

CONTROL STRUCTURES FOR STABILIZING DEGRADING STREAM CHANNELS POTTAWATTAMIE COUNTY

**FINAL REPORT
IOWA HIGHWAY RESEARCH BOARD
PROJECT HR-236**

SEPTEMBER 1987

Highway Division



**Iowa Department
of Transportation**

Final Report
Iowa Highway Research Board
Project HR-236

CONTROL STRUCTURES
FOR
STABILIZING DEGRADING STREAM CHANNELS
POTTAWATTAMIE COUNTY

(STRUCTURE #6)

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DISCLAIMER

The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of Pottawattamie County or the Iowa Department of Transportation.

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ABSTRACT

Stream degradation due to steep stream gradients and large deposits of loess soil is a serious problem in western Iowa. One solution to this problem is to construct grade stabilization structures at critical points along the length of the stream. Iowa Highway Research Board project HR-236, "Pottawattamie County Evaluation of Control Structures for Stabilizing Degrading Stream Channels", was initiated in order to study the effectiveness of such structures in preventing stream degradation.

This report describes the construction and four-year performance of a gabion drop structure constructed along Keg Creek during the winter of 1982-83.

ACKNOWLEDGEMENTS

Research project HR-236 was sponsored by the Iowa Highway Research Board and the Iowa Department of Transportation. Partial funding of the project was from the Secondary Road Research Fund in the amount of \$53,540.

The authors wish to extend appreciation to the Pottawattamie County Board of Supervisors, Iowa State University, Iowa State Water Resources Research Institute, and Iowa DOT for their support in developing and conducting this project. The Pottawattamie County inspection personnel also deserve recognition for the extra effort put forth on the project.

INTRODUCTION

In western Iowa, soil erosion is acute due to the large deposits of loess soil and the steep gradient of the streams in the Missouri River Basin. Extensive stream channel straightening has increased water velocity, causing streams to degrade and widen rapidly. This creates loss of soil and undercuts culverts and bridge foundations. Many channels have eroded to as much as two times the original depth and from two to four times the original width; thus, research project HR-236 was initiated with the cooperation of Pottawattamie County, the Engineering Research Institute of Iowa State University and the Iowa Highway Research Board of the Iowa DOT.

OBJECTIVE

The purpose of this project was to find an economical method to control stream degradation by constructing various types of stream stabilization structures. The effectiveness of each structure was to be evaluated by monitoring the structure and streambed after construction.

FUNDING

The participants in the funding were Pottawattamie County Secondary Roads Department, Iowa State Water Resources Research Institute of Iowa State University and the Iowa Highway Research Board. Funding was a major hurdle to overcome. Several agencies were approached for assistance. In addition to the agencies mentioned above, Golden Hills Resource Conservation and Development, Soil Conservation Service, Army Corps of Engineers, and United States Department

of Agriculture - Area Research Service were also contacted. All the agencies were interested in the project but many were unable to help in the funding due to their individual inter-agency regulations.

PROJECT LOCATION

The project is located on Keg Creek in the central part of Pottawattamie County (Figure 1). Drainage at the project location is 90 square miles (32,400 acres). This stream empties into the Missouri River five miles southwest of Glenwood in Mills County.

Characteristics of Keg Creek in Pottawattamie County are:

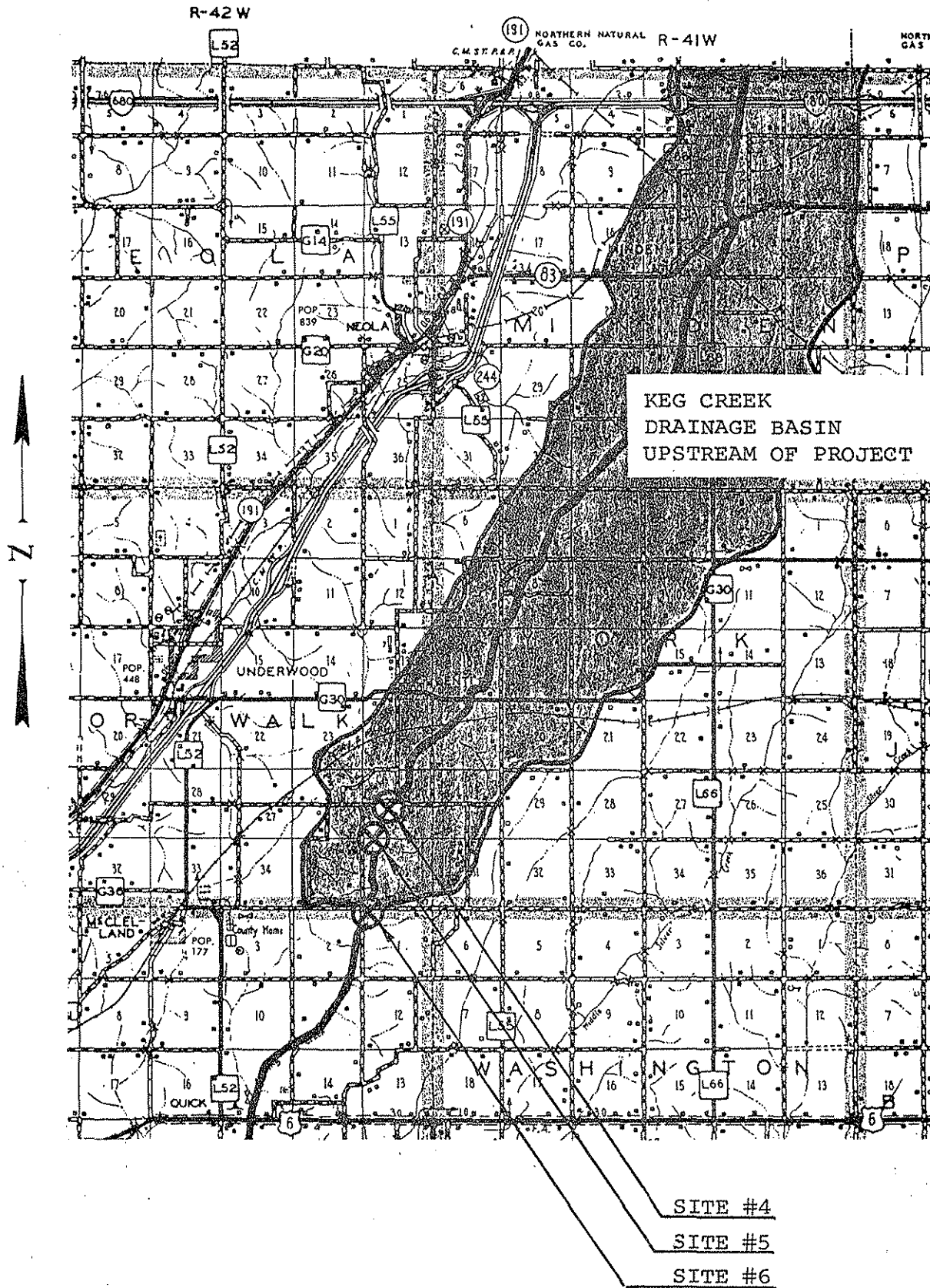
Streamslope 3 to 5 feet per mile at the south Pottawattamie County line.

Streamslope 6 to 8 feet per mile directly downstream from the project.

Several nick-points (or overfalls) between sites 5 and 6.

Streamslope 10 to 12 feet per mile directly upstream from site 4.

POTTAWATTAMIE COUNTY IOWA



INITIAL PROJECT DESIGN AND DEVELOPMENT

The three structures were designed to stabilize the entire upper Keg Creek watershed channel from future degradation. Structure 6 was to be located downstream from the nick-points. Structures 4 and 5 were to be located upstream of the nick-points to prevent the nick points from progressing upstream.

Structures proposed by ISU were:

Structure 4 - Precast p.c. concrete crest with a vertical drop to a soil cement stilling basin.

Structure 5 - Soil cement ramp type drop to a soil cement stilling basin floor.

Structure 6 - Vertical steel sheetpile with a vertical drop to a soil cement stilling basin floor.

Total net drop from the crest of structure 4 to the endsill of structure 6 was to be 30 feet.

The location chosen for structure 6 is on the north side of Section 1-T75N-R42W, just downstream from a county bridge. The east bridge abutment has been undermined by stream degradation since the bridge was built in 1957. At this location the stream depth is relatively stable. The experimental structure was designed to pond water upstream and eventually accumulate silt upstream to protect the undermined bridge abutment.

Structure number 6 was the only project to be constructed. The design concept for the structure was changed to a gabion-p.c. con-

crete ramp type structure at the request of Pottawattamie County. Gabions have been used for flumes, weirs, retaining walls and ditch checks in the county with satisfactory performance. Gabions have proven to be a durable, flexible building material. Also, rock is readily available. For these reasons, a gabion structure was chosen for this research project. Construction plans and special provisions for the project are in Appendix A.

Iowa State University personnel designed the structure to contain a 50-year flood of 9930 cfs. The hydraulic jump created was taken into consideration in the design. Prior to construction of the structure, the channel had the capacity to contain the 100-year flood of about 12,000 cfs. It is expected that the structure will cause a 4-foot rise in the water surface elevation upstream of the structure during the 100-year flood, but this should not cause overbank flow. The construction plans and special provisions were developed by Pottawattamie County.

The weir and ramp structure is approximately 90 feet wide and 130 feet long with a net drop in elevation of 12.6 feet. The crest of the structure is raised approximately nine feet above the existing streambed. Raising the flowline reduces the slope of the stream flowline for a distance of about one mile upstream. Raising the flowline will also cause silting in the streambed at the bridge directly upstream.

Steel sheeting and p.c. concrete were used as a cut off wall at the inlet end to prevent the stream from undercutting the structure. The floor of the structure was covered with two inches of concrete to protect the gabion material. As concrete is placed and vibrated, some concrete will intrude into the gabions. The concrete must be vibrated to assure a bond with the gabion wire mesh; therefore, twenty-five percent was added to the estimated concrete quantity.

An important factor to consider when using gabions as a building material is the rock durability. The rock must be a sound material and must have good freeze-thaw characteristics. Abrasion characteristics should also be considered. If the rock breaks down too much, it will be lost through the openings in the gabion wire mesh.

The limestone revetment used for the gabions was from the Winterset ledge of the Fort Calhoun quarry in Fort Calhoun, Nebraska. The stone was 8-inch maximum size with less than 25 percent smaller than 4 inches. Freeze and thaw durability for material from this ledge is 5 for Method A and 2 for Method C of Iowa DOT Laboratory Test Method 211. Abrasion loss is 26 percent of the original aggregate sample weight.

LETTING AND CONTRACTOR

The project was advertised through the local paper, Iowa Department of Transportation, and contractor publications. Contractors were furnished a standard bid proposal form, supplemental specifications

and a set of plans. Bids were read at the county courthouse on September 16, 1982, with three bidders submitting proposals.

V. M. DeBuse Construction Inc. of Omaha, Nebraska, was the low bidder with a sum of \$97,287.03. A copy of the contract is shown in Appendix B.

CONSTRUCTION

The contractor moved onto the job December 2, 1982. A 48-inch diameter CMP culvert was used to divert the stream flow to the east side of the work area. Earthen dams were constructed both upstream and downstream of the site. By mid December, preparatory excavation work was being done so gabion installation at the stilling basin could begin. Water seepage created a problem, making pumping necessary. Several loads of crushed limestone were placed to form a good foundation for the gabion structure.

Engineering fabric was placed over the rock and the foundation area of the stilling basin before gabion placement commenced (Figure 2). The fabric used was in accordance with Iowa Department of Transportation I.M. 491.14, Embankment Erosion Control. No problems were encountered placing the fabric.



Figure 2 - Placement of Gabions for Stilling Basin

Gabion baskets, 1 ft. x 3 ft. x 12 ft. in size, were assembled on the job with empty baskets being set in place and wired together. A bottomless wooden box was placed in each gabion compartment before the rock was loaded from a dragline bucket into the gabion. The box was then removed and the rock was leveled in the gabion basket (Figure 3). After each gabion was filled, the lid was hand wired to the gabion basket. Two to three people were required to do this operation. Depending on the location of gabion placement and people available, the daily placement ranged from 20 to 60 CY of gabions. The gabion rock was hauled 30 miles to the project site.

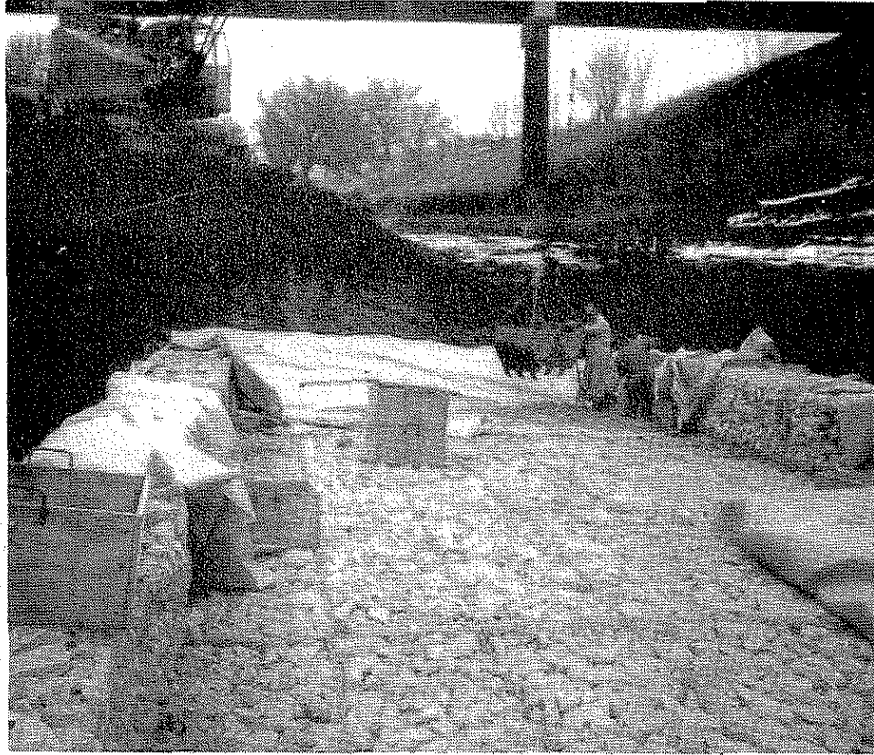


Figure 3 - Filling Gabion Baskets With Revetment Stone

The ramp gabion, steel sheeting cutoff wall and 2-inch concrete cap in the stilling basin were constructed next. The steel sheeting was driven by a drop hammer.

Warm temperatures in February caused an early ice breakup and fast snow melt which produced a runoff exceeding the capacity of the 48-inch CMP, thus topping the earthen dams and undercutting the ramp and cutoff wall (Figure 4).

After the flooding subsided, a new diversion channel was excavated on the west side of the structure. Three 48-inch CMP culverts were placed through an earthen dam to allow stream flow to the diversion channel.

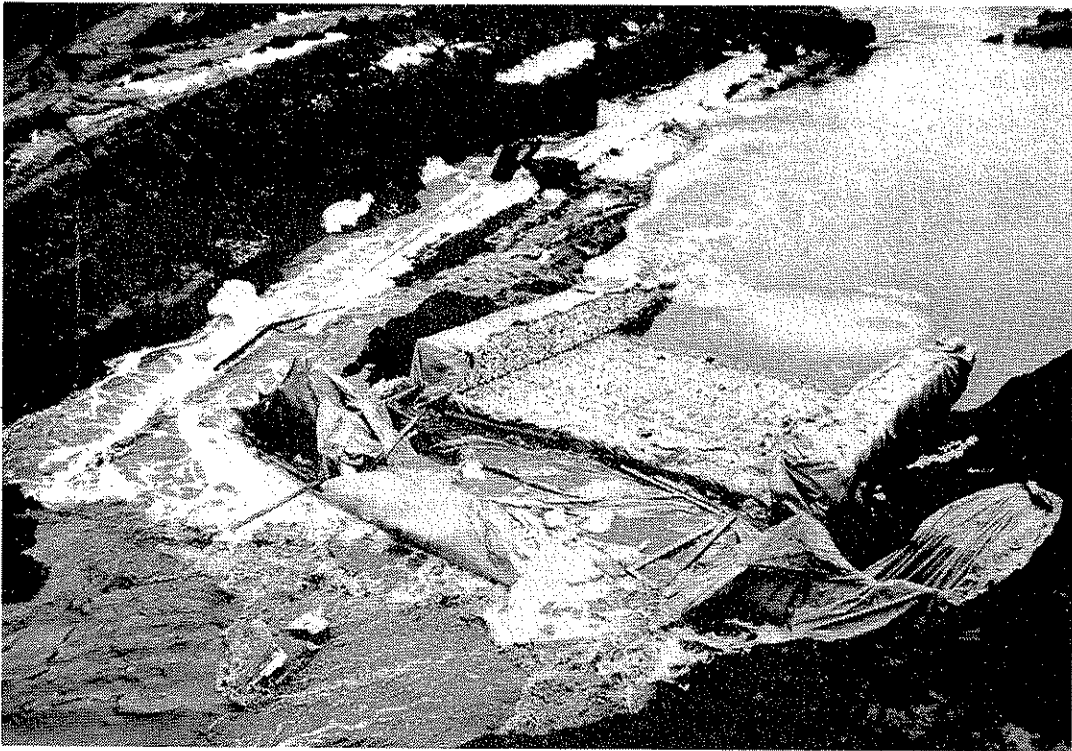


Figure 4 - Wash-out From February Flooding

The flood damaged structure was repaired, and a 2-inch concrete cap was placed on the crest and ramp floor. There was a total of eight concrete pours with a 40% overrun, due mainly to the vibration of the concrete into the gabion rock voids. Placement of gabions for the 2:1 bank slope on the east side was completed in May (Figure 5).

Heavy rains in May caused a second flood. However, enough of the construction was completed to accommodate the storm through the structure. Damage was minimal, although much soil was lost and the gabion deflectors showed some movement. It was decided that an additional row of gabions should be placed adjacent to the existing deflectors for insurance against future floods. After this, normal stream flow was carried through the structure while the west slope was constructed.



Figure 5 - Construction of East Bank Slope

By late May 1983 most of the structure had been completed (Figure 6), but it was now apparent that there was going to be a shortage of 4,000 CY of soil because of losses incurred during the two floods. Pottawattamie County cross sectioned the area to determine the quantity of soil required. A borrow site was selected approximately 1/4 mile away and the fill was completed by a separate contract.

Total working days used for the project were 73 1/2. The specified number of working days was 40.



Figure 6 - Completed Structure in June 1983.
Before Borrow Material Was Placed

PROJECT COSTS

The total cost of the structure, including material overruns, one extra work order and the contract for completing the earth fill was \$107,080. Funding for the project was as follows:

Iowa State Water Resources Research Institute	\$17,369
Pottawattamie County	36,171
Iowa Highway Research Board	53,540

The benefits of the project go beyond those of the county road system. Partial funding for the project was sought from other agencies without success, particularly in the area of soil conservation on both the state and federal levels. All of this was to no avail.

PROJECT EVALUATION

Fifty bench marks were placed across the structure for use in making settlement determinations. The most recent (March 1986) elevation information of the 50 concrete bench marks indicate very little settlement. The durability of the rock used in the gabion baskets seems to be adequate. The structure has been through four winters with virtually no sign of deterioration due to freeze-thaw cycles or abrasion. Current Iowa DOT Supplemental Specification #1011, which was adopted after this project, covers all aspects of gabion and the rock quality.

All stream gauges have been destroyed. Previously, they had malfunctioned. Therefore, all high water information has been determined by high water marks left by debris. There has not been a flow rate over 1,200 cfs, well below the 50-year projection of 9,900 cfs.

At high water, Keg Creek carries much debris and large trees can be found within the existing banks. Logs have torn holes in the gabion material, most of which have been located within the 3' vertical wall along the entire length of the structure. There have been 3 or 4 tear areas, all of which have been repaired with wire of equal or greater gage than the gabion material. The wire mesh material shows no signs of rust or corrosion.

Some minor distress in a 15 foot section of the 3 foot vertical flume wall was corrected in the summer of 1986. This section of

wall had shown some distress prior to the completion of the project, but seemed to increase over the following three years. It is believed the minor deformation was caused by non-homogeneous backfill as this is the area of flood damage which occurred during construction. County crews have corrected the problem by facing that section of gabions with a vertical concrete wall.

There continues to be minor side slope scour just beyond the outlet end of the stilling basin. The scour has not yet caused any problems.

The cutoff wall at the inlet end of the structure is functioning well. There are no signs of undercutting anywhere along the structure. There has been much siltation upstream from this structure and the channel now seems to be stabilizing for approximately 5,500 feet upstream. The nick-point region is just upstream of the pool created by structure #6.

There needs to be another structure at the active nick-point region and possibly one more structure further upstream to totally control this actively degrading reach of Keg Creek.

FUTURE PROJECT DEVELOPMENT

At this time, proposed structures 4 and 5 are not in the planning stages. Some local residents have expressed the obvious need and concern for the development of the two remaining structures, which

are necessary to stabilize the nick-points in the reach between sites #4 and #6.

Due to funding problems, none of the original sponsors of the project have pursued further design and development of structures #4 and #5. The county would have difficulty justifying the expenditure of its funds (roadway purposes) on structure #5 as its location would have to be as much as 3/4 mile from a roadway crossing. As structure #5 would be the next structure to be constructed, and considering the county's position, further project development seems unlikely.

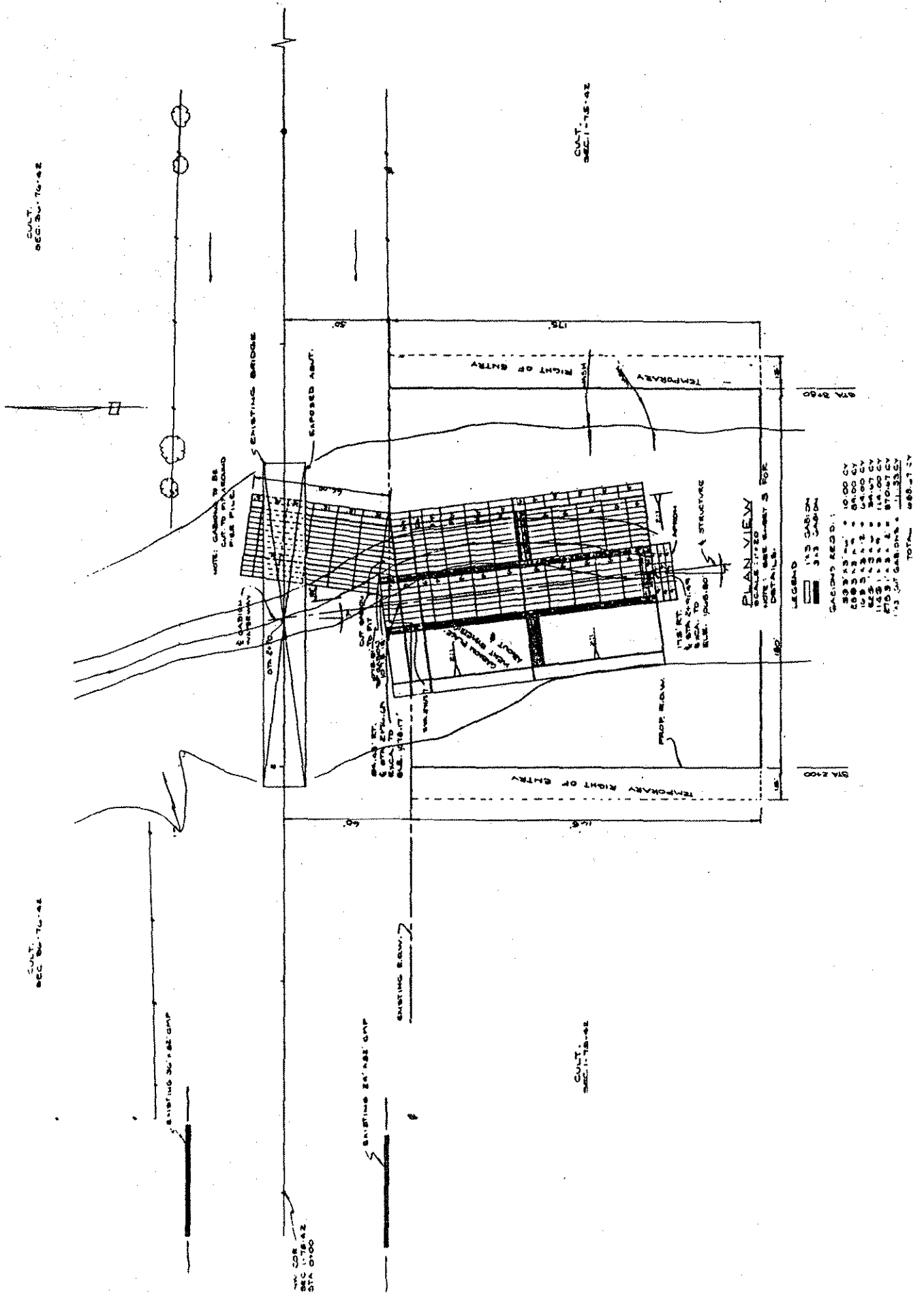
CONCLUSIONS AND RECOMMENDATIONS

From observations and data collected to date, the following conclusions and/or recommendations can be made:

1. The 3' x 3' gabions on either side of the flume floor should have at least a 2" thick grout surface. This would better protect the gabions from damage due to driftwood, ice, etc.
2. A longer stilling basin would correct the minor channel slope erosion at the outlet end of the basin.
3. The structure could have been constructed easier and at less cost if it could have been located in the oxbow of the stream and the stream rerouted through the structure. Existing conditions did not allow that option.
4. Overall, the structure is functioning well and is doing the job for which it was designed; that is, stabilization of this highly active degrading reach of Keg Creek. The stream bed is silted to the new upstream flow line. More structures need to be installed to totally eliminate degradation in this reach.
5. Although no other types of structures have been built to date, it is unlikely there are any cheap alternatives which will control stream degradation in a stream of this size and high susceptibility to erosion.

There is an urgent need to control degradation in many of the streams of western Iowa. On large streams it is not feasible to expect the public road system to entirely fund projects of this size and cost. It can be shown that lengthening a bridge by an additional fifty feet would be less expensive than this project. However, it would not solve the degradation problem. Funding from other agencies is needed, particularly when stream control work is several thousand feet from any road.

APPENDIX A
Construction Plans and Special Provisions



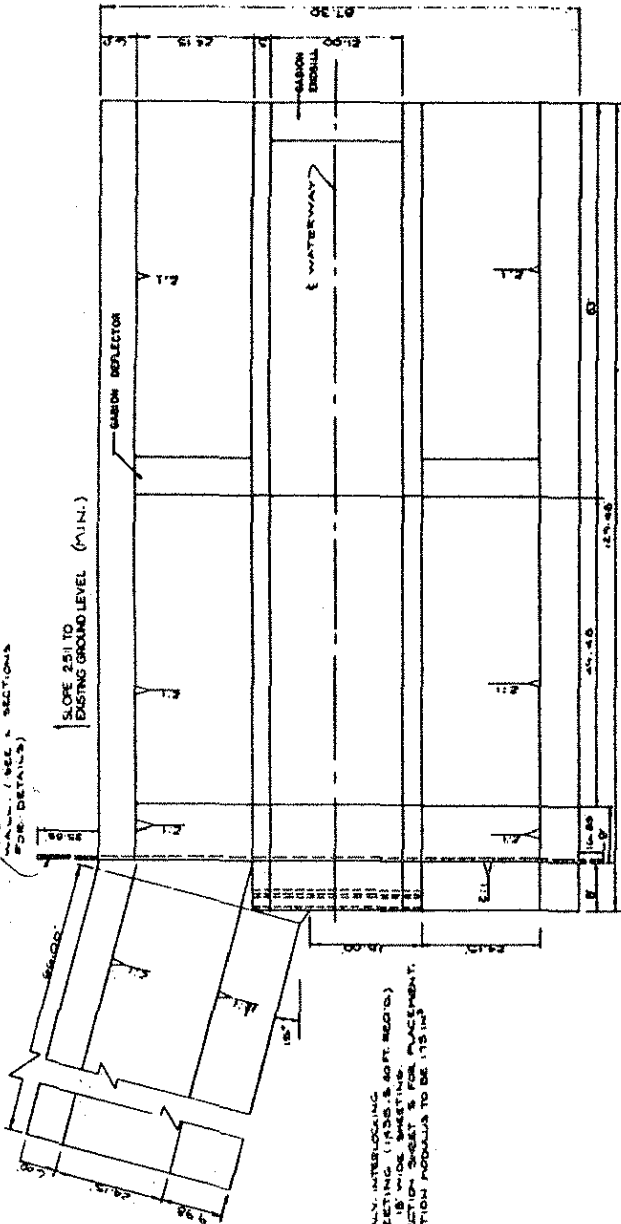
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97	1/2"	10.0	1.1
98	1/2"	10.0	1.1
99	1/2"	10.0	1.1
100	1/2"	10.0	1.1

NOTES:
1. BARS TO BE USED IN STEEL SHEETING FOR CURTAIN WALL. SEE DETAILS THIS SHEET.
2. 50 BARS TO BE USED TO STAKE GABIONS. SEE SHEET C.

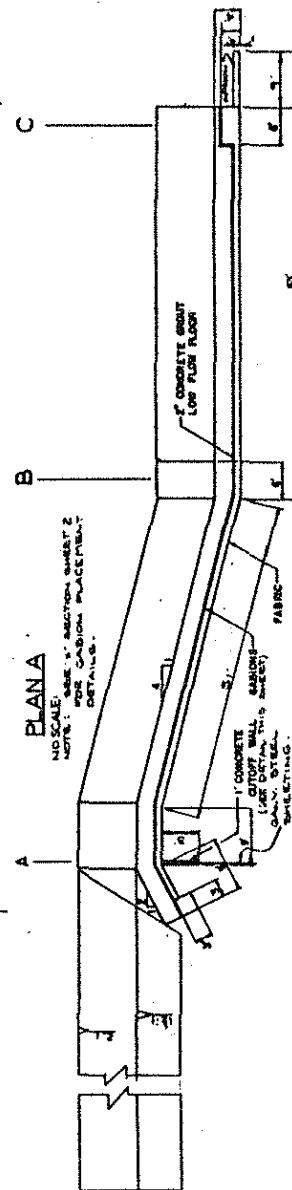
102 TOTAL EST. WT.

LONG AND STEEL SHEETING CURTAIN WALL (SEE SHEET C FOR DETAILS)

SLOPE 25:1 TO EXISTING GROUND LEVEL (MIN.)

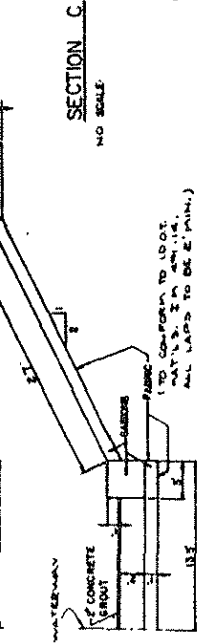
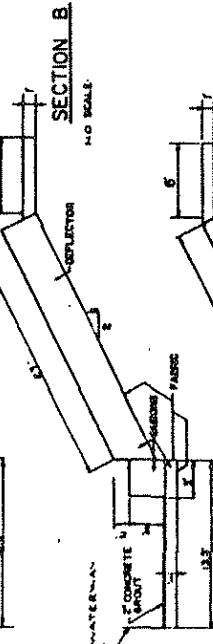
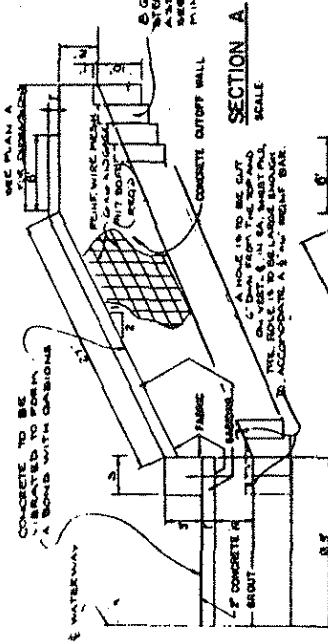


PLAN A
NO SCALE
NOTE: SEE SECTION SHEET 2 FOR GABION PLACEMENT DETAILS.



PROFILE at C
NO SCALE

GABION NOTES:
1. ALL GABION MATERIAL TO CONFORM TO SUPPLEMENTAL SPECIFICATIONS ATTACHED TO THE PROPOSAL FORM.
2. GABION MATERIAL TO BE OF THE GREATER "MAY" TYPE TO HAVE CHARACTERISTICS OF CLASS "D" REVEALED AS PER I.D.T. STD. SPEC. SHEET 101. GABION MUST BE ALLOWED A GABION END ITEM.
3. GABION MATERIAL TO BE COVERED WITH CHAINLINK FENCE TO CONFORM TO I.D.T. MAT. 101.14 (16.25' x 31' FOR LARS = 10,205.60 sq. ft.)
4. COST TO FURNISH AND PLACE GABIONS AND CHAINLINK TO PLACE STRUCTURE IS TO BE INCLUDED IN THE BID PRICE OF THE GABIONS.



(TO CONFORM TO I.D.T. MAT. 101.14, ALL LARS TO BE 2" MIN.)

GABION STREAM STABILIZATION STRUCTURE
POTTAWATTAMIE COUNTY

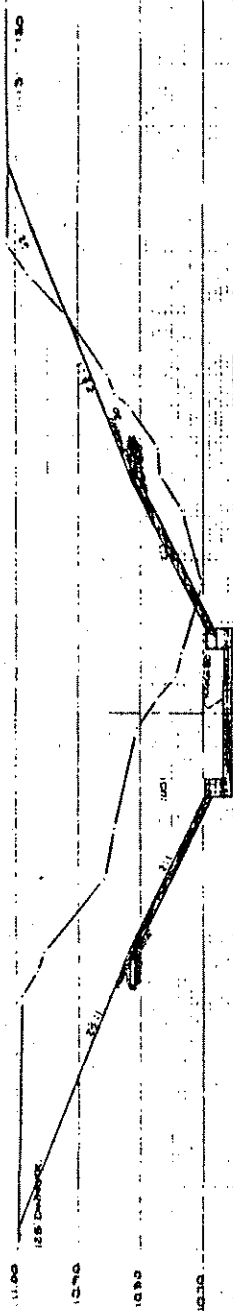
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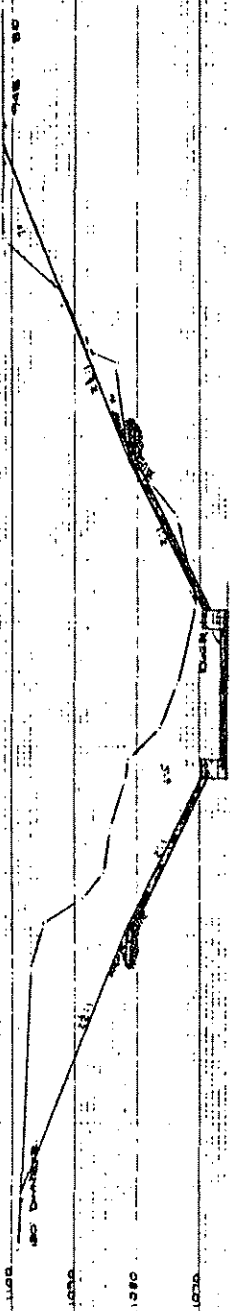
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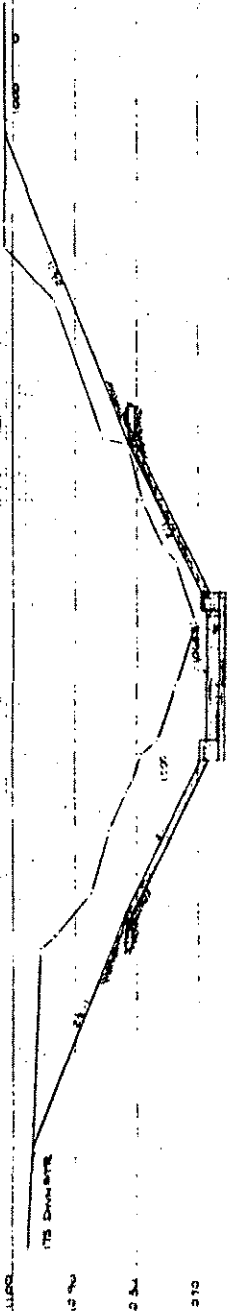
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16.30



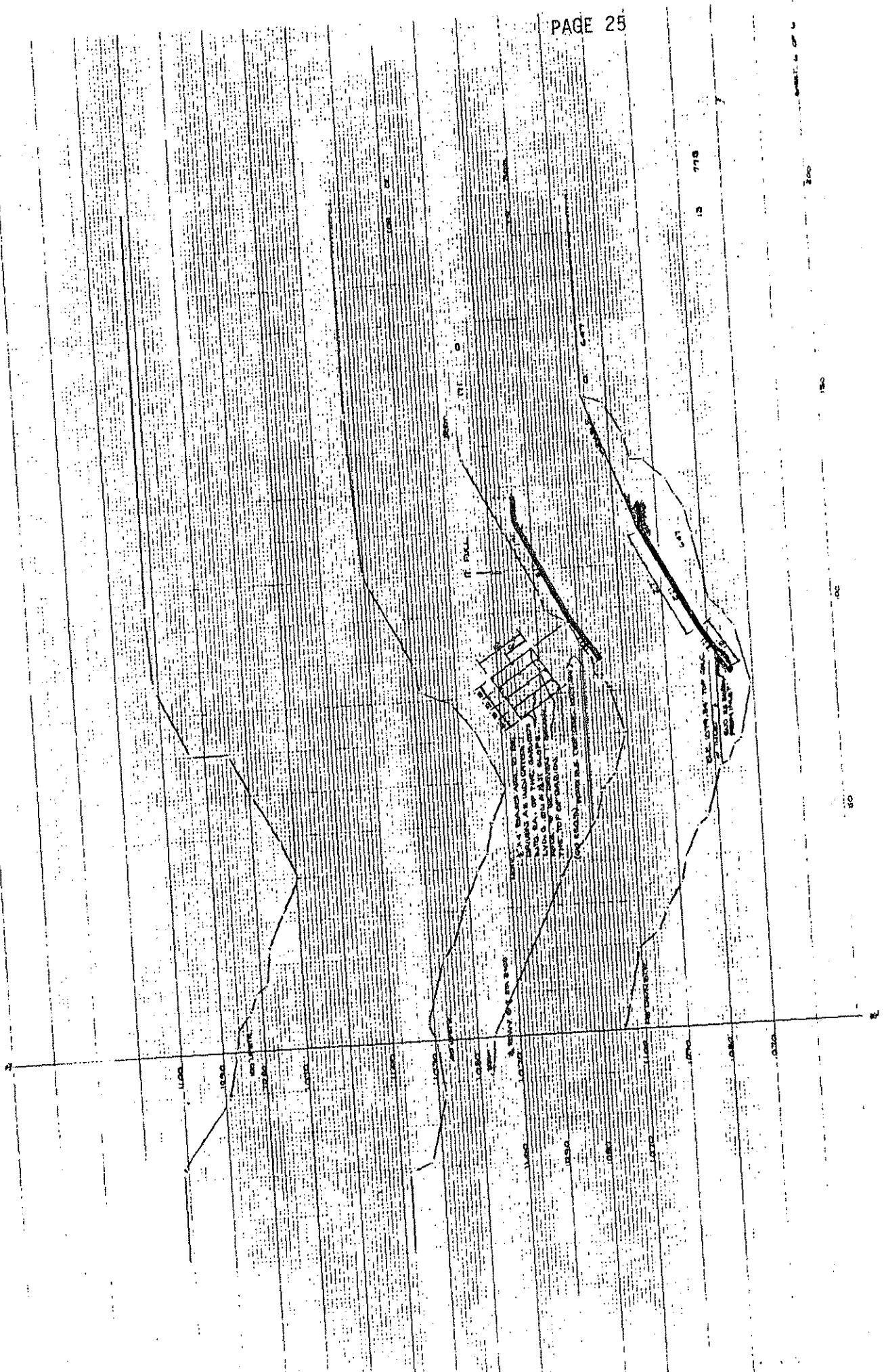
16.30



16.30

1. 16.30
2. 15.10
3. 13.90
4. 12.70
5. 11.00





Pottawattamie County Project SSS-1-82

Special Provisions Continued

(1 of 2) Structures

SPECIFICATIONSWIRE MESH GABIONS & MATTRESSESS-1. MATERIAL

- a. General The baskets shall be made of hexagonal triple twist mesh with heavily galvanized steel wire.
- b. Dimensions, Gabion The maximum linear dimension of the mesh opening shall not exceed $4\frac{1}{2}$ inches and the area of the mesh opening shall not exceed 8 square inches. Gabions shall be supplied, as specified, in various lengths and heights. The lengths shall be multiples (2, 3, or 4) of the horizontal width. The horizontal width shall not be less than 36 inches. However, all gabions furnished by a manufacturer shall be of uniform width. Dimensions for heights, lengths, and widths are subject to a tolerance limit of 3% of manufacturer's stated sizes.
- c. Dimension, Mattress The maximum linear dimension of the mesh opening shall not exceed $2\frac{3}{4}$ inches. Mattresses shall be supplied as specified, in various lengths. Dimensions for heights, lengths and widths are subject to a tolerance limit of 3% of manufacturer's stated sizes.

S-2. FABRICATION

These structures shall be fabricated in such a manner that the sides, ends, lid, and diaphragms can be assembled at the construction site into a rectangular basket of the specified sizes. They shall be of single-unit construction - the base, lid, and sides shall be woven into a single unit and the ends shall be connected to the base section of the wire structure in such a manner that strength and flexibility at the point of connection is at least equal to that of the mesh.

Where the length of the gabion exceeds four (4) feet the gabion shall be divided by diaphragms, of the same mesh and gauge as the body of the gabions, into cells of equal length and width. The gabion shall be furnished with the necessary diaphragms secured in proper position on the base in such a manner that no additional tying at this juncture will be necessary.

Where the length of the mattress exceeds (4) four feet the mattress shall be divided by diaphragms, of the same mesh and gauge as the body of the mattress, into cells of equal width. The mattress shall be furnished with the necessary diaphragms secured in proper position on the base in such a manner that no additional tying at this juncture will be necessary.

Pottawattamie County Project SSS-1-82

(2 of 2) Structures

All perimeter edges of the mesh forming the gabion shall be securely selvaged with wire of not less than 0.144" diameter so that the joints formed by tying the selvages have at least the same strength as the body of the mesh.

Lacing wire shall be supplied in sufficient quantity for securing and fastening all edges of the gabion, mattress, and diaphragms and connecting each unit to adjacent unit. Stay wire will be supplied in sufficient quantity to provide for the necessary internal connecting wires in each cell. For gabions, the lacing and stay wire shall meet the same specifications as the wire used in the mesh except its diameter shall not be less than 0.091". For mattresses, the wire shall not be less than 0.077"

The wire mesh shall be made of galvanized steel wire having a minimum diameter of 0.114" for gabion and 0.077" for the mattress with a tensile strength of at least 70,000 psi. The minimum zinc coating of the wire shall be 0.80 oz/sq.ft. as per Federal Specification QQ-W-461g.

S-3. CERTIFICATES OF COMPLIANCE

Each shipment of wire structures to a job site shall be accompanied by a certification which states that the material conforms to the requirements of this specification. A shipment shall consist of all material arriving at the job site at substantially the same time. The certification shall be on company letterhead and shall be signed by an officer of the company having legal authority to bind the company.

SPECIAL PROVISIONS

1. Supplier being manufacturer's representative shall furnish on site supervision of wire structure installation at the initial state of construction. He shall also be readily available to either the engineer or owner for on-site inspections as required.
2. Wire structures shall be subject to be tested by an independent testing laboratory to verify their compliance with contract specifications when required by either the owner, consultant, contractor or manufacturer.

APPENDIX B
Project Contract

CONTRACT

Gabion Flume
SSS-1-82

Miles _____
County Pottawattamie

AGREEMENT made and entered by and between Pottawattamie County, Iowa, by its Board of Supervisors, consisting of the following members: Hubert Houser, Arlene Steege, Wayne Rodenburg,
Elliott Butler and Roy Geiger

V.M. DeBuse Construction Co., Inc. of Omaha, Nebraska, party of the first part, and _____, party of the second part.

WITNESSETH: That the party of the second part, for and in consideration of Ninety-seven thousand

two hundred eighty-seven and 03/100 ----- Dollars (\$ 97,287.03)

payable as set forth in the specifications constituting a part of this contract, hereby agrees to construct in accordance with the plans and specifications therefore, and in the locations designated in the notice to bidders, the various items of work as follows:

Item No.		Quantity	Unit Price	Amount
1	Class ¹⁰ 20 Channel Excavation CY	4,250	4.00	\$17,000.00
2	Gabions CY	688.67	72.00	49,584.24
3	Structural Concrete Class "C" CY	55.5	200.00	11,100.00
4	Steel Sheet Piling SQFT	1,534.5	10.50	16,112.25
5	Engineering Fabric SQFT	18,303	0.18	3,294.54
6	Reinforcing Steel LB	192	0.50	96.00
7	Clearing and Grubbing (Engr. Est. \$100)	% of Est.	100%	<u>100.00</u>
TOTAL				\$97,287.03
As per bid opening September 16, 1982.				

Said specifications and plans are hereby made a part of and the basis of this agreement, and a true copy of said plans and specifications are now on file in the office of the County Auditor under date of _____, 19____.

That in consideration of the foregoing, the party of the first part hereby agrees to pay to the party of the second part, promptly and according to the requirements of the specifications the amounts set forth, subject to the conditions as set forth in the specifications.

That it is mutually understood and agreed by the parties hereto that the notice to bidders, proposal, the specifications for Pottawattamie Project No. SSS-1-82 Pottawattamie County, Iowa, the within contract, the contractor's bond, and the general and detailed plans are and constitute the basis of contract between the parties hereto.

That it is further understood and agreed by the parties of this contract that the above work shall be commenced on or before, and shall be completed on or

before: _____	Approx. or Specified Starting Date or Number of Working Days	Specified Completion Date or Number of Working Days
	40 Working Days	May 31, 1983

That time is the essence of this contract and that said contract contains all of the terms and conditions agreed upon by the parties hereto.

It is further understood that the second party consents to the jurisdiction of the courts of Iowa to hear, determine and render judgment as to any controversy arising hereunder.

IN WITNESS WHEREOF the parties hereto have set their hands for the purposes herein expressed to this and three other instruments of like tenor, as of the 23rd day of September, 1983.

Approved: _____ Pottawattamie County, Iowa

Contracts Engineer
Date OCT 28 1982

By _____ Chairman
V. M. DeBuse Construction Co., Inc.

By _____

APPENDIX C
Monument Locations and Settlement Readings

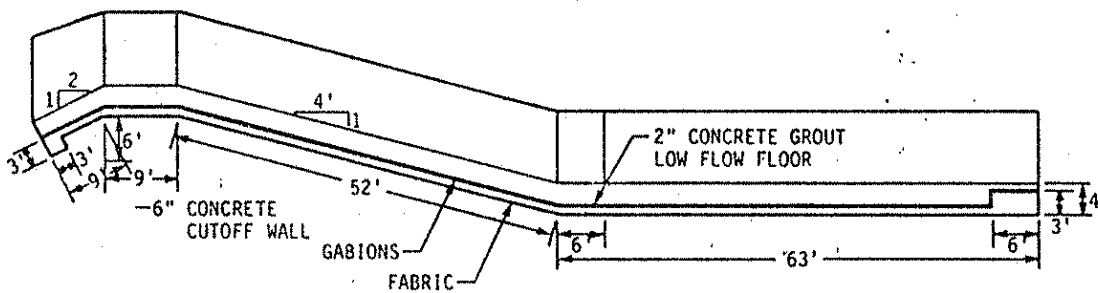
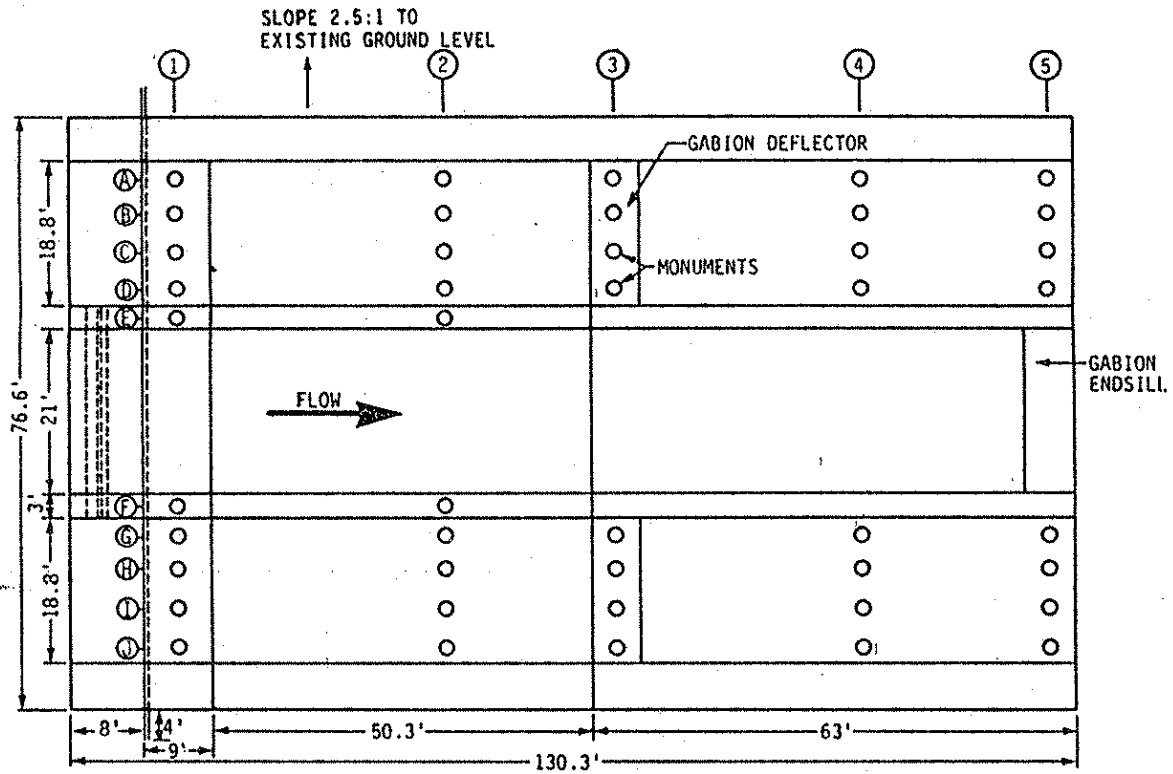


Figure 1. Plan of gabion drop structure showing location of monuments.

Monument No.	Elevation, Ft.					
	06-29-83	11-17-83	06-08-84	08-22-84	06-05-85	03-27-87
1A	1092.29	1091.80	1091.75	1091.85	1091.73	1091.75
B	1088.52	1088.51	1088.51	1088.65	1088.58	1088.53
C	1085.44	1085.44	1085.40	1085.53	1085.47	1085.43
D	1082.46	1082.46	1082.40	1082.60	1082.53	1082.52
E	1081.54	1081.49	1081.70	1081.66	1081.29	---
F	1081.45	1081.41	1081.45	1081.62	1081.27	---
G	1082.14	1082.18	1082.24	1082.41	1082.31	---
H	1085.42	1085.34	1085.35	1085.48	1085.46	1085.37
I	1088.33	1088.33	1088.23	1088.39	1088.28	1088.21
J	1091.98	1091.88	1091.80	1091.92	1091.76	1091.76
2A	1085.18	1085.15	1085.21	1085.36	1085.28	1085.17
B	1082.48	1082.52	1082.53	1082.69	1082.54	1082.50
C	1079.50	1079.49	1079.42	1079.61	1079.41	1079.42
D	1076.59	1076.80	1076.57	1076.68	1076.53	1076.44
E	1075.35	1075.44	1075.36	1075.50	1075.27	---
F	1075.31	1075.26	1075.24	1075.36	1075.14	1075.00
G	1075.96	1075.92	1075.94	1076.04	1075.92	1075.91
H	1078.88	1078.89	1078.89	1078.82	1078.94	1078.96
I	1081.67	1081.61	1081.65	1081.79	1081.68	1081.67
J	1083.74	1083.76	1083.78	1083.91	1083.96	1083.87

Monument No.	Elevation, Ft.					
	06-29-83	11-17-83	06-08-84	08-22-84	06-05-85	03-27-87
3A	1082.86	1082.70	1082.84	1083.00	1082.84	1082.82
B	1080.40	1080.37	1080.30	1080.48	1080.34	1080.27
C	1076.83	1076.85	1076.76	1076.93	1076.74	1076.60
D	*	1073.26	1073.29	1073.30	1073.29	1073.20
G	*	1073.28	1073.28	1073.42	1073.12	1072.96
H	1076.65	1076.70	1076.64	1076.82	1076.57	1076.60
I	1079.45	1079.52	1079.47	1079.66	1079.51	1079.60
J	1082.33	1082.26	1082.27	1082.42	1082.28	1082.30
4A	1080.43	1080.36	1080.38	1080.52	1080.40	1080.26
B	1077.37	1077.38	1077.25	1077.49	1077.28	1077.27
C	1074.15	1074.16	1074.09	1074.25	1074.10	1074.04
H	*	1073.61	1073.56	1073.67	1073.53	1073.62
I	1076.69	1076.72	1076.74	1076.88	1076.76	1076.72
J	1079.79	1079.76	1079.77	1079.94	1079.80	1079.84
5A	1080.63	1080.53	1080.57	1080.63	1080.58	1080.48
B	1077.83	1077.82	1077.81	1077.98	1077.85	1077.71
C	1074.99	1075.03	1075.03	1075.15	1075.01	1074.92
H	*	1074.08	1074.09	1074.13	1074.14	1074.02
I	1076.77	1076.87	1076.78	1076.93	1076.76	1076.73
J	1079.53	1079.51	1079.54	1079.75	1079.53	1079.53

* Monument under water