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Report on

# Kansas River Water Intake Investigations

for the

## Regulatory Plan Commercial Sand and Gravel Dredging Kansas River

Kansas City District, Corps of Engineers
DACW 41-86-D-0024

1986

85-809-4-004

Burns & McDonnell
ENGINEERS - ARCHITECTS - CONSULTANTS

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January 7, 1987

Department of the Army
Kansas City District, Corps of Engineers
700 Federal Building
Kansas City MO 64106-2896

Attention: Mr. Philip Rotert
Chief, Planning Division

Contract DACW41-86-D-0024
Delivery Order No. 4, Task 1
Kansas River Water Intake Investigations
B&McD Project 85-809-4-004

Gentlemen:

We present herewith a Report on Kansas River Water Intake Investigations in accordance with our Contract Delivery Order No. 4 dated May 30, 1986. The report includes engineering investigations of river intakes on the lower reach of the Kansas River used by the Sunflower Army Ammunition Plant and Water District No. 1 of Johnson County, Kansas.

We wish to thank the staff of the Environmental Resources Branch Planning Division for their assistance provided during the course of this study. We remain ready to discuss the details of the report at your convenience.

FRANK LAVERN SHORNEY
LICENSED
6011
KANSAS
PROFESSIONAL ENGINEER

Sincerely,

John E. Dieter III

John E. Dieter III, P.E.
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# INTRODUCTION

# INTRODUCTION

## PURPOSE

The purpose of this report is to quantify the impact of lowering the channel bed of the Kansas River from 1 to 5 feet on raw water intakes operated by the Sunflower Army Ammunition Plant near DeSoto, Kansas and Water District No. 1 of Johnson County, Kansas. This report is prepared for use in the development of a regulatory plan for commercial sand and gravel dredging in the Kansas River by the Department of the Army, Kansas City District, Corps of Engineers.

## SCOPE

This report includes:

- Identification of impacts to the raw water intakes at the Sunflower Army Ammunition Plant and Water District No. 1 of Johnson County caused by lowering the water surface elevation in 1-foot increments from 1 to 5 feet as a result of river channel degradation.

- Development of improvements and maintenance schemes required to prolong the original capacity and integrity of the raw water intakes.

- Estimates of cost for each improvement and maintenance alternative.

* * * * *

# SUMMARY

# SUMMARY

Channel degradation has occurred in the lower reaches of the Kansas River in recent years which is believed attributable to commercial sand and gravel dredging operations. The U.S. Army Corps of Engineers has concluded that a regulatory plan should be developed to use as a guide for processing future dredging permits. This report will be used in conjunction with the development of the regulatory plan to identify and evaluate the impacts of declining river water levels caused by channel degradation at two river water intakes.

## RIVER INTAKES

One of the river intakes is near DeSoto, Kansas and is maintained by the Sunflower Army Ammunition Plant (AAP). This intake was constructed in 1942 at River Mile (R.M.) 32.8. The intake was last used in 1970, but is intended to be reactivated in the event of a national emergency. The maximum quantity of water required from the intake is 37 million gallons per day (MGD).

The other river intake is near the Interstate 435 crossing of the Kansas River and is used by Water District (W.D.) No. 1 of Johnson County. This intake was constructed in 1964 at R.M. 15.0. Over the years, various improvements have been added to the intake to offset the effects of declining river stages. These improvements include a low lift pump station, a stone-filled jetty and a low flow weir. The raw water delivery capacity of the intake is approximately 70 MGD.

## RIVER STAGE DATA AND INTAKE ELEVATIONS

The most recent 10-year period of river stage data from the DeSoto gauging station and intake operating records have been used to evaluate the impacts of channel degradation on the two intakes. The Sunflower AAP intake has a "calculated" minimum river stage of 765.5 feet USGS (United States Geological Survey) and a fixed sill elevation of 763.9 feet USGS. The intake at W.D. No. 1 of Johnson County has a "controlled" minimum water surface of 734.0 feet USGS and a fixed sill elevation of 732.0 feet USGS. The minimum water surface at the water district's intake is controlled by a stone-filled jetty and low flow river weir (and the addition of sandbags to the intake apron sill during periods of low river flows).

## CHANNEL DEGRADATION IMPACTS

Both intakes will not be able to hydraulically deliver required river flows to pumping units at minimum river stages if additional channel degradation of 1 foot or more is allowed to occur. This is because both intakes have openings with fixed sills through which river water is withdrawn for pumping. In recent years, the effects of river channel degradation at the W.D. No. 1 of Johnson County intake have been mitigated by the addition and maintenance of a jetty and low flow weir.

Hydraulic calculations of pumping systems at both intakes indicate that minimum river stages currently provide insufficient suction head conditions for proper pump operation. A water surface elevation of 773.4 feet USGS at the Sunflower AAP intake is needed to provide recommended pump suction submergence; and, a water surface elevation of 736.4 feet USGS at the W.D. No. 1 of Johnson County

intake is needed to meet net positive suction head requirements of the low service pumps. The addition of suction bells to the pumps at the Sunflower AAP intake will improve hydraulic conditions, reduce submergence requirements and lower the required water surface elevation to 769.5 feet USGS for recommended pump suction submergence.

Any additional channel degradation up to 1 foot will not cause further deterioration of pumping operations at the intake of Water District No. 1 of Johnson County unless the weir is severely damaged or destroyed. This is because the water level at the intake is controlled by the weir. However, additional channel degradation at the intake for Sunflower AAP will cause further deterioration of the pumping operations. At low flow periods and with additional channel degradation of 2 to 5 feet, the result will be a total shutdown of pumping operations.

SUNFLOWER AAP INTAKE ALTERNATIVES

Three improvement alternatives are evaluated for the Sunflower AAP intake to offset the effects of channel degradation. These alternatives include:

- Alternative No. 1 - Low flow river weir consisting of a stone-filled jetty (crest elevation 770.5 feet USGS) and flow directional structure with pump suction bell improvements (for pump operation at a minimum water surface elevation of 769.5 feet USGS).

- Alternative No. 2 - Low flow river weir of coffer cells (crest elevation 770.5 feet USGS) and flow directional structure with pump suction bell

improvements (for pump operation at a minimum water surface elevation of 769.5 feet USGS).

- Alternative No. 3 - New river intake at R.M. 32.8 at (existing intake site) and two additional stem dikes on left river bank to provide a 450-foot-wide rectified channel at the intake site.

Cost estimates for improvement alternatives include:

- For Alternative No. 1 (Stone-Filled Jetty): Construction cost estimates for this alternative range from $0.7 million for 1 foot of channel degradation to $1.1 million for 5 feet of channel degradation. Annual maintenance costs range from $42,000 for 1 foot of channel degradation to $80,000 for 5 feet of channel degradation.

- For Alternative No. 2 (Coffer Cells): The construction cost and annual maintenance cost for this alternative are estimated respectively at $2.7 million and $10,000 for 1 to 5 feet of channel degradation.

- Alternative No. 3 (New River Intake): The construction cost and annual maintenance cost for this alternative are estimated respectively at $3.4 million and $75,000 for 1 to 5 feet of channel degradation.

W.D. NO. 1 OF JOHNSON COUNTY INTAKE ALTERNATIVES

Intake operation with continued maintenance of the existing stone-filled jetty and low flow weir appears to be the most economical alternative for the

W.D. No. 1 of Johnson County to offset the effects of channel degradation. A 30-foot-wide, stone-filled berm has been added on the downstream side of the weir and stone has been placed a distance of 300 feet downstream in an effort to reduce channel degradation in the immediate intake area. Estimated annual maintenance costs for the jetty and weir due to the effects of channel degradation range from $20,000 to $60,000. Costs vary according to the frequency and amount of stone fill required to offset channel degradation and do not include normal maintenance to replace stone lost due to high water or ice floes.

The construction of a new intake structure with adjustable sill and channel jetty to accommodate continued river bed degradation is a possible, although expensive, alternative to continued operation with the existing intake, jetty and low flow weir. These improvements are estimated to have a construction cost of approximately $3 million and will require continued maintenance of a stone-filled jetty to keep the river channel next to the intake. Annual maintenance costs for this alternative are estimated to range from $5,000 to $15,000 for 1 to 5 feet of channel degradation.

* * * * *

# PART I – BACKGROUND INFORMATION

# PART I

# BACKGROUND INFORMATION

## A. GENERAL

This report section discusses historical geomorphic trends in the lower reaches of the Kansas River, the operating history of the intakes used by the Sunflower Army Ammunition Plant and Water District No. 1 of Johnson County and the collection and use of river stage data. The general location of the Kansas River study area is shown in Figure I-1.

## B. GEOMORPHIC CONDITIONS

A 1984 report published by the Corps of Engineers includes a qualitative geomorphic analysis of the lower reaches of the Kansas River. The relationships between geomorphic trends and the operation of federal reservoirs, sand and gravel dredging and natural controls (such as channel rock outcroppings) are discussed in the geomorphic analysis. The study notes that intensive sand and gravel dredging operations have been conducted between Turner Bridge (R.M. 9.6) and Bonner Springs (R.M. 22) since the 1940s. Pertinent findings of the 1984 study are summarized as follows:

- River stage and discharge levels have declined at the Bonner Springs (not in operation since 1973) and Desoto (in operation since 1973) gauging stations. As an example, the 25 percent occurrence discharge at the Bonner Springs station declined approximately 8.5 feet between 1950 and 1973.

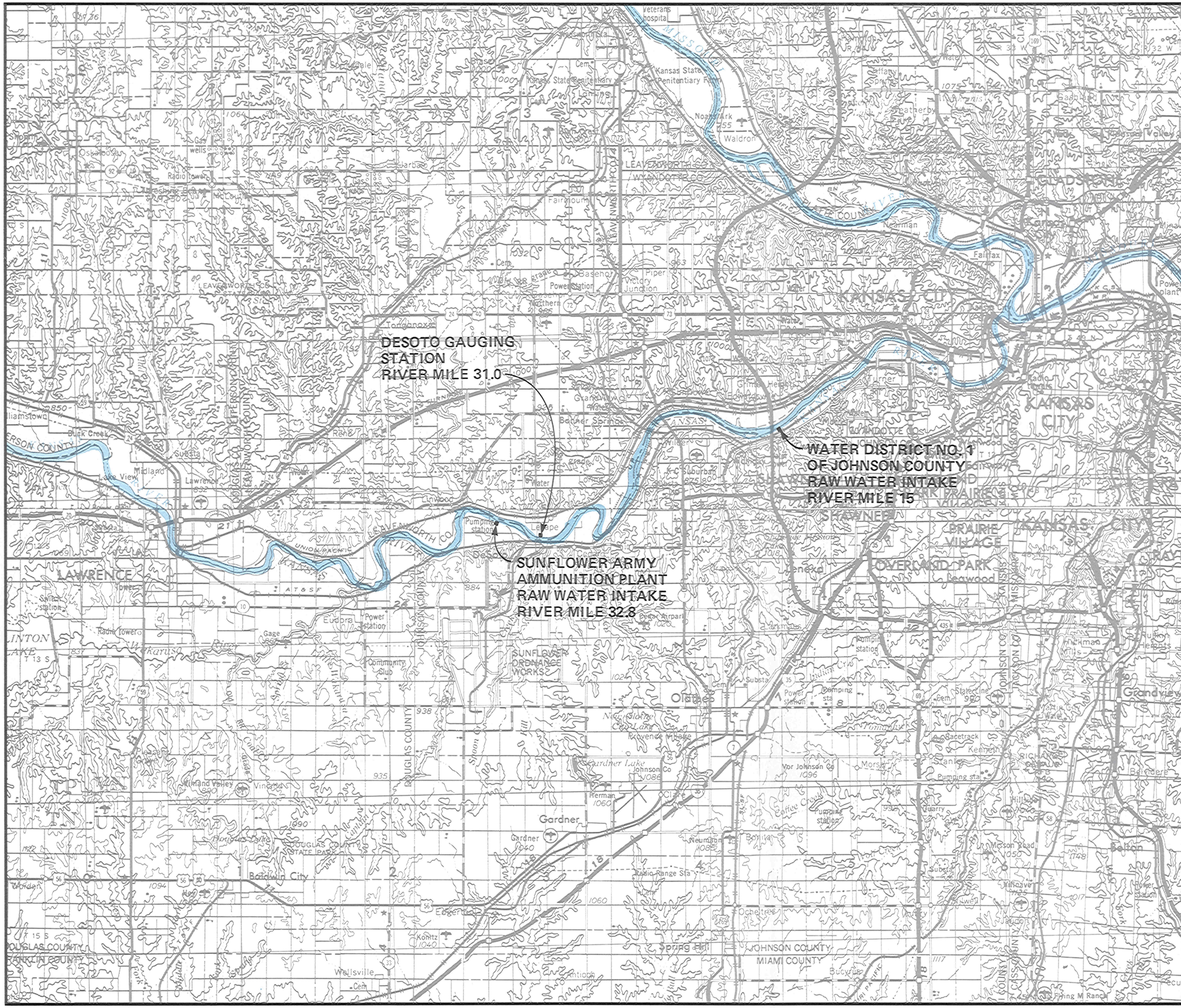


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Figure I-1
KANSAS RIVER
STUDY AREA

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- Sand and gravel dredging are the primary causes of channel degradation and channel widening between Bonner Springs (R.M. 22) and the Turner Bridge (R.M. 9.6).

C. SUNFLOWER ARMY AMMUNITION PLANT INTAKE

The Sunflower Army Ammunition Plant raw water intake was constructed in 1942 at R.M. 32.8. Operation of the intake ceased in 1970. As a result, little is known about possible operating problems related to declining river stages. To date, no major modifications to the intake have been made to maintain hydraulic capacity. The operating staff reports that the structure operated satisfactorily prior to shutdown in 1970. The desired operating capacity of the intake is 37 million gallons per day (MGD).

D. WATER DISTRICT NO. 1 OF JOHNSON COUNTY INTAKE

In 1964, Water District No. 1 of Johnson County completed construction of a raw water intake at approximate R.M. 15 with a design flow capacity of 100 MGD. The structure has a fixed sill elevation and decreasing river stages over the years have reduced the capacity of the intake to approximately 70 MGD. Three major improvements to the intake have been undertaken to maintain the 70 MGD capacity. The first improvement included the construction of a low lift pump station in 1966. The station was initially constructed with two 14,000 gallons per minute (gpm) pumps; one 8,000 gpm pump was added at a later date. The second improvement included the construction of a stone-filled jetty in 1967. The jetty extended from the north side of the Kansas River to within 50 feet of the intake. The purpose of the jetty is to keep the main channel of the river near the

intake. The third improvement included the construction of a low flow weir in 1985 to ensure that some water would be available at the intake even during low flow periods.

## E. RIVER STAGE DATA

Gauging stations have been installed at several points along the Kansas River to measure river stages and to record other pertinent data such as suspended sediment load and temperature. Prior to 1973, this type of information was recorded at Bonner Springs, Kansas (R.M. 22). After 1973, the gauging station was moved to DeSoto, Kansas (R.M. 31). Since this study is concerned with only the recent effects of channel degradation in the lower reach of the Kansas River, information from the DeSoto gauge is believed to be applicable to this investigation.

The information available from the DeSoto station consists of river stage levels in feet above the gauge datum which is set at elevation 758.9 feet USGS. The average river stage recorded for the station from 1973 to 1983 is 765.9 feet USGS. Data over a continuous ten-year period has been examined and the most recent five-year data period is used in the analysis. Using this data, minimum, maximum, and average river stages are calculated for each month as shown in Figure I-2. Over the last 60 plus years, the average river flow measured at the Bonner Springs and DeSoto stations is approximately 7,000 cubic feet per second (cfs).

River stages are recorded daily from a staff gauge located at the Sunflower AAP raw water intake (refer to data in Appendix). Since part of these

- Kansas River Intake Facilities Study, Water District No. 1 of Johnson County, Kansas, Burns & McDonnell Engineering Company, January 1977.

- Preliminary Design and Environmental Assessment of a Low Weir Across Across the Kansas River at Topeka, Kansas, Simons, Li, and Associates, February 1984.

- River Supply facilities, Water District No. 1 of Johnson County, Kansas, Burns & McDonnell Engineering Company, 1963.

- Summary Report Low Water Weir, Water Treatment Plant, Topeka, Kansas, Van Doren-Hazard-Stallings, January 1984.

- Symposium on Channel Stabilization Problems, U.S. Army Corps of Engineers Technical Report No. 1, Volume 2, May 1964.

## G. CONCLUSIONS

Studies by others of geomorphic conditions in the lower reach of the Kansas River indicate that both stage and discharge levels have declined since 1950 at the Bonner Springs (now abandoned) and DeSoto gauging stations. Sand and gravel dredging operations are believed to be the primary causes of channel degradation and channel widening between Bonner Springs (R.M. 22) and the Turner Bridge (R.M. 9.6).

The operation of two river intakes is expected to be adversely affected by continued channel degradation. The intake for the Sunflower Army Ammunition

plant at R.M. 32.8 was constructed in 1942 and has not been in operation since 1970. The intake will be reactivated if needed during a national emergency. The intake for W.D. No. 1 of Johnson County at R.M. 15 was constructed in 1964 and has undergone several major improvements over the years to offset the effects at declining river stages caused by channel degradation.

River stage/discharge data is available from the Bonner Springs (now abandoned at R.M. 22) and DeSoto gauging (R.M. 31) stations. River stage data is also available at both intakes. Because part of the intake data is questionable or missing and for ease in manipulating data, river stage data is calculated for each intake based on the most recent five-year data period from the DeSoto gauging station.

* * * * *

# PART II – SUNFLOWER ARMY AMMUNITION PLANT RAW WATER INTAKE

## PART II

## SUNFLOWER ARMY AMMUNITION PLANT RAW WATER INTAKE

### A. GENERAL

The Sunflower Army Ammunition Plant (AAP) has two sources for raw water available for use in the production of ordnance for the U.S. Government. One source includes groundwater from wells along the north and south sides of the Kansas River and the second source includes surface water from the Kansas River. At the present time, only the groundwater source is being used in the operation of the plant.

The general location of the Sunflower AAP's raw water intake and pump station on the Kansas River is shown in Figure II-1. The intake was constructed in 1942 to supply water for the Sunflower Army Ammunition Plant during World War II. The intake was last used in November 1970 and is now deactivated. The intake is to be restored if a national emergency should occur which would require increased production at the Sunflower ordnance works.

The Sunflower AAP has surface water rights permitting the extraction of 50 million gallons per day (MGD) from the Kansas River. During maximum production, however, plant operators anticipate that only 37 MGD will be required. The 37 MGD flow rate is, therefore, used in all subsequent investigations of the intake's hydraulic capacity.

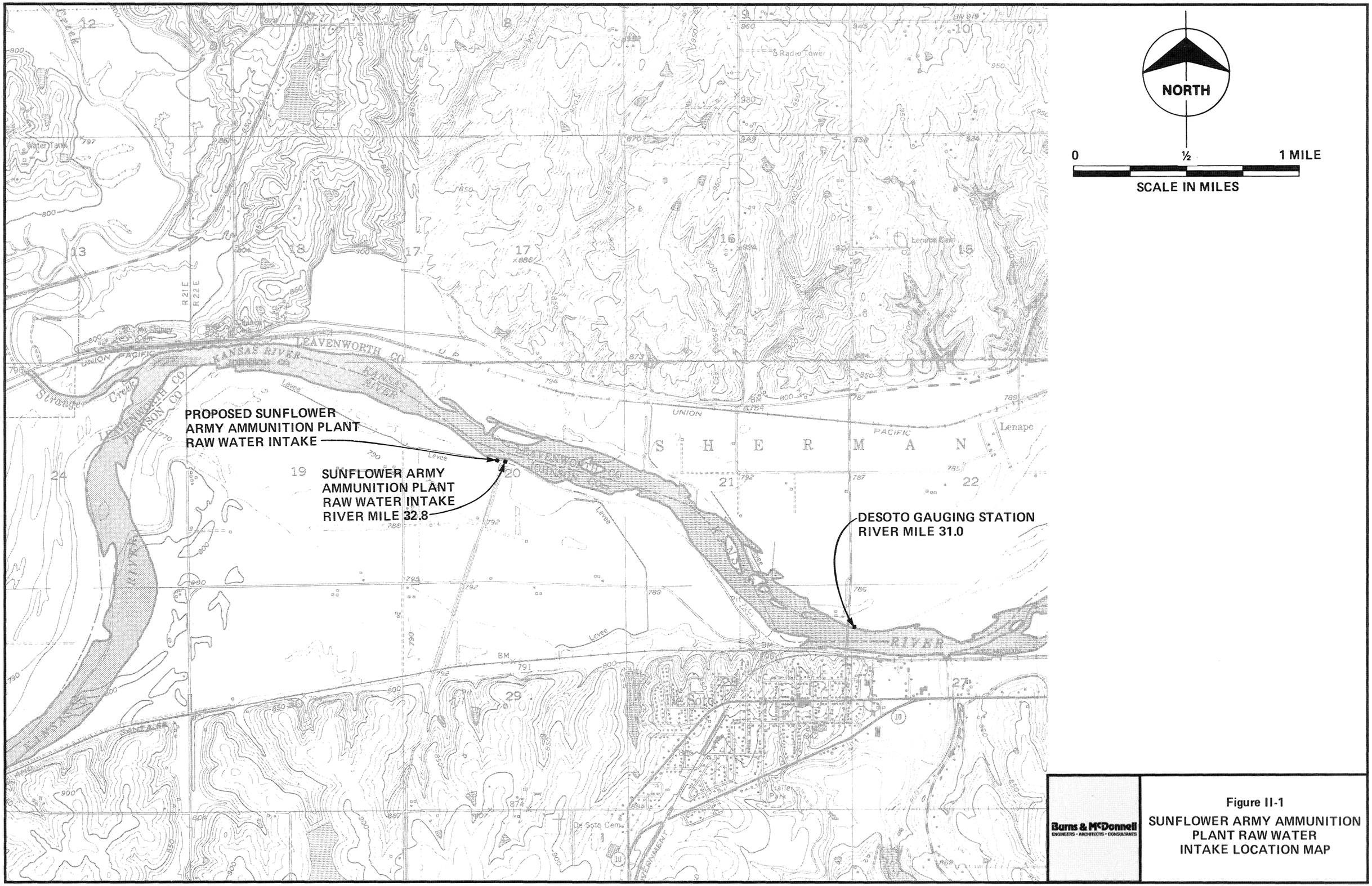


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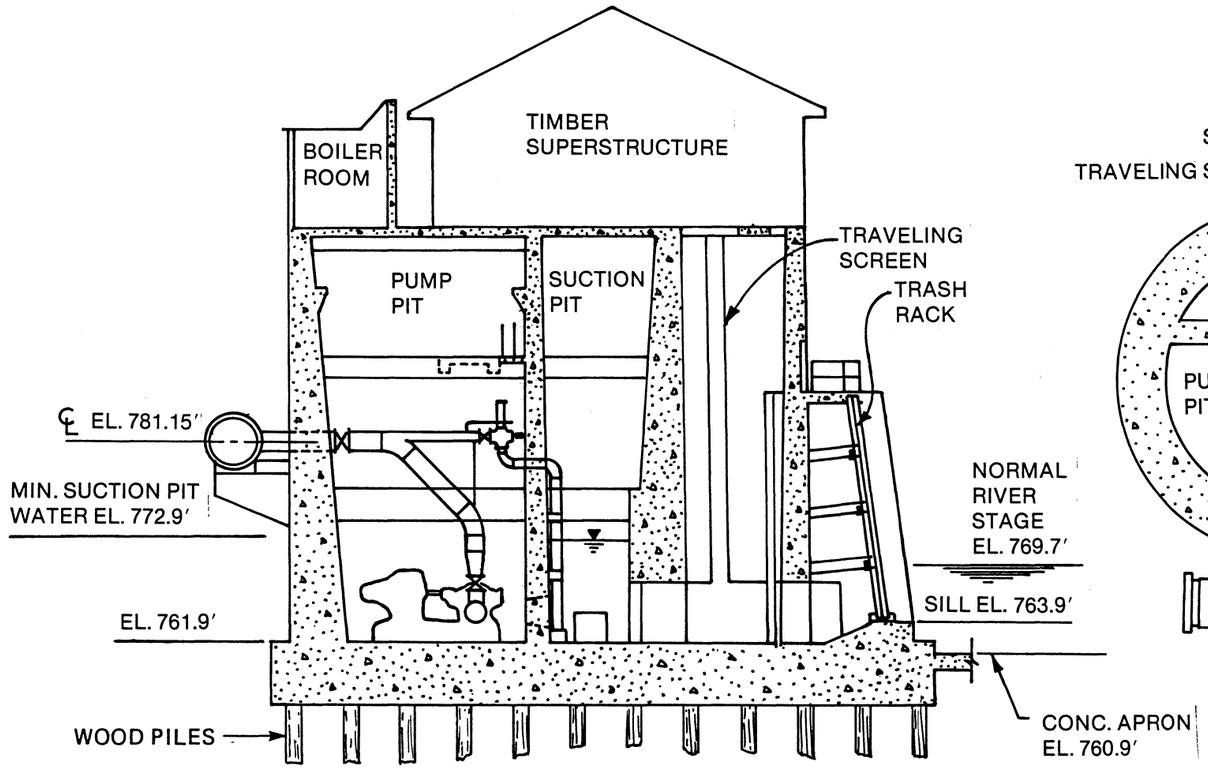
**Figure II-1**

**SUNFLOWER ARMY AMMUNITION PLANT RAW WATER INTAKE LOCATION MAP**

Plan and section views of the raw water intake are shown in Figure II-2. Since the structure was built during World War II when the availability of steel for construction was minimal, much of the structure consists of wooden or concrete components. The concrete portion of the structure appears to be of sturdy construction with only minor deterioration. The concrete walls taper from a thickness of 2.5 feet at the top to 5.5 feet near the base of the structure. The intake is built on wooden piles. No direct observation of the piles is possible, but as long as the piles remain submerged no major deterioration is expected.

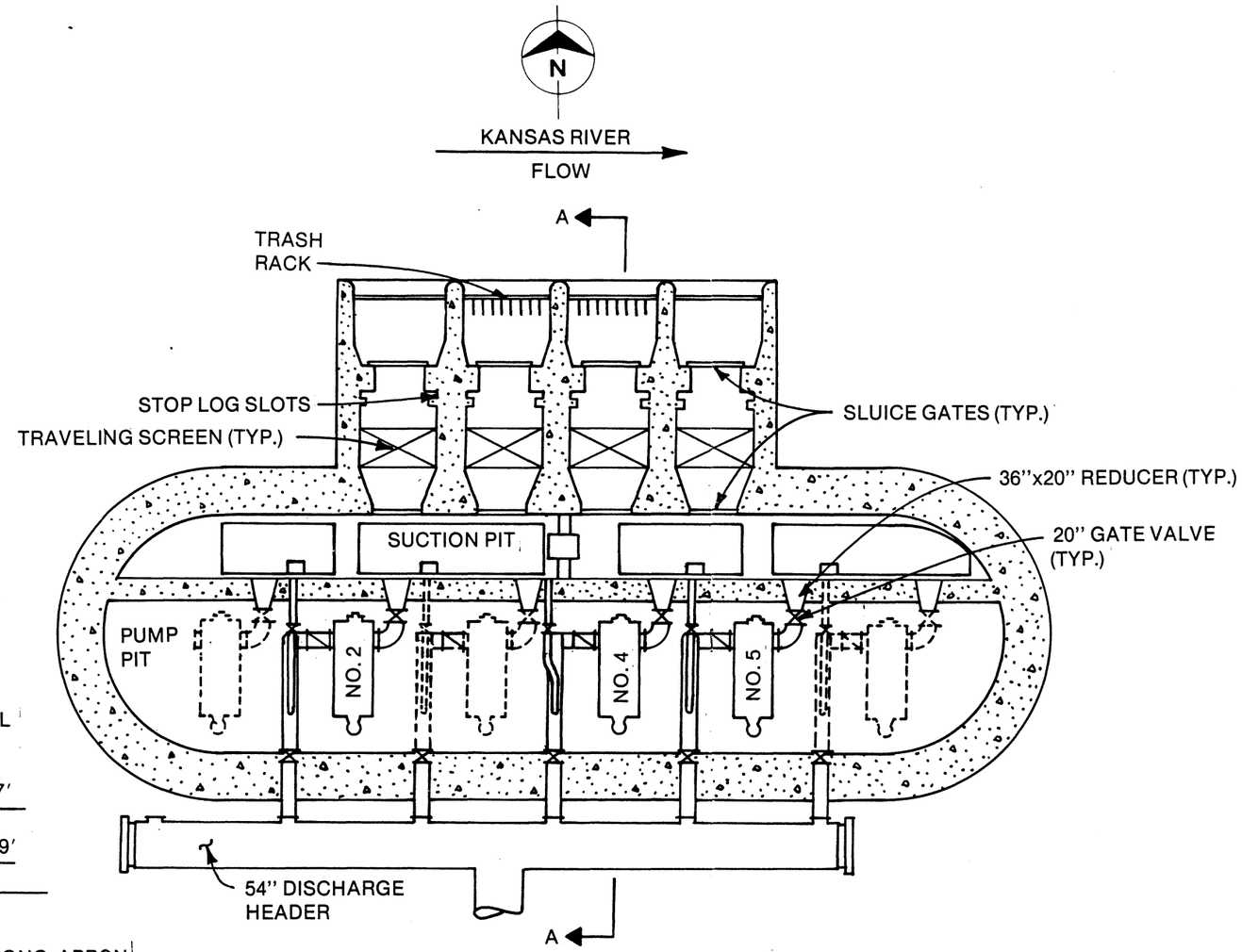
Photographic views of the intake are shown in Figures II-3 and II-4. The timber superstructure appears to be in relatively good condition despite its age. Other components have fared less well. The original wooden trash racks have been replaced by steel railroad rails on the two inner intake bays. The two outer bays no longer have trash racks. The sluice gates appear to have bent stems and may be unworkable. The interior of the structure appears to be only slightly damp, indicating that the sluice gates and wall fittings do not leak.

Although a thorough inspection is beyond the scope of this study, the general condition of the structure appears good. Many of the mechanical components, however, will need reconditioning or replacement if the intake is ever to be put back in service.




SECTION A

7.5 0 7.5 15
SCALE IN FEET




PLAN

8 0 8 16
SCALE IN FEET

NOTE: 1. MINIMUM SUCTION PIT ELEVATION OF 772.9′ IS REQUIRED FOR PROPER PUMP SUBMERGENCE TO PREVENT VORTEXING.

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Figure II-2
SUNFLOWER ARMY AMMUNITION PLANT
RAW WATER INTAKE
PLAN AND SECTION VIEWS

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TOP : VIEW OF INTAKE FROM NORTH SIDE OF KANSAS RIVER

BOTTOM : VIEW OF INTAKE SHOWING CONDITION OF SLUICE GATES AND MISSING TRASH RACKS

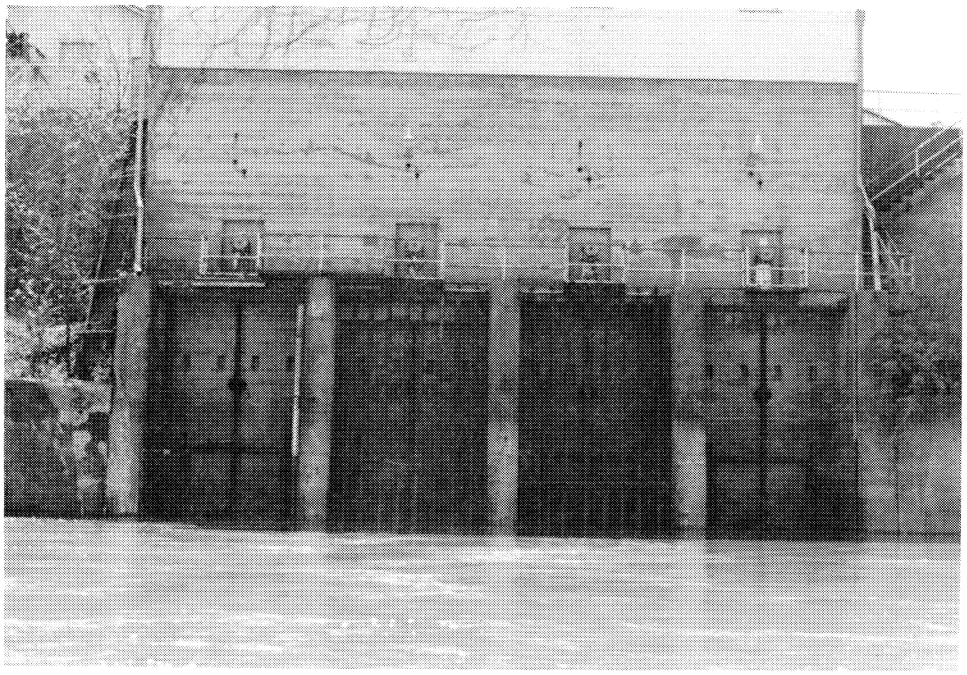

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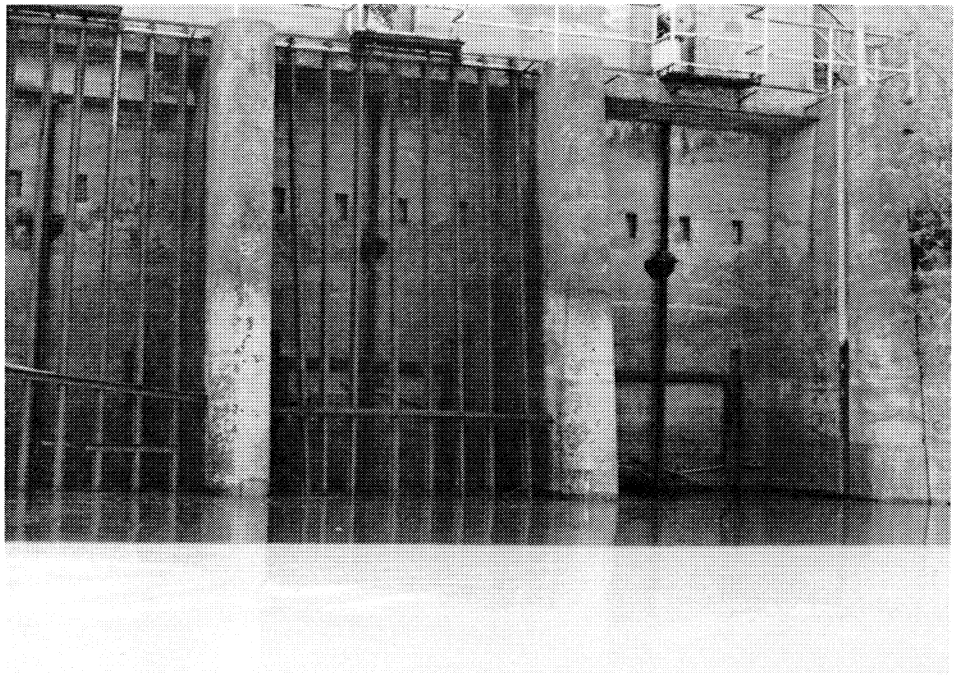
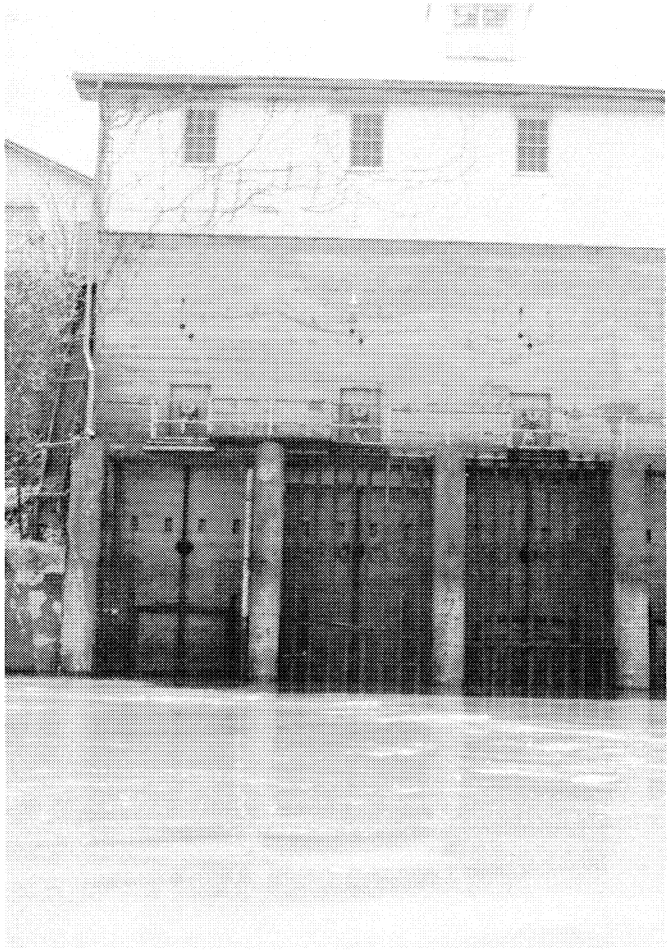
Figure II-3

PHOTOS OF
KANSAS RIVER INTAKE
SUNFLOWER ARMY
AMMUNITION PLANT



TOP : VIEW OF TRASH RACKS CONSTRUCTED FROM RAILROAD RAILS



BOTTOM: VIEW OF INTAKE FROM RIVER SHOWING SUPERSTRUCTURE

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Figure II-4

PHOTOS OF
KANSAS RIVER INTAKE
SUNFLOWER ARMY
AMMUNITION PLANT

## B. OPERATION

The raw water intake is a wet-pit/dry-pit installation. In this type of installation, pumps are installed in a dry-pit with pump suction pipes extending through a pit dividing wall to water in the wet (suction) pit. During operation, water from the river passes through trash racks, sluice gates, and traveling screens into the wet (suction) pit (refer to Figure II-2). From the suction pit, water flows through reducer wall fittings to the suction side of three horizontal, split-case centrifugal pumps.

Information on the three pumps is shown in Table II-1. According to Sunflower AAP representatives, all pumps were installed in 1978.

TABLE II-1
RAW WATER PUMPS AT
SUNFLOWER AAP INTAKE

| Pump Number | Manufacturer | Flow (gpm) | Head (feet) |
|---|---|---|---|
| 2 | Worthington | 10,200 | 198 |
| 4 | Worthington | 10,200 | 198 |
| 5 | Dayton-Dowd | 10,200 | 198 |

Hydraulic calculations indicate that future pumping operations at the intake will be adversely affected by declining river stages. For the pumps described, water submergence of 8 feet over the suction pipes is required to prevent vortexing in the suction pit with resulting air suction and cavitation problems. With consideration of submergence requirements and

pipe friction losses at 37 MGD, a minimum acceptable river stage of 773.4 feet USGS is needed for proper pump operation. Part of the reason for the high submergence requirement of 8 feet for the pumps is due to the lack of suction bells in the suction pit. Submergence requirements could be reduced by one-half with the addition of suction bells.

Pump life and capacity can be significantly reduced by air suction and cavitation. Pump life is affected by increased wear on impellers and casings and pump capacity is affected by air displacement of water. The impact of inadequate submergence is difficult to predict and depends on many variables. For pumps which operate on a daily basis, pump life may be shortened by 5 to 10 years and the internal parts may be replaced twice as often as would be the case for a properly operating pump.

## C. EFFECTS OF DECREASING RIVER STAGE

The raw water intake has a staff gauge which is read by the operators on a daily basis, except for Saturdays and Sundays. The gauge is in poor condition. Above the 10-foot level, the gauge is broken off; and, below the 3-foot level, the gauge is virtually unreadable. A zero reading on the gauge is reported to be equivalent to an elevation of 765.9 feet USGS.

Since recordkeeping is questionable, a correlation betwen the DeSoto gauging station and the Sunflower AAP gauging records is believed necessary for this report. Comparison of data at the two locations gives an average stage

difference of 3.76 feet. This value is added to the DeSoto gauging station readings to obtain "calculated" intake river stage readings.

The "calculated" maximum, minimum and average river stages at the intake for a partial data collection period from April 1980 through November 1983 are shown in Table II-2.

TABLE II-2
CALCULATED RIVER STAGE DATA
SUNFLOWER AAP INTAKE

| Stage Condition | Elevation (Feet, USGS) |
|---|---|
| Maximum | 788.6 |
| Minimum | 765.5 |
| Average | 769.7 |

Based on previous discussions concerning pump operation, the calculated minimum and average river stages shown in the table are inadequate for efficient pump operation (the minimum stage required is 773.4 feet USGS). Under ideal design and operating conditions, the pumps should be capable of operating under all river stages (from minimum to maximum) with proper water submergence over pump suction.

At the present time, the intake would be unable to draw in river water with an additional lowering of the minimum river stage by 1.6 feet down to the intake's fixed sill elevation of 763.9 feet USGS. Since the purpose of this study is to determine impacts to the intake with a lowering of river stage from one to five feet, some construction improvements will be needed if the

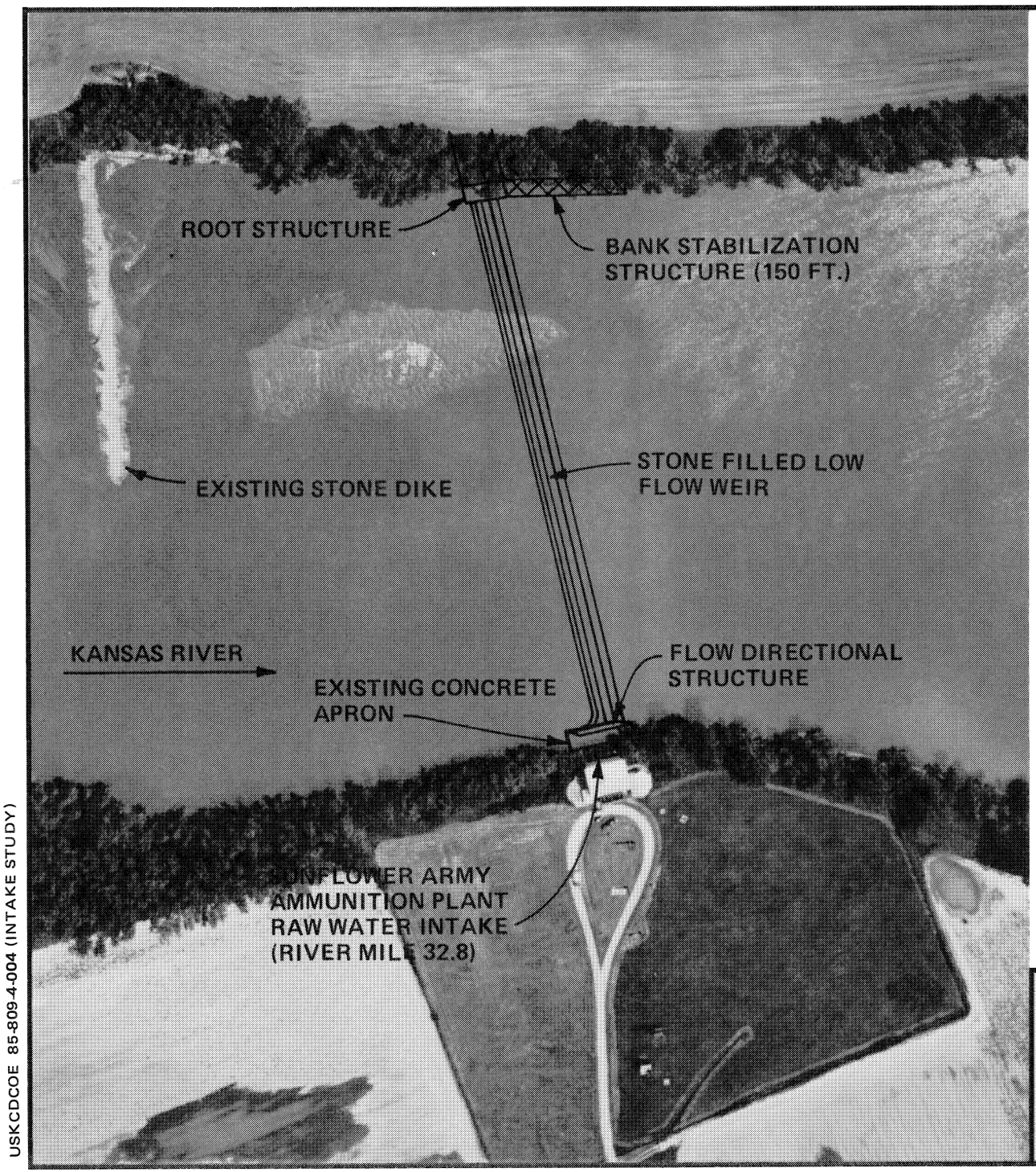
intake is to be returned to service in the future under the condition of continued channel degradation.

## D. IMPROVEMENT ALTERNATIVES

Three improvement alternatives for the river intake are developed to maintain a raw water supply of 37 MGD under the assumed conditions of additional river channel degradation of one to five feet. Alternatives No. 1 and No. 2 consist of two types of low flow weirs (stone-filled jetty and coffer cells) and modifications to the pump suction pit. Alternative No. 3 consists of a new raw water intake. Each alternative is feasible, but will have different construction, operation and maintenance costs. The minimum flow in the Kansas River for all alternatives is assumed to be 500 cubic feet per second (cfs).

### 1. ALTERNATIVE NO. 1 - STONE-FILLED LOW FLOW WEIR

Figure II-5 shows the plan view of Alternative No. 1 which includes a proposed stone-filled, low flow weir and associated appurtenances on the river near the existing intake. The crest elevation of the weir is set at 770.5 feet USGS which is based on improved hydraulics resulting from the addition of 36-inch suction bells to the 36-inch by 20-inch reducers for each pump. These pump suction improvements reduce pump submergence requirements and permit acceptable pump operation at a minimum suction well water level of 769.5 feet USGS. The weir crest is set one foot above the minimum suction well elevation to provide a margin for



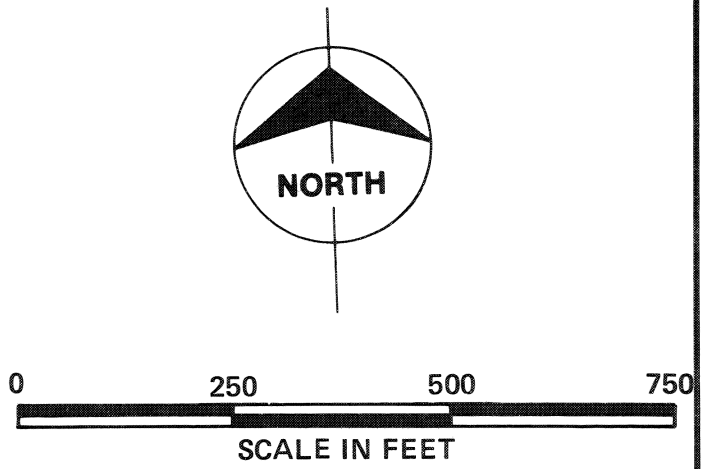




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Figure II-5

SUNFLOWER ARMY AMMUNITION PLANT INTAKE IMPROVEMENTS– STONE-FILLED LOW FLOW WEIR ALTERNATIVE NO. 1

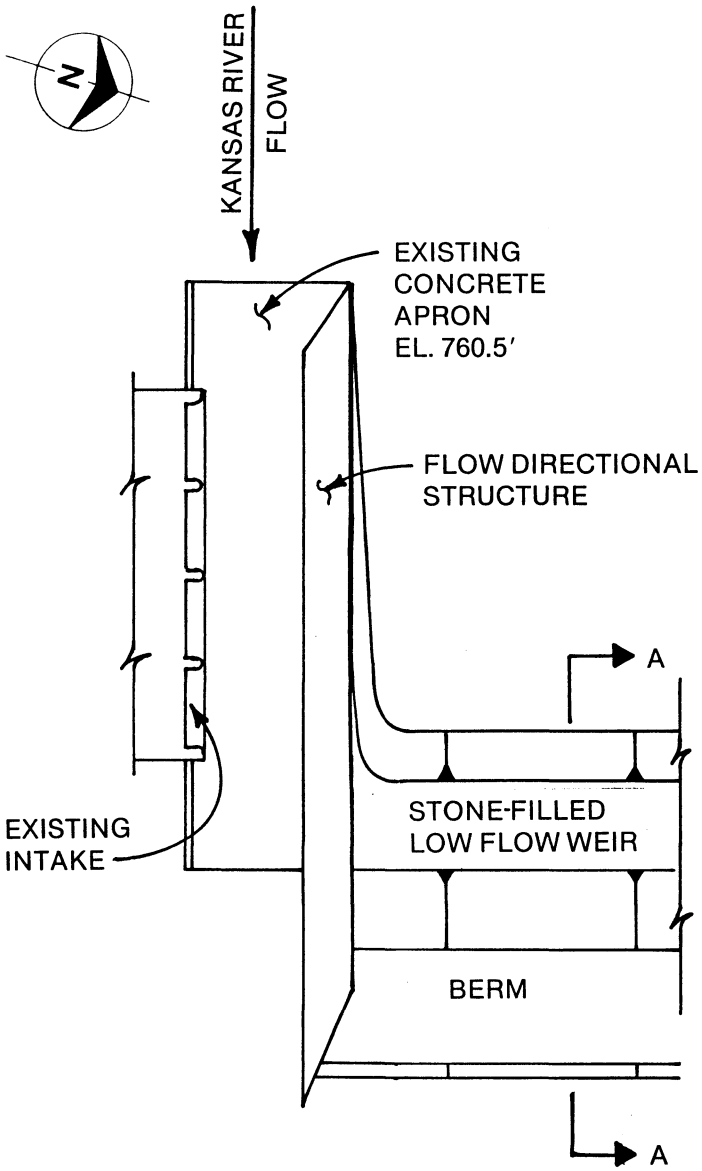
USKCDCOE 85-809-4-004 (INTAKE STUDY)

miscellaneous head losses. The weir bottom elevation will vary according to the channel bed.

The main components of the low flow weir consist of a concrete flow directional structure and a stone-filled dike. The concrete flow directional structure is shown in Figure II-6 and is designed to direct water along the existing concrete apron in front of the intake. The face of the structure is parallel to the existing intake to prevent log jams in the 18-foot channel formed between the structures.

When flows in the Kansas River fall below elevation 769.5 feet USGS, concrete blocks weighing 3.6 tons each will be placed on the concrete apron to increase the water level to 769.5 feet USGS. A mobile crane will be used to move the concrete blocks and will have access to the east end of the intake by a paved road. When the blocks are in place, some silting of the intake will likely occur. Some maintenance activities to remove silt may be required to keep the traveling screens operational. During the more normal high flow conditions, the concrete blocks will be removed which will cause the silt to pass over the concrete apron without settling.

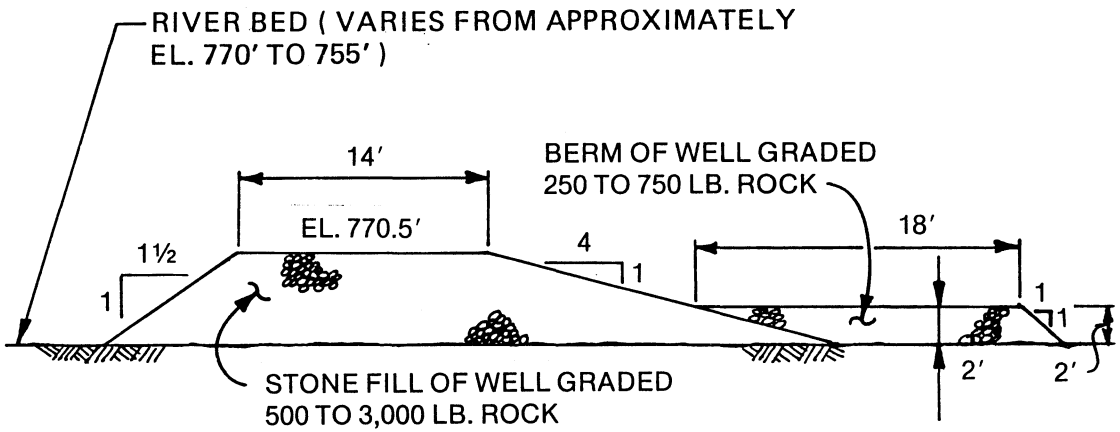
A section view of the low flow weir is shown in Figure II-6. The weir will be constructed of stone weighing 750 pounds to 3,000 pounds. A 20-foot-wide, stone-filled berm will be placed on the downstream side of the weir to help stabilize the weir and to trap moving stones in voids




PLAN

30 0 30

SCALE IN FEET




SECTION A

8 0 8

SCALE IN FEET

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Figure II-6

STONE FILLED
LOW FLOW WEIR
PLAN AND SECTION VIEWS

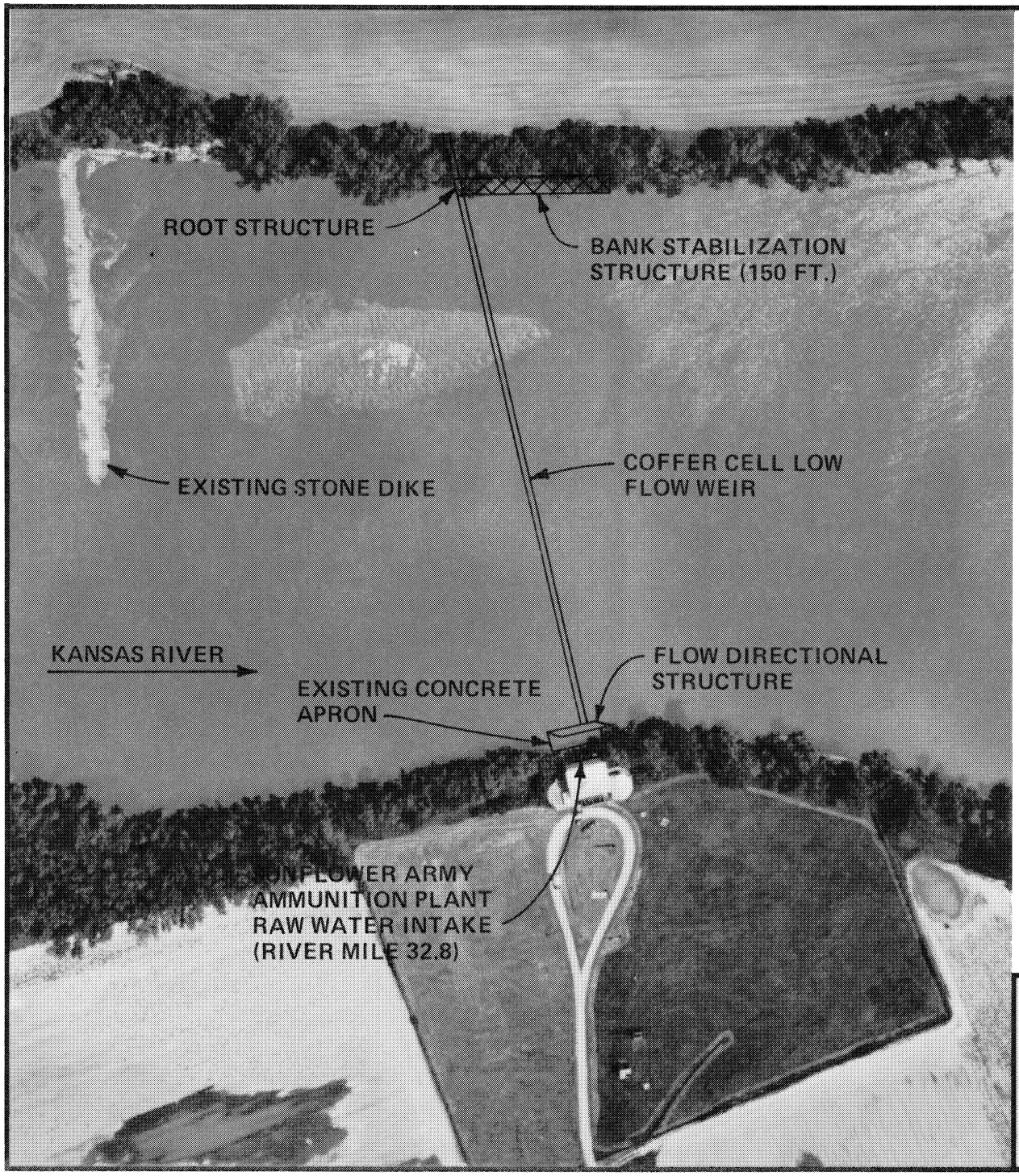
created by water flowing over the weir. Replacement of stone in the berm will be required at variable time intervals.

Other maintenance to the stone jetty will consist of replacing approximately 1,000 to 1,500 tons of stone every 2 to 3 years due to ice floes and high water flows. Logs and other debris will also require periodic removal from the flow channel adjacent the intake structure. The mobile crane can be used to dislodge large materials.

2. ALTERNATIVE NO. 2 - COFFER CELL LOW FLOW WEIR

Figure II-7 shows the plan view of Alternative No. 2 which includes a proposed coffer cell, low flow weir and associated appurtenances on the river near the existing intake. The weir has a crest elevation of 770.5 feet and has many identical features to the stone-filled weir.

The coffer cells consist of sheet piling arranged in a series of circles and semicircles and driven down to bedrock. Bedrock in this location is expected to consist of shale at approximately elevation 735 feet USGS. Each cell is filled with material taken from the channel to within 5 feet of the top. The remaining 5 feet is capped with concrete to ensure the sand and gravel remain in place inside the cell. A partial coffer cell plan and a cell section are shown in Figure II-8. Cells stand vertically in the channel and are subject to collisions with ice and large floating debris. Occasional repair or replacement of cells may be



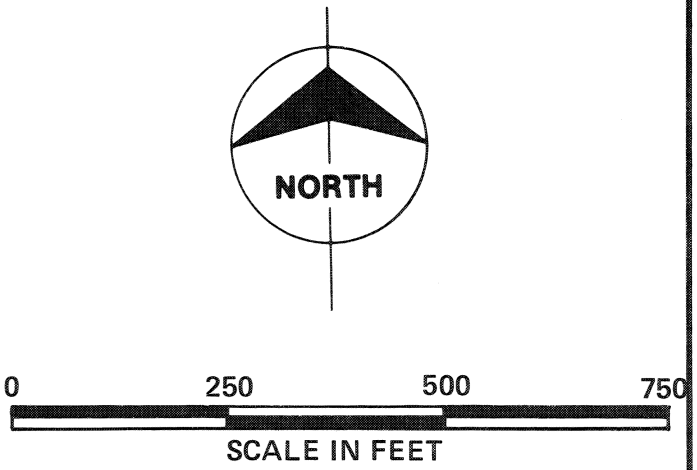




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Figure II-7

SUNFLOWER ARMY AMMUNITION PLANT INTAKE IMPROVEMENTS– COFFER CELL LOW FLOW WEIR ALTERNATIVE NO. 2

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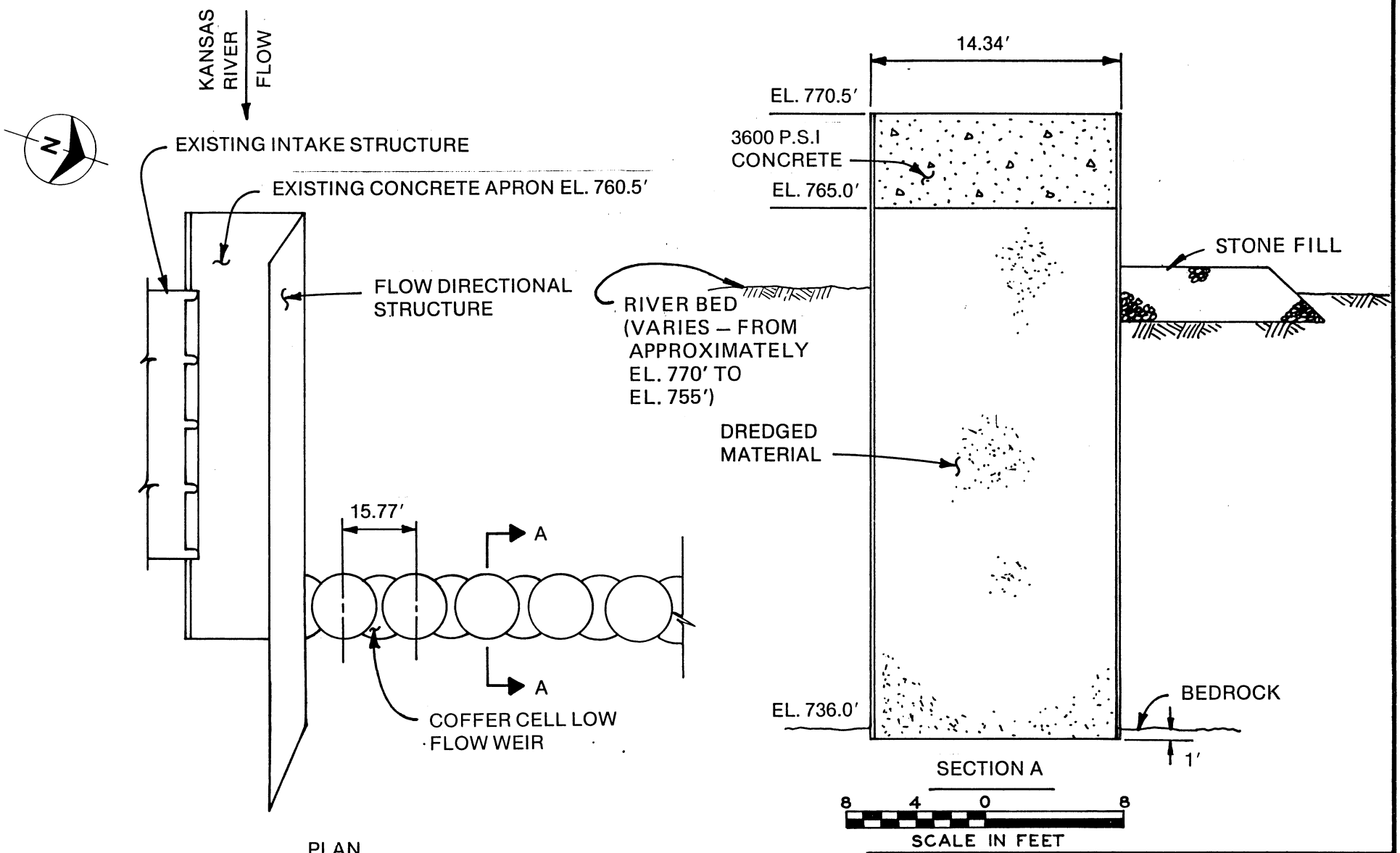


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Figure II-8
COFFER CELL
LOW FLOW WEIR
PLAN AND SECTION VIEWS

necessary. Under normal conditions, a coffer cell should last at least 20 years.

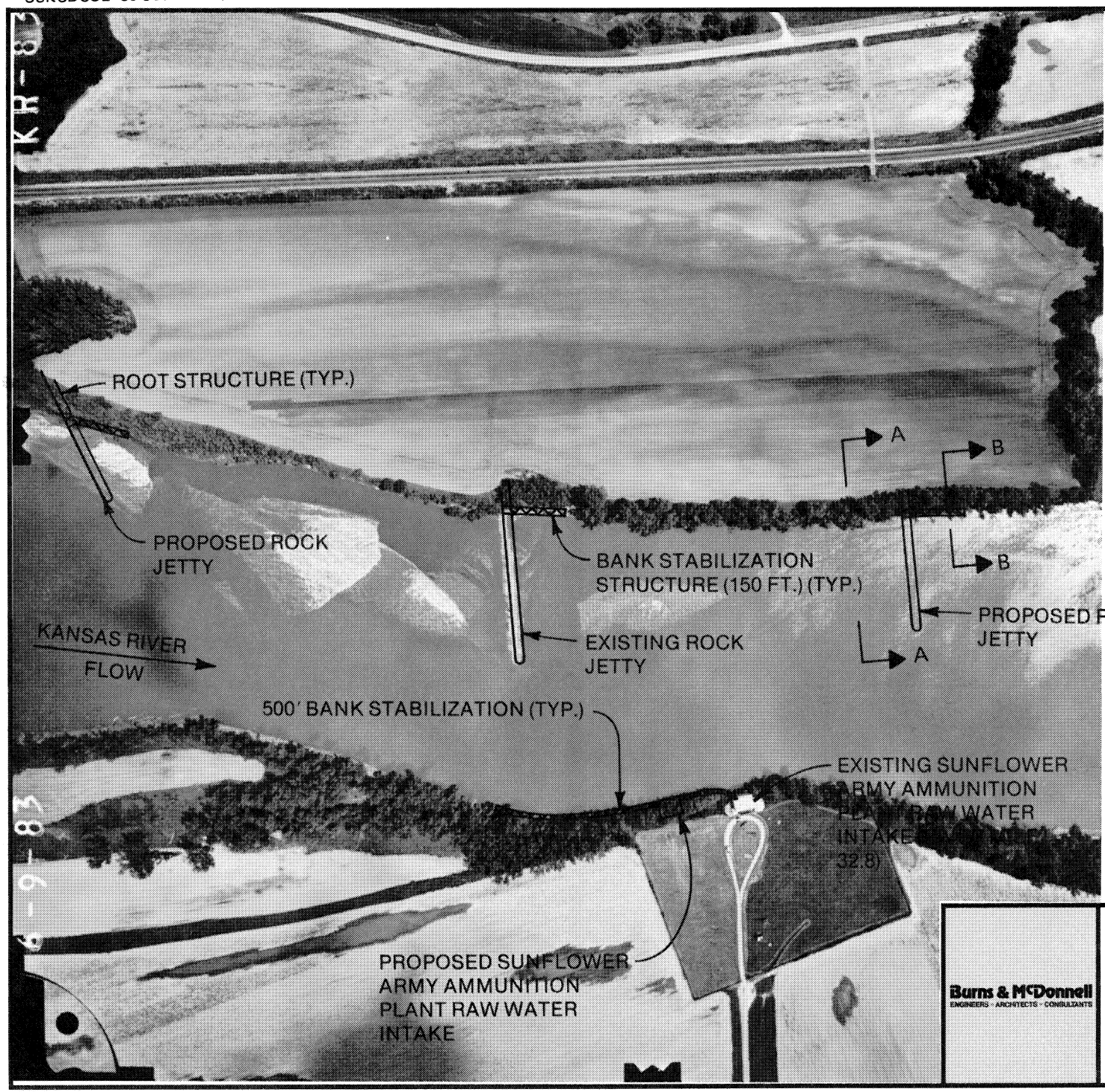
Some river channel degradation downstream of the coffer cell low flow weir is expected to occur. A stone-filled berm on the downstream side will help reduce degradation and protect the stability of the cells. The berm should be monitored periodically and stone fill should be added to areas where rock is washed downstream.

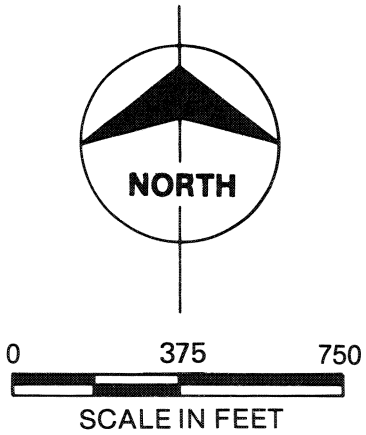
3. ALTERNATIVE NO. 3 - NEW RAW WATER INTAKE

Figure II-9 shows the location of a proposed new raw water intake, stone-filled jetties and associated appurtenances. The intake is located at R.M. 32.8 on the right bank at the existing intake site. Three stone-filled jetties (2 new, 1 existing) are located on the left bank to ensure that a rectified channel is maintained in front of the intake.

The new intake and pump station will have several features which will increase the reliability and flexibility of operation over that of the existing intake. These include:

- Use of vertical turbine pumps instead of horizontal, centrifugal pumps. This eliminates the need for a dry pit for the pumps along with the potential danger of flooding pumps and motors due to a pipe or wall leak. A bridge crane will be




NOTE:

1. REFER TO FIGURE II-10 FOR SECTION A AND B

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**Figure II-9**

**SUNFLOWER ARMY AMMUNITION PLANT NEW RAW WATER INTAKE ALTERNATIVE NO. 3**

provided to aid in setting and removing the pumps. The pump station will house four vertical turbine pumps, each rated at 8,600 gpm at 200 feet of total dynamic head.

- Multiple components (such as structural chambers, gates, traveling screens and pumps) will be provided in each intake to permit the independent operation of the intake while certain components are out of service for repairs and maintenance.

- Adjustable trash racks and sill will permit the lowering of the sill in increments of one foot to in excess of five feet below the river bed. The sill and trash racks will be installed in a grooved wall. The sill will be designed to accommodate removable concrete stop logs. As the water surface lowers, sections of the sill will be removed and additional sections of the trash racks will be placed into position.

- Use of a low flow weir is not required to offset declining water levels which eliminates the need for maintenance of a rock dike across the entire river width. Stem dikes will be used to keep the channel near the intake.

The new intake site will not require the purchase of additional land since it is located on U.S. Government property and electrical service can be readily extended to the new site. A new pipe connection (225

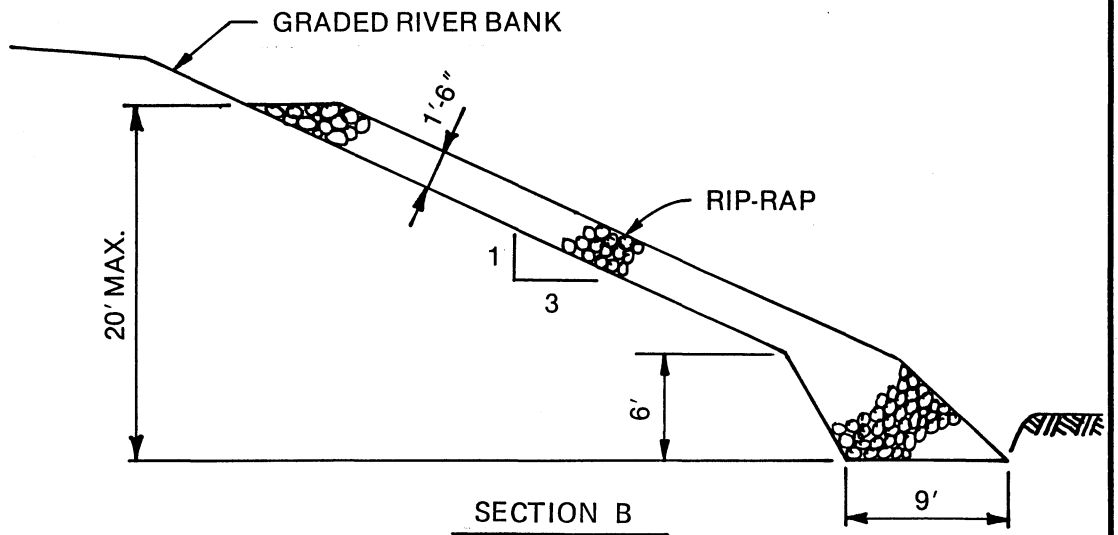
l.f. of 54-inch diameter pipe) will be required between the new intake and the existing 54-inch diameter raw water transmission main which extends from the existing intake to the ammunition plant production facilities.

A typical section of a stone-filled jetty associated with the new intake is shown in Figure II-10. The jetty has a crest elevation which varies from 781.07 feet USGS at the north river bank to elevation 765.07 feet near the river channel mid-point. The low end of the jetty (elevation 765.07 feet USGS) is set one foot above the 500 cfs stage elevation which the Corps of Engineers considers to be the probable future minimum flow which will be maintained in the river. Bank stabilization is provided 500 feet upstream and 150 feet downstream of the proposed intake and 150 feet downstream of each stone-filled jetty. The purpose of bank stabilization is to reduce erosion along the river banks in the vicinity of the intake. Once the new intake is operational, the existing intake may be abandoned in place.

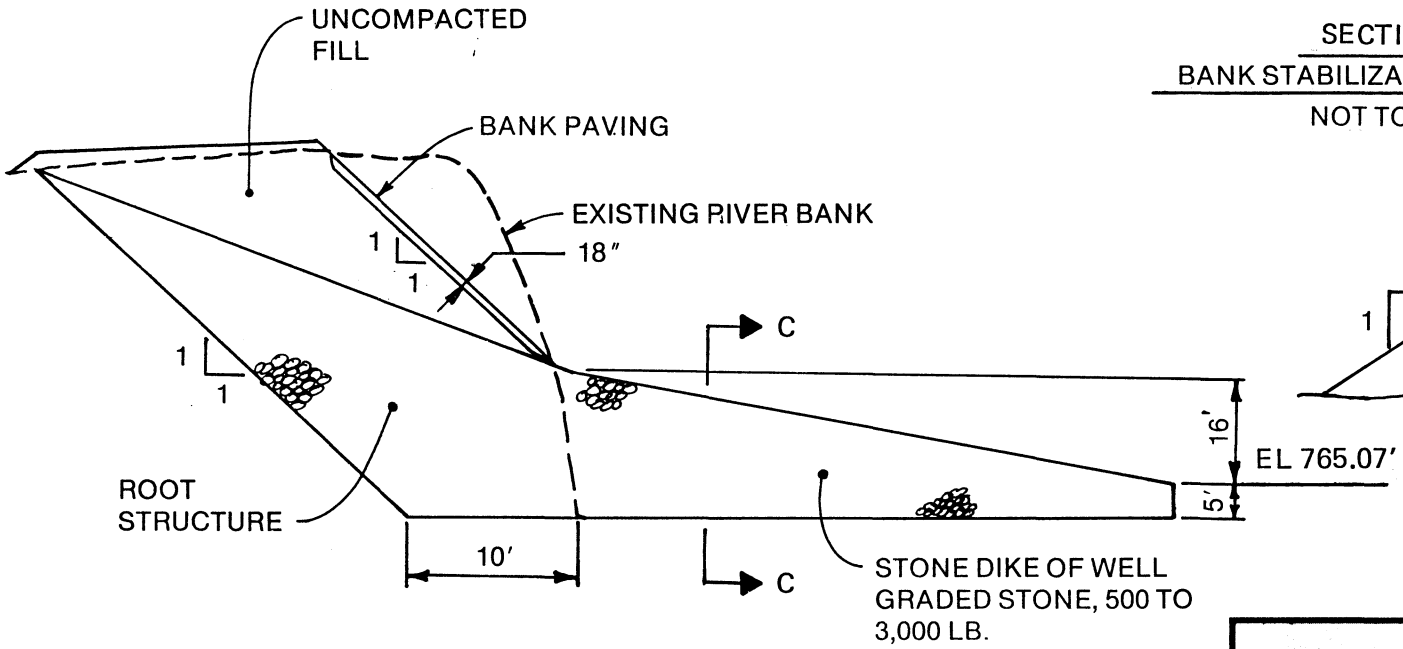
The existing intake and pump station is 44 years old and many of the components will have to be replaced or restored if it is to be returned to service. A new intake will have brand new, "state-of-the-art" components which should increase reliability, reduce long-term maintenance, and improve operational efficiency.

NOTE:

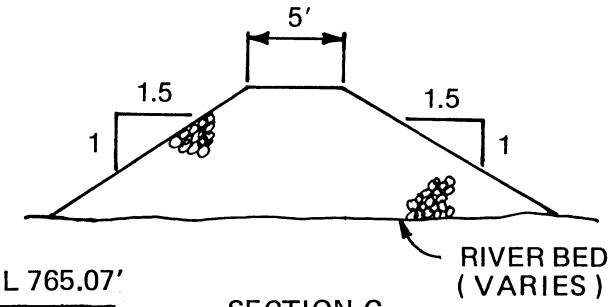
1. REFER TO FIGURE II-9 FOR LOCATION OF SECTION CUTS A AND B




SECTION B
BANK STABILIZATION STRUCTURE
NOT TO SCALE




SECTION A
ROCK JETTY
NOT TO SCALE




SECTION C
NOT TO SCALE

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**Figure II-10**
**NEW RAW WATER INTAKE STONE DIKE SECTIONS AND DETAILS**

## E. COST ESTIMATES

Estimates of construction and maintenance costs for the three improvement alternatives to the Sunflower AAP intake are included herein. All costs are in 1986 dollars and are related to an Engineering News Record construction cost index of 4450.12. Construction cost estimates are based on quantity takeoffs with unit price estimates and historical project cost information (refer to Appendix for more detail). Annual maintenance costs are based on estimates of average material and labor costs required to keep facilities in a condition similar to their original construction.

Table II-3 lists the costs associated with construction of Improvement Alternative No. 1. This alternative consists of a stone-filled, low flow weir, flow directional structure, bank stabilization and the addition of suction bells on the suction inlets of the raw water pumps. Annual maintenance costs are based on the replacement of 10% of the rock in the stone-filled weir on an average annual basis.

TABLE II-3
COST ESTIMATE
ALTERNATIVE NO. 1 - STONE-FILLED LOW FLOW WEIR
SUNFLOWER AAP INTAKE

| Channel Degradation (Feet) | Construction Cost ($) | Annual Maintenance Cost($) |
|---|---|---|
| 1 | $ 691,000 | $42,000 |
| 2 | 785,000 | 50,000 |
| 3 | 890,000 | 58,000 |
| 4 | 1,005,000 | 68,000 |
| 5 | 1,130,000 | 80,000 |

Table II-4 lists the costs associated with the construction of Improvement Alternative No. 2. This alternative consists of a coffer cell low flow weir, flow directional structure, bank stabilization and the addition of suction bells on the inlets to the raw water pumps.

TABLE II-4
COST ESTIMATE
ALTERNATIVE NO. 2 - COFFER CELL LOW FLOW WEIR
SUNFLOWER AAP INTAKE

| Item | Capital Cost($) |
|---|---|
| Coffer Cell Low Flow Weir | $2,500,000 |
| Bank Stabilization | 30,000 |
| Flow Directional Structure | 200,000 |
| Suction Pit Modification | 40,000 |
| TOTAL | $2,770,000 |

The annual maintenance cost for Improvement Alternative No. 2 is estimated at $10,000. This cost is based on replacement of the concrete and 25 percent of the steel in one coffer cell every 8 years and replacement of 10 percent of the rock in the downstream rock apron each year.

Table II-5 lists the costs associated with the construction of Improvement Alternative No. 3. This alternative consists of a new river intake, three stone-filled jetties, bank stabilization, transmission main and associated appurtenances.

TABLE II-5
COST ESTIMATE
ALTERNATIVE NO. 3 - NEW RAW WATER INTAKE
SUNFLOWER AAP INTAKE

| Item | Construction Cost $ |
|---|---|
| Pump Station and Intake | $2,300,000 |
| 2 Stone-Filled Dikes* | 750,000 |
| 54-Inch Transmission Main | 40,000 |
| Bank Stabilization | 180,000 |
| Mobilization, Bonds and Insurance | 100,000 |
| Site Clearing and Grubbing | 30,000 |
| TOTAL | $3,400,000 |

*A third dike is already in place.

The annual maintenance cost for Improvement Alternative No. 3 is estimated at $75,000. This cost is based on replacement of 10% of the rock in the stone-filled dikes and bank stabilization areas on an average annual basis.

## F. CONCLUSIONS

Channel degradation with declining river stages has already caused inadequate pump suction conditions which will create inefficient pump operation at minimum and average river stages. Since the intake has not been used since 1970, the impact of declining river stages on intake operation has not been noticed. Any further channel degradation of from 1 to 5 feet will significantly reduce intake capacity or cause total intake shutdown at average and minimum river flows.

Three improvement alternatives are investigated to offset the negative effects of channel degradation. Alternative No. 1 includes a stone-filled

low flow weir and Alternative No. 2 includes a coffer cell low flow weir. Both alternatives include suction bell improvements to the existing pumps. Alternative No. 3 includes the construction of a new intake with adjustable sill and stone-filled stem dikes to control the river channel. Alternative No. 1 is the most economical option and Alternative No. 3 is the most expensive option.

* * * * *

# PART III – WATER DISTRICT NO. 1 OF JOHNSON COUNTY RAW WATER INTAKE

PART III

WATER DISTRICT NO. 1 OF JOHNSON COUNTY RAW WATER INTAKE

## A. GENERAL

Water District No. 1 of Johnson County has several sources of raw water including surface water from the Kansas and Missouri Rivers and groundwater from the Kansas River alluvium. In 1984, the water district placed new raw water delivery facilities from the Missouri River into service with initial flow capacity for 25 MGD (ultimate flow capacity for 100 MGD). The water district's maximum day water demand was 65 MGD in 1986 and is projected to increase to over 150 MGD by year 2025. Because of the anticipated need for water in the future and the low intake pumping energy costs, the water district continues to include the Kansas River intake in both immediate and long range water supply plans.

The general location of the water district's raw water intake and pump station on the Kansas River is shown on Figure III-1. The intake is located at approximately R.M. 15 on the right bank downstream of the I-435 bridge near Edwardsville, Kansas. A site plan of facilities associated with the raw water intake is shown in Figure III-2 and plan and section views of the intake and pump structure are shown in Figure III-3.

The original intake was constructed in 1964 with an ultimate design flow capacity of 100 MGD. Because of declining river stages, the current pumping and hydraulic capacity of the intake is approximately 70 MGD. The intake

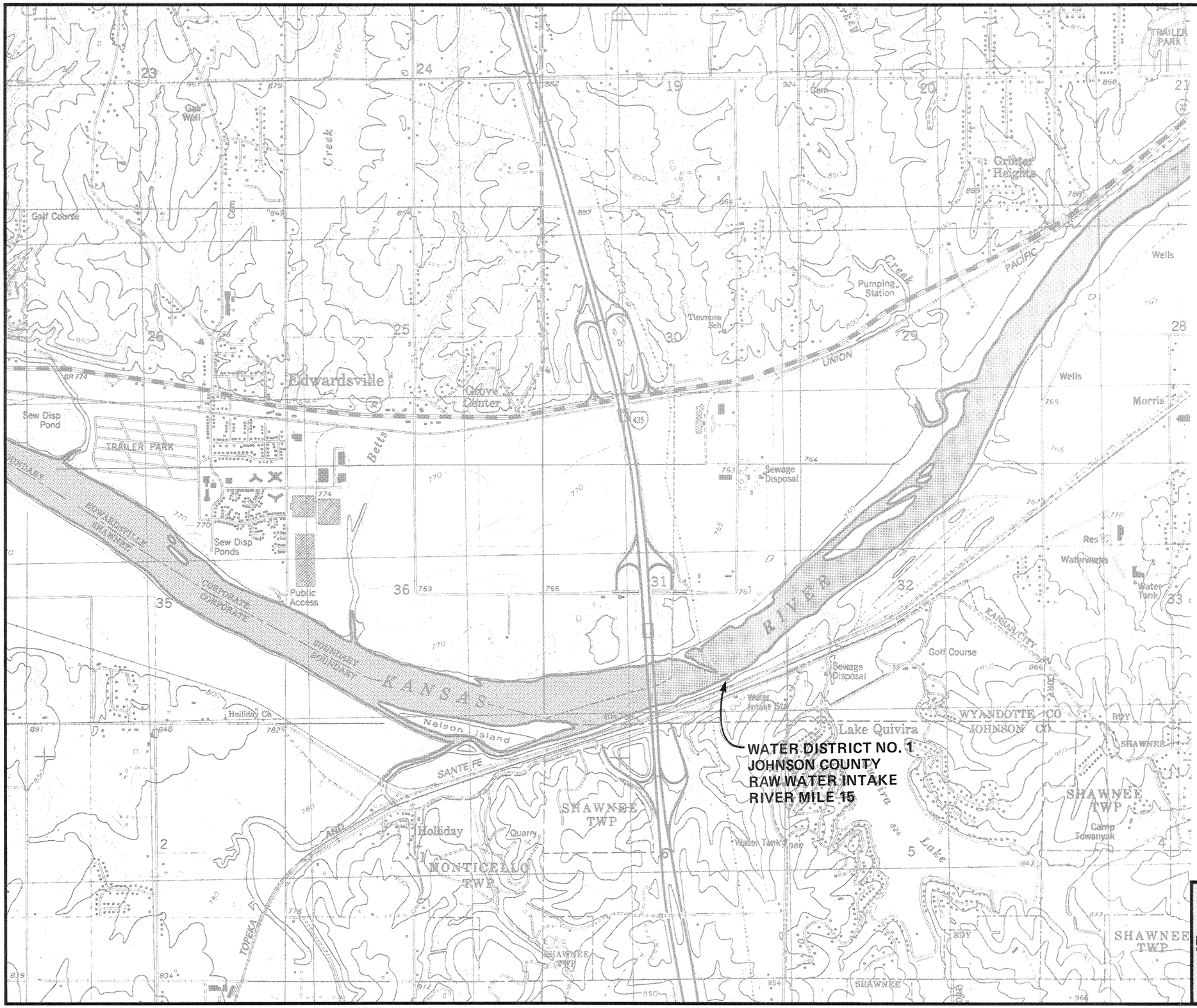


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**Figure III-1**

**W.D. NO. 1 OF JOHNSON COUNTY RAW WATER INTAKE LOCATION MAP**

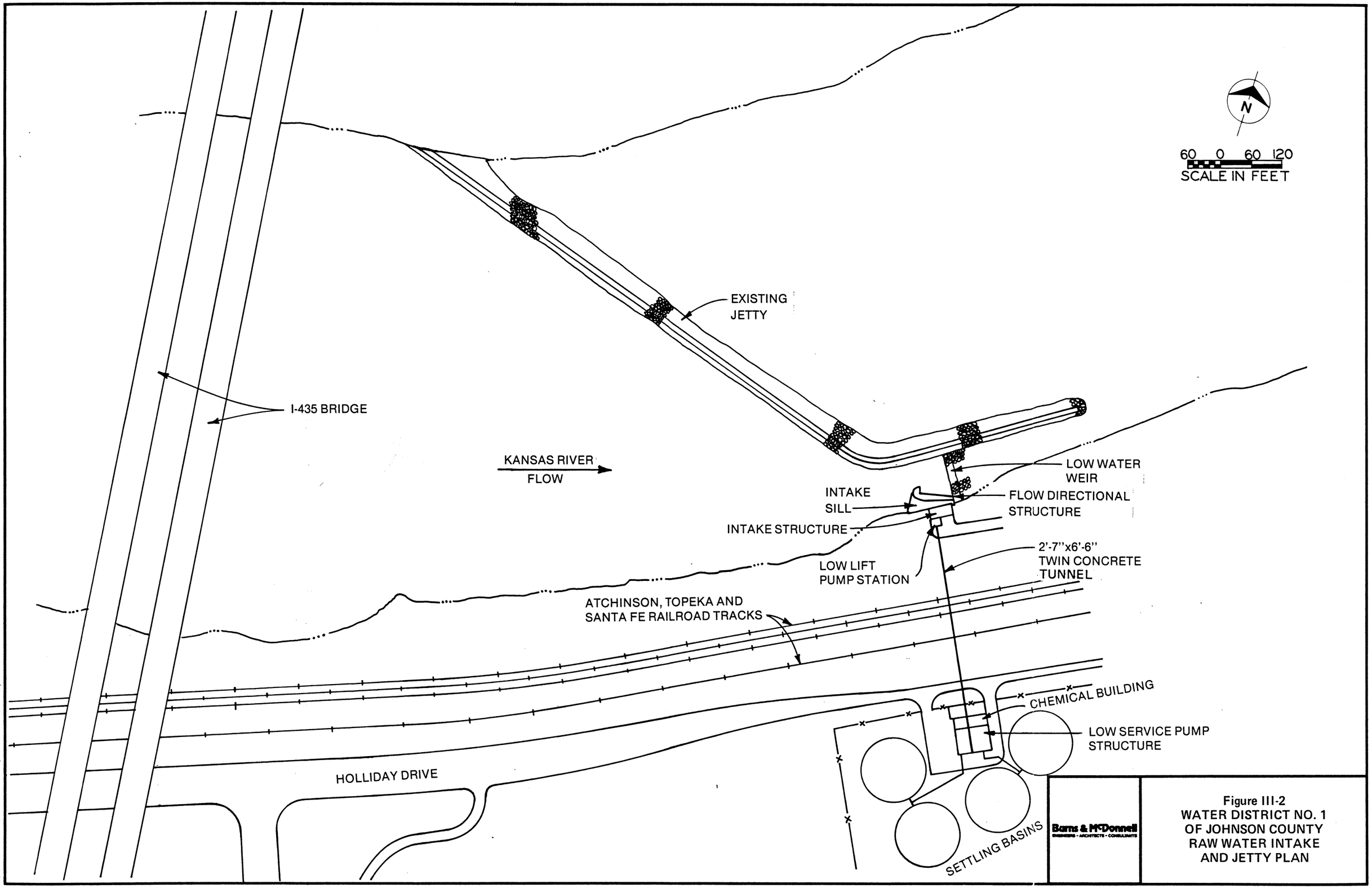


Figure III-2
WATER DISTRICT NO. 1
OF JOHNSON COUNTY
RAW WATER INTAKE
AND JETTY PLAN

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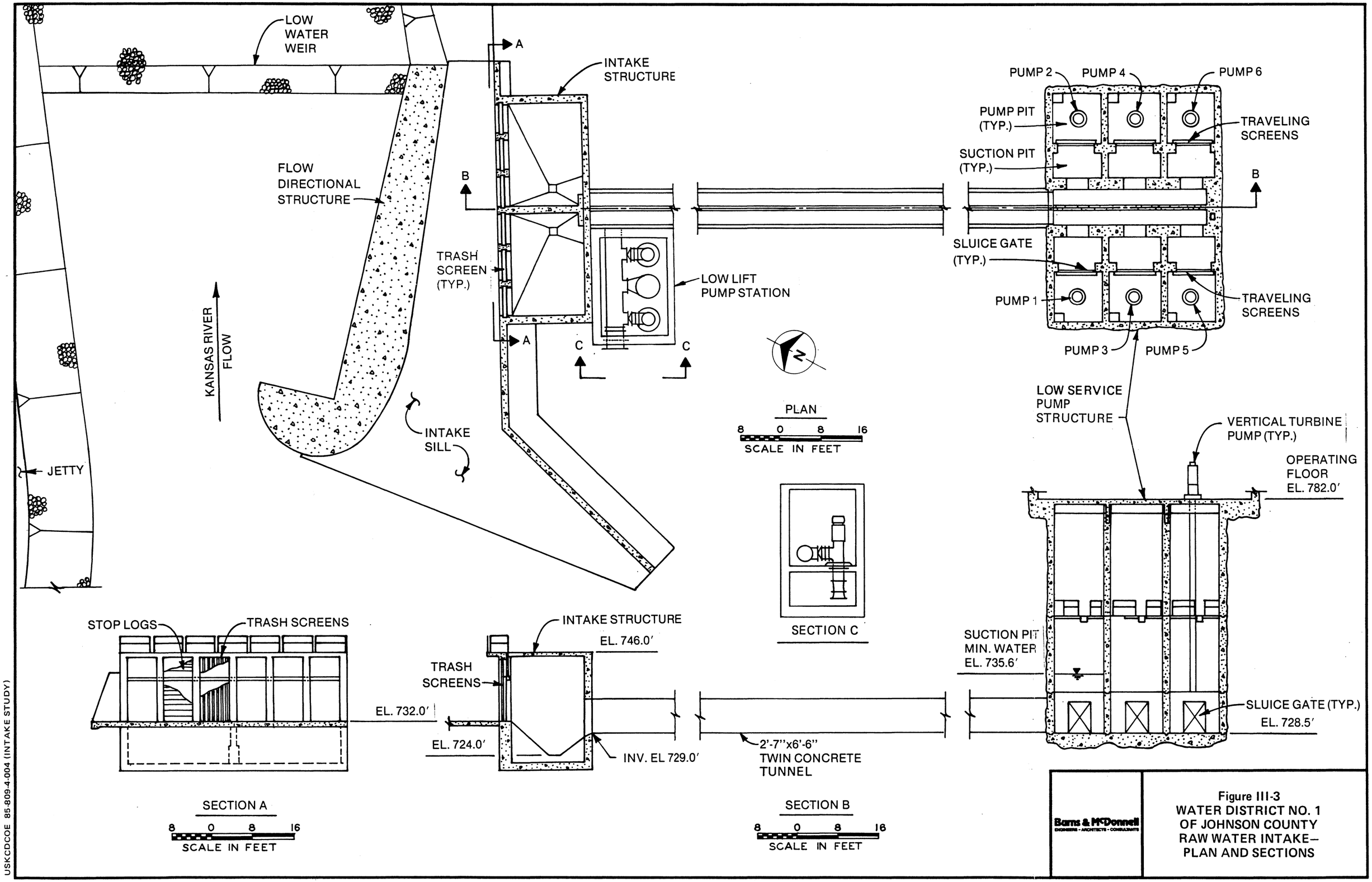


Figure III-3
WATER DISTRICT NO. 1
OF JOHNSON COUNTY
RAW WATER INTAKE–
PLAN AND SECTIONS

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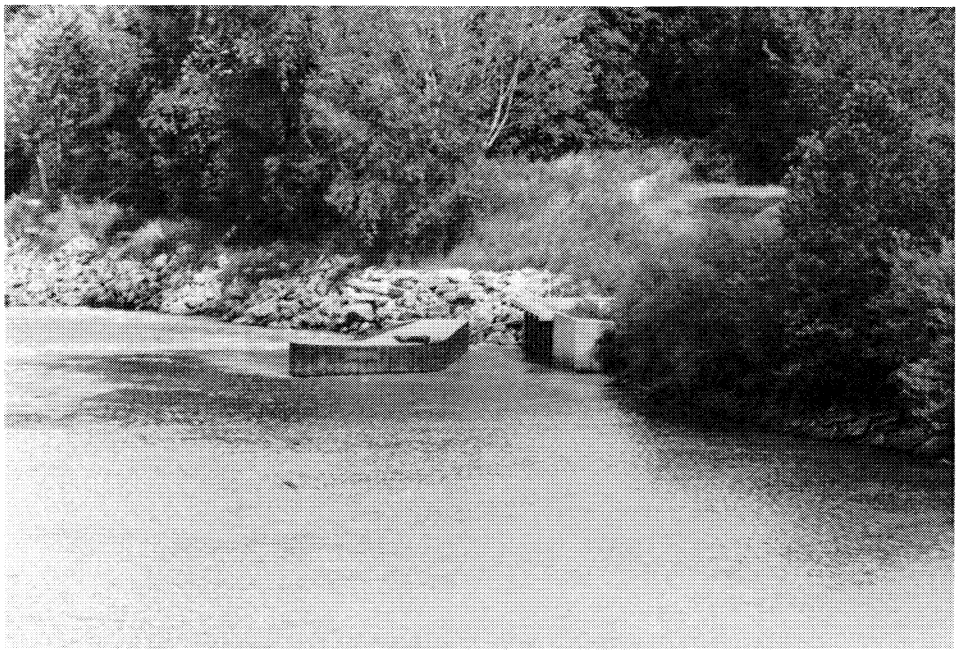
has a fixed-sill with the sill apron set at elevation 732.0 feet USGS. Hydraulic calculations indicate that a river stage of 734.5 feet USGS is required to deliver 70 MGD to the pump suction pit.

The original design was based on historical river stage data and provided for the gravity flow of raw water from the intake to the low service pump structure located south of Holliday Drive. Because of early problems with low flows and declining river stages, a low lift pump station was added in 1966. The purpose of the low lift pump station was to convey water to the suction pit of the low service pump structure to provide water for pump submergence during periods of low river stages.

In 1967, the water district constructed a rock jetty to maintain a low flow channel next to the intake and to raise the water surface level in the river. The jetty extended from the left bank to within 50 feet of a flow directional structure located adjacent the intake. The jetty was expanded in 1978 and a low flow weir of rock fill was added in 1985. The low flow weir (crest elevation 734.0 feet USGS) closed the remaining open channel in the Kansas River. During low river stages, the water district is permitted to place sandbags across the concrete sill apron to a height of 2 feet to an elevation of 734.0 feet USGS. Photographs of the jetty, flow directional structure and intake are shown in Figures III-4 and III-5.

Rock has been placed downstream of both the jetty and the low flow weir to prevent undermining of the structures. In 1978, modifications to the jetty included replacing the interior of the jetty with stone to a depth of 5 feet

TOP : VIEW EAST TO RIVER JETTY



BOTTOM : VIEW OF FLOW DIRECTIONAL STRUCTURE

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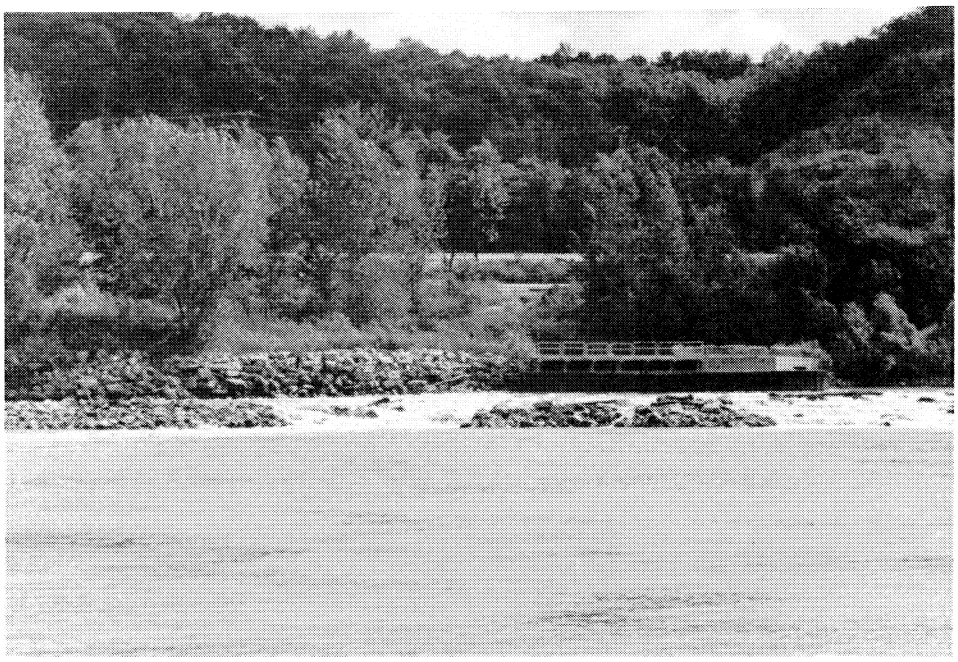
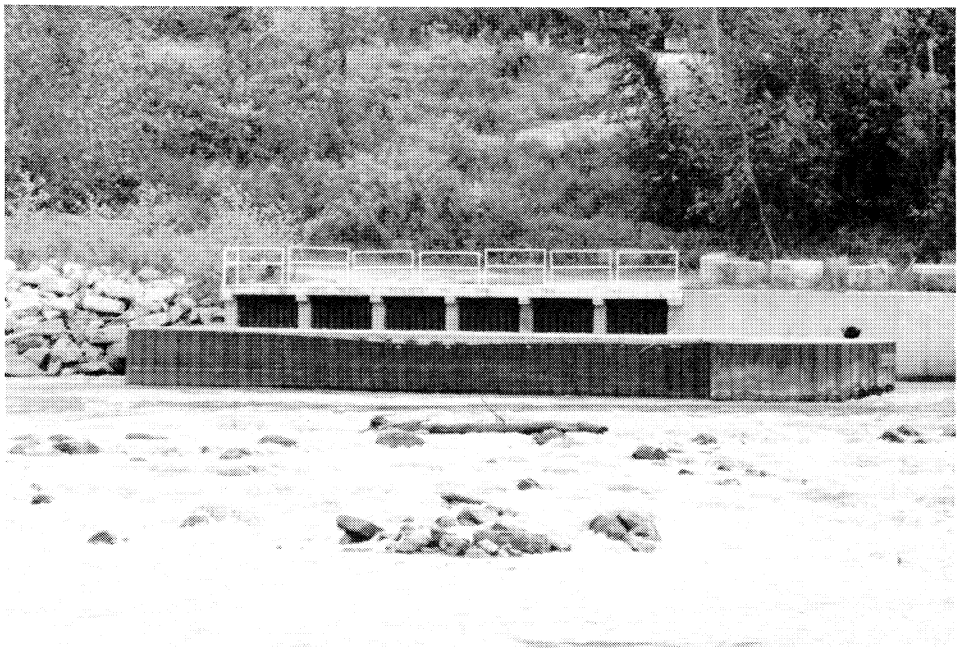
Figure III-4

PHOTOS OF
KANSAS RIVER INTAKE
W.D. NO. 1 OF JO. CO.



TOP : VIEW OF JETTY AND INTAKE



BOTTOM : VIEW OF INTAKE AND DIRECTIONAL STRUCTURE

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Figure III-5

PHOTOS OF
KANSAS RIVER INTAKE
W.D. NO. 1 OF JO. CO.

USKCDCOE 85-809-4-004 (INTAKE STUDY)

below the existing channel bottom. A 30-foot-wide stone-filled berm is located on the downstream side of the jetty and stone has been placed along the channel bottom for a distance of 300 feet downstream of the low flow weir.

The jetty is frequently damaged during ice floes and high river flows (refer to Figure III-6). The jetty is currently in need of repairs which the water district estimates will cost approximately $40,000.

## B. OPERATION

During normal operation, flow from the Kansas River enters the flow directional structure where part of the raw water is withdrawn through trash racks into two adjoining intake chambers. From the chambers, raw water flows by gravity through a double box tunnel a distance of 400 feet to a low service pump structure located south of Holliday Drive. During low river stages (below elevation 735.0 feet USGS), low lift pumps at the raw water intake can be used to transfer water from the intake to the low service structure. These pumps are rarely used because the river stage is normally adequate and because they diminish the overall pumping capacity.

The low service pump structure contains traveling screens and low service pumps. The pumps convey raw water to presedimentation basins near the intake where heavy solids are removed by sedimentation and discharged back to the river. Settled water from the basins flows by gravity approximately 2 miles to the water treatment plant.

TOP : VIEW OF JETTY DEBRIS TOWARD I-435 BRIDGE

BOTTOM : VIEW OF DEBRIS ON JETTY

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Figure III-6

PHOTOS OF
KANSAS RIVER INTAKE
W.D. NO. 1 OF JO. CO.

The water district has surface water rights which allow a maximum daily withdrawal rate of 72 MGD from the Kansas River. Table III-1 lists pertinent data for the pumps at the low lift pump station and the low service pump structure.

TABLE III-1

RAW WATER PUMPS AT
W.D. NO. 1 OF JOHNSON COUNTY INTAKE

| Function | Pump No. | Manufacturer | Flow gpm | Head ft. |
|---|---|---|---|---|
| Low Lift | 1 | Johnston | 14,000 | 10 |
| Low Lift | 2 | Cascade | 8,500 | 10 |
| Low Lift | 3 | Johnston | 14,000 | 10 |
| Low Service | 1 | Johnston | 9,000 | 75 |
| Low Service | 2 | Johnston | 9,000 | 75 |
| Low Service | 3 | Worthington | 10,500 | 90 |
| Low Service | 4 | Worthington | 10,500 | 90 |
| Low Service | 5 | Worthington | 10,500 | 90 |
| Low Service | 6 | Worthington | 10,500 | 90 |

The firm pumping capacity of the low service pump station is 71.3 MGD and the firm pumping capacity of the low lift pump station is 32.4 MGD. Firm pumping capacity is defined as the pumping capacity with the largest pump assumed to be out of service for repairs. According to water district representatives, the low lift pumps are seldom used because they diminish the overall flow capacity of the intake.

Through experience, the water district has developed operating criteria which requires maintaining a water surface elevation of at least 734.5 feet USGS at the raw water intake. At elevation 735.0 feet USGS, operators begin to observe problems with the operation of the low service pumps. Hydraulic calculations performed for this study conclude these operating problems are the result of inadequate net positive suction head (NPSH) which can cause

pump cavitation and reduced pumping capacity. A river stage elevation of 736.3 feet USGS is required to maintain a gravity flow of 72.0 MGD and to provide the required net positive suction head (NPSH) for the Worthington pumps which were recently installed in the low service pump station.

## C. EFFECTS OF DECREASING RIVER STAGE

Over the years, decreasing river stages have seriously affected the capability of the intake to deliver 70 MGD on a reliable basis. The intake's fixed sill at elevation 732.0 feet USGS was based on historical river stage data and river bed elevations available in the early 1960s and does not accommodate declining river stages due to channel degradation.

Dredging operations in the Kansas River are believed to have contributed to the problems associated with declining river stages at the water district's intake. Much of the dredging on the river occurs between the Turner Bridge and Bonner Springs where the intake is located. In the future, the amount of continued channel degradation in the vicinity of the intake will depend on how extensively the river is dredged and on how the existing jetty and low flow weir are maintained.

When the intake was constructed in 1964, a flow of 1,000 cfs (88 percent duration) had a water surface elevation of 735.5 feet USGS at the intake. A hydrographic survey of the river indicated a fairly flat bottom at an average elevation of 734.5 feet USGS. Based on this information, setting the intake sill elevation at 732.0 feet USGS appeared to be a reasonable design criteria.

In spite of this information, difficulties were experienced immediately after the intake became operational in 1964. Low river stages and low flows prompted the construction of a low lift pump station in 1966 and a jetty in 1967. Even with the jetty, water surface elevations dropped to elevation 733.0 feet USGS on several occasions. An extreme low elevation of 732.3 feet USGS was recorded on January 17, 1972 which was the result of bed scour through the river channel at the intake.

Records of river stages are recorded daily at the raw water intake by the water district. Records for the period 1976 to 1983 (latest year available) are used to determine the variation in river stage. For ease in manipulating data, the average difference in recorded river stage elevations between the DeSoto gauging station and the river intake is calculated to be 29.2 feet and is used to calculate the average water surface elevation at the intake. This method was employed due to potential variations in stage readings at thhe Johnson County intake due to holes in the jetty, logs jammed between the flow directional structure and intake, and ice buildup. Each of these factors affect the river stage at the intake.

The maximum, minimum, and "calculated" average river stages at the river intake for the period 1976 to 1983 are shown in Table III-2. Maximum and minimum figures are actual values from intake records.

TABLE III-2

RIVER STAGE DATA
W.D. NO. 1 OF JOHNSON COUNTY INTAKE

| Stage Condition | Elevation (Feet, USGS) |
|---|---|
| Maximum | 750.0 |
| Minimum | 732.6 |
| Average (Calculated) | 736.7 |

As a result of the construction of the low flow weir in 1985 (and use of sandbags on the intake sill), river stages at the intake can be controlled at or above elevation 734.5 feet USGS which will improve hydraulic conditions for pump operation under low flow conditions. Even so, insufficient NPSH for the Worthington pumps will still occur whenever the river stage drops below 736.3 feet USGS which will impair pump operation and result in reduced pumping capacity.

For this study, the impacts of channel degradation in increments of 1 foot to a maximum of 5 feet are investigated. These impacts are evaluated as follows:

- Undermining of Intake Structure: The bottom of the base slab of the raw water intake is set at elevation 722.0 feet USGS (more than 10 feet below the lowest recorded river stage) and structure undermining does not appear to be a problem as long as the stone-filled jetty and low flow weir remain in place. Stone fill in the river channel and bank stabilization of the intake should continue to be maintained by the water district to prevent channel scour. The large quantity of

stone already in place should help control channel degradation below the jetty and low flow weir.

- Declining Water Stages: Continued maintenance of the existing jetty and low flow weir at a crest elevation of 734.0 feet USGS and a minimum water surface elevation of 734.5 feet USGS should prevent declining river stages and permit the facility to operate at a capacity of 70 MGD. Intake flow capacity will drop below 70 MGD for river stages below elevation 734.5 feet USGS; and reduced pumping efficiency will occur for river stages below elevation 736.3 feet USGS (because of NPSH requirements).

- Upstream Stability of Jetty and Low Flow Weir: No additional channel degradation upstream of the toe of the jetty and low flow weir should be allowed to occur to protect the structure from undermining. Degradation in this area is not expected, but the area should be monitored periodically by means of a hydrographic survey. If degradation is observed, stone fill should be placed as necessary to maintain the stability of the structure. Some natural sedimentation occurs in the area immediately upstream of the weir which should help reduce the potential for channel degradation.

- Downstream Stability of Jetty and Low Flow Weir: The channel immediately downstream of the jetty and low flow weir has essentially already been stabilized to protect the structure. A 30-foot-wide, stone-filled berm on the downstream side of the jetty is used to fill

any voids created by channel degradation and stone has been placed along the channel bottom a distance of 300 feet downstream of the low flow weir to reduce any channel degradation. The amount of rock fill in the berm should be assessed periodically and additional rock fill should be added when necessary.

- Continued Maintenance: Because the problems of channel degradation occurred early in the life of the intake, the solutions to the problems of channel degradation have essentially already been implemented. Periodic monitoring and continued rock fill placement will be required to assure the structural integrity of the facilities.

## D. IMPROVEMENT ALTERNATIVE

One possible improvement alternative to the continued operation of the existing intake and maintenance of the low flow weir is the construction of a completely new intake. A concept design for a new intake located near the existing intake is presented in a Burns & McDonnell report titled Kansas River Intake Facilities Study prepared for W.D. No. 1 of Johnson County, Kansas in January 1977. This alternative is considerably more expensive than the continued use of the existing intake and is presented only for the purpose of comparing the costs of available options.

## E. COST ESTIMATES

Estimates of construction and maintenance costs are included herein for two alternatives. The first alternative includes the continued operation of the existing intake with maintenance of the jetty and low flow weir and the second alternative includes the construction of a new intake to accommodate future channel degradation. All cost development criteria is the same as established in PART II of this report.

Table III-3 includes estimates of costs for maintaining the existing jetty and low flow weir with channel degradation from 1 to 5 feet. The cost estimates are based on repairing damage caused by loss of material as a result of high water flows and ice floes as related to channel degradation. These estimates do not include a projected cost of approximately $40,000 for normal maintenance on the existing jetty and low flow weir. This projected cost for maintenance assumes less stone replacement will be required in the future because of recent restoration work which should improve the stability of the jetty.

TABLE III-3

ANNUAL MAINTENANCE COSTS
EXISTING JETTY AND LOW FLOW WEIR,
W.D. NO. 1 OF JOHNSON COUNTY INTAKE

| Channel Degradation (Feet) | Annual Maintenance Cost($) |
|---|---|
| 1 | 20,000 |
| 2 | 30,000 |
| 3 | 40,000 |
| 4 | 50,000 |
| 5 | 60,000 |

The estimated construction cost for a new intake with 70 MGD raw water delivery capacity is approximately $3.0 million. This cost is based on the escalation of cost estimates included in the water district's 1977 intake study with consideration of the estimated construction cost for the new Sunflower AAP intake in PART II of this report. Continued annual maintenance of a stone-filled jetty will be required to keep the river channel next to the intake. This maintenance is estimated to approximate 25 percent of the existing jetty and low flow weir maintenance cost estimates and ranges from $5,000 per year for 1 foot of degradation to $15,000 per year for 5 feet of degradation.

## F. CONCLUSIONS

Channel degradation with declining river stages has adversely impacted the operation of the W.D. No. 1 of Johnson County intake since its start-up in 1964. A stone-filled jetty and low flow weir have been added to prevent further degradation and to maintain minimum river stages for intake operation.

Even with these improvements, the river intake still does not operate without problems at low river flows. The pumps at the intake do not operate at optimum efficiency because of insufficient NPSH for pump suction below river stage 736.3 feet USGS; and, sandbags must be placed on the intake sill to maintain a minimum water stage elevation 734.5 feet USGS to obtain a hydraulic capacity of 70 MGD. In the future, water levels must be maintained by the existing weir and jetty to prevent any reduction in intake

capacity. If channel degradation takes place and does not affect the weir and jetty, then no water surface lowering should occur.

Because facilities are already in-place, continued operation of the existing intake, jetty and low flow weir appears to be the most economical alternative to accommodate continued channel degradation of from 1 to 5 feet. To maintain stability, the condition of facilities must be periodically monitored and rock must be added as necessary to prevent channel degradation in the immediate area of the jetty and low flow weir.

One alternative to continued operation of existing facilities includes the construction of a new river intake. The new intake would have an adjustable sill to accommodate future channel degradation, but would still require continued maintenance of a rock-filled jetty to control the river channel. This alternative is expensive and is presented only for the purpose of comparing the costs of alternatives.

* * * * *

# APPENDICES

# APPENDIX A—PROJECT LETTERS AND MEMORANDA

MEMORANDUM

Date: August 19, 1986

To: John Dieter, Burns & McDonnell Engineering Company

From: John W. Manning, Consultant

Re: Report Concerning Degradation of Kansas River Channel

The interest discussed on August 18, 1986 at Burns & McDonnell's office concerning the above subject dealt with conditions and solutions to such conditions at intake structures in the lower reaches of the Kansas River. The intake structures discussed were the Water District No. 1 of Johnson County intake and the Sunflower Ordnance Plant intake. Channel degradation has progressed at these two facilities to the point where corrective measures have been undertaken or proposed to maintain their operation.

The degradation problem at the Water District No. 1 of Johnson County intake has been overcome by the construction of a stone-filled jetty and a low head weir. These structures have been effective in supplying sufficient water to the intake at extremely low river stages. The history of the construction of the jetty and low head weir has provided valuable information for the use of such structures in the Kansas River. The structure is functioning satisfactorily. At the present time, however, some maintenance work is needed on the structure to make it fully effective. The Water District is considering maintenance work in the near future.

Although the above-mentioned structure for the Water District intake has functioned satisfactorily, considerable maintenance has been required to keep it in operation. The maintenance is the result of improper design of the structure at the time it was originally constructed, the manner in which it was constructed, and emergency repair work performed to keep it functioning. This type of structure requires proper design and proper construction procedures for it to function as intended.

Concerning the problem at the Sunflower Ordnance intake, two solutions were considered. One was the construction of a low head weir to control extreme low river flows. This would provide ample water in the pump suction pit of the intake. The elevation of the crest of the river and its location were discussed. It was decided that the crest elevation should be at least one foot above the minimum water surface elevation required for the proper operation of the intake pumps. The weir should extend from the left or north bank of the river to the riverward edge of the concrete apron adjacent to the intake. At the junction of the river and the concrete apron a vertical sheet pile structure would be required to provide a vertical face for the weir. Cross sections of the weir were discussed to the extent that the crest should be not less than 14' with an upstream side slope of 1 on 1-1/2, a downstream side slope of 1 on 4 and a 20' berm or apron from the 1 on 4 side slope downstream with a thickness of not less than 3'. Stone for

the weir should be well graded stone, free from fines, with a maximum weight of 3,000 pounds and a minimum weight of 500 pounds. The stone should be run over a grizzly. Care should be taken in placing the stone to prevent segregation.

Another alternative for resolving the intake problem for the Sunflower Ordnance Plant was the construction of a new intake. A tentative location was considered on the right or south bank of the river upstream from the existing intake. Consideration was also given to controlling the channel to the new intake by the construction of a series of stone-filled dikes on the opposite bank. The type of stone-filled dike considered was a series of three structures sloping from about 16' above El. 766.84 feet at the riverbank riverward to within 450' of the opposite bank at El. 766.84 feet elevation. Stone for such structures would consist of quarry run stone with an ample bank head for each structure.

Also discussed during the meeting was a cellular weir similar to a proposed design for such a structure for the intake at Topeka. Concern was expressed about the durability of such a structure and its design and location regarding control of riverbed material and sediment past the intake.

As mentioned during the meeting, various alternatives were to be considered for the study. This, of course, will require cost estimates for considering the various alternatives. In preparing such estimates, consideration must be given to construction procedures since the construction of the low head weirs will have to take place at low stages with land plant or floating equipment at normal stages.

In determining possible flow conditions past an intake with either type of weir being considered, hydraulic analysis should be made of the flow pattern through the chute created by either weir to determine the possible sediment transport at extreme low stages. Such analysis may indicate that such means of sediment transport may be sufficient to pass material and not be detrimental in filling in the screen wells of the intake with sediment.

In evaluating each alternative, consideration must be given to determining a maintenance program for each type of structure. The stone-filled dikes and stone-filled low head weir will require considerable amount of small repairs such as restoration of the stone fill to grade in small sections of the structure due to ice runs, debris and high flows. The cellular structure could function some time without repair. However, a severe ice run or flood flows with a large amount of debris could cause damage that would require a considerable degree of maintenance. The construction of such structures will require competent contractors. This could cost more than the going rate for normal construction.

JWM/skb785

**Burns & McDonnell**
MEMORANDUM

Date: August 11, 1986

To: Project Files

From: Frank Shorney FS

Re: Project Progress Review Meetings for Kansas River Sand Deposit Study and River Intake Study
B&McD Project 85-809-4-004-01 and 85-809-4-004

On August 8, 1986, progress review meetings on subject projects were held at the Kansas City District Corps of Engineers' office in Kansas City, Missouri. Those in attendance included:

Mr. Mike Bronoski, KCD COE
Mr. Tom Gurss, KCD COE
Mr. John Hoyt, KCD COE
Mr. Dave Stous, Burns & McDonnell
Mr. John Dieter, Burns & McDonnell
Mr. Frank Shorney, Burns & McDonnell

The following items were discussed for the Sand Deposit Study:

- Over 300 soil boring and well drilling logs have been entered into a computer program. The computer will map sand deposit contours and sand layer thicknesses in the river valley. Very little sieve analysis data has been obtained from information sources. Driller's log information is available which simply denotes "fine," "medium" and "coarse" sands. Information sources have included the Kansas Geological Survey, Layne-Western, the Kansas Department of Transportation and the Kansas Department of Health and Environment.

- Engineer has not had good response to letter to dredgers requesting project information. Dredger Dave Penney will be contacted to obtain confidential information on sand pit operation and Builders Sand has invited Engineer to visit their sand and gravel pit and review their operations. KCD COE said Lawrence Ready-Mix, which operates a sand and gravel pit east of Lawrence off I-70 and may be helpful in providing information.

- Engineer reported that dredgers claim sand deposits on the north side of the river are not economical because of weight limits on bridges across the Kansas River. The closest bridge for access to the south is at Bonnor Springs.

The following items were discussed for the River Intake Study:

- Field inspection trips have been made to both the Sunflower Army Ammunition Plant Intake and the Water District No. 1 of Johnson

County, Kansas Intake. The intake sill elevation for the Sunflower AAP intake is 763.9 feet (USGS) and the intake sill elevation for the JCWD NO. 1 Intake is 732.0 feet (USGS).

- River stage data for the last 10 years is being used to determine the impacts of lowering the river stage at each intake. River gauging station data will be correlated with intake staff gauge readings to extend existing data bases.

- The Sunflower AAP intake has not been used since 1970. The staff gauge at the intake is not in good condition. The lower 3 feet does not have clear numbers and the upper part of the gauge is missing. The gauge is measured in tenths of a foot and all data is recorded in inches which creates the potential for recording errors.

- The Sunflower AAP intake average river stage has been calculated to be 769.66 feet. The maximum stage has been established at 788.58 feet and the minimum river stage has been established at 765.46 feet. The intake has a maximum water right withdrawal rate of 60 MGD and a normal operating flow rate of 37 MGD.

- The Sunflower AAP intake had three new pumps installed in 1978. The pumps have not been operated since their installation. Each pump is rated at 10,200 gpm at 198 feet total dynamic head. Pump suction piping is not in accordance with Hydraulic Institute Standards and requires 8 feet of submergence or a minimum operating water level of 772.9 feet for good pump operation. With improvements to pump suction piping, 4 feet less submergence is required which will reduce the minimum required operating water level to approximately 768.9 feet.

- The Sunflower AAP intake structure appears to be in relatively good condition for its age. Substructure walls are of concrete which are 5.5 feet thick at the base. The superstructure is of wooden construction and the concrete substructure is supported on wooden piles.

- A low flow weir or stone jetty will be investigated as improvements to raise the water level to the Sunflower AAP intake. KCD COE would like negative impact costs for each incremental foot of lowering the river water level. Construction cost estimates, operating and main- tenance cost estimates, and expected life of proposed improvements should be provided. A general cost estimate for an entirely new intake is also desired. KCD COE requested that Engineer discuss operation of pumps at below standard operating conditions, reduction in pump life, and costs for pump replacement.

- JCWD No. 1 intake was constructed in 1962. Various stone jetty improvements have been made at the intake over the years with the latest improvement permitting sandbagging to elevation 734 feet. The intake has a water right for a 50,000 gpm maximum flow rate and an average annual use right for only ~~5,000~~ 24,409 acre-feet per year.

- JCWD No. 1 intake contains 6 pumps with a capacity of 10,500 gpm each. Hydraulic calculations indicate that a wet well water level of 735.5 feet is required to provide necessary NPSH for satisfactory pump operation. This reuires a river stage elevation of 736.3 feet. JCWD No. 1 has reported that at wet well water level 735 feet, pumping problems occur; and, with any additional lowering of water level, pumping capacity drops to two-thirds of rated pumping capacity.

- Low lift pumps are available at JCWD No. 1 to pump water to the main intake pump station. For various reasons, JCWD No. 1 chooses not to use the low lift pumps. ~~and they~~ The sand eductors have not been used for the last 10 years.

- The average elevation of the stone jetty at the JCWD No. 1 intake is 736.0 feet. The average river level at the intake is 736.7 feet. Each year ice damage occurs to the jetty and some stones have to be replaced. Undermining of the intake structure does not appear to be a problem with limited additional river degradation.

- According to JCWD No. 1, the intake will remain as an important part of JCWD No. 1's long-range water supply plans. JCWD No. 1 recently completed construction of a pipeline and intake to obtain raw water from the Missouri River. These facilities have a current delivery capacity of 25 MGD and an ultimate capacity of 100 MGD.

- Upstream versus downstream degradation of the stone jetty at the JCWD No. 1 intake was discussed. Tom Gurss will check with KCD COE river hydrologists and Engineer will check with John Manning, retired COE river hydrologist, for more insight into possible degradation scenarios.

- A stage-discharge relationship at the JCWD No. 1 intake may be used to correlate river stage data with local intake water level readings.

- Determining costs for a 1-foot incremental lowering of the river at the JCWD No. 1 intake appears difficult and may not be possible. The primary improvement at the JCWD No. 1 intake may include continued maintenance of the existing rock jetty. The development of a fixed weir at this location does not appear necessary because of JCWD No. 1's prior work with the rock jetty. The primary concern with continued lowering of the river is the possible undermining of the rock jetty which is currently keyed into the river bed by a 5-foot deep trench.

ACTION ITEMS:

- KCD COE and Engineer shall confer in the future regarding river bed degradation at JCWD No. 1 rock jetty.

- Engineer to proceed with finishing report drafts for review by KCD COE.

FLS/skb776

cc: Mr. John Bronoski, KCD COE
Mr. Dave Stous, B&McD
Mr. John Dieter, B&McD

**Burns & McDonnell**
ENGINEERS - ARCHITECTS - CONSULTANTS

*101080 Form GCO-42*

| Routing |
|---|
| Project Manager |
| Department Manager |

# Field Trip Report Form

**Project Name** Kansas River Intake Study **Date** July 28, 1986

**Project Number** 85-809-4-004 **By** John Dieter

**Reason for trip** Site Inspection Visit - Raw Water Intake Structure at Water District No. 1 of Johnson County, Kansas

**Authorized by** Frank Shorney

**Hours charged including overtime and travel time** _____

(Include only travel time between 8:00 a.m. and 5:00 p.m.)

**Summary of Trip**

1. Trip Participants:

Tom Gurss - U.S. Army Corps of Engineers, Kansas City District
Lloyd Buck - Burns & McDonnell
Bruce Hattig - Burns & McDonnell
John Dieter - Burns & McDonnell

2. General:

The trip participants arrived at the raw water intake on the Kansas River at approximately 1:30 p.m. on July 11, 1986. We were met by Robert A. Smith, Project Engineer, and Doug McQuitty, Superintendent of Plant Maintenance both of whom worked for Water District No. 1 of Johnson County, Kansas. We looked at the intake and associated flow control structures and discussed the operation of the intake. The trip participants left the site at approximately 3 p.m.

3. Intake:

a. Staff gauge location is inside the intake structure. The new staff gauge was installed three years ago. It was moved from its previous location which was on the flow directional structure approximately 8 feet from the eastern end.

b. Stone jetty extends from northern bank of Kansas River at a diagonal to the bank and bends downstream. The jetty was originally constructed in 1966 and modified or restored in 1978, 1979, and 1982. A low water weir was added in 1985. The 1978 modifications included replacing the interior of the jetty with stone and placing the stone to a depth of 5 feet below the existing channel bottom.

c. Bob Smith is concerned that if the river bottom degrades further it will undermine the jetty foundation. Until the 1978 modification to the jetty it was common for portions of the jetty to be substantially damaged from ice or high flows. In fact, Bob says the jetty currently needs to be repaired at an approximate cost of $60,000.

d. Bob Smith described ice damage to the jetty as being caused by sheets of ice being pushed up on the jetty to a height of 12-14 feet. The ice creates the effect of a dam. Water rushes through the rip-rap in the jetty at high velocities scouring holes in the jetty which lead to failure of that jetty section.

e. Bob Smith provided a sketch of the jetty and low flow weir.

f. The water surface elevation at 1:45 p.m. on 7-11-86 at the raw water intake was 740.9 feet.

g. The capacity of the raw water intake is presumed to be 45 MGD based on the firm pumping capacity at the presedimentation facility.

h. Doug McQuitty said that pumping capacity at the presedimentation facility is reduced by two-thirds when the low lift pumps at the intake are operated.

i. As part of the permit to construct the low flow weir, W. D. No. 1 has permission to place sand bags on the weir to maintain a minimum water surface elevation of 734 feet. The intent is to keep the water surface level at the intake at approximately 736 feet. This is to avoid vortexing of the pumps at the presedimentation facility. These pumps are already equipped with umbrellas to reduce vortexing. The low lift pumps are intended for use when the water elevation at the intake is at El. 735 feet or below.

j. The eductor lines at the intake intended to remove sand have not been used in the last ten years.

k. Sheet piling on the flow directional structure has pulled away from the concrete in places. The railing along the intake structure is bent and is barely secured.

l. Bob Smith mentioned that a report was prepared by Simons, Li and Associates regarding proposed dredging operations in the Kansas River. The Johnson County intake is on Reach 18.

m. Doug McQuitty provided pump curves for the low head pumps at the raw water intake. Bob Smith said he would send drawings on a survey of the channel bottom in the area of the intake.

n. The intake on the Kansas River is intended to function as one of two raw water supply sources. The other intake is on the Missouri River. Currently, the Kansas River intake supplies half of the District's demand. The Missouri River intake supplies up to 25 MGD. Eventually, 100 MGD can be supplied from the Missouri River.

o. The District is also concerned that tailings from pit dredging operations in the vicinity of their well field may plug the aquifer and interfere with pumping operations.

p. Six or seven jetties have been constructed along the Kansas River near the Johnson County well field for bank stabilization.

q. Well No. 9 has been dry for 8 or 9 years.

4. Conclusions:

a. Water District No. 1 of Johnson County has made substantial modifications to the Kansas River near the raw water intake. These modifications involve construction of a jetty and low flow weir to maintain a water surface level of 736 feet at the intake.

b. The District is committed to continued use of the intake. Any increase in consumption at the intake would probably require construction of a new intake slightly upstream.

c. The District has spent its money modifying the river channel rather than using low lift pumps during low flow conditions.

d. Further degradation of the river channel bottom is likely to increase maintenance costs of the jetty.

e. No physical inspection of the raw water lines from the intake structure to the presedimentation facility has been made. Moderate silting of these lines is suspected.

Burns & McDonnell
ENGINEERS - ARCHITECTS - CONSULTANTS

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| Project Manager |
| Department Manager |

# Field Trip Report Form

**Project Name** Kansas River Intake Study **Date** July 21, 1986

**Project Number** 85-809-4-004 **By** John Dieter

**Reason for trip** Site Inspection Visit - Raw Water Intake Structure at Sunflower Army Ammunition Plant near DeSoto, Kansas.

**Authorized by** Frank Shorney

**Hours charged including overtime and travel time** _____

(Include only travel time between 8:00 a.m. and 5:00 p.m.)

**Summary of Trip**

1. Trip Participants:

Tom Gurss - U.S. Army Corps of Engineers, Kansas City District
Lloyd Buck - Burns & McDonnell
Bruce Hattig - Burns & McDonnell
John Dieter - Burns & McDonnell

2. General:

The trip participants arrived at the Sunflower Army Ammunition Plant at 8:45 a.m. on July 11, 1986. After the necessary security checks, Ray Goff, the maintenance supervisor for the water treatment plants, wells and intake structure showed us the intake structure and his office files related to river stage elevations. The trip participants left the site at approximately 12 noon.

3. Intake:

a. Intake is a concrete structure with a wooden superstructure originally constructed in 1942.

b. The intake structure has not been used since the latter part of 1970.

c. The intake has been "laid away." This means that very little maintenance has been performed. Only the heaters for the motors to the pumps operate currently.

d. Three dry transformers were installed one year ago to replace transformers disabled by lightning.

e. At the time of site visit, electric service to the building was not working. Reports by maintenance staff state power had been out at the intake for at least two days.

f. Pump Nos. 2, 4 and 5 were replaced in 1978 or 1979. These pumps have not been operated since installation. Pumps are horizontal, split-case centrifugal type.

(1) Pump No. 5

Mfgr.: Dayton-Dowd Company
Size: 16A-28
Serial No.: 46625
Rating Point: 10,200 gpm @ 198 ft.
Speed: 900 rpm
Motor Mfg.: Westinghouse
Rated h.p.: 600
Rated amp.: 150
Power Factor: 80%
3 Ø, 60 hz, 900 rpm
Serial No.: 2819P564

(2) Pump No. 4

Order Date: 11-12-75
Consignee Order No.: SUN-1587
Mfgr.: Worthington
Size: 16LN-28
Serial No.: 74Z001121-2
Rating Point: 10,200 gpm @ 198 ft.
Speed: 900 rpm
Rated h.p.: 600

(3) Pump No. 2

Mfgr.: Worthington
Size: 16LN-28
Serial No.: 74Z001121-1
Rating Point: 10,200 gpm @ 198 ft.
Speed: 900 rpm
Rated h.p.: 600

g. The original wooden trash racks have been replaced with railroad rails in the two inner bays. The approximate spacing of the rails is approximately 16 inches from rail to rail. The two outer bays do not have trash racks presently. The railroad rails are welded to pieces of angle iron across the bottom of the sill. The three eastern bays are used.

h. In 1966 or 1967, Ray Goff reported that due to low flows in the Kansas River, three steel jack jetties were installed on the north side of the river. In the early 1970's, a single rock jetty was installed.

i. Staff gauge at intake has a reading range from 0-10 feet. Readings above 10 feet are displayed as 10+ feet. Readings are taken daily except for weekends. River stage elevations are normally within the 1'-2" - 6'-0" range. During the period of 6-27-86 to 7-10-86, Ray Goff says there have been several readings above 10 feet. Maximum and minimum stage readings are summarized monthly.

j. On 7-11-86 at 10:45 a.m., gauge reading is 8'-6". The water level is 11'-6" from the top of concrete in the main structure. The estimated sill elevation is 763'-9". The zero reading on the staff gauge is estimated to be 1 foot above the sill.

k. Sunflower Army Ammunition Plant is operated by Hercules, Inc. on a contract basis.

l. The facility is supplied by two water sources: wells and surface water. Since 1970, wells have been the sole source of supply.

m. The wells are located on both sides of the Kansas River and are drilled to bedrock. According to Ray Goff, three new wells and a telemetry system are needed. Static water levels on each well are read as the distance from ground level to the water level.

4. Conclusions:

a. It is somewhat difficult to evaluate operation of the intake since it has not been used in nearly 16 years. Pumps, valves, and slide gates may need major maintenance before the intake could be reused.

b. The intake structure was fairly dry indicating that the slide gates and wall fittings are leaking very little. However, we were unable to look at the wet pit portion of the intake due to the power outage. Ray Goff says there are no suction bells for each of the pumps, just wall fittings.

c. Pump No. 3 pad was empty, but could be fitted with a new pump. We were told that a pump was being stored in a warehouse for this spot.

d. The layout of the structure does not permit any simple modifications. In places, the concrete walls are 5'-6" thick.

e. The facility was in good physical condition considering that it had not been used in 16 years. The superstructure of the intake is wooden and it appeared to be free of rot and water damage.

**Burns & McDonnell**
ENGINEERS - ARCHITECTS - CONSULTANTS

*101080 Form GCO-42*

# Field Trip Report Form

| Routing |
|---|
| Project Manager John Dieter |
| Department Manager Frank Shorney |

**Project Name** USKCDCOE **Date** July 11, 1986

**Project Number** 85-809-4-004 **By** Lloyd G. Buck

**Reason for trip** Kansas River Intake Study

Structural Observations of:

A. Sunflower Army Ammunition Plant Intake

B. Water District No. 1 of Johnson County Intake

**Authorized by** John Dieter

**Hours charged including overtime and travel time** (001022) 8 Hours

(Include only travel time between 8:00 a.m. and 5:00 p.m.)

**Summary of Trip**

A. Sunflower Army Ammunition Plant Intake:

Observation of the intake was hampered by high water and no interior lighting. The exterior surfaces of the concrete structure appeared to be in good condition with only very slight concrete deterioration due to freeze-thaw action. None of the original wood trash racks remain, however, several of the intake channels did have racks made of railroad rails. These did not appear to have been designed. If the structure is to be modified, these trash racks should be checked and replaced if necessary, along with replacements designed for the missing trash racks. Any detailed observations of the sill and intake channels were not possible due to the high river level. The interior of the concrete structure appeared to be damp, however, no significant amount of water was found on the dry well floor, indicating the concrete walls remain reasonably water tight. Thorough observations of the interior surfaces of the dry well concrete were not possible due to the lack of interior lighting. It was noted that the dry well access consisted of wood stairs and platforms. If the structure is to be retained and the current trend for prolonged periods of dis-use continue, it is my opinion that these access stairs and platforms be replaced with an aluminum system. This recommendation is made to eliminate personal hazards related to rotted or rotting wood. Also, if the structure is to be retained, I recommend that the timber super-structures be replaced by either a CMU or precast concrete structure, to enhance security and reduce maintenance.

Burns & McDonnell
ENGINEERS - ARCHITECTS - CONSULTANTS

101080 Form GCO-42

# Field Trip Report Form

| Routing |
|---|
| Project Manager John Dieter |
| Department Manager Frank Shorney |

Project Name USKCDCOE Date July 11, 1986

Project Number 85-809-4-004 By Lloyd G. Buck

Reason for trip Kansas River Intake Study

Structural Observations of:

A. Sunflower Army Ammunition Plant Intake

B. Water District No. 1 of Johnson County Intake

Authorized by John Dieter

Hours charged including overtime and travel time (001022) 8 Hours

(Include only travel time between 8:00 a.m. and 5:00 p.m.)

**Summary of Trip**

B. Water District No. 1 of Johnson County Intake:

Observation of the intake was hampered by high water. The concrete surfaces of the structure did not exhibit any significant deterioration due to freeze-thaw action, and in general, the intake appeared to be sound. However, the flow diversion structure did exhibit distress. The flow directional structure consists of a comma shaped structure which was formed by filling sheet pile walls with concrete, resulting in a mass concrete structure having sheet pile armor. This sheet pile has been pushed away from the concrete by freeze-thaw action and its resulting ice pressures. At present, this is unsightly but does not pose an immediate threat to the diversion structures. The trash rack cover plates and handrail need replacing due to having been damaged by trash removal operations.

In general, I do not recommend that the intake structure be retained and modified due to operational shortcomings.

- o Engineer will obtain information on the Water District No. 1 of Johnson County intake on the Kansas River and make arrangements for site visits. Engineer has river intake drawings in record files.

- o Engineer will possibly need a boat and a probe when visiting the Sunflower Army Ammunition Plant intake on the Kansas River.

- o Engineer will investigate the following alternatives for each intake as a result of the 1 to 5-foot lowering of the river water level:

  - Undermining of structure.

  - New intake.

  - Transfer structure.

  - Low flow weir.

- o Intake operators should have information on river stage level at each intake. Additional information may be obtained from daily readings pertaining to mean discharge at the DeSoto gage station. An effort may be made to relate daily river discharge to daily stage readings.

- o The Corps prefers quantity take-off values for cost estimates of intake improvements.

DR JOHN DIETER

- o Ben Anderson (333-4375) will serve as Engineer's contact while Frank Shorney is on vacation.

FS

ACTION REQUIRED:

Engineer will proceed with making initial contacts with intake operators for the purpose of collecting additional information and setting up field visits.

FLS/skb654

cc: Mr. Tom Gurss, KCD COE

# APPENDIX B – KANSAS RIVER STAGE DATA

KANSAS RIVER INTAKE STUDY

USKCDCOE 85-809-4-004

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 4-1-80 | 16.8 | 775.7 | 12.25 | 778.15 | 2.45 | 3.35 |
| 2 | 14.8 | 773.7 | 10.00 | 775.90 | 2.20 | |
| 3 | 14.1 | 773.0 | 11.67 | 777.57 | 4.57 | |
| 7 | 13.9 | 772.8 | 10.00 | 775.90 | 3.10 | |
| 8 | 13.4 | 772.3 | 9.67 | 775.57 | 3.27 | |
| 9 | 13.4 | 772.3 | 10.00 | 775.90 | 3.60 | |
| 10 | 13.5 | 772.4 | 10.00 | 775.90 | 3.50 | |
| 11 | 13.3 | 772.2 | 10.00 | 775.90 | 3.70 | |
| 14 | 13.3 | 772.2 | 10.00 | 775.90 | 3.70 | |
| 16 | 13.0 | 771.9 | 9.50 | 775.40 | 3.50 | |
| 18 | 11.9 | 770.8 | 8.00 | 773.90 | 3.10 | |
| 21 | 9.8 | 768.7 | 6.25 | 772.15 | 3.45 | |
| 22 | 9.7 | 768.6 | 6.25 | 772.15 | 3.55 | |
| 23 | 9.5 | 768.4 | 6.17 | 772.07 | 3.67 | |
| 24 | 9.4 | 768.3 | 6.00 | 771.90 | 3.60 | |
| 28 | 8.0 | 766.9 | 3.67 | 769.57 | 2.67 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 8-4-80 | 4.5 | 763.4 | 1.42 | 767.32 | 3.92 | 3.66 |
| 5 | 4.7 | 763.6 | 1.42 | 767.32 | 3.72 | |
| 6 | 6.1 | 765.0 | 2.00 | 767.90 | 2.90 | |
| 7 | 5.4 | 764.3 | 2.00 | 767.90 | 3.60 | |
| 8 | 4.9 | 763.8 | 1.58 | 767.48 | 3.68 | |
| 11 | 4.6 | 763.5 | 1.50 | 767.40 | 3.90 | |
| 12 | 4.4 | 763.3 | 1.50 | 767.40 | 4.10 | |
| 13 | 4.4 | 763.3 | 1.00 | 766.90 | 3.60 | |
| 15 | 4.3 | 763.2 | 1.00 | 766.90 | 3.70 | |
| 17 | 4.5 | 763.4 | 1.00 | 766.90 | 3.50 | |
| 18 | 4.8 | 763.7 | 1.00 | 766.90 | 3.20 | |
| 19 | 4.4 | 763.3 | 1.00 | 766.90 | 3.60 | |
| 20 | 4.4 | 763.3 | 1.00 | 766.90 | 3.60 | |
| 21 | 4.3 | 763.2 | 0.75 | 766.65 | 3.45 | |
| 22 | 4.1 | 763.0 | 0.75 | 766.65 | 3.65 | |
| 25 | 4.2 | 763.1 | 0.50 | 766.40 | 3.30 | |
| 28 | 4.0 | 762.9 | 1.50 | 767.40 | 4.50 | |
| 30 | 4.1 | 763.0 | 1.00 | 766.90 | 3.90 | |
| 31 | 4.0 | 762.9 | 0.75 | 766.65 | 3.75 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 9-2-80 | 4.4 | 763.3 | 1.00 | 766.90 | 3.60 | 3.53 |
| 3 | 5.0 | 763.9 | 1.00 | 766.90 | 3.00 | |
| 4 | 4.8 | 763.7 | 1.00 | 766.90 | 3.20 | |
| 5 | 4.7 | 763.6 | 1.00 | 766.90 | 3.30 | |
| 8 | 4.7 | 763.6 | 0.75 | 766.65 | 3.05 | |
| 9 | 4.8 | 763.7 | 1.08 | 766.98 | 3.28 | |
| 10 | 4.4 | 763.3 | 1.00 | 766.90 | 3.60 | |
| 11 | 4.3 | 763.2 | 1.00 | 766.90 | 3.70 | |
| 17 | 4.3 | 763.2 | 1.00 | 766.90 | 3.70 | |
| 18 | 4.3 | 763.2 | 1.00 | 766.90 | 3.70 | |
| 19 | 4.5 | 763.4 | 1.00 | 766.90 | 3.50 | |
| 20 | 4.2 | 763.1 | 1.00 | 766.90 | 3.80 | |
| 21 | 4.3 | 763.2 | 1.00 | 766.90 | 3.70 | |
| 22 | 4.3 | 763.2 | 0.75 | 766.65 | 3.45 | |
| 25 | 4.0 | 762.9 | 0.75 | 766.65 | 3.75 | |
| 26 | 4.0 | 762.9 | 0.67 | 766.57 | 3.67 | |
| 27 | 3.9 | 762.8 | 0.67 | 766.57 | 3.77 | |
| 28 | 3.9 | 762.8 | 0.67 | 766.57 | 3.77 | |
| 29 | 4.0 | 762.9 | 0.58 | 766.48 | 3.58 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 10-1-80 | 4.0 | 762.9 | 0.42 | 766.32 | 3.42 | 3.35 |
| 2 | 4.1 | 763.0 | 0.42 | 766.32 | 3.32 | |
| 3 | 4.1 | 763.0 | 0.42 | 766.32 | 3.32 | |
| 4 | 4.1 | 763.0 | 0.42 | 766.32 | 3.32 | |
| 5 | 4.0 | 762.9 | 0.50 | 766.40 | 3.50 | |
| 9 | 4.0 | 762.9 | 0.42 | 766.32 | 3.42 | |
| 10 | 4.0 | 762.9 | 0.42 | 766.32 | 3.42 | |
| 11 | 4.0 | 762.9 | 0.42 | 766.32 | 3.42 | |
| 12 | 4.0 | 762.9 | 0.42 | 766.32 | 3.42 | |
| 14 | 4.0 | 762.9 | 0.67 | 766.57 | 3.67 | |
| 15 | 4.1 | 763.0 | 0.67 | 766.57 | 3.57 | |
| 24 | 4.4 | 763.3 | 0.58 | 766.48 | 3.18 | |
| 25 | 4.3 | 763.2 | 0.58 | 766.48 | 3.28 | |
| 28 | 4.8 | 763.7 | 0.67 | 766.57 | 2.87 | |
| 31 | 4.4 | 763.3 | 0.58 | 766.48 | 3.18 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 11-3-80 | 4.2 | 763.1 | 0.42 | 766.32 | 3.22 | 4.66 |
| 4 | 4.3 | 763.2 | 0.42 | 766.32 | 3.12 | |
| 5 | 4.3 | 763.2 | 0.42 | 766.32 | 3.12 | |
| 8 | 4.2 | 763.1 | 2.25 | 768.15 | 5.05 | |
| 9 | 4.4 | 763.3 | 2.58 | 768.48 | 5.18 | |
| 10 | 4.2 | 763.1 | 2.25 | 768.15 | 5.05 | |
| 11 | 4.4 | 763.3 | 2.25 | 768.15 | 4.85 | |
| 14 | 4.5 | 763.4 | 2.08 | 767.98 | 4.58 | |
| 16 | 4.4 | 763.3 | 1.58 | 767.48 | 4.18 | |
| 17 | 4.4 | 763.3 | 1.58 | 767.48 | 4.18 | |
| 20 | 4.4 | 763.3 | 5.50 | 771.40 | 8.10 | |
| 21 | 4.4 | 763.3 | 5.50 | 771.40 | 8.10 | |
| 22 | 4.4 | 763.3 | 0.42 | 766.32 | 3.02 | |
| 24 | 4.4 | 763.3 | 3.58 | 769.48 | 6.18 | |
| 25 | 4.3 | 763.2 | 3.58 | 769.48 | 6.28 | |
| 27 | 4.4 | 763.3 | 1.33 | 767.23 | 3.93 | |
| 28 | 4.4 | 763.3 | 1.33 | 767.23 | 3.93 | |
| 29 | 4.1 | 763.0 | 0.08 | 765.98 | 2.98 | |
| 30 | 4.2 | 763.1 | 0.75 | 766.65 | 3.55 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 12-1-80 | 4.2 | 763.1 | 1.42 | 767.32 | 4.22 | 4.93 |
| 2 | 3.9 | 762.8 | 1.42 | 767.32 | 4.52 | |
| 8 | 6.3 | 765.2 | 1.17 | 767.07 | 1.87 | |
| 15 | 5.3 | 764.2 | 2.00 | 767.90 | 3.70 | |
| 16 | 5.3 | 764.2 | 2.00 | 767.90 | 3.70 | |
| 20 | 4.5 | 763.4 | 3.33 | 769.23 | 5.83 | |
| 22 | 4.3 | 763.2 | 3.33 | 769.23 | 6.03 | |
| 23 | 3.9 | 762.8 | 5.50 | 771.40 | 8.60 | |
| 24 | 4.0 | 762.9 | 4.00 | 769.90 | 7.00 | |
| 25 | 4.0 | 762.9 | 2.67 | 768.57 | 5.67 | |
| 30 | 4.3 | 763.2 | 0.42 | 766.32 | 3.12 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 11-1-82 | 4.3 | 763.2 | 0.83 | 766.73 | 3.53 | 3.37 |
| 2 | 4.7 | 763.6 | 0.83 | 766.73 | 3.13 | |
| 3 | 4.5 | 763.4 | 0.83 | 766.73 | 3.33 | |
| 4 | 4.5 | 763.4 | 0.92 | 766.82 | 3.42 | |
| 5 | 4.5 | 763.4 | 0.83 | 766.73 | 3.33 | |
| 6 | 4.4 | 763.3 | 1.00 | 766.90 | 3.60 | |
| 9 | 4.7 | 763.6 | 1.17 | 767.07 | 3.47 | |
| 10 | 4.6 | 763.5 | 1.00 | 766.90 | 3.40 | |
| 11 | 4.5 | 763.4 | 1.00 | 766.90 | 3.50 | |
| 12 | 4.6 | 763.5 | 1.67 | 767.57 | 4.07 | |
| 16 | 4.5 | 763.4 | 1.00 | 766.90 | 3.50 | |
| 17 | 4.6 | 763.5 | 0.83 | 766.73 | 3.23 | |
| 19 | 4.7 | 763.6 | 0.83 | 766.73 | 3.13 | |
| 20 | 4.7 | 763.6 | 1.00 | 766.90 | 3.30 | |
| 22 | 4.8 | 763.7 | 1.00 | 766.90 | 3.20 | |
| 28 | 4.8 | 763.7 | 1.00 | 766.90 | 3.20 | |
| 29 | 5.1 | 764.0 | 1.00 | 766.90 | 2.90 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 1-3-83 | 5.9 | 764.8 | 2.67 | 768.57 | 3.77 | 3.49 |
| 4 | 5.7 | 764.6 | 2.67 | 768.57 | 3.97 | |
| 5 | 5.7 | 764.6 | 2.33 | 768.23 | 3.63 | |
| 6 | 5.6 | 764.5 | 2.33 | 768.23 | 3.73 | |
| 7 | 5.6 | 764.5 | 2.33 | 768.23 | 3.73 | |
| 10 | 5.7 | 764.6 | 2.50 | 768.40 | 3.80 | |
| 11 | 5.7 | 764.6 | 2.50 | 768.40 | 3.80 | |
| 14 | 5.6 | 764.5 | 3.00 | 768.90 | 4.40 | |
| 19 | 6.1 | 765.0 | 3.00 | 768.90 | 3.90 | |
| 20 | 6.2 | 765.1 | 2.67 | 768.57 | 3.47 | |
| 21 | 5.9 | 764.8 | 2.33 | 768.23 | 3.43 | |
| 22 | 6.2 | 765.1 | 2.00 | 767.90 | 2.80 | |
| 24 | 5.9 | 764.8 | 1.67 | 767.57 | 2.77 | |
| 25 | 5.5 | 764.4 | 1.58 | 767.48 | 3.08 | |
| 26 | 5.5 | 764.4 | 1.58 | 767.48 | 3.08 | |
| 27 | 5.3 | 764.2 | 1.50 | 767.40 | 3.20 | |
| 28 | 5.2 | 764.1 | 1.50 | 767.40 | 3.30 | |
| 29 | 5.2 | 764.1 | 1.50 | 767.40 | 3.30 | |
| 30 | 5.4 | 764.3 | 1.50 | 767.40 | 3.10 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 2-1-83 | 5.9 | 764.8 | 2.00 | 767.90 | 3.10 | 3.03 |
| 2 | 5.7 | 764.6 | 2.00 | 767.90 | 3.30 | |
| 3 | 5.4 | 764.3 | 2.00 | 767.90 | 3.60 | |
| 4 | 5.2 | 764.1 | 2.33 | 768.23 | 4.13 | |
| 7 | 6.0 | 764.9 | 2.50 | 768.40 | 3.50 | |
| 8 | 5.8 | 764.7 | 2.50 | 768.40 | 3.70 | |
| 9 | 6.1 | 765.0 | 2.50 | 768.40 | 3.40 | |
| 10 | 6.3 | 765.2 | 2.67 | 768.57 | 3.37 | |
| 11 | 6.6 | 765.5 | 3.00 | 768.90 | 3.40 | |
| 14 | 7.1 | 766.0 | 3.00 | 768.90 | 2.90 | |
| 15 | 8.2 | 767.1 | 4.00 | 769.90 | 2.80 | |
| 16 | 8.8 | 767.7 | 4.00 | 769.90 | 2.20 | |
| 17 | 8.8 | 767.7 | 4.00 | 769.90 | 2.20 | |
| 18 | 8.4 | 767.3 | 4.67 | 770.57 | 3.27 | |
| 21 | 8.8 | 767.7 | 5.00 | 770.90 | 3.20 | |
| 22 | 8.7 | 767.6 | 4.58 | 770.48 | 2.88 | |
| 23 | 8.7 | 767.6 | 5.00 | 770.90 | 3.30 | |
| 24 | 8.6 | 767.5 | 5.00 | 770.90 | 3.40 | |
| 25 | 9.6 | 768.5 | 5.00 | 770.90 | 2.40 | |
| 28 | 9.5 | 768.4 | 2.00 | 767.90 | 0.50 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 3-1-83 | 9.4 | 768.3 | 5.42 | 771.32 | 3.02 | 3.44 |
| 2 | 9.4 | 768.3 | 5.50 | 771.40 | 3.10 | |
| 3 | 9.0 | 767.9 | 5.42 | 771.32 | 3.42 | |
| 7 | 11.4 | 770.3 | 7.00 | 772.90 | 2.60 | |
| 8 | 9.8 | 768.7 | 7.25 | 773.15 | 4.45 | |
| 9 | 9.5 | 768.4 | 6.00 | 771.90 | 3.50 | |
| 10 | 8.7 | 767.6 | 5.00 | 770.90 | 3.30 | |
| 11 | 8.5 | 767.4 | 4.42 | 770.32 | 2.92 | |
| 14 | 7.3 | 766.2 | 4.58 | 770.48 | 4.28 | |
| 16 | 7.0 | 765.9 | 4.67 | 770.57 | 4.67 | |
| 17 | 6.9 | 765.8 | 4.50 | 770.40 | 4.60 | |
| 18 | 6.8 | 765.7 | 3.67 | 769.57 | 3.87 | |
| 21 | 6.8 | 765.7 | 3.67 | 769.57 | 3.87 | |
| 22 | 6.7 | 765.6 | 3.42 | 769.32 | 3.72 | |
| 23 | 6.6 | 765.5 | 3.25 | 769.15 | 3.65 | |
| 24 | 6.3 | 765.2 | 3.25 | 769.15 | 3.95 | |
| 25 | 6.2 | 765.1 | 3.08 | 768.98 | 3.88 | |
| 28 | 14.5 | 773.4 | 5.00 | 770.90 | 2.50 | |
| 29 | 12.0 | 770.9 | 5.00 | 770.90 | 0.00 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 4-4-83 | 14.0 | 772.9 | 10.00 | 775.90 | 3.00 | 3.92 |
| 5 | 14.1 | 773.0 | 12.42 | 778.32 | 5.32 | |
| 7 | 14.5 | 773.4 | 11.00 | 776.90 | 3.50 | |
| 8 | 12.5 | 771.4 | 10.67 | 776.57 | 5.17 | |
| 10 | 12.5 | 771.4 | 10.00 | 775.90 | 4.50 | |
| 11 | 12.1 | 771.0 | 8.42 | 774.32 | 3.32 | |
| 14 | 11.1 | 770.0 | 7.00 | 772.90 | 2.90 | |
| 19 | 9.9 | 768.8 | 6.50 | 772.40 | 3.60 | |
| 20 | 9.8 | 768.7 | 6.50 | 772.40 | 3.70 | |
| 21 | 9.8 | 768.7 | 6.50 | 772.40 | 3.70 | |
| 22 | 9.9 | 768.8 | 6.58 | 772.48 | 3.68 | |
| 25 | 9.6 | 768.5 | 6.42 | 772.32 | 3.82 | |
| 27 | 9.1 | 768.0 | 5.42 | 771.32 | 3.32 | |
| 31 | 10.7 | 769.6 | 9.00 | 774.90 | 5.30 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 5-3-83 | 9.2 | 768.1 | 6.00 | 771.90 | 3.80 | 3.88 |
| 4 | 9.0 | 767.9 | 5.75 | 771.65 | 3.75 | |
| 5 | 8.7 | 767.6 | 5.42 | 771.32 | 3.72 | |
| 6 | 8.6 | 767.5 | 5.00 | 770.90 | 3.40 | |
| 9 | 8.5 | 767.4 | 5.00 | 770.90 | 3.50 | |
| 10 | 8.4 | 767.3 | 5.00 | 770.90 | 3.60 | |
| 11 | 8.4 | 767.3 | 5.00 | 770.90 | 3.60 | |
| 17 | 10.0 | 768.9 | 6.25 | 772.15 | 3.25 | |
| 18 | 9.0 | 767.9 | 5.67 | 771.57 | 3.67 | |
| 19 | 9.8 | 768.7 | 6.00 | 771.90 | 3.20 | |
| 22 | 14.8 | 773.7 | 6.00 | 771.90 | 1.80 | |
| 24 | 10.7 | 769.6 | 7.42 | 773.32 | 3.72 | |
| 25 | 9.9 | 768.8 | 7.42 | 773.32 | 4.52 | |
| 28 | 10.3 | 769.2 | 8.25 | 774.15 | 4.95 | |
| 29 | 9.8 | 768.7 | 8.25 | 774.15 | 5.45 | |
| 30 | 9.6 | 768.5 | 8.75 | 774.65 | 6.15 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 6-1-83 | 9.5 | 768.4 | 6.42 | 772.32 | 3.92 | 3.81 |
| 2 | 9.4 | 768.3 | 6.00 | 771.90 | 3.60 | |
| 3 | 8.9 | 767.8 | 6.00 | 771.90 | 4.10 | |
| 4 | 8.9 | 767.8 | 6.00 | 771.90 | 4.10 | |
| 6 | 6.4 | 765.3 | 5.00 | 770.90 | 5.60 | |
| 8 | 6.5 | 765.4 | 4.50 | 770.40 | 5.00 | |
| 10 | 6.0 | 764.9 | 4.50 | 770.40 | 5.50 | |
| 13 | 9.3 | 768.2 | 2.67 | 768.57 | 0.37 | |
| 14 | 8.6 | 767.5 | 6.00 | 771.90 | 4.40 | |
| 15 | 10.0 | 768.9 | 7.42 | 773.32 | 4.42 | |
| 16 | 9.9 | 768.8 | 6.42 | 772.32 | 3.52 | |
| 17 | 9.1 | 768.0 | 5.50 | 771.40 | 3.40 | |
| 20 | 13.8 | 772.7 | 9.00 | 774.90 | 2.20 | |
| 23 | 8.8 | 767.7 | 5.42 | 771.32 | 3.62 | |
| 24 | 8.7 | 767.6 | 5.08 | 770.98 | 3.38 | |
| 27 | 8.6 | 767.5 | 5.42 | 771.32 | 3.82 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 7-5-83 | 6.9 | 765.8 | 4.00 | 769.90 | 4.10 | 4.14 |
| 6 | 8.0 | 766.9 | 5.00 | 770.90 | 4.00 | |
| 7 | 8.6 | 767.5 | 5.00 | 770.90 | 3.40 | |
| 8 | 8.3 | 767.2 | 4.75 | 770.65 | 3.45 | |
| 11 | 11.0 | 769.9 | 6.42 | 772.32 | 2.42 | |
| 14 | 11.2 | 770.1 | 6.33 | 772.23 | 2.13 | |
| 15 | 11.2 | 770.1 | 8.00 | 773.90 | 3.80 | |
| 18 | 11.4 | 770.3 | 8.00 | 773.90 | 3.60 | |
| 19 | 10.9 | 769.8 | 7.42 | 773.32 | 3.52 | |
| 20 | 10.9 | 769.8 | 7.42 | 773.32 | 3.52 | |
| 21 | 10.8 | 769.7 | 7.42 | 773.32 | 3.62 | |
| 22 | 10.1 | 769.0 | 6.42 | 772.32 | 3.32 | |
| 27 | 6.4 | 765.3 | 2.08 | 767.98 | 2.68 | |
| 28 | 6.0 | 764.9 | 5.42 | 771.32 | 6.42 | |
| 29 | 5.8 | 764.7 | 8.00 | 773.90 | 9.20 | |
| 30 | 5.4 | 764.3 | 5.42 | 771.32 | 7.02 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 8-1-83 | 5.1 | 764.0 | 2.00 | 767.90 | 3.90 | 4.23 |
| 2 | 5.2 | 764.1 | 2.00 | 767.90 | 3.80 | |
| 3 | 4.8 | 763.7 | 1.67 | 767.57 | 3.87 | |
| 7 | 4.6 | 763.5 | 2.50 | 768.40 | 4.90 | |
| 8 | 4.6 | 763.5 | 2.50 | 768.40 | 4.90 | |
| 10 | 4.6 | 763.5 | 1.50 | 767.40 | 3.90 | |
| 11 | 4.6 | 763.5 | 1.50 | 767.40 | 3.90 | |
| 16 | 4.6 | 763.5 | 1.50 | 767.40 | 3.90 | |
| 18 | 4.5 | 763.4 | 1.67 | 767.57 | 4.17 | |
| 19 | 4.1 | 763.0 | 1.67 | 767.57 | 4.57 | |
| 22 | 4.3 | 763.2 | 1.42 | 767.32 | 4.12 | |
| 23 | 4.2 | 763.1 | 1.42 | 767.32 | 4.22 | |
| 24 | 4.1 | 763.0 | 1.00 | 766.90 | 3.90 | |
| 25 | 4.1 | 763.0 | 1.00 | 766.90 | 3.90 | |
| 26 | 4.1 | 763.0 | 1.00 | 766.90 | 3.90 | |
| 28 | 4.0 | 762.9 | 2.00 | 767.90 | 5.00 | |
| 29 | 4.0 | 762.9 | 2.00 | 767.90 | 5.00 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 9-1-83 | 4.0 | 762.9 | 1.00 | 766.90 | 4.00 | 4.18 |
| 2 | 3.9 | 762.8 | 1.00 | 766.90 | 4.10 | |
| 6 | 3.7 | 762.6 | 1.00 | 766.90 | 4.30 | |
| 7 | 3.7 | 762.6 | 1.00 | 766.90 | 4.30 | |
| 8 | 3.6 | 762.5 | 1.00 | 766.90 | 4.40 | |
| 9 | 3.6 | 762.5 | 1.00 | 766.90 | 4.40 | |
| 12 | 3.9 | 762.8 | 1.00 | 766.90 | 4.10 | |
| 13 | 4.0 | 762.9 | 1.00 | 766.90 | 4.00 | |
| 14 | 4.0 | 762.9 | 1.00 | 766.90 | 4.00 | |
| 15 | 4.0 | 762.9 | 1.00 | 766.90 | 4.00 | |
| 16 | 3.8 | 762.7 | 1.00 | 766.90 | 4.20 | |
| 19 | 3.8 | 762.7 | 1.00 | 766.90 | 4.20 | |
| 20 | 3.8 | 762.7 | 1.00 | 766.90 | 4.20 | |
| 21 | 3.9 | 762.8 | 1.00 | 766.90 | 4.10 | |
| 27 | 3.8 | 762.7 | 1.00 | 766.90 | 4.20 | |
| 30 | 3.7 | 762.6 | 1.00 | 766.90 | 4.30 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 10-3-83 | 3.7 | 762.6 | 1.00 | 766.90 | 4.30 | 3.59 |
| 4 | 6.1 | 765.0 | 3.00 | 768.90 | 3.70 | |
| 11 | 4.8 | 763.7 | 2.42 | 768.32 | 4.62 | |
| 13 | 5.1 | 764.0 | 2.75 | 768.65 | 4.65 | |
| 18 | 5.4 | 764.3 | 2.00 | 767.90 | 3.60 | |
| 19 | 5.5 | 764.4 | 2.00 | 767.90 | 3.50 | |
| 20 | 5.6 | 764.5 | 2.25 | 768.15 | 3.65 | |
| 21 | 6.1 | 765.0 | 2.00 | 767.90 | 2.90 | |
| 24 | 5.6 | 764.5 | 2.00 | 767.90 | 3.40 | |
| 25 | 5.6 | 764.5 | 2.00 | 767.90 | 3.40 | |
| 28 | 5.1 | 764.0 | 1.00 | 766.90 | 2.90 | |
| 29 | 5.1 | 764.0 | 1.00 | 766.90 | 2.90 | |
| 30 | 5.1 | 764.0 | 1.00 | 766.90 | 2.90 | |

| DATE | DESOTO STAGE READING (ft.) | DESOTO STAGE ELEV. (ft.) | S.A.A.P. STAGE READING (ft.) | S.A.A.P. STAGE ELEV. (ft.) | DIF. IN ELEV. (ft.) | MONTHLY AVERAGE DIF IN EL (ft.) |
|---|---|---|---|---|---|---|
| 11-1-83 | 4.6 | 763.5 | 1.67 | 767.57 | 4.07 | 3.46 |
| 2 | 4.6 | 763.5 | 1.42 | 767.32 | 3.82 | |
| 3 | 4.6 | 763.5 | 1.67 | 767.57 | 4.07 | |
| 4 | 4.7 | 763.6 | 1.67 | 767.57 | 3.97 | |
| 7 | 4.5 | 763.4 | 1.17 | 767.07 | 3.67 | |
| 8 | 4.5 | 763.4 | 1.17 | 767.07 | 3.67 | |
| 9 | 4.5 | 763.4 | 1.17 | 767.07 | 3.67 | |
| 10 | 4.7 | 763.6 | 1.17 | 767.07 | 3.47 | |
| 11 | 5.2 | 764.1 | 2.00 | 767.90 | 3.80 | |
| 16 | 4.8 | 763.7 | 1.67 | 767.57 | 3.87 | |
| 18 | 4.7 | 763.6 | 1.67 | 767.57 | 3.97 | |
| 21 | 5.1 | 764.0 | 1.67 | 767.57 | 3.57 | |
| 23 | 5.3 | 764.2 | 2.00 | 767.90 | 3.70 | |
| 28 | 6.2 | 765.1 | 1.67 | 767.57 | 2.47 | |
| 30 | 7.9 | 766.8 | 1.00 | 766.90 | 0.10 | |

AVERAGE DIFFERENCE IN ELEV. 3.76

STANDARD DEVIATION 1.02

WATER DISTRICT No. 1
OF JOHNSON COUNTY

| YEAR | MONTH | MIN. ELEV. (ft.) | MAX. ELEV. (ft.) |
|---|---|---|---|
| 1976 | JAN | 732.6 | 736.2 |
| | FEB | 734.8 | 736.2 |
| | MARCH | 735.4 | 736.8 |
| | APRIL | 735.3 | 739.2 |
| | MAY | 735.4 | 739.5 |
| | JUNE | 734.6 | 737.0 |
| | JULY | 735.2 | 736.0 |
| | AUG | 734.0 | 735.4 |
| | SEPT | 734.3 | 735.4 |
| | OCT | 734.6 | 736.2 |
| | NOV | 733.2 | 735.6 |
| | DEC | 733.2 | 735.4 |

| YEAR | MONTH | MIN. ELEV. (ft.) | MAX. ELEV. (ft.) |
|---|---|---|---|
| 1977 | JAN | 733.6 | 734.9 |
| | FEB | 734.2 | 736.0 |
| | MARCH | 734.8 | 735.8 |
| | APRIL | 734.7 | 735.7 |
| | MAY | 733.8 | 737.4 |
| | JUNE | 733.6 | 742.4 |
| | JULY | 732.9 | 736.0 |
| | AUG | 734.0 | 738.2 |
| | SEPT | 736.4 | 749.5 |
| | OCT | 733.6 | 740.0 |
| | NOV | 735.3 | 742.9 |
| | DEC | 732.9 | 737.5 |

| YEAR | MONTH | MIN. ELEV. (ft.) | MAX. ELEV. (ft.) |
|---|---|---|---|
| 1978 | JAN | 733.6 | 737.3 |
| | FEB | 735.2 | 736.5 |
| | MARCH | 737.8 | 740.6 |
| | APRIL | 736.4 | 739.6 |
| | MAY | 735.6 | 738.0 |
| | JUNE | 735.2 | 737.9 |
| | JULY | 735.2 | 736.7 |
| | AUG | 734.1 | 737.2 |
| | SEPT | 734.4 | 737.6 |
| | OCT | 734.4 | 736.3 |
| | NOV | 734.5 | 735.5 |
| | DEC | 734.6 | 736.1 |

| YEAR | MONTH | MIN. ELEV. (ft.) | MAX. ELEV. (ft.) |
|---|---|---|---|
| 1979 | JAN | 734.0 | 734.9 |
| | FEB | 734.8 | 739.9 |
| | MARCH | 738.6 | 743.0 |
| | APRIL | 737.9 | 743.0 |
| | MAY | 736.0 | 738.2 |
| | JUNE | 739.2 | 734.3 |
| | JULY | 736.4 | 739.4 |
| | AUG | 734.4 | 738.8 |
| | SEPT | 733.8 | 736.4 |
| | OCT | 733.6 | 733.6 |
| | NOV | 734.4 | 738.8 |
| | DEC | 735.0 | 736.5 |

| YEAR | MONTH | MIN. ELEV. (ft.) | MAX. ELEV. (ft.) |
|---|---|---|---|
| 1980 | JAN | 734.0 | 737.4 |
| | FEB | 735.2 | 739.0 |
| | MARCH | 736.6 | 747.0 |
| | APRIL | 737.7 | 746.5 |
| | MAY | 736.9 | 738.4 |
| | JUNE | 736.8 | 740.9 |
| | JULY | 735.2 | 736.9 |
| | AUG | 734.4 | 739.0 |
| | SEPT | 734.3 | 736.4 |
| | OCT | 734.0 | 736.8 |
| | NOV | 734.1 | 735.4 |
| | DEC | 733.0 | 739.4 |

| YEAR | MONTH | MIN. ELEV. (ft.) | MAX. ELEV. (ft.) | AVG. ELEV. (ft.) |
|---|---|---|---|---|
| 1981 | JAN | 734.0 | 735.7 | 734.2 |
| | FEB | 733.2 | 737.0 | 734.5 |
| | MARCH | 734.6 | 735.6 | 739.9 |
| | APRIL | 734.4 | 735.8 | 734.0 |
| | MAY | 734.3 | 739.7 | 735.4 |
| | JUNE | 736.8 | 740.8 | 737.2 |
| | JULY | 736.8 | 747.9 | 737.9 |
| | AUG | 736.3 | 740.6 | 738.2 |
| | SEPT | 736.0 | 737.8 | 735.4 |
| | OCT | 735.8 | 737.9 | 735.0 |
| | NOV | 735.8 | 739.3 | 736.5 |
| | DEC | 736.3 | 738.9 | 736.7 |

| YEAR | MONTH | MIN. ELEV. (ft.) | MAX. ELEV. (ft.) | AVG. ELEV. (ft.) |
|---|---|---|---|---|
| 1982 | JAN | 734.5 | 740.0 | 736.0 |
| | FEB | 735.2 | 738.9 | 739.4 |
| | MARCH | 735.2 | 737.1 | 737.9 |
| | APRIL | 734.8 | 736.5 | 736.1 |
| | MAY | 734.6 | 747.5 | 739.5 |
| | JUNE | 738.5 | 750.0 | 743.8 |
| | JULY | 735.3 | 746.0 | 742.2 |
| | AUG | 734.9 | 736.3 | 736.5 |
| | SEPT | 734.2 | 735.8 | 736.0 |
| | OCT | 733.8 | 734.5 | 734.4 |
| | NOV | 734.0 | 734.5 | 734.5 |
| | DEC | 734.5 | 735.8 | 735.9 |

| YEAR | MONTH | MIN. ELEV. (ft.) | MAX. ELEV. (ft.) | AVG. ELEV. (ft.) |
|---|---|---|---|---|
| 1983 | JAN | 734.5 | 735.7 | 735.4 |
| | FEB | 734.8 | 737.5 | 737.2 |
| | MARCH | 735.5 | 740.2 | 738.5 |
| | APRIL | 737.4 | 744.5 | 741.4 |
| | MAY | 734.4 | 741.8 | 739.5 |
| | JUNE | 736.0 | 742.5 | 738.5 |
| | JULY | 736.7 | 740.8 | 738.3 |
| | AUG | 735.4 | 736.9 | 734.1 |
| | SEPT | 735.0 | 735.8 | 733.5 |
| | OCT | 735.1 | 738.1 | 735.0 |
| | NOV | 736.4 | 739.6 | 734.9 |
| | DEC | 735.0 | 739.0 | 736.1 |

# APPENDIX C – COST INFORMATION

Client USKCD COE Project No. 85-809-4-004

Sunflower Army Ammunition Plant - Stone Filled Low Water Weir Summary

☒ Concept ☐ Preliminary ☐ Prefinal ☐ Final ☐ Other

Page 1 of 3
Date 8-26-86
Estimator J.E. Dieter
Checked by

| Description | Quantity | Unit Meas. | ~~LABOR~~ Total Unit MH | MH | Unit* | Cost | MATERIAL Unit | Cost | EQUIPMENT Unit | Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| Flow Directional Structure with Coated Pile | 1 | EA | | | | 185,600 | | | | |
| Bank Stabilization | | | | | | 27,000 | | | | |
| Suction Pit Modification (Addition of 4 suction bells) | | | | | | 40,000 | | | | |
| The above listed features will be incorporated into each case of the stone filled low water weir | | | | Subtotal | | $252,600 | | | | |
| 1 Ft. Case | | | | | | | | | | |
| Stone Filled Low Flow Weir | | | | | | 438,226 | | | | |
| Subtotal (from above) | | | | | | 252,600 | | | | |
| | | | | Total | | $690,826 | | | | |
| | | | | Use | | $691,000 | | | | |

*Cost/manhour or cost/unit measure

Burns & McDonnell
ENGINEERS - ARCHITECTS - CONSULTANTS

061683 Form TS-E-7

Client USKCDCOE Project No. 85-809-4-004

Sunflower Army Ammunition Plant - Stone Filled Low Water Weir Summary

☒ Concept ☐ Preliminary ☐ Prefinal ☐ Final ☐ Other

Page 2 of 3

Date 8-26-86

Estimator J. E. DIETER

Checked by

| Description | Quantity | Unit Meas. | ~~LABOR~~ Total Unit MH | MH | Unit* | Cost | MATERIAL Unit | Cost | EQUIPMENT Unit | Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 Ft. Case | | | | | | | | | | |
| Stone Filled Low Flow Weir | | | | | | 532,688 | | | | |
| Subtotal (from previous page) | | | | | | 252,600 | | | | |
| | | | | Total | | $785,288 | | | | |
| | | | | Use | | $785,000 | | | | |
| 3 Ft. Case | | | | | | | | | | |
| Stone Filled Low Flow Weir | | | | | | 637,598 | | | | |
| Subtotal (from previous page) | | | | | | 252,600 | | | | |
| | | | | Total | | $890,198 | | | | |
| | | | | Use | | $890,000 | | | | |
| 4 Ft. Case | | | | | | | | | | |
| Stone Filled Low Flow Weir | | | | | | 752,300 | | | | |
| Subtotal (from previous page) | | | | | | 252,600 | | | | |
| | | | | Total | | $1,004,900 | | | | |
| | | | | Use | | $1,005,000 | | | | |

*Cost/manhour or cost/unit measure

Burns & McDonnell
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061683 Form TS-E-7

Client USKCDCOE Project No. 85-809-4-004

Sunflower Army Ammunition Plant - Stone Filled Low Water Weir

Summary

☒ Concept ☐ Preliminary ☐ Prefinal ☐ Final ☐ Other

Page 3 of 3

Date 8-26-86

Estimator J. E. DIETER

Checked by

| Description | Quantity | Unit Meas. | ~~LABOR~~ Total Unit MH | MH | Unit* | Cost | MATERIAL Unit | Cost | EQUIPMENT Unit | Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 Ft. Case | | | | | | | | | | |
| Stone Filled Low Flow Weir | | | | | | 877,218 | | | | |
| Subtotal (from 2nd page previous) | | | | | | 252,600 | | | | |
| | | | | Total | | $1,129,818 | | | | |
| | | | | Use | | $1,130,000 | | | | |

*Cost/manhour or cost/unit measure

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061683 Form TS-E-7

Client USKCDCOE Project No. 85-809-4-004

☒ Concept ☐ Preliminary ☐ Prefinal ☐ Final ☐ Other

Page 1 of 1
Date 8/25/86
Estimator D. Moyes
Checked by

Directional Structure

| Description | Quantity | Unit Meas. | ~~LABOR~~ Unit MH | MH | Unit* | Total Cost | MATERIAL Unit | Cost | EQUIPMENT Unit | Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| Sheet Pile PDA 27 | 143 | tons | | | 1000 | 143000 | | | | |
| Sand & Gravel Fill | 127 | CY | | | 2 | 254 | | | | |
| 7 x (91.4 + 38 - 7) x 4 = | | | | | | | | | | |
| Concrete Cap | 127 | CY | | | 250 | 31750 | | | | |
| 7 x (91.4 + 38 - 7) x 4 = 126.9 CY | | | | | | | | | | |
| | | | | | | $175,004 | | | | |
| Option: Coated Pile Surface | 10600 | SF | | | 1 | $10,600 | | | | |

*Cost/manhour or cost/unit measure

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061683 Form TS-E-7

Client USKCDCOE Project No. 85-809-4-004

☒ Concept ☐ Preliminary ☐ Prefinal ☐ Final ☐ Other

Page 1 of 1
Date 8/23/86
Estimator D. Mayes
Checked by

Rip Rap @ Low Water Weir

| Description | Quantity | Unit Meas. | ~~LABOR~~ Unit MH | MH | Unit* | Total Cost | MATERIAL Unit | Cost | EQUIPMENT Unit | Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| Bank Stabilization 150 LF | 1 | Loc. | | | | 27000 | | | | |
| 150 x 180 = 27000 | | | | | | | | | | |

*Cost/manhour or cost/unit measure

Burns & McDonnell
ENGINEERS - ARCHITECTS - CONSULTANTS

061683 Form TS-E-7

Client USKCDCOE Project No. 85-809-4-004

☒ Concept ☐ Preliminary ☐ Prefinal ☐ Final ☐ Other

Page 1 of 1
Date 8-21-86
Estimator BAA
Checked by

INSTALL 90° FLANGE AND FLARE

| Description | Quantity | Unit Meas. | LABOR Unit MH | LABOR MH | LABOR Unit* | LABOR Cost | MATERIAL Unit | MATERIAL Cost | EQUIPMENT Unit | EQUIPMENT Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| INSTALL 36" FLG | 4 | EA | 24. | 96 | | | 850. | 3400 | | |
| ↓ 36" FLARE | 4 | EA | 10. | 40 | | | 3410 | 13640 | | |
| 36" BOLT-UPS | 4 | EA | 16. | 64 | | | 150. | 600 | | |
| PREP EXISTING REDUCER END FOR WELDING | 4 | EA | 8 | 32 | | | — | | | |
| | | | | 232, | | | | 17640 | | |
| FACTOR FOR EXISTING WORKING CONDITIONS | | | 25% | 58 | | | ST. 5% | 1764 | | |
| | | | | 290 | 21.30 | 6177 | | 19,404 | | |
| OVERHEAD | | | | | 70% | 4,324 | | | | |
| | | | | | | 10,501 → | | 10,501 | | |
| | | | | | | | | 29,905 | | |
| SUB PROFIT 10% | | | | | | | | 2991 | | |
| | | | | | | | | 32,896 | | |
| PRIME PROFIT 10% | | | | | | | | 3290 | | |
| | | | | | | | $ | | | |
| | | | | | | | | 36,186 | | |
| | | | | | | | | | | |
| | | | incl. contingency | | | | | $40,000 | | |
| | | | | | | | or | 10,000 / ea | | |

*Cost/manhour or cost/unit measure

Burns & McDonnell
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061683 Form TS-E-7

Client USKCDCOE Project No. 85-809-4-004

☒ Concept ☐ Preliminary ☐ Prefinal ☐ Final ☐ Other

Page 1 of 2
Date 8/26/86
Estimator D. Moyes
Checked by

Low Water Weir (Rock)

| Description | Quantity | Unit Meas. | ~~LABOR~~ Unit MH | MH | Unit* | Total Cost | MATERIAL Unit | Cost | EQUIPMENT Unit | Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| For +1 Case | | | | | | | | | | |
| 500# - 3000# Rock incl. Root | 8560 | CY | | | 48 | 410880 | | | | |
| $28-32/ton @ 1.5 ton/CY | | | | | | | | | | |
| Use $32/ton and $48/CY | | | | | | | | | | |
| Excavation in River | 2887 | CY | | | 8 | 23096 | | | | |
| $6-8/CY Use $8/CY | | | | | | | | | | |
| Excavation of Root | 850 | CY | | | 5 | 4250 | | | | |
| | | | | | | $438226 | | | | |
| For +2 Case | | | | | | | | | | |
| 500# - 3000# Rock incl. Root | 10240 | CY | | | 48 | 491520 | | | | |
| Excavation in River | 4521 | CY | | | 8 | 36168 | | | | |
| Excavation for Root | 1000 | CY | | | 5 | 5000 | | | | |
| | | | | | | $532688 | | | | |
| For +3 Case | | | | | | | | | | |
| 500# - 3000# Rock incl. Root | 12098 | CY | | | 48 | 580704 | | | | |
| Excavation in River | 6393 | CY | | | 8 | 51144 | | | | |
| Excavation for Root | 1150 | CY | | | 5 | 5750 | | | | |
| | | | | | | $637598 | | | | |

*Cost/manhour or cost/unit measure

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ENGINEERS - ARCHITECTS - CONSULTANTS

061683 Form TS-E-7

Client USKCDCOE Project No. 85-809-4-004

☒ Concept ☐ Preliminary ☐ Prefinal ☐ Final ☐ Other

Page 2 of 2
Date 8/26/86
Estimator D. Moyos
Checked by

Low Water Weir (Rock) cont.

| Description | Quantity | Unit Meas. | ~~LABOR~~ Unit MH | MH | Unit* | Total Cost | MATERIAL Unit | Cost | EQUIPMENT Unit | Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| For +4 Case | | | | | | | | | | |
| 500# - 3000# Rock incl. Root | 14120 | CY | | | 48 | 677760 | | | | |
| Excavation in Water | 8505 | CY | | | 8 | 68040 | | | | |
| Excavation for Root | 1300 | CY | | | 5 | 6500 | | | | |
| | | | | | | $752300 | | | | |
| For +5 Case | | | | | | | | | | |
| 500# - 3000# Rock incl. Root | 16315 | CY | | | 48 | 783120 | | | | |
| Excavation in Water | 10856 | CY | | | 8 | 86848 | | | | |
| Excavation for Root | 1450 | CY | | | 5 | 7250 | | | | |
| | | | | | | $877218 | | | | |

*Cost/manhour or cost/unit measure

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Kansas City, Missouri

041581 Form GCO-29

Client USKCDCOE

Project No. 85-809-4-004 Date 8/22/86

Page 1 Of 5

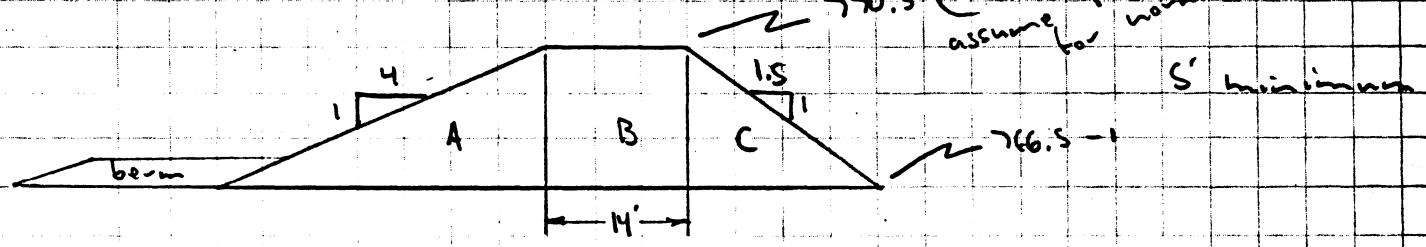
Made By D. Moyes

Checked By [illegible]

Preliminary ____ Final ____

# Low Water Weir +1 Case
(Rock Calculations)

## Low Water Weir




5' minimum, Area A .5 x 4 x 5 x 5 = 50
B 14 x 5 = 70
C .5 x 5 x 1.5 x 5 = 18.8
berm 20 x 2 = 40

Total 178.8, use 179 SF for 480 LF

@760.5, Area A = .5 x 4 x $10^2$ = 200
B = 14 x 10 = 140
C .5 x 1.5 x $10^2$ = 75
berm 20 x 2 = 40

455, use 455 SF for 200 LF

@763, Area A = .5 x 4 x $7.5^2$ = 112.5
B = 14 x 7.5 = 105
C = .5 x 1.5 x $7.5^2$ = 42.2
berm 20 x 2 = 40

299.7, use 300 SF for 120 LF

Total = (179 x 480 + 455 x 200 + 300 x 120) ÷ 27 = 7886 CY

for Root allow
40' x 455 SF = 674

8560 CY

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Client USACOE
Project No. 75-809-4-004 Date 5/26/84
Page 2 Of 5
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Checked By
Preliminary ____ Final ____

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Low Water Weir +2 Case
(Rock Calculations)

Low Water Weir, +2 Case

| | | | | |
|---|---|---|---|---|
| 6' min | Area A | .5 x 4 x 6 x 6 | = | 72 |
| | B | 14 x 6 | = | 84 |
| | C | .5 x 6 x 1.5 x 6 | = | 27 |
| | berm | 20 x 2 | = | 40 |
| | | | | 223 SF for 480 LF |

| | | | | |
|---|---|---|---|---|
| @ 759.5 | A | .5 x 4 x 11² | = | 242 |
| | B | 14 x 11 | = | 154 |
| | C | .5 x 1.5 x 11² | = | 90.75 |
| | berm | 20 x 2 | = | 40 |
| | | | | 526.75, use 527 SF for 200 LF |

| | | | | |
|---|---|---|---|---|
| @ 762 | A | .5 x 4 x 8.5² | = | 144.5 |
| | B | 14 x 8.5 | = | 119 |
| | C | .5 x 1.5 x 8.5² | = | 54.2 |
| | berm | 20 x 2 | = | 40 |
| | | | | 357.7, use 358 SF for 120 LF |

Total $\left(223 \times 480 + 527 \times 200 + 358 \times 120\right) \div 27 =$ 9459 CY

for Root allow
40' x 527 SF 781

10240 CY

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Client USKCDCOE

Project No. 85-809-4-004 Date 8/26/86

Page 3 Of 5

Made By D. Moyes

Checked By

Preliminary ____ Final ____

Low Water Weir +3 Case
(Rock Calculations)

| | | | | |
|---|---|---|---|---|
| 7' min | Area | A | $.5 \times 4 \times 7^2$ | = 98 |
| | | B | $14 \times 7$ | = 98 |
| | | C | $.5 \times 1.5 \times 7^2$ | = 36.8 |
| | berm | | $20 \times 2$ | = 40 |
| | | | | 272.8, use 273 SF for 480 LF |
| @ 758.5 | | A | $.5 \times 4 \times 12^2$ | = 288 |
| | | B | $14 \times 12$ | = 168 |
| | | C | $.5 \times 1.5 \times 12^2$ | = 108 |
| | berm | | $20 \times 2$ | = 40 |
| | | | | 604 SF for 200 LF |
| @ 761 | | A | $.5 \times 4 \times 9.5^2$ | = 180.5 |
| | | B | $14 \times 9.5$ | = 133 |
| | | C | $.5 \times 1.5 \times 9.5^2$ | = 67.7 |
| | berm | | $20 \times 2$ | = 40 |
| | | | | 421.2, use 422 SF for 120 LF |

Total $(273 \times 480 + 604 \times 200 + 422 \times 120) \div 27 = 11203$ CY

for Root allow
$40' \times 604 = 845$

12098 CY

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Client USACDCOE

Project No. 85-809-4-004 Date 8/26/86

Page 4 Of 5

Made By D. Mayes

Checked By [illegible]

Preliminary ____ Final ____

Low Water Weir +4 Case
(Rock Calculations)

| | | | | |
|---|---|---|---|---|
| 8' min | Area A | $.5 \times 4 \times 8^2$ | = | 128 |
| | B | $14 \times 8$ | = | 112 |
| | C | $.5 \times 1.5 \times 8^2$ | = | 48 |
| | berm | $20 \times 2$ | = | 40 |
| | | | | 328 SF for 480 LF |

| | | | | |
|---|---|---|---|---|
| @ 757.5 | A | $.5 \times 4 \times 13^2$ | = | 338 |
| | B | $14 \times 13$ | = | 182 |
| | C | $.5 \times 1.5 \times 13^2$ | = | 126.8 |
| | berm | $20 \times 2$ | = | 40 |
| | | | | 686.8 SF, use 687 SF for 200 LF |

| | | | | |
|---|---|---|---|---|
| @ 760 | A | $.5 \times 4 \times 10.5^2$ | = | 220.5 |
| | B | $14 \times 10.5$ | = | 147 |
| | C | $.5 \times 1.5 \times 10.5^2$ | = | 82.7 |
| | berm | $20 \times 2$ | = | 40 |
| | | | | 490.2 SF, use 491 SF for 120 LF |

Total $(328 \times 480 + 687 \times 200 + 491 \times 120) \div 27 = 13{,}102$ CY

for Root allow
$40 \times 687$ 1018

14,120 CY

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Client USACDCOE

Project No. 85-809-4-004 Date 8/26/86

Page 5 Of 5

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Preliminary ✓ Final

Low Water Weir, +5 Case
(Rock Calculations)

| | | | | |
|---|---|---|---|---|
| 9' min | Area A | .5 × 4 × 9² | = | 162 |
| | B | 14 × 9 | = | 126 |
| | C | .5 × 1.5 × 9² | = | 60.8 |
| | berm | 20 × 2 | = | 40 |
| | | | | 388.8 SF, use 389 SF for 480 LF |
| @ 356.5 | A | .5 × 4 × 14² | = | 392 |
| | B | 14 × 14 | = | 196 |
| | C | .5 × 1.5 × 14² | = | 147 |
| | berm | 20 × 2 | = | 40 |
| | | | | 775 SF for 200 LF |
| @ 359 | A | .5 × 4 × 11.5² | = | 264.5 |
| | B | 14 × 11.5 | = | 161 |
| | C | .5 × 1.5 × 11.5² | = | 99.2 |
| | berm | | = | 40 |
| | | | | 564.7 SF, use 565 SF for 120 LF |

Total (389 × 480 + 775 × 200 + 565 × 120) ÷ 27 = 15 167 CY
(187000 155000 67800)

for Root allow
40 × 775 = 1148 CY

16315 CY

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Kansas City, Missouri

041581 Form GCO-29

Client USKCDCOE

Project No. 85-809-4-004 Date 8/25/86

Page 1 Of 2

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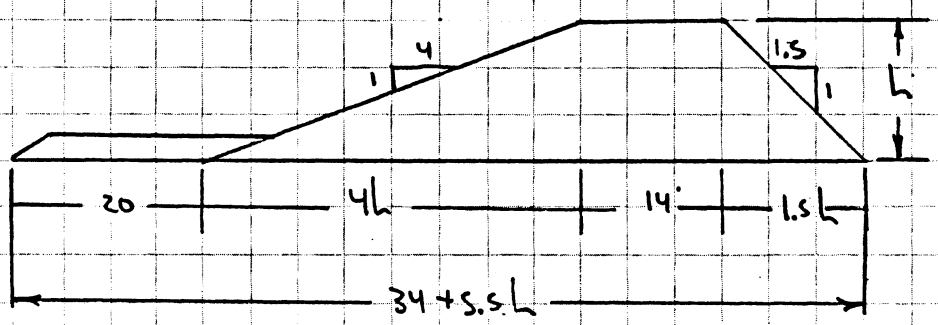
Preliminary ____ Final ____

# Low Water Weir - Exc. Calculations

Typical Weir Section

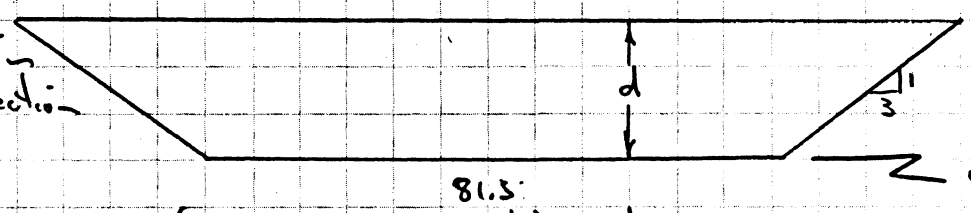



For overall length @ base allow 10' addition / side or 20'

$\Longrightarrow$ $54 + 5.5\,L$ , where $L = 5$

$= 81.5$

For Excavation assume this section




$$A_{area} = .5(81.5 + 81.5 + 6d) \times d$$
$$= (81.5 + 3d) \times d$$
$$= 81.5\,d + 3d^2$$

(+1 Case)

for 80 LF, $d = 2.5$ $\quad Vol = [\overset{222.5}{81.5(2.5)} + 3(2.5)^2] \times 80 \div 27 = 659$ CY

for 100 LF, $d = 4$ $\quad Vol = [\overset{354}{81.5(4)} + 3(4)^2] \times 100 \div 27 = 1385$

for 80 LF, $d = 2.5$ $\quad = 659$

for 120 LF, $d = .5$ $\quad Vol\ [\overset{41.5}{81.5(.5)} + 3(.5)^2] \times 120 \div 27 = 184$

2887 CY

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Client USKCDCOE

Project No. 85-809-4-001 Date 8/26/86

Page 2 Of 2

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Preliminary ____ Final ____

## Low Water Weir - Exc. Calculations

+2 Case

for 80 LF, d = 3.5 Vol = [87(3.5) + 3(3.5)²] × 80 ÷ 27 = 1011 CY

for 100 LF, d = 5 Vol = [87(5) + 3(5)²] × 100 ÷ 27 = 1889

for 80 LF, d = 3.5 = 1011

for 120 LF, d = 1.5 Vol = [87(1.5) + 3(1.5)²] × 120 ÷ 27 = 610

4521 CY

+3 Case

for 80 LF, d = 4.5 Vol = [92.5(4.5) + 3(4.5)²] × 80 ÷ 27 = 1413 CY

for 100 LF, d = 6 Vol = [92.5(6) + 3(6)²] × 100 ÷ 27 = 2456

for 80 LF, d = 4.5 = 1413

for 120 LF, d = 2.5 Vol = [92.5(2.5) + 3(2.5)²] × 120 ÷ 27 = 1111

6393 CY

+4 Case

for 80 LF, d = 5.5 Vol = [98(5.5) + 3(5.5)²] × 80 ÷ 27 = 1866 CY

for 100 LF, d = 7 Vol = [98(7) + 3(7)²] × 100 ÷ 27 = 3085

for 80 LF, d = 5.5 = 1866

for 120 LF, d = 3.5 Vol = [98(3.5) + 3(3.5)²] × 120 ÷ 27 = 1688

8505 CY

+5 Case

for 80 LF, d = 6.5 Vol = [103.5(6.5) + 3(6.5)²] × 80 ÷ 27 = 2369 CY

for 100 LF, d = 8 Vol = [103.5(8) + 3(8)²] × 100 ÷ 27 = 3778

for 80 LF, d = 6.5 = 2369

for 120 LF, d = 4.5 Vol = [103.5(4.5) + 3(4.5)²] × 120 ÷ 27 = 2340

# Telephone Call Memo

Date 8/21/86 Time _____ AM PM

Person ☐ Called ☐ Calling Ron Stanley Phone No. ( ) 441-4242

Representing Loering Quarry Info. Acct. _____

Project Name USKCDCOE Project No. 85-809-4-004

Contract Name _____ Contract No. _____

RE: Installation Max Rieke & Son Leon 631-7111

$6-8 / ton
$4-5 / delivery 15 mile haul

1000 - 2000 ton / day

$8-$12 Use $10 / ton delivered + profit

→ 3 men, dozer & backhoe
Say 2 operators + foremen

$15 / CY delivered + profit

? waste
? excavation
How far out of water on jetties (Slam Dike)

8/25 8:10 Installation $18-22 / ton $6-8 excavation
Total installed $28-32 / ton @ 1.5 ton / CY
Bank Rip-Rap $18-20 / ton @ 1.5 tons / CY
Commanche - Joe Ritz Sheet Pile

Signed _____ Page ____ of ____

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Kansas City, Missouri

Client USKCDCOE

Project No. 85-809-4-004 Date 8/25/86

Made By D. Moyes

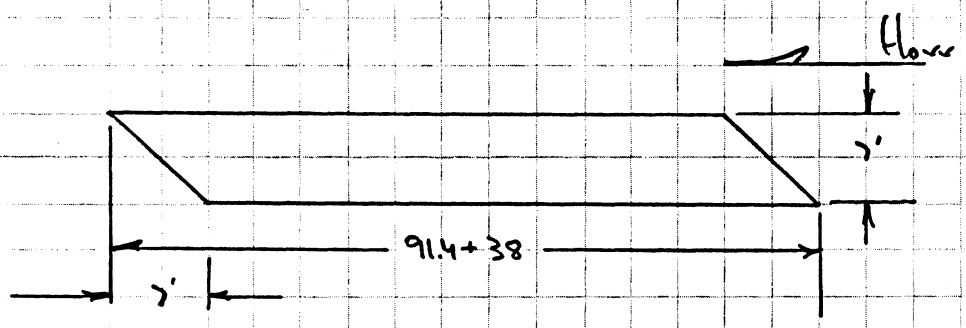
Checked By

041581 Form GCO-29

Preliminary Final

Page Of

Directional Structure
PDA 27 sheet piles, effective width = 16", 1.333' @ 36#/LF
Rock elev. @ 735'




Total Length = 2(91.4+38) - 2(7) + 2 x 1.414 x 7 = 264.8

Total SF = (750.5 - 735) 264.8 = 9400.4 SF or 7052 LF

or 7050 LF x 36#/LF ÷ 2000 = 126.9 tons
for 40' piles 40/35.5 x 126.9
= 143 tons

Concrete =

Client USKCDCOE Project No. 85-809-4-004

Sunflower Army Ammunition Plant
Low Water Weir (Cofferdam)

☒ Concept
☐ Preliminary
☐ Prefinal
☐ Final
☐ Other

Page 1 of 1
Date 8/25/86
Estimator D. Moyes
Checked by

| Description | Quantity | Unit Meas. | ~~LABOR~~ Unit MH | MH | Unit* | Total Cost | MATERIAL Unit | Cost | EQUIPMENT Unit | Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| Sheet Pile Cofferdam incl. cut-off | 1739 | tons | | | 1000 | 1,739,000 | | | | |
| Excavation for Cofferdam | none | required | | | | — | | | | |
| Sandfill for Cofferdam | negligible, if any required | | | | | — | | | | |
| Concrete Cap Weighted average river bottom = 765'-0" Height = 5'-6" | 2560 | CY | | | 250 | 640,000 | | | | |
| | | | | | | $2,379,000 | | | | |
| Option: Coated Sheet Pile | 99360 | SF | | | 1 | $99,360 | | | | |
| Repair One Cell of damaged Cofferdam, assume 25% of steel replaced & all concrete | | | | | | $40,000 | | | | |

*Cost/manhour or cost/unit measure

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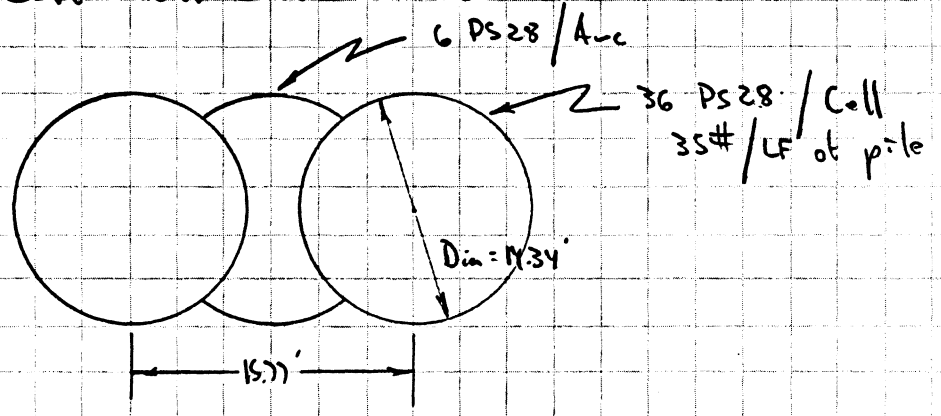
Kansas City, Missouri

041581 Form GCO-29

Client USKCDCOE
Project No. 85-809-4-004 Date 8/25/86
Made By D. Moyes
Checked By
Preliminary Final

Cofferdam Weir

Per Cofferdam see sketch




For 800' crossing use 52 cells and 2 x 51 arcs

Rock @ elev 735 ⟹ total length of 770.5 - 735 = 35.5' / ea

Total Length = 52 cells x 36 PS28/cell x 35.5' = 66456
2x51 arcs x 6 PS28/arc x 35.5' = 21726
Total 88182 LF

or 88182 LF x 35 lb/LF ÷ 2000 = 1543.2 tons
for 40' pile, 40/35.5 x 1543.2
= 1739 tons

Concrete, weighted average height = 5'-6"

for 52 ϕ x 3.1416 x 14.34² ÷ 4 ÷ 27 x 5.5 = 1711 CY
for 51 arcs let ϕ use 50%
or 51 x 3.1416 x 14.34² ÷ 4 ÷ 27 x 5.5 x .5 = 839
Total 2550 CY

or 52 x 33 = 1716
+ 51 x .5 x 33 = 842
2558 CY
Use 2560 CY

# Telephone Call Memo

Date 8/25/86 Time _____ AM PM

Person ☐ Called ☐ Calling Joe Ritz - Jerry Phone No. ( ) 782-2980

Representing Comanche Const. Inc. Info. Acct. _____

Project Name USKCDCOE Project No. 85-809-4-004

Contract Name _____ Contract No. _____

RE: .26 - .28 / lb cost to sub material + freight
Comanche not that experience w/ this type installation
deferred to below

Bovens — Dick Horner — 621-1100

Wilkerson / Maxwell — Don Clark — 371-1003

Massman — H.B. McCoy — 523-1000

Cofferdam PS28 1543.2 tons × 40/35.5 = 1739 tons
Directional Structure PDA 27 126.9 tons × 40/35.5 = 143 tons

H.B. McCoy Do not make PS28, PS27.5? >35 material

Totally installed $950-1000, use $1000 incl. cutoff

Sand fill $2 CY using existing sand $10/CY if new

Concrete $150 if free concrete allowed
Use $250/CY → $250 if form dewatered incl. bracing
$1/SF coating if required

Signed [signature] Page ____ of ____

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# Telephone Call Memo

Date 8/26/86 Time 3:15 ± PM

Person ☐ Called ☐ Calling H.B. McCoy Phone No. ( ) 523-1000

Representing MASSMAN Info. Acct.

Project Name USKCDCOE Project No. 85-809-4-004

Contract Name Contract No.

RE: Repair 1 Cofferdam Cell

Steel for 1 total Cell

48 x 40' x 35'/LF = 33.6 tons/cell, say 25% damaged

or 8.4 tons @ 250 removal = 2100

Concrete for 1 total Cell 8.4 tons @ 1000 reinstall = 8400

33 x 1.5 = 50 CY x 15/CY removal = 750

50 CY x 250 12500

Mobilization $15000

$38750

Say $40,000

if at original base cost 33.6 x 1000 = $33600

total cell 50 x 250 = 12500

$46100

$250/ton remove

$1000/ton reinstall

$250/concrete

Signed

Page ____ of ____

080382 Burns & McDonnell ENGINEERS · ARCHITECTS · CONSULTANTS Form GCO-1

COST ESTIMATE
SUNFLOWER ARMY AMMUNITION PLANT
NEW PUMP STATION AND INTAKE

| | Item | Cost |
|---|---|---|
| 1. | Substructure | $820,000 |
| 2. | Sheet Piling | 220,000 |
| 3. | Excavation | 50,000 |
| 4. | Backfill | 50,000 |
| 5. | Superstructure | 150,000 |
| 6. | Bridge Crane | 70,000 |
| 7. | Concrete Apron | 95,000 |
| 8. | Bar Racks | 32,000 |
| 9. | Traveling Screens | 40,600 |
| 10. | Sluice Gates | 138,400 |
| 11. | Raw Water Pumps and Motors | 256,000 |
| 12. | Piping and Valves: | |
| | 4ft.x5ft. Butterfly Valves | 56,000 |
| | 36-inch Butterfly Valves | 52,000 |
| | Compressed Air System | 10,000 |
| | 36-inch Ductile Iron Pipe and Fittings | 49,000 |
| 13. | Screen Wash System | 30,000 |
| 14. | Walkway Bridge | 5,000 |
| 15. | Walkway Fence | 10,000 |
| 16. | Surge Tank | 20,000 |
| 17. | Miscellaneous Metals | 20,000 |
| 18. | Security Systems | 10,000 |
| 19. | Heating and Ventilating | 10,000 |
| 20. | Pad Mounted Transformer | 15,000 |
| 21. | Motor Control Center | 120,000 |
| 22. | Local Equipment Controls | 30,000 |
| | Total Cost | $2,359,000 |

Client USKCD COE Project No. 85-809-4-004

Sunflower Army Ammunition Plant - Proposed New Intake Jetties (Stem Dikes), 2 each @ 364 LF & 264 LF

☒ Concept ☐ Preliminary ☐ Prefinal ☐ Final ☐ Other

Page 1 of 1

Date 9-16-86

Estimator J. E. DIETER

Checked by

| Description | Quantity | Unit Meas. | ~~LABOR~~ Unit MH | MH | Unit* | Total Cost | MATERIAL Unit | MATERIAL Cost | EQUIPMENT Unit | EQUIPMENT Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| For bottom of jetties @ elev. 761.84 | | | | | | | | | | |
| 500# to 3000# Rock incl. Root $28-32/ton @ 1.5 ton/CY Use $32/ton and $48/CY | 126660 | CY | | | 48 | 607,680 | | | | |
| Excavation in water $6-8/CY Use $8/CY | 11371 | CY | | | 8 | 90,965 | | | | |
| Excavation for Root | 4667 | CY | | | 5 | 23,333 | | | | |
| | | | | | | $721,978 | | | | |
| | | | | Use | | $750,000 | | | | |

*Cost/manhour or cost/unit measure

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061683 Form TS-E-7

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Kansas City, Missouri

041581 Form GCO-29

Client: USKCD COE
Page 1 Of 2
Project No. 85-809-4-004 Date 9-16-86 Made By J. E. DIETER
COST ESTIMATE FOR PROPOSED ROCK JETTY AT SAAP
Checked By
Preliminary Final

Ref.: Cost Estimates by D. Moyes on 8-26-86

Rock Jetties

Volume = $L(a + A + \sqrt{A \times a}) \div 3$ where $L$ = length

Cross-section @ river end = 62.5 $ft^2$ = a

Cross-section @ bank = 766.5 $ft^2$ = A

} from D. Moyes

For 360 LF Dike, Vol. = $\frac{360(62.5 + 766.5 + \sqrt{62.5 \times 766.5})}{27} / 3$

Volume = 4,657 $yd^3$

For 264 LF Dike, Vol. = $\frac{264(62.5 + 766.5 + \sqrt{62.5 \times 766.5})}{27} / 3$ (12.94)

Volume = 3,415 $yd^3$

Volume of Root = 911 x 68/27 = 2294 $yd^3$ x 2ea = 4588 $yd^3$

Total rock volume = 4,657 + 3,415 + 4,588 = 12,660 $yd^3$

Installed cost @ \$48/$yd^3$ = 12,660 x 48 = \$607,680

Use \$610,000

From D. Moye's notes: add lengths of dike and divide by 3

(360 + 264)/3 = 208 Lt.

Assume for purposes of excavation @ R.M. 32.8 a constant depth of excavation of 6.0 ft. → d = 6'

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Client USKCDCOE

Page 2 Of 2

Project No. 85-809-4-004 Date 9-16-86 Made By J. E. DIETER

COST ESTIMATE FOR PROPOSED ROCK JETTY AT SAAP

Checked By

Preliminary Final

Cross-Sectional area $= (W + 20 + 3d) \times d$

$= [W + 20 + 3(6)] \times 6$

$= (W + 38) \times 6$

Use W = 60, 44, & 28

$Vol. = \frac{(60+38) \times 6 \times 208}{27} = 4530\ yd^3$

$Vol. = \frac{(44+38) \times 6 \times 208}{27} = 3790\ yd^3$

$Vol. = \frac{(28+38) \times 6 \times 208}{27} = 3051\ yd^3$

Total $= 11,371\ yd^3$

Total cost $= 11,371 \times \$8/yd^3 = \$90,965$

Use $100,000

Excavation for Root

From D. Moye's notes, 7000 CY was used.

Assume $2/3 \times 7000$ CY for 2 roots $= 4,667$ CY

Installed cost $= \$5/CY \times 4,667 = \$23,333$ Use $25,000

Total cost $= \$610,000 + 100,000 + 25,000 = \$735,000$

Use $750,000

Client USKCDCOE Project No. 85-809-4-004

Sunflower Army Ammunition Plant - Proposed New Intake
Bank Stabilization & 54" Transmission Main

☒ Concept
☐ Preliminary
☐ Prefinal
☐ Final
☐ Other

Page 1 of 1
Date 9-17-86
Estimator J. E. DIETER
Checked by

| Description | Quantity | Unit Meas. | LABOR Unit MH | LABOR MH | LABOR Unit* | LABOR Total Cost | MATERIAL Unit | MATERIAL Cost | EQUIPMENT Unit | EQUIPMENT Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| BANK STABILIZATION | | | | | | | | | | |
| Stem Jetties (150 LF x 2) | 300 | LF | | | 180 | 54,000 | | | | |
| Intake (550 LF + 150 LF) | 700 | LF | | | 180 | 126,000 | | | | |
| | | | | Total | | $180,000 | | | | |
| 54-INCH TRANSMISSION MAIN | 225 | LF | | | 175 | $39,375 | | | | |
| | | | | Use | | $40,000 | | | | |

*Cost/manhour or cost/unit measure

Burns & McDonnell

061683 Form TS-E-7