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FINAL REPORT

OF THE

LECLAIR IRRIGATION REHABILITATION PROJECT
LEVEL II

PREPARED FOR

WYOMING WATER DEVELOPMENT COMMISSION
CHEYENNE, WYOMING

AND

LECLAIR IRRIGATION DISTRICT
RIVERTON, WYOMING

DECEMBER 1, 1988
PHASE II REPORT
LECLAIR IRRIGATION REHABILITATION PROJECT
LEVEL II

Prepared for
Wyoming Water Development Commission
Cheyenne, Wyoming
and
LeClair Irrigation District
Riverton, Wyoming

By
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INTRODUCTION

The LeClair Irrigation District is located in Water Division No. 3 of the State of Wyoming, and just to the west and north of the City of Riverton, Wyoming. The District is comprised of approximately 31 miles of canals and provides water to approximately 850 operators, irrigating just over 13,000 acres.

In 1984 the district requested the United States Department of Agriculture (USDA), Soil Conservation Service (SCS) study their irrigation water delivery system. An item to be studied included an evaluation of structural rehabilitation required for the various structures along the canal. In September 1987 the SCS released its report, the LeClair Irrigation District RB-09 Study, and identified six structures estimated to have a remaining useful life from zero to two years. The failure of any one of these structures could shut down the entire portion of the irrigation system below the point of failure.

The LeClair Irrigation District then submitted an application for assistance in evaluating design alternatives to replace the six structures to the Wyoming Water Development Commission. The Wyoming Legislature early in 1988 authorized the Water Development Commission to conduct this Level II Feasibility Study of the LeClair Irrigation Rehabilitation Project. The Water Development Commission then issued its Request for Proposals No. 88-13, and subsequently entered into an agreement with Crank Companies, Incorporated (CCI) to perform this study.

PROJECT PURPOSE

The purpose of this study is to determine the feasibility of options available to the District to prevent a shut down of the system should a failure in any of the following structures occur:

A. Cooper No. 1 Chute, station 839+68
B. Jake Haun Chute (Cooper No. 2), station 897+60
C. Sievelcribs Chute (Cooper No. 3), station 908+16
D. Flume, Station 913+44
E. Stagg Chute (Stagg Drop), station 982+08
F. Hog Farm Chute, station 1452+00

This study has been conducted in two phases. Phase I being the evaluation of at least two preliminary design alternatives and cost estimates for the rehabilitation of each of the six structures. Phase II being the development of the preferred alternative, determined in Phase I, into conceptual designs, cost estimates, ability to pay and finance, and any additional right of way acquisition that may be required. This report is presented as the culmination of Phase II of this project.
PHASE I REVIEW

A. CONDITION OF EXISTING STRUCTURES

The condition of the existing structures have been evaluated based on a site visit and photographs made in March 1988 when the structures were dry and site visits made at the time of the scoping meetings. A brief statement as to the condition of each structure and our recommendations of the structures need for replacement follow:

1. Cooper No. 1 Chute

The inlet structure to this chute is in good shape, but the chute itself has a limited amounting of spalling. The outlet structure has limited cracking and undercutting at the end. The outlet structure has been completely rebuilt at least once, and acts as a flow deflector, not as a stilling basin. Flow down the chute does not land in the outlet structure until near the structures end. The flow is then deflected by the concrete floor of the outlet structure out into the large rip rapped pool below the structure. The energy of the flow is then disipated in the turbulance within the rip rapped pool. The pool below the structure does not have enough freeboard and water was flowing out over the dike on the north end at the time of our site visit on July 13. This structure should be replaced.

2. Cooper No. 2 Chute

The inlet structure on this chute is in good shape, and there is very limited spalling in the chute. The outlet structure has been completely rebuilt at least once and has several cracks in the walls and is being undercut at the outlet. Again this outlet structure acts as a flow deflector and flows just touch the outlet end and all the energy of the flow is dissipated in the pool below the structure. This structure should be replaced.

3. Cooper No. 3 Chute

This structure is in relatively good shape and has only limited spalling in the chute, and limited cracking in the walls of the stilling basin. There is some undercutting of the outlet but this is not seen as a threat to the structure. The freeboard on the west wall of the structure below the angle in the structure is not adequate. During our survey of the area on July 14, 1988 water was washing up over the concrete wall of the stilling basin and cutting a small trench along the outside of the west wall. We concur with the SCS that this structure should be replaced.

4. Flume at 913+44

The walls on the flume are cracked and honeycombed. The canal has apparently washed out on the south east corner of the flume in the past and has been rebuilt and concrete lined. This concrete lining is undercut and a wash out in this area is very possible. The flume appears to be hydraulicly undersized, but this may have been intended to provide a higher tailwater at the Cooper No. 3 Chute. This structure should be replaced.
5. Stagg Drop

The inlet to this structure is in good shape, but the chute itself has quite a bit of spalling and some cracking. The irrigation lateral that comes off the canal near the inlet of the structure overflows and is causing some washout on the north side of the chute where the lateral goes into a pipe. The outlet structure is very deep and some of the walls are cracked where the cross over beams join the walls. The sill wall in the bottom has deteriorated to the point that rebar are exposed along its entire length. The entire structure is enclosed with a high chain link fence, but is still a safety problem. This structure should be replaced.

6. Hog Farm Chute

The inlet structure of the Hog Farm Chute is on a sharp bend to the right. The outside of this bend is timber lined to deflect the flow to the concrete structure. Should this timber deteriorate enough the canal could wash out the inlet structure. The concrete chute has extensive spalling and some cracking and appears to have been repaired with an asphalt or mastic compound in the past. There is really no outlet structure. At the base of the chute there is only a hand placed concrete pad which is cracked and undercut. The outfall of the chute is also undercut. This structure should be replaced.

During our right-of-way acquisition surveys of October, 1988, all of the structures were again observed in the dry state. No additional damages were readily visible in the top four structures, but additional deterioration was noted at the Stagg Drop Chute and Hog Farm Chute. The sink holes on the outside of the stilling basin walls at the head of the Stagg Drop Chute have increased in size, as well as additional erosion being noted along the north side of the chute above the bridge. The chute at Hog Farm has spalled considerably since last spring. It is recommended by Crank Companies, Incorporated that these two structures be reconstructed as soon as possible.

B. PRELIMINARY ALTERNATIVES REVIEW

Several meetings were held during Phase I in which various design alternatives were discussed for each of the six structures in question. These meetings began the elimination process of potential designs down to two to four alternatives for each structure. The finalized preliminary design alternatives considered in Phase I are as listed below.

1. Cooper No. 1 and Cooper No. 2 Chutes
   a) Replace both with a single pipeline and channel realignment.
   b) Replace both with similar structures.
   c) Replace both with a single concrete chute and channel realignment.
2. Cooper No. 3 Chute and Flume at 913+44
   a) Replace both with a single pipeline and canal realignment.
   b) Replace both with similar structures.
   c) Replace the flume with a raised channel over culverts at the drainage crossing.
   d) Replace both with a single concrete chute and canal realignment.

3. Stagg Chute
   a) Replace with a similar structure.
   b) Replace with a pipe drop.

4. Hog Farm Chute
   a) Replace with a similar structure.
   b) Replace with a pipeline and channel realignment.
   c) Replace with a concrete chute and canal realignment.

At the scoping meetings in early July it was reported that the upper five canal structures should be designed to handle a flow of 200 cfs. It was also reported at this time that the flow in the canal can vary greatly during the day and is dependent on the amount of water taken out of the canal above by the City of Riverton. All of the upper five structures pipelines were thus designed for an average flow of 200 cfs, but can handle a maximum flow of 300 cfs without causing excessive backwater depths above the pipe inlets.

Design flows at the Hog Farm Chute are considerably lower than the five other structures in this study. Based on measurements made in March 1988 of the existing chute, and a measured water mark (stain on side of chute) an average flow of 175 cfs was calculated at this chute. Then as a factor of safety all design calculations for the Hog Farm Chute were based on a maximum flow of 225 cfs. All pipeline designs were based on culvert design procedures, as the pipes are relatively short, on steep grades, must handle large volumes without excessive backwater depths at the inlets, and pipeline submergence below the tailwater depths of the outlets would cause stilling basin drainage problems when the system is shut down for the winter.

All preliminary designs of replacement with similar structures involved installing an inlet structure and chute of the same size as the original ones but replacing the outlet structures with a modified design sized to better handle the design flows.

A more detailed description of each of the preliminary designs can be found in the Alternatives Review section of the Phase I report.

C. PRELIMINARY ALTERNATIVES COST COMPARISONS

Preliminary cost estimates of each of the preliminary design alternatives were preformed and are presented in Table 1 of the following page. All cost estimates reflect 1989 construction costs,
<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>1986-SCS REPLACEMENT CONSTRUCTION COST</th>
<th>SCS - COST PROJECTED TO 1989 PLUS 10% ENGINEERING</th>
<th>CCI-1989 ESTIMATED REPLACEMENT COST OF SIMILAR STRUCTURE (a)</th>
<th>CCI - ALTERNATIVE REPLACEMENT COST</th>
<th>ALTERNATIVE #1 (b)</th>
<th>ALTERNATIVE #2(c),(d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COOPER #1</td>
<td>Replace w/pipe drop $64,500</td>
<td>$78,300</td>
<td>$55,400</td>
<td>Pipeline to replace both Cooper #1 and Cooper #2</td>
<td>$150,800*</td>
<td>Concrete Chute to replace both Cooper #1 and Cooper #2 $120,000</td>
</tr>
<tr>
<td>COOPER #2</td>
<td>Replace w/pipe drop $39,000</td>
<td>$47,350</td>
<td>$46,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COOPER #3</td>
<td>Replace w/pipe drop $58,000</td>
<td>$70,400</td>
<td>$76,200</td>
<td>Pipeline to replace both Cooper #3 and Flume</td>
<td>$140,000</td>
<td>Concrete Chute to replace both Cooper #3 and Flume (c) $128,500</td>
</tr>
<tr>
<td>FLUME 913+44</td>
<td>Replace w/siphon $43,000</td>
<td>$52,200</td>
<td>$25,850</td>
<td></td>
<td></td>
<td>Channel over Culverts(d)</td>
</tr>
<tr>
<td>STAGG DROP</td>
<td>Replace w/pipe drop $54,000</td>
<td>$65,550</td>
<td>$85,950</td>
<td>Replace w/pine drop $89,700</td>
<td></td>
<td>Concrete Lined $27,025 Unlined $20,550</td>
</tr>
<tr>
<td>HOG FARM CHUTE</td>
<td>Replace w/conc. chute $30,000</td>
<td>$36,400</td>
<td>$26,300</td>
<td>Pipeline and Channel Realign $91,150</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SCS costs taken from "Wyoming Cooperative Irrigation Water Conservation Study" for LeClair Irrigation District, Sept. 1987
* Revised after meeting 8/18/88 to match alignment of Alternative #2
** Added as Addendum No. 1 to Phase I Report 9/20/88
plus an additional 15% for contingencies, and an additional 10% for engineering of the structures. All cost estimates were based on the same unit prices for similar items, and due to discounting on larger projects and mobilization factors, the smaller the cost estimate presented the larger the possible percent error in cost. It is thus recommended that in bidding any of the smaller alternatives, they should be included with at least one other larger alternative to reduce the overall cost of the structures.

Also presented in Table 1 are cost estimates the SCS prepared and presented in its report Wyoming Cooperative Irrigation Water Conservation Study for the LeClair Irrigation District, dated September 1987. The SCS report presented its construction cost estimates for replacement alternatives based on 1986 prices. Crank Companies, Incorporated then projected these costs to 1989 using 3% inflation for 1987 and 1988 and 4% inflation to 1989. Then an additional 10% engineering fee was added to the construction cost.

D. SOILS REPORT CONCLUSIONS

Our subconsultant, Chen and Associates, performed soils testing at the five drill hole sites identified below:

<table>
<thead>
<tr>
<th>Drill Hole No.</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Middle of access road next to Cooper No. 1 Concrete Basin</td>
</tr>
<tr>
<td>2.</td>
<td>Between access road on bottom end of Cooper No. 3 Stilling Basin</td>
</tr>
<tr>
<td>3.</td>
<td>Middle of access road at approximately canal station 916+80</td>
</tr>
<tr>
<td>4.</td>
<td>Between access road and middle of Stilling Basin at Stagg Drop</td>
</tr>
<tr>
<td>5.</td>
<td>North edge access road at Stilling Basin Hog Farm Chute</td>
</tr>
</tbody>
</table>

The basic conclusions of the report are as follows:

1. Structures at drill hole locations 1, 3, 4 and 5 will be placed on bedrock and can be designed for allowable soil bearing pressures up to 10,000 psf. Structure located at drill hole No. 2 will be placed on dense gravel with a maximum soil bearing pressure of 5,000 pcf.

2. All overburden materials above bedrock are suitable for backfill and bedrock materials may be suitable provided they do not excavate in large chunks.

3. All of the soils and bedrock can be excavated with conventional equipment, such as large backhoes. Some layers in bedrock may require percussion hammers or light blasting.
4. Type II cement is recommended for use of all concrete structures.

5. All backfill should be compacted to at least 95% standard proctor density.

6. Concrete placement for structure support should not be placed on loose material over bedrock, but should rest directly on bedrock or grout cap.

The report did not identify any soil conditions that would cause cost increases above that of general construction work. A copy of the complete report can be found in Appendix E of this report.

E. PHASE I RECOMMENDED ALTERNATIVES

During the alternatives review meeting of August 18, 1988 the preliminary designs and cost estimates of each alternative were presented. At that time each of the alternatives were discussed and the pros and cons of the alternatives compared. All of the cost comparisons generally evaluate an open canal system and its cost verse a pipeline and its improved safety and cost. The concenses at the meeting was to try and install a safer pipeline if the costs were not prohibitive. In all cases except the Stagg Drop replacement alternative the pipe drops and pipelines were considered cost prohibitive. Thus based on economics the following were Crank Companies, Incorporated recommended alternatives.

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>Replacement Alternative</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooper # 1</td>
<td>Similar Structure</td>
<td>$55,400</td>
</tr>
<tr>
<td>Cooper # 2</td>
<td>Similar Structure</td>
<td>46,500</td>
</tr>
<tr>
<td>Cooper # 3</td>
<td>Similar Structure</td>
<td>76,200</td>
</tr>
<tr>
<td>Flume 913+44</td>
<td>Channel over Culverts</td>
<td>20,550 to 27,050</td>
</tr>
<tr>
<td>Stagg Drop</td>
<td>Pipe Drop</td>
<td>89,700</td>
</tr>
<tr>
<td>Hog Farm Chute</td>
<td>Similar Structure</td>
<td>26,300</td>
</tr>
</tbody>
</table>

The pipe drop was selected at the Stagg Drop as this structure is a known safety problem and the increased cost of installing the pipe drop was not seen as excessive.

It should again be pointed out that the smaller structures estimates are subject to a larger percent error than the larger structures, because of price discounting and mobilization cost variations.
F. PHASE I PREFERRED ALTERNATIVES

At the completion of Phase I a report presentation meeting was held on September 15, 1988. The following alternatives were selected as the preferred alternatives for each of the structures studied:

Cooper #1 and Cooper #2 Chutes - replace both structures with a single concrete chute and channel realignment.

Cooper #3 Chute and Flume @ 913+44 - replace both with a single concrete chute and channel realignment.

Stagg Drop - replace with a pipe drop without a pipe size reduction.

Hog Farm Chute - replace with a concrete chute and channel realignment if right of way is obtainable. This alternative was not previously evaluated and was asked to be incorporated in an addendum to the Phase I report. This alternative was the preferred one provided the District could get right of way for the channel realignment onto tribal land. If right of way was not obtainable the replacement of the existing structure with a similar one would be the preferred alternative. The LeClair Irrigation District board later reconsidered their options at the Hog Farm Chute and selected as the preferred alternative the replacement of the existing structure with a similar one.

PHASE II

STUDY PROCEDURE

Phase II of this project consists of taking data and information compiled during Phase I and refining it so that conceptual designs and cost estimates could be prepared for each of the preferred alternatives selected in Phase I. Economic analysis was then preformed based on the conceptual design cost estimates so that the most economical financing plan could be identified to the LeClair Irrigation District. Additional items included in Phase II were archeological site identification maps so that archeological clearance can be obtained for the project, maps and descriptions so that easements can be obtained on lands in which reconstruction is to take place, and ownership mapping in areas of the proposed reconstruction.

CONCEPTUAL DESIGNS

Conceptual designs of each of the four preferred alternatives were prepared based on refined information from Phase I and more detailed design calculations for the specific alternatives. Design calculations were intended to properly size the systems to handle the design flows, but not to design the structural integrity of the various components of the systems. Actual wall thicknesses, reinforcing steel, footing design, slope anchors, etc., would be designed during Level III, construction design, of the project. Conceptual designs of each of the
four preferred alternatives are presented in Appendix A of this report.

CONCEPTUAL COST ESTIMATES

Cost estimates were prepared from take off of the conceptual designs. These cost estimates are based on 1990 construction costs, with a 10% fee added for construction engineering, and an additional 15% of construction cost added for construction contingencies. In addition the cost to provide construction inspection for each recommended alternatives was prepared. Construction inspection costs are estimated on the basis that each alternative structure would be let for construction by competent contractors. A cost breakdown of each alternative is presented below.

I. COOPER NO. 1 AND COOPER NO. 2 - (Replace both structures with relocated canal and concrete)

A. Inlet Structure $6,150.00
B. Concrete Chute 67,050.00
C. Outlet Structure 9,500.00
D. Channel Rip Rap 5,196.00
E. Earthwork 9,174.00
Subtotal Rip Rap $97,070.00
Contingency 15% 14,561.00
Engineering Design 10% 9,707.00
Construction Inspection 8% 7,765.00
Total $129,103.00

II. COOPER NO. 3 AND FLUME @ 913+44 - (Replace both structures with concrete chute and on canal realignment)

A. Removal of Old Structures $12,400.00
B. Inlet Structure 3,625.00
C. Concrete Chute 54,180.00
D. Outlet Structure 7,125.00
E. Channel Rip Rap 5,131.00
F. Earthwork 12,957.00
G. 36" CMP 8,000.00
H. Irrigation Lateral Headgates (2) 3,690.00
I. Overhead Pipe Irrigation Lateral 4,350.00
Subtotal Irrigation Lateral $111,458.00
Contingency 15% 16,719.00
Engineering Design 10% 11,146.00
Construction Inspection 8% 8,916.00
Total $148,239.00

III. STAGG DROP CHUTE - (Replace with pipe drop)

A. Removal of Old Structures $13,800.00
B. Inlet Structure 5,500.00
C. Pipe Drop 88"x54" RCA Pipe 33,750.00
D. Outlet Structure 27,240.00
E. Channel Rip Rap 3,594.00
F. Basin Drainage System 2,750.00
G. Relocate Existing Lateral Headgate 1,845.00
H. New Fencing 2,530.00

Subtotal Construction $ 91,009.00
Contingency 15% 13,651.00
Engineering Design 10% 9,101.00
Construction Inspection 8% 7,280.00

Total $121,041.00

IV. HOG FARM - (Replace with similar structure)

A. Removal of Old Structures $ 2,450.00
B. Inlet Structure 2,625.00
C. Concrete Chute 6,750.00
D. Outlet Structure 7,125.00
E. Channel Rip Rap 2,707.00
F. Earthwork 690.00

Subtotal Construction $22,347.00
Contingency 15% 3,352.00
Engineering Design 10% 2,235.00
Construction Inspection 8% 1,788.00

Total $29,722.00

SUMMARIZING THE ABOVE ESTIMATES COSTS

TOTAL ESTIMATED CONSTRUCTION COST $321,884.00
TOTAL ESTIMATED CONTINGENCY 48,283.00
TOTAL ESTIMATED ENGINEERING 32,189.00
TOTAL ESTIMATED CONSTRUCTION INSPECTION 25,749.00
TOTAL ESTIMATED PROJECT COST $428,105.00

ECONOMIC ANALYSIS

Some of the options available to the District to finance the improvements selected by the District include loans from the private sector and the state and of course the grant-loan program available through the Wyoming Water Development Commission.

For the purposes of this report we have assumed that a commercial loan for a twenty year period could be obtained at an interest rate of 12.5 percent for 25 years, a state loan (Wyoming Land Commission) should be obtained at an interest rate of 6.0 percent for 25 years, and the Wyoming Water Development loan-grant would be obtainable for a 50 percent grant and a loan for 50% at a rate of 4% for a period of 25 years. In kind services provided by the District are eligible for consideration in reducing the loan requirements.

Since the annual cost analysis is to be developed for the same period for all financing arrangements it is obvious that the WWDC program with 50% grant and 50% loan will have the lowest annual cost. For comparison however, the analysis based on a capital recovery method for annual costs provides the following:
1. Commercial loan - 25 years at 12½%  
   Total Cost $428,105.00  
   Annual Cost 56,484.18

2. State loan - 25 years at 6%  
   Total Cost $428,105.00  
   Annual Cost 33,490.65

3. WWDC - loan, grant  
   Total Cost $428,105.00  
   Grant 50% 214,052.50  
   Loan 50% 214,052.50  
   Annual Cost 13,701.50

The number of acres within the District on the last assessment was approximately 12,000. Under a special agreement there is an additional 1,045 acres that is only assessed for operation and maintenance. Under this special agreement these 1045 acres are not assessed for any capital improvements. Based on the 12,000 assessable acres the annual assessment to retire the debt for the three types of loans would be:

1. Commercial loans $4.7070 per acre per year  
2. State loan $2.7909 per acre per year  
3. WWDC grant-loan $1.1418 per acre per year

There is approximately 31 miles of canal to maintain. The combined length of the preferred modifications is only about 0.3 miles long. Therefore, no significant change in the operation and maintenance costs for the system is expected due to the construction of the proposed improvements. The District should consider the possibility of increased operation and maintenance costs due to deterioration of other structures on the system and possible additional capital cost outlay requirements to replace other structures.

In the original Wyoming Water Development Commissions RFP No. 88-13, the Scope of Services to be provided were to include a feasibility study of in-line hydropower generation in conjunction with a proposed pipeline realignment that would bypass the Cooper No. 1 Chute, Cooper No. 2 Chute, Cooper No. 3 Chute, and the flume at canal station 913+44. This pipeline alternative was subsequently dropped from consideration during meetings held during Phase I of the project. Therefore, the requirement to complete a cost analysis for the hydropower generation was not necessary.

**BENEFIT-COST ANALYSIS**

The development of a benefit-cost analysis for the purpose of this study has been based on a worst case scenario in which a comparison is made between costs associated with the failure of the upper most canal structure, the Cooper No. 1 Chute, to that of replacing it and the Cooper No. 2 Chute with the preferred alternative previously evaluated.
Our worst case scenario is as outlined below:

<table>
<thead>
<tr>
<th>Day</th>
<th>Description of days events</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 5</td>
<td>Chute fails. Damage inspected. Headgate at river shut down to reduce flow in canal.</td>
</tr>
<tr>
<td>July 6</td>
<td>Dam placed in canal just above failure so that irritation above it can continue uninterrupted. Discussion made to place 72&quot; CMP bypass line around failure to temporarily get system back in operation. The 240 feet of pipe and a flared end section are ordered. Some clean up work around failure is done.</td>
</tr>
<tr>
<td>July 7</td>
<td>Pipe in transit and arrives late in day. Pipe bedding and grade are done prior to pipe arrival. The existing canal is enlarged for stilling pool at pipe discharge.</td>
</tr>
<tr>
<td>July 8</td>
<td>Begin pipe installations.</td>
</tr>
<tr>
<td>July 9</td>
<td>Finish placing pipe. Place earth headwall around flared end section at pipe inlet. Place concrete around flared end section in headwall for erosion control. Begin rip rapping stilling pool.</td>
</tr>
<tr>
<td>July 10</td>
<td>Finish placing rip rap. Let concrete cure at inlet and place plastic cover over concrete to help prevent water damage until concrete set is complete.</td>
</tr>
<tr>
<td>July 11</td>
<td>Open river headgate and release temporary dam above failure to return flow to lower canal reaches. Begin clean up of construction site.</td>
</tr>
<tr>
<td>July 12</td>
<td>Finish clean up site.</td>
</tr>
</tbody>
</table>

The following costs have thus been estimated for the installation of this temporary structure.

A. Material cost $13,235.00
B. Equipment cost $6,560.00
C. Labor cost $3,120.00
Total cost of temporary construction $22,915.00

Once the growing season is over and the canal is shut down for winter, we have assumed that the District would proceed with the installation of the preferred alternative as a permanent replacement of the failed chute. In this case the preferred alternative being the replacement of both the Cooper No. 1 and Cooper No. 2 Chutes with a single concrete chute on a different canal alignment than the exiting canal configuration. The cost of this installation as previously estimated is $129,100.00. The temporary pipe drop could then be salvaged at 50% of the initial pipe cost less the cost of salvaging it, giving a salvage value of $4008.00. The total estimated cost for the construction of temporary and permanent structures would then be
$148,010.00.

Thus far we have not considered any costs that may be associated with reduced crop yield that the farmers below the failure may face as a result of the canal being shut down for 5 or 6 days during the growing season. Once the canal shuts down for the emergency repairs the lack of irrigation water will cause varying degrees of crop stress that will result in reduction in the crop yields. This reduction in yield will vary with the length of time the water is off, the time of the growing season when the shortage occurs, and the type of crops being grown.

During the November 2, 1988 draft final report review meeting it was agreed that the Riverton area has a crop pattern similar to that of the Worland area. The crop pattern we used was then taken from the publication, "Costs of Producing Crops, Worland Area, Wyoming. 1985-86" published by the Cooperative Extension Service, Division of Agricultural Economics, at the University of Wyoming. The crop pattern selected for our study is the same as that of the case farm identified on page 9 of the above identified publication, and listed below:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Percent of Acreage</th>
<th>Yield per Acre</th>
<th>Price $/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malting Barley</td>
<td>40%</td>
<td>45 cwt</td>
<td>$6.75/cwt</td>
</tr>
<tr>
<td>Sugar Beets</td>
<td>33%</td>
<td>22 ton</td>
<td>$36.00/ton</td>
</tr>
<tr>
<td>Corn Grain</td>
<td>18%</td>
<td>78.4 cwt</td>
<td>$5.00/cwt</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>9%</td>
<td>4.5 ton</td>
<td>$70.00/ton</td>
</tr>
</tbody>
</table>

Yield losses for these crops based on a 5 day drought at the same time period, but with a crop pattern of 34% malt barley, 34% sugar beets, 18% corn and 14% alfalfa were evaluated for the Wyoming Water Development Commission for its Northern Washakie County Flood Control Study - Level I. The 5 day drought was determined to cause a theoretical direct income loss to the producers of $29.59/acre based on a weighted average of the crop pattern. Adjusting the crop pattern from the Northern Washakie County Flood Control Study - Level I to our crop pattern as listed above gives a theoretical weighted direct income loss of $30.94/acre. There are approximately 5000 acres of irrigated land below the Cooper No. 1 Chute. The total direct income loss to the producers below the failure is thus $154,700.00.

The total cost to the farmers who make up the LeClair Irrigation District for a failure of the Cooper No. 1 Chute theoretically may approach $302,700 as compared to the estimated cost of $129,100 for replacing the structure before a failure occurs. The cost of waiting for a failure to occur may be 2.34 times greater than that of replacement before a failure occurs.

The Directors of the District, in carrying out their responsibilities as custodians of the system, have to ultimately make the decision on the maintenance required on the system and the time and the scope of improvements to be made.
PERMITTING AND LAND ACQUISITION/EASEMENTS

A. Archeological Site Identification

Archeologist site identification maps have been prepared to provide the Wyoming Water Development Commission and the Office of the Wyoming State Archeologist site specific locations so that archeological project clearance can be obtained. The archeologist site identification maps are presented in Appendix B of this report.

B. Ownership Map

An ownership map has been prepared by Crank Companies, Incorporated based on our review of the records available at the Fremont County Clerk's Office and the LeClair Irrigation District. This map is presented as Appendix C of this report.

C. State Engineers Office Requirements

Crank Companies, Incorporated personnel have talked with the State Engineers Office on two occasions to verify any requirements that would be necessary to file with the State Engineer's Office concerning this project. It is our understanding that because we are changing the internal means of conveyance, no petitions, or maps are required to be filed with the State Engineer's Office. However, they would like to see construction plans along with an explanation of what is being done and would like the same submitted to them. The State Engineer's Office indicated they would use the information to help keep the file current.

D. County Construction Permit

A telephone conversation with the Fremont County Planning Office confirmed that no county construction permits would be required.

E. Right of Way Easements

A map and legal description for a right of way easement for an irrigation canal and access road has been prepared for each property owner in which right of way is needed. The LeClair Irrigation District currently has a right of way where the existing canal is, but Crank Companies, Incorporated could find no written confirmation as to the width of the right of way. There is a record of title of the LeClair Canal to the Wyoming Central Irrigation Company from the State of Wyoming which can be found in Miscellaneous Records, Fremont County, Wyoming in Book G, on page 53. This title conveys the canal to the irrigation company and states the canal is conveyed to the irrigation company where it is located on the ground. Crank Companies, Incorporated has prepared maps and descriptions for easements through all lands needed for the construction of the four preferred alternatives. These easement maps and descriptions are presented in Appendix D of this report.
CONCLUSIONS

1. All six structures reviewed are in need of replacement in the near future. The Stagg Drop Chute and the Hog Farm Chute are both undergoing rapid deterioration at this time and should be replaced as soon as possible.

2. Existing subsurface soil investigations identified no areas of exceptional rock and soil conditions that would cause cost increases above that of normal heavy construction costs. No subsurface soils testing was performed in the area of the stilling basin of the Cooper No. 2 Chute. A test hole should be completed in this area before the final design of the stilling basin in this area is performed. All other structures should have adequate soils testing in their vicinity, except perhaps additional tests should be performed at approximately station 4+50 of the chute and canal realignment to replace the Cooper No. 3 Chute and Flume at 913+44.

The complete soils report can be found as Appendix E at the end of this report.

3. The total cost of reconstructing all of the proposed structures has been estimated at $428,105.00. This cost does not include any costs for obtaining rights of way, or the cost of having appraisals done on any of the lands affected.

4. The LeClair Irrigation District should pursue a grant-loan from the Wyoming Water Development Commission in order to finance the proposed reconstruction project. This method of financing is two to four times less costly than the other types of financing.

5. Benefit-Cost analysis has been performed based on a worst case scenario in which it was demonstrated that it would be 2.3 times cheaper to replace a structure before a failure occurs. The actual cost of a failure may vary considerably but it can be concluded that waiting for a failure to occur only increases the cost of replacing a structure. The cost associated with the loss of revenue the producers may face because of crop stress can easily exceed that of the replacement structure. The structures are all nearing the end of their useful life to the district and will need replaced in the near future. The District will ultimately have to make the decision on the time and scope of the improvements needed to maintain the system.
APPENDIX A
EXISTING LATERAL CANAL HEADGATE HANGS OFF OF INLET STRUCTURE

PLAN VIEW

PROFILE VIEW

EXISTING STAGG DROP CHUTE
CANAL STA. 982+08
SCALE: 1" = 30'

TDC
INSTALL A NEW LATERAL CANAL HEADWATE & PIPING ABOVE INLET STRUCTURE TO REPLACE EXISTING HEADGATE HANGING OF INLET STRUCTURE

PLAN VIEW

SECTION A-A

PROFILE VIEW

CONCEPTUAL DESIGN OF PREFERRED ALTERNATIVE TO REPLACE

STAGG DROP CHUTE

CANAL STA. 982+08

SCALE: 1" = 30'
CONCEPTUAL DESIGN OF PREFERRED ALTERNATIVE TO REPLACE

HOG FARM CHUTE

CANAL STA. 1452+00
APPENDIX B
T. 1 N., R. 4 E., WIND RIVER MERD IAN, FREMONT COUNTY, WYOMING

ARCHEOLOGIST SITE IDENTIFICATION MAP

SCALE: 1" = 2000'

SITE IDENTIFICATION NO.  DESCRIPTION
1.  REALIGNMENT OF COOPER NO. 1 & NO. 2 CHUTES
2.  REALIGNMENT OF COOPER NO. 3 CHUTE & FLUME
3.  EXISTING STAGG DROP CHUTE LOCATION

WYOMING WATER DEVELOPMENT COMMISION
LECLAIR IRRIGATION REGABLIGATION PROJECT
LEVEL II
ARCHEOLOGIST SITE IDENTIFICATION MAP

SHEET 1 OF 2
T. 2 N., R. 5 E., WIND RIVER MERIDIAN, FREMONT COUNTY, WYOMING

ARCHEOLOGIST SITE IDENTIFICATION MAP

SCALE: 1" = 2000'

SITE IDENTIFICATION NO.  DESCRIPTION

4. EXISTING HOG FARM CHUTE LOCATION

WYOMING WATER DEVELOPMENT COMMISSION
LECLAIR IRRIGATION REHABILITATION PROJECT
LEVEL II
ARCHEOLOGIST SITE IDENTIFICATION MAP
APPENDIX C
APPENDIX D
A right of way easement for an irrigation canal and access road in the SE1/4 of Section 20, T1N, R4E, of the Wind River Meridian, Fremont County, Wyoming. Said easement being 120 feet wide, being 60 feet on each side of the following described center line:

Commencing at the NE corner of Section 21, T1N, R4E of the Wind River Meridian, Fremont County, Wyoming, where is found a 5/8 inch rebar with a 2 inch aluminum cap stamped WRE 579 with a punch mark near its center; thence N89°50'W along the north section line of said Section 21 a distance of 2640.92 feet to the Northwest corner of said Section 21 where is found a 5/8 inch rebar with a 2 inch aluminum cap stamped WRE 579 with a punch mark near its center; thence S20°02'55"W a distance of 3213.98 feet; thence S63°08'08"E a distance of 380.86 feet to the point of curvature of a curve to the left; thence along the arc of said curve to the left a distance of 207.82 feet to a point of beginning of this description. Said curve to the left having a radius of 245.00 feet and a central angle of 48°36'03". Said point of beginning being a point on a curve to the left; thence continuing along the arc of said curve to the left a distance of 72.26 feet; thence curve to the left having a radius of 245.00 feet and a central angle of 16°53'57"; thence N51°21'52"E a distance of 195.00 feet to the point of termination. Said point of termination being a point on the centerline of the existing Riverton Number 2 (LeClair) Canal. Length of said easement being 267.26 feet.
A right of way easement for an irrigation canal and access road in the SE1/4 of Section 20, T1N, R4W, of the Wind River Meridian, Fremont County, Wyoming. Said easement being 120 feet wide, being 60 feet on each side of the following described center line:

Commencing at the NW corner of Section 21, T1N, R4E of the Wind River Meridian, Fremont County, Wyoming, where is found a 5/8 inch rebar with a 1 inch aluminum cap stamped WRE 579 with a punch mark near its center; thence N89°50'W along the north section line of said Section 21 a distance of 2640.92 feet to the Northwest corner of said Section 21 where is found a 5/8 inch rebar with a 1 inch aluminum cap stamped WRE 579 with a punch mark near its center; thence S63°08'08"E a distance of 380.86 feet to a point which is the point of curvature of a curve to the left; thence along the arc of said curve to the left a distance of 280.08 feet. Said curve to the left having a radius of 245.00 feet and a central angle of 65°30'; thence S51°21'52"E a distance of 195.00 feet to the point of termination. Said point of termination being a point on the centerline of the existing Riverton No. 2 (LeClair) Canal. Length of said easement being 855.94 feet in length.
A right of way easement for an irrigation canal and access road in the NE § of Section 20 and the NW § of Section 21, TIN, R4E, of the Wind River Meridian, Fremont County, Wyoming. Said easement being 120 feet wide, being 60 feet on each side of the following described center line:

Commencing at the NW corner of Section 21, TIN, R4E of the Wind River Meridian, Fremont County, Wyoming, where is found a 5/8 inch rebar with a 2 inch aluminum cap stamped WRE 579 with a punch mark near its center; thence N89°50'W along the north section line of said Section 21 a distance of 2640.92 feet to the Northwest corner of said Section 21 where is found a 5/8 inch rebar with a 2 inch aluminum cap stamped WRE 579 with a punch mark near its center; thence S89°00'E along the west section line of said section 21 a distance of 2,156.51 feet to the point of beginning of this description, said point of beginning being a point on the centerline of the Riverton #2 Canal; thence N32°52'22"E along the center line of said easement a distance of 352.84 feet to the point of termination. Said point of termination being a point on the common boundary line between the E. Wayne Major Jr. and Wanda P. Major parcel as described and recorded in Book 79, Page 87 on file at the Fremont County Clerk's Office, Lander, Wyoming and the Double S Farms, Inc. parcel as described and recorded in Book 79, Page 87 on file at the Fremont County Clerk's Office, Lander, Wyoming. Said point of Termination bears 55°52'41"E a distance of 1870.00 feet from the Northwest corner of said Section 21. Length of said easement being 352.84 feet.
DESCRIPTION

A right of way easement for an irrigation canal and access road in the NW¼ of Section 21, T1N, R4E, of the Wind River Meridian, Fremont County, Wyoming. Said easement being 120 feet wide, being 60 feet on each side of the following described center line:

Commencing at the N¼ corner of Section 21, T1N, R4E of the Wind River Meridian, Fremont County, Wyoming, where is found a 5/8 inch rebar with a 2 inch aluminum cap stamped WRE 579 with a punch mark near its center; thence N89°50'W along the north section line of said Section 21 a distance of 2640.92 feet to the Northwest corner of said Section 21 where is found a 5/8 inch rebar with a 2 inch aluminum cap stamped WRE 579 with a punch mark near its center; thence S00°00'E along the west section line of said section 21 a distance of 2,156.51 feet to the point of beginning of this description, said point of beginning being a point on the centerline of the Riverton #2 Canal; thence N32°52'22"E along the center line of said easement a distance of 352.84 feet to the point of termination. Said point of termination being a point on the common boundary line between the E. Wayne Major Jr. and Wanda P. Major parcel as described and recorded in Book 28 Page 547 on file at the Fremont County Clerks Office, Lander, Wyoming and the Double S Farms, Inc. parcel as described and recorded in Book 79, Page 87 on file at the Fremont County Clerk's Office, Lander, Wyoming. Said point of Termination bears S5°52'41"E a distance of 1870.00 feet from the Northwest corner of said Section 21. Length of said easement being 352.84 feet.
A right of way easement for an irrigation canal and access road in NE\(^2\) of Section 20 and the NW\(^4\) of Section 21, TIN, R4E, of the Wind River Meridian, Fremont County, Wyoming. Said easement being 120 feet wide, being 60 feet on each side of the following described center line:

Commencing at the NE corner of Section 21, TIN, R4E of the Wind River Meridian, Fremont County, Wyoming, where is found a 5/8 inch rebar with a 2 inch aluminum cap stamped WRE 579 with a punch mark near its center; thence N89°50'W along the north section line of said Section 21 a distance of 2640.92 feet to the Northwest corner of said Section 21 where is found a 5/8 inch rebar with a 2 inch aluminum cap stamped WRE 579 with a punch mark near its center, thence S5°52'14"E a distance of 1870.00 feet to the point of beginning of this description; said point of beginning being a point on the common boundary between the E. Wayne Major Jr. and Wanda P. Major parcel as described and recorded in Book 28, Page 547 on file in the Fremont County Clerks Office, Lander, Wyoming, and the Double S Farms, Inc. Parcel as described and recorded in Book 79 Page 87 on file in the Fremont County Clerks Office, Lander, Wyoming; thence N32°52'22"E along the centerline of said easement a distance of 287.03 feet to the point of termination. Said point of termination being a point on the easterly boundary of the said E. Wayne Major Jr. and Wanda P. Major parcel. Length of said easement being 287.03 feet.
A right of way easement for an irrigation canal and access road in the SE1/4NW1/4 of Section 16, T1N, R4E, of the Wind River Meridian, Fremont County, Wyoming. Said easement being 90 feet wide, 45 feet each side of the following described centerline.

Commencing at the Northeast corner of the SE1/4NW1/4 of Section 16, T1N, R4E, of the Wind River Meridian, Fremont County, Wyoming; thence S0°31'E along the east line of said SE1/4, a distance of 595.14 feet to the centerline of the Riverton #2 Canal; thence S87°10'W along said centerline, a distance of 82.00 feet to the point of beginning; thence continuing S87°10'W along the centerline of said canal, a distance of 260.00 feet to the point of terminus. Said easement being 260.00 feet in length.
DESCRIPTION

A right of way easement for an irrigation canal and access road in the SE1NW1 of Section 16 of T1N, R4E, of the Wind River Meridian, Fremont County, Wyoming. Said easement being 90 feet wide, 45 feet each side of the following described centerline.

Commencing at the northeast corner of the SE1NW1 of Section 16, T1N, R4E, of the Wind River Meridian, Fremont County, Wyoming; thence S0°31'E, along the east line of said SE1, a distance of 595.14 feet to the centerline of the Riverton #2 Canal; thence S87°10'W along said centerline, a distance of 82.00 feet to the point of beginning; thence continuing S87°10'W along the centerline of said canal, a distance of 260.00 feet to the point of terminus. Said easement being 260.00 feet in length.
DESCRIPTION

A right of way easement for an irrigation canal and access road in Lot 2 (SE\(\text{NW}_1\)), of Section 30, T2N, R5E, of the Wind River Meridian, Fremont County, Wyoming. Said easement being 90 feet wide, 45 feet each side of the following described centerline.

Commencing at the northwest corner of the SE\(\text{NW}_1\) of Section 30, T2N, R5E, Wind River Meridian, Fremont County, Wyoming, where is found a 5/8 inch diameter rebar with a 1/2 inch diameter aluminum cap stamped RI, LS 488, 1/16; thence S12°22'30"W, a distance of 2273.50 feet to the point of beginning; thence N80°16'56"W, a distance of 175.00 feet to the Point of Terminus of this description. Said easement being 175.00 feet in length.
SUBSURFACE STUDY FOR THE
LECLAIR DITCH REHABILITATION PROJECT
TO BE LOCATED NORTH AND WEST OF
RIVERTON, WYOMING

PREPARED FOR:

CRANK COMPANIES, INC.
722 CEDAR
KEMMERER, WYOMING 83101

ATTN: MR. DALE CRANK

JOB NO. 3-72-88

AUGUST 12, 1988
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FIGURES 1 and 2 - LOCATION OF EXPLORATORY BORINGS
FIGURE 3 - LOGS OF EXPLORATORY BORINGS
FIGURE 4 - LEGEND AND NOTES
FIGURE 5 - SWELL-CONSOLIDATION TEST RESULTS
FIGURES 6 and 7 - GRADATION TEST RESULTS

TABLE I - SUMMARY OF LABORATORY TEST RESULTS
TABLE II - SUMMARY OF RESISTIVITY TEST RESULTS
CONCLUSIONS

(1) Structures located at Borings 1, 3, 4 and 5 will be placed on claystone, siltstone or sandstone bedrock. Structures placed on these materials can be designed for an allowable soil bearing pressure up to 10,000 psf. Structures located at Boring 2 will be founded on dense gravels. Structures placed on the dense gravel can be designed for a maximum soil pressure of 5,000 psf.

(2) All of the overburden materials above bedrock are suitable for backfilling of the structures. The bedrock materials may be suitable for use as backfill providing they do not excavate in large chunks, but excavate in a size which will allow them to be placed in a controlled compacted fill.

(3) All of the soils and bedrock can be excavated with conventional excavating equipment, such as large backhoes. It is possible that some cemented layers may be encountered in the bedrock material and that excavations in depth or within confirmed areas of the bedrock, such as in Boring 4, may require the use of percussion hammers or drills or light blasting.

(4) Other design and construction recommendations are presented in the body of the report.
PURPOSE AND SCOPE OF STUDY

This report presents the results of a subsurface study for the LeClair Ditch Rehabilitation Project to be located north and west of Riverton, Wyoming, and more specifically in Sections 16, 20 and 21 of T1N, R4E and Section 30 in T2N, R5E, Fremont County, Wyoming. The subsurface study was conducted for the purpose of classifying soil and bedrock conditions at selected structure locations, developing foundation recommendations for selected structures, evaluating the suitability of materials for reuse as backfill, and determining the potential excavatability of the materials from required excavations. The project site is shown on Figs. 1 and 2.

This report has been prepared to summarize the data obtained during this study and to present our conclusions and recommendations based on the proposed construction and the subsurface conditions encountered. Design parameters and a discussion of geotechnical engineering considerations related to construction of the proposed project are included in the report.

PROPOSED CONSTRUCTION

It is proposed to rehabilitate the existing LeClair Ditch. This rehabilitation work will include the reconstruction of concrete chutes, a flume, and possible construction of a pipeline to replace the existing flume located in Section 21. All of the structures will be of concrete construction. We anticipate the pipeline will be either of steel or concrete construction.

FIELD EXPLORATION

The field exploration for the project was conducted on July 15, 1988. Five exploratory borings were drilled at the locations shown on Figs. 1 and
2 to explore subsurface conditions. Locations and elevations of the exploratory borings were determined in the field by personnel with Crank Companies, Inc. Borings were located as close as possible to each respective structure.

The borings were advanced through the overburden and bedrock using 7½-inch diameter hollow stem augers. The borings were logged by a representative of Chen & Associates, Inc.

Samples of the subsurface materials and bedrock were taken using a 2-inch spoon sampler. The sampler was driven into the various strata with blows from a 140 pound hammer falling 30 inches. This test is similar to the Standard Penetration Test described by ASTM Method D1586. Penetration resistance values, when properly evaluated, indicate the relative density or consistency of the soils. Depths at which the samples were taken and penetration resistance values are shown on the Logs of Exploratory Borings, Fig. 3.

Measurements of the water level were made in the borings immediately after drilling. The water table measurements are shown on the Logs of Exploratory Borings, Fig. 3.

The corrosive potential of the subsoils was evaluated by conducting shallow resistivity surveys centered at each of the boring locations. Values of apparent resistivity were obtained with a Nelson soil resistance meter using a 4-probe array. Resistivity values are presented in Table II. It should be noted that the resistivities measured are apparent resistivities for field moisture contents at the time the measurements were made and represent an average value over the test depth.
LABORATORY TESTING

Samples obtained from the exploratory borings were examined visually and visually classified in the laboratory by the project engineer. Laboratory testing included standard property tests such as natural moisture content (ASTM D2216), dry unit weights, grain size analysis (ASTM D422), and liquid and plastic limits (ASTM D4318). Swell-consolidation tests similar to ASTM D2435 were conducted on typical samples of the bedrock to determine the compressibility or swell characteristics under loading and when submerged in water. The percent of water soluble sulfates was determined in general accordance with the "Standard Methods For The Examination of Water and Wastewater, 15th Edition", for selected samples.

SUBSOIL CONDITIONS

Subsoil conditions encountered in the exploratory borings were erratic. In general, they consisted of an erratic mixture and depth of fill and sands overlying bedrock. Fill was encountered in Borings 2 and 4. In Boring 2, the fill consisted of a clayey gravel; in Boring 4 the fill consisted of an erratic mixture of silts, sands and sandstones. The sands ranged from a medium dense, clean to slightly sand in Boring 3 to a loose to medium dense, silty to very silty sand in Borings 1, 2 and 5. Sands were not encountered in Boring 4. The fill and sands in Boring 2 overlie a dense gravel to the depth investigated, 20 feet. Bedrock was not encountered in Boring 2. Bedrock in the remaining four borings consisted of either a hard to very hard claystone bedrock, a hard siltstone bedrock with interbedded sandstones and claystones, or a hard to very hard, weakly to moderately cemented sandstone bedrock to the depth investigated, 26 feet. The consolidated characteristics for typical samples of the bedrock
are shown on Fig. 5. These consolidation characteristics indicate the bedrock varies from being non-expansive to possessing a low swell potential under load and when wetted. Standard engineering index properties for typical samples of the sands, gravels and bedrock are presented on Figs. 6 and 7. All laboratory testing is presented in Table I. All laboratory testing was conducted in general accordance with applicable ASTM standards.

Water was encountered in Borings 1, 2 and 3 at depths on the order of 4.5 to 6 feet below the existing ground surface. Water was also encountered in Boring 4 at a depth on the order of 20 feet. All of the test borings caved at varying elevations as shown on the Logs of Exploratory Borings, Fig. 3. We anticipate the water levels, as shown on the logs, are directly related to the flow of water in the existing canal. Fluctuations in the water levels should be anticipated with corresponding flow in the canal.

FOUNDATION RECOMMENDATIONS

The approximate bearing elevations of respective structures is shown on the Logs of Exploratory Borings, Fig. 3. These approximate elevations were obtained from personnel with Crank Companies, Inc. and should be considered approximate. The foundation recommendations presented herein are based on these approximate bearing elevations.

The design and construction criteria presented below should be observed for the structures.

1. Foundations placed on the bedrock should be designed for a maximum allowable soil bearing pressure up to 10,000 psf. Foundations placed on the gravel should be designed for a maximum soil bearing pressure up to 5,000 psf.
(2) Resistance to sliding at the bottom of the concrete structures can be calculated based on a coefficient of friction of 0.5 for structures placed on the dense gravels and 0.4 for structures placed on the bedrock materials.

(3) Foundations should be provided with adequate soil cover above bearing elevation for frost protection. This may be difficult for the type of structures proposed. If possible, foundations should be placed at least 5 feet below the existing grade to provide for frost protection.

(4) Areas of loose of soft materials observed within the foundation excavations should be removed and the footings extended to adequate natural bearing material. It is possible that the bedrock may excavate in chunks and in an uneven surface. It is extremely important that all of the loose materials be excavated from required excavations to ensure that concrete is placed directly on the undisturbed natural materials. The bottom of the excavation can be leveled with a lean cement grout prior to the placement of the structural concrete.

(5) Depending upon the time of construction, we anticipate the canal will not be flowing water and the water table elevations will be significantly lower than those shown on the logs of exploratory borings. The contractor should be aware that dewatering of the excavations may be required. Dewatering can be accomplished by installation of perimeter trenches and sumps. This may require laying the side slopes of the excavation back to provide adequate slope protection during construction. Slopes should be laid back to at least 2 horizontal to 1 vertical or properly supported to provide the necessary protection during construction.
The excavation in Boring 2 will be extended to the dense gravel layer. It is possible that at this elevation the excavation may deform or pump under light construction traffic loads. It may be necessary to place a layer of concrete or clean gravel in the bottom of the excavation to provide a stable surface for construction of the structure.

All of the soils excavated from required excavation should be suitable for use as backfill against the structures. Depending upon the way in which the bedrock excavates, it may be more desirable to waste the bedrock and replace it with the silty sands or existing fill. If the bedrock excavates in chunks, it may be difficult to place it in a controlled compacted fill. All backfill should be compacted to at least 95% standard Proctor density. All the fill should be observed and tested during construction to ensure that fill is placed to the above specification.

EXCAVATABILITY

All of the soils and bedrock can be excavated using normal conventional excavation equipment such as backhoes. Large backhoes may be required to excavate the bedrock, especially where the bedrock will need to be excavated in depth. The sandstone bedrock and possibly the siltstone-claystone may have cemented layers which could be more difficult to excavate. It is possible that in confined excavations, excavations with depth and if cemented layers are encountered, that percussion drills or light blasting may be required to remove the bedrock materials. All of the overburden materials can be readily excavated; however, during construction these materials should be laid back at safe slopes to allow adequate
protection during construction. All cut slopes in the overburden materials should be laid back to at least 2 horizontal to 1 vertical slopes or be properly supported to allow safe working conditions. The bedrock can be excavated at vertical slopes if excavations extend into the bedrock less than 5 feet. For excavations greater than 5 feet, these slopes should be laid back at 1 horizontal to 1 vertical. The bedrock should stand vertically and if desired, can be excavated to neat line dimensions and concrete placed directly against the bedrock.

WATER SOLUBLE SULFATES

Typical samples of the bedrock were tested to determine water soluble sulfate content. Test results indicate the water soluble sulfate contents to be less than 0.01 percent. These conditions indicate the conditions are negligible for the potential sulfate attack of concrete. We recommend that Type II cement be used for all concrete.

LIMITATIONS

This report has been prepared in accordance with generally accepted soil and foundation engineering practices in this area for use by the client for design purposes. The conclusions and recommendations submitted in this report are based upon the data obtained from the exploratory borings drilled at the locations indicated on the exploratory boring plan and the proposed type of construction. The nature and extent of subsurface variations across the site may not become evident until excavation is performed. If during construction, fill, soil, rock, or water conditions appear to be different from those described herein, this office should be advised at once so re-evaluation of the recommendations may be made. We
recommend on-site observation of excavations and foundation bearing strata
by a soil engineer.

CHEN AND ASSOCIATES, INC.

BY

Kenneth E. Temme, P.E.

REVIEWED BY

Michael Staffileno

Chen & Associates
Note: Elevations of borings B-1, B-2 and B-3 are referenced to a common bench mark. Elevations of Borings B-4 and B-5 were referenced to separate bench marks. All bench marks were established by personnel with Cran Companies, Inc. In general, bench marks were located on top of the concrete wingwalls at the top of the structure at Borings B-1, B-4 and B-5. Exact locations and additional information on bench marks is available from Cran Companies, Inc.
Legend:

Fill, erratic composition and density. In Boring 2 fill consists of clayey gravels, light brown, moist. In Boring 4 fill consists of erratic mixture of silts, sands and sandstone, light brown to grey, dry to slightly moist.

Sand (SP), clean to slightly silty, medium dense, brown to yellow, moist to wet.

Sand (SM), silty to very silty, loose to medium dense, brown to grey, moist to wet.

Gravel (GP), sandy, dense, brown, wet.

Claystone Bedrock, hard to very hard, green to brown, moist.

Siltstone Bedrock, interbedded sandstones and claystones, hard, brown-grey, moist to wet.

Sandstone Bedrock, hard to very hard, weakly to moderately cemented, brown-yellow-orange, moist.

Undisturbed Drive Sample. The symbol 10/12 indicates that 10 blows of a 140 lb. hammer falling 30 inches were required to drive the sampler 12 inches.

Indicates depth interval at which a disturbed soil sample was obtained from auger cuttings.

Indicates water level measured at the time of drilling.

Indicates water level and depth at which test boring caved at the time of drilling.

Indicates depth at which test boring caved immediately after drilling.

Notes:

(1) Exploratory borings were drilled July 15, 1988 using 7½-inch hollow stem auger.

(2) Locations and elevations of borings were established in the field by personnel with Crank Companies, Inc.

(3) The lines between materials shown on the boring logs represent the approximate boundaries between material types and the transitions may be gradual.

(4) WC = Water Content (%)  
DD = Dry Density (pcf)  
LL = Liquid Limit (%)  
PI = Plasticity Index (%)  
NP = Non-plastic  
UC = Unconfined Compressive Strength (psf)  
-200 = Passing No. 200 Sieve (%)  
WSS = Water Soluble Sulfate Content (%)
chen and associates, inc.

Moisture Content = 21.7 percent
Dry Unit Weight = 101.4 pcf
Sample of: Siltstone Bedrock
From: Boring 4 at depth 24.0'

Expansion under constant pressure due to wetting

Moisture Content = 12.1 percent
Dry Unit Weight = 116.2 pcf
Sample of: Claystone Bedrock
From: Boring 5 at depth 14.0'

No movement upon wetting

SWELL-CONSOLIDATION TEST RESULTS

Fig. 5
GRADATION TEST RESULTS

**SAMPLE OF** Very Silty Sand **FROM** Boring 1 at depth 4.0'

**SAMPLE OF** Sand and Gravel **FROM** Boring 2 at depth 14.0'

**HYDROMETER ANALYSIS**

**TIME READINGS**

**SIEVE ANALYSIS**

**CLEAR SQUARE OPENINGS**

**U. S. STANDARD SERIES 80**

**Diameter of Particle in Millimeters**

**Percent Retained**

**Percent Passing**

**CLAY (PLASTIC) TO SILT (NON-PLASTIC)**

**FINE**

**MEDIUM**

**COARSE**

**FRAVE**

**COBBLES**

**GRAVEL** 0 %

**SAND** 57 %

**SILT AND CLAY** 43 %

**LIQUID LIMIT** 22 %

**PLASTICITY INDEX** 6 %

**SAMPLE OF** Very Silty Sand **FROM** Boring 1 at depth 4.0'

**HYDROMETER ANALYSIS**

**TIME READINGS**

**SIEVE ANALYSIS**

**CLEAR SQUARE OPENINGS**

**U. S. STANDARD SERIES 80**

**Diameter of Particle in Millimeters**

**Percent Retained**

**Percent Passing**

**CLAY (PLASTIC) TO SILT (NON-PLASTIC)**

**FINE**

**MEDIUM**

**COARSE**

**FRAVE**

**COBBLES**

**GRAVEL** 57 %

**SAND** 38 %

**SILT AND CLAY** 5 %

**LIQUID LIMIT** %

**PLASTICITY INDEX** NP %

**SAMPLE OF** Sand and Gravel **FROM** Boring 2 at depth 14.0'

Fig. 6
SAMPLE OF Siltstone Bedrock FROM Boring 4 at depth 24.0'

HYDROMETER ANALYSIS

- Gravel: 0%
- Sand: 13%
- Silt and Clay: 87%

LIQUID LIMIT: 52%
PLASTICITY INDEX: 15%

SAMPLE OF Claystone Bedrock FROM Boring 5 at depth 14.0'

HYDROMETER ANALYSIS

- Gravel: 0%
- Sand: 13%
- Silt and Clay: 87%

LIQUID LIMIT: 36%
PLASTICITY INDEX: 18%

GRADATION TEST RESULTS

Fig. 7
### Summary of Laboratory Test Results

<table>
<thead>
<tr>
<th>BORING</th>
<th>DEPTH (FEET)</th>
<th>NATURAL MOISTURE (%)</th>
<th>NATURAL DRY DENSITY (PCF)</th>
<th>ATTERBERG LIMITS</th>
<th>UNCONFINED COMPRRESSIVE STRENGTH (PSF)</th>
<th>WATER SOLUBLE SULFATE (%)</th>
<th>GRADATION ANALYSIS +4 %</th>
<th>-4 %</th>
<th>-200 %</th>
<th>SOIL TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>7.1</td>
<td>NP</td>
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<td>57 38 5</td>
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<td></td>
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<td></td>
<td>Sand and Gravel</td>
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<tr>
<td>4</td>
<td>14.0 24.0</td>
<td>15.2 21.7</td>
<td>115.7 101.4</td>
<td>52</td>
<td>15</td>
<td>0.01</td>
<td>0</td>
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<td>87</td>
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<tr>
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<td>16.1 12.1</td>
<td>110.2 116.2</td>
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<td>18</td>
<td>0.01</td>
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<td>87</td>
<td>Claystone Bedrock</td>
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**Job No. 372-88**
# TABLE II

**RESISTIVITY TEST DATA**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>SPACING</th>
<th>GAUGE READING (OHM)</th>
<th>RANGE SWITCH</th>
<th>RESISTANCE (OHM)</th>
<th>MULTIPLIER</th>
<th>RESISTIVITY (OHM/CM²)</th>
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<td>B-1</td>
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### SPACING MULTIPLIER

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### SPACING FEET-INCHES MULTIPLIER

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