 1.08 |
| ***Top of Inactive Pool*** | 978.0 | 5,240 | 76,360 | 0.22 |
| [1] ***Contributing drainage area above the dam site is 6,652 square miles. The spillway design drainage area is 8,975 square miles. The total drainage area is 46,530 square miles.*** | | | | |

(4) Sand Lake Reservoir. The proposed Sand Lake reservoir was authorized as a Federal Multiple purpose reservoir in 1962 but was never constructed and was deauthorized in 1999. In addition, the project, as authorized, no longer meets Federal criteria for development due to insufficient flood control benefits. This study evaluated Sand Lake as a non federal water supply only lake, including development of cost estimates. Table 4 below outlines Sand Lake Data as it was originally proposed for Federal Authorization.

| *Table 4: Sand Lake (as Proposed for Federal Authorization)* | | | | |
|---|---|---|---|---|
| ***Feature*** | Elevation (feet) | Area (acres) | Capacity (acre-feet) | Equivalent Runoff (inches) |
| ***Top of Dam*** | 808.0 | - | - | - |
| ***Top of Flood Control Pool*** | 786.0 | 3,520 | 51,700 | N/A |
| ***Spillway Crest*** | 786.0 | 3,520 | 51,700 | N/A |
| ***Top of Conservation Pool***[1] | 766.5 | 1,940 | 35,000 | N/A |
| ***Conservation Storage*** | 734.0-766.5 | 1,940 | 35,000 | N/A |
| ***Top of Inactive Pool*** | 734.0 | - | 4,300 | N/A |
| [1] ***Contributing drainage area above the dam site is 137 square miles. Water Supply Yield is 12.0 mgd*** | | | | |

(5) Hydrologic Basin Comparison of Hulah, Copan, Kaw and Sand Lake. Although there are many factors which influence the dependable yield of a reservoir, the two most significant to the four lakes under evaluation are drainage area above the reservoir and the amount of water supply storage in the reservoir. Drainage basin comparisons between the four lakes shows that Kaw Reservoir has by far the most drainage area of the four hydrologic basins with 6,652 square miles. The Hulah Lake drainage area is 732 square miles, the Copan Lake drainage basin is 505 square miles, and the deauthorized Sand Lake would have had a drainage area of 137 square miles. Kaw Lake also has significantly more water supply storage than the other 3 lakes, with 330,180 acre-feet of storage. The originally authorized water supply storage of Hulah Lake is 16,000, Copan Lake has 7,500 acre-feet, and Sand Lake would have had 35,000 acre-feet of water supply storage. Comparison of the four hydrologic basins indicates that Kaw reservoir has the most available water supply of the four basins, and, because of the size of the drainage area above it, it would be the least likely to be impacted by long term localized droughts. That is particularly significant to the city of Bartlesville because of the drought the Hulah Lake drainage area experienced in 2001-2002.

**b. Phase II Alternative Study Criteria.** Dependable water supply yield, drought frequency effect on dependable water supply yield, impacts to flood control, and cost were the primary study criteria that were analyzed for each alternative in Phase II. Phase II also included a sensitivity analysis to evaluate the effects on dependable water supply yields if the input model parameters of inflows and sediment are modified. Upstream conservation measures were also looked at at Hulah and Copan Lakes.

**c. Water Supply Alternatives.** After a review of a variety of options, the study team and the Bartlesville Water Committee developed a set of five alternatives. These five alternatives represent approaches that have the highest potential to most efficiently meet the city's future water demand. Alternative #1, the No Action alternative looked at yields assuming no change in existing water supply sources. Alternative #2 studied 2055 water supply storage assuming Bartlesville initiates new water supply storage agreements recommended in the April 2006 Hulah-Copan reallocation study. Alternative #3 evaluated potential reallocation of flood control storage at Hulah and Copan Lakes. Alternative #4 studied Sand Lake as a privately developed water supply alternative. Alternative #5 studied Kaw Lake as a potential long term water supply alternative.

(1) Alternative 1: No Action Alternative - Maintain Hulah Reservoir as its sole water supply Source. This alternative evaluated the dependable yield in Hulah Lake in 2055.

(2) Alternative 2: Implement new water supply agreements proposed in April 2006 Water Supply Storage Reallocation Study at Hulah and Copan Lakes Oklahoma. This alternative evaluated the water supply yield availability through year 2055 assuming that new water supply agreements outlined in the 2006 Hulah and Copan Reallocation study are implemented. The new water supply agreements approved by HQUSACE would provide through year 2035, 1,230 acre-feet (0.82 mgd) of new storage at Hulah Reservoir, 2,185 acre-feet (0.97mgd) of originally authorized water supply at Copan Reservoir, and 10,305 acre feet (4.57 mgd) of new storage at Copan. The three proposed water supply agreements provide 13,720 acre feet of storage to Bartlesville and would provide an additional yield of 6.4 mgd through year 2035 for immediate use.

(3) Alternative 3: Reallocate Flood Pool at Hulah and Copan Reservoirs. This alternative evaluated multiple flood control to water supply reallocation scenarios. Alternative #3 also evaluated potential upstream environmental impact costs and downstream flood control benefits foregone.

(4) Alternative 4: Private Sand Lake Reservoir with pipeline to Hudson Lake. This alternative assumes no Federal Authorization. This alternative evaluated Sand Lake as a non-Federally constructed lake and water supply source. It also included evaluation of costs for construction of a pipeline to the city owned Lake Hudson.

(5) Alternative 5: Purchase water supply storage from Kaw Reservoir with Pipeline to Hudson Lake. This alternative evaluated Kaw Reservoir as a water supply source, including development of costs for constructing a pipeline to Lake Hudson.

d. Evaluation of Alternatives

(1) Alternative #1 - No Action Alternative. The 2006 Hulah and Copan Reallocation study indicated that the City of Bartlesville has 6.4 mgd of dependable yield through year 2035 using historical data for the 50 year drought of record and the latest 2002 sediment survey. Based on the latest 2002 sediment survey, assuming no measurable protection measures are enacted, the dependable yield is projected to decline from 6.4 mgd in year 2035 to 4.35 mgd by year 2055. *Given the water needs assessment of 14.8 mgd projected by IWR Main, an additional 10.45 mgd of new water sources will be required in 2055.*

(2) Alternative #2 - Implement Hulah-Copan Reallocation Report Water Supply Agreements. The April 2006 Reallocation Study and new water supply agreements would provide through year 2035, 1,230 acre-feet (0.82 mgd) of new storage at Hulah Reservoir, 2,185 acre-feet (0.97mgd) of originally authorized water supply at Copan Reservoir, and 10,305 acre feet (4.57 mgd) of new storage that was reallocated from water quality at Copan. The three proposed water supply agreements provided an additional 13,720 acre-feet of storage to Bartlesville and would provide an additional yield of 6.4 mgd through year 2035. Added to their existing contracts for water supply at Hulah Lake, that provides the city with 12.74 mgd through

2035 which is sufficient to meet their needs through 2035. Because of continued sedimentation of the lakes, the water supply storage available will continue to decline as will the water supply yield. The evaluation of yield for 2055 indicates that that yield available at Hulah and Copan Lakes will total 6.85 mgd and will not be sufficient to meet demand projections of 14.8 mgd as projected by IWR Main through year 2055. *Assuming a water demand of 14.8 mgd and a dependable yield of 6.85, Bartlesville will still have a deficiency 7.95 mgd by year 2055.*

(3) Alternative #3 - Reallocate Flood Pool At Hulah And Copan. This option investigated the potential water available from a future reallocation of the flood pool to water supply at Hulah and Copan Reservoirs. Table 10 provides a multiple list of water supply yields that would be available from potential future reallocations from flood control storage to water supply. The yields shown for each alternative include both the yield from originally authorized water supply storage and the yield which would result from the storage identified in the April 2006 Reallocation Report. Any reallocation of storage from flood control, and any associated water supply contracts, would require that the storage reallocated as a result of the April 2006 report be contracted for first, before any additional reallocation could be approved. The alternatives evaluated reallocating some percentage of flood control storage (1%, 2.5%, 5%, and 10%) at either Hulah Lake alone, at Copan Lakes alone, or at both lakes.

The criteria used in selecting alternatives to carry forward was that the total yield had to meet or exceed 14.8 mgd. Alternatives 3A, 3B, 3F, and 3G were rejected because they did not meet the minimum yield required. Alternative E was rejected because it had significantly more yield than was needed. Alternative 3H was rejected because it provided a greater yield than was needed and utilized more flood control storage than did similar Alternative3 I. Alternative 3C provided a total yield of 16.76 mgd while requiring reallocation of 5% of the flood control storage at both Hulah and Copan Lakes. Alternative 3D provided a total yield of 15.07 while requiring reallocation of 10% of the flood control storage at Hulah Lake and no changes at Copan Lake. Alternative 3I provided 16.36 mgd while requiring reallocation of 1% of the flood control storage at Hulah Lake and 10% of the flood control storage at Copan Lake. Each of those 3 alternatives, Alternatives 3C, 3D, and 3I, met the selection criteria and were carried forward for more detailed study.

Table 5
HULAH AND COPAN
REALLOCATION ALTERNATIVES

| Alternative Option | Relocations Options Hulah and Copan | Total Available Yield Hulah (mgd)* | Total Available Yield Copan (mgd)* | TOTAL YIELD (mgd)* |
|---|---|---|---|---|
| *3A* | 2.5% FC Reallocation at Hulah and Copan | 6.21 | 6.88 | 13.09 |
| *3B* | 5.0% FC Reallocation at Hulah<br>Existing WS at Copan | 8.51 | 0.88 | 9.39 |
| *3C* | 5.0% FC Reallocation at Hulah and Copan | 8.33 | 8.43 | 16.76 |
| *3D* | 10.0% FC Reallocation at Hulah<br>Existing WS at Copan | 14.19 | 0.88 | 15.07 |
| *3E* | 10.0% FC Reallocation at Hulah and Copan | 13.75 | 11.47 | 25.22 |
| *3F* | Existing WS at Hulah<br>10% FC Reallocation at Copan | 4.35 | 5.79 | **10.14 |
| *3G* | 2.5% FC Reallocation at Hulah<br>5% Reallocation at Copan | 6.18 | 8.43 | 14.61 |
| *3H* | 2.5% FC Reallocation at Hulah<br>10% FC Reallocation at Copan | 6.06 | 11.47 | 17.53 |
| *3I* | 1% FC Reallocation at Hulah<br>10.0% FC Reallocation at Copan | 4.89 | 11.47 | 16.36 |

(4) Selected Flood Pool Reallocation Alternatives. Table 6 identifies that Bartlesville could obtain sufficient water supply to meet the projected demand of 14.8 mgd through a reallocation of the flood control pool at Hulah and Copan Reservoirs. Alternatives 3C, 3D, and 3I are summarized in Table 6.

*Table 6*
*REALLOCATION ALTERNATIVES*

| *Alternative* | **RelocationsOptions Hulah and Copan** | **TotalYield Hulah (mgd)*** | **Total Yield Copan (mgd)*** | **Total Yield (mgd)** |
|---|---|---|---|---|
| ***3C*** | 5.0% FC Reallocation at Hulah and Copan | 8.33 | 8.43 | 16.76 |
| ***3D*** | 10.0% FC Reallocation at Hulah Existing WS at Copan | 14.19 | 0.88 | 15.07 |
| ***3I*** | 1% FC Reallocation at Hulah, 10.0% FC Reallocation at Copan | 4.89 | 11.47 | 16.36 |

(5) Reallocation Alternative Cost Summary. Reallocating from flood control would require additional water supply contracts to reimburse the government for the investment in flood control storage given up in the reallocation and for other impacts. Those costs include both environmental and physical costs, both of which were estimated for this study. Costs that were considered include pipeline costs from Copan to Lake Hudson, pipeline energy costs, additional storage costs, costs associated with upstream and downstream environmental and cultural resource impacts, upstream replacement costs of capital improvements within the new conservation pool, and downstream flood benefits that would be foregone over the study period.

(6) Alternative 3C - evaluated reallocating 5.0% of the flood control storage at both Hulah and Copan Lakes. This alternative would increase the conservation pool at Hulah from elevation 733.0 to 736.67 feet. For Copan the conservation pool would increase from elevation 710.0 to 711.99. The total estimated cost for this alternative was about $54.7 million (M). The majority of this cost was from pipeline costs from Copan ($25 M) and additional water supply storage costs ($27.2 M). Upstream replacement costs to replace reservoir facilities, mineral leasehold interests, and also to mitigate cultural and environmental assets was estimated at $2.3 million. Somewhat surprising was that the flood control benefits foregone where rather small in relation to the overall projected cost for this alternative. The flood control benefits foregone can be expressed as an increase in average annual damages from the current, or baseline, condition. The increase in average annual damages for Alternative 3C is $ 10,090. The present value of the total damages that could be anticipated over the 50 year study period is estimated to be $188,000.

(7) Alternative 3D - evaluated reallocation of 10% of the flood pool at Hulah Lake, and no changes at Copan Lake. The conservation pool would increase from elevation 733.0 to 739.46 feet at Hulah with no change in the current conservation pool elevation of 710.0 at Copan. The total cost for this alternative was $56.5 M, which was slightly higher than alternative 3C. Pipeline construction and energy costs for the pipeline was slightly greater at $26.8 M, due to necessary pipeline improvements. Water supply storage costs were estimated at $20.8 M, about $6.4 M less than alternative 3C. Storage costs were less because storage costs are a partial function of the initial costs to build Hulah and Copan reservoirs. However, a large change in the conservation pool from elevation 733.0 to 739.46 would result in significantly more upstream replacement of reservoir facilities and environmental mitigation; the total cost was estimated to be $8.6 M. Downstream flood benefits foregone increased the average annual damages by $11,920. The present value of the total damages that could be anticipated over the 50 year study period is estimated to be $222,000

(8) Alternative 3I - evaluated reallocation of 1% of the flood pool at Hulah Lake and a 10% reallocation at Copan Lake. Pipeline and energy costs were $26.5 M. Storage Costs were higher at $37.6 M because of the higher initial construction costs of Copan compared to Hulah. Upstream reservoir replacement costs and environmental mitigation was much lower however and was estimated to be $605,000. Downstream flood benefits foregone increased the average annual damages by $9,044, the least impact of any of the alternatives. The present value of the total damages that could be anticipated over the 50 year study period is estimated to be $176,000

(9) Alternative 4: Private Sand Lake Reservoir with pipeline to Hudson Lake. This alternative assumes no Federal Authorization. Alternative 4 investigated potential sites for non-Federal development of a water supply project at or near the deauthorized Sand Lake site. The location of the previously studied site is about 8.5 miles west and 1.5 miles south of Bartlesville on Sand Creek in Osage County, just upstream of the Town of Okesa. The sit is heavily wooded and the normal pool would back water upstream along Sand Creek past a Boy Scout Camp and Osage Hills State Park. A brief site visit identified that some portions of the park would be permanently inundated by the conservations pool and additional facilities would be temporarily inundated during flood events. Given the concerns identified, a very preliminary search was conducted to see if any other potential locations upstream of the Federal Authorized lake on Sand Creek could be suitable and provide the necessary water supply source to minimize construction costs.

The yield at the deauthorized site was projected to be about 12 mgd. Added to the yield available through the city's existing contract at Hulah Lake or 4.35, that would provide the city with a total of 16.35 mgd which meets the 2055 needs.

The total estimated first cost for this alternative is about $86 M. A breakdown of these costs reveals pipeline construction costs of $23.9 M, with energy costs over a 50 year period of $10.5 M, reservoir construction costs of $32.8 M, land acquisition and relocation costs of $7.6 M, and with contingencies of $10 M. Environmental and cultural impacts analysis costs were estimated at $900,000, but environmental and cultural resources costs were not evaluated and could be significant, as could the costs associated with acquisition of mineral rights.

(10) Alternative 5: Purchase water supply storage from Kaw Reservoir with Pipeline to Hudson Lake Alternative 5 investigated the purchase of water supply storage from Kaw Reservoir and the cost to build a Pipeline to the city owned Hudson Lake. The city's net need of 10.45 mgd is available from Kaw Lake and the estimated cost of a contract for water supply storage at Kaw Lake is $4.8 M.

The cost of this alternative is estimated to be about $106 M, including pipeline construction costs of $86 M, energy costs of $14 M over a 50 year period, and the $4.8 M cost of storage at Kaw Lake. Cost to assess the environmental and cultural impacts is estimated at $200,000, but costs to mitigate for those impacts were not specifically and could increase the $106 M estimate for this alternative.

e. **Summary of Water Supply Alternatives.** This study looked at multiple alternatives to meet the city of Bartlesville's long term water supply needs. The first two alternatives looked at the existing water supply sources to estimate the available yield through year 2055. Alternative # 1 identified a 2055 daily average yield of 4.35 from existing water supply from Hulah Reservoir. Alternative #2 evaluated the water supply yield available through year 2055 assuming that new water supply agreements outlined in the 2006 Hulah and Copan Reallocation study are implemented. This alternative provided sufficient water supply to meet year 2035 water supply demand, but was insufficient to meet projected demand through year 2055. Alternative #2 identified a projected average daily yield of 6.85 mgd through year 2055.

Alternatives 3C, 3D, 3I, 4, and 5 will all supply sufficient water supply to meet 2055 demand requirements. Alternative 3C, 3D, and 3I analyzed reallocation of the flood control pool to water supply at Hulah and Copan lakes. Alternative 4 evaluated constructing a new non-Federal reservoir and pipeline in Osage County at the deauthorized Sand Lake site and

Alternative 5 evaluated water supply and pipeline costs from Kaw reservoir. The table below summarizes the potential costs for Alternatives 3C, 3D, 3I, 4 and 5.

| Option | Water Source | Total New Storage Ac-Ft | Total Yield mgd | Total Pipeline Cost Plus Present Value 50 Year Energy Costs | Total Water Supply Storage Cost | Upstream Reservoir & Environment Mitigation | PV of Downstream Reservoir Flood Damages | Total Alternative Cost |
|---|---|---|---|---|---|---|---|---|
| *3C* | 5% FLOOD POOL + WQ REALLOCATION AT HULAH & COPAN | 22,131 | 16.76 | $24,965,845 | $27,253,140 | $2,312,000 | $188,000 | $54,718,988 |
| *3D* | 10% Flood Pool + WQ REALLOCATION AT HULAH & 0% REALLOCATION AT COPAN | 27,354 | 15.07 | $26,827,593 | $20,796,700 | $8,627,000 | $222,000 | $56,473,293 |
| *3I* | 1% FLOOD POOL + WQ REALLOCATION AT HULAH & 10% REALLOCATION AT COPAN | 20,524 | 16.36 | $26,533,348 | $37,593,486 | $605,000 | $176,000 | $64,927,834 |
| *4* | SAND LAKE | 30,479 | 14.80 | $34,561,484 | $50,511,250 | $900,000* | $0 | $85,972,734* |
| *5* | KAW RESERVOIR | 10,710 | 14.80 | $100,832,244 | $4,788,731 | $200,000* | $0 | $105,820,975** |

* Costs do not include mitigation or costs of other environmental or cultural resource impacts and do not include costs associated with the acquisition of mineral rights.
** Costs do not include mitigation or costs of other environmental or cultural resource impacts

## 10. RECOMMENDATIONS

Increasing future demand for adequate water is being recognized as a high priority for many municipalities. It is a complex issue that has many variables to consider. Assumptions related to supply and demand, economic construction costs, environmental impacts, land and easement costs, and reallocation of project purposes from flood control to water supply all impact the final projected cost for each alternative.

For the near term, through year 2035, the approval of new water supply agreements that reallocate storage from water quality to water supply at Hulah and Copan Lakes would provide 7.2 mgd from Hulah and 5.54 mgd from Copan. A total of about 12.74 mgd would be added to the water supply available for the City of Bartlesville, to meet demand through year 2035.

For the longer term, to year 2055, information has been presented for Bartlesville to make an informed long term water supply decision. Based on the evaluation of the costs of the alternatives presented in this study, a future reallocation of the flood pool from both Hulah and Copan appears to be the least costly alternative. These costs would be analyzed in more detail as part of any future flood pool reallocation study. The least costly alternative is alternative 3C, reallocating 5% from the flood pool at both Hulah and Copan lakes.

Downstream flood damage increases were not significant to the final alternative costs. In addition, the buyout of homes and/or businesses highly susceptible to recurrent flood damages could also be effective in reducing flood damages. The costs associated with a flood plain buyout should be looked at in more detail if reallocation of storage from the flood pool is pursued.

# APPENDIX A

# Letter Agreement

## LETTER AGREEMENT
## PLANNING ASSISTANCE TO STATES

# CITY OF BARTLESVILLE

# BARTLESVILLE WATER SUPPLY AND CONVEYANCE STUDY

THIS AGREEMENT, entered into this ____ day of____, 2006, by and between the United States of America (hereinafter called the "Government"), represented by the District Engineer for the Tulsa District, U.S. Army Corps of Engineers; and the City of Bartlesville (hereinafter called the "Sponsor").

WITNESSETH, THAT

WHEREAS, Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251), as amended, authorizes the Secretary of the Army, acting through the Chief of Engineers, to assist the states in the preparation of comprehensive plans for the development, utilization and conservation of water and related land resources; and

WHEREAS, Section 319 of the Water Resources Development Act of 1990 (Public Law 101-640) authorizes the Secretary of the Army to collect from non-Federal entities fees for the purpose of recovering 50 percent of the cost of the program established by Section 22; and

WHEREAS, the Sponsor has reviewed the State's comprehensive water plans and identified the need for planning assistance as described in the Scope of Studies incorporated into this Agreement; and

WHEREAS, the Sponsor has the authority and capability to furnish the cooperation hereinafter set forth and is willing to participate in the study cost-sharing and financing in accordance with the terms of this Agreement;

NOW THEREFORE, the parties do mutually agree as follows:

1. The Government, using funds contributed by the Sponsor and appropriated by the Congress, shall expeditiously prosecute an investigation of potential surface water sources of water supply conveyance systems for the City of Bartlesville, substantially in compliance with Scope of Work attached as Appendix A and in conformity with applicable Federal laws and regulations and mutually acceptable standards of engineering practice. Three alternatives will be developed with the input of the Sponsor that address the present and future water supply needs of the City of Bartlesville and its customers. Alternatives

include supplemental supply from Kaw Lake and additional supply from Hulah and Copan lakes.

2. The Government shall contribute in cash 50 percent of the total study cost, and the Sponsor shall contribute in cash and work-in-kind 50 percent of the total study cost, which total study cost is $245,000; provided, that the Government shall not obligate any cash contribution toward Study costs, until such cash contribution has actually been made available to it by the Sponsor. The Sponsor agrees to provide $_30,000__ in-kind services and funds in the amount of $_92,500__ which shall be made payable to the Finance and Accounting Officer, Tulsa District, 1645 South 101 East Avenue, Tulsa, Oklahoma 74128-4609.

3. No Federal funds may be used to meet the local Sponsor's share of study costs under this Agreement unless the expenditure of such funds is expressly authorized by statute as verified by the granting agency.

4. Before any Party to this Agreement may bring suit in any court concerning any issues relating to this Agreement, such party must first seek in good faith to resolve the issue through negotiation or other form of nonbinding alternative dispute resolution mutually acceptable to the Parties.

5. This Agreement shall terminate upon the completion of the Study; provided, that prior to such time and upon thirty (30) days written notice, either party may terminate or suspend this Agreement without penalty. It is further understood and agreed that if the Study is not completed by December 30, 2007, or cannot be completed within the total study cost of $245,000, this Agreement may be renewed or amended by the mutual written agreement of the parties.

6. Within ninety days after termination of this Agreement, the Government shall prepare a final accounting of the study costs, which shall display (1) cash contributions by the Federal Government, (2) cash and work-in-kind contributions by the Sponsor, and (3) disbursements by the Government of all funds. Subject to the availability of funds, within thirty days after the final accounting, the Government shall reimburse the Sponsor for non-Federal cash contributions that exceed the Sponsor's required share of the total study costs. Within thirty days after the final accounting, the Sponsor shall provide the Government any cash contributions required to meet the Sponsor's required share of the total study costs.

7. In the event that any (one or more) of the provisions of this Agreement is found to be invalid, illegal, or unenforceable by a court of competent jurisdiction, the validity of the remaining provisions shall not in any way be affected or impaired and shall continue in effect until the Agreement is completed.

8. This Agreement shall become effective upon the signature of both Parties.

FOR THE SPONSOR:

By:______________________________

Julie Daniels,
Mayor
City of Bartlesville, Oklahoma

Date:_______________

FOR THE GOVERNMENT:

By:___________________________

Miroslav P. Kurka
Colonel, U.S. Army
District Commander

Date:_______________

Attest:

By:______________________________
Secretary

Date:_______________

(Seal)

FOR THE OKLAHOMA WATER RESOURCES BOARD (OWRB):

The OWRB hereby attests that this Planning Assistance to States study, to investigate water supply needs and alternatives for the City of Bartlesville and its service area, and promotes the goals and objectives of the State of Oklahoma Water Plan.

By:______________________________
Rudolf J. Herrmann,
Chairman
Oklahoma Water Resources Board

Date:_______________

Attest:

By: ______________________________
Bill Secrest, Secretary

Date:_______________
(Seal)

# APPENDIX A

# SCOPE OF STUDY
# PLANNING ASSISTANCE TO STATES
# BARTLESVILLE WATER SUPPLY AND CONVEYANCE STUDY

## BARTLESVILLE, OKLAHOMA

1. GENERAL. The Corps shall investigate potential water supply sources for the City of Bartlesville. The evaluation shall define the City of Bartlesville water supply needs through year 2055, provide an evaluation of water conservation measures that could be implemented upstream of Hulah and Copan watersheds, and further analyze additional water supply options from Hulah, Copan, and Kaw Lakes. A quantitative analysis of future municipal and industrial water needs for the City of Bartlesville and its customers shall be conducted. Differing growth scenarios shall be evaluated to determine the most likely future water needs of the City of Bartlesville and its customers. This study is being conducted under authority given in Section 22 of the 1974 Water Resources Development Act, Planning Assistance to States Program. The information developed as a result of this study will enable the determination of the amount and cost of water available for water supply from the respective sources.

2. WORK TO BE PERFORMED. The Corps PAS study Shall develop, with sponsor input, the present and future water supply demand and net water supply needs of the City of Bartlesville and its customers.

*Once the City of Bartlesville water supply needs through year 2055 are determined (as outlined in Task a. below, a determination shall be made by City of Bartlesville officials as to the level of effort required for remaining tasks (Tasks b, c, & d outlined below) to be completed.. The sponsor shall identify how future funding will be allocated for the remaining study tasks, upon acceptance of the defined water needs identified in Task a, below. If required, a revision of the scope of work for the remaining tasks shall also be completed.*

Primary water supply options to be studied include supplemental water supply from Kaw

Lake and reallocation of water from flood control storage to water supply at Hulah and/or Copan Lake. If upon review by City of Bartlesville and Corps officials, it is determined that Copan Lake and/or Kaw Lake water is considered a viable alternative, engineering pipeline costs for transport of Copan and or Kaw Lake water to Hulah and/or Hudson Lake shall be studied. A fourth study measure shall be to define conservation measures that reduce the sediment load and prolong the available water supply yield through year 2055 for Hulah and Copan Lakes. Tasks necessary to complete the scope of work include:

a. Define Future Needs of Bartlesville And Its Service Area. Based on existing 2006 conditions and in coordination with the Sponsor and other interests in the service area, projections of future water demands shall be made. Categories for users are residential, commercial, industrial, public, and other uses, including losses; however, other categories or subcategories may be developed as required during the conduct of the study. Demographic and economic variables, such as population, employment by North American Industry Classification System (NAICS), housing density, and median household income, shall be used as a basis for projecting future water needs. Types of commercial and industrial use shall be categorized by NAICS Classification. The Institute for Water Resources Municipal and Industrial Needs (IWR-MAIN) Water Demand Management Suite software shall be used to forecast future water needs. Water Conservation shall also be considered in the analysis.

b. Evaluate the engineering and environmental pipeline costs that would be required for purchasing water supply storage from Kaw and Copan Lakes.

(1) Prepare Preliminary Engineering Estimates. The Corps shall review and update existing engineering planning details for water supply delivery alternatives from Kaw Lake and Copan Lake. The routes to be studied will be reviewed with City of Bartlesville representative's prior initiation of this task. It is anticipated that the selected pipeline routes from Kaw and Copan reservoirs shall be to Lake Hudson (or intersect with the existing Hulah pipeline from Hulah Lake to Lake Hudson.) Costs of alternative water supply sources from previous Corps reallocation studies will be used and referred to in preparing preliminary engineering planning revisions. The engineering planning tasks shall update preliminary engineering costs Kaw and Copan water supply alternatives.

(2) Environmental Studies

(a) Endangered Species Coordination. The Corps shall coordinate the study of Kaw and Copan pipeline routes with the United States Fish and Wildlife Service and the Oklahoma Department of Wildlife Conservation Service to learn the impacts, if any, on any listed endangered species. If endangered species are found in the project area, the Corps shall recommend that the Sponsor conduct a biological assessment and possibly formal consultation.

(b) NEPA and Other Environmental Requirements. The Corps shall discuss, in narrative format, National Environmental Policy Act (NEPA) and other environmental requirements that the Sponsor will need to address prior to development of detailed engineering designs. The Corps shall also prepare discussion concerning the requirements for future coordination with Federal, State, and local agencies having legislative and administrative responsibilities for environmental protection.

(3) Real Estate Studies

(a) Real estate activities necessary for the project consist of all tasks related to determining general real estate requirements and identifying and providing general real estate cost estimates.

(b) The Corps shall conduct a limited gross appraisal of the selected alternatives to decide the estimated real estate costs and estates purchase requirements, i.e., fee or type of easement. The Corps shall use available maps of the study area that contain sufficient detail to identify the types of land and improvements that the proposed project would affect. The Corps shall briefly search the local real estate market to gather data concerning a sample of recent sales of improved and unimproved properties comparable to the right-of-way required. The research may involve searching deed records and contacting local appraisers, brokers, attorneys, central appraisal district, and others knowledgeable of the local real estate market. The Corps shall use the market information as a basis for the values of the various types of properties within the proposed project. Cost information shall be incorporated into the MCACES cost estimate.

(4) Prepare Cost Estimates. Cost estimates shall be provided that include preliminary engineering costs, real estate costs, environmental costs, operations and maintenance costs, and cost per 1,000 gallons of water for Kaw and Copan reservoir alternative.

c. Estimate the environmental and flood benefit losses that would be incurred for reallocating part of the flood control pool in Hulah and Copan Lake to water supply storage, dependent on net needs identified in task 1a.

(1) Upstream Flood Pool Losses Depending on the water needs identified in task (a); NEPA, environmental, cultural and real estate (structures, roads, buildings etc.) impacts will be estimated upstream in the conservation and flood pool. These costs will be analyzed upstream of Hulah and or Copan Lake depending on water needs identified. This review shall look for primary impact areas affected by the normal and seasonal conservation pool raise and will provide an evaluation of environmental, cultural, and economic losses incurred upstream/in-lake in the conservation pool area.

(2) Downstream Flood Damages Depending on the water needs identified to be reallocated from flood control in task (a), flood damages will be estimated downstream from Hulah and Copan lakes based on flood pool changes. Economic flood control losses will be determined for Hulah and Copan. Depending on the demand needed the collective combined losses from a flood control reallocation from both lakes will also be estimated. This review will provide a cost estimate of flood benefit losses.

d. Water Supply Initiatives and Conservation Measures for Hulah & Copan and the City of Bartlesville

(1) Evaluate the feasibility and costs associated with studying potential actions to lengthen the longevity and viability of Hulah and Copan Lakes. Possible study actions include dredging to remove silt accumulations; in-stream silt traps, erosion control for adjacent uplands, natural stream restoration on tributaries to restore stability and thus reduce sedimentation.

(2) Evaluate the potential of stream restoration and watershed Natural Resource Conservation Service (NRCS) impoundments on Caney River tributaries upstream from Bartlesville, and tributaries that flow into Hulah and Copan Lakes, to compensate for reduced flood control on Hulah and Copan Lakes resulting from potential reallocation of some flood control storage to water supply.

(3) Institutional Analysis. Focusing on addressing Hulah and Copan Reservoirs, the study will review existing authorities, agreements and other basin-wide institutional arrangements that could be used to address water supply related issues. The review will include local, state, and federal memorandums of agreement, compacts, regulations, and laws. Water supply issues include such as stream flow, inflow of nutrients and control of sediments into the lake which impact the quality and quantify of water in the lake for the purposes of water supply. The study will outline how those existing institutional arrangements might be used to develop best management practices in the basins above these two reservoirs, including areas in the State of Kansas.

e. Project Management.

(1) This work item shall include all scheduling and organizing of the study; regular periodic meetings with technical elements to review progress; preparing budget documentation; monitoring and managing all funds being obligated and expended; preparing project-related correspondence; coordinating with Federal, Tribal, State, and local agencies; and providing guidance and support as required to ensure that they have answered all questions and they have solved all study-related problems. The Corps shall do this task for the duration of the study.

(2) The Corps shall manage the tasks associated with overall

coordination of the various study work items including funds management and work item scheduling. The overall purpose of this work item is to ensure that the study shall accomplish the goals established, maintain schedule and cost estimates, and address all items in the Scope of Study.

f. Report Preparation.

(1) Report preparation shall consist of preparing a draft report, duplicating and distributing the draft report, reviewing and editing the draft report to final form, and then duplicating and distributing the final report. The report will be direct, concise, and written in a style that is easy to understand and may include graphics, illustrations, and photographs. The report shall also include the study findings and recommendations.

(2) The Corps shall document the study results in report form. The Corps shall base the report on all studies and investigations conducted and on published reports applicable to the study area.

3. DATA TO BE PROVIDED BY NON FEDERAL SPONSOR

The City of Bartlesville shall provide all data available and related to water availability and water use in the study area. The demand for water study area includes the City of Bartlesville and its customers in Washington, Osage, and Nowata counties, Oklahoma. The City shall provide data and information about the current monthly water usage by major use category, as explained below, and the capability of the existing and planned future supply/treatment facilities. Specific information to be gathered shall include:

Name of customer, or user, and service area
Description of distribution system
Location, capacity, and description of treatment facilities
Cost of water, price to consumers
Quantity of water used by month and major use category, if available

4. DELIVERY AND SCHEDULE.

(a) Draft Document. The Corps shall provide a draft copy of the report to the Sponsor and Oklahoma Water Resources Board. The report shall include discussion concerning methodology, data sources, findings, and other appropriate data for review and approval. The report shall identify all data sources and references.

(b) Final Document. Upon the Sponsor's approval and return of the edited draft to the Corps, the Corps shall furnish the final original document to the Sponsor.

(c) Meetings and Conferences. The Corps and the Sponsor shall hold meetings, either face-to-face or through telephone conference calls as needed upon request to discuss problems as identified.

(d) Schedule. The Corps shall submit the above items according to the following schedule.

| Item | Schedule |
|---|---|
| Task (a) Water Supply & Conveyance Study | 120 Calendar days after the date of the receipt of funds. |
| Task (a) Water Supply & Conveyance Draft Document | 150 Days after receipt of Funds |
| Task (a) Water Supply & Conveyance Draft Sponsor Review | 180 Days after Receipt of Funds |
| DECISION POINT* | |
| Task (b) Engineering Kaw and or Copan Pipeline Evaluation | 330 Days after Receipt of Funds |
| Task (c) Estimate Environmental and Flood benefit losses for reallocation of flood pool at Hulah and/or Copan. | 330 Days after Receipt of Funds |
| Task (d) Water Supply Initiatives and Conservation Measures | 330 Days after Receipt of Funds |
| Final Document | 360 Days after Receipt of Funds |

* THE CITY OF BARTLESVILLE WILL REVIEW TASK (a) WITH THE CORPS OF ENGEENERS AND DISCUSS POTENTIAL SCOPE MODIFICATIONS AS TO THE LEVEL OF EFFORT REQUIRED FOR THE REMAINING SCOPE OF WORK TASKS. REMAINING TASKS (b,c,&d)SHALL NOT START UNTIL THIS DECISION POINT IS FINALIZED AND APPROVED BY THE CITY OF BARTLESVILLE AND THE CORPS OF ENGINEERS. THERE WILL BE NO NET CHANGE IN THE TOTAL STUDY COST.

(e) Coordination. The Corps of Engineers shall maintain a close working relationship with the City of Bartlesville and its representative throughout the execution of the study.

(f) Report and Documentation. The computation and procedures used in this study shall be documented in a final report. The report shall include pertinent table, graphs, plots, maps, and other related documents.

(g) Review. All computations shall be reviewed by qualified personnel for soundness and legitimacy. All comments and discussion shall be documented and included as part of the study file.

(h) Final Delivery. Final delivery shall include a bound report and documentation along with a CD or DVD with all computations and backup data.

5. PROJECT MANAGER

The Government manager for this contract shall be Ms. Cynthia Kitchens, Project Manager for the Planning Assistance to States Program, Programs and Project Management Division, Tulsa District, U.S. Army Corps of Engineers. Questions or problems that may arise during the performance of the work specified in this Agreement shall be discussed with Ms Kitchens. The Sponsor shall coordinate entry clearance with Ms. Kitchens before planning site or office visits. The Sponsor shall appoint a project coordinator to serve as a single point of contact or liaison with the Corps of Engineers. The name of the individual so designated shall be furnished in writing to the Corps. The project coordinator shall be responsible for complete coordination of the work.

# APPENDIX B

## TIME AND COST ESTIMATE
## PLANNING ASSISTANCE TO STATES

## WATER SUPPLY AND CONVEYANCE STUDY
## BARTLESVILLE AREA, OKLAHOMA

| Study Item | Duration (Workdays) | Cost ($) |
|---|---|---|
| Water Supply Needs And Conservation Measures | 180 | 50,000 |
| 2. Preliminary Planning-Copan to Lake Hudson | 330 | 70,000 |
| 3. Preliminary Planning-Kaw Lake to Lake Hudson | 330 | 50,000 |
| 4. Evaluate Hulah/Copan upstream restoration measures | 330 | 25,000 |
| 5. Report Preparation and Study Management | 360 | 50,000 |
| Total PAS Project Cost | | 245,000 |

# APPENDIX B

# Water Supply Needs Analysis

APPENDIX B

Water Supply Needs Analysis

# Phase I
## Introduction

**Background.** Phase I of a two-phase study effort was completed in March 2007. This first phase determined future net water needs for the City of Bartlesville and the surrounding communities, rural water systems, and other areas to which the City provides water. The first phase contains an estimate of future demand for water based on three different population growth scenarios Washington County could experience from 2005 to 2055, with year 2005 representing the base year. The City of Bartlesville expects population growth in the city and in Washington County to occur at a much faster rate than historic growth. Population forecast scenarios were made for the City of Bartlesville, two rural water districts the City supplies, and Washington County. The City supplies water to approximately 99% of the residents in Washington County. Since nearly all of the water demands in Washington County are supplied by the City of Bartlesville, forecasts are based on Washington County data.

## Water Demand

**Introduction.** Estimates of the quantities of water needed in the future require the use of appropriate econometric models. These models are used to project future water use that is statistically consistent with long-term water supply planning. In order to forecast Municipal & Industrial (M&I) water demand the Institute for Water Resources-Municipal and Industrial Needs (IWR-MAIN) Water Demand Management Suite, a Windows based PC software package, was used to translate existing population, housing, and employment into estimates of existing water demands for the 2005 base year. These base year estimates are then used to fine-tune the water use equations for translating the long-term projections of population, housing, and employment into disaggregated forecasts of water use. Washington County is the basic study area unit for forecasting water demand due to the availability of demographic data for the county and for the sub-sectors as well. Actual water use data for year 2005 was supplied by the City of Bartlesville and included Washington County and the City of Dewey. Some of the included rural water districts may overlap into neighboring counties. Residential and non-residential are the major water use sectors specified within IWR-MAIN. The residential sector includes both single-family and multi-family sub-sectors. The non-residential sector includes the sub-sectors of commercial, manufacturing, and government. The commercial sub-sector includes construction, transportation, wholesale, retail, finance, and services. The public use sector and unaccounted for water use are also included in the evaluation.

**Projection Scenarios**. Three water demand scenarios were presented to the Water Resource Committee of Bartlesville. The Baseline Projection Scenario is based on historical growth and weather pattern trends experienced in the study area. Due to the fact that the population of Washington County has not increased significantly over the past ten years, the baseline water demand forecasts have not deviated from the base year by a substantial amount. The baseline projection is based on a 2055 population of 53,000 in Washington County.

The City of Bartlesville provided information on actual water use for the base year 2005. This information was disaggregated into different sectors of water use such as residential, municipal, industrial, commercial, water districts, and public schools. In addition to this, the City also provided information on population and housing projections for years 2000-2050. This data was then used to develop a high growth scenario for the water system that Bartlesville supplies. The City developed these growth projections based on the current level and pace of development. The water demand forecast for the high growth projection was based on a 2055 population of 73,000 and developed by the Tulsa District using the Institute of Water Resources Municipal and Industrial Needs (IWR-MAIN) forecast system. The Oklahoma Department of Commerce (ODC) provided the demographic data of population estimates as the basis for employment and housing projections. Other sources of information include, the U.S. Department of Labor, the U.S. Census, and the Oklahoma State Climate Center, and the National Weather Service.

A third projection, called the mid projection, was interpolated from the baseline and high projections. Water demand forecasts for the mid projection population were not conducted with IWR-MAIN but are derived as an average of the baseline and high-growth projections.

**Projection Scenario Variables**

The projection scenarios were developed using the following variables:

***Population***

Population is a key parameter used in IWR-MAIN to project residential water demand. In 2002, the Oklahoma Department of Commerce, under contract with the OWRB, expanded their 2000-2030 projections of the resident population of Oklahoma by county. The projections were made using a cohort component projection model. With this method, each component of the population, births, deaths, and migration, is projected separately, based on algorithms developed by the U.S. Bureau of the Census. The base population used is April 1, 2000, the date of the U.S. Census of Population and Housing count of the United States resident population. Fertility, death, and migration rates are applied to that base population to arrive at the near year projection period. For this analysis, the medium set of 5,000 person in-migration per year was used. Year 2005 was interpolated between 2000 and 2010. Table 1 shows the baseline and the high population projections for Washington County.

| Table 1: Population Projections for Washington County | | | | | | |
|---|---|---|---|---|---|---|
| **Year** | **2005** | **2015** | **2025** | **2035** | **2045** | **2055** |
| **Baseline Projection** | 48,996 | 50,300 | 51,100 | 51,600 | 52,300 | 53,000 |
| **High Projection** | 48,996 | 53,436 | 58,065 | 63,877 | 69,685 | 73,169 |

***Employment***

Commercial and industrial water use is also considered in determining current and future water demand in Washington County. IWR-MAIN projects water demand for commercial, industrial, and public use categories using the number of persons employed in a city or county by each Standard Industrial Classification (SIC) category, and, since 1997, the North American Industry Classification System (NAICS) code. Data used in IWR-MAIN utilizes the NAICS system. National water use survey data was utilized to provide water use coefficients for each industrial sector, by two or three digit code, based on the number of employees.

To project future industrial water demand, the model utilizes a linear relationship using employment and water use per employee by NAICS code. Employment in Washington County by place of work is the basic unit of analysis for projecting future water demand. Because future employment in Washington County for the 50-year projection period has not been completed by the State, a method was developed to estimate future employment using State employment data for the base year and the U.S. Census Bureau County Business Patterns and U.S. Department of Labor projections of future labor force conditions. Table 2 displays employment projections for Washington County by year.

| Table 2: Employment Projections for Washington County | | | | | | |
|---|---|---|---|---|---|---|
| **Year** | **2005** | **2015** | **2025** | **2035** | **2045** | **2055** |
| **Baseline Projection** | 16,100 | 18,330 | 20,746 | 22,625 | 23,103 | 23,530 |
| **High Projection** | 16,100 | 19,473 | 23,574 | 28,008 | 30,783 | 32,484 |

### *Housing*

Another parameter used by IWR-MAIN to project future residential water use is housing units. Data from the U.S. Bureau of Census and Housing were used to develop housing units for the 2005 base year. Because the Census is released decennially, population and housing information from 2000 was used in lieu of developing new baseline data for the year 2005. It is assumed that the person- per -household ratio will remain constant over the entire projection range. Table 3 shows the baseline and high projections for housing for Washington County.

**Table 3: Housing Projections for Washington County**

| Year | 2005 | 2015 | 2025 | 2035 | 2045 | 2055 |
|---|---|---|---|---|---|---|
| **Baseline Projection** | 22,511 | 23,110 | 23,478 | 23,707 | 24,029 | 24,351 |
| **High Projection** | 22,511 | 25,040 | 27,441 | 30,446 | 33,462 | 35,135 |

## Future Water Demand

**Introduction.** The forecasting algorithm of IWR-MAIN is built to operate on data corresponding to study areas, water use sectors/sub-sectors, months, and forecast years. The needs and data available dictate the degree of detail required to use the model. The methodology utilized is known as the "Driver Times Rate of Use." In other words, for a given study area, sector, month, and forecast year, water use can be calculated as a product of the number of users, the rate of use, and the number of days in the given month. This allows the disaggregation of a water demand forecast and permits unit water use rate, such as gallons per household, gallons per employee, etc, to be assumed or predicted via the water use model. The algorithm used in the projection of residential water demand uses persons per household, population divided by number of housing units, as well as housing density. The housing density variable is a parameter used to characterize the outdoor component of water use for the summer season

**Methodology.** The method that was selected for forecasting residential water demand uses median household income, persons per household, housing density, marginal price of water, maximum temperature, and precipitation, to adjust per unit usage rates for residential information, but not for non-residential variables. For the non-residential sector, a model for water demand was customized using values for intercept terms, model variables, and associated coefficients and elasticities. The base year per unit water use rate is calculated from the base year water use and the number of counting units for the sub-sector. This calculated rate of use is then adjusted by the relationship between sub-sector water use and those explanatory variable selected for the sub-sector, which are selected by the user and may change over time. Year-to-year changes in water use are explained by the change in the selected explanatory variables and the counting units. Counting units derived from population projections, are the driver variables, such as employee counts, housing units, acres, etc., associated with each sub-sector.

**Unaccounted Water Usage/System Losses**. The amount of unaccounted water use and system losses was calculated by taking the difference in the amount of water that Bartlesville draws to supply to the system (raw water) and the amount of water reported as being used by the City of Bartlesville for the year 2005. This calculation showed that approximately 13% of the water is not accounted for in Washington County.

**Peak Demand**. Another output IWR-Main can forecast is peak water demand. Peak use for a community can vary month to month depending mainly on temperature and rainfall. Typically record peak use will occur in the hottest summer months, because this is a period where water demand significantly increases as homeowners are watering their lawns and gardens more frequently and precipitation rates are low. The system peak use may be specified in gallons per day, thousand gallons per day, or million gallons per day. The user must select the month in which the base system peak occurs and enter the peak use value. For this study, the City of Bartlesville supplied the peak use in million gallons per day which occurred in the month of July.

**Results.** Table 4 displays the results of the water demand evaluation for the baseline projection by sector and projection year for Washington County. The baseline demand projection reflects the minimum water demand by year 2055 in order to determine net needs from water supply sources.

**Table 4: Water Demand by Sector and Year**
**Washington County**
**Baseline Projection**
**(million gallons a day)**

| Year | 2005 | 2015 | 2025 | 2035 | 2045 | 2055 |
|---|---|---|---|---|---|---|
| **Residential** | 5.89 | 6.18 | 6.20 | 6.31 | 6.30 | 6.60 |
| **Commercial** | 1.3 | 1.38 | 1.39 | 1.4 | 1.46 | 1.44 |
| **Industrial** | 0.65 | 0.71 | 0.76 | 0.81 | 0.82 | 0.827 |
| **Municipal** | 0.26 | 0.27 | 0.275 | 0.28 | 0.29 | 0.29 |
| **Unmetered/Unaccounted** | 1.2 | 1.26 | 1.28 | 1.3 | 1.33 | 1.34 |
| **Total** | 9.3 | 9.8 | 9.9 | 10.1 | 10.2 | 10.5 |

Table 5 displays the results of the water demand evaluation for the high projection by sector and projection year for Washington County. The high demand projection reflects the maximum water demand by year 2055 in order to determine net needs from water supply sources.

**Table 5: Water Demand by Sector and Year**
**Washington County**
**High Projection**
**(million gallons a day)**

| **Year** | **2005** | **2015** | **2025** | **2035** | **2045** | **2055** |
|---|---|---|---|---|---|---|
| **All Residential** | 5.9 | 6.8 | 7.4 | 8.2 | 9.0 | 9.5 |
| **Commercial** | 1.3 | 1.4 | 1.6 | 1.8 | 1.9 | 2.0 |
| **Industrial** | .65 | .76 | .83 | .93 | .98 | 1.0 |
| **Municipal** | .26 | .30 | .31 | .36 | .39 | .40 |
| **Unmetered/ Unaccounted** | 1.2 | 1.4 | 1.6 | 1.8 | 1.8 | 1.9 |
| **Total** | 9.3 | 10.7 | 11.7 | 13.1 | 14.1 | 14.8 |

On March 1, 2007, the City agreed to proceed with the water demand projections based on the mid and high population growth projections ranging from 63,000 to 73,000 by 2055, which equates to water demand in 2055 being 12.8 to 14.8 million gallons per day (mgd). Due to the uncertainty of both demand and supply 50 years in the future, a range of net needs was determined to estimate future water supply needs.

## Existing Water Supply

**Introduction.** Currently, Bartlesville obtains most of its water from Hulah Lake, which is then pumped to Hudson Lake prior to treatment. During periods of insufficient supply from Hulah Lake and Hudson Lake, water can be pumped from the Caney River under emergency conditions.

**Hulah Lake.** Hulah Lake construction started in May 1946, and was completed in February 1951 for flood control, water supply, low flow regulation, and conservation purposes. Embankment closure began in February 1950 and was completed in June 1950. Impoundment of the conservation pool began on September 23, 1951, and was completed on September 24, 1951. The project was placed in full flood control operation in September 1951.

Table 6 outlines pertinent data for Hulah Lake. Lake data is based on the 2002 sedimentation survey.

| Table 6: Hulah Lake Pertinent Data | | | | |
|---|---|---|---|---|
| **Feature** | **Elevation (feet)** | **Area (acres)** | **Capacity (acre-feet)** | **Equivalent Runoff* (inches)** |
| **Top of Dam** | 779.5 | - | - | - |
| **Top of Flood Control Pool** | 765 | 13,000 | 289,000 | 7.40 |
| **Flood Control Storage** | 733.0-765.0 | - | 257,900 | 6.61 |
| **Spillway Crest** | 740.0 | 5,160 | 61,400 | 1.57 |
| **Top of Conservation Pool** | 733.0 | 3,120 | 22,565** | 0.80 |
| **Conservation Storage** | 710.0-733.0 | - | 22,553 | 0.80 |
| **Top of Inactive Pool** | 710.0 | 0 | 12 | - |

* From a 732-square-mile drainage area above the dam site.

** Includes 16,600 acre-feet for water supply, 5,953 acre-feet for water quality control, and 12 acre-feet for sediment reserve.

**Copan Lake.** Copan reservoir construction began in November 1972, and the project was placed in useful operation in April 1983. Copan Reservoir provides flood control benefits to Bartlesville and is a second close water supply alternative that Bartlesville is considering. Copan currently has one million gallons per day (mgd) of available water supply and a reallocation of water quality storage to water supply was recommended by the Tulsa District and approved by the United States Army Corps of Engineers Headquarters (USACEHQ) in September 2007. Table 7 displays pertinent data for Copan Reservoir.

| Table 7: Copan Lake Pertinent Data | | | | |
|---|---|---|---|---|
| **Feature** | **Elevation (feet)** | **Area (acres)** | **Capacity (acre-feet)** | **Equivalent Runoff* (inches)** |
| **Top of Dam** | 745.0 | | | |
| **Maximum Pool** | 739.1 | 17,850 | 338,200 | 12.57 |
| **Top of Flood control Pool** | 732.0 | 13,380 | 227,700 | 8.45 |
| **Flood Control Storage** | 710.0-732.0 | | 184,300 | 6.84 |
| **Top of Conservation Pool** | 710.0 | 4,449 | 34,634 | 1.61 |
| **Conservation Storage** | 687.5-710.0 | | 33,887** | 1.59 |
| **Spillway Crest** | 696.5 | 1,080 | 4,700 | 0.17 |
| **Top of Inactive Pool** | 687.5 | 110 | 747 | 0.02 |

* Drainage area is 505 square miles.

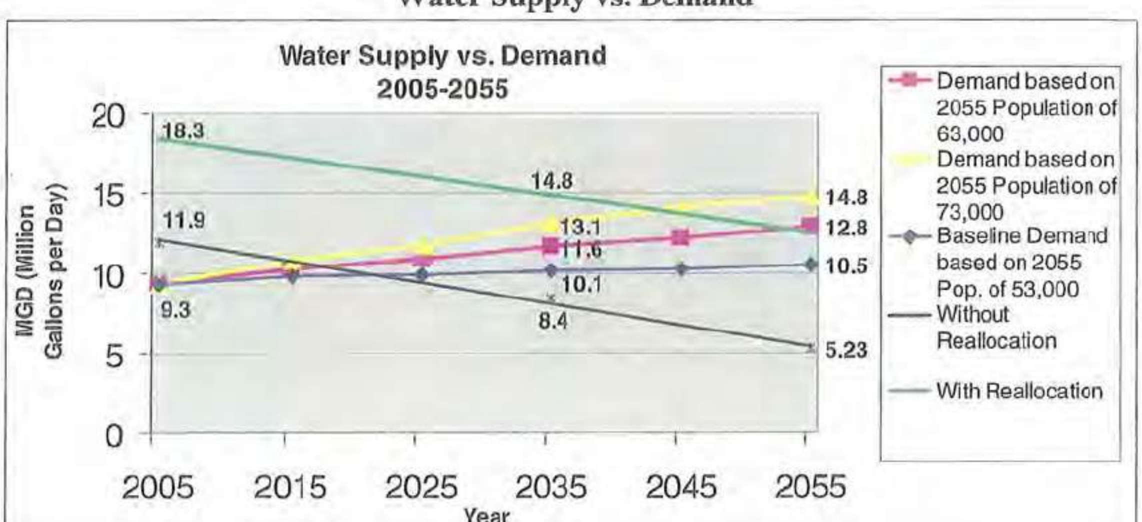
** Includes 7,500 acre-feet for water supply (3.0 mgd yield), 26,100 acre-feet for water quality control (16 mgd yield), and 9,200 acre-feet for sediment based on 1983 survey..(In year 2002, useable storage=34,634acre-feet less 747 acre-feet)

**Dependable Yield**. The Corps of Engineers' 2006 Hulah and Copan Reallocation study indicated that the City of Bartlesville has 6.4 million gallons a day (mgd) of dependable yield from Hulah Lake through year 2035 using historical data for the 50 year drought of record and the latest 2002 sediment survey for Hulah Lake. Based on the latest 2002 sediment survey, assuming no measurable reduction in the rate of sediment deposition, the dependable yield at Hulah Lake is projected to decline from 6.4 mgd in year 2035 to 4.35 mgd by year 2055. The total available water supply only yield from both reservoirs is 5.23 mgd in year 2055.

## Net Water Needs

**Results.** . Net water needs for Washington County are based on existing water supply sources for the City of Bartlesville from Hulah Lake and Hudson Lake. In addition, Copan Lake provides 2.0 mgd of water supply to the Copan Public Works Authority. Water is also obtained from the Caney River from releases at Copan Lake in emergency situations. Figure 1 shows the existing supply of water and the available supply after the recommended reallocation against the demand for water based on the three different projection scenarios by year 2055. Based on these projections, water demand will exceed available supply(depicted by the without reallocation line) beginning around year 2015 and continuing over the next 40 years if no reallocation of the existing sources of water supply or the addition of new water supply sources. The with reallocation line depicts the water supply after the recommended reallocation is complete. There, demand exceeds supply before year 2045 for the high projection demand or before 2050 for the mid projection demand. However, the baseline projection demand does not exceed the reallocation supply through the study period. Based on the population projection of 73,000 and water demand of 14.8 mgd, an additional 10.45 mgd of water will be required by year 2055.

**Figure 1:**
**Washington County**
**Water Supply vs. Demand**



# APPENDIX C

# H&H Analysis - Bartlesville PAS Water Supply Analysis for Year 2055

# APPENDIX C

## H&H Analysis
## Bartlesville PAS Water Supply Analysis for Year 2055 for the City of Bartlesville Using SUPER

The city of Bartlesville experienced a critical shortage in available water supply at Hulah Lake, beginning in the summer of 2001. The lake experienced a drawdown to 20 percent of the conservation pool by early April 2002. Fortunately, the pool filled with a large, single event in early May 2002. The drought conditions prompted the city to investigate and possibly develop other sources of water supply to meet future water supply demands.

The City of Bartlesville has estimated their regional water supply need to be 14.8 mgd through 2055. Current yield projections show that without any reallocations the city will have 4.35 mgd of yield available at Hulah and 0.88 mgd of yield available at Copan, for a combined yield of 5.23 mgd through 2055. This combined yield will not meet Bartlesville's future requirements. This portion of the study provides yield analysis for reallocating various portions of flood control storage at both Hulah and Copan Lakes, and looks at the sensitivity of the yields developed, since there is a degree of uncertainty with developing projections and yields this far into the future. Therefore, this study looks at specific, possible alternatives to meet the city's future water supply needs including reallocations from the flood control pools at both Hulah and Copan.

Yield projections through the year 2055, required that pool sediment projections be made through the year 2055 at both Hulah and Copan based on past sediment surveys, historic rates of sedimentation, soil types, and inflows. There is a great deal of uncertainty when projecting this far into the future. The sediment projections were used to establish the elevation-area-capacity relationship of both Hulah and Copan Lakes through 2055.

All modeling for this study was accomplished with the Corps of Engineers Southwest Division Modeling System for the Simulation of the Regulation of a multi-purpose Reservoir System, otherwise known as SUPER. The SUPER Model is a suite of computer programs used to model multi-purpose reservoir system regulation.

**Overview of SUPER Model**

The suite of programs used to model multi-purpose reservoir system regulation known as SUPER, was developed over a thirty-year period by Ronald L. Hula, primarily as a planning tool to perform period-of-record analysis, to evaluate changes in operational scenarios. The model has the ability to simulate flood control operations, and conservation pool operations including hydropower, water supply, water quality, diversions, and returns. In addition to period-of-record analysis, it has the capability to perform conservation pool yield analysis, and firm energy analysis. It has the capability to develop unregulated conditions models, simulating systems with some or all reservoirs "dummied" out or non-existent. Besides system modeling, SUPER can perform economic analyses of impacts between plans, and it can provide a wide variety of output from which to evaluate scenarios including tabular or graphical formats of hydrographs, duration plots, and frequency curves at all reservoirs and control points within the system model.

SUPER is a daily simulation model that assumes all reservoirs are in place for the entire period of record specified for each model, based on data availability. For each SUPER model, a complex set of intervening area flows is developed for the entire period of record. This is the culmination of the pre-processing of data, before any simulation is done. When simulation is begun, headwater reservoir inflows and subsequent derived releases based on current and future forecast conditions, are then routed through the system on a daily basis. These routed flows are combined with intervening area flows at all control point locations. Reservoir releases are made for flood control, hydroelectric power generation, water supply requirements, and stream flow requirements such as water quality and irrigation. Other regulating considerations include channel capacities and bank stability. All releases are analyzed to determine their impact on current and future forecasted conditions, and are adjusted as needed to meet predefined system constraints. In addition to the above requirements, SUPER works to achieve a target uniform balance between all competing reservoirs during the draw down of system flood storage, and a target uniform balance in system conservation storage remaining, as defined by the model, during a conservation pool draw down. SUPER continues to evolve to meet the complex challenge of modeling system operations while meeting system and local constraints, and balancing requirements. The SUPER algorithms and data will soon be incorporated into the RiverWare modeling program which is a more object oriented and flexible platform for reservoir system modeling.

The Arkansas River SUPER model has a hydrologic period of record from January 1940 to December 2000, based on observed gage data. Therefore, all analyses using SUPER reflect actual hydrologic conditions which occurred during this 61 year period.

**Yield Analysis**

Water supply yield analysis using SUPER was performed to determine how much yield would be available for the City of Bartlesville, for a number of possible alternatives including:

- Existing Conditions through year 2055 at both Hulah and Copan.
- Reallocate available water quality storage to water supply storage at both projects for 2055 conditions.
- Reallocate 2.5% and 5.0% of flood control storage along with available water quality storage at both projects for 2055 conditions.
- Find combinations of the above alternatives and other possible percentages of flood control reallocation, to achieve enough yield to meet the estimated 2055 demand.
- Perform a yield sensitivity analysis by varying the monthly demand to reflect demands similar to the 2002 drought, vary sedimentation rates by 10 and 20%, and reducing inflows by 10 and 20%.

The yields determined in this study were the critical period dependable yields, meaning there were no deficiencies in water supply experienced during the worst drought in the historic period of record from 1940-2000. Water supply demands are input into the model as a monthly value for each month, and are modeled as continuous flows out of the reservoir for the entire period of record. A typical, conservative monthly demand distribution exists in the SUPER model for all water supply reservoirs, based on historical usage, however in reality, this is a dynamic parameter and can change over time. Super however, uses the same monthly distribution for the entire 61 year period of record. The yield computation is an iterative solution to determine the maximum water that can be continually removed from the lake based on the storage, inflow, evaporation, and any required releases such as water quality demands. The reservoir is drawn down just to the bottom of conservation pool, at the end of one modeling time period, only once during the period of record. For existing conditions at Hulah, however, there was one day of water supply deficiency during the critical period, based on existing contracts. The yields determined in the modeling of Hulah and Copan reflect the necessity to meet water quality requirements at Hulah outflow, Copan outflow, and Bartlesville. Minimum water quality requirements at these locations are shown in Table 1. To ensure water supply and water quality requirements are met at these three locations, a systems approach to yield analysis was required. Reservoir yields determined this way may be less than if analyzing each reservoir, Hulah and Copan, individually. However, yields shown in the analyses, meet water supply and water quality requirements at all times during the critical period without deficiencies, with the exception of Hulah existing conditions for 2055. The historic drawdown period for the yield analysis began in Oct 1955, reaching the maximum drawdown in Mar 1957, and fully recovering by April to May 1957.

**Table 1 Current Water Quality Demands**

| Month | **Water Quality Demands below Hulah in cfs** | **Water Quality Demands below Copan in cfs** | **Water Quality Demands at Bartlesville in cfs** |
|---|---|---|---|
| Jan | 2 | 5 | 10 |
| Feb | 2 | 5 | 10 |
| Mar | 2 | 5 | 10 |
| Apr | 2 | 5 | 10 |
| May | 2 | 5 | 10 |
| Jun | 4 | 8 | 11 |
| Jul | 4 | 8 | 13 |
| Aug | 4 | 8 | 13 |
| Sep | 2 | 5 | 10 |
| Oct | 2 | 5 | 10 |
| Nov | 2 | 5 | 10 |
| Dec | 2 | 5 | 10 |

Existing conditions storages and yields for Hulah and Copan are shown in Tables 2 and 3 for 2055 conditions.

**Table 2**

| **Hulah – Existing Conditions based on 2055 conditions – if no changes are made** | | | | | |
|---|---|---|---|---|---|
| | Elevation (ft) | Usable Storage for 2055 Conditions (ac-ft) | Yield (mgd) | Percent of | |
| | | | | Usable Total Storage (%) | Usable Conservation Storage (%) |
| Flood Control | 733-765 | 251,824 | | 96.77 | |
| | | | | | |
| Conservation | 710-733 | 8397 | 5.94 | 3.23 | 100.00 |
| Water Supply | | 6180 | 4.37 | 2.37 | 73.60 |
| City of Bartlesville | | 4807 | 3.40 | 1.85 | 57.249 |
| City of Bartlesville, MOD | | 687 | 0.49 | 0.26 | 8.178 |
| Hulah Water District, Inc | | 31 | 0.02 | 0.01 | 0.37 |
| City of Bartlesville | | 656 | 0.46 | 0.25 | 7.807 |
| | | | | | |
| Water Quality | | 2217 | 1.57 | 0.85 | 26.40 |
| | | | | | |
| Total Usable Storage | | 260,221 | | 100.00 | |

- There is no storage below El 725
- Note: 1 day of WS deficiency at Hulah during the drought of record, with both Hulah and Copan modeled as existing conditions.
- City of Bartlesville requires 14.8 mgd in year 2055.
- WS available to Bartlesville at Hulah = 4.35 mgd and WS available to Bartlesville at Copan = 0.88 mgd, for a total of 5.23 mgd.

**Table 3**

| **Copan – Existing Conditions based on 2055 conditions – if no changes are made** | | | | | |
|---|---|---|---|---|---|
| | Elevation (ft) | Usable Storage for 2055 Conditions (ac-ft) | Yield (mgd) | Percent of | |
| | | | | Usable Total Storage (%) | Usable Conservation Storage (%) |
| Flood Control | 710-732 | 180,126 | | 86.97 | |
| | | | | | |
| Conservation | 687.5-710 | 26,980 | 11.81 | 13.03 | 100.00 |
| Water Supply | | 6,022 | 2.64 | 2.91 | 22.32 |
| Copan Public Works | | 4,015 | 1.76 | 1.94 | 14.881 |
| Uncontracted | | 2,007 | 0.88 | 0.97 | 7.44 |
| | | | | | |
| Water Quality | | 20,958 | 9.17 | 10.12 | 77.68 |
| | | | | | |
| Total Usable Storage | | 207,106 | | 100.00 | |

Tables 4 and 5 show the modified condition storages and yields for Hulah and Copan when all unused water quality storage is reallocated to water supply for 2055 conditions.

**Table 4**

**Hulah – Existing Conditions based on 2055 conditions – There is no WQ available to reallocate to WS**

| | Elevation (ft) | Usable Storage for 2055 Conditions (ac-ft) | Yield (mgd) | Percent of | |
|---|---|---|---|---|---|
| | | | | Usable Total Storage (%) | Usable Conservation Storage (%) |
| Flood Control | 733-765 | 251,824 | | 96.77 | |
| | | | | | |
| Conservation | 710-733 | 8397 | 5.94 | 3.23 | 100.00 |
| Water Supply | | 6180 | 4.37 | 2.37 | 73.60 |
| City of Bartlesville | | 4807 | 3.40 | 1.85 | 57.249 |
| City of Bartlesville, MOD | | 687 | 0.49 | 0.26 | 8.178 |
| Hulah Water District, Inc | | 31 | 0.02 | 0.01 | 0.37 |
| City of Bartlesville | | 656 | 0.46 | 0.25 | 7.807 |
| | | | | | |
| Water Quality | | 2217 | 1.57 | 0.85 | 26.40 |
| | | | | | |
| Total Usable Storage | | 260,221 | | 100.00 | |

There is no storage below El 725

**Table 5**

**Copan – Modified Conditions based on 2055 conditions – Reallocate all available WQ storage to WS**

| | Elevation (ft) | Usable Storage for 2055 Conditions (ac-ft) | Yield (mgd) | Percent of | |
|---|---|---|---|---|---|
| | | | | Usable Total Storage (%) | Usable Conservation Storage (%) |
| Flood Control | 710-732 | 180,126 | | 86.97 | |
| | | | | | |
| Conservation | 687.5-710 | 26,980 | 11.81 | 13.03 | 100.00 |
| Water Supply | | 9,732 | 4.26 | 4.70 | 36.07 |
| Copan Public Works | | 4,015 | 1.76 | 1.94 | 14.881 |
| Uncontracted | | 5,717 | 2.50 | 2.76 | 21.19 |
| | | | | | |
| Water Quality | | 17,248 | 7.55 | 8.33 | 63.93 |
| | | | | | |
| Total Usable Storage | | 207,106 | | 100.00 | |

- Maintains only 1 day of WS deficiency at Hulah during the drought of record (Mar 1957)
- City of Bartlesville requires 14.8 mgd in year 2055.
- WS available to Bartlesville at Hulah = 4.35 mgd and WS available to Bartlesville at Copan = 2.50 mgd, for a total of 6.85 mgd.

After modeling existing conditions and the reallocation of all available water quality water at both Hulah and Copan, additional analysis was done to model reallocation of 2.5% and 5% of the flood pool at both lakes in addition to water quality storage. From this analysis, it was determined that an approximate10% reallocation of flood pool would be required at either lake to obtain enough yield to meet 2055 demands. Table 6 shows a listing of the possible system combinations that were analyzed and the determined yields available to Bartlesville.

**Table 6 System Yield Analysis**

| System Combinations | | | | | |
|---|---|---|---|---|---|
| **Hulah** | **Available Yield for Bartlesville (mgd)*** | **Copan** | **Available Yield for Bartlesville (mgd)*** | **Total Available Yield for Bartlesville (mgd)*** | **Deficiencies during Drought of Record (Mar 1957)** |
| Existing | 4.35 | Existing | 0.88 | 5.23 | 1 day WS @ Hulah |
| Existing | 4.35 | Available WQ Reallocation | 2.50 | 6.85 | 1 day WS @ Hulah |
| 2.5% FC Realloc + avail WQ | 6.21 | 2.5% FC Realloc + avail WQ | 6.88 | 13.09 | None |
| 5.0% FC Realloc + avail WQ | 8.51 | Existing | 0.88 | 9.39 | None |
| 5.0% FC Realloc + avail WQ | 8.33 | 5.0% FC Realloc + avail WQ | 8.43 | 16.76 | None |
| 10.0% FC Realloc + avail WQ | 14.19 | Existing | 0.88 | 15.07 | None |
| 10.0% FC Realloc + avail WQ | 13.75 | 10.0% FC Realloc + avail WQ | 11.47 | 25.22 | None |
| Existing | 4.35 | 10.0% FC Realloc + avail WQ | 5.79 | 10.14 | 1 day WS @ Hulah |
| 2.5% FC Realloc + avail WQ | 6.18 | 5.0% FC Realloc + avail WQ | 8.43 | 14.61 | None |
| 2.5% FC Realloc + avail WQ | 6.06 | 10.0% FC Realloc + avail WQ | 11.47 | 17.53 | None |
| 1% FC Realloc + avail WQ | 4.89 | 10.0% FC Realloc + avail WQ | 11.47 | 16.36 | None |

*All yields above are based on 2055 sediment conditions at Hulah and Copan
Estimated water supply requirement for the City of Bartlesville in 2055 is 14.8 mgd.

**Selected Alternatives for Period of Record Analysis**

The system combinations highlighted in Table 4, which met the city's required 2055 water supply demand of 14.8 mgd, were further analyzed to determine the associated costs versus damages to provide an economic basis from which to analyze the alternatives. Period of record runs were made of these selected alternatives, to develop discharge-frequency data that was input into a backwater model of the Caney River and the Little Caney to develop stage-damages. Also, a volume-duration relationship was established to aid in determining damages due to event durations.

**Sensitivity Analysis**

**1. Update Yield using updated monthly peak distribution data from drought of record that occurred in the 2002 drought.**

Based on the 2001, 2002, and 2003 water demand records from the City of Bartlesville, the average monthly water demand from Hulah Lake was calculated, and the distribution was input into the existing conditions Hulah yield SUPER model. The current and drought water supply distributions for Hulah Lake are shown in Table 7, along with the reservoir yields for these two conditions. The 2001-2003 drought distribution was modeled throughout the entire 61 year period of record, and since the distribution is based on a drought period, it is a more severe or worst case distribution compared to the existing or typical distribution. As can be seen in Table 7, the summer demands are greater in the drought distribution compared to the existing distribution, and this continues through the fall and early winter months, a time of year when conditions are drier. The drawdown period for this yield run began in October 1955 with the maximum drawdown occurring in February 1957, and recovering in April 1957. The maximum drawdown occurred earlier than yield runs made with the existing demand distribution, Because of the higher demands during a drier period, a lower overall yield at Hulah was experienced for this condition. It is highly unlikely that this more severe distribution would occur for a prolonged period of time. It is more realistic to use a more conservative, typical distribution, based on longer term historic demands. However, this analysis shows the sensitivity of the overall yield to drought, or possible long term climate change, towards a drier period. As shown in the table, the existing conditions 2055 yield available to the City of Bartlesville with the revised monthly water demand distribution = 3.92 mgd versus 4.35 mgd with the original distribution.

**Table 7**

| Average Monthly Water Demand from Hulah Lake | | |
|---|---|---|
| **Month** | **Current Distribution-Existing Conditions (mgd)** | **2001-2003 Distribution-Existing Conditions (mgd)** |
| January | 3.66 | 4.94 |
| February | 3.66 | 2.94 |
| March | 3.92 | 2.42 |
| April | 3.92 | 1.11 |
| May | 4.18 | 2.28 |
| June | 4.98 | 2.96 |
| July | 5.75 | 6.16 |
| August | 5.75 | 6.18 |
| September | 4.98 | 4.17 |
| October | 4.21 | 4.36 |
| November | 3.66 | 4.41 |
| December | 3.66 | 5.15 |
| **Yield available to Bartlesville** | **4.35** | **3.92** |

**2. Using updated monthly peak distribution data, determine the % of time that demands are met.**

With the updated monthly peak distribution data from 2001-2003 for existing conditions, there are 27 days during the 61 year period of record when there are water supply deficiencies (Jan-Mar 1957 drought), which is 0.12% of the time. This means that 99.88% of the time demands are met. With the current distribution for existing conditions, there is 1 day in the 61 year period of record (Mar 1957) when there are deficiencies. This means that 99.9955119% or rounded to 100% of the time water supply demands are met.

**3. Vary sedimentation rates in both Hulah and Copan by 10%and 20%, and determine respective change in yields.**

Modeling results are shown in Table 8.

**Table 8**

| Impacts to Yield due to Variable Rates of Sedimentation | | | |
|---|---|---|---|
| **Lake** | **Condition** | **Available Yield for Bartlesville (mgd)** | **Change from Existing Conditions (mgd)** |
| **Hulah** | Existing | 4.35 | |
| | 10% decrease in sedimentation rate (more storage available) | 5.43 | 1.08 |
| | 10% increase in sedimentation rate (less storage available) | 4.26 | -0.09 |
| | 20% decrease in sedimentation rate (more storage available) | 5.62 | 1.27 |
| | 20% increase in sedimentation rate (less storage available) | 3.87 | -0.48 |
| **Copan** | Existing | 0.88 | |
| | 10% decrease in sedimentation rate (more storage available) | 0.89 | 0.01 |
| | 10% increase in sedimentation rate (less storage available) | 0.87 | -0.01 |
| | 20% decrease in sedimentation rate (more storage available) | 0.90 | 0.02 |
| | 20% increase in sedimentation rate (less storage available) | 0.86 | -0.02 |

**4. Reduce the inflows into Hulah and Copan by 10% and 20% and determine respective changes in yields.**

Modeling results are shown in Table 9.

**Table 9**

| **Bartlesville PAS<br>Sensitivity Analysis<br>Impacts to Yield due to Decreased Inflow Rates** | | | |
|---|---|---|---|
| **Lake** | **Condition** | **Available Yield for Bartlesville (mgd)** | **Change from Existing Conditions (mgd)** |
| **Hulah** | Existing | 4.35 | |
| | 10% decrease in inflow | 3.92 | -0.43 |
| | 20% decrease in inflow | 3.54 | -0.81 |
| **Copan** | Existing | 0.88 | |
| | 10% decrease in inflow | 0.87 | -0.01 |
| | 20% decrease in inflow | 0.85 | -0.03 |

As seen in tasks 3 and 4 in the sensitivity analysis, Hulah yield is much more sensitive to changes in inflow and sedimentation, as compared to Copan yield. This is likely due to the much smaller conservation pool at Hulah (8397 ac-ft in 2055) versus Copan (26,980 ac-ft in 2055). Yield is dependent on storage, inflow, evaporation, and required releases such as water quality releases. So, slight changes to inflow and storage are not dampened as much at Hulah, as they are at Copan Lake.

# APPENDIX D

# Cost of Alternative Water Supply Sources

# APPENDIX D
# COST OF ALTERNATIVE WATER SUPPLY SOURCES

The U.S. Army Corps of Engineers-Tulsa District (USACE-Tulsa), the Oklahoma Water Resources Board (OWRB) and the City of Bartlesville, Oklahoma (Bartlesville or City) are cooperating under Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251), Planning Assistance to the States Program to develop a comprehensive water plan. C.H. Guernsey & Company (GUERNSEY) was contracted by the USACE-Tulsa to assist in evaluating least cost alternatives for providing additional water supply to the City of Bartlesville and their customers in the region.

## 1.1 CUSTOMER NEEDS

Bartlesville is working proactively to plan for their community and regional customer long-term water needs. In this regard, the City wants to explore alternative sources of water to supplement their primary supply from Hulah Lake. Recent short-term drought episodes resulted in significantly lowered lake levels in Oklahoma lakes. Even though 2007 has been an above average (and in some areas a record) year for rain and runoff, the City leaders vividly remember the impacts of drought and want to prepare a comprehensive plan to meet their community's future water needs and those of its customers. This is especially timely in the midst of growing evidence of global warming and its potential negative impact on the region's rainfall.

## 1.2 CLIMATE CHANGE AND ITS IMPLICATIONS FOR WATER RESOURCES PLANNING

The Intergovernmental Panel on Climate Change recently issued a landmark report [*Climate Change 2007: The Physical Basis - Summary for Policymakers* (IPCC, February 2007 Geneva, Switzerland)] concluding that it is very likely that hot extremes, heat waves, and heavy (short intensity) precipitation events will continue to become more frequent on a global scale. The report states there is strong observational evidence and results from modeling indicate that, at least over the last 50 years, human activities are a major contributor to climate change and global warming. Annual precipitation is projected to decrease across the southwestern United States, especially during the summer. Warmer temperatures will cause more evaporation in summer resulting in less available soil moisture. These drier conditions will lead to episodes of extreme heat, particularly across the southwest. It is projected that our typical drought episodes may transform into a more prolonged 1930s and 1950s style drought. The warmer/drier weather could increase the risk for and intensity of wildfires. It is important to keep in mind that climate model projections are uncertain because the impact depends on our socio-economic responses to climate change.

It is important to put this climate change information in context with what the City has experienced recently. Figure 1 provides a climatological perspective of rainfall in the North Central climate division of Oklahoma for the period 1895-2006, and is representative of the study region watershed as a whole. It is clear that the study region has enjoyed a recent, prolonged wet period whose duration has lasted some 15-20 years versus the more normal 8-12 year wet cycle. Additionally, the magnitude of the recent wet cycle has been greater (more annual precipitation) than any other wet cycle during the period of record, and is similar in magnitude to the droughts of the 1910s, 1930s, and 1950s. The bottom line is the City should approach this study from the perspective that their recent "memory" of rainfall conditions is far and away from what would be considered "normal." In fact, recent rainfall history has been quite abnormally high. Furthermore, the City may indeed be conducting this long-range planning effort on the doorstep of a much more prolonged period of dry weather should the climate change forecasts prove accurate.

Whatever one's view is of climate change – be it man-made or part of a normal cycle – the globe is currently warming. That fact means the City should exercise due diligence to plan, develop and protect their water resources for the future. In this regard, a "no regrets" strategy offers the best of both worlds. Should a major climate shift not occur, the benefits of a no regrets strategy would be significant. There would be no complaints about a more robust and better protected water supply.

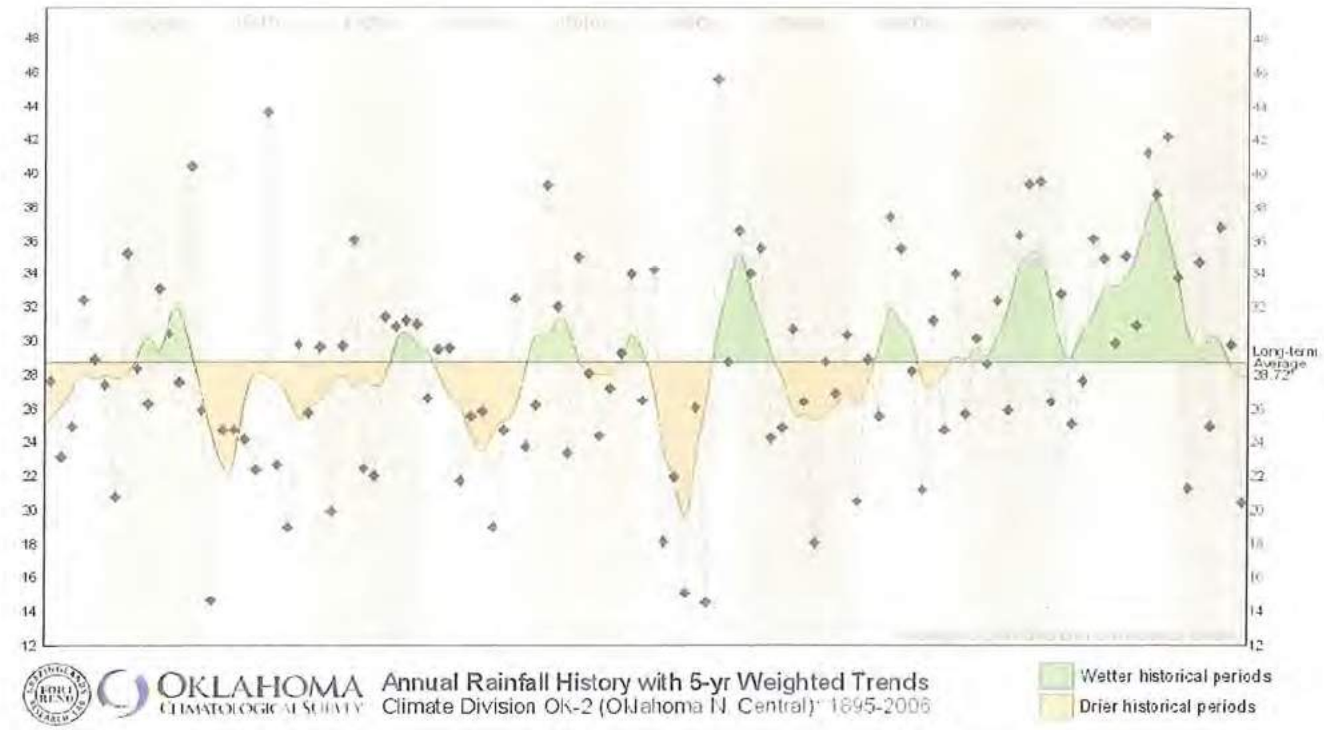



**Figure 1: Rainfall History for North Central Oklahoma**

**NOTE:** This climate change discussion was excerpted, in part, from a recent presentation by Dr. Kenneth Crawford (State Climatologist, Oklahoma Climatological Survey and Regents' Professor of Meteorology at the University of Oklahoma) to the Oklahoma Water Resources Board.

## 1.3 SITE DESCRIPTION

Bartlesville is located in Washington County in northeast Oklahoma. The general study area includes Washington and Osage Counties. Figure 2 (Oklahoma Comprehensive Water Plan, OWRB, 1995) provides a vicinity map.

Originally a part of the Cherokee Nation, Indian Territory, Washington County was created at statehood and named for President George Washington. The County has an area of approximately 417 square miles and a population of approximately 49,000 in 2000. Bartlesville, the County seat, was the first oil boom town in Indian Territory and has historically been home to the Phillips Petroleum Company (now ConocoPhillips).

In 1872, the United States Government purchased land from the Cherokee Nation for the Osage Tribe and it was then that the Tribe moved to Indian Territory. As statehood (1907), this Osage Reservation became Osage County, the largest county in Oklahoma. The County has an area of approximately 2,251 square miles and a population of approximately 44,000 in 2000. Pawhuska serves as the County seat. Oil and gas, as well as horse and cattle ranching on the famous bluestem grass, contribute to the economy of Osage County. Attractions to the County include Native American cultural activities, the Tall Grass Prairie Reserve north of Pawhuska, the Osage Tribal Museum and Headquarters in Pawhuska, and the Osage Hills State Park.

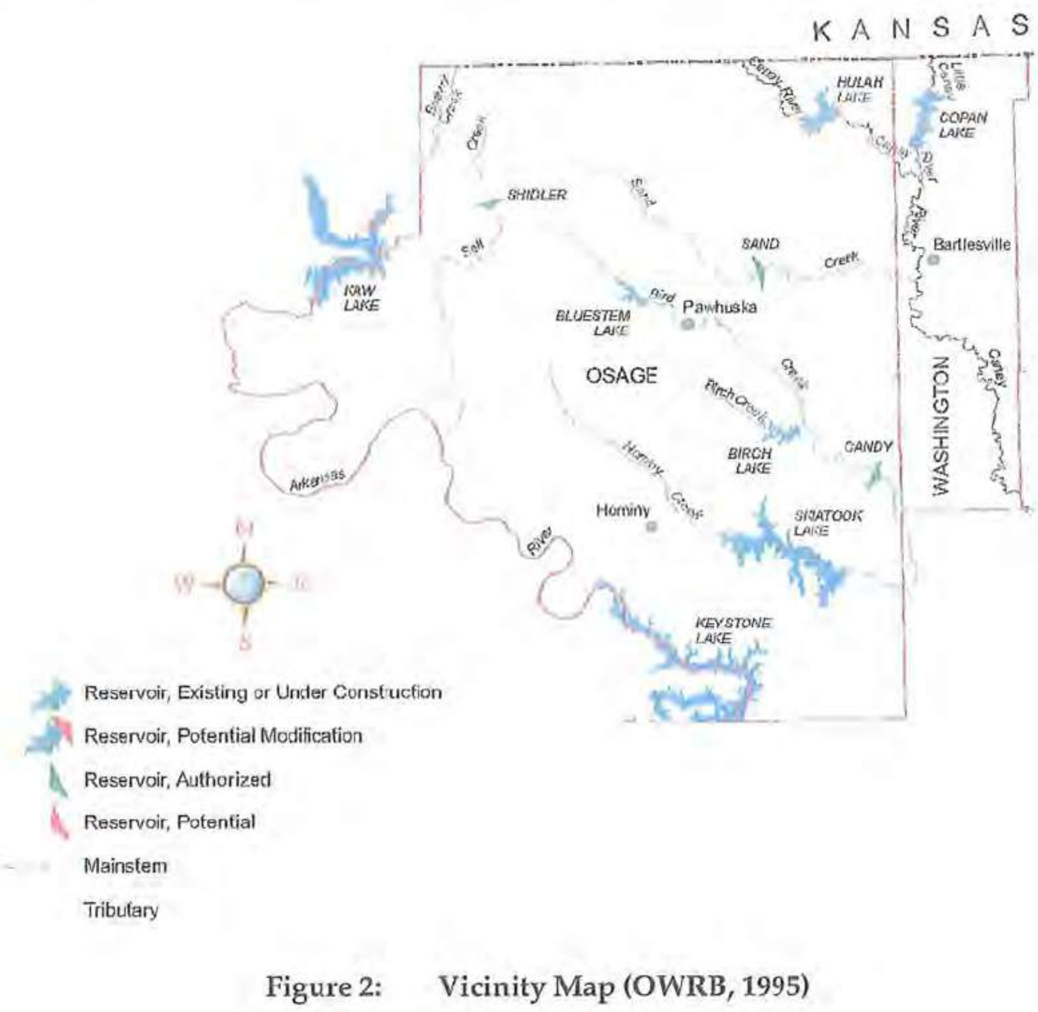



**Figure 2: Vicinity Map (OWRB, 1995)**

# 2.0 STUDY METHODOLOGY

The study will evaluate several water supply alternatives for the City of Bartlesville. The results will aid in decision-making for a 50-year planning horizon.

## 2.1 PROJECT KICK-OFF MEETING

A project kick-off meeting was held on October 2, 2007 at which USACE-Tulsa personnel provided some historical context of the USACE's water supply study work at Bartlesville. This included background of the Hulah-Copan Reallocation Study and more recent Planning Assistance to the States study work on evaluating long-term water supply alternatives for the City and its customer systems.

## 2.2 ALTERNATIVES FOR INVESTIGATION

The USACE-Tulsa has been assisting Bartlesville in evaluating reallocation of storage at both Hulah and Copan Lakes. Hulah storage is the lower cost alternative as it is an older project. USACE-Tulsa is developing updated yield projections through the year 2055 for both sites. Additionally, they are evaluating opportunities to reallocate flood control storage to water supply as an option to meet long-term needs.

The Tulsa District has tasked GUERSNEY to examine/update costs from the 2004 Tetra-Tech report on water supply and transmission options from Hulah, Copan, Kaw, and the proposed Sand Lake sites. Additionally, GUERNSEY has been requested to develop a non-federal design/constructed Sand Lake cost estimate based on the original USACE Sand Lake design information.

## 2.3 STUDY AREA RECONNAISSANCE

GUERNSEY personnel conducted a visual observation of the overall project region to observe identified project features in the 2004 Tetra-Tech report. This included:

- Potential intake location at Kaw Lake
- Kaw water transmission line potential alignment
- Hudson Lake outside of Bartlesville
- Copan Lake outlet, and potential intake location
- Copan Lake transmission line potential alignment to Hulah Lake
- Hulah Lake outlet and intake location
- Bartlesville transmission line from Hulah to Hudson Lake
- Pertinent feature locations around the original Sand Lake dam site

The following provides observations relevant to the current study.

### 2.3.1 KAW WATER TRANSMISSION LINE

The Kaw water transmission line would begin from a potential water intake structure in Kaw Lake just off the southeast bank of the State Highway 11 (SH-11) crossing (Photograph 1). The transmission line would then traverse an east/west section line alignment parallel and just south of SH-11 to Shidler. As this pipeline alignment crosses SH-11/18 south of Shidler, a high voltage power transmission line begins an east/west alignment that could prove ideal for sharing easement with the Kaw line (Photograph 2). The power/Kaw pipeline alignment then runs cross country to the east until crossing Highway 99 northeast of Pawhuska (Photograph 3) where it then parallels US Highway 60 (US-60) to within close proximity to Lake Hudson. The general countryside varies from open range lands to forested and rocky terrain. Access to the alignment was limited in many areas due to the cross country nature of the power line and the open range private land it runs through with extremely limited county road access.

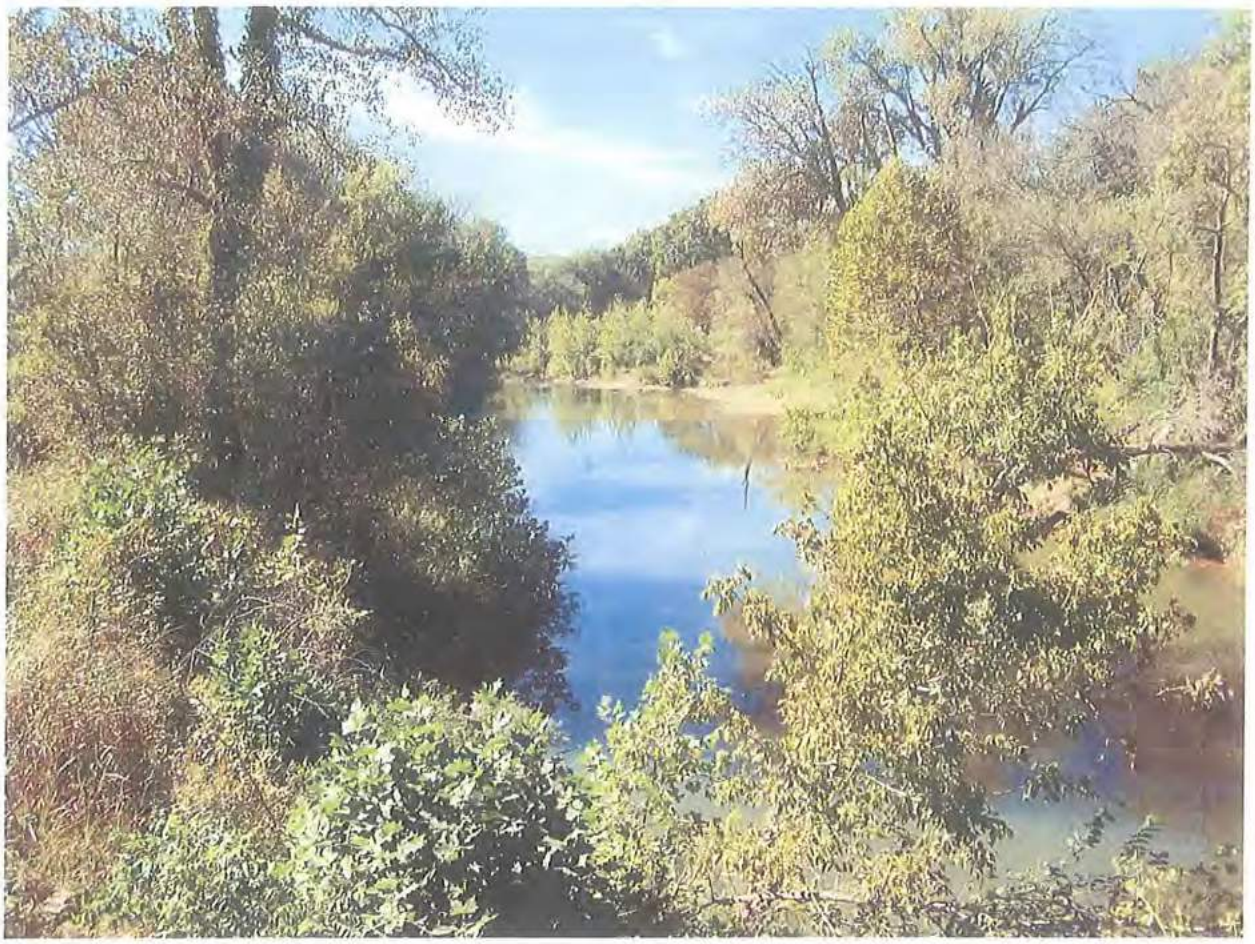
**Photograph 1: Kaw Lake at SH-11 Bridge Crossing**

**Photograph 2: Power Transmission Line Easement South of Shidler**

**Photograph 3: Highway 99 Power Transmission Line Crossing**

### 2.3.2 SAND LAKE DAM SITE

The Sand Lake dam site is located about 8.5 miles west and 1.5 miles south of Bartlesville on Sand Creek in Osage County, just upstream of the Town of Okesa. The site is heavily wooded (Photograph 4) and the normal pool would back upstream along Sand Creek past a Boy Scout Camp and Osage Hills State Park. The Kaw water transmission line runs parallel and just a short distance north of the Sand Lake site and would be a logical connect/alignment for a Sand Lake water line.



**Photograph 4: Sand Lake Vicinity**

While performing the site visit, the Park Manager at Osage Hills State Park (OHSP) expressed deep concern for construction of the Sand Lake project as he fears that some portions of the park (Photograph 5) will be permanently inundated by the conservations pool and additional facilities temporarily inundated during flood events. The park manager also expressed concerns that the free flowing nature of Sand Creek would be lost to park visitors including the scenic "Falls" (Photograph 6). He encouraged exploring an alternative upstream dam site that would not inundate OHSP features and therefore would not be as controversial.

**Photograph 5: Osage Hills State Park Swimming Pool**

**Photograph 6: The "Falls" at Osage Hills State Park**

Additionally, the Boy Scout Camp manager expressed similar concerns that the proposed Sand Lake dam site would likely inundate significant portions of the camp facilities (Photograph 7) and remove the free flowing nature experience of Sand Creek for the visiting campers. The camp manager encouraged exploring opportunities to locate the dam site to an upstream location that would not impact the camp or the state park and therefore be less controversial.

**Photograph 7: Boy Scout Camp**

## 2.4 DATA REVIEW

USACE-Tulsa personnel provided several reference reports and maps including; two Caney River Basin Reports; Draft Environmental Assessment Report for Hulah/Copan Reallocation; Cost of Alternative Water Supply Sources, Hulah-Copan Reallocation Study; Hulah-Copan Draft Water Supply Reallocation Report and Water Supply Agreements; Kaw Lake Wholesale Water Treatment and Conveyance Study; and miscellaneous Sand Lake historical planning documents.

## 3.0 WATER QUALITY ANALYSIS

The water quality of Hulah, Copan, Kaw, Hudson and Sand (proposed) Lakes are all suitable for public water supply purposes. The following generalized water quality information is taken from the Oklahoma Water Resources Board's 2006 Beneficial Use Monitoring Program Report.

### 3.1 HULAH LAKE

Hulah Lake is considered to be eutrophic, indicative of high primary productivity and nutrient levels. The lake is currently listed as a Nutrient Limited Watershed in the Oklahoma Water Quality Standards. Water clarity was rated "poor" based on true color, turbidity, and secchi disk depth. Specific conductivity measurements indicated moderate concentrations (242 – 358 μS/cm) of electrical current conducting compounds (salts) in the lake system.

### 3.2 COPAN LAKE

Copan Lake is considered to be eutrophic, indicative of high primary productivity and nutrient levels. Water clarity was rated "poor" based on true color, turbidity and secchi disk depth. Specific conductivity measurements indicated low to occasionally moderate levels (176-344 μS/cm) of current conducting compounds (salts) in the lake system.

### 3.3 KAW LAKE

Kaw Lake is considered to be eutrophic, indicative of high primary productivity and nutrient levels. Water clarity was rated "average" based on true color, turbidity, and secchi disk depth, better than observed in 2003. Specific conductivity measurements indicated high levels (563-1172 μS/cm) of current conducting compounds (salts) in the lake system. The highest salinity and specific conductivity values were found in the Arkansas River arm during the spring and summer.

### 3.4 HUDSON LAKE (OSAGE COUNTY)

Hudson Lake is considered to be eutrophic, indicative of high primary productivity and nutrient levels. Water clarity was rated "good" based on true color, turbidity, and secchi disk depth. Specific conductivity measurements indicated low to occasionally moderate levels (178-297 μS/cm) of current conducting compounds (salts) in the lake system.

### 3.5 SAND LAKE (PROPOSED)

Unfortunately, the OWRB does not have an ambient trend monitoring station on Sand Creek; however, there is a permanent monitoring station on the Caney River near Ramona. Water enters the Caney River at Ramona from Sand Creek, Keeler Creek, and Rabb Creek, among other smaller tributaries. Therefore, this station is considered representative of the Caney River from the confluence of Sand Creek downstream to the confluence of the Caney River with Rabb Creek. While this station can give some indication as to what might be expected of the water quality in Sand Creek, actual sampling of Sand Creek should be conducted to more clearly identify its water quality characteristics. This segment of the Caney River is considered to be nutrient-threatened. Turbidity exceeded standards 50% of the time. Total dissolved solids ranged between 100 – 400 mg/L. Minerals and nutrients were consistently below standards. The Public and Private Water Supply beneficial use is supported.

## 4.0 RAW WATER SUPPLY INFRASTRUCTURE AND ENERGY COSTS

Five alternative water supply source combinations were studied in-depth. Alternative Source Cost Estimates are presented in Appendix A. These alternatives, labeled as Case 1 through Case 5, are described as follows:

- Case 1 – 5% Flood Pool + Water Quality Reallocation at Hulah and Copan
- Case 2 – 10% Flood Pool + Water Quality Reallocation at Hulah
- Case 3 – 1% Flood Pool + Water Quality Reallocation at Hulah and 10% Reallocation at Copan
- Case 4 – No Reallocation at Hulah and Construct Sand Lake
- Case 5 – No Reallocation at Hulah and Kaw Pipeline

### 4.1 COST CRITERIA

For each source combination, an average raw water supply of 14.80 million gallons per day (MGD) will be required. Intake structures, pumps, and pipelines will be required to handle twice this flow rate, or 29.60 MGD, during times of peak demand. To evaluate the cost of each source combination, a present value has been calculated. Construction costs have been estimated in 2007 dollars, with the present value set equal to the estimated cost. For energy costs, the electricity required for pumping the average of 14.80 MGD was assumed to be level during a 50-year period. Electricity costs were escalated using a 2.5% per year (compounded) inflation rate. The present value of the resulting cost series was determined using a 4-7/8% discount rate.

Three potential electricity suppliers have been identified for the various pump locations. These are PSO, Indian Electric Cooperative, and Verdigris Valley Electric Cooperative (VVEC). VVEC has a transmission line near the site of the proposed Sand Lake. Therefore, to standardize the cost projections, their rates have been used for all electricity costs:

- Base Electric Charge = $50 per month
- Energy Charge = $0.02743 per kilowatts per hour (KWH)
- Demand Charge = $6.50 per KW

Pump replacements, for existing pumps at Hulah Lake as well as all proposed pumps, have been assumed to be made during the 25th year. The same 4-7/8%% discount rate was used to calculate the present value of these replacements.

Pump size has been shown as the required calculated horsepower for the given flow and head. A 70% efficiency was assumed for all pumps. Horsepower for the existing pumping station at Hulah Lake was also calculated in the same manner. Pump head was determined by assuming a hydraulic grade line running through a point 35 feet above the high point along the pipeline route. This would mean that the minimum pressure in the pipeline at the high point is 15 pounds per square inch (psi). (For all designs, the pipeline will operate by gravity flow once past the high point.) The hydraulic grade line was then projected back to the pump location based on the peak flow rate (at double the average flow) and the pipe size. Concrete cylinder pipe with a "C" value of 130 was used for all pipes.

Bartlesville maintains a run-of-the-river pump station on the Caney River (Photograph 8), located near the old water treatment plant. When the new treatment plant was constructed, an existing 30-inch pipe was "reversed" in flow direction so that the river pump station could supply raw water to the new treatment plant. Both Hulah Lake and Copan Lake discharge into the Caney River upstream of this pump station. Water from either lake could be discharged and then pumped by the river pump station to the treatment plant. However, there would be significant water losses if this method was used as a primary mode of transferring water from either of these lakes to the treatment plant. Therefore, only the small flow required from Copan Lake for Case 2 uses the river pump station. In all other supply scenarios, a pump and pipeline were used to transfer water to Lake Hudson (Photograph 9).

**Photograph 8: City of Bartlesville, Caney River Intake Structure**

**Photograph 9: Lake Hudson (City of Bartlesville)**

## 4.2 CASE 1 – 5% FLOOD POOL + WATER QUALITY REALLOCATION AT HULAH AND COPAN

Under Case 1, the required water supply can be met by pumping an average of 7.36 MGD from Hulah Lake and an average of 7.44 MGD from Copan Lake to Lake Hudson. Two existing 24-inch pipelines, one cast iron and one ductile iron, already convey water from the Hulah Lake pump station to Lake Hudson. These pipes will handle the required average flow of 7.36 MGD. For energy costs at the existing pump station, the inactive pool elevation of 710.0 for Hulah Lake was used. The high point along the pipeline occurs at elevation 923 located 32,100 feet away from the pump. Projecting the hydraulic grade line back to the pump gives an elevation of 1,036 for a pump head of 326 feet or 141 psi.

At Copan Lake, a new intake structure and pump station will be required. Flow to Lake Hudson will be transferred by a 30-inch pipeline. The inactive pool elevation of 687.5 for Copan Lake was used for energy costs. The 30-inch pipeline will run from the northeast to the southwest, entering an upstream arm of Lake Hudson. The high point along the pipeline occurs at elevation 919 located 21,900 feet away from the pump. Projecting the hydraulic grade line back to the pump gives an elevation of 1,003 for a pump head of 316 feet or 137 psi.

Estimated present value of the infrastructure and energy costs for Case 1 is $24,965,000 for the 50-year period.

## 4.3 CASE 2 – 10% FLOOD POOL + WATER QUALITY REALLOCATION AT HULAH

Almost all of the required water supply is available from Hulah Lake in Case 2. The average flow of 14.19 MGD from Hulah Lake is too much for the two existing 24-inch pipelines. A parallel 30-inch pipeline has been added, with a modified intake structure and a supplemental pump station. With this arrangement, the two existing pipes will convey an average of 6.88 MGD and the parallel 30-inch pipeline will convey an average of 7.31 MGD. The 30-inch pipeline will parallel the two existing pipes from Hulah Lake to Lake Hudson. The hydraulic grade line at the pump will be at elevation 1,027 for a pump head of 317 feet or 137 psi.

The remaining 0.61 MGD of average flow is assumed to be pumped from the Caney River back to the new treatment plant. For this level of analysis, the energy costs for this pumping were prorated using the horsepower calculated for the Hulah Lake water supply.

Estimated present value of the infrastructure and energy costs for Case 2 is $26,828,000 for the 50-year period.

## 4.4 CASE 3 – 1% FLOOD POOL + WATER QUALITY REALLOCATION AT HULAH AND 10% REALLOCATION AT COPAN

Case 3 is similar to Case 1, with some water supplied from Hulah Lake and the balance supplied from Copan Lake. For Case 3, the required water supply can be met by pumping an average of 4.89 MGD from Hulah Lake and an average of 9.91 MGD from Copan Lake to Lake Hudson. The two existing 24-inch pipelines from Hulah Lake to Lake Hudson will handle the required average flow of 4.89 MGD. Given this flow and the design points identified in Case 1, the projected hydraulic grade line at the pump is at elevation 994 for a pump head of 284 feet or 123 psi.

At Copan Lake, a new intake structure and pump station will be required. As the required flow is higher for Case 3 than Case 1, water to Lake Hudson will be transferred by a 36-inch pipeline instead of the 30-inch pipeline used in Case 1. The alignment of the 36-inch pipeline will be the same as described for Case 1, entering an upstream arm of Lake Hudson. With the design points identified in Case 1, the projected hydraulic grade line at the pump is at elevation 988 for a pump head of 301 feet or 130 psi.

Estimated present value of the infrastructure and energy costs for Case 3 is $26,553,000 for the 50-year period.

## 4.5 CASE 4 – NO REALLOCATION AT HULAH AND CONSTRUCT SAND LAKE

The September 1984 Reconnaissance Report of the Caney River Basin identified Sand Lake as a potential reservoir location at Mile 19.1 (upstream from the confluence with the Caney River) of Sand Creek. The Reconnaissance Report presented a conceptual design that included both a flood control component and a water supply component for Sand Lake.

For the purposes of this report, a cost estimate has been prepared assuming the elimination of the flood control component of Sand Lake. This allowed the top of dam elevation to be reduced from 808.5 to 788.5 and the maximum pool elevation to be reduced from 802.7 to 783.5. The top of the conservation pool was left at elevation 766.5 and the top of the inactive pool was left at 734.0. The Reconnaissance Report identified a water supply yield of 12.0 MGD, which is slightly higher than the 10.45 MGD required for this alternative. Construction of Sand Lake at this location will inundate 1,930 acres at the top of the conservation pool elevation and 3,216 acres at the maximum pool elevation. Issues regarding this inundation were previously identified in Section 2.0.

The cost estimate for Sand Lake reflects the purchase of 4,300 acres of property, including the inundated area and immediately adjacent land. Relocation costs have been included for two short sections of US-60, structures in OHSP, the Boy Scout camp, oil-field wells and pipelines, and power lines. Reservoir construction would include clearing, construction of the main dam embankment and spillway, construction of an outlet works and water supply intake, construction of access roads, and erection of a small equipment storage building. An allocation has been made for recreational facilities, although these are not specifically identified.

A pump station and 36-inch pipeline will be required to transfer raw water from Sand Lake to Lake Hudson. The pipeline will run northeast from the dam site, then parallel US-60 for several miles. The pipeline will leave the highway alignment and run northeast, then north to an arm of Lake Hudson located just upstream from the dam. The inactive pool elevation of 734.0 was used for energy costs. The high point along the pipeline occurs at elevation 970 located 36,200 feet away from the pump. Projecting the hydraulic grade line back to the pump gives an elevation of 1067 for a pump head of 333 feet or 144 psi.

The balance of the water required for Case 4 will be supplied from Hulah Lake. The required water supply can be met by pumping an average of 4.35 MGD from Hulah Lake to Lake Hudson. The two existing 24-inch pipelines from Hulah Lake to Lake Hudson will handle the required average flow. Given this flow and the design points identified in Case 1, the projected hydraulic grade line at the pump is at elevation 987 for a pump head of 277 feet or 120 psi.

Estimated present value of the infrastructure and energy costs for Case 4 is $85,073,000 for the 50-year period.

A second dam site on Sand Creek, Lake of the Osage, was identified in the Reconnaissance Report at Mile 6.8. This location is closer to Bartlesville and would require less pipeline length to convey water to Lake Hudson. As described in the Reconnaissance Report, a multi-use reservoir at this location would inundate 5,067 acres at the maximum flood pool elevation of 753.3. This elevation would also require extensive realignment of US-60. Eliminating the flood control component would reduce the maximum flood pool elevation by 22.3 feet to 731.0. This would reduce the inundated area, but would still require extensive relocation of US-60. The location of the dam site for Lake of the Osage is shown on Sheet 5 of the maps (see Appendix B).

An alternative dam site for Sand Lake is identified on Sheet 4 of the maps (Appendix B). This location is at Mile 26.8 of Sand Creek, and thus is upstream from the location identified in the Reconnaissance Report. Using this location would eliminate the inundation of the valley at

OHSP and the Boy Scout camp. To provide the required water supply yield of 10.45 MGD, the top of the conservation pool is estimated to be at elevation 793.0 and the top of the inactive pool is estimated to be at elevation 760.5. These are both 26.5 feet higher than at the original location. The maximum flood pool elevation is estimated at 810.0. The dam at this alternative location will be approximately the same height as at the original location, but will be approximately 340 feet longer. In addition, a dike would be required at a low saddle south of the dam site to contain the flood pool. Therefore, the dam construction costs will be more than for the original location. Also, a 36-inch raw water pipeline will still be required from this location to Lake Hudson. This pipeline will be approximately 18,000 feet longer than the pipeline from the original location. A slightly larger pump will be required as the head at the pump will increase from 333 feet to 344 feet.

### 4.6 CASE 5 – NO REALLOCATION AT HULAH AND KAW PIPELINE

The final alternative is to pump raw water from Kaw Reservoir to Lake Hudson. The intake structure at Kaw would be located at an upstream bend of the reservoir. The top of the inactive pool at Kaw is at elevation 978.0. This will require that the intake structure be located in the middle of the lake to provide enough depth during times of low water. Access to this structure will need to be from the SH-11 causeway, immediately east of the east end of the bridge. A large pump station will be required to transfer raw water through a 36-inch pipeline. The inactive pool elevation of 978.0 was used for energy costs. The 36-inch pipeline will run east from the pump station. Much of the pipeline will follow an electric transmission line until turning north, entering an arm of Lake Hudson located just upstream from the dam. The high point along the pipeline occurs at elevation 1,290 located 81,200 feet away from the pump. Projecting the hydraulic grade line back to the pump gives an elevation of 1464 for a pump head of 486 feet or 211 psi. Additional study of this 45-mile long pipeline is required to determine if an intermediate pump station will be required for pipeline integrity or will be more energy cost effective than having a single pump station.

The balance of the water required for Case 5 will be supplied from Hulah Lake. The required water supply can be met by pumping an average of 4.35 MGD from Hulah Lake to Lake Hudson. The two existing 24-inch pipelines from Hulah Lake to Lake Hudson will handle the required average flow. Given this flow and the design points identified in Case 1, the projected hydraulic grade line at the pump is at elevation 987 for a pump head of 277 feet or 120 psi.

Estimated present value of the infrastructure and energy costs for Case 5 is $100,832,000 for the 50-year period.

As discussed in previous sections, the water quality of Kaw Lake is different from the water quality of other supply sources. One major concern is the introduction of a large quantity of water with a much higher salinity level into Hudson Lake over a long period of time. This has the potential to change the environmental quality of Hudson Lake. Additional study is required to determine if this change will be harmful to the Hudson Lake aquatic environment. A potential terminal storage reservoir site is indicated on Sheet 5 of the maps (Appendix B). The pipeline from Kaw could discharge into a small reservoir at this location. From this terminal storage reservoir, raw water could be moved by gravity to the treatment plant.

## 4.7 LAKE HUDSON TO WATER TREATMENT PLANT

As a part of the relocation of Bartlesville's water treatment plant, a new 36-inch pipeline was installed essentially parallel to two existing pipelines (20-inch and 30-inch) from Lake Hudson to west of the water treatment plant site. From this location, a 42-inch pipeline was installed to the treatment plant. All of these pipelines operate by gravity flow using the head generated by the elevation of the water in Lake Hudson. The available head is sufficient to meet the demands used in this report. Therefore, no costs have been added for this system.

Bartlesville Water Supply Study
Alternative Source Estimated Costs
Case 1 - 5% Flood Pool + WQ Reallocation at Hulah & Copan

| Case 1 | Hulah Existing | | | | Copan Lake | | | | Case 1 | Case 1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pipe Size & Flow | Ex 2 @ 24" - 7.36 MGD | | | | 30" - 7.44 MGD | | | | Total | Present Value |
| | Quantity | Unit | Cost | Total | Quantity | Unit | Cost | Total | | |
| *Pipeline* | | | | | | | | | | |
| R.O.W. | | | | | | | | | | |
| Land Cost | | Acre | $0.00 | $0 | 17 | Acre | $1,500.00 | $25,500 | | |
| Acquisition | | LS | $0.00 | $0 | 1 | LS | $8,000.00 | $8,000 | | |
| **Total R.O.W.** | | | | **$0** | | | | **$33,500** | | |
| | | | | | | | | | | |
| **Pipe & Pump Station** | | | | | | | | | | |
| Pipe | | LF | $0.00 | $0 | 30,295 | LF | $190.00 | $5,756,050 | | |
| Highway Boring | | EA | $0.00 | $0 | 0 | EA | $70,000.00 | $0 | | |
| Pump Station | | HP | $0.00 | $0 | 1,181 | HP | $2,855.00 | $3,371,755 | | |
| Intake Structure | | LS | $0.00 | $0 | 1 | LS | $620,000.00 | $620,000 | | |
| Engineering | | LS | $0.00 | $0 | 1 | LS | $975,000.00 | $975,000 | | |
| S.I.O.H. | | LS | $0.00 | $0 | 1 | LS | $585,000.00 | $585,000 | | |
| **Total Pipe & Pump Station** | | | | **$0** | | | | **$11,307,805** | | |
| | | | | | | | | | | |
| **Pipeline Costs** | | | | **$0** | | | | **$11,341,305** | | |
| **Contingency @ 25%** | | | | **$0** | | | | **$2,835,326** | | |
| **Total Pipeline Costs** | | | | **$0** | | | | **$14,176,631** | **$14,176,631** | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Lake* | | | | | | | | | | |
| R.O.W. | | | | | | | | | | |
| Land Cost | | Acre | $0.00 | $0 | | Acre | $0.00 | $0 | | |
| Residential Relocation | | EA | $0.00 | $0 | | EA | $0.00 | $0 | | |
| Acquisition | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| **Total R.O.W.** | | | | **$0** | | | | **$0** | | |
| | | | | | | | | | | |
| **Reservoir** | | | | | | | | | | |
| Infra. & Facility Reloc. | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| Dam/Equip./Bldg. | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| Recreation | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| Engineering | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| S.I.O.H. | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| **Total Reservoir** | | | | **$0** | | | | **$0** | | |
| | | | | | | | | | | |

Bartlesville Water Supply Study
Alternative Source Estimated Costs
Case 1 - 5% Flood Pool + WQ Reallocation at Hulah & Copan

| Case 1 | Hulah Existing | | | | Copan Lake | | | | Case 1 | Case 1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pipe Size & Flow | Ex 2 @ 24" - 7.36 MGD | | | | 30" - 7.44 MGD | | | | Total | Present Value |
| | Quantity | Unit | Cost | Total | Quantity | Unit | Cost | Total | | |
| Lake Costs | | | | $0 | | | | $0 | | |
| Contingency @ 25% | | | | $0 | | | | $0 | | |
| Total Lake Costs | | | | $0 | | | | $0 | $0 | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| Total Construction Cost | | | | $0 | | | | $14,176,631 | $14,176,631 | $14,176,631 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Energy Costs* | | | | | | | | | | |
| Base Charge | 12 | Mo | $50.00 | $600 | 12 | Mo | $50.00 | $600 | | |
| Energy Charge (Yearly) | 3,929,000 | KWH | $0.02743 | $107,772 | 3,859,000 | KWH | $0.02743 | $105,852 | | |
| Demand Charge (Yearly) | 10,764 | KW | $6.50 | $69,966 | 10,572 | KW | $6.50 | $68,718 | | |
| Energy Cost, Year 1 | | | | $178,338 | | | | $175,170 | $353,508 | |
| Energy Cost, Year 50 | | | | $598,017 | | | | $587,394 | $1,185,411 | |
| | | | | | | | | | | |
| Total Energy Cost | | | | $17,385,164 | | | | $17,076,333 | $34,461,497 | $10,644,221 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Pump Replacement* | | | | | | | | | | |
| Year 25 | 1,202 | HP | $200.00 | $240,400 | 1181 | HP | $200.00 | $236,200 | $476,600 | $144,996 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Total Present Value* | | | | | | | | | | $24,965,848 |
| | | | | | | | | | | |

**Bartlesville Water Supply Study**
**Alternative Source Estimated Costs**
**Case 2 - 10% Flood Pool + WQ Reallocation at Hulah**

| Case 2 | Hulah Existing | | | | Hulah Parallel | | | |
|---|---|---|---|---|---|---|---|---|
| Pipe Size & Flow | Ex 2 @ 24" - 6.88 MGD | | | | 30" - 7.31 MGD | | | |
| | Quantity | Unit | Cost | Total | Quantity | Unit | Cost | Total |
| *Pipeline* | | | | | | | | |
| R.O.W. | | | | | | | | |
| Land Cost | | Acre | $0.00 | $0 | 14 | Acre | $1,500.00 | $21,000 |
| Acquisition | | LS | $0.00 | $0 | 1 | LS | $5,000.00 | $5,000 |
| **Total R.O.W.** | | | | **$0** | | | | **$26,000** |
| | | | | | | | | |
| **Pipe & Pump Station** | | | | | | | | |
| Pipe | | LF | $0.00 | $0 | 39,561 | LF | $190.00 | $7,516,590 |
| Highway Boring | | EA | $0.00 | $0 | 0 | EA | $70,000.00 | $0 |
| Pump Station | | HP | $0.00 | $0 | 1,162 | HP | $2,855.00 | $3,317,510 |
| Intake Structure (Mod) | | LS | $0.00 | $0 | 1 | LS | $300,000.00 | $300,000 |
| Engineering | | LS | $0.00 | $0 | 1 | LS | $1,114,000.00 | $1,114,000 |
| S.I.O.H. | | LS | $0.00 | $0 | 1 | LS | $668,000.00 | $668,000 |
| **Total Pipe & Pump Station** | | | | **$0** | | | | **$12,916,100** |
| | | | | | | | | |
| **Pipeline Costs** | | | | **$0** | | | | **$12,942,100** |
| **Contingency @ 25%** | | | | **$0** | | | | **$3,235,525** |
| **Total Pipeline Costs** | | | | **$0** | | | | **$16,177,625** |
| | | | | | | | | |
| | | | | | | | | |
| *Lake* | | | | | | | | |
| R.O.W. | | | | | | | | |
| Land Cost | | Acre | $0.00 | $0 | | Acre | $0.00 | $0 |
| Residential Relocation | | EA | $0.00 | $0 | | EA | $0.00 | $0 |
| Acquisition | | LS | $0.00 | $0 | | LS | $0.00 | $0 |
| **Total R.O.W.** | | | | **$0** | | | | **$0** |
| | | | | | | | | |
| **Reservoir** | | | | | | | | |
| Infra. & Facility Reloc. | | LS | $0.00 | $0 | | LS | $0.00 | $0 |
| Dam/Equip./Bldg. | | LS | $0.00 | $0 | | LS | $0.00 | $0 |
| Recreation | | LS | $0.00 | $0 | | LS | $0.00 | $0 |
| Engineering | | LS | $0.00 | $0 | | LS | $0.00 | $0 |
| S.I.O.H. | | LS | $0.00 | $0 | | LS | $0.00 | $0 |
| **Total Reservoir** | | | | **$0** | | | | **$0** |
| | | | | | | | | |

**Bartlesville Water Supply Study**
**Alternative Source Estimated Costs**
**Case 2 - 10% Flood Pool + WQ Reallocation at Hulah**

| Case 2 | Hulah Existing | | | | Hulah Parallel | | | |
|---|---|---|---|---|---|---|---|---|
| Pipe Size & Flow | Ex 2 @ 24" - 6.88 MGD | | | | 30" - 7.31 MGD | | | |
| | Quantity | Unit | Cost | Total | Quantity | Unit | Cost | Total |
| **Lake Costs** | | | | $0 | | | | $0 |
| **Contingency @ 25%** | | | | $0 | | | | $0 |
| **Total Lake Costs** | | | | $0 | | | | $0 |
| | | | | | | | | |
| | | | | | | | | |
| **Total Construction Cost** | | | | $0 | | | | $16,177,625 |
| | | | | | | | | |
| | | | | | | | | |
| ***Energy Costs*** | | | | | | | | |
| Base Charge | 12 | Mo | $25.00 | $300 | 12 | Mo | $25.00 | $300 |
| Energy Charge (Yearly) | 3,574,000 | KWH | $0.02743 | $98,035 | 3,798,000 | KWH | $0.02743 | $104,179 |
| Demand Charge (Yearly) | 9,792 | KW | $6.50 | $63,648 | 10,404 | KW | $6.50 | $67,626 |
| Energy Cost, Year 1 | | | | **$161,983** | | | | **$172,105** |
| Energy Cost, Year 50 | | | | **$543,174** | | | | **$577,116** |
| | | | | | | | | |
| **Total Energy Cost** | | | | **$15,790,807** | | | | **$16,777,544** |
| | | | | | | | | |
| | | | | | | | | |
| ***Pump Replacement*** | | | | | | | | |
| Year 25 | 1,094 | HP | $200.00 | **$218,800** | 1162 | HP | $200.00 | **$232,400** |
| | | | | | | | | |
| | | | | | | | | |
| ***Total Present Value*** | | | | | | | | |
| | | | | | | | | |

| Caney River | | | | Case 2 | Case 2 |
|---|---|---|---|---|---|
| 0.61 MGD | | | | Total | Present Value |
| Quantity | Unit | Cost | Total | | |
| | | | | | |
| | | | | | |
| | Acre | $0.00 | $0 | | |
| | LS | $0.00 | $0 | | |
| | | | **$0** | | |
| | | | | | |
| | | | | | |
| | LF | $0.00 | $0 | | |
| | EA | $0.00 | $0 | | |
| | HP | $0.00 | $0 | | |
| | LS | $0.00 | $0 | | |
| | LS | $0.00 | $0 | | |
| | LS | $0.00 | $0 | | |
| | | | **$0** | | |
| | | | | | |
| | | | **$0** | | |
| | | | **$0** | | |
| | | | **$0** | **$16,177,625** | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | Acre | $0.00 | $0 | | |
| | EA | $0.00 | $0 | | |
| | LS | $0.00 | $0 | | |
| | | | **$0** | | |
| | | | | | |
| | | | | | |
| | LS | $0.00 | $0 | | |
| | LS | $0.00 | $0 | | |
| | LS | $0.00 | $0 | | |
| | LS | $0.00 | $0 | | |
| | LS | $0.00 | $0 | | |
| | | | **$0** | | |
| | | | | | |

| Caney River 0.61 MGD | | | | Case 2 Total | Case 2 Present Value |
|---|---|---|---|---|---|
| Quantity | Unit | Cost | Total | | |
| | | | $0 | | |
| | | | $0 | | |
| | | | $0 | $0 | |
| | | | | | |
| | | | | | |
| | | | $0 | $16,177,625 | $16,177,625 |
| | | | | | |
| | | | | | |
| | | | | | |
| 12 | Mo | $50.00 | $600 | | |
| 315,000 | KWH | $0.02743 | $8,640 | | |
| 864 | KW | $6.50 | $5,616 | | |
| | | | $14,856 | $348,944 | |
| | | | $49,816 | $1,170,106 | |
| | | | | | |
| | | | $1,448,227 | $34,016,578 | $10,506,798 |
| | | | | | |
| | | | | | |
| | | | | | |
| 97 | HP | $200.00 | $19,400 | $470,600 | $143,170 |
| | | | | | |
| | | | | | |
| | | | | | $26,827,593 |
| | | | | | |

Bartlesville Water Supply Study
Alternative Source Estimated Costs
Case 3 - 1% Flood Pool + WQ Reallocation at Hulah & 10% Reallocation at Copar

| Case 3 | Hulah Existing | | | | Copan Lake | | | | Case 3 | Case 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pipe Size & Flow | Ex 2 @ 24" - 4.89 MGD | | | | 36" - 9.91 MGD | | | | Total | Present Value |
| | Quantity | Unit | Cost | Total | Quantity | Unit | Cost | Total | | |
| *Pipeline* | | | | | | | | | | |
| R.O.W. | | | | | | | | | | |
| Land Cost | | Acre | $0.00 | $0 | 17 | Acre | $1,500.00 | $25,500 | | |
| Acquisition | | LS | $0.00 | $0 | 1 | LS | $8,000.00 | $8,000 | | |
| **Total R.O.W.** | | | | **$0** | | | | **$33,500** | | |
| | | | | | | | | | | |
| **Pipe & Pump Station** | | | | | | | | | | |
| Pipe | | LF | $0.00 | $0 | 30,295 | LF | $216.00 | $6,543,720 | | |
| Highway Boring | | EA | $0.00 | $0 | 0 | EA | $70,000.00 | $0 | | |
| Pump Station | | HP | $0.00 | $0 | 1,496 | HP | $2,855.00 | $4,271,080 | | |
| Intake Structure | | LS | $0.00 | $0 | 1 | LS | $620,000.00 | $620,000 | | |
| Engineering | | LS | $0.00 | $0 | 1 | LS | $1,144,000.00 | $1,144,000 | | |
| S.I.O.H. | | LS | $0.00 | $0 | 1 | LS | $686,000.00 | $686,000 | | |
| **Total Pipe & Pump Station** | | | | **$0** | | | | **$13,264,800** | | |
| | | | | | | | | | | |
| **Pipeline Costs** | | | | **$0** | | | | **$13,298,300** | | |
| **Contingency @ 25%** | | | | **$0** | | | | **$3,324,575** | | |
| **Total Pipeline Costs** | | | | **$0** | | | | **$16,622,875** | **$16,622,875** | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Lake* | | | | | | | | | | |
| R.O.W. | | | | | | | | | | |
| Land Cost | | Acre | $0.00 | $0 | | Acre | $0.00 | $0 | | |
| Residential Relocation | | EA | $0.00 | $0 | | EA | $0.00 | $0 | | |
| Acquisition | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| **Total R.O.W.** | | | | **$0** | | | | **$0** | | |
| | | | | | | | | | | |
| **Reservoir** | | | | | | | | | | |
| Infra. & Facility Reloc. | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| Dam/Equip./Bldg. | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| Recreation | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| Engineering | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| S.I.O.H. | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| **Total Reservoir** | | | | **$0** | | | | **$0** | | |
| | | | | | | | | | | |

**Bartlesville Water Supply Study**
**Alternative Source Estimated Costs**
**Case 3 - 1% Flood Pool + WQ Reallocation at Hulah & 10% Reallocation at Copar**

| Case 3 | Hulah Existing | | | | Copan Lake | | | | Case 3 | Case 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pipe Size & Flow | Ex 2 @ 24" - 4.89 MGD | | | | 36" - 9.91 MGD | | | | Total | Present Value |
| | Quantity | Unit | Cost | Total | Quantity | Unit | Cost | Total | | |
| Lake Costs | | | | $0 | | | | $0 | | |
| Contingency @ 25% | | | | $0 | | | | $0 | | |
| Total Lake Costs | | | | $0 | | | | $0 | $0 | |
| | | | | | | | | | | |
| Total Construction Cost | | | | $0 | | | | $16,622,875 | $16,622,875 | $16,622,875 |
| | | | | | | | | | | |
| *Energy Costs* | | | | | | | | | | |
| Base Charge | 12 | Mo | $50.00 | $600 | 12 | Mo | $50.00 | $600 | | |
| Energy Charge (Yearly) | 2,278,000 | KWH | $0.02743 | $62,486 | 4,888,000 | KWH | $0.02743 | $134,078 | | |
| Demand Charge (Yearly) | 6,240 | KW | $6.50 | $40,560 | 13,392 | KW | $6.50 | $87,048 | | |
| Energy Cost, Year 1 | | | | $103,646 | | | | $221,726 | $325,372 | |
| Energy Cost, Year 50 | | | | $347,554 | | | | $743,509 | $1,091,063 | |
| | | | | | | | | | | |
| Total Energy Cost | | | | $10,103,863 | | | | $21,614,815 | $31,718,678 | $9,797,038 |
| | | | | | | | | | | |
| *Pump Replacement* | | | | | | | | | | |
| Year 25 | 697 | HP | $200.00 | $139,400 | 1496 | HP | $200.00 | $299,200 | $438,600 | $133,435 |
| | | | | | | | | | | |
| *Total Present Value* | | | | | | | | | | $26,553,348 |

**Bartlesville Water Supply Study**
**Alternative Source Estimated Costs**
**Case 4 - No Reallocation at Hulah & Construct Sand Lake**

| Case 4 | Hulah Existing | | | | Sand Lake | | | | Case 4 | Case 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pipe Size & Flow | Ex 2 @ 24" - 4.35 MGD | | | | 36" - 10.45 MGD | | | | Total | Present Value |
| | Quantity | Unit | Cost | Total | Quantity | Unit | Cost | Total | | |
| *Pipeline* | | | | | | | | | | |
| R.O.W. | | | | | | | | | | |
| Land Cost | | Acre | $0.00 | $0 | 29 | Acre | $1,500.00 | $43,500 | | |
| Acquisition | | LS | $0.00 | $0 | 1 | LS | $10,000.00 | $10,000 | | |
| **Total R.O.W.** | | | | $0 | | | | $53,500 | | |
| | | | | | | | | | | |
| **Pipe & Pump Station** | | | | | | | | | | |
| Pipe | | LF | $0.00 | $0 | 49,915 | LF | $216.00 | $10,781,640 | | |
| Highway Boring | | EA | $0.00 | $0 | 1 | EA | $70,000.00 | $70,000 | | |
| Pump Station | | HP | $0.00 | $0 | 1,745 | HP | $2,855.00 | $4,981,975 | | |
| Intake Structure | | LS | $0.00 | $0 | 1 | LS | $620,000.00 | $620,000 | | |
| Engineering | | LS | $0.00 | $0 | 1 | LS | $1,645,000.00 | $1,645,000 | | |
| S.I.O.H. | | LS | $0.00 | $0 | 1 | LS | $987,000.00 | $987,000 | | |
| **Total Pipe & Pump Station** | | | | $0 | | | | $19,085,615 | | |
| | | | | | | | | | | |
| **Pipeline Costs** | | | | $0 | | | | $19,139,115 | | |
| **Contingency @ 25%** | | | | $0 | | | | $4,784,779 | | |
| **Total Pipeline Costs** | | | | $0 | | | | $23,923,894 | $23,923,894 | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Lake* | | | | | | | | | | |
| R.O.W. | | | | | | | | | | |
| Land Cost | | Acre | $0.00 | $0 | 4,300 | Acre | $1,500.00 | $6,450,000 | | |
| Residential Relocation | | EA | $0.00 | $0 | 4 | EA | $200,000.00 | $800,000 | | |
| Acquisition | | LS | $0.00 | $0 | 1 | LS | $400,000.00 | $400,000 | | |
| **Total R.O.W.** | | | | $0 | | | | $7,650,000 | | |
| | | | | | | | | | | |
| **Reservoir** | | | | | | | | | | |
| Infra. & Facility Reloc. | | LS | $0.00 | $0 | 1 | LS | $3,875,000.00 | $3,875,000 | | |
| Dam/Equip./Bldg. | | LS | $0.00 | $0 | 1 | LS | $22,866,000.00 | $22,866,000 | | |
| Recreation | | LS | $0.00 | $0 | 1 | LS | $1,500,000.00 | $1,500,000 | | |
| Engineering | | LS | $0.00 | $0 | 1 | LS | $2,824,000.00 | $2,824,000 | | |
| S.I.O.H. | | LS | $0.00 | $0 | 1 | LS | $1,694,000.00 | $1,694,000 | | |
| **Total Reservoir** | | | | $0 | | | | $32,759,000 | | |
| | | | | | | | | | | |

Bartlesville Water Supply Study
Alternative Source Estimated Costs
Case 4 - No Reallocation at Hulah & Construct Sand Lake

| Case 4 | Hulah Existing | | | | Sand Lake | | | | Case 4 | Case 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pipe Size & Flow | Ex 2 @ 24" - 4.35 MGD | | | | 36" - 10.45 MGD | | | | Total | Present Value |
| | Quantity | Unit | Cost | Total | Quantity | Unit | Cost | Total | | |
| Lake Costs | | | | $0 | | | | $40,409,000 | | |
| Contingency @ 25% | | | | $0 | | | | $10,102,250 | | |
| Total Lake Costs | | | | $0 | | | | $50,511,250 | $50,511,250 | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| Total Construction Cost | | | | $0 | | | | $74,435,144 | $74,435,144 | $74,435,144 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Energy Costs* | | | | | | | | | | |
| Base Charge | 12 | Mo | $50.00 | $600 | 12 | Mo | $50.00 | $600 | | |
| Energy Charge (Yearly) | 1,975,000 | KWH | $0.02743 | $54,174 | 5,703,000 | KWH | $0.02743 | $156,433 | | |
| Demand Charge (Yearly) | 5,412 | KW | $6.50 | $35,178 | 15,624 | KW | $6.50 | $101,556 | | |
| Energy Cost, Year 1 | | | | $89,952 | | | | $258,589 | $348,541 | |
| Energy Cost, Year 50 | | | | $301,634 | | | | $867,120 | $1,168,754 | |
| | | | | | | | | | | |
| Total Energy Cost | | | | $8,768,912 | | | | $25,208,380 | $33,977,292 | $10,494,663 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Pump Replacement* | | | | | | | | | | |
| Year 25 | 604 | HP | $200.00 | $120,800 | 1745 | HP | $200.00 | $349,000 | $469,800 | $142,927 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Total Present Value* | | | | | | | | | | $85,072,734 |
| | | | | | | | | | | |

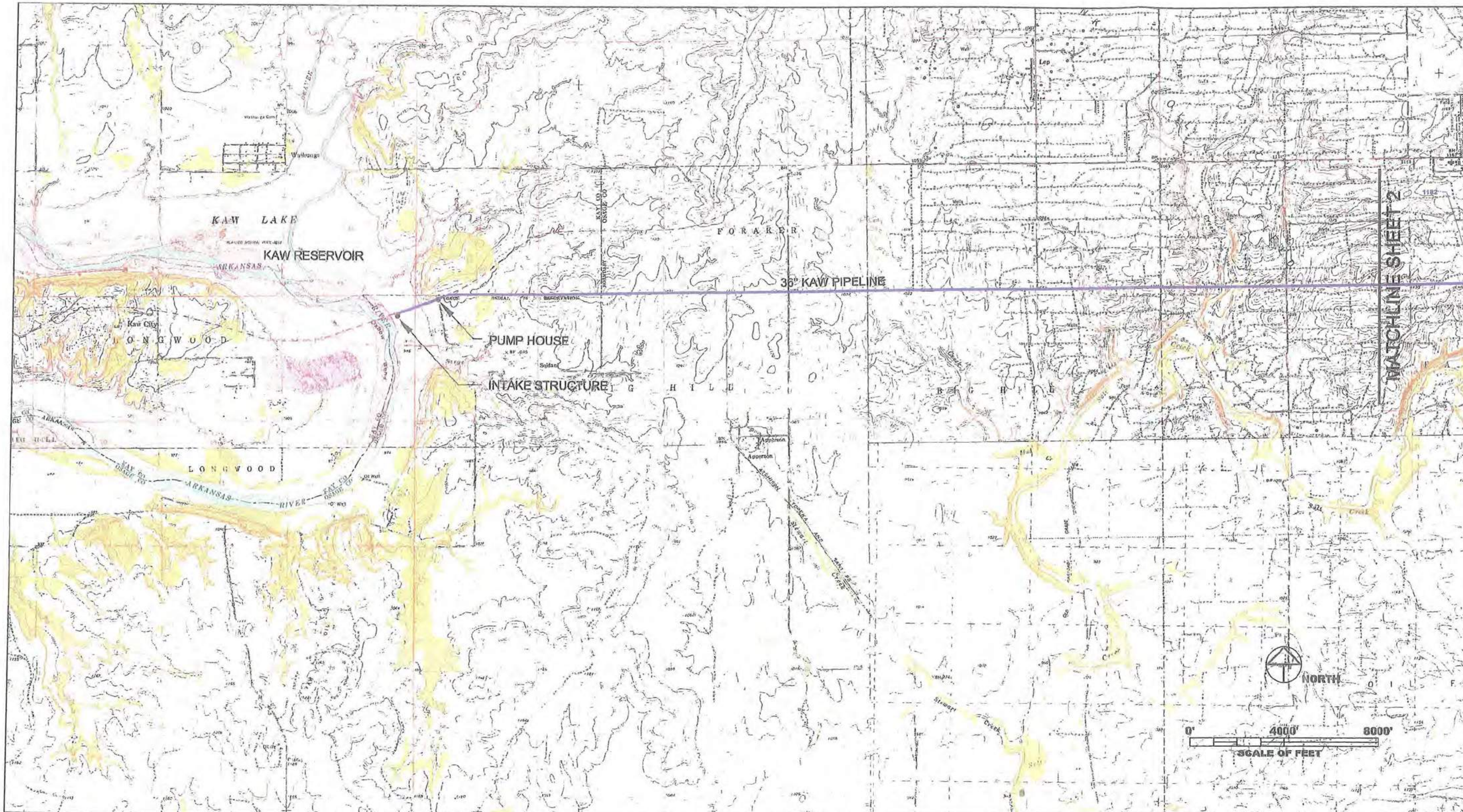
Bartlesville Water Supply Study
Alternative Source Estimated Costs
Case 5 - No Reallocation at Hulah & Kaw Pipeline

| Case 5 | Hulah Existing | | | | Kaw Reservoir | | | | Case 5 Total | Case 5 Present Value |
|---|---|---|---|---|---|---|---|---|---|---|
| Pipe Size & Flow | Ex 2 @ 24" - 4.35 MGD | | | | 36" - 10.45 MGD | | | | | |
| | Quantity | Unit | Cost | Total | Quantity | Unit | Cost | Total | | |
| *Pipeline* | | | | | | | | | | |
| R.O.W. | | | | | | | | | | |
| Land Cost | | Acre | $0.00 | $0 | 137 | Acre | $1,500.00 | $205,500 | | |
| Acquisition | | LS | $0.00 | $0 | 1 | LS | $40,000.00 | $40,000 | | |
| **Total R.O.W.** | | | | **$0** | | | | **$245,500** | | |
| | | | | | | | | | | |
| **Pipe & Pump Station** | | | | | | | | | | |
| Pipe | | LF | $0.00 | $0 | 238,266 | LF | $216.00 | $51,465,456 | | |
| Highway Boring | | EA | $0.00 | $0 | 2 | EA | $70,000.00 | $140,000 | | |
| Pump Station | | HP | $0.00 | $0 | 2,547 | HP | $2,855.00 | $7,271,685 | | |
| Intake Structure | | LS | $0.00 | $0 | 1 | LS | $620,000.00 | $620,000 | | |
| Engineering | | LS | $0.00 | $0 | 1 | LS | $5,950,000.00 | $5,950,000 | | |
| S.I.O.H. | | LS | $0.00 | $0 | 1 | LS | $3,570,000.00 | $3,570,000 | | |
| **Total Pipe & Pump Station** | | | | **$0** | | | | **$69,017,141** | | |
| | | | | | | | | | | |
| **Pipeline Costs** | | | | **$0** | | | | **$69,262,641** | | |
| **Contingency @ 25%** | | | | **$0** | | | | **$17,315,660** | | |
| **Total Pipeline Costs** | | | | **$0** | | | | **$86,578,301** | **$86,578,301** | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Lake* | | | | | | | | | | |
| **R.O.W.** | | | | | | | | | | |
| Land Cost | | Acre | $0.00 | $0 | | Acre | $0.00 | $0 | | |
| Residential Relocation | | EA | $0.00 | $0 | | EA | $0.00 | $0 | | |
| Acquisition | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| **Total R.O.W.** | | | | **$0** | | | | **$0** | | |
| | | | | | | | | | | |
| **Reservoir** | | | | | | | | | | |
| Infra. & Facility Reloc. | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| Dam/Equip./Bldg. | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| Recreation | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| Engineering | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| S.I.O.H. | | LS | $0.00 | $0 | | LS | $0.00 | $0 | | |
| **Total Reservoir** | | | | **$0** | | | | **$0** | | |
| | | | | | | | | | | |

**Bartlesville Water Supply Study**
**Alternative Source Estimated Costs**
**Case 5 - No Reallocation at Hulah & Kaw Pipeline**

| Case 5 | Hulah Existing | | | | Kaw Reservoir | | | | Case 5 Total | Case 5 Present Value |
|---|---|---|---|---|---|---|---|---|---|---|
| Pipe Size & Flow | Ex 2 @ 24" - 4.35 MGD | | | | 36" - 10.45 MGD | | | | | |
| | Quantity | Unit | Cost | Total | Quantity | Unit | Cost | Total | | |
| Lake Costs | | | | $0 | | | | $0 | | |
| Contingency @ 25% | | | | $0 | | | | $0 | | |
| Total Lake Costs | | | | $0 | | | | $0 | $0 | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| Total Construction Cost | | | | $0 | | | | $86,578,301 | $86,578,301 | $86,578,301 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Energy Costs* | | | | | | | | | | |
| Base Charge | 12 | Mo | $50.00 | $600 | 12 | Mo | $50.00 | $600 | | |
| Energy Charge (Yearly) | 1,975,000 | KWH | $0.02743 | $54,174 | 8,322,000 | KWH | $0.02743 | $228,272 | | |
| Demand Charge (Yearly) | 5,412 | KW | $6.50 | $35,178 | 22,800 | KW | $6.50 | $148,200 | | |
| Energy Cost, Year 1 | | | | $89,952 | | | | $377,072 | $467,024 | |
| Energy Cost, Year 50 | | | | $301,634 | | | | $1,264,427 | $1,566,061 | |
| | | | | | | | | | | |
| Total Energy Cost | | | | $8,768,912 | | | | $36,758,618 | $45,527,530 | $14,062,218 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Pump Replacement* | | | | | | | | | | |
| Year 25 | 604 | HP | $200.00 | $120,800 | 2547 | HP | $200.00 | $509,400 | $630,200 | $191,725 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| *Total Present Value* | | | | | | | | | | $100,832,244 |
| | | | | | | | | | | |

| Bartlesville Water Supply Study - Unit Costs | | |
|---|---|---|
| Rates | Unit | Cost |
| | | |
| Land Value | Acre | $1,500.00 |
| | | |
| Pipeline Costs | | |
| 30" | LF | $190.00 |
| 36" | LF | $216.00 |
| | | |
| Highway Boring | EA | $70,000.00 |
| | | |
| Pump Stations | HP | $2,855.00 |
| | | |
| Power Costs | | |
| Base Charge | MO | $50.00 |
| Energy Charge | KWH | $0.0274 |
| Demand Charge | KW | $6.50 |
| | | |
| Pump Replacement | HP | $200.00 |
| | | |
| | | |
| Inflation Rate | | 2.500% |
| | | |
| Discount Rate | | 4.875% |
| | | |
| | | |
| | | |
| | | |

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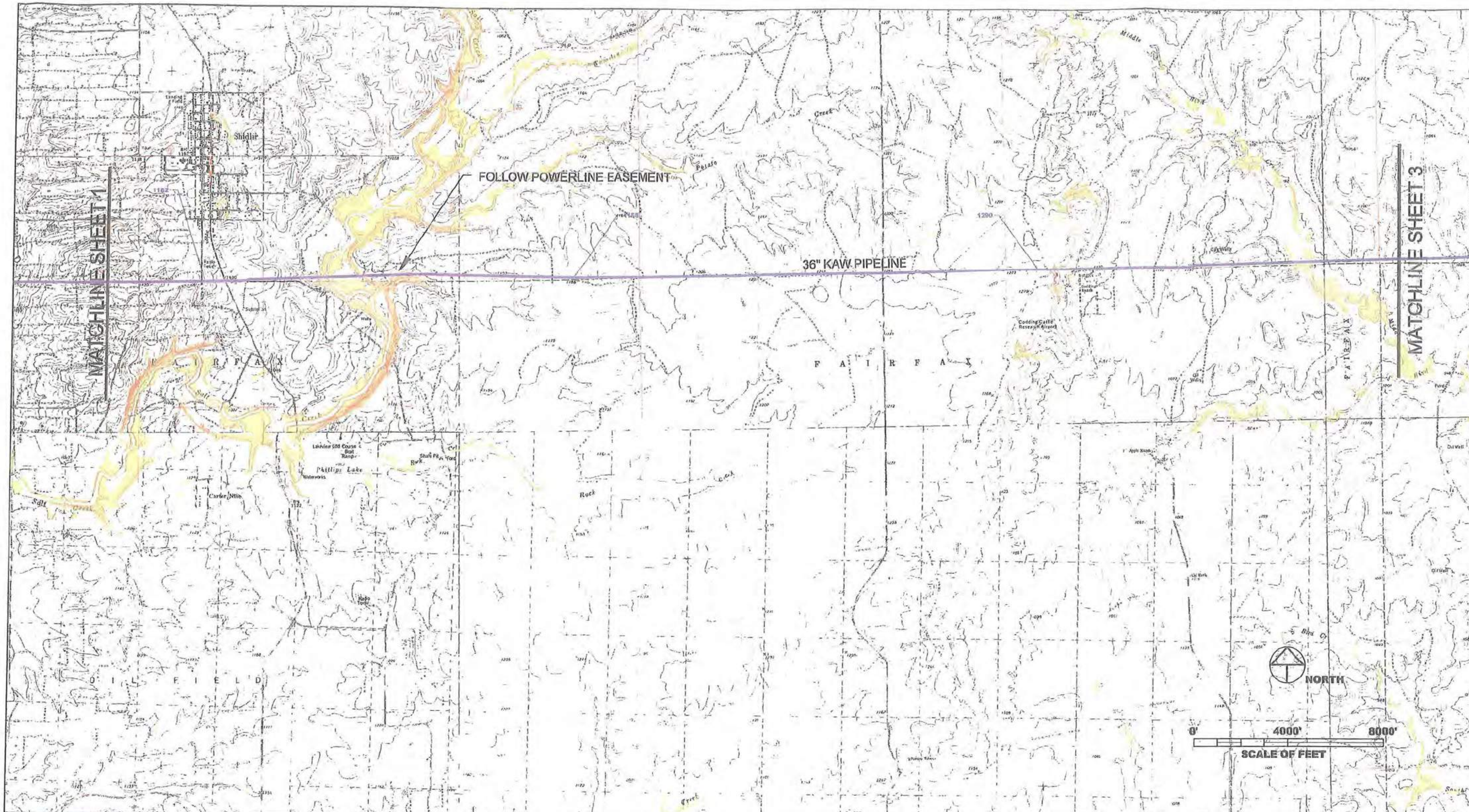


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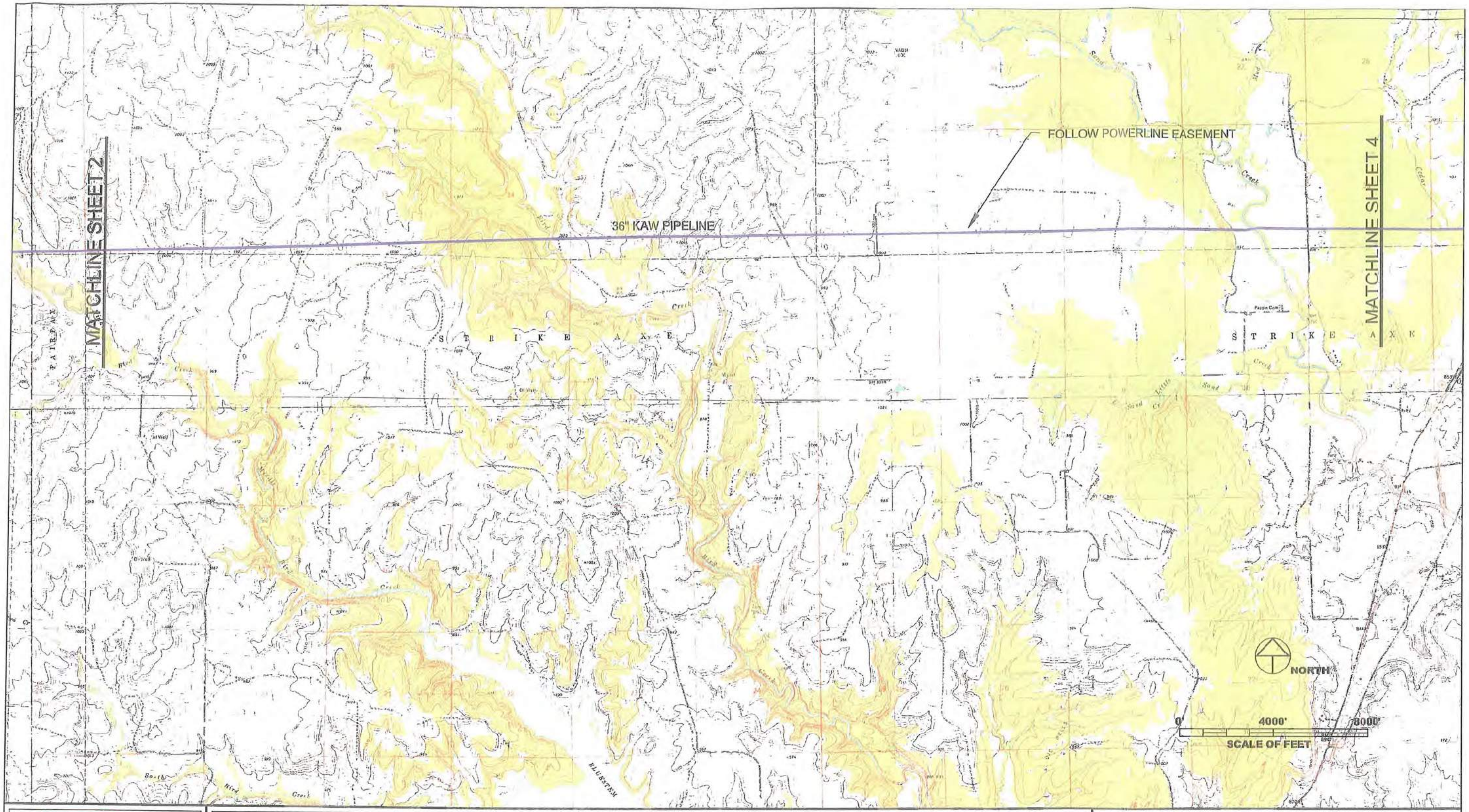


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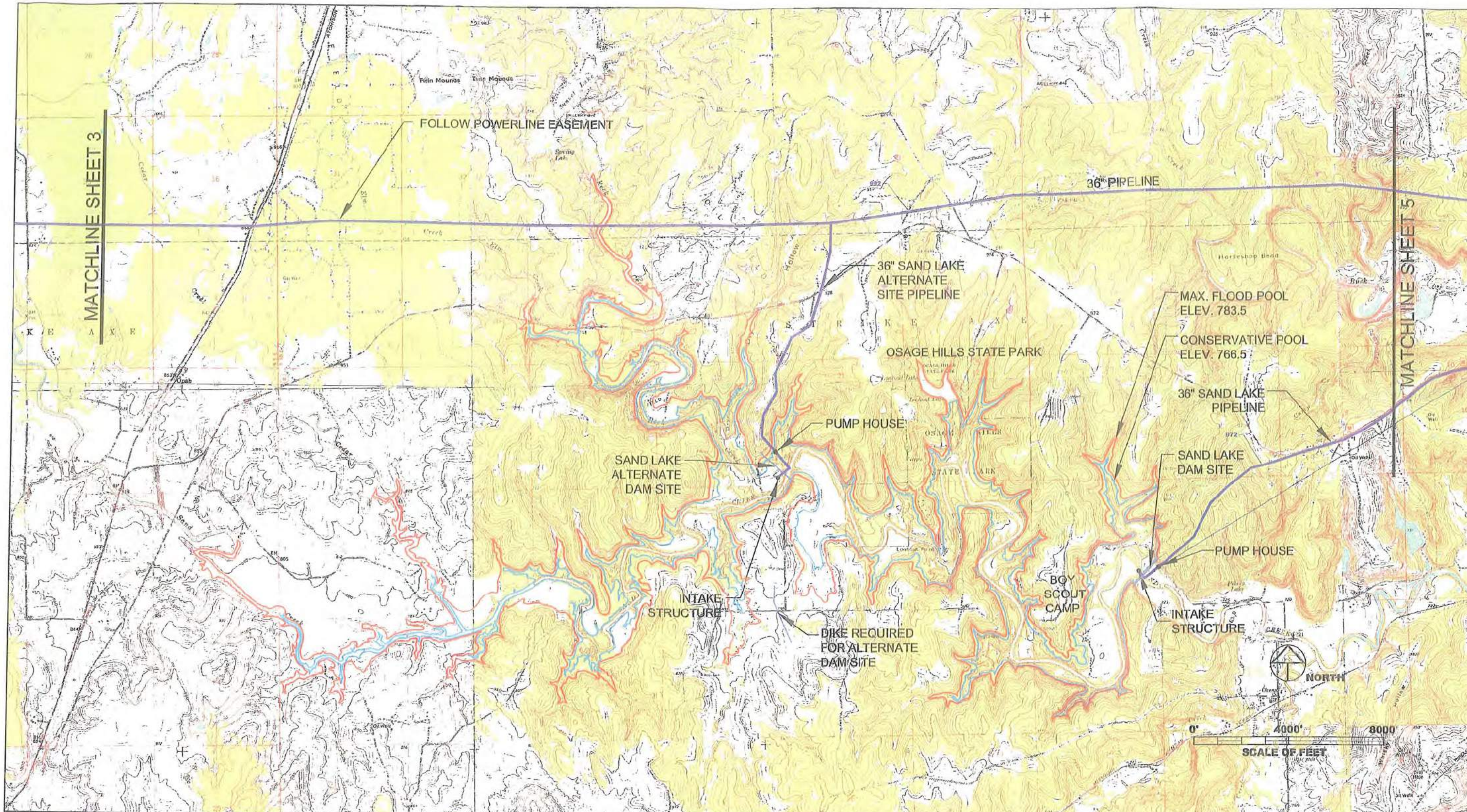


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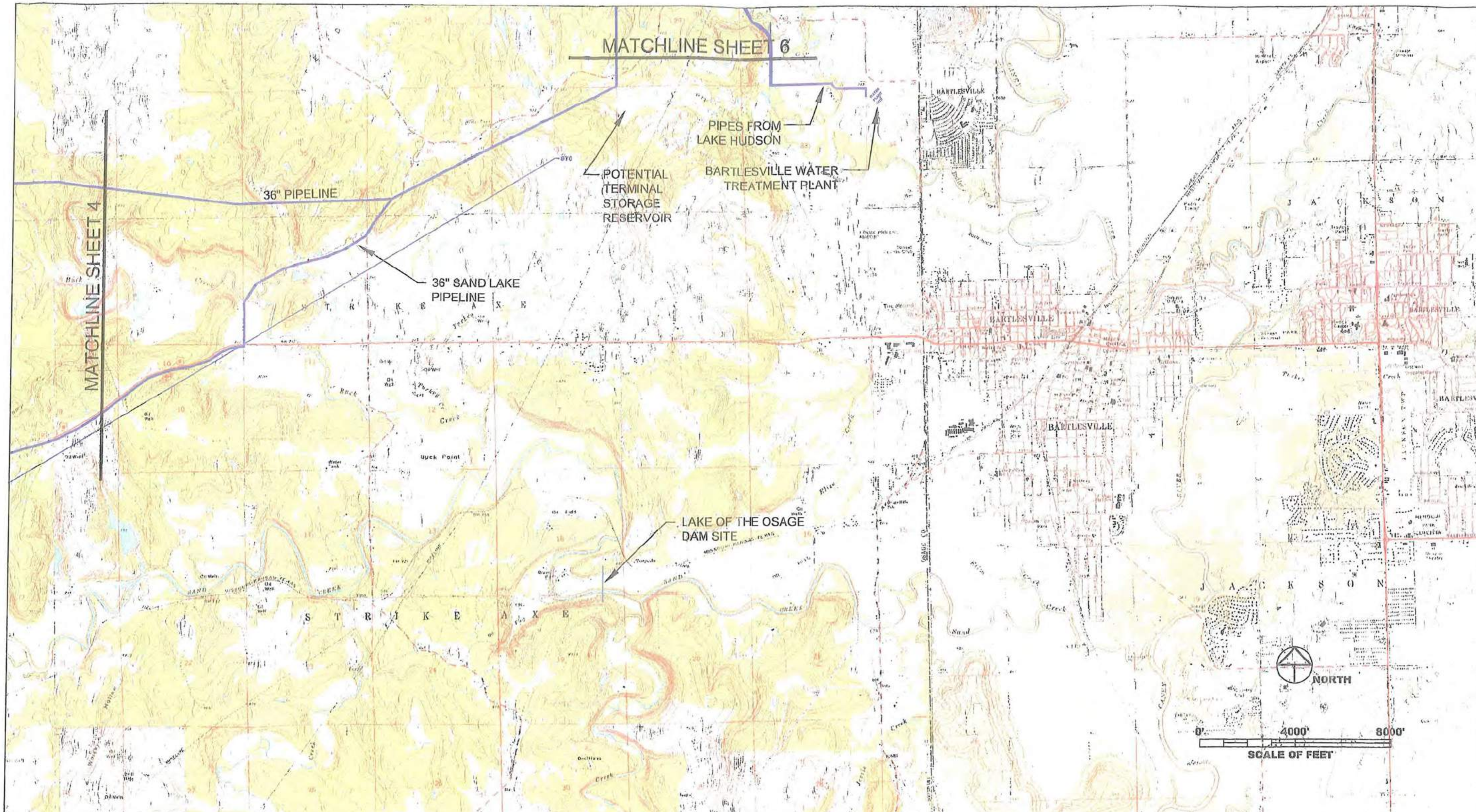


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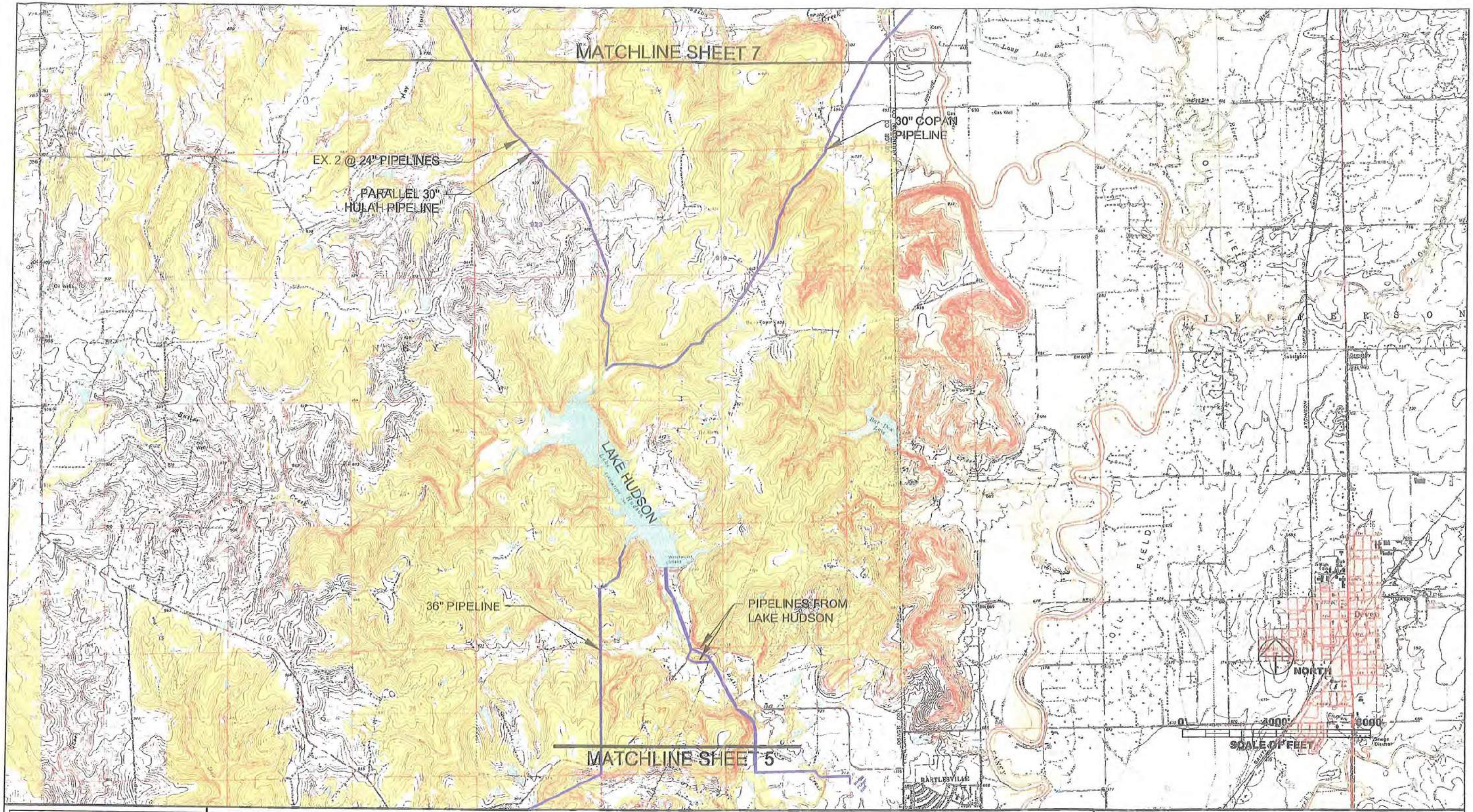
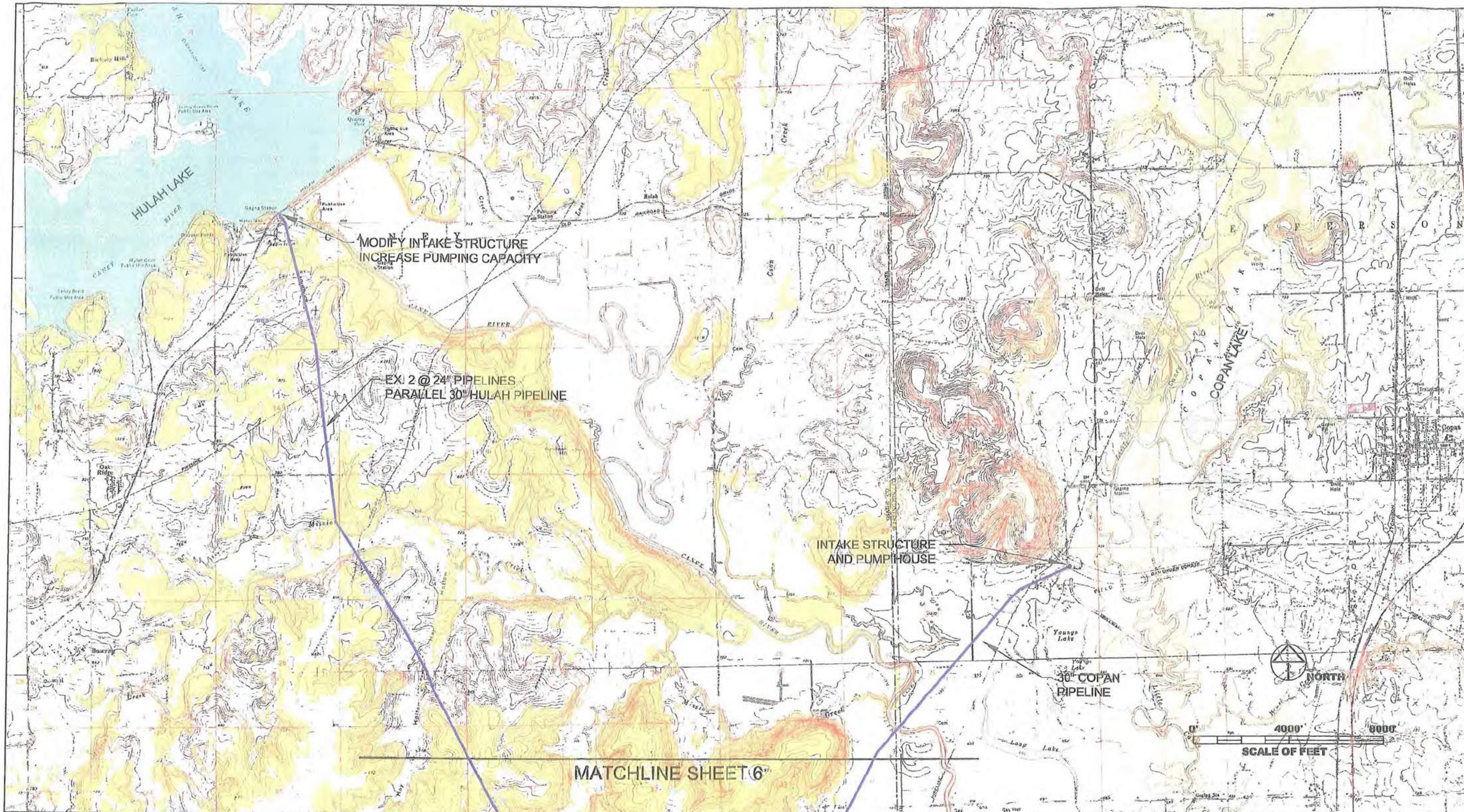



US Army Corps of Engineers®

# BARTLESVILLE WATER SUPPLY STUDY

BARTLESVILLE, OK
SCALE 1"=4000'


GUERNSEY
C.H. GUERNSEY & COMPANY
*Engineers • Architects • Consultants*
5555 North Grand Boulevard
Oklahoma City, OK 73112-5507
405-416-8100

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SHEET 7 OF 7

# APPENDIX E

# Cultural Resource Analysis

# APPENDIX E

## Bartlesville Water Supply Alternatives

### Cultural Resources Overview

Northeastern Oklahoma has shown evidence of human occupation dating from the Paleoindian Period through the Archaic, Woodland, Caddoan, Plains Village, and up through the Historic period. The study area that includes Copan and Hulah lakes in Washington County has recorded sites dating back to the Archaic Period in Oklahoma, and extensive evidence for Woodland and Plains Village occupation. These sites are in various settings around the Lakes and include camps, processing areas, habitation sites, trash dumps, rock shelters, and more. In addition, there is the likelihood for finding additional sites buried beneath alluvial soils and in areas that have not been surveyed.

### Cultural Resources Impacts

The proposed alternatives for the reallocation at Hulah and Copan Lakes all have the potential to impact historic properties. Sections 106 and 110 of the National Historic Preservation Act (NHPA) of 1966 (as amended) require agencies to evaluate the impacts of federal undertakings on historic properties, which include prehistoric and historic archaeological sites, and historic standing structures. Section 106 requires the identification of all historic properties, which emphasizes an evaluation of eligibility for listing on the National Register of Historic Places (NRHP). Agencies must then determine which historic properties (those eligible for listing on the NRHP) will be adversely impacted. Sections 106 and 110 require that agencies resolve adverse effects to these properties. Plans for resolving adverse effects will be determined through consultation with the Oklahoma State Historic Preservation Office (SHPO), Oklahoma Archeological Survey (OAS), potentially the Advisory Council on Historic Preservation (ACHP), and appropriate and interested Native American tribes and other interested parties.

To fulfill the requirements outlined in Sections 106 and 110 of the NHPA, several tasks will require funding and execution within the feasibility phase of this project. In order to accomplish these tasks, the project area should be expanded to its fullest extent possible, so that design considerations can incorporate multiple variables, including cultural resources. Archaeological reconnaissance investigations, to include archival research, will be necessary to identify archaeological sites and standing structures that exist within the proposed project area. Each site and structure will require National Register evaluation; some will require sub-surface evaluation, detailed archival research or architectural documentation. NRHP-eligible sites and structures that will be adversely impacted by the undertaking will require mitigation, which will be determined through formal consultation with the SHPO and OAS, and potentially the ACHP. Mitigation requirements will be established in a Memorandum of Agreement (MOA).

Based on previous survey reports and cultural resources maps, there are several important sites in the impact area at both lakes, including a few sites related to the Delaware Big House religion at Copan Lake. The initial survey of Copan Lake by Rohn and Smith in December-January of 1971/72 was performed quickly and inhibited by bad weather and lack of access to many areas. No map of surveyed areas is available, and therefore it is unknown exactly what areas have been surveyed near the shoreline. The subsequent archaeological work at the lake in the following years focused on the excavation of river bottom sites that would be lost when the lake filled. The portion of the lake between the top of the current conservation pool (710 ft) and the top of the highest alternative raise (10% = 713.76ft) has not been thoroughly surveyed and should be investigated before a pool raise. This investigation would encompass up to 610 acres and could be a combination of shoreline survey by boat at the southern end of the lake, more intensive pedestrian surveys in the northern end of the lake where larger surface areas are affected, and possible re-examination of known sites in the impact area. Additionally, the impact to the historic properties in the area was not well assessed in the early investigations and this oversight will have to be amended in the proposed investigation.

Hulah Lake was built in 1946-1951 and was not surveyed for cultural resources until 1986. The survey at that time consisted of a random sampling strategy with additional areas included based on intuition and environmental potential for habitation. The survey encompassed 113.14 of 20,676 acres of project lands and 18.67 miles of 62 miles of shoreline (conservation pool). Both historic and prehistoric resources were included in this survey, and some preliminary recommendations on National Register eligibility were made for sites located in the survey area. Though many of the sites were not determined to be eligible, five sites were recommended for further testing to determine eligibility. The random nature of the sampling and the additional work to be done at Hulah would require additional survey of the area of potential impact, including shoreline survey by boat and pedestrian reconnaissance in larger areas of impact at the western and northern edges of the lake. The survey report estimated that based on their sample nearly 350 sites could exist on federal lands at the lake. The raise of the pool from 733 ft up to 739.46ft (the 10% alternative) would include approximately 800 acres of land of which a large portion appears to have not been covered by the previous survey.

**Cultural Resources Investigation Costs**

*This is only an estimate for the purposes of this document and does not include the cost of mitigation if it becomes necessary. If the scope of the project changes the estimates will not be valid. Estimates are based on the current cost of work in Oklahoma in 2007 and will need to be amended if used in future planning work. Costs are based on a very broad, generalized view of the project and may vary based on contractor's research design.*

The work that would need to be performed during the cultural resource investigations at Copan and Hulah would be generally the same at each lake. The variations would arise from the length of shoreline, the amount of acreage impacted by the pool raise, and the variations in the alternative pool raises being considered. Three alternatives were selected for further analysis in the discussion of the flood pool reallocation: #1) 5% reallocation at both lakes; #2) 10% reallocation at Hulah, none at Copan; #3) 1% reallocation at Hulah and 10% at Copan. Although option #3 was most favored based on water quality needs, all three options will be presented in this cost estimate to provide as much information as possible.

The initial fieldwork would be focused on identifying historic properties and cultural resources as defined in the NHPA. This would involve such actions as pre-field research, field reconnaissance, and report preparation and delivery. More in-depth work on identifying National Register eligible sites and assessing any adverse effects would be done at a later time after coordination with the appropriate agencies. Again, these estimates DO NOT include any possible mitigation costs. Table 1 is a breakdown of costs by reallocation option and project. It is based on current labor and overhead on cultural resources work in Oklahoma and on the following assumptions:

- Copan Lake has 30 miles of shoreline, 307 acres of impact at 5%, and 610 acres at 10%.
- Hulah Lake has 62 miles of shoreline, 100 acres of impact at 1%, 400 acres of impact at 5%, and 800 acres of impact at 10%.
- New sites will be discovered at each Lake
    - Hulah = 10, 20, and 40 sites per 1%, 5%, and 10% raise;
    - Copan = 20 and 30 sites per 5% and 10% raise
    - 10% of located sites will need testing for National Register Eligibility.
- These costs DO NOT include the additional investigations necessary if roads, facilities, or other lake amenities are relocated due to a pool raise. It is recommended that those relocations be planned in advance of the cultural resource investigations so that the cost may be added to the total and they may be all completed at one time.

**Table 1: Cost Estimate Breakdown By Reallocation Option and Project**

| OPTION 1: 5% POOL RAISE EACH LAKE | COPAN | HULAH | TOTAL |
|---|---|---|---|
| Identify Historic Properties | 150,000.00 | 150,000.00 | 300,000.00 |
| Determine National Register Eligibility | 100,000.00 | 100,000.00 | 200,000.00 |
| | | | |
| **OPTION 2: 10% POOL RAISE HULAH** | **COPAN** | **HULAH** | **TOTAL** |
| Identify Historic Properties | 0.00 | 200,000.00 | 200,000.00 |
| Determine National Register Eligibility | 0.00 | 160,000.00 | 160,000.00 |
| | | | |
| **OPTION 3: 1% POOL RAISE HULAH, 10% POOL RAISE COPAN** | **COPAN** | **HULAH** | **TOTAL** |
| Identify Historic Properties | 150,000.00 | 90,000.00 | 240,000.00 |
| Determine National Register Eligibility | 120,000.00 | 50,000.00 | 170,000.00 |

**Other Alternatives**

The two alternatives not discussed above are the construction of Sand Lake and the construction of a pipeline from Kaw Lake to Bartlesville. These alternatives are generally larger, costlier options that would entail a high level of effort to identify cultural resources in the area of potential effect. Each would have the potential to impact prehistoric and historic properties based on their size and locations. The area surrounding Kaw Lake has well-known archaeological sites related to the French and Wichita trading settlements that were located in the area, including the Deer Creek site which is listed as a National Historic Landmark. Investigations in these areas would include background research, full pedestrian survey with subsurface testing including backhoe trenching and/or coring, and testing for National Register Eligibility as described for the previous alternatives.

Assumptions made with each project are as follows:

- Sand Lake has 4,300 subject acres of land of which 3,216 would be affected by the lake at maximum elevation.
- For Sand Lake, all relocations of US-60, Osage Hills State Park structures, Boy Scout Camps, oil-field wells and pipelines, power lines, pump station, 36" pipeline to Lake Hudson, and other utilities ARE NOT included in this cost estimate and should be included in the initial planning for the cultural resources investigation to save on cost and time. These additions will likely increase the estimate depending on their location and extent.
- Possible location of up to 100 sites with testing of 10% for National Register Eligibility at Sand Lake, and 25 sites with 10% testing at Kaw Lake Pipeline.
- The Kaw Lake Pipeline will be a 36" pipe that extends 45 miles from the east side of Kaw Lake to Lake Hudson, assuming a 100 foot total easement = 545.5 acres.
- Any potential reservoir, pipeline, and water treatment facility that may be necessary depending on water quality issues or any relocation of other structures and utilities for the Kaw Lake Pipeline ARE NOT included in this estimate and should be included in initial planning as mentioned for Sand Lake.
- <u>None of the estimates for cultural resource investigations include the cost of mitigation should it become necessary</u>.

**<u>Cost Estimates for Sand Lake and Kaw Lake Pipeline</u>**

| | | |
|---|---|---|
| Sand Lake | = | $500,000 Identify Historic Properties |
| | | <u>$400,000 National Register Testing</u> |
| | | $900,000 Approximate Cost |
| Kaw Lake Pipeline | = | $125,000 Identify Historic Properties |

$75,000 National Register Testing
$200,000 Approximate Cost

# APPENDIX F

# Downstream Flood Impacts From Flood Pool

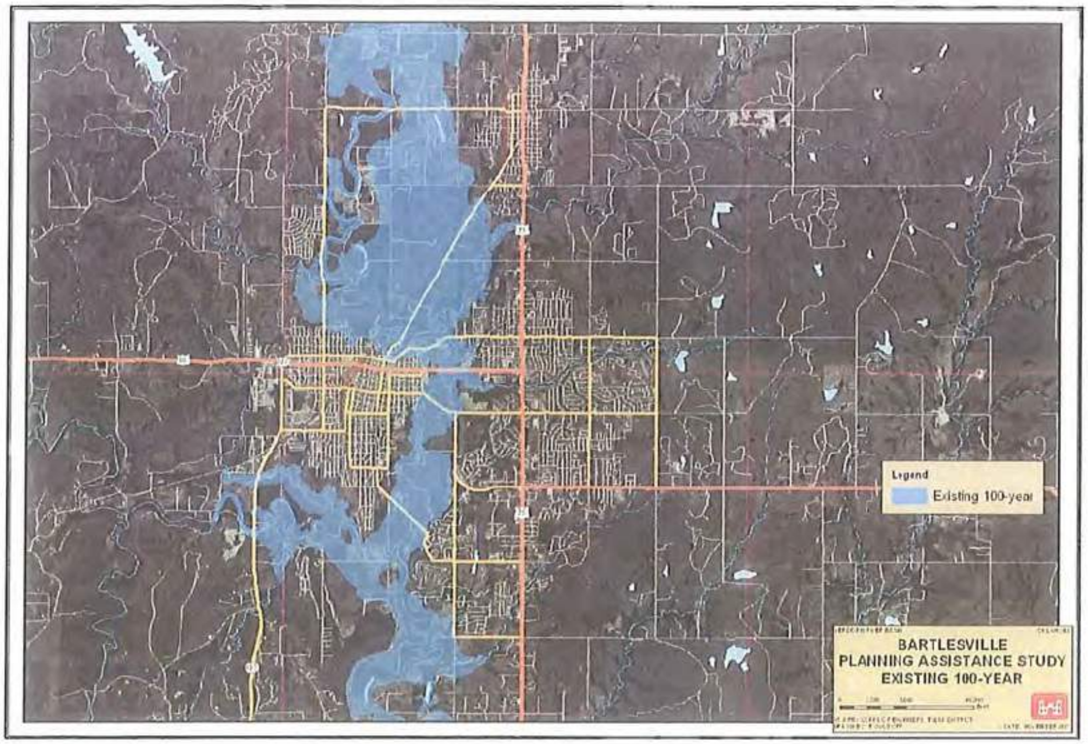
## APPENDIX F

## DOWNSTREAM FLOOD IMPACTS FROM FLOOD POOL REALLOCATION ALTERNATIVES e, f, k

There will be some minor downstream flood impacts due to any future reallocation of the flood pool to water supply storage. The level of impact to downstream flooding, is predicated on the reallocation alternative selected. The greatest difference of flood levels and flood duration (compared to existing flood conditions) will occur for the smaller frequency flood events. You will see slightly greater flood events for the 2, 5,10,25 and 50 flood events, and minimal if any difference in the greater storm events of 100, 250 years and above. The reallocations being proposed will have no measurable impact for these larger storm events.

For easy reference, Figure 3 below delineates the 100-year flood map through the City of Bartlesville. Economic projections estimate that for the three different reallocation scenario's 3a, 3b, and 3c, downstream flood damages would increase approximately \$10,000 to \$12,000 annually over a 50-year time period. Over a 50-year period, assuming a discount interest rate of 4 7/8%, approximately \$200,000 in additional flood losses above current levels could be expected. Summarized below is the estimated flood damage increases that could be expected from a potential flood reallocation.

| Plan Name | Description | Increased Annual Flood Damages Induced | Present Value of Additional Flood Damages - (50 years at 4-7/8%, 2007 Prices) |
|---|---|---|---|
| | | | |
| Existing | Existing Conditions | $ - | - |
| Plan 3a | 5% Hulah, 5% Copan | $ 10,090 | $188,000 |
| Plan 3b | 10% Hulah, Exist Copan | $ 11,920 | $222,000 |
| Plan 3c | 1% Hulah, 10% Copan | $ 9,044 | $176,000 |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Existing 100-year
BARTLESVILLE
PLANNING ASSISTANCE STUDY
EXISTING 100-YEAR

# APPENDIX G

# Sediment Protection Measures above Hulah and Copan

# APPENDIX G

## SEDIMENT PROTECTION MEASURES ABOVE HULAH AND COPAN

Reducing the existing sediment deposits and implementing sediment protection measures above Hulah and Copan Reservoirs is highly desirable. Based on existing sediment rates, the water supply yield at Hulah reservoir will decline to 4.35 million gallons per day (mgd) by year 2055 at the existing conservation storage elevation of 733.0. The water supply yield at Copan will also decline to 5.23 mgd by year 2055 at the existing conservation storage elevation of 710.00. Sediment deposits also reduce flood storage benefits that currently exist from both reservoirs. This study looked at potential sediment sources and outlined protection measures that could be encouraged above Hulah and Copan Lakes.

In Kansas just above Hulah and Copan Reservoirs, there are 7 conservation watershed districts which provide flood prevention and watershed protection, under the Federal PL-566 program. These programs help prevent sediment deposits into Hulah and Copan Reservoirs, which protects both water supply and flood storage. **Although not specifically addressed in this study, future joint venture water supply and flood protection initiatives could be explored with these upstream Conservation Watershed Districts.**

Grant-Schanghai, and Upper and Lower Caney watersheds are located above Hulah Reservoir. Bee Creek, Twin Caney, Middle Caney and Aiken Creek watersheds are situated above Copan Reservoir. All seven watershed projects have completed all measures planned to address flooding concerns in their respective drainage areas. Table 13 below lists the number of floodwater retarding structures (FRD) for each watershed district.

| | TABLE 12 | |
|---|---|---|
| ***Watershed District*** | No. of FRD's Complete | Multi-Purpose Structures (in addition to flood control) |
| ***Grant-Shanghai*** | 7 | 0 |
| ***Big Caney (Upper and Lower)*** | 31 | 0 |
| ***Bee Creek*** | 7 | 0 |
| ***Aiken Creek*** | 1 | 0 |
| ***Twin Caney*** | 15 | 2 (1 recreation, 1 municipal water supply) |
| **Middle Caney** | 15 | 1 (1 municipal water supply) |

Each watershed has individual project maps that provide the location of each watershed structure. You can contact each individual watershed district listed above, or request these maps from the Natural Resource Conservation Service (NRCS) thru the local District Conservationist, Ronald Rader, Chautauqua County at Howard Service Center, 131 N. Wabash, Howard, KS 67349; Phone 620-374-2410 (or 2511) Email:ron.rader@ok.usda.gov. You can also view other watershed district contact information at:
http://scc.ks.gov/index.php?option=com_contact&catid=54&Itemid=141

**Potential Sediment Sources and Protection Measures above Hulah and Copan Lakes**

U.S. Geological Survey (USGS) Digital Elevation Model (DEM, USGS, 1999) and National Land Cover Database (NLCD, USGS, 2006) data were used to delineate watershed boundaries, stream channels, and land use/cover in the Hulah Lake and Copan Lake Watersheds.

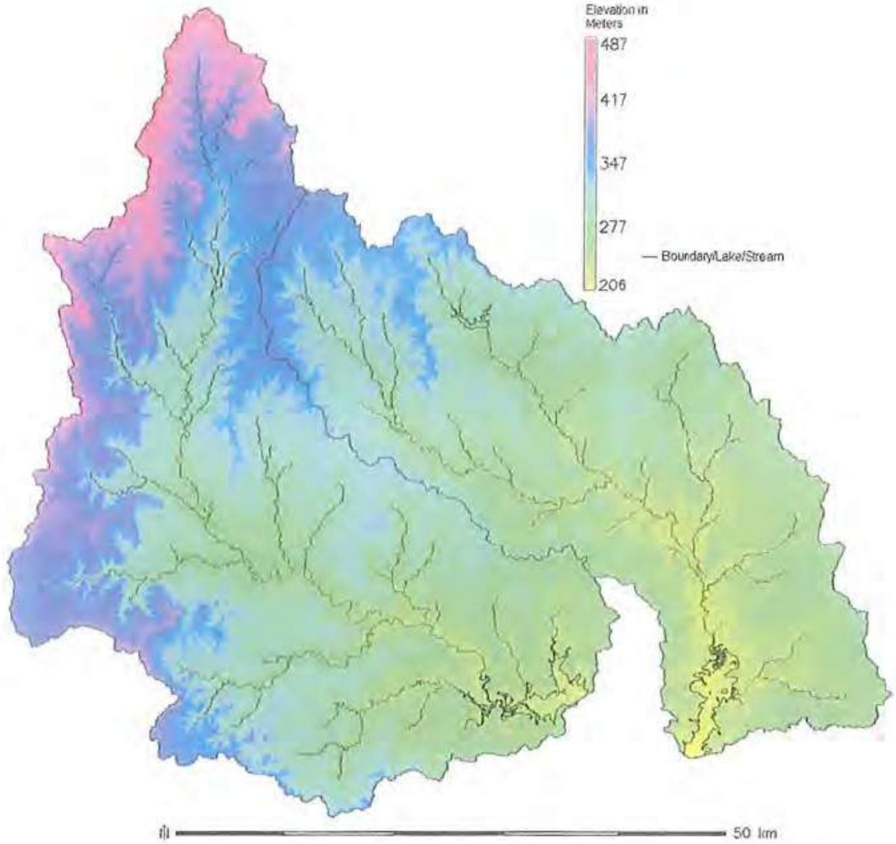


**Figure 1. Elevation (in meters, NAVD88) from USGS NED. Locations of Hulah and Copan Lakes are indicated by black polygons in the lower portions of each watershed**

Analysis of the digital elevation data included watershed delineation completed using Geographic Resources Analysis Support System software (GRASS 6.2, GRASS Development Team, 2006) and the 'watershed' script (GRASS Development Team, 2005). Drainage areas, slope, aspect, and drainage channel accumulation files were generated from the 30-meter resolution digital data (Figure 1). USGS NLCD data, developed from Landsat Enhanced Thematic Mapper Plus (ETM+) images collected between 1999 and 2002, also 30-meter resolution, was extracted for the defined watersheds to determine recent land use/cover classifications within each of the watersheds. Detailed data are pictured in Figure 2 and listed in Table 14 below.

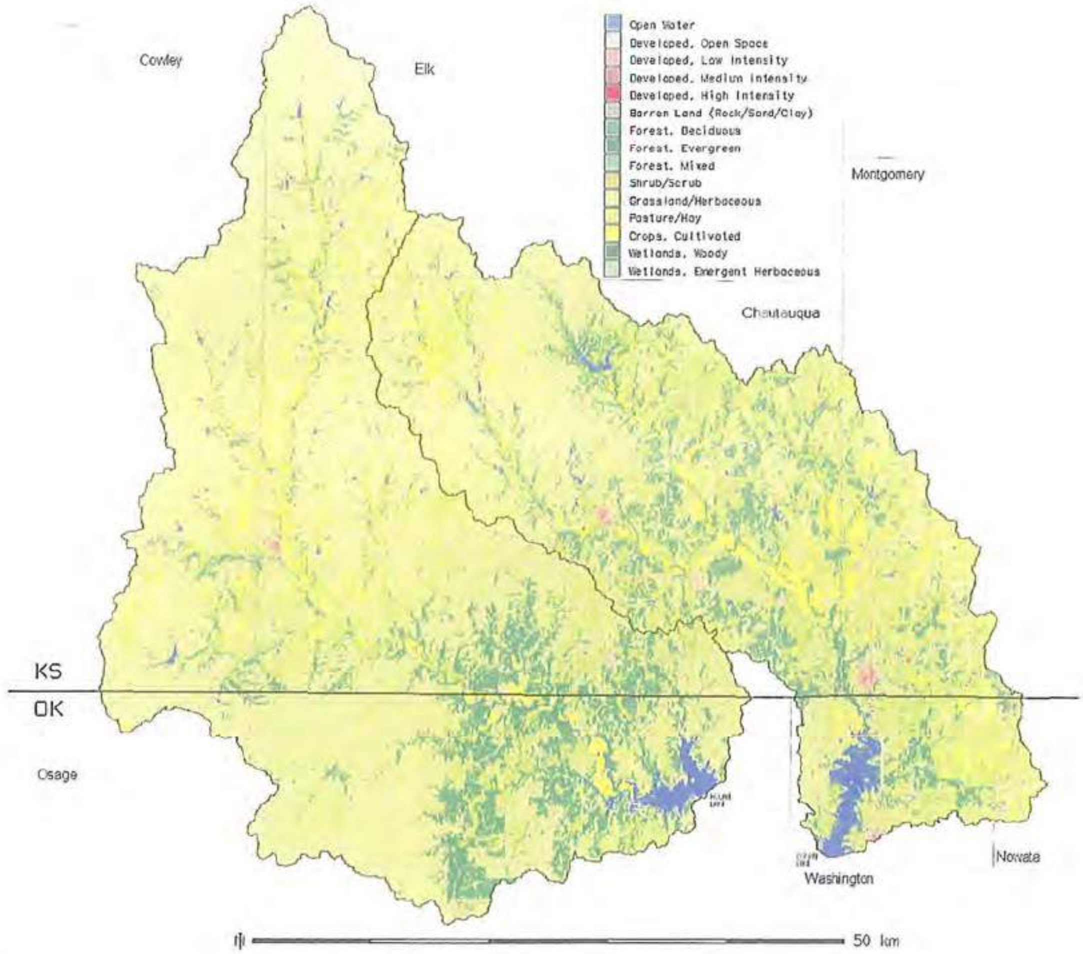


**Figure 2.** **Land use/cover in the Hulah Lake and Copan Lake Watersheds from NLCD (USGS, 2006).**

Based on the NLCD data, each watershed is dominated by grassland, pasture, and forest. The 455,570 acre Hulah Lake watershed is comprised of 66.3% grassland, 13.6% pasture, 12.0% forest, 3.5% developed (urban, residential, transportation, commercial, and industrial land uses), 3.0% cropland, 1.4 % open water (lakes, ponds, streams), 0.1% barren land (bedrock, surface mines, and gravel pits), and 0.1% wetlands. The 324,160 acre Copan Lake watershed is comprised of 43.4% grassland, 29.3% pasture, 14.9% forest, 5.4% cropland, 4.7% developed, 2.3% open water, and the remainder a combination of wetlands, shrub land, and barren lands.

Common upland sources of sediment delivered to streams and impoundments are croplands, overgrazed pasture and range lands, and unvegetated developed areas. Stream bank erosion and stream channel down-cutting are also potential sources of sediment.

**Table 14. Land use/cover statistics derived from DEM (USGS, 1999) and NLCD (USGS, 2006) for the Hulah Lake and Copan Lake Watersheds.**

| | Hulah Lake Watershed | | Copan Lake Watershed | |
|---|---|---|---|---|
| **LULC classes** | **acres** | **%** | **acres** | **%** |
| Open Water | 6,152.64 | 1.35 | 7,398.03 | 2.28 |
| Developed, Open Space | 14,812.06 | 3.25 | 13,235.32 | 4.08 |
| Developed, Low Intensity | 1,226.04 | 0.27 | 1,828.71 | 0.56 |
| Developed, Medium Intensity | 89.85 | 0.02 | 224.61 | 0.07 |
| Developed, High Intensity | 7.78 | 0.00 | 68.72 | 0.02 |
| Barren Land (Rock/Sand/Clay) | 378.51 | 0.08 | 47.15 | 0.01 |
| Forest, Deciduous | 53,337.13 | 11.71 | 46,704.57 | 14.41 |
| Forest, Evergreen | 1,061.02 | 0.23 | 649.82 | 0.20 |
| Forest, Mixed | 374.06 | 0.08 | 193.03 | 0.06 |
| Shrub/Scrub | 89.18 | 0.02 | 147.44 | 0.05 |
| Grassland/Herbaceous | 302,131.72 | 66.32 | 140,788.66 | 43.43 |
| Pasture/Hay | 62,135.54 | 13.64 | 95,024.36 | 29.31 |
| Crops, Cultivated | 13,458.60 | 2.95 | 17,490.75 | 5.40 |
| Wetlands, Woody | 281.32 | 0.06 | 312.01 | 0.10 |
| Wetlands, Emergent Herbaceous | 32.91 | 0.01 | 43.14 | 0.01 |
| Total | 455,568.36 | 100.00 | 324,156.32 | 100.00 |

Additional analysis of land use within the two watersheds involved determining land use/cover within buffer zones of major drainage channels. A buffer zone of 500 meters around stream channels, developed from the DEM data, was generated and land use/cover within these zones was identified based on the NLCD data. The purpose of this exercise was to determine if 'managed' land uses within this zone are really significant in terms of potential sediment sources and contributions to the lakes. Assuming that forest, grassland, wetland, and water land use classes are either well-vegetated or insignificant sources of sediment from the land surface, an extraction of the acreage of developed, barren, pasture, and cropland was performed (Figure 3).

In the Hulah Lake Watershed, areas within 500 meters of stream channels and the lake include 3,680 acres classified as developed, 6,090 acres of cropland, and 20,325 acres classified as pasture/hay land use. In the Copan Lake Watershed, areas within 500 meters of stream channels and the lake include 3,195 acres classified as developed, 16 acres of barren land, 17,680 acres classified as pasture/hay, and 7,195 acres of cropland. Best management practices applied to these areas could potentially provide the greatest reductions of upland sources of sediment carried by storm runoff to streams and eventually to downstream reservoirs.

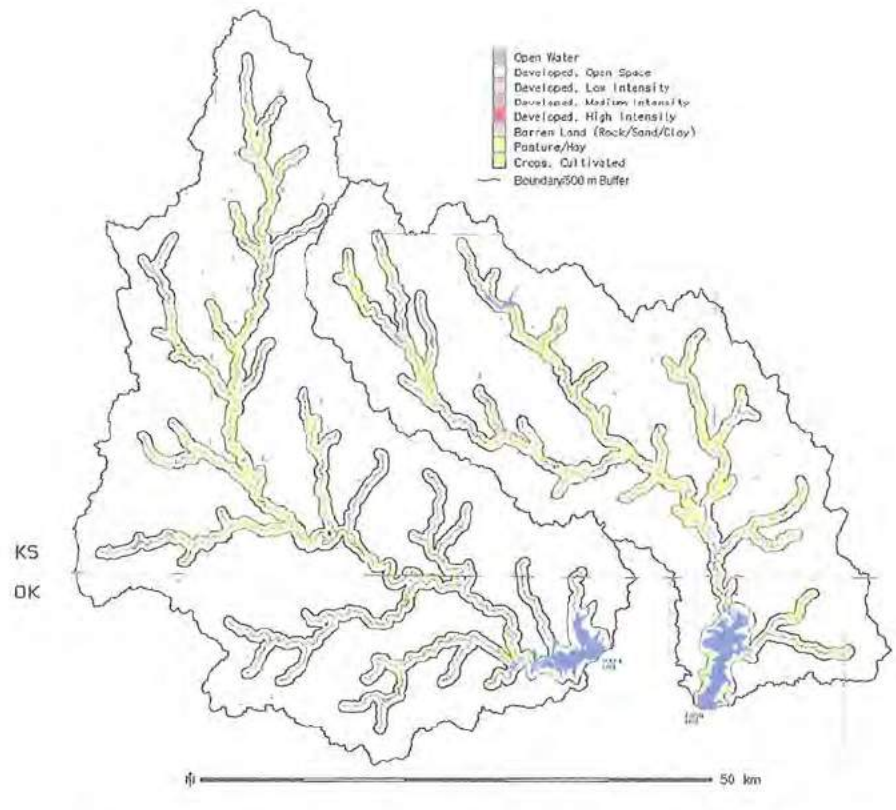


**Figure 3.** **Buffer zones (500 meters) around stream channels indicating the relative proximity of potential sediment contributing land use/cover classes to stream channels and the lakes, based on NLCD (USGS, 2006) land use data.**

**Potentially effective Best Management Practices:**

The following compilation of Best Management Practices (BMPs) have been found to be effective, to varying degrees depending on site specific criteria, in reducing runoff water velocity and erosion from the land surface. Detailed information on many applicable BMPs is available from a variety of sources including *Best Management Practices for Soil Erosion* by the Purdue Research Foundation (2001). Incentives for landowner implementation of some of these practices may be available through state and federal agencies. The list is not exhaustive. Cropping practices stress maintenance of vegetative cover during critical time periods and the primary objective is a reduction of soil erosion by decreasing soil particle detachment. Structural practices stress reduction in runoff water velocity enabling settling of heavier suspended particles before the water reaches stream channels and/or downstream impoundments.

**Filter strips around croplands** - Strips of closely-grown vegetation placed between field edges and water bodies or riparian areas to control sediment loss and erosion. The strip inhibits the transport of sediment by reducing storm runoff water velocity and allows sediment and adsorbed pollutants to drop out before reaching the stream or lake. Effective width is partially dependent on field size and drainage area and can vary from five to 100 meters.

**Grassed waterways in drainages on croplands** - Areas in croplands where storm water runoff channelizes are planted with a dense grass cover to reduce runoff velocity and prevent channel erosion.

**Conservation tillage agriculture** – Tillage practices utilizing non-inversion plowing techniques leave significant quantities of crop residue at or near the soil surface. Crop residue reduces soil erosion and storm runoff, and helps maintain soil moisture through the growing season.

**No-Till agriculture** – A form of conservation tillage where no tillage is used to establish the seed bed. Former crop residues remain at the soil surface and reduce potential soil erosion.

**Residue management on cropland** – Residue from former or cover crops is maintained at or near the soil surface. Landowners manipulate (maximize) the amount of residue remaining after crop harvest or/and plant close-growing cover crops between harvested crop growing seasons.

**Contour farming** – Cropland planted parallel to elevation contours to reduce runoff velocity.

**Contour strip-cropping** – Croplands planted parallel to elevation contours with different crops in parallel strips reducing runoff velocity.

**Parallel Terraces (newly constructed or repaired/refurbished)** – Graded terraces across the slope reduce the effective land slope and reduce runoff velocity.

**Pasture and hay land management** – A system of practices designed to protect vegetative cover on improved pasture or range land which includes seeding or reseeding, brush management, proper stocking rates and grazing use, and deferred rotational systems. Maintaining permanent land cover with high quality vegetation decreases soil erosion.

**Riparian (re)Vegetation and protection zones** – Vegetated areas along water bodies or drainage channels are maintained or enhanced and can filter both surface and subsurface flows.

**Cattle exclusion from waterways** – Excluding livestock from areas where grazing, trampling, and watering denude stream banks. The practice reduces deposition of fecal material in streams, turbidity caused by in-stream trampling, and erosion of denuded stream banks.

**Wetland development and/or restoration** – Development or enhancement of wetland areas where increased retention time of runoff allows for pollutant settling and utilization of nutrients by wetland vegetation.

**Pond development and/or restoration** – Development and restoration of ponds that function as collection areas of runoff from fields for storage and pollution control by stopping water flow and allowing heavier suspended particles to settle.

**Grade stabilization structures** – Structures used to control grade and gully-head in drainage channels (fields, pastures, etc.) that reduce water velocity of runoff.

**Stream channel stabilization** – Structural and vegetative methods to reduce stream bank erosion using riprap, concrete, wood, rock gabions, and/or vegetation to stabilize stream banks. Vegetative methods have the additional benefits of shading the stream leading to decreased water temperatures, and increases in floodwater storage and hydrologic assimilative capacity. Efforts to identify areas of concern are required to effectively focus expensive stabilization strategies.

# APPENDIX H

# Upstream Impacts from Reallocation Alternatives

## APPENDIX H

## UPSTREAM IMPACTS FROM REALLOCATION ALTERNATIVES

**Hulah Lake Upstream Impacts:**

Reallocation of the flood pool would look at all impacts that would occur because of the conservation pool raise. A reallocation of the conservation pool for water supply would require that water supply users pay for the costs required by the reallocation of flood storage which is financed 100% from federal funds to water supply which is financed 100% by non federal funds. For planning purposes these costs were roughly estimated based on a 1%, 5% and 10% reallocation of the flood pool to water supply. If a reallocation was pursued these costs would be more accurately refined for repayment by eventual water supply users.

**Physical Upstream Replacement Cost Impact for 1% Reallocation at Hulah**

For Hulah Reservoir, a 1% reallocation would raise the Conservation pool from elevation 733.0 feet to elevation 733.9 feet and would increase the conservation pool by about 80 acres. Initial observations indicate that only a few oil facilities would be impacted. Total estimated costs are estimated at about $100,000.

**Physical Upstream Replacement Cost Impact for 5% Reallocation at Hulah**

For Hulah Reservoir, a 5% reallocation would raise the Conservation pool from elevation 733.0 feet to elevation 736.7 feet and would increase the conservation pool by about 400 acres. Initial observations indicate the following items that would need to be addressed.

1. Raise 1 mile of road 7 feet that runs along side the Waterfowl Refuge – $500, 000

2. Skull Creek – Either abandon all of the facilities or relocate all of the facilities to higher ground. The entrance road to this park area will go under water and render the entire park unusable. If abandoned – Removal and cleanup of old sites, toilets, and facilities - $150,000

3. If relocated – 24 campsites - $3000 per site = $72,000; 1 boat ramp - $50,000; 1 group shelter - $50,000; 1 water system (hook to rural water) - $500,000; 2 sets of pit toilets – $10,000

4. Turkey Creek - Either abandon part of the facilities or relocate them to higher ground. One road in the middle of the park will go under water. If abandoned – removal and cleanup of old sites, toilets, and facilities - $150,000

5. If relocated – 10 campsites - $3000 per site = $30,000; 1 set of toilets - $5,000

6. Rural water intake structure will need to be raised to higher ground. - $100,000

7. An estimated 300 acres of State Waterfowl Refuge that is normally not covered with water at elevation 733.0 might go under water. This action may require mitigation with the State of Oklahoma. $800 per acre = $240,000

8. Oil and gas field related facilities may be affected. The superintendant with the Osage Indian Tribe will have to be contacted for current data on active oil and gas wells, tank batteries, pipelines, and electric lines. This action may require tribal coordination and compensation. A $200,000 value was estimated but by operations and could be significantly more than projected.

9. One A&G lessee will loose usage of an estimated 50 acres of substandard prairie grass. A $500 adjustment to the lease was estimated by operations.

10. To meet needs of the National Environmental Policy Act (NEPA) an environmental Assessment will be required for any future reallocation alternative. This estimate does not include fish & wildlife mitigation requirements which could be defined through the NEPA process.

11. A cultural resource survey would be required with any future reallocation alternative. These costs are outlined below under Table 13.

Based on the above estimate, a 5% reallocation would require $2,307,000 in upstream physical replacements within the Hulah Reservoir.

**Physical Upstream Replacement Cost Impact for 10% Reallocation at Hulah**

For Hulah Reservoir, a 10% reallocation would raise the conservation pool from elevation 733.0 feet to elevation 739.5 feet and would increase the conservation pool about 800 acres. Initial observations indicate the following items that would need to be addressed:

1. Raise 2.5 miles of road 10 feet that run along side the Waterfowl Refuge and near Elgin, KS – $1,500, 000
2. Skull Creek – Either abandon all of the facilities or relocate all of the facilities to higher ground. The entrance road to this park area will go under water and render the entire park unusable.
3. If abandoned – Removal and cleanup of old sites, toilets, and facilities - $150,000
4. If relocated – 24 campsites - $3000 per site = $72,000; 1 boat ramp - $50,000; 1 group shelter - $50,000; 1 water system (hook to rural water) - $500,000; 2 sets of pit toilets – $10,000
5. Turkey Creek - Either abandon all of the facilities or relocate them to higher ground.
6. If abandoned – Removal and cleanup of old sites, toilets, and facilities - $150,000
7. If relocated – 20 campsites - $3000 per site = $60,000; 2 set of toilets - $10,000;
8. Rural water intake structure will need to be raised to higher ground. - $100,000
9. An estimated 1800 acres of State Waterfowl Refuge that is normally not covered with water at elevation 733.0 might go under water. This action may require replacement with the State of Oklahoma. $800.00 per acre = $1,440,000 or total relocation.
10. Oil and gas field related facilities may be affected. The superintendant with the Osage Indian Tribe will have to contacted for current data on active oil and gas wells, tank batteries, pipelines, and electric lines. This action may require tribal coordination and compensation. - $2,000,000 conservatively

11. One A&G lessee will loose usage of an estimated 150 acres of prairie grass. A $900 adjustment to the lease was estimated.
12. Dry land hunters will loose use of an estimated 3,000 acres of hunting land. This issue may have to be mitigated with the State of Oklahoma. $800 per acre = $2,400,000
13. To meet needs of the National Environmental Policy Act (NEPA) an environmental Assessment will be required for any future reallocation alternative. This estimate does not include fish & wildlife mitigation requirements which could be defined through the NEPA process.
14. A cultural resource survey would be required with any future reallocation alternative. These costs are outlined below under Table 13.

Based on the above estimate, a 10% reallocation would require $8,627,000 in upstream physical replacements within the Hulah Reservoir.

**Physical Upstream Replacement Cost Impact for 5% Reallocation at Copan**
For Copan Reservoir, a 5% reallocation would raise the Conservation pool from elevation 710.0 feet to elevation 712.0 feet and would increase the conservation pool by 307 acres. Initial observations indicate that there would be few replacement items within the flood pool that would need to be addressed. The only major item needing attention would be shoreline erosion issues in the park area. Shoreline erosion was estimated at $5,000 at Copan Reservoir.

**Physical Upstream Replacement Cost Impact for a 10% Reallocation at Copan**
For Copan Reservoir, a 10% reallocation would raise the Conservation pool from elevation 710.0 feet to elevation 713.76 feet and would increase the conservation pool by 610 acres. The 10% reallocation would require additional erosion control on the face of the Copan Dam in addition to the other shoreline erosion issues estimated at $5,000 above. The face of the dam is partially rip rapped. Additional material may have to be added above the first level of riprap to control erosion. Estimated cost is $500,000. The total estimated upstream physical replacement cost is estimated to be $505,000 for a 10% reallocation. These costs do not include required NEPA environmental assessment costs, as well as cultural resource survey costs, that would also be required with any new reallocation.