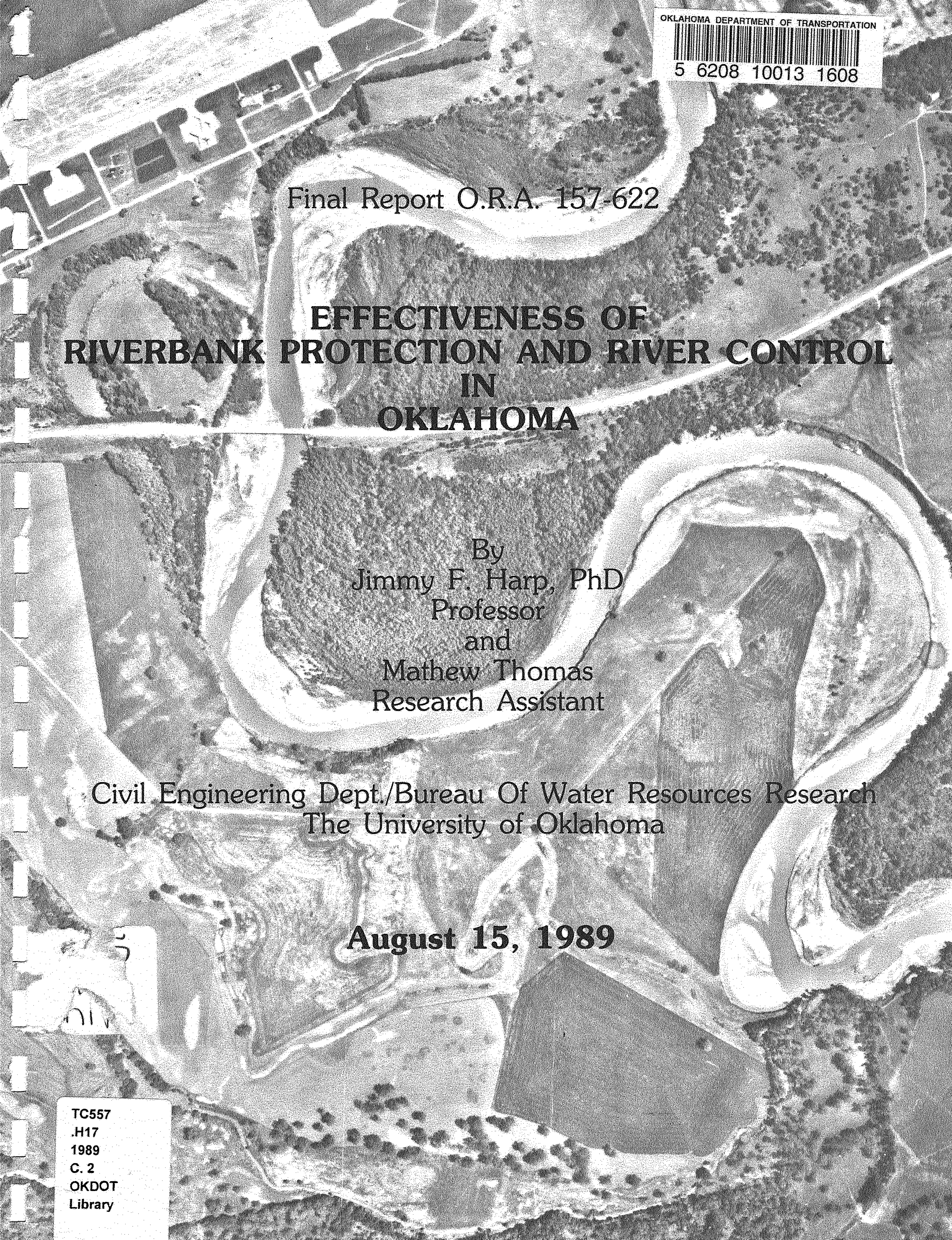

Final Report O.R.A. 157-622

EFFECTIVENESS OF RIVERBANK PROTECTION AND RIVER CONTROL IN OKLAHOMA

By
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Research Assistant

Civil Engineering Dept./Bureau Of Water Resources Research
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August 15, 1989

FINAL REPORT

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Submitted To

OKLAHOMA DEPARTMENT OF TRANSPORTATION

OKLAHOMA CITY, OKLAHOMA

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16. ABSTRACT

Bank stabilization and protection from flood ravages have been a continuing problem in Oklahoma as well as in the surrounding states for a very long time. Bridges and hydraulic structures are situated at river sites where the river must become mature and conform to a desirable or controlled regime. In Oklahoma, several large rivers and streams flow through the state. Primarily, two major systems exist in Oklahoma, the Red River and the Arkansas River systems and tributaries.

A detailed literature survey has been conducted to find various aspects of river training and bank stabilizing methods. Newer methods have also been investigated. A detailed case study of twenty-five river sites in Oklahoma has been conducted to determine the effectiveness of river training at these sites. Possible reasons for the success or failure of these methods have been elucidated and recommendations have been made for sites in which failures are evident or have already occurred.

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-- DISCLAIMER --

EXECUTIVE SUMMARY

The Oklahoma Department of Transportation has the tremendous responsibility for stabilizing the streambanks and river channels at the more than 6000 bridges and hydraulic structures that exist in Oklahoma.

Bridges and hydraulic structures require that the river or stream become mature there, or else bank stabilization has not been achieved. It was the purpose and goal of this study that the project should entail a historical evaluation of typical sites and a literature survey of existing and new methodologies of bank stabilization.

A computerized literature survey was performed using INFOTRAC, NTIS, COMPENDEX, and HRIS. A manual survey was conducted by contacting the USGS, the Corps of Engineers, the Waterways Experiment Station, the Bureau of Reclamation, and other sources. The relevant papers and articles were secured and reported.

Riverbank stabilization techniques were covered in sufficient detail for design purposes. The older techniques such as riprap, fences, gabions, bulkheads, spurdikes, and jetties were reported in detail. The newer techniques such as used tires, vanes , car bodies, palisades, and cellular blocks were presented in the context of their importance and relevence. Bank stabilization is deemed to be as much an art as a science.

Evidence of this conclusion lies in the fact that custom bank rebuilding, stabilization , and protection service is available from at least one

private source. The liability from such a noble venture is indeed great, and absolute success is not possible.

The twenty sites studied by ODOT in 1971 were re-examined, along with five new sites designated by ODOT. Each site was visited, photographed, inventoried, and studied. An assessment of each site was made in light of the success of the original stabilization procedure and the existing conditions there at this time. Some site structures had been replaced, some relocated, and additional stabilization works had been added.

Other work was performed during the study, and other new work is planned, some of it being the result of the field investigation during this project.

Recommendations and conclusions are presented with regard to the appropriatness of different bank stabilization techniques.

Possible reasons for past success and failures are also presented as a result of the site studies and specific investigational procedures. The project results are deemed applicable not only in Oklahoma, but nationwide.

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CHAPTER I

INTRODUCTION

Bank stabilization and protection from flood ravages has been a continuing problem in Oklahoma, as well as in the surrounding States, for a very long time. The problem of stabilizing banks near hydraulic structures is even of greater magnitude than is immediately apparent. This is further evidenced because of the applied solution technique, which has been to configure the structure so that the elevation of low beam is greater than the recorded high water mark, and to provide a sufficient waterway opening for safe operation.

Bridges and hydraulic structures are situated at river sites where the river must become mature, and conform to a desirable or controlled regime. So, with urban and rural development, the rivers in the state are steadily becoming more mature all the time.

In Oklahoma, several large rivers and streams flow through the state.

Primarily two major systems exist in Oklahoma, the Red River and the Arkansas River systems and tributaries. These systems generally flow from northwest to southeast and are located on alluvial flood plains. The alluvium, which makes up the valley floor and the relatively flat gradients, allows the river systems to braid and meander.

It is generally agreed among experts that the north/south rivers meander while the east/west rivers braid. This process is further complicated by accretion and avulsion processes. Accretion is defined as the slow and imperceptible action whereby the streambed erodes on one bank and deposits on the other over a period of time. Avulsion is a revolutionary movement of the river which occurs over a short period of time when the river channel moves to a new position and abruptly abandons the old channel.

In any event, Oklahoma rivers attack banks, destroy farmlands, and take lives and property on a regular basis. The problem has virtually been a plague to cities, states and federal agencies responsible for safety and roadway integrity.

On a local basis, landowners have sought to straighten, align, and to armor banks in their effort to contain the river and to protect themselves from flooding and its effects.

Besides the cost of the initial bank stabilization action, a significant maintenance cost is required to sustain any improvement, if in fact it can be sustained. Another major problem with river channel changes is the great likelihood of induced movement of the river either upstream or downstream from any so-called improvement. The associated liability with any action is cause to consider closely any form of bank stabilization.

Meandering is a result of flow fluctuations or the rotation of the earth, or both. In recent times, great emphasis has been placed on the site changes at one place and the resultant site changes at other places with and by means of aerial photography sequences from the 1930's until the present time at about eight year intervals. These photographs are generally available from the Aerial Field Photography Laboratory, United States Department of Agriculture, Salt Lake City, Utah. The older photographs, pre-1950, have been moved to Washington D.C., in the National Archives, and are available only by special order.

River bank stabilization is achieved at bridges or hydraulic structures because the channel there becomes fixed or mature. In Oklahoma and Arkansas, the Arkansas river has been dammed with locks and structures until a high degree of maturity has been achieved. Actually, the original goal of control and stability has been achieved, as well as the goal of navigability. With increased stability of the river itself comes the stability of the bank protection measures. The other Oklahoma rivers are not navigable, and are not mature generally, except at hydraulic structure locations, or at natural geologic barriers. Similarly, with the maturity of the river channels, once the bank protection measures have been installed, they tend to be permanent. One might say that in mature rivers, once channelized, always channelized, as a general rule.

Summarily, bank stabilization protection measures are designed as much as an art, as a science. What works in one place may not be the solution at another place. The frontier of knowledge exists close at hand in this disciplinary area of endeavor.

PURPOSE AND SCOPE :

The goals and intents of the present effort are stated as follows:

1) To examine bank stabilization structures, both selected new and the sites originally investigated by Keeley (9).

2) To evaluate the performance of bank stabilization techniques on a rational basis based on a review of the various techniques used on some Oklahoma rivers.

3) To document the changes noted in river channel location and deposits associated with the river control structures.

4) To provide an assessment of the present condition of various devices and make repair recommendations where appropriate.

5) An investigation of new countermeasure techniques that might be useful or fruitful to the Oklahoma Department Of Transportation.

CHAPTER II

LITERATURE SURVEY

In order to arrive at the frontier of knowledge in the area of bank and stream stabilization techniques a literature survey was conducted. This survey was done by computer access and manual techniques.

a. **MANUAL SURVEY:**

This was done mainly at the University of Oklahoma, Norman Library. Available books and journals were scanned to find the literature relevant to the subject. The INFOTRAC, a computerized databank, was also used to help in locating the articles and papers. References that could not be located in the libraries were secured from other institutions through interlibrary loan. A trip to the Corps of Engineers office in Tulsa was also made in order to secure the information available. The USGS and the Bureau of

Reclamation in Oklahoma City were also solicited. The Soil Conservation Service, in Norman, was also contacted for their input. Some of the references were purchased from various sources.

b. COMPUTERIZED SURVEY:

This survey was performed using computerized databanks from The Highway Research Information Service (HRIS), The National Technical Information Service (NTIS), and COMPENDEX. The HRIS was conducted through the auspices of the Oklahoma Department of Transportation. Several key words were used to scan the databases to retrieve relevant articles and papers. Some of the key words were BANK, PROTECTION, RIVER, STREAM, KELLNER, GABION, ARMOR, RIPRAP, GEOFABRICS, etc. Once the references were located abstracts were printed out. The abstracts which were printed were then examined for relevancy to the topic under consideration. Selected references could be ordered from the relevant agencies. The references, that were used, were extracted from over 15,000 references on all the three systems combined. Figure 1 gives a typical response from the computerized literature survey that was conducted on the HRIS system. Similar procedures were conducted for the other two systems.

Set	Items	Description
1	1118	BANK
2	9993	PROTECTION
3	33	BANK(W)PROTECTION
4	0	
5	14	RIVERBANK?
6	15	STREAMBANK?
7	3009	RIVER?
8	2193	STREAM?
9	1859	BANK?
10	82	(RIVER? OR STREAM?)(2N)BANK?
11	108	RIVERBANK? OR STREAMBANK? OR (RIVER? OR STREAM?)(2N)BANK?
12	1096	VEGETATION
13	5469	TIRE?
14	2893	FABRIC?
15	1	KELLNER?
16	45	GABION?
17	309	RIP?
18	128	ARMOR?
19	9785	VEGETATION OR TIRE? OR FABRIC? OR KELLNER? OR GABION? OR RIP? OR ARMOR?
20	13	11AND19
21	40	3OR20
22	4934	7OR8
23	222	22AND19
24	1859	BANK?
25	33	23AND24
26	57	21OR25

A typical response from the HRIS survey

FIGURE 1

THE ART OF BANK STABILIZATION

Bank stabilization is generally defined as the configuration methodology by which the bank is protected from the erosive action of the river. It is also called river training. It is the process by which the river is prevented from meandering in order to protect bank and bridge structures located downstream.

Streambank erosion is largely influenced by the river mechanics and the geometry of the stream. In a meandering stream, the place of maximum stream velocity and the thalweg lie close to the eroding concave bank. It has also been noted that, in case of large floods, the position of the maximum velocity of the water usually lies close to the convex bank (11)*.

If a stream carries a large amount of sediment then, in certain situations, increased deposition will occur on the banks which in turn leads to better erosion resistance. Conversely, the presence of fine sediment can increase the fluid density and viscosity whereby the transport capacity of the water is increased, which enhances erosion. The tendency of a bank to erode is also governed by vegetal cover. Studies have revealed that there is little correlation between the soil particle size gradation of a bank and its erodability (12).

When bank stabilization is referred to it usually applies to the lower bank of a river which is subjected to periodic flooding and hence to erosive action.

* Numbers in parentheses indicate REFERENCES

In the case of upper banks which are rarely exposed to flooding action, natural overgrowth is usually sufficient for its protection.

The eroding bank that has to be stabilized usually has to be sloped and graded before any stabilization work can be done. The guidelines for bank slopes in most areas are as follows (5):

Soil Type	Maximum Slope
Clay	1 - 1.25 : 1
Loam	1.50 - 2 : 1
Sand or Gravel	2 -4 : 1

Causes of Riverbank Erosion:

1. **Abrasion** - The process whereby debris carried by the stream impinges against the bank causing bank materials to be dislodged and to be carried away by the current.

2. **Transport** - The process by which the turbulence and flow of the water in the stream dislodges soil particles, which are then suspended and transported by the water.

3. **Toe Failure** - The case, where the flowing water attacks the toe of the bank which causes it to fail. This phenomenon generally occurs when the water is receding in the river after a flood.

4. **Sloughing** - The action, usually confined to cohesive soil banks, where failure occurs due to the rapid fall of the river level, and the inability of the bank to drain rapidly.

5. **Liquefaction** - The process whereby sandy and silty banks simply flow away due to the excessive water content of the soil.

6. Wave Action - Wave action, due to wind or boat travel, is one of the causes of bank failures. This is because wave action causes erosion by transport as well as abrasion.

7. Seepage - This is also a prominent type of bank failure in which water seeping out of the banks may produce erosion at the bank mainly due to abrasion.

STREAMBANK PROTECTION METHODS:

Since early times, efforts in river stabilization have resulted in a number of methods that have been used effectively, and ineffectively, in many places. Every imaginable process or procedure has been attempted at one time or another.

Some of the most commonly used protection systems are listed below:

a. Riprap

b. Fences

c. Spur Dikes

d. Gabions

e. Bulkheads

f. Pile Diversions

g. Steel Jetties

h. Other

The effectiveness of these structures are notoriously site-specific. Experience has shown that a structure which works effectively at one site may be a total disaster in another. Selection of a particular countermeasure requires site specific analysis and engineering judgement. Some brief details of the above listed protection systems are given below:

RIPRAP

INTRODUCTION:

Riprapping a bank or embankment consists of placing rocks, or other hard material, so as to absorb the impact of water on the banks and hence prevent erosion. Riprap is placed with or without filter blankets depending on various factors. Riprap protection is dependent upon economic considerations. It depends upon the availability of hard, sound, and low absorbency stones, locally. Transportation and equipment utilization also play an important part in the decision. Car bodies or old tires are not genuine riprap applications. Certain precast concrete interlocking elements are available which are manufactured by private companies that have certain advantages. Gabions are also considered to be a proper riprap method.

ADVANTAGES OF RIPRAP:

1. Riprap is economical, when available in a large quantity locally.
2. Riprap protection is flexible, and its usefulness is not affected by embankment movement due to minor settlements. Moreover, local damage can be repaired easily.
3. Riprap construction is not a complicated process.
4. There are little or no foundation problems.
5. Riprap appears to be a natural element, and hence can be used to blend into the natural environment. Riprap also encourages the growth of vegetation which gives the structure added integrity and stability.

6. The rock constituting riprap can possibly be reused after its useful application life.

PLACEMENT OF RIPRAP:

Riprap should be placed in such a way that no segregation takes place. It should be dumped directly from a truck, and should not be placed by dropping down the slope in a chute, or pushed downhill with a bulldozer. Riprap placed by hand gives a very smooth appearance, but this is a costly process as compared to placement with power machinery. The thickness of the riprap should be enough to accommodate the largest stones in the riprap. This is particularly true for well graded riprap. If strong wave action is expected to act on the riprap then the recommended thickness should generally be increased by about 50% (4).

FILTERS BLANKETS FOR RIPRAPS:

Filters are used in the prevention of erosion of soil beneath the riprap (4). Before placing the riprap, a filter blanket material should usually be placed. Filters are used to prevent erosion of the soil beneath the riprap.

Types of Filters:

1. **Gravel Filters**:

Layers of well graded gravel are to be placed over the embankment or riverbank prior to the placement of riprap. The thickness of the filter layer should be at least half the size of the riprap layer. Some gradation specifications are as follows (4):

a. $\frac{D_{50}\text{(filter)}}{D_{50}\text{(base)}} < 40$

b. $5 < \frac{D_{15}\text{(filter)}}{D_{15}\text{ (base)}} \leq 40$

c. $\frac{D_{15}\text{(filter)}}{D_{85}\text{ (base)}} \leq 40$

where D_{15} is the median diameter of sediment particles of which 15 percent are finer.

D_{50} is the median diameter of sediment particles of which 50 percent are finer.

and D_{85} is the median diameter of sediment particles of which 85 percent are finer.

2. **Plastic Filter Fabric:**

In this case filter fabric is laid beneath the riprap. Care must be taken to prevent damage to the fabric material while placing the riprap. There are many commercially available materials of various strengths that will cater to specific needs. The influx of many geo-synthetic fabrics into the market recently, meets a wide variety of applications.

DESIGN OF RIPRAP:

One of the important factors that should be remembered in riprap design is that it is rarely economically feasible to design for the extreme conditions (3). Hence small damages during major floods should be anticipated. Since the repair of riprap is not difficult, this has not been a problem. The following design elements of riprap have been taken from (3).

Factors governing the design of riprap:

1. It is usually the outer bank that is exposed to the direct attack of the river. Hence, it should be kept in mind that the riprap should be more resistant to erosion on the outer bank than on the inner bank. The riprap should be so placed that the transition from non-riprapped to riprapped banks is smooth.

2. Side-slopes should not be greater than about 1.5V to 1H, wherever possible. This requirement is necessary because flatter slopes need thinner riprap cover and is also helpful to stimulate the growth of vegetation. Exceptions may be made in narrow channels where the necessary space may not be available. The angle of repose should always be considered in the design.

3. Stones of adequate weight, granite, gypsum, etc., should be used to resist erosion and a section of at least two layers of overlapping stones should be provided, especially in cases where wave action is expected.

4. It is always advisable to use one or more layers of filter materials to prevent the wash out of bank materials beneath the riprap. Stones like granite and gypsum are adequate for this purpose.

5. The critical areas of the outer bank subjected to the maximum stress should be reinforced using heavier and thicker riprap, making the slope as flat as possible and by using a stronger riprap toe.

SPECIFICATIONS:

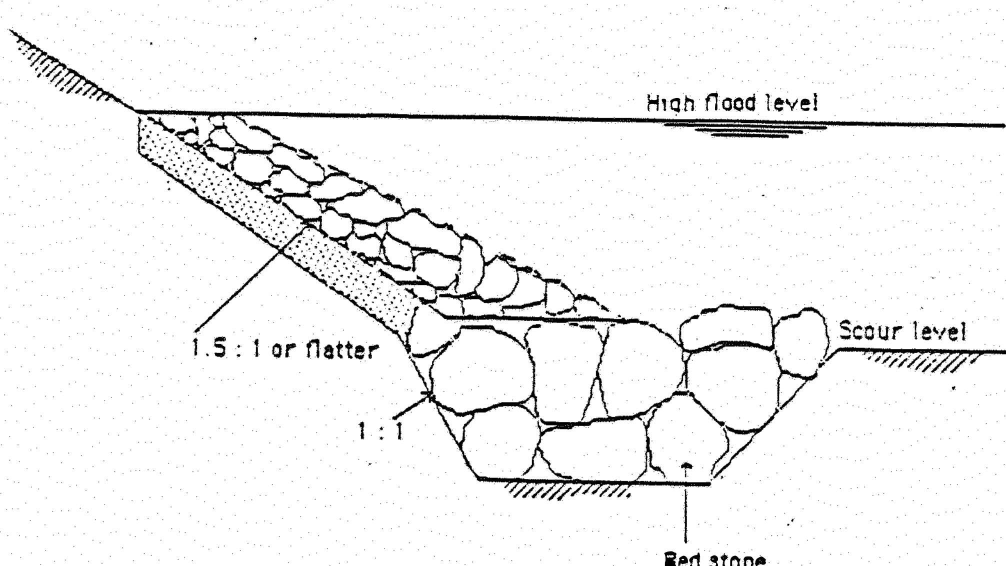
There is an important difference in the specification of riprap and other structural emplacement material. This arises from the fact that the stone available for riprap construction may vary from region to region and hence appropriate allowances should be made.

1) <u>RIPRAP PLACEMENT:</u>

There are basically two methods of placement of rocks. Placement is specified with respect to the rock-toe as well as to the arrangement of the riprap on the side slope. They are as follows:

a. Method A Placement

This method involves excavating a footing trench, and placing larger rocks in the trench. Surface rocks are placed with their longitudinal axis perpendicular to the rock surface or dipping gently inward. Rock dumping is not permitted and local irregularities shall not vary by more than about one foot from the slope. The thickness of the riprap should be about 1.5 times the diameter of the smallest "immovable" rock. An illustration of this type of placement can be seen in Figure 2.



Method "A" Placement of Riprap

FIGURE 2

b. Method B Placement:

This method involves excavating a footing trench and placing the rocks so that the larger ones are located in the foundation, and a minimum of voids is present. Rocks may be dumped and leveled by bulldozers. Local irregularities shall not vary by more than one foot from the proposed slope face. The thickness of the riprap should be about 1.9 times the diameter of the smallest "immovable" rock.

2. <u>OPTIMUM SIZE OF THE RIPRAP:</u>

The procedure used by most engineers to design riprap applications has been initially to determine the weight of the outside stones required and to subsequently compute the size of the stones from the specific gravity of the material available. The computed weight of stones required has been well presented by (3):

$$W = \frac{0.00002\ V^6\ sg_r}{(sg_r - 1)^3\ \sin^3(\rho - \alpha)}$$

where: V = stream velocity in fps to which bank is exposed

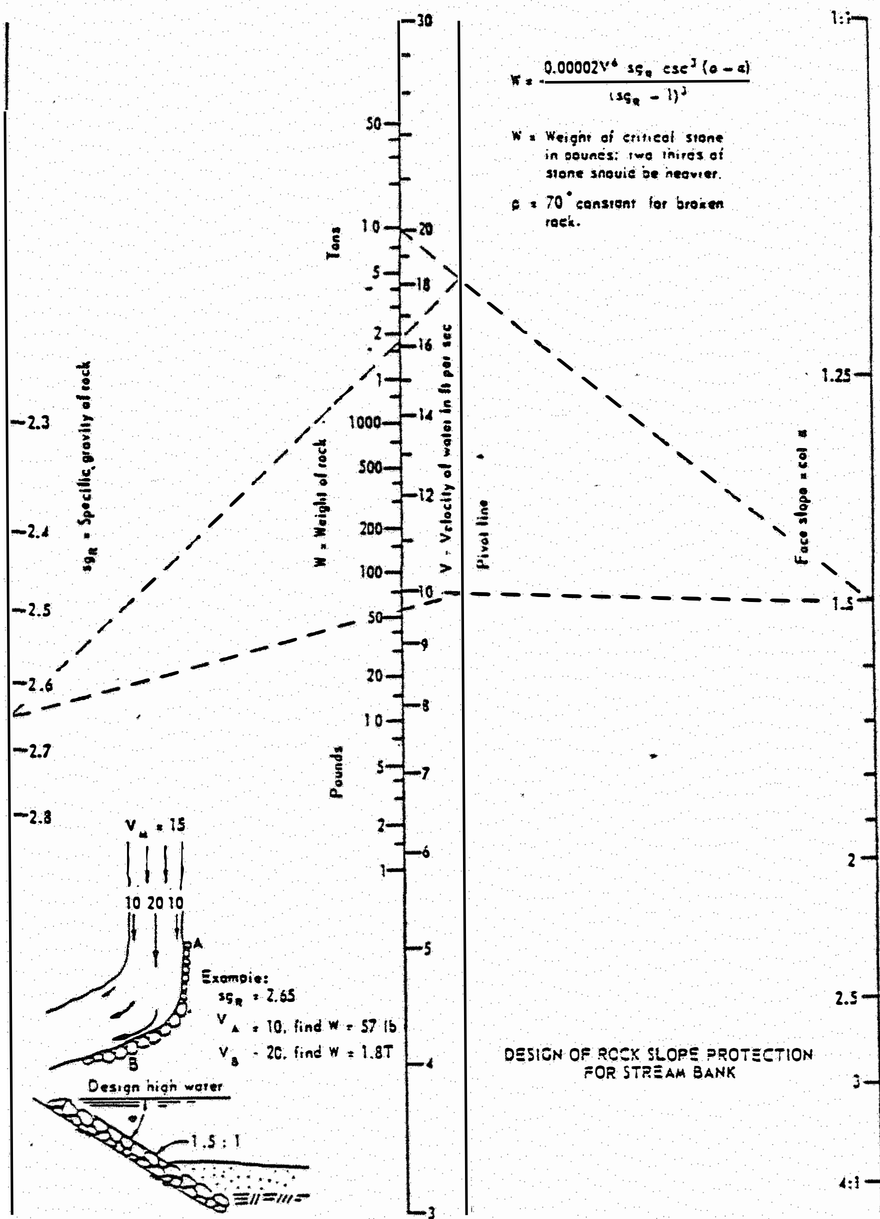
sg_r = specific gravity of stones

ρ = 70° for random placement

α = face slope (in degrees)

W = minimum weight, in lbs, of the outside stones

Upon computation of the stone weight, the physical size of the stone may be determined from the relation $W = 62.4(sg_r)(\text{volume})$. If the stone is assumed



Nomograph for Design of Riprap (3)

FIGURE 3

Mean stream velocity V_M	Parallel flow along tangent bank: Current velocity V_A	Minimum stone W	Protection class W_C	Placement method	Section thickness T	Impingement flow against curved bank: Current velocity V_B	Minimum stone W	Protection class W_C	Placement method	Section thickness
fps	fps	lb		A or B	ft	fps	lb or T		A or B	ft
4.5	3		None			6	3 lb	None		
6	4		None			8	15	Facing	B	1.8
7.5	5	1	None			10	57	1/4 ton	B	3.3
9	6	3	None			12	170	1/3 ton	B	3.3
10.5	7	7	Facing	B	1.8	14	430	1/2 ton	A	3.3
									B	4.2
12	8	15	Facing	B	1.8	16	950	1 ton	A	4.2
									B	5.3
13.5	9	30	Light	B	2.5	18	1.0 T	2 ton	A	5.3
15	10	57	1/4 ton	B	3.3	20	1.8	4 ton	A	6.7
18	12	170	1/3 ton	B	3.3	24	5.5	8 ton	A	8.3
21	14	430	1/2 ton	A	3.3	28	13.7	Special		
				B	4.2					
24	16	950	1 ton	A	4.2	32	30.4	Special		
				B	5.3					

Basic data and assumptions: velocity ratios $V_A:V_M:V_B = 2:3:4$; specific gravity of rock is $sg_r = 2.65$; face slope of revetment is 1.5:1; stones grade uniformly between specified minima for class with two thirds heavier than minimum required on face; $T = \frac{1}{3} \sqrt[3]{W_c}$, plus 25% for Method B.

$$W = \frac{2 \times 10^{-5}\, V^6\, sg_r}{(sg_r - 1)^3 \sin^3(\rho - \alpha)} = \frac{.00002\; V^6 \cdot 2.65}{1.65^3 \quad .592^3} = .000057\, V^6$$

FIGURE 4

Application of Figure 3 in Revetment Design (3) spherical, then:

$$D = \frac{(6W)^{1/3}}{(62.4\ sg_r)^{1/3}}$$

where D is the diameter of an ideal sphere.

In engineering practice, spherical stones are not feasible or practical, so that a stone of "equivalent diameter" is used. Angular stones may be selected on the basis of weight, equivalent diameter, or other equivalent quantities. Flat stones are obviously not desirable. The optimum size of riprap is the minimum size necessary to provide a stable bank or bottom to resist the specified design flow.

3. <u>SOUNDNESS AND DURABILITY OF THE ROCKS:</u>

Durability of rocks is also important, especially in applications where there is exposure to wave action. A durability of 52 minutes, as recommended by California Test 229 E, is usually sufficient (3).

<u>GROUTED RIPRAP:</u>

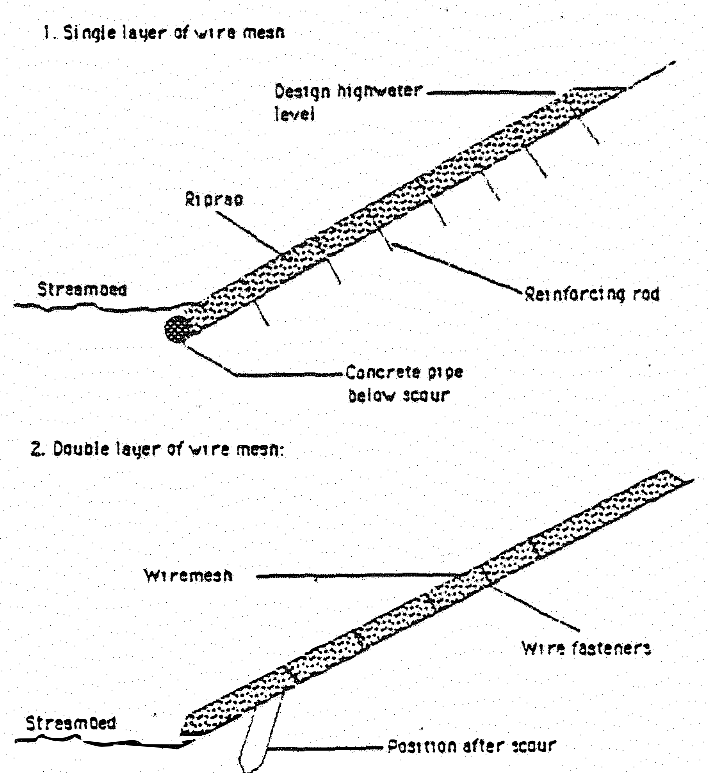
Grouted riprap is used in some applications primarily due to the nonavailability of large, sound, and durable rocks. For small smooth riprap the grout should penetrate, at least 6 in., while in larger rocks the penetration should be about 18 in. (3). Grout should be used only above the usual water level and all instances of use of riprap underwater should be done with the use of larger riprap or with gabions (5).

ROCK RIPRAP AND WIRE MESH:

1. Single Layered Wire Mesh - In this case the riprap is laid out and then a layer of wire mesh is placed over the riprap. A heavy weight or anchor is used to hold down the ends of the wire mesh.

2. Double Layered Wire Mesh - In this case two layers of wire mesh are used, one below and one above the riprap. This gives additional stability to the structure and allows the structure to shift in case of loss of support due to undermining by scour.

The wire mesh is held down by pins which are made of high tension steel. Figure 5 shows an illustration of these types of wire mesh riprap structures.



Types of Rock Riprap and Wire Mesh

FIGURE 5

FENCES

This method of bank protection has been used for a long time. It consists of putting up fences (usually permeable) into the stream so as to reduce the water current velocity in order to induce deposition. Different types of fences are available catering to high and low bank protection. These two basic types can be seen in Figure 6. The two main commercially used types of fencing are:

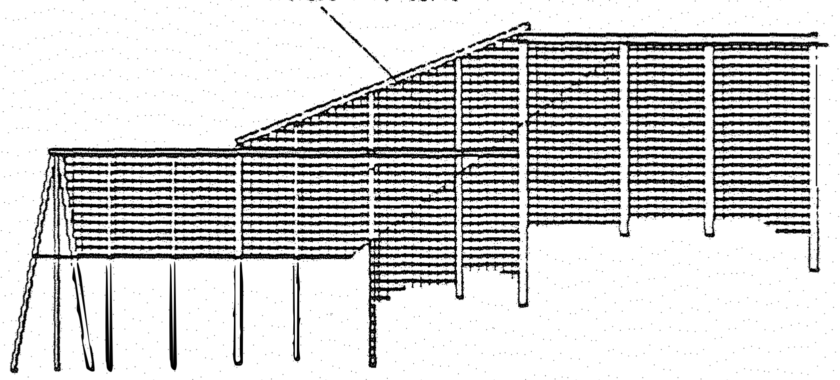
a. Henson Type:

The Henson type consists of 2 in. by 8 in. wood segments mounted on a frame on 18 in. centers. Individual units are about 20 ft. in length. The type patented by a commercial corporation known as "Hold That River", a Houston based company, (U.S. Patent No. 3,333,320),also known as "ERCON", allows the wood panels to move in the vertical direction. This is to account for the scour that is induced due to the presence of the fence. An illustration of this type of fence is shown in Figure 7.

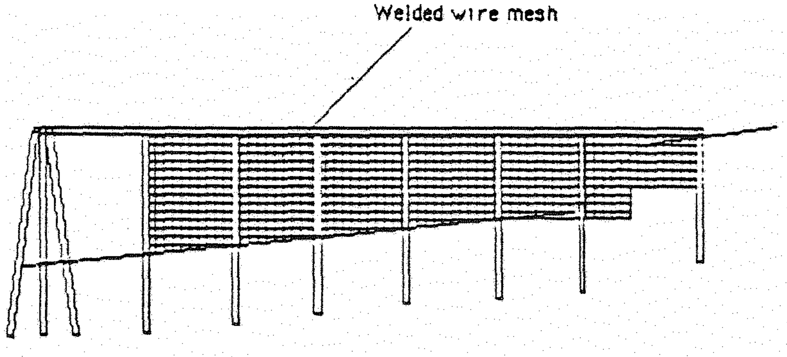
b. Palisade:

The Palisade procedure is a relatively new method in the art of bank protection. It has also been developed by Ercon Development Corporation, with their design still patent pending. A comprehensive study has been done on this method according to (10).

The Palisade basically consists of placing a net (either nylon or other strap material) between steel pilings.



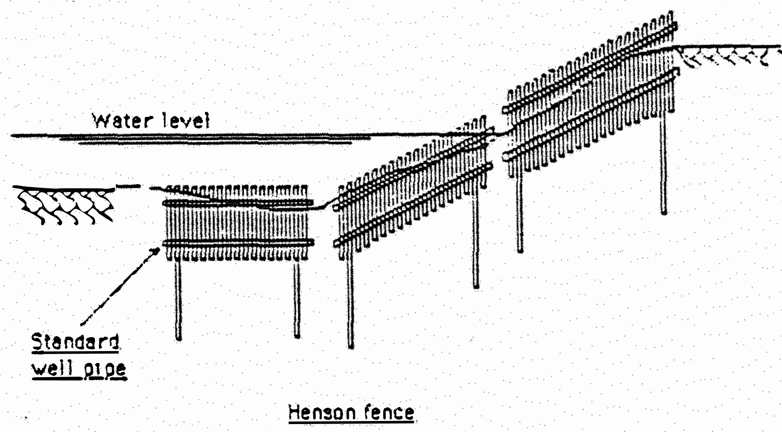
Steel pile and wire mesh fence (high bank design)



Steel pile and wire mesh fence (low bank design)

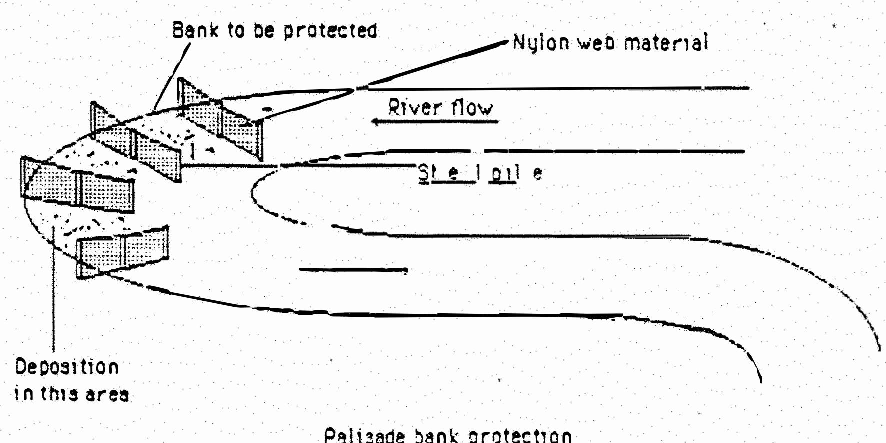
High and Low Bank Fencing Methods

FIGURE 6



Henson Type Fence Structure

FIGURE 7



Palisade Bank Protection Unit

FIGURE 8

This structure extends from the river bank out into the river. An illustration of the palisade can be seen in Figure 8. The construction of this system is done by Shoreline Technology, a construction company based in California.

The construction involves driving steel piles, placed at a spacing of 16 feet center-to-center, and are oriented normal to the streambank. Each row has several pilings, and each row is placed at about 40 foot intervals, depending upon the stream conditions and the bank to be protected. The theory behind the Palisade protection lies in the fact that the netting will reduce the velocity of water in that area thus encouraging deposition of silt, hence reducing the erosive potential.

After a three year evaluation of the system the following results were drawn (10).

1. Noticeable deposition was observed in between the palisade structures which mainly consists of silt.

2. The construction of the system does not disturb the environment and there was no observed change in the vegetation pattern of the bankline.

3. There was a noticeable reduction in the water velocities in the palisade field and outside the field, the reduction being from 4.8 fps to 0.8 fps, on an average.

4. There was no major impact on aquatic and terrestrial wildlife.

5. For certain fish species this system apparently had a better effect than riprapped sites.

On the whole this system seems to be very effective when the environment is a major factor under consideration. No statement can be made about the survivability of the system in the event of a major flood.

GABIONS

Gabions are basically wire baskets (usually rectangular in shape) filled with rocks. They are a variation of riprap except that in this case the rocks are kept together by a wire basket. The steel wires used are usually galvanized and are woven or welded in a hexagonal pattern. The use of a particular size of gabion is site specific. Different types of Gabion baskets are shown in Figure 9.

Advantages of Gabions:

Advantages of using gabions are listed below (2):

1. **Flexibility** - Since gabions are not rigid structures they can adjust to settlement differential.

2. **Strength** - The wire that binds the rocks together gives the gabion strength to withstand water and earth forces. They are particularly suitable to absorb wave action.

3. **Durability** - Soil that fills the gabion voids and flora that grow on it aids in the bonding of stones. The woven design of the wire has been demonstrated to be durable.

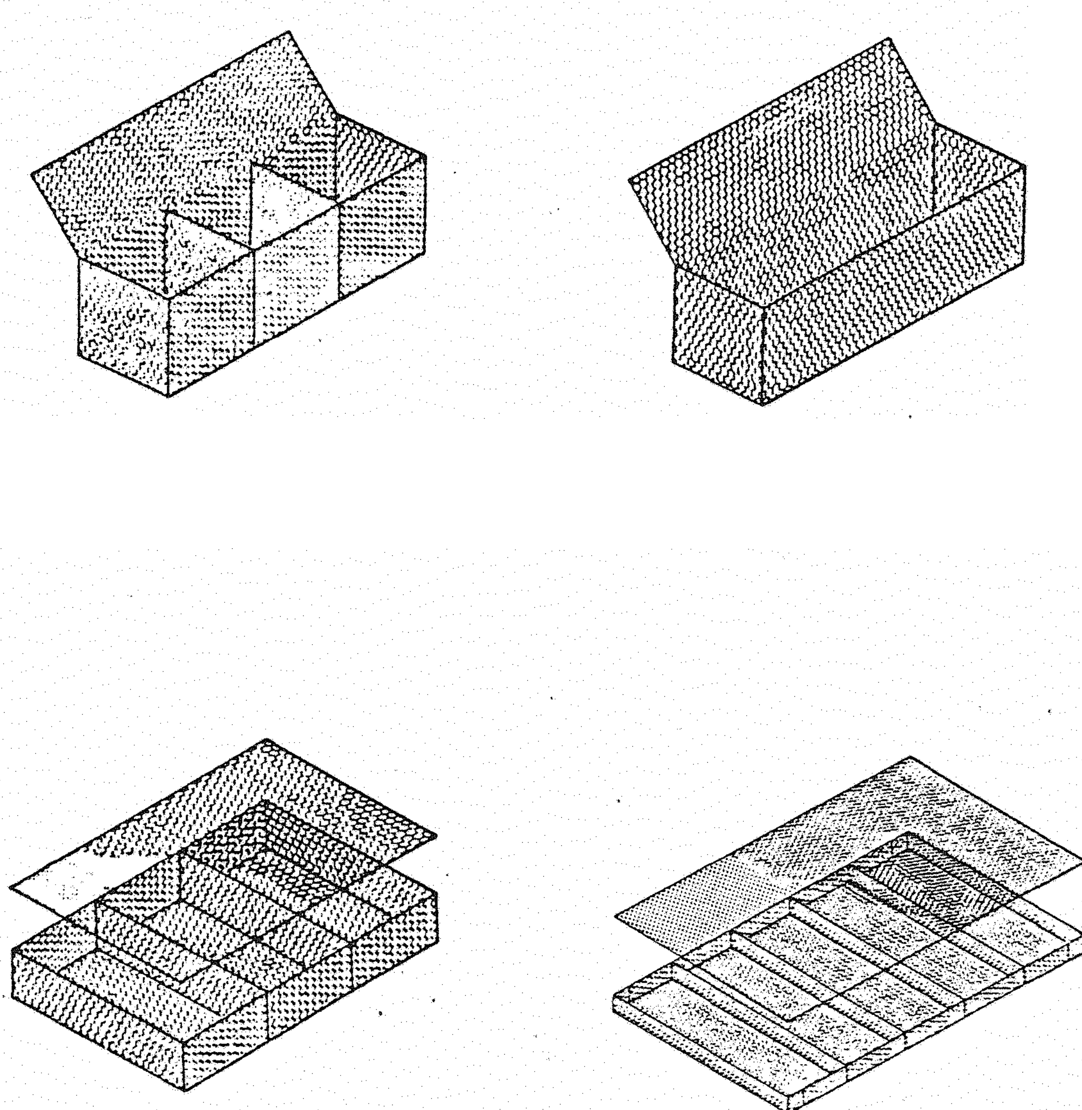
4. **Natural Appearance** - Gabions tend to encourage plant growth and hence will blend into the surroundings.

5. Filter fabrics may be used behind the walls to prevent sloughing, piping and settlement.

Disadvantages of Gabions:

Some of the arguments against the use of gabions are (2):

1. Gabions can easily be undermined by scour and hence can be a potential hazard.



Some Types of Gabion Cages (27)

FIGURE 9

2. Gabion appearance may be adjusted with rock size and rock type.

3. The wire baskets may be dangerous to fish due to abrasion.

4. If the sediment transported by the stream is coarse then the wire can be abraded and the gabion may fail.

5. In high chloride water, rapid deterioration of the wire is a factor.

6. High density polyethylene baskets are available for highly corrosive conditions.

<u>Gabion Groins:</u>

Gabions are used extensively in the form of gabion groins. A groin may be defined as a structure which extends from the river bank into the channel. Some of the types of groins are (2):

a. **Straight Type** 1. Normal to the stream
2. Inclined upstream/downstream

b. **Hammer-Head or T-Head type**

c. **Bayonet/Hockey stick type**, inclined upstream/downstream.

d. **J-Head**

e. **L-Head**

The names of these structures are due to their shapes or orientation. Illustrations of these types of groins are shown in Figure 10.

The groins primarily function by diverting the flow away from the river bank and hence protecting it. They can and have also been used in river training works.

<u>Design of Gabion Groins:</u>

The design of groins has been taken from (2) and some of the essential features are as follows:

a. **Foundation:**

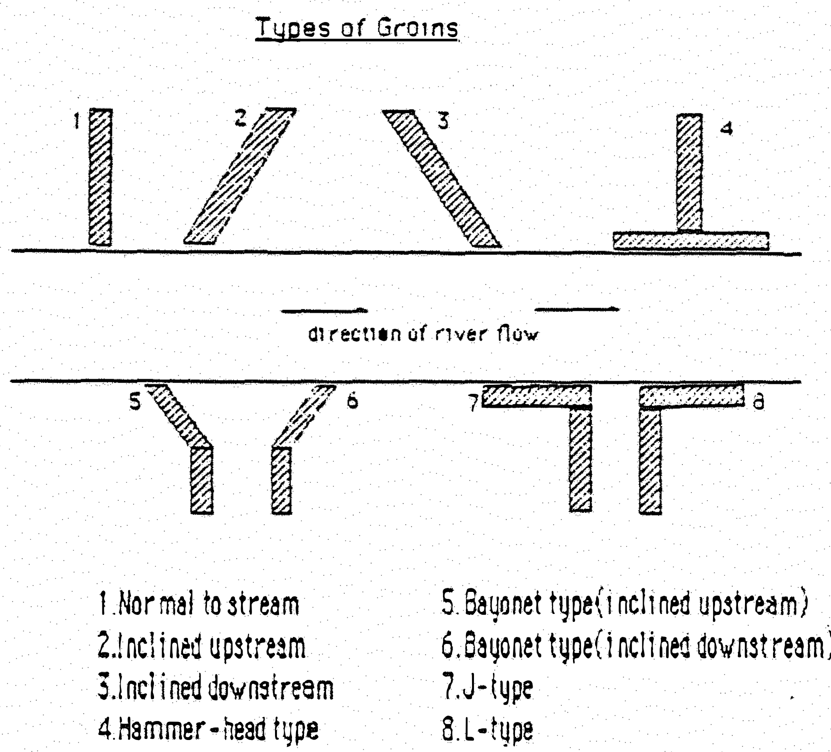
Gabions generally do not require an excavated foundation. If major scour problems are expected then some excavation is beneficial. In general, gabions are directly placed on streambeds and banks. Gabion mattresses are required for extensive applications to prevent undermining due to scour. Figure 11 shows a gabion spur supported with a gabion mattress. A gabion mattress consists of a number of gabions placed flat on the streambed and tied together. The mattress thickness should be sufficient to prevent lifting by the buoyant action of the water. Projection of the apron into the stream is basically estimated by the extent of the scour.

b. **Dimensions:**

Groin heights are usually designed to prevent the flood waters from cutting the root of the groin with the maximum height limited to the height of the flood plain. Gabion width can be in the range of 1 to 3 meters depending on the stability needed and the importance of the structure.

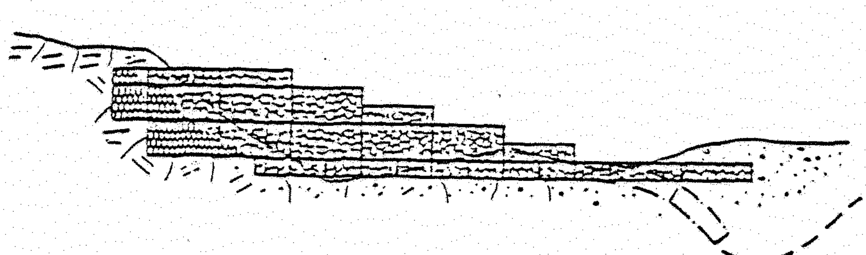
Some design features noted from (2) are as follows:

1. Since the upstream gabions absorb most of the erosive power of the stream, careful design is needed to ensure their placement stability.
2. Greater scour occurs for upstream inclined and normal oriented groins than for downstream inclined structures.
3. In narrow streams the ratio of the groin length to the stream width should be less than about 0.5 to prevent attack on the opposite bank.
4. Groins that are upstream oriented give the maximum bank protection compared to other orientations with the downstream orientation providing



Types of Gabion Groins

FIGURE 10



Gabion Groin Response to Scour (2)

FIGURE 11

the least protection.

Gabions have been used extensively and provide a good solution to some stabilizing problems. It is also a cost effective solution in bank protection.

BULKHEADS

In situations where the river bank slope is unstable, or too steep, bulkheads are used as a bank protection measure. Bulkheads are different from other types of bank protection devices such as riprap, revetments etc., in the fact that bulkheads need no support from the bank. On the contrary, bulkheads are usually placed to actually provide support to the river bank. Bulkheads usually stand vertically and are impermeable.

One of the important factors that has to be considered in bulkhead design is protection against scour. Bulkheads are generally used to provide lower bank and toe protection (13). They are used in a variety of applications such as abutments (in bridges), steep slopes, or places to be protected from intense wave action. They are also used in places where there is limited access to land and hence slope grading is not possible. Different types of bulkheads are as follows (13):

a. Concrete/Masonry walls

b. Crib bulkheads

c. Pile bulkheads

d. Sheet pile bulkheads

e. Wooden bulkheads

f. Other

Apart from these types there are others which are made from a combination of available materials.

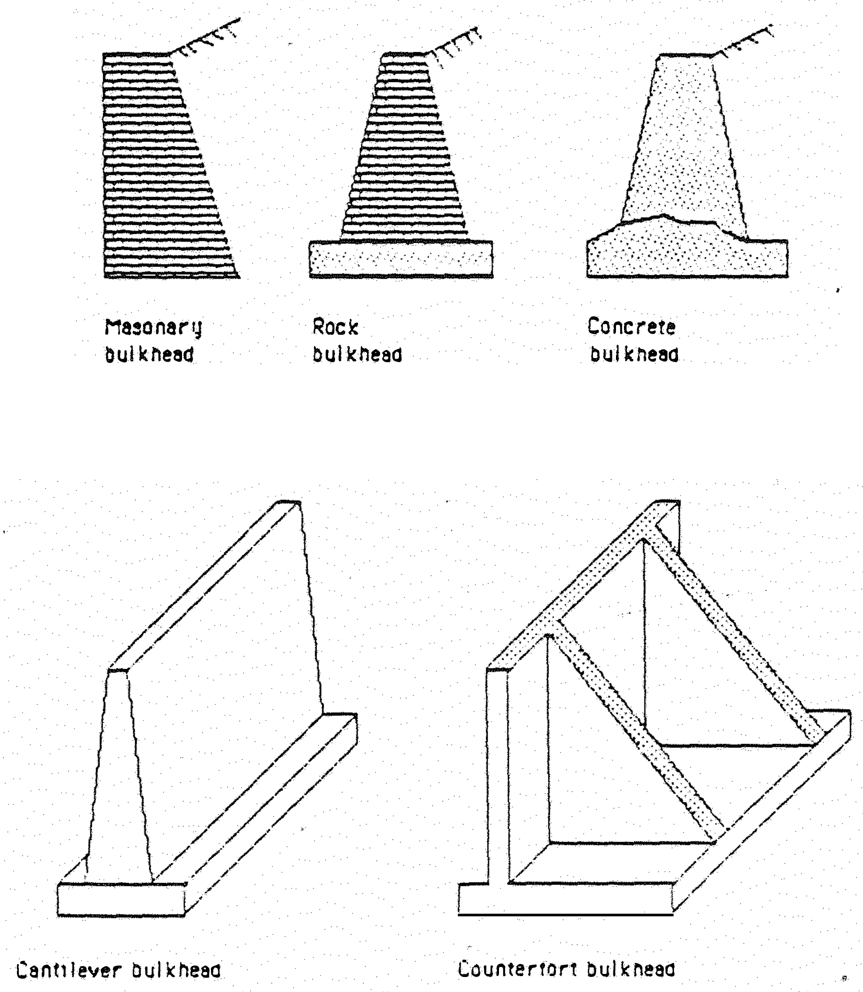
a. <u>Concrete/ Masonry Retaining walls:</u>

These are some of the most commonly used type of bulkheads. The unique advantage of this type is that they are cost effective and are less susceptable to wear and tear, and hence reducing maintenance costs. Some types of these bulkheads are in Figure 12. The detailed design of these types of structures can be found in (14).

Concrete bulkheads essentially provide resistance to erosion by nature of their bulk and weight (13). Weep holes are usually provided in these structures to relieve hydrostatic pressures that build up in the soil supported by them. If the bank to be supported is extensive then special designs like cantilever walls and counterfort walls are used.

b. <u>Crib Bulkheads:</u>

These structures are generally used on slopes which are not highly unstable, but which need some protection from sloughing and failure. They basically consists of a box type structure , which is filled with rocks and soil to give them the necessary mass and stiffness to resist erosion. The box is generally made of materials like timber or steel which are treated to prevent the decaying effects due to exposure to water. Locally available materials can be used effectively in the construction of a box (also known



Concrete/Masonary Retaining Walls

FIGURE 12

as a crib, and hence the name). Cribs have to be designed so as to counter erosion problems at the toe. An illustration of a crib is shown in Figure 13.

Pile Bulkheads:

This type of bulkhead consists of piles (either wood or metal) driven into the edge of the slope to be supported. They are usually used for slopes that are not extensive and basically comprised of cohesive soils. Usually the piles are driven into the bedrock and hence pile bulkheads are usually not subject to toe erosion. Figure 14 shows an illustration of pile bulkheads.

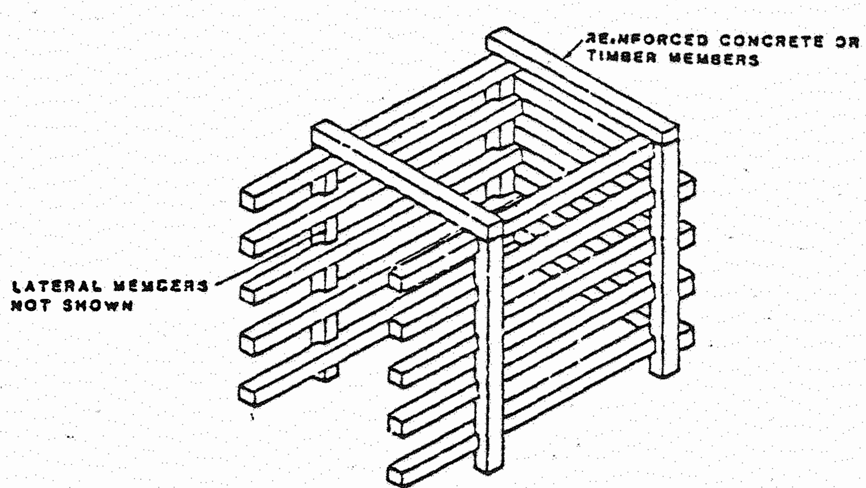
Sheet pile Bulkheads:

These structures are generally used in areas where there is an extensive slope to be protected and the soil is basically sandy or silty in nature. There are many sheet piles that are readily commercially available. The piles are attached to an anchorline which is connected to a deadman. This is done to prevent possible buckling due to the earth pressure. Sheet piles are usually used to protect steep slopes. Figure 15 shows an illustration of sheet pile bulkheads.

Wooden Bulkheads:

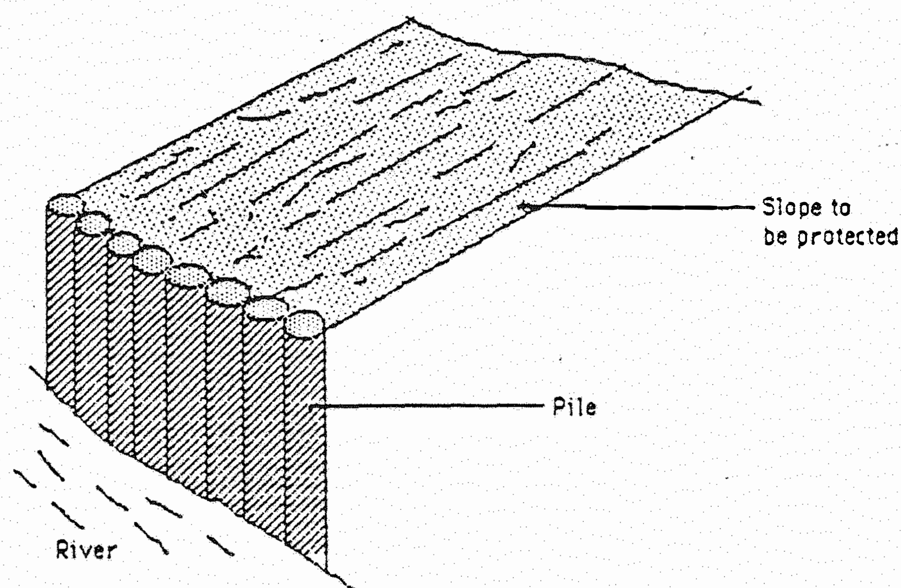
This is basically a fence type structure in which wooden piles are driven down to the bedrock and wooden slats are then attached to them. The wood that is used has to be treated to prevent decay due to the water. An illustration of wooden bulkheads can be seen in Figure 16.

Besides these bulkheads that are mentioned above, other types are also constructed from locally available materials like used tires, gabions, etc.



Crib Bulkhead Wall (13)

FIGURE 13



Pile Bulkhead

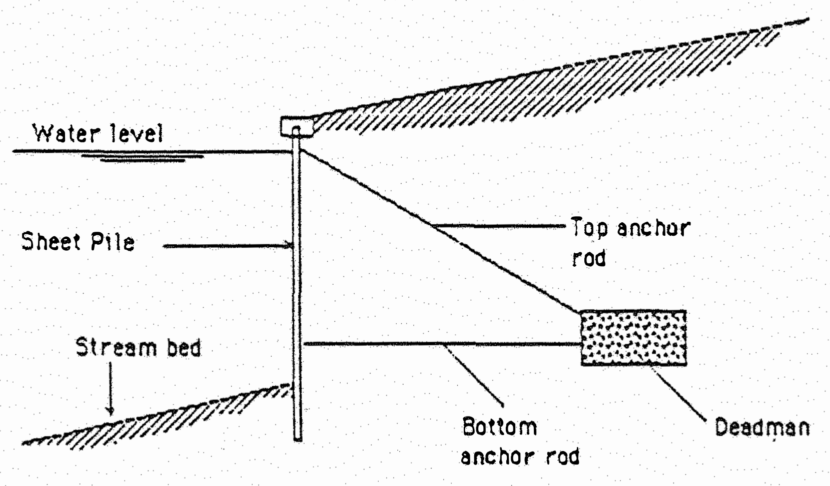
FIGURE 14

Applications that are most appropriate for the use of bulkheads are as follows (13):

a. In narrow, confined places where only a vertical bank is economical.

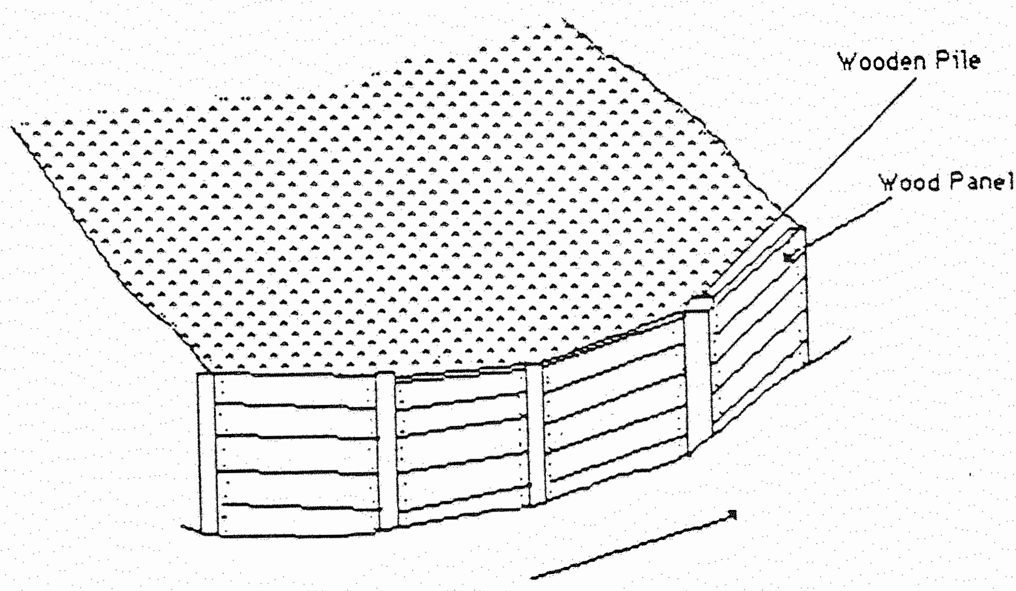
b. In places where land is scarce and slope grading cannot be done.

c. In places where the river has steep banks which require erosion protection.



Sheet Pile Bulkheads

FIGURE 15



Wooden Bulkheads

FIGURE 16

PILE DIVERSIONS

Pile diversions have been widely used in the State of Oklahoma for river training purposes. The first type of pile diversions that were used had no surface planking but used a mat made of felled trees. These types were phased out soon due to the high rate of deterioration of the untreated wood. The pile diversions that were later used had surface planks that were composed of treated wood.

Pile diversions are primarily used in diverting the river flow away from the bank, and in this process encourage the bank building process in between the diversions. Wherever pile diversions have been used they have been shown to be effective in diverting the river flow, but they are relatively less effective in the bank building process than other structures.

In recent years pile diversions have found, relatively, less application in the State of Oklahoma. This can be primarily attributed to the relatively high costs of construction and installation of such structures. Design features and other related material about pile diversions can be found in the Keeley Report (9).

STEEL JETTIES

Since there are different types of river conditions, there are different types of river stabilization and bank protection methods. Streams with low sediment concentrations call for the use of impermeable structures, and as the sediment concentration increases more and more permeable type structures are used.

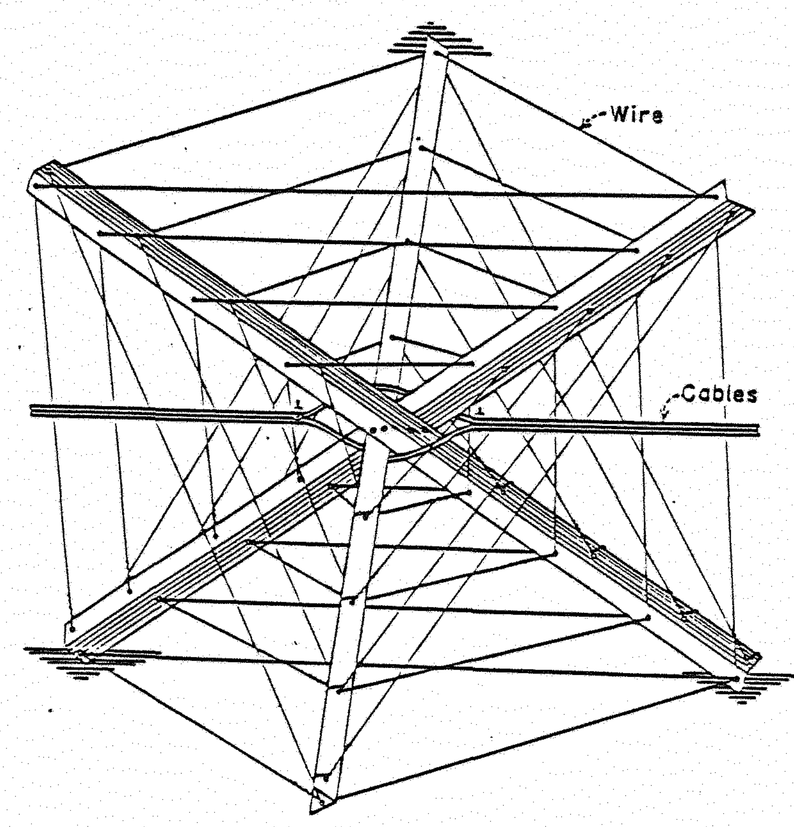
Steel jetties are used in streams in which the bank slopes are not more than 1V to 2H, and in which the sediment concentration is high (1). The primary function of the jetties is to reduce the velocity of water flowing in the jetty fields and hence encourage deposition, whereby the higher velocities are moved from a near bank position to a channel position. Steel jetties have been used more as a bank protection device rather than a river stabilization procedure.

Steel jetties that are most often used are the Kellner jetties. Kellner jetty fields are primarily made up of Kellner jacks which are tied together by cables. Jetty fields are usually placed at 45 to 70 degrees from the downstream bank and the spacing may be from 50 to 200 feet depending upon the debris and sediment content of the stream (1).

Description of a Kellner Jetty:

The Kellner jetty system was developed by Mr. H.F. Kellner in the early 1920's (1). Early research was done by Mr. Kellner on a small stream near Topeka, in the state of Kansas. It was a patented system of the Kellner Jetties Company of Topeka, Kansas. A single Kellner jack consists of three 4 in. by 4 in. by 1/4 in. steel angles about 16 feet long (1). All the three angles are bolted together at their centers with bolts and are tied together by No.6 wire as shown in Figure 17.

Each jack is placed at a distance of approximately 12.5 feet center-to-center from each other and are connected by a wire rope (usually about 3/4 in. in diameter). The end of the wire rope running through the jacks is connected to an anchor or deadman. The anchors are usually made of solid blocks of concrete with dimensions of about 2 ft by 3 ft by 2 ft (1).



Typical Kellner Jack

FIGURE 17

Functioning of a Kellner Jetty System:

The Kellner jetty system is basically a permeable bank protection system with the unique advantage that it is not rendered totally ineffective when undermined by scour. The system is most effective in rivers with banks not more than 20 feet high, and on moderately sinous and sediment laden streams. It is best suited for the protection of bridge structures and other flood control structures like weirs, levees, etc. When used in conjunction with methods like bank sloping (the method, to grade banks to a slope at which they are stable without any additional support) on steep slopes it has been proven to be as effective as riprapping. Proper design and installation can give the Kellner jetty system a life expectancy of up to fifty years.

The Kellner jetty field functions in the following manner:

1) It reduces the direct impact of the river water on the banks and hence reducing the possibility of the washing away of bank material.

2) The jetty fields provide a relatively calm area in the stream which allows the sediment to be deposited.

3) Debris which collects on the jetties help to divert the flow away from the bank, thus reducing erosion. The debris which is collected helps the growth of vegetation in the jetty field which makes the bank side look natural, especially after long periods of application.

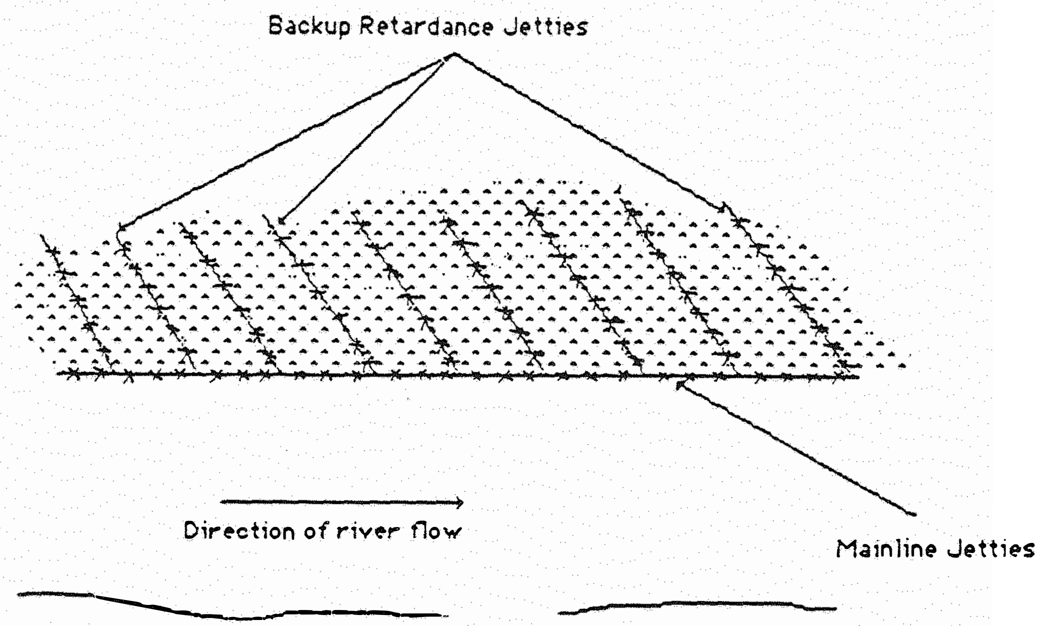
Design of a Kellner Jetty System:

The design of a Kellner jetty system is as much an art as it is a science. Significant on-site experience is needed to effectively design a system which is cost effective. One of the prime factors that has to be considered is the maturity of the river at that site. It is well known that it is extremely difficult to stabilize a river which has not reached a high degree of maturity. Another important factor that has to be considered is the regime, the equilibrium condition, of the river. The jetty field design has to essentially conform to the regime of the river.

The Kellner jetty field is almost always installed in the concave bend of the river which is usually under direct attack of the river waters. There are basically two configurations of Kellner jetty systems (1), which can be seen in Figure 18. They are the :

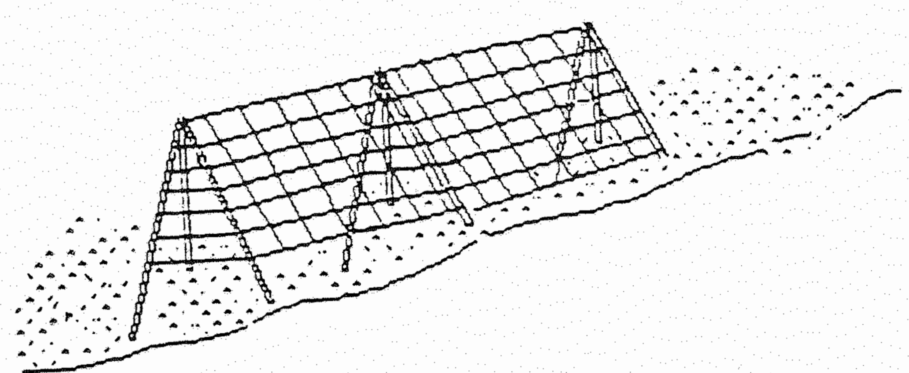
a) <u>Diversion Lines</u>

Diversionary lines are placed approximately parallel to the bankline which is being attacked by the river. Diversionary lines are placed only on rivers where the angle of attack is less than 45 degrees. The number of diversionary lines is dependent on the scour which is predicted due to the river flow and is also a function of the angle of attack of the flow. For best results these systems should be used in environments in which the angle of attack is between 20 and 45 degrees. If the angle of attack is about 20 degrees, two lines of diversionary jetties should be used. If the angle of attack is 45 degrees, then three lines of jetties should be used. However, it is best to place two lines in any case to prevent damage in case of a strong unexpected flood. The diversion lines also act as the anchorage for the back-up retard jetty lines.



Basic Configurations of Kellner Jetties

FIGURE 18



Type "B" Jetty

FIGURE 19

b) <u>Backup Retardance Lines</u>

Backup retardance jetties usually start from the water-line, i.e. from the diversion jetties, and extend all the way to the bank, where they are tied back by anchors. The main purpose of these jetties is to reduce the velocity of the water flowing through it and hence encourage deposition. For a severe angle of attack a spacing of about 75 feet is used between two jetty lines while in normal cases a spacing of 200 feet is generally used. A general rule of design states that if the angle of attack is 20 degrees the current should cut 4 lines of jetties including the diversion jetty. If the angle of attack is about 45 degrees the current should cut 6 lines of jetties.

<u>Vegetation To Be Used In Jetty Fields:</u>

One of the important considerations in the construction of the jetty fields is the rapidity with which the jetty field is covered with vegetation. Hence it is important to choose the right type of vegetation which should be planted to cover up the silt deposited areas. The most appropriate vegetation planted in jetty fields are willows, cottonwoods and salt cedars, in an Oklahoma environment.

<u>Conclusions:</u>

1) The Kellner jetty is a very cost effective way of protecting river banks and flood plains in Oklahoma.

2) Kellner jetties are quite simple to install and no complicated machinery is needed for the erection of a jetty field.

3) It compares favorably in terms of cost of maintenance compared to other

bank protection systems.

4) Kellner jetties are not used in the constriction of flow of a river, or to reestablish the course of a river. This is an important factor to be considered.

5) The advantage of the system comes from the fact that the unit is still effective in its application even when undermined by scour.

<u>OTHER TYPES OF STEEL JETTIES:</u>

Besides Kellner jetties(also known as Type "A" jetties) there are other jetties that have been developed over a long period of time. They are basically steel frames that have been linked together in a different configuration. Some of them have been discussed below :

1) <u>Type "B" Jetties:</u>

These jetties consist of steel angles fastened together in the form of a tetrahedron and they are tied together with steel wires to retard the current and to catch the drift. Figure 19 depicts one of these types.

2) <u>Type "C" Jetties:</u>

These jetties were basically used in the 1940's and they consist of three automobile frames tied together, perpendicular to each other. Their use depends upon automobile frame availability.

3) <u>Rayfield Jetties:</u>

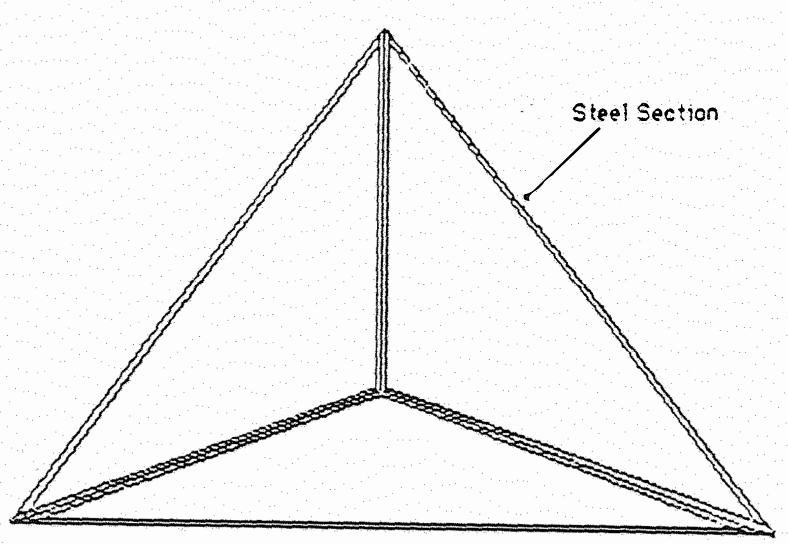
They are also called the six member tripod jetties. They consist of six steel sections tied together in the form of a tripod. They are also tied together with steel cables. Figure 20 depicts one of these types.

4) <u>Six Member Tetrahedron:</u>

In this case six steel sections are tied together to form a tetrahedron. A jetty field of this type consists of many tetrahedrons placed one next to the other and a wire net is stretched along one face of the tetrahedrons. One such structure is shown in Figure 21.

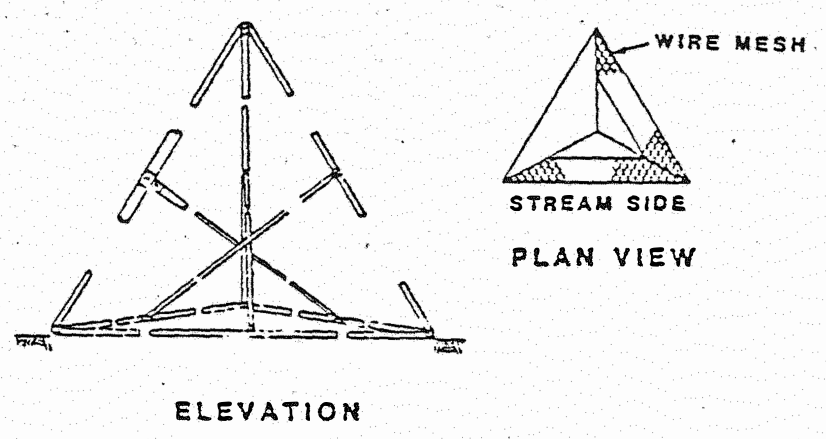
<u>Life and Maintenance of Steel Jetties:</u>

From various sites that have been studied, it has been observed that the life of jetties is about 50 years, on the average. Although a future flood could do serious damage to the installation, the cost of maintenance is usually drastically reduced, due to the bank stabilization induced by it. This is due to the fact that during the passage of time, the sand bars that are built up because of the jetties eventually become so high that only an unusual flood may submerge it.



Rayfield Jetty

FIGURE 20



Six Member Tetrahedron (13)

FIGURE 21

Kellner Jetties Used By ODOT:

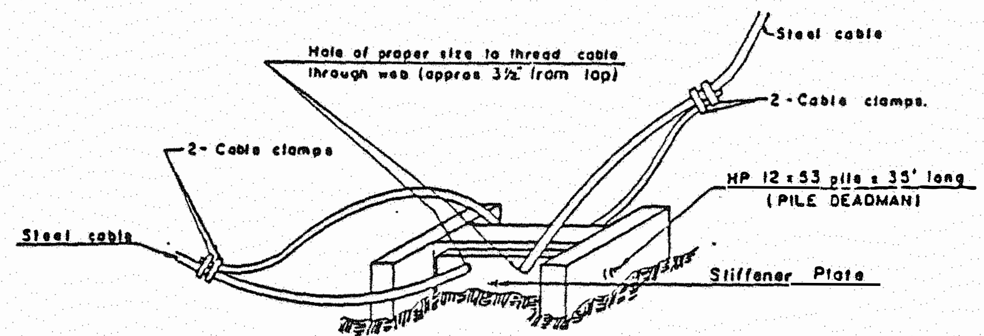
Kellner jetties are used by the Oklahoma Department of Transportation (ODOT) all over Oklahoma for bank stabilization projects. Some of the details of Kellner jetties installed by ODOT are as follows:

1) The angles used have the dimensions of 4 in. x 4 in. x 1/4 in. and a length of 16 ft. Three angles are placed perpendicular to each other, and tied together by three 3/4 in. x 2 in. bolts with lock washer.

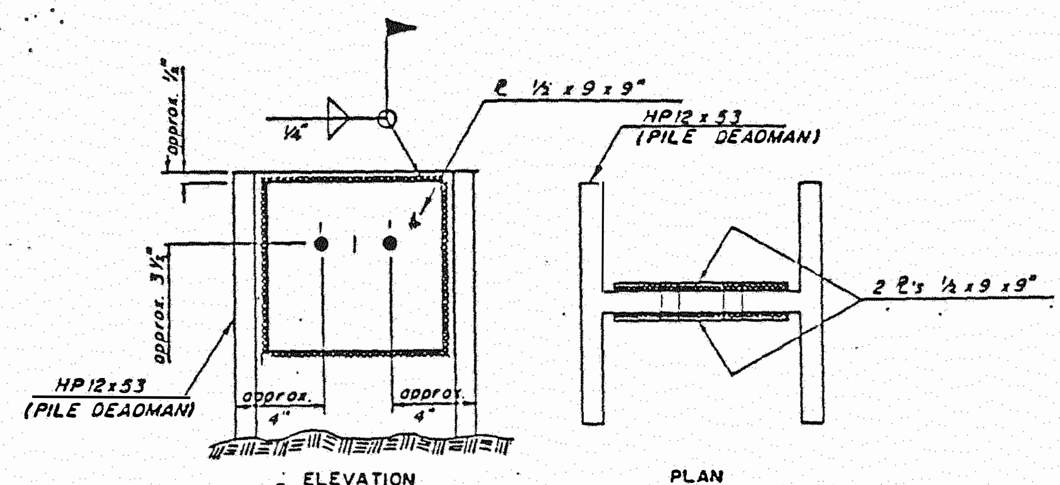
2) The concrete deadman is placed 50 ft from the last jetty on the diversionary line and it is buried 6 in. under the ground. The concrete deadman has a dimensions of 1.5 ft x 3 ft x 2 ft and is made of Class "A" Concrete.

3) The mainline jetties are anchored by a pile deadman, which consists of a pile with specifications HP 12 x 53 and 35 ft long. Stiffner plates of dimensions 1/2 in. x 9 in. x 9 in. are welded near the top end of the pile.

Other details of the jetty field can be seen in Figures 22 and 23. These drawings were furnished by the ODOT.



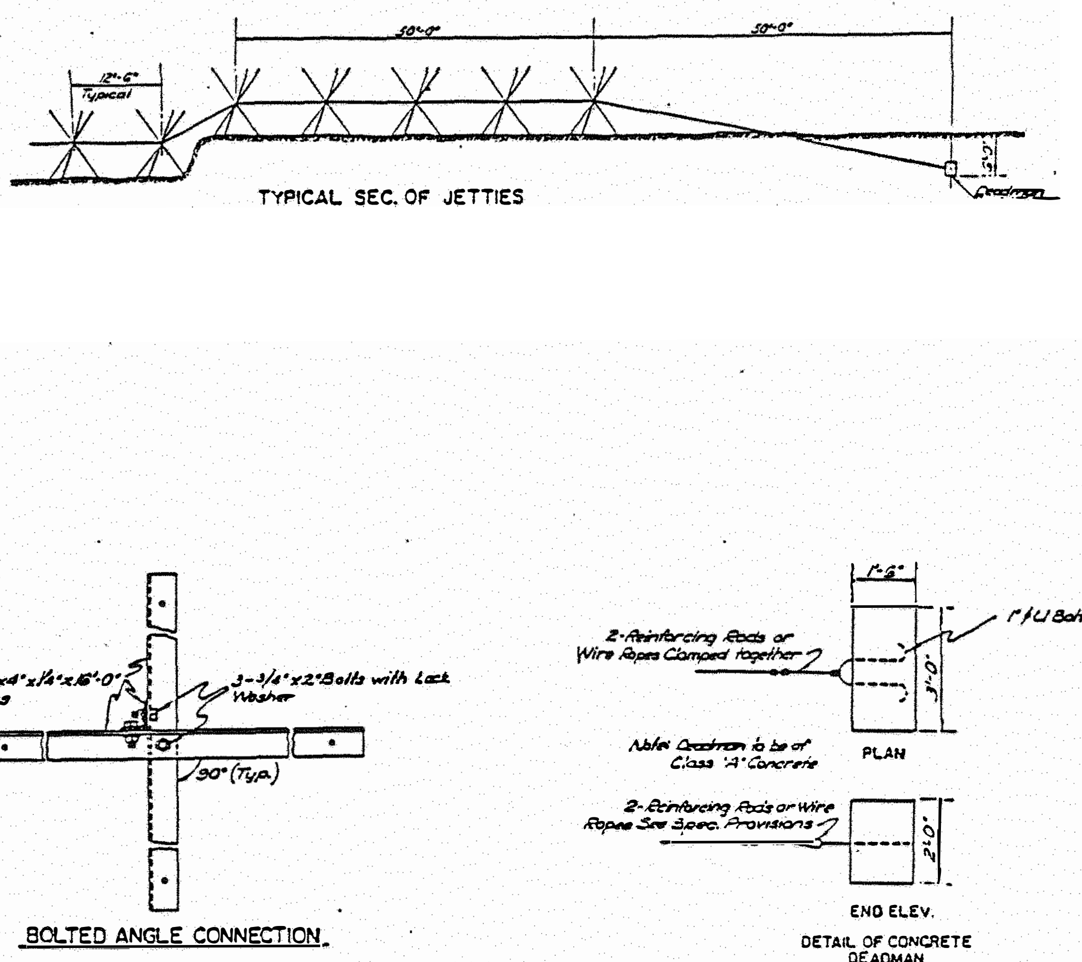
TYPICAL METHOD OF FASTENING CABLES TO PILE DEADMAN



DETAIL OF STIFFENER PLATE

Details of a Kellner Jetty System

FIGURE 22



Details of a Kellner Jetty System (contd.)

FIGURE 23

SPUR DIKES

INTRODUCTION:

Spurs have been used extensively over a long period of time to protect river banks and to discourage the meander loops of the river. Spurs are defined as permeable or impermeable structures which project into a river/channel for altering river flow direction, for bank protection, etc. This is basically achieved by reducing the velocity of the flowing water and hence encouraging deposition. There are three major classifications of spurs (6):

1) Retardance type structures

2) Retardance/Diverter type structures

3) Diverter type structures

The advantage of using spur type structures lies in the ability of spur type structures to provide flow control, constriction and reestablishment of a previous channel flow path. Among all the erosion mechanisms which act on the river bank spur type structures are best suited for resisting abrasion as well as flow induced shear stresses. This is basically done by diverting the high energy currents and by slowing down the flow to induce deposition. The use of a particular type of structure depends primarily on the river bank characteristics. This can be explained as follows (5):

1) Spur structures are not suited to channels of small width (less than 150 feet). This is primarily due to the fact that spurs often cause flow constriction which cause the currents to be deflected to the other bank and undermine it. However, if the basic function is to shift the channel, then spurs are ideally suited for this situation.

2) If the channel radius is small (i.e. less than about 350 feet) then spur type structures are not cost effective. This is because spurs are costly structures and a smaller radius would mean more structure.

3) Spurs are best suited for banks up to about 20 feet in height. Above this height the use of spur banks become uneconomical.

4) Spurs can be used effectively on steep banks. This is true because spurs do not need banks that are well graded.

5) Spurs should be placed in and near recreational areas only after careful consideration because they can pose a danger to marine activity.

Classification of spur types:

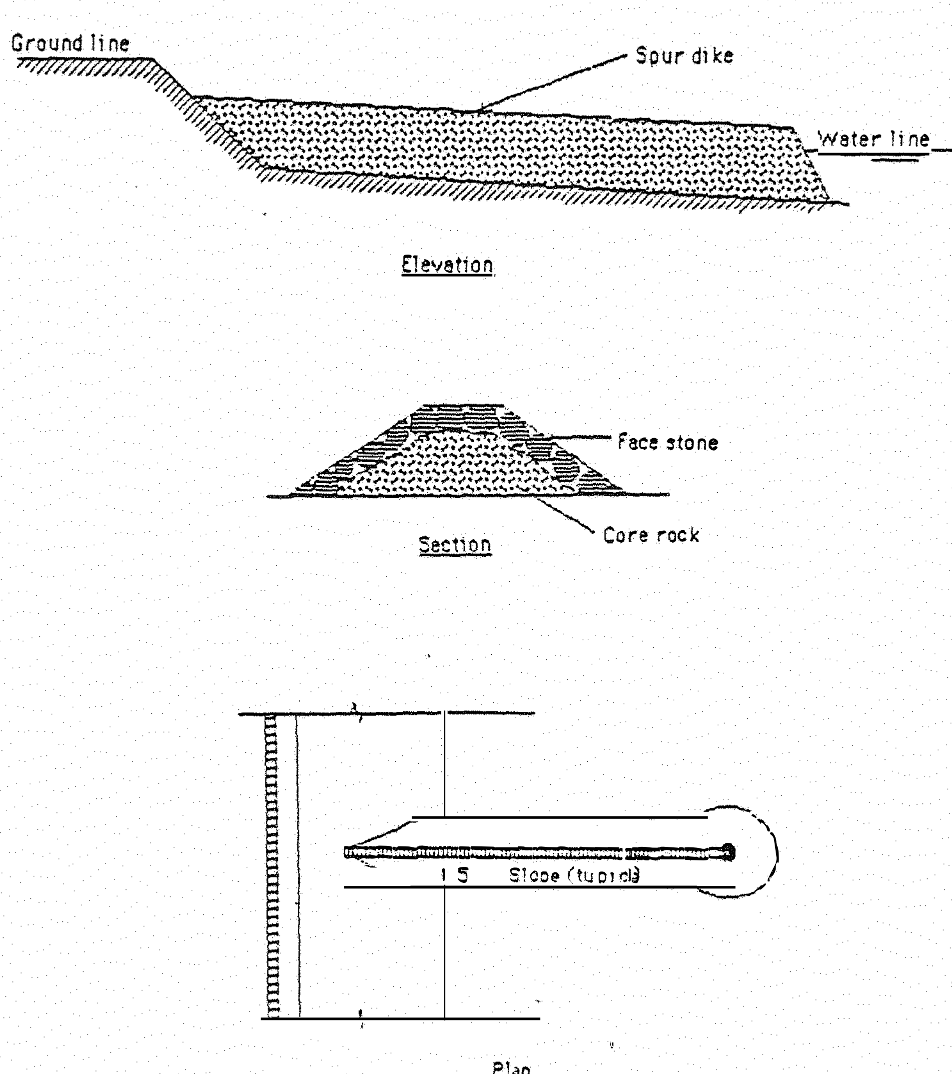
The classification of spur types given before can be extended as follows (6):

* RETARDANCE SPURS
    - Fence and Jack type (Kellner and Rayfield jetties)
* RETARDANCE/DIVERTER SPURS
    - Light or heavy fence
* DIVERTER SPURS
    - Hardpoints
    - Transverse dike spurs

Most spur dike applications deal with spurs that extend into the water and which are impermeable and perpendicular to the riverbank. An illustration and crossection of a typical spur dike can be seen in Figure 24.

Hardpoints are similar to spurs. The main difference is that they are shorter in length. Hardpoints are to be used in narrow streams, and streams with a low radius of curvature.

Spur structures are basically trapezoidal in crossection with the crown widths of 10 ft. or more depending on the severity of the attack by the water and also governed by construction and maintenance requirements.



Typical Spur Dike

FIGURE 24

OTHER METHODS OF BANK PROTECTION

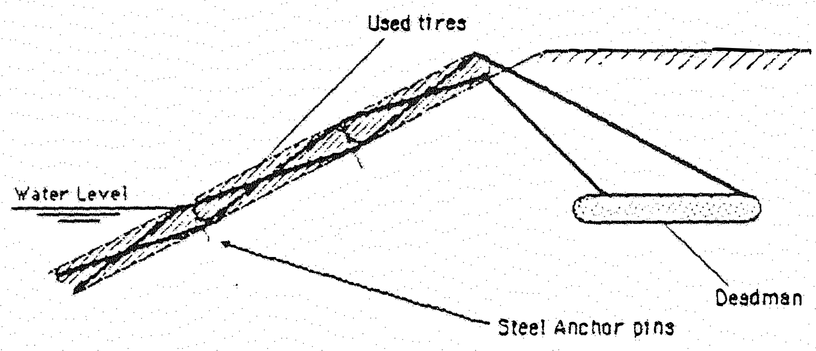
USED TIRES

Used tires are an innovative use of waste materials toward the efforts of bank stabilization. This a low budget but effective way of bank stabilization and has been put to use by local landowners to protect agricultural lands from erosion. Two important factors to be considered in the use of old tires into bank stabilization are (16):

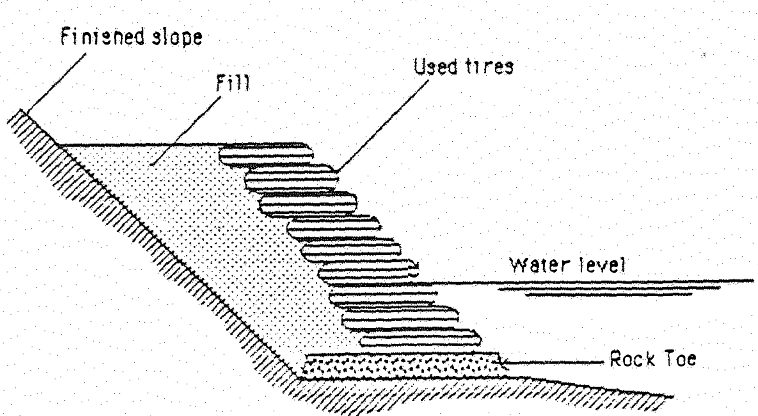
1. All the tires that are used should be banded together so as to form a blanket which is effective in holding down the structure and so that the structure can act homogeneously.
2. The ends of the blanket of tires should be perfectly anchored (such as the use of a deadman) and the toe should be protected with riprap to reduce settlement due to scour.
3. Holes should be made in the tire walls to prevent the flotation of tires due to buoyant action.
4. The tire blanket should be placed in such a way that it can be effectively anchored. Presorting tires according to different sizes is also helpful in placing them together.
5. Tires can be filled with stones and rubble so as to give them enough mass to resist the impact of water. Anchors should be provided for the flatter slopes and trees can be planted to give better integrity to the structure.

In case the tires are to be used so as to form a bulkhead, they should be placed so as to have a stepped surface, and the joints between different tire layers should be broken. The foundation behind the tires should be filled with free draining soil so as to prevent excessive soil pressure due to the accumulation of water behind the tires.

Tires should not be placed in applications where there is a history of excessive toe erosion and on banks that that have a low radius of curvature. Tire mattresses tend to be more susceptable to vandalism than other types of protection structures. Figure 25 depicts the use of tires, as a blanket protection and as a bulkhead protection.



Tire mattress in bank protection



Used tire bulkhead

Applications of Used Tires

FIGURE 25

VEGETAL APPLICATION IN BANK STABILIZATION

The introduction of vegetation as one of the methods in bank stabilization is considered to be cost-effective in specific places. Vegetation is usually not considered as a primary method of bank protection, but is used in conjunction with other known methods. Vegetation provides an excellent cover in holding together the soil particles on the bank and hence is quite an effective method in combating erosion. Basically, there are two major classes of vegetation that are used in erosion control and they are (13):

a. Woody plants

b. Herbaceous vegetation

Vegetation has been effectively used in upper bank protection and also successfully in lower bank protection when used along with retardance structures. Many retardance structures like jetty fields rely on the growth of vegetation in the deposition area in order to be effective.

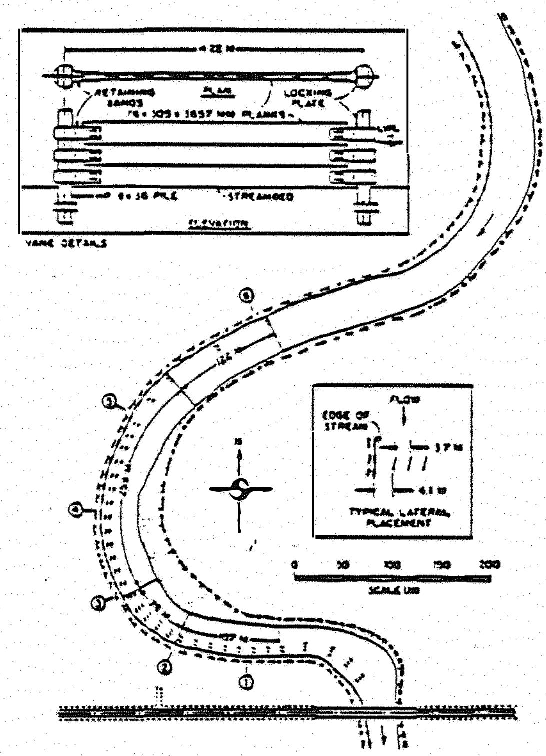
Vegetation is not used alone in streams that are subjected to strong scouring action. A study in the channel degradation pattern is a key to the success in providing protection against erosion. Vegetation requires a well graded slope and hence if scouring action is expected then it should be used alongside with structural members. The main aim in giving banks a layer of vegetative cover is to improve the structural integrity of the bank. Woody plants with deep roots are effective to a certain degree in helping prevent toe scour.

A major factor on which the success of providing vegetative cover depends on the species naturally found in that area. In Oklahoma trees like willows (salix), cottonwoods (populus) and salt cedars (tamarix) are found to provide effective vegetative cover. More information can be obtained by contacting local Soil Conservation Service, Plant Materials Centers.

VANES

This method has been primarily developed by the Iowa Institute of Hydraulic Research and has been tested on the East Nishnabotna River, Iowa, quite successfully. It has been developed on the theory that the interaction between the vertical gradient of velocity and the curvature of the flow generates a secondary, spiralling flow."The secondary moves the high velocity, near surface current outwards (and low velocity near bed current inward) and thereby produces larger depths and velocities near the outer banks. The deepening of the channel diminishes the toe support of the bank, and the larger velocities attack it, setting the stage for bank erosion" (18). Vanes have been used to counter this effect.

The vanes are placed at an angle of 10-20 degrees to the mean flow, with the height of the vanes at 20-40 percent of the high water flow depth (29). Detailed theory and designs of the system can be found in (18). Figure 26 depicts the layout of the vane system in the East Nishnabotna Bend.



Vane System Layout in East Nishnabotna Bend (17)

FIGURE 26

A brief evaluation of the system installed on the East Nishnabotna River, is highlighted as follows (18):

1) A reduction of high flow transverse bed slope of about 50 percent was observed and a reduction of nearly 10-20 percent of the near bank velocity was also observed. The system observed no measurable change in the longitudnal slope of the water surface.

2) Since the vanes system does not significantly affect the energy slope of the flow, it should not significantly affect the overall sediment balance and the stability of the channel.

3) The system is not very complex to construct, and may be more economical than the construction of riprap.

While more research may be needed to understand the system completely, as it stands, it seems to be a viable alternative to other expensive bank protection methods.

AUTOMOBILE BODIES

This method of bank protection involves the random placement of old automobiles bodies along the bank to be protected. This method is essentially a low cost alternative to the other bank protection methods available. The automobile bodies are placed at random on the river bank and tied together by steel cables which are then anchored on the bank with the help of a deadman.

This method of protection should be used only in small streams and creeks where the velocity of the flowing water is not very high, and also in waters that will not rust the bodies excessively. This is a rarely used method since, in some places it may do more harm than good. This is possibly due to the fact that the random placement of the bodies may divert the water flow towards the bank rather than away from the bank. Another factor that limits the use of this type of protection is the very fact that the placement of automobile bodies is an eyesore and makes the stream look like a junkyard. This method should be considered more as an emergency bank protection method rather than as a permanent solution to bank erosion problems.

Precast Concrete Cellular Blocks:

This method of bank protection consists of placing prefabricated concrete blocks in the bank to be protected. There are many commercial sources for these products. Most of the designs are basically concentrated on the use of interlocking concrete blocks that hold the entire placement together. The voids in them also encourage the use of grass, which is also helpful in holding together the bank. The blocks are placed either by hand or by the use of specialized machines. One major factor that has to be considered in the placement of these structures is that they should be protected from undermining due to the action of the water. Very often filter fabric is used under such structures to prevent the washout of soil from beneath the blocks. Concrete revetments can also be considered as an example of one of these type of structures. A photograph showing a typical placement of cellular blocks is shown in Figure 91 (b).

Soil stabilization using Cement, Flyash etc.:

This method is not used as a direct stabilization measure but as a backup method. Soils behind stabilization structures are often treated with 10 to 15 percent of cement or flyash to improve soil characteristics. The use of blocks made of soil and cement are also used. This method is rarely used due to the high cost of cement and other factors such as the lack of flexibility, and low permeability (15).

CHAPTER III

SITE STUDY METHODOLOGY

The current project under investigation is a continuation of the report submitted by Keeley in 1971 (9) to the Oklahoma Department of Transportation. Many bank protection structures at the sites under study were based on that report. In addition to the sites by Keeley, five new sites were chosen where river stabilization was attempted. The period of this investigation was about 15 months starting in May 1988. A rational method of problem approach was sought, and the simple and logical methodology eventually used is described below:

1. Site Familiarization:

In this phase, a detailed study of the sites (except the 5 new sites) was done with the help of Keeley's report of 1971 (9). The history of river stabilization at the sites was noted with special emphasis on the aerial photographs, snapshots, and other related sketches. There were two cases where the original structure was moved and other instances of new bridges or river stabilization structures. All structures that were analysed were first noted and studied prior to field examination during later visits to the sites. River meander patterns were observed and an evaluation of the present status of the sites was made. Topographical maps of the sites were acquired at the Geological Survey Office in Norman, Oklahoma, to get an idea of the terrain through which the river flows. The topographical maps also helped in studying the flood plains, and ancient banks of the rivers.

2. Literature Survey:

A literature survey was conducted both manually (at the University of Oklahoma Libraries, Norman), and with the help of computerized data banks like the Highway Research Information Service (HRIS), the National Technical Information Service (NTIS), and COMPENDEX. Many State and Federal agencies were also contacted for their feedback in this matter. This lead to a relatively easy access to the literature that was available on the topics under consideration, and potential countermeasures that might be applied.

3. Aerial Photography:

A set of the latest aerial photographs was needed so as to obtain the latest site information. Aerial photography guidelines were made with the help of the acquired topographical maps. The flights were conducted internally by the Oklahoma Department of Transportation in two and one half days which covered all the twenty five sites in Oklahoma. The area covered by each frame was about 2 square miles. The photographs were taken from an altitude of 7000 to 8000 feet, depending upon the topography. Most photographs were taken during late winter, when most plants were devoid of their foliage and a clear view of the site was possible. This was very important since most of the river stabilization structures are covered by shrubs and other vegetation which could make them invisible from the air. Once the photographs were developed, they were examined carefully and they were compared to older photographs of the site that were available. The aerial photographs played a very important part in the success of the project.

4. **Site Visits:**

Before visiting the site, topographic maps and photographs were examined, to research each site in advance to know what to look for, and where to look for it. Most of the sites had a very difficult access which made it extremely difficult in locating the expected countermeasure structures. In many cases structures that were supposed to be in place were never found. This was due to many reasons, the most common being a shift in the course of the river. A detailed log was kept on the structures found and their condition. A Field Survey Sheet was prepared, on which the data at the site were recorded. Approximate on-site drawings were made for future reference. Photographs were taken at the site of all subjects of interest. The photographs were instrumental in recreating the site when analyses of the site were to be made later. Note of the approximate soil conditions, bank nature, temperature, climate, river conditions and other bank and embankments features were made for future reference.

5. Site Analysis:

A total of twenty five sites spread all over Oklahoma were studied. Figure 27 gives a list of the sites that were studied. Figure 28 gives their approximate locations. Site analysis comprised a detailed study of the riverine site and its meandering nature. Available aerial photographs, in some instances from about 1930, were studied to understand the meandering pattern of the river. In many cases topographical maps were used to study the meander plains of the river. Oxbow lakes and other bodies of water were also noted because these constituted weak integrity land sections where the river might retraverse with relative ease. Comparative analysis of the most recent and older aerial photographs were made to study the present location of the river compared to older locations. Site visits permitted the evaluation of the present condition of the structures that were erected. Emphasis was placed on studying the tendency of the river to cut behind the structures. This was important because any cutting of the banks by the river could give an insight into the next movement of the river.

Another important aspect of the study was the careful observance of the previous orientation of the river. Any major movement tendency of the river was noted, whereby the possibility that the river might return to its original or some other undesirable path was high which might prompt the need for bank stabilizing structures. Bank erosion was studied, which was basically based on the type of the soil and its propensity to erode.

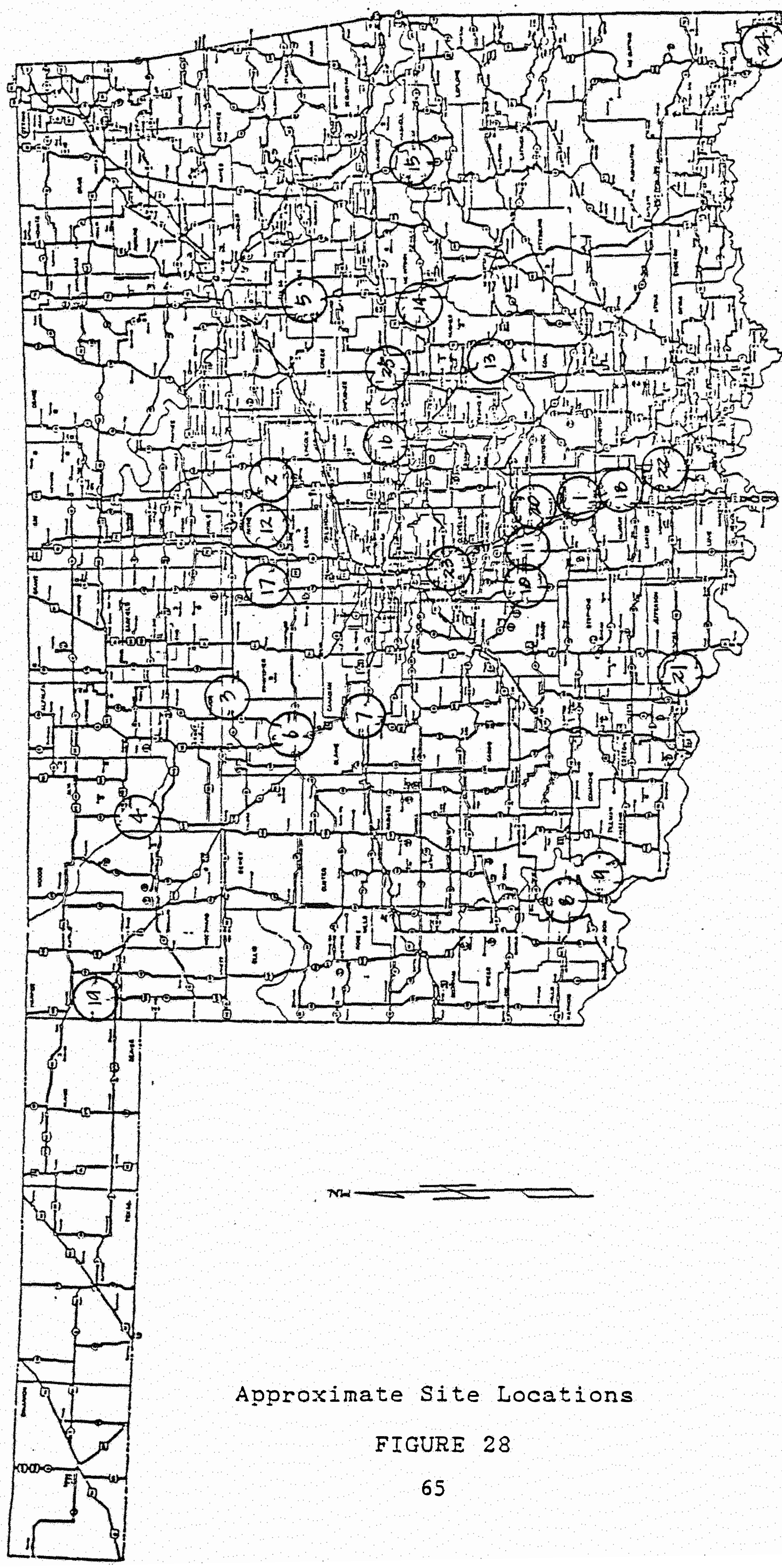
The last but not the least factor studied was the river itself. All the major rivers in Oklahoma are very different from each other on the basis of discharge, silt load capacity, and angle of attack at the bank. Note was taken of the upstream flood control hydraulic structures, which greatly

SITES INVESTIGATED

Site No.	Location	River	Highway
1	N.W. of Wynnewood	Washita River	US 77
2	S. of Perkins	Cimarron River	US177
3	E. of Okeene	Cimarron River	SH 51
4	S. of Waynoka	Cimarron River	US281
5	N. of Bixby	Arkansas River	US 64
6	S. of Watonga	N. Canadian River	US281
7	E. of Bridgeport	S. Canadian River	US281
8	W. of Altus	Salt fork Red River	US 62
9	W. of Tipton	North fork Red River	SH 5
10	S. of Lindsay	Washita River	SH 76
11	N. of Maysville	Washita River	SH 74
12	N. of Coyle	Cimarron River	SH 33
13	N. of Atwood	S. Canadian River	SH 48
14	N. of Dustin	N. Canadian River	SH 84
15	N. of Whitefield	S. Canadian River	SH 2
16	E. of Shawnee	N. Canadian River	SH 3
17	S. of Crescent	Cimarron River	SH 74
18	S. of Davis	Washita River	I- 35
19	N. of Laverne	Beaver River	US283
20	S.W. of Paoli	Washita River	I- 35
21	W. of Waurika	Red River	SH 79
22	E. of Gene Autry	Washita River	SH 53
23	S.W. of Norman	Canadian River	I- 35
24	S. of Harris	Red River	SH 87
25	N. of Bearden	N. Canadian River	SH 48

Lists of Sites Investigated

FIGURE 27



Approximate Site Locations

FIGURE 28

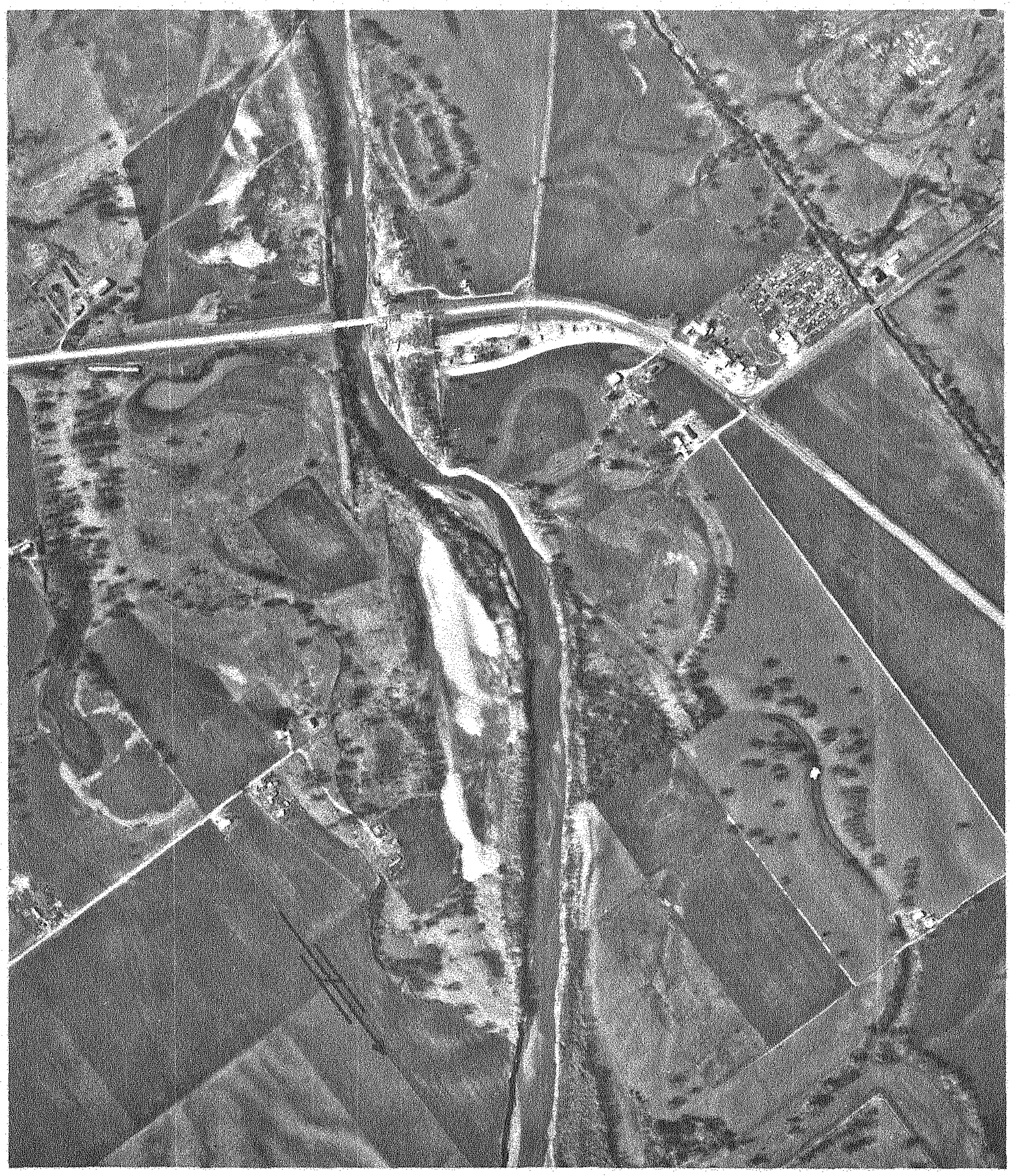
influences the discharge of the river. Land use was noted, along with relevent site change elements.

The detailed site analysis of the twenty five sites are presented in the following pages.

CASE STUDIES

WASHITA RIVER - US77
West of Wynnewood (Garvin County)

Site No. 1



Scale: 1" = 814'

1989 Site Aerial Photograph

FIGURE 29

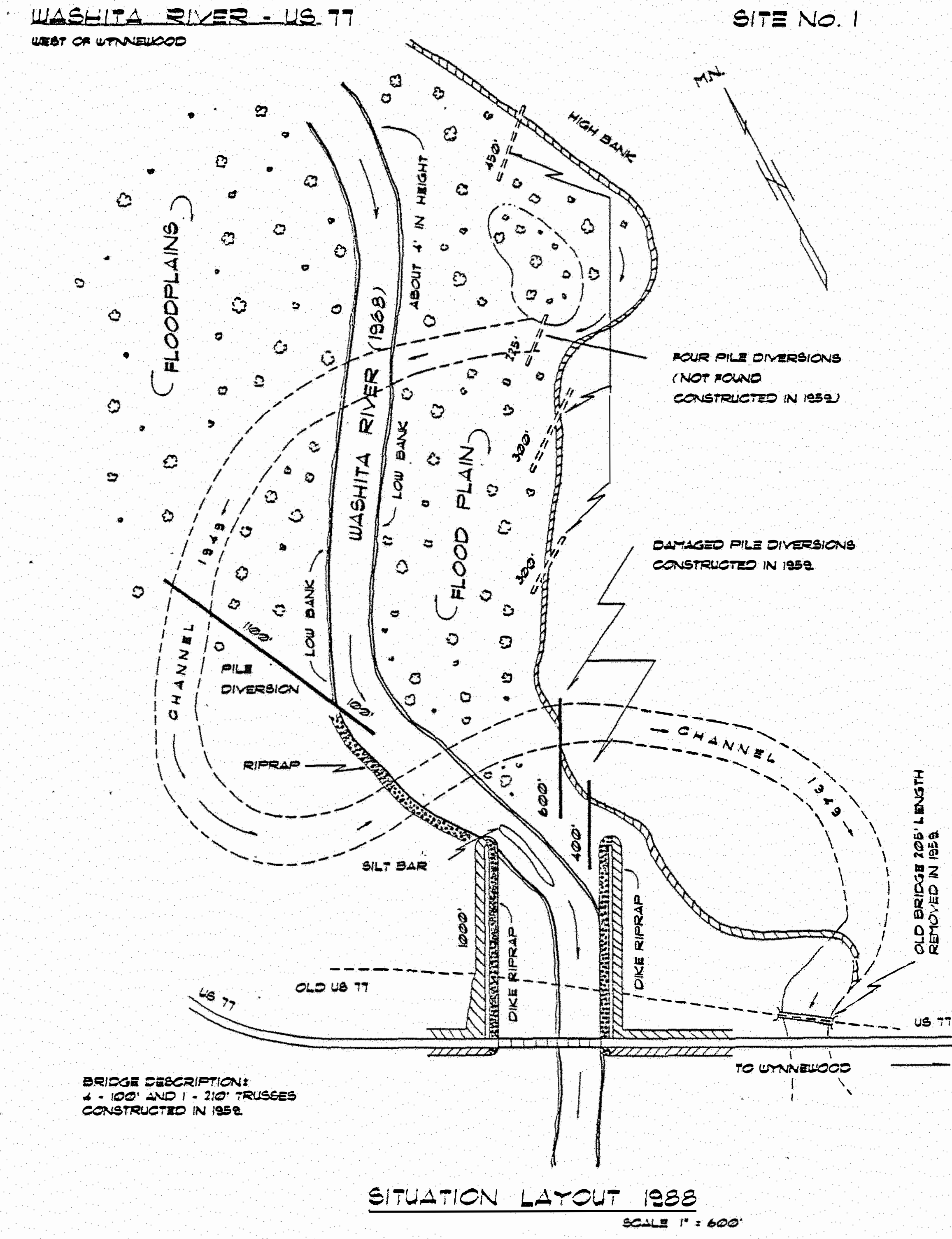

WASHITA RIVER - US 77
WEST OF WYNNEWOOD
SITE No. 1
M.N.
HIGH BANK
FLOODPLAINS
WASHITA RIVER (1988)
ABOUT 4' IN HEIGHT
LOW BANK
FLOOD PLAIN
450'
225'
300'
300'
FOUR PILE DIVERSIONS
(NOT FOUND
CONSTRUCTED IN 1959)
DAMAGED PILE DIVERSIONS
CONSTRUCTED IN 1959
CHANNEL 1949
PILE DIVERSION
1100'
100'
LOW BANK
RIPRAP
CHANNEL 1949
600'
400'
SILT BAR
1000'
DIKE RIPRAP
DIKE RIPRAP
OLD BRIDGE 205' LENGTH
REMOVED IN 1959
OLD US 77
US 77
US 77
TO WYNNEWOOD
BRIDGE DESCRIPTION:
4 - 100' AND 1 - 210' TRUSSES
CONSTRUCTED IN 1959
SITUATION LAYOUT 1988
SCALE 1" = 600'

FIGURE 30

WASHITA RIVER - US77 Site No. 1
West of Wynnewood (Garvin County)

Bridge and Site Data:

The present structure was built in 1959 and consists of four, 100 ft trusses and one, 210 ft truss. The site has a drainage area of about 5,500 sq. miles, and a floor elevation of 848.8 ft was used for the design of the bridge. The Washita river at this site is narrow, has steep banks and is subject to concentrated local flooding during periods of heavy rainfall. For other details see Keeley (9).

History of Stabilization Procedures:

In 1949 Kellner jetty fields were erected along the old channel which was about 2300 ft in length from the old bridge (about 1000 ft east of the present bridge location). This was constructed to prevent any further eastward movement of the channel. This jetty field can no longer be located and seems to have effectively served the purpose.

In 1958 a major realignment of the channel occured which washed out a section of US77. This prompted the construction of a new bridge along a new alignment. Riprapped spur dikes were built along both the road approaches to hold the river in between. Six pile diversions were constructed on the eastern bank and two pile diversions were constructed on the western bank.

The western bank has been riprapped all the way up to the first pile diversion. This riprap was constructed in about 1959.

Site Evaluation:

Site No.1 is a good example of a successful river training project. By nature, the Washita river is highly erratic and has a constantly changing channel alignment. The 6 pile diversions constructed on the eastern bank are at present in a deteriorated condition. However they have lasted for over 30 years and have been absolutely effective. In the event of a major flood event the river might cut back into its original channel. With the loss of these pile diversions the river may cut behind the spur dikes at the bridge and render them ineffective. These pile diversions definitely need repair, or new diversionary structures should be installed. The extolling virtue at this site is that the floodplain in between the diversionary structures is quite extensive and has a mature vegetal cover that will likely prevent the river from changing course.

Only a small part of the first pile diversion (situated on the western bank) can be seen in the river and it is in very bad condition. This may not need immediate attention due to the heavily riprapped banks downstream to the structure all the way to the western spur dike. The old river channel on the western bank seems to be heavily silted and overgrown and it is unlikely that the river will flow there again.

The river is constantly attacking the eastern spur dike at the bridge and a loss of the face riprap is in evidence. The river is also attacking the toe of the dike which may cause some slope failure. Although this is not a cause for immediate concern some maintenance work is needed to keep the whole system effective.

Comparison of the 1968 aerial photograph and the 1989 aerial photograph shows a clear push of the river into the eastern spur dike. The presence of the heavily riprapped western bank may be one of the reasons that the river is pushing into the eastern bank. The composite situation must be watched carefully to prevent any major movement of the river. The upstream configuration of the river seems to be in well defined banks and there is only normal cause for concern.

In conclusion it can be stated that the river training and stabilizating structures have worked very well at this site. Site visits in 1988 have shown that the river has been kept under control as was originally intended. Regular maintenance at this site would clearly sustain a very successful stabilization procedure for a long time to come.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JULY 29th 1988 SITE NO.: 1

HIGHWAY NO.: US 77 COUNTY: GARVIN

BRIDGE LOCATION: WASHITA RIVER , WEST OF WYNNEWOOD.

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1959

Span Description: FOUR 100' TRUSS
ONE 210' TRUSS

2) Yr. of constr.: ______

Span Description: ______

EMBANKMENT TYPE:

SLOPE: EASTERN BANK STEEP , WESTERN BANK MORE GENTLE

PROTECTION: SPUR DIKE AND RIPRAP ON BOTH ABUTMENTS.

SPECIAL NOTES: EASTERN ABUTMENT IN DIRECT CONTACT WITH THE RIVER

RIVER BANK:

SOIL NATURE: SILTY VEGETATION: WILLOWS

COMMENTS: ______

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: SPUR DIKE WITH RIPRAP

a) Description: TWO SPUR DIKES 100' LONG, WITH RIPRAP FACING AT BOTH ABUTMENTS.
CONSTRUCTED IN 1959.

b) Present Condition: THE EASTERN SPUR DIKE IS IN CONTACT WITH THE RIVER. AND THERE IS A LOSS OF RIPRAP.
THE WESTERN SPUR DIKE SEEMS TO BE OKAY.

TYPE: 6 PILE DIVERSIONS

a) Description: CONSTRUCTED IN 1959, TO PREVENT THE RIVER TO FLOW IN THE OLD CHANNEL, ON THE EASTERN BANK.

b) Present Condition: THE PILES ARE IN THE EXTREMELY DAMAGED STATE, OR NO LONGER EXIST.

TYPE: 2 PILE DIVERSIONS (WESTERN BANK)

a) Description: TWO PILE DIVERSIONS, ONE 200' AND ANOTHER 2000' CONSTRUCTED IN 1959, TO PREVENT THE RIVER FROM CUTTING BEHIND THE WESTERN EMBANKMENT.

b) Present Condition: ONLY A SECTION OF THESE DIVERSIONS COULD BE FOUND.

TYPE: RIPRAP (ON WESTERN BANK)

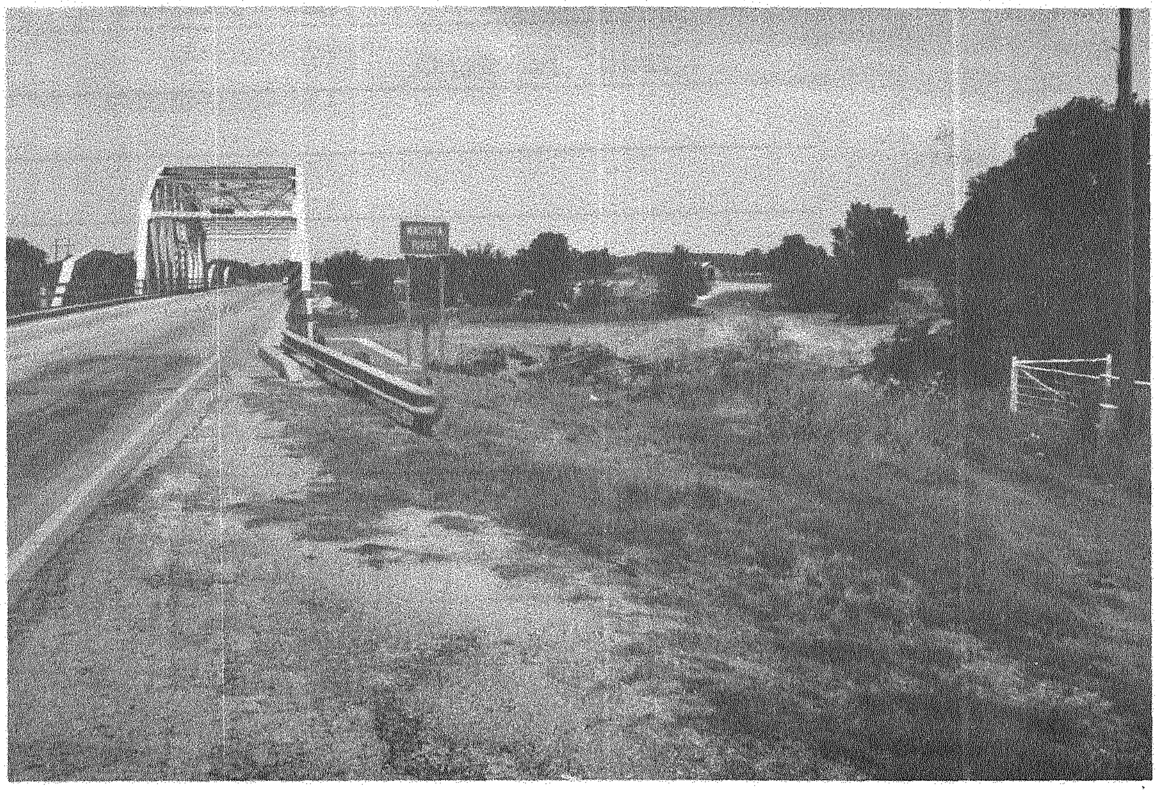
a) Description: HEAVY RIPRAP ON THE WESTERN BANK TO PREVENT MEANDER OF THE RIVER.

b) Present Condition: FOUND IN FAIRLY GOOD CONDITION.

TYPE: ______

a) Description: ______

b) Present Condition: ______



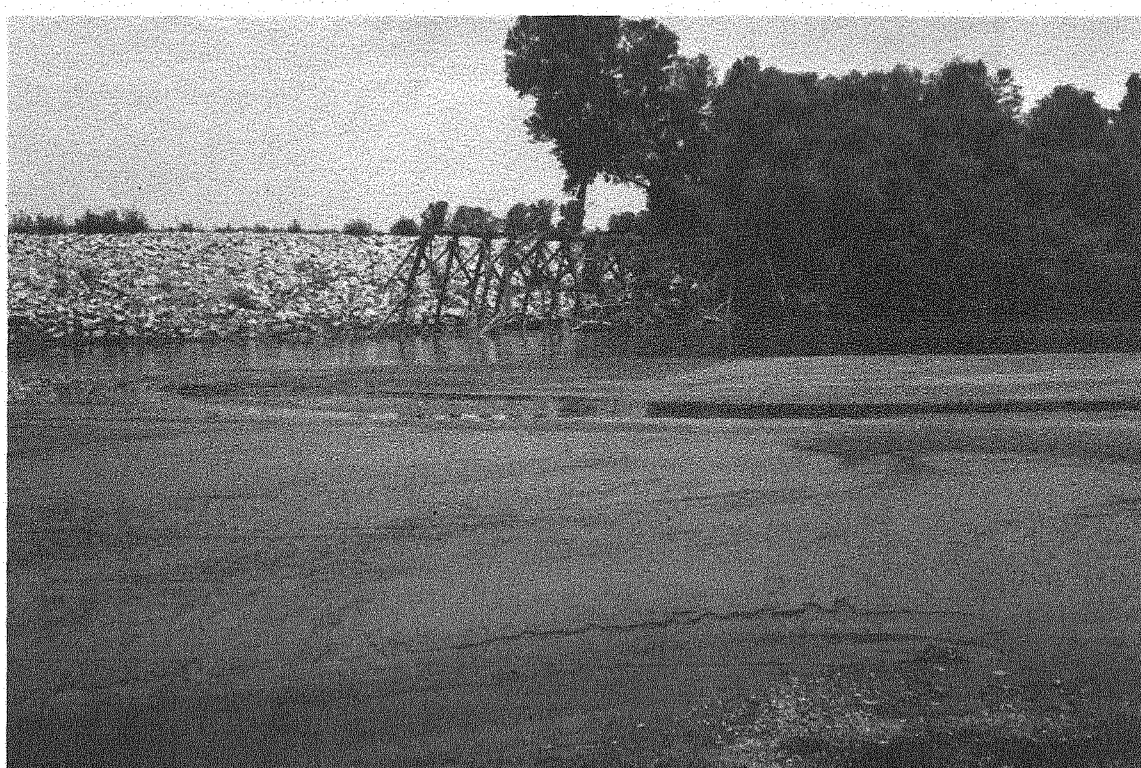
VIEW OF THE BRIDGE SITE

FIGURE 31a

RIVER FLOW AGAINST THE EASTERN EMBANKMENT

FIGURE 31b

VIEW OF DAMAGED PILE DIVERSION
FIGURE 31c

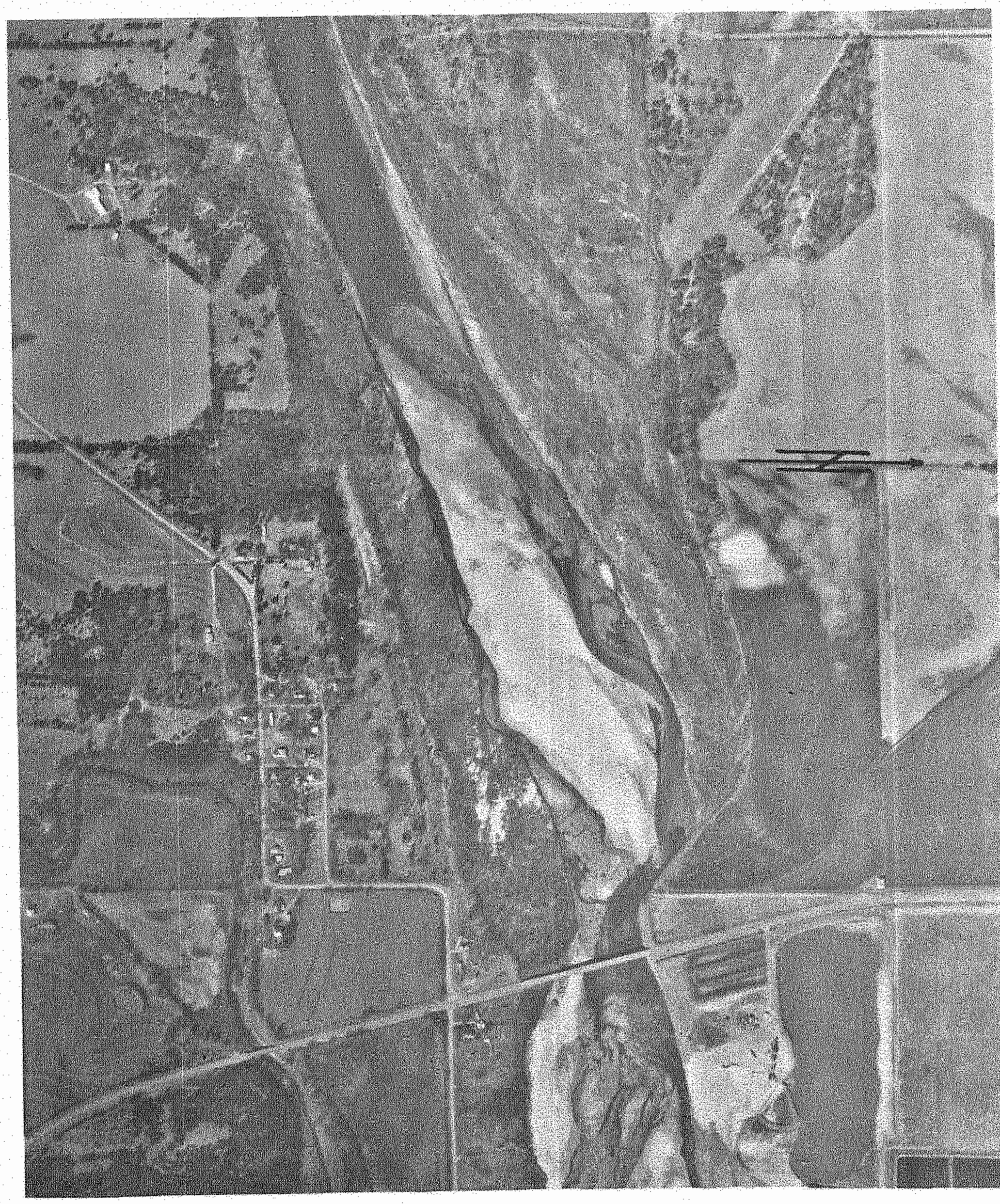


RIPRAP AND PILE DIVERSION ON WESTERN BANK

FIGURE 31d

CIMARRON RIVER - US77
South of Perkins (Payne County)

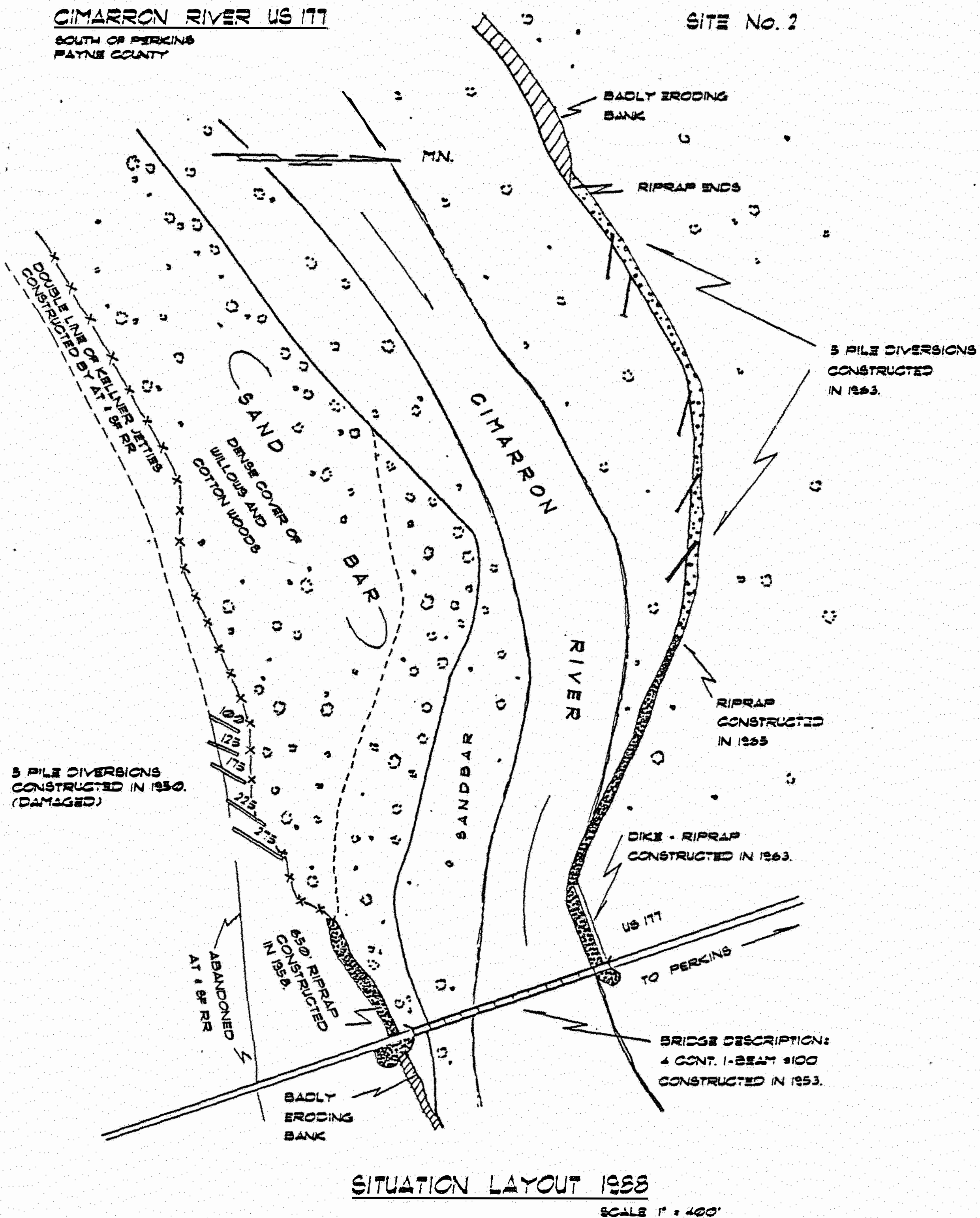
Site No. 2



Scale: 1" = 581'

1989 SITE AERIAL PHOTOGRAPH

FIGURE 32



CIMARRON RIVER US 177
SOUTH OF PERKINS
PAYNE COUNTY
SITE No. 2
BADLY ERODING BANK
M.N.
RIPRAP ENDS
3 PILE DIVERSIONS CONSTRUCTED IN 1963.
DOUBLE LINE OF KELLNER JETTIES CONSTRUCTED BY AT & SF RR
SAND BAR
DENSE COVER OF WILLOWS AND COTTON WOODS
CIMARRON
RIVER
RIPRAP CONSTRUCTED IN 1955
SANDBAR
3 PILE DIVERSIONS CONSTRUCTED IN 1950. (DAMAGED)
100
125
175
225
275
DIKE - RIPRAP CONSTRUCTED IN 1963.
US 177
TO PERKINS
ABANDONED AT & SF RR
650' RIPRAP CONSTRUCTED IN 1958.
BRIDGE DESCRIPTION: 4 CONT. I-BEAM #100 CONSTRUCTED IN 1953.
BADLY ERODING BANK
SITUATION LAYOUT 1958
SCALE 1" = 400'

FIGURE 33

CIMARRON RIVER - US77 Site No. 2
South of Perkins (Payne County)

Bridge and Site Data:

The bridge structure in place was constructed in 1953 and is comprised of 2 sets of four, 100 ft continuous I-Beam spans. It is situated across the Cimarron river which is known for its wide meander loops. The span of the bridge is about 800 ft, while the flood plain is about 2000 ft. This site has a constant history of both the northern and the southern banks being attacked as the river tends to meander. There has been a constant effort to stabilize the northern and southern banks as a result of riverine action of the Cimarron. The southern flood plain shows an extensive sandbar deposition, which is being rapidly vegetated with shrubs and tall grass.

History of Stabilization Procedures:

The first stabilization that was done at the old bridge site was the construction of a Kellner jetty field by the AT & SF Railroad Company. In 1950, 5 pile diversions were constructed at the point of impact of the 1949 floods. In 1953, the present bridge was constructed and dikes and riprap were constructed at both the abutments. In 1957, 650 ft of riprap was constructed on the south bank from the first abutment to the downstream unit of the pile diversion system.

In 1963, 5 pile diversions were constructed on the northern bank of the river. The riprap on the northern abutment was relaid, and extended, at the same time. Presently, there are pile diversions on both the northern and southern banks diverting the flow toward the center of the bridge structure.

Site Evaluation:

As stated earlier there are pile diversions on both the northern and the southern river banks which are meant to divert the river flow inward. The situation in 1989 shows that neither set of the diversions are in contact with the river. This is because of the low flow condition of the river at present. These diversionary structures will be active in the event of a large flood. The present northern bank in contact with the river is riprapped and appears to be in good condition. There is an extensive sandbar deposition in the river and the major part of the river seems to be confined on a braid to the northern bank.

Comparision of the 1969 and 1989 aerial photographs show a well behaved river condition at present. The pile diversions on the southern bank seems to be in perfect condition and are densely overgrown. The riprapped dike on the southern bank also seems to be in perfect condition and does not show signs of distress.

Most of the Kellner jetties constructed by the Railroad company seem to be covered up and none of them could be located during the field visit. The southern bank has a dense cover of willows and cottonwoods. At the bridge location the river now seems to be attacking the southern bank. There is, however, no cause for immediate alarm.

Site No. 2 is a very good site to study river action which alternately attacks both of the banks. The stabilizing structures that have been installed have been very successful in controlling the river and keeping it under the bridge structure. Diversionary structures have been, and are clearly effective in controlling the river at this site.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JULY 25th 1988 SITE NO.: 2

HIGHWAY NO.: US 177 COUNTY: PAYNE

BRIDGE LOCATION: SOUTH OF PERKINS

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1953

Span Description: 4 CONTINUOUS I-BEAM @ 100'

2) Yr. of constr.: ____________

Span Description: ____________

EMBANKMENT TYPE:

SLOPE: STEEP NORTHERN ROAD APPROACH AND GENTLE SOUTHERN ROAD APPROACH.

PROTECTION: SPURDIKE WITH RIPRAP ON NORTH ABUTMENT AND RIPRAP ON SOUTHERN ABUTMENT.

SPECIAL NOTES: HEAVY BUILDUP OF SANDBAR IN THE RIVER.

RIVER BANK:

SOIL NATURE: SILTY VEGETATION: WILLOWS

COMMENTS: SOUTHERN BANK IS HEAVILY WOODED, BUT ACCESSIBLE.

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: SPUR DIKE AND RIPRAP (NORTHERN BANK)

a) Description: BUILT IN 1963. TO PREVENT THE RIVER FROM CUTTING BEHIND THE BRIDGE.

b) Present Condition: FAIRLY GOOD CONDITION WITH NO NEED FOR IMMEDIATE MAINTANENCE.

TYPE: UPSTREAM RIPRAP (NORTHERN BANK)

a) Description: BUILT IN 1965 AS EXTENSION TO ON SITE RIPRAP TO PREVENT MEANDER LOOP.

b) Present Condition: LITERALLY NO EXISTING SIGNS OF THE RIPRAP.

TYPE: 5 PILE DIVERSIONS (NORTHERN BANK)

a) Description: BUILT IN 1963. TO DIVERT RIVER FLOW AWAY FROM THE BANK.

b) Present Condition: NO EVIDENCE OF ANY OF THE PILE DIVERSIONS, SO THIS MATTER WILL HAVE TO BE LOOKED INTO.

TYPE: 5 PILE DIVERSIONS (SOUTHERN BANK)

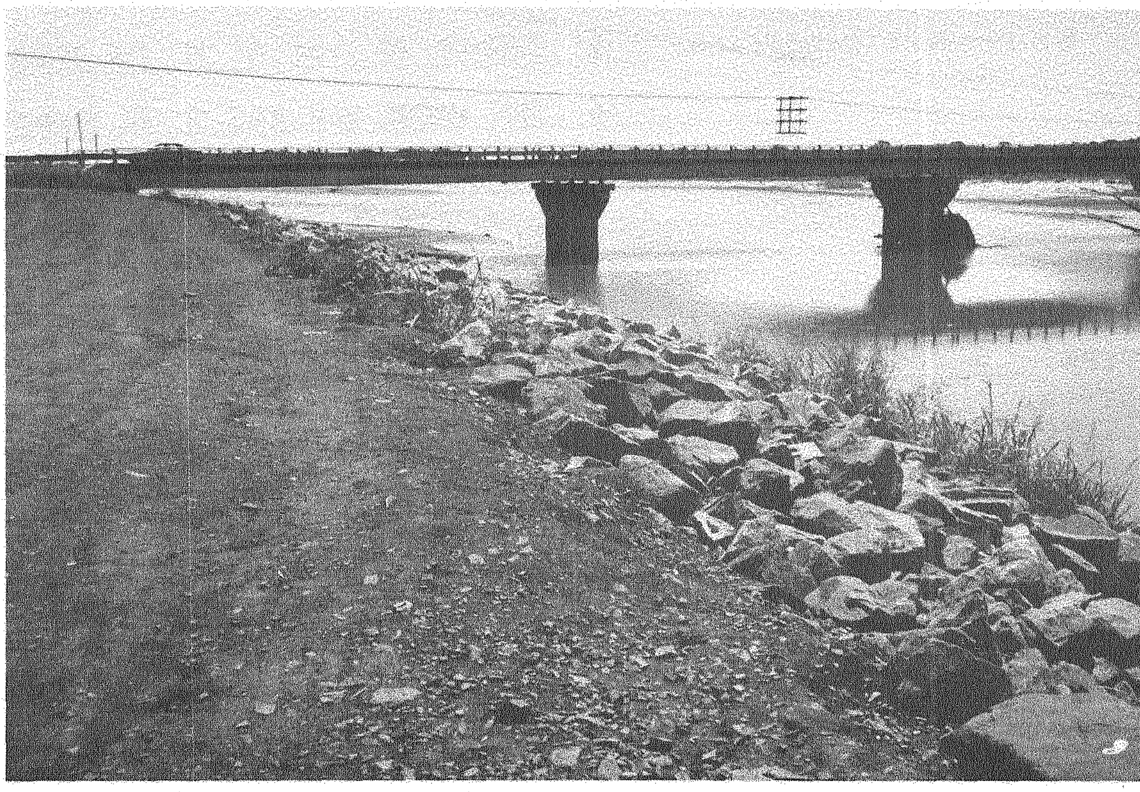
a) Description: BUILT IN 1950, TO PREVENT BANK EROSION IN CASE OF A FLOOD.

b) Present Condition: BADLY DAMAGED CONDITION WITH SOME SECTIONS MISSING. IT HAS WORKED EFFECTIVELY EVIDENT FROM THE PRESENCE OF LARGE SANDBAR WITH DENSE VEGETATION.

TYPE: ______________________

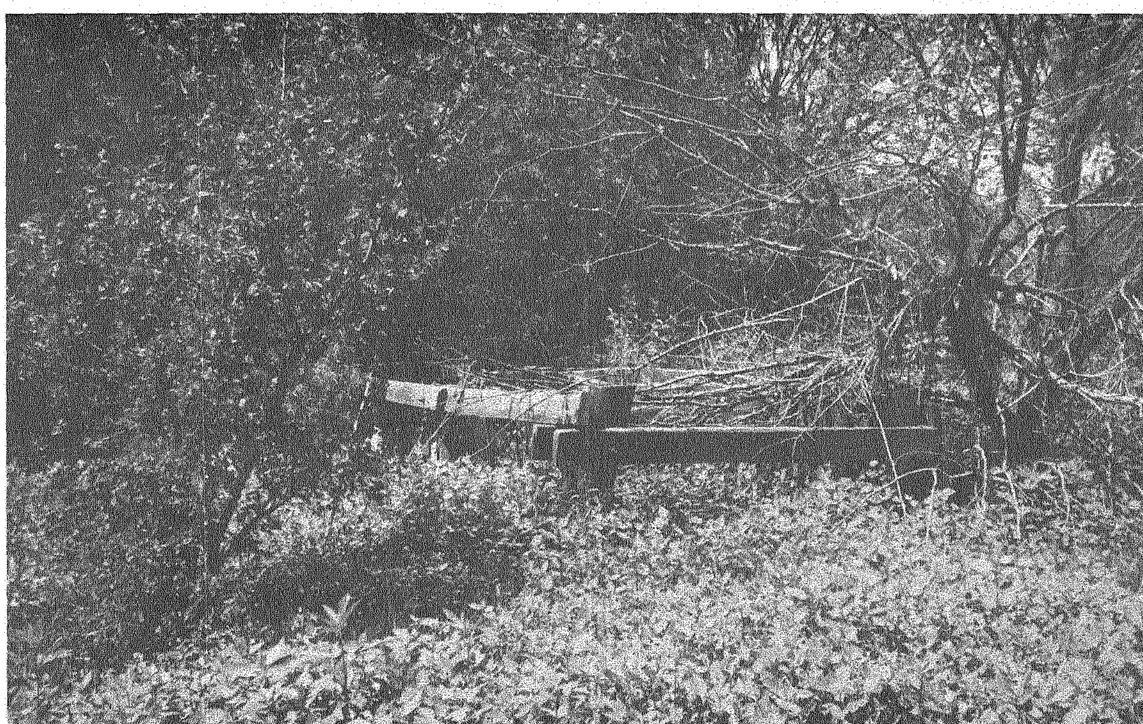
a) Description: ______________________

b) Present Condition: ______________________



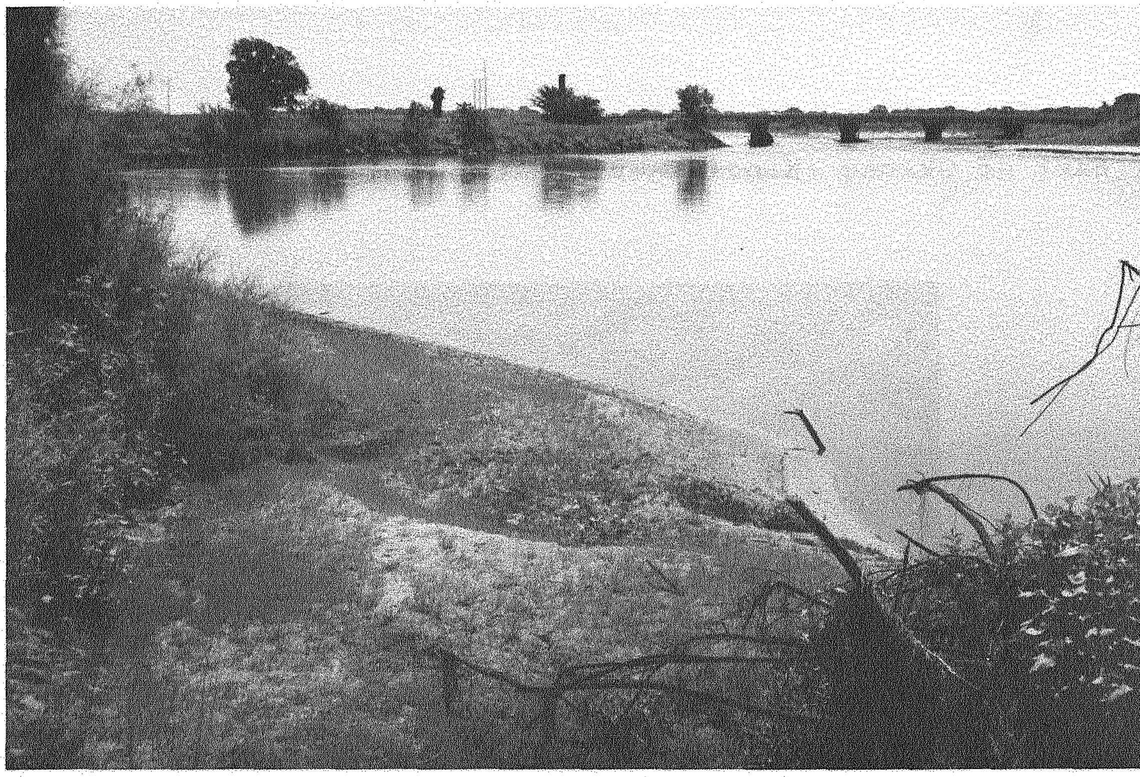
Riprap on Upstream Abutment

Figure 34a



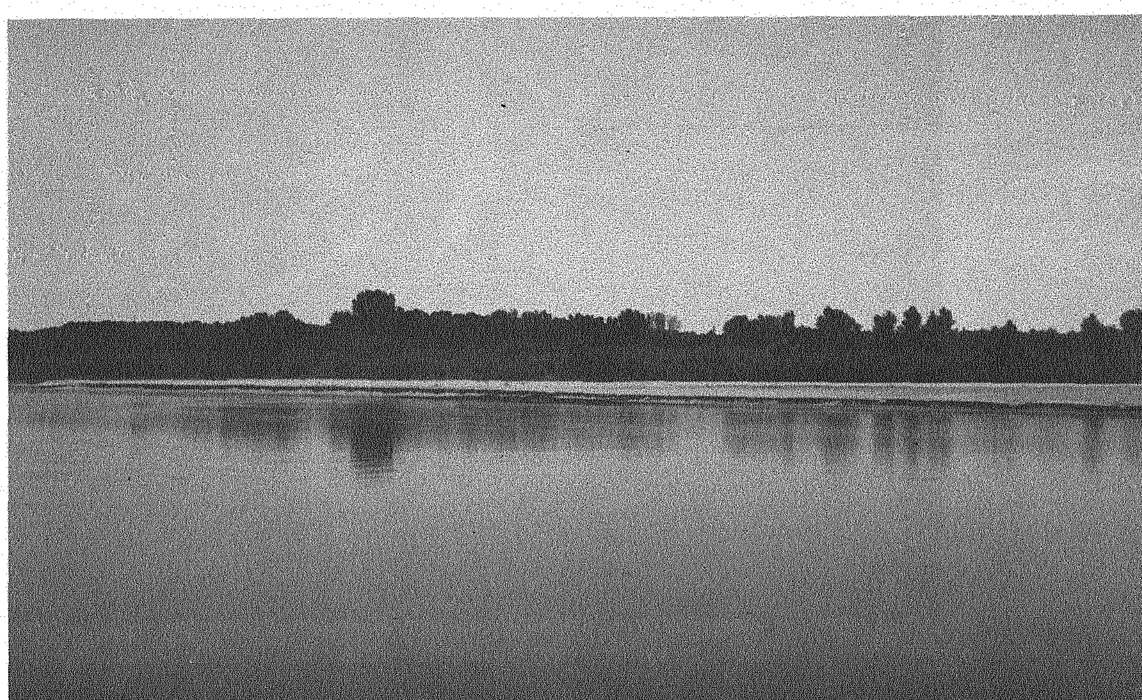
Overgrown Pile Diversion on South Bank

FIGURE 34b



River Cutting into North Bank

FIGURE 34c

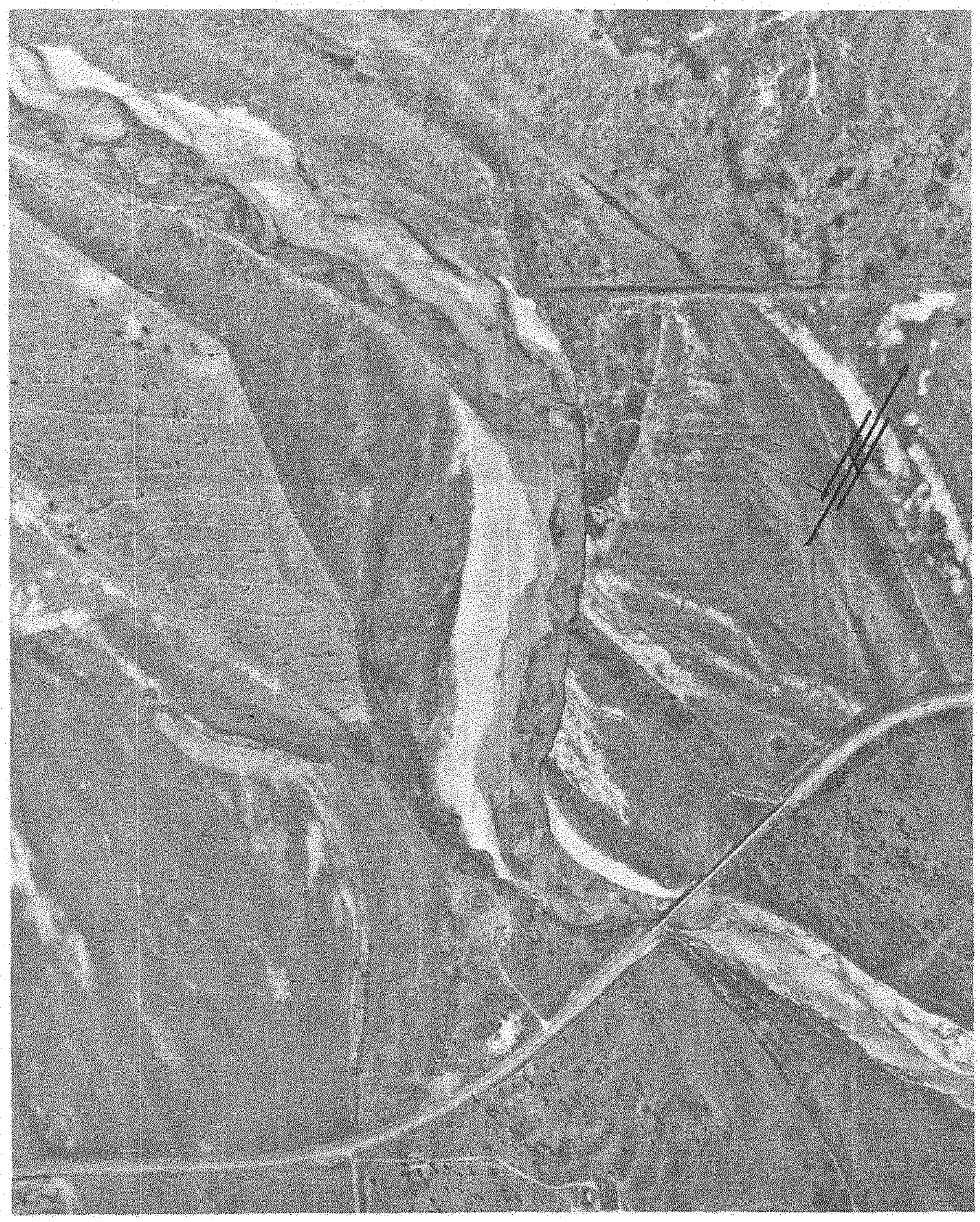


Sandbar in Midstream

FIGURE 34d

CIMARRON RIVER - SH 51
East of Okeene (Kingfisher County)

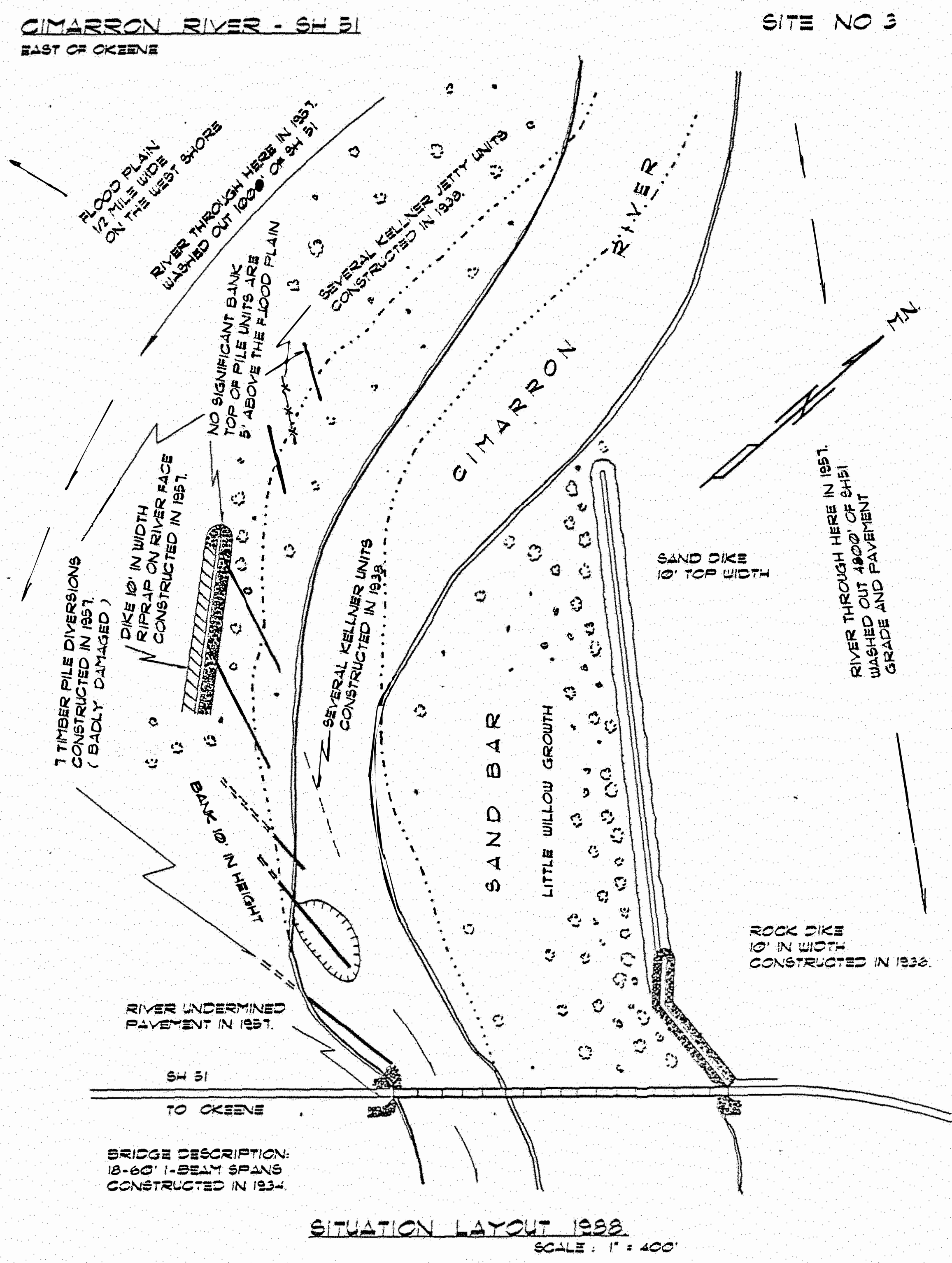
Site No. 3



Scale: 1" = 1152'

1989 Site Aerial Photograph

FIGURE 35



CIMARRON RIVER - SH 51
EAST OF OKEENE
SITE NO 3
FLOOD PLAIN 1/2 MILE WIDE ON THE WEST SHORE
RIVER THROUGH HERE IN 1957. WASHED OUT 1000' OF SH 51
SEVERAL KELLNER JETTY UNITS CONSTRUCTED IN 1938.
NO SIGNIFICANT BANK TOP OF PILE UNITS ARE 5' ABOVE THE FLOOD PLAIN
DIKE 10' IN WIDTH RIPRAP ON RIVER FACE CONSTRUCTED IN 1957.
7 TIMBER PILE DIVERSIONS CONSTRUCTED IN 1957. (BADLY DAMAGED)
SEVERAL KELLNER UNITS CONSTRUCTED IN 1938
BANK 10' IN HEIGHT
CIMARRON RIVER
SAND BAR
LITTLE WILLOW GROWTH
SAND DIKE 10' TOP WIDTH
RIVER THROUGH HERE IN 1957. WASHED OUT 4800' OF SH51 GRADE AND PAVEMENT
M.N.
ROCK DIKE 10' IN WIDTH CONSTRUCTED IN 1936.
RIVER UNDERMINED PAVEMENT IN 1957.
SH 51
TO OKEENE
BRIDGE DESCRIPTION: 18-60' I-BEAM SPANS CONSTRUCTED IN 1934.
SITUATION LAYOUT 1958
SCALE: 1" = 400'

FIGURE 36

CIMARRON RIVER - SH 51 Site No. 3

East of Okeene (Kingfisher County)

Bridge and Site Data:

The present bridge structure on the site was built in 1934 and consisted of 18, 60 ft I-Beam spans. The bridge floor elevation is at 1010.5 ft and the High Water Elevation for the design of the bridge was estimated at 1002.0 ft. The river has an extensive but well-defined floodplain, about one mile wide, and during periods of low flows extensive sandbar deposition has been observed. The southern bank under attack of the river is on an average of about 10 ft in height.

History of Stabilization Procedures:

In 1934, along with the construction of the bridge a dike was also constructed west of the bridge on the northern bank. It was 10 ft in width at the top, made of rock near the bridge and of sand extending westward. The sand dike was rockfaced for additional protection.

Nearly 1500 ft of Kellner jetties were installed in 1938 to protect the badly eroding southwest bank.

In 1957 the construction of seven pile diversions was completed along the southwest bank to prevent the river from cutting into that bank. A riprapped dike along the overflow channel was constructed to reduce high water flows of the river from flowing back into the channel. Extensive riprap was also placed along the southern bank, where the river undermined the approach in 1957.

Site Evaluation:

This site is a clear example of the advantages and disadvantages of pile diversions. In 1957, the seven pile diversions were placed on the southern bank of the river along with a backup dike across the old river channel. One clear observation at this site elucidates the effectiveness of pile diversions in shifting the channel erosion locations from the bridge structure to a safe position upstream. Comparison of the 1968 and 1989 aerial photographs indicate an overall decrease in the radius of the meander loop upstream of the bridge. This is due to the shifting of the river either because of the pile diversions or due to riverine behavioral causes. Except for the first upstream diversion all the others in contact with the river are in a highly deteriorated state. Many of them are not even standing. The river is definitely cutting behind the first diversion and is moving toward the roadway. There seems to be erosion problems on the banks between the pile diversions and there is not enough vegetal cover to prevent the impact of the river from eroding the stream banks.

A decrease in the radius of the meander loop is something to be carefully monitored. A decrease in the radius of the meander loop can mean an increase in the angle of attack of the water on the bank and an increase in the erosive velocity impacts of the water. These two factors are important since most erosional problems have there origins in these parameters. The river has also become much narrower due to the extensive deposition of sandbars on both the concave and convex banks.

The northern abutment and dike seems to be in perfect condition. The inward movement of the river has put the upstream end of the dike in contact with the river. This seems to be no cause of concern, mainly due to the inability the river to sustain any movement of the river into the northern flood plain.

For now, increased attention should be focused on the river action at the southern bank. In the event of a major flood, the river may erode the southern bank extensively, given the present conditions. The pile diversions should be repaired or an alternative river training technique should be looked into. As an observation, the present bridge structure is likely scheduled for replacement in the next decade or so. Consideration should be given to moving the bridge site downstream. This would also correct the highway alignment.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: SEP. 9th, 1988 SITE NO.: 3

HIGHWAY NO.: SH 51 COUNTY: KINGFISHER

BRIDGE LOCATION: CIMARRON RIVER, EAST OF OKEENE

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1934

Span Description: 18, 60' I-BEAM SPANS

2) Yr. of constr.:

Span Description:

EMBANKMENT TYPE:

SLOPE: MEDIUM SLOPE ON BOTH BANK

PROTECTION: RIPRAP ON THE SOUTHERN ABUTMENT.

SPECIAL NOTES: NORTHERN ABUTMENT IS NOT IN DIRECT CONTACT WITH THE RIVER

RIVER BANK:

SOIL NATURE: SANDY VEGETATION: WILLOWS

COMMENTS: THE FLOOD PLAIN ON THE NORTHERN BANK IS EXTENSIVE.

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: ROCK DIKE

a) Description: 10' IN WIDTH
CONSTRUCTED IN 1934, ON NORTHERN
FLOOD PLAIN.

b) Present Condition: SEEMS TO BE IN PERFECT CONDITION
AND HAS A LOT OF OVERGROWTH.

TYPE: SAND DIKE

a) Description: BUILT IN CONTINUATION TO THE ROCK DIKE
IN 1934, AND AROUD 1300' IN LENGTH.
THIS DIKE HAS A RIPRAPPED FACING.

b) Present Condition: MOST OF THE DIKE IS IN GOOD CONDITION.
THE OUTERMOST EDGE OF THE DIKE IS UNDER
DIRECT ATTACK OF THE RIVER.

TYPE: PILE DIVERSIONS

a) Description: CONSTRUCTED IN 1957, ON THE SOUTHERN BANK
TO DIVERT FLOW AWAY FROM THE BANK.
7 UNITS IN ALL CONSTRUCTED.

b) Present Condition: MOST OF THE DIVERSIONS NEED REPAIR. THEY HAVE PERFORMEDEXCELLENTLY IN DIVERTING FLOW AND INDUCING DEPOSITION. THE RIVER IS CUTTING BEHIND THE FIRST PILE DIVERSION. MOST OF THEM NEED REPAIR. SAND DEPOSITION NOT ENOUGH TO ENCOURAGE VEGETAL GROWTH.

TYPE: KELLNER JETTIES

a) Description: CONSTRUCTED IN 1938, BETWEEN THE SIXTH AND SEVENTH DIVERSIONS AND ALSO ON THE SAND BAR IN FRONT OF THE DIVERSIONS.

b) Present Condition: THERE ARE NO TRACES OF ANY OF THE JETTIES THAT WERE CONSTRUCTED, EITHER DESTROYED OR VIRTUALLY COVERED UP.

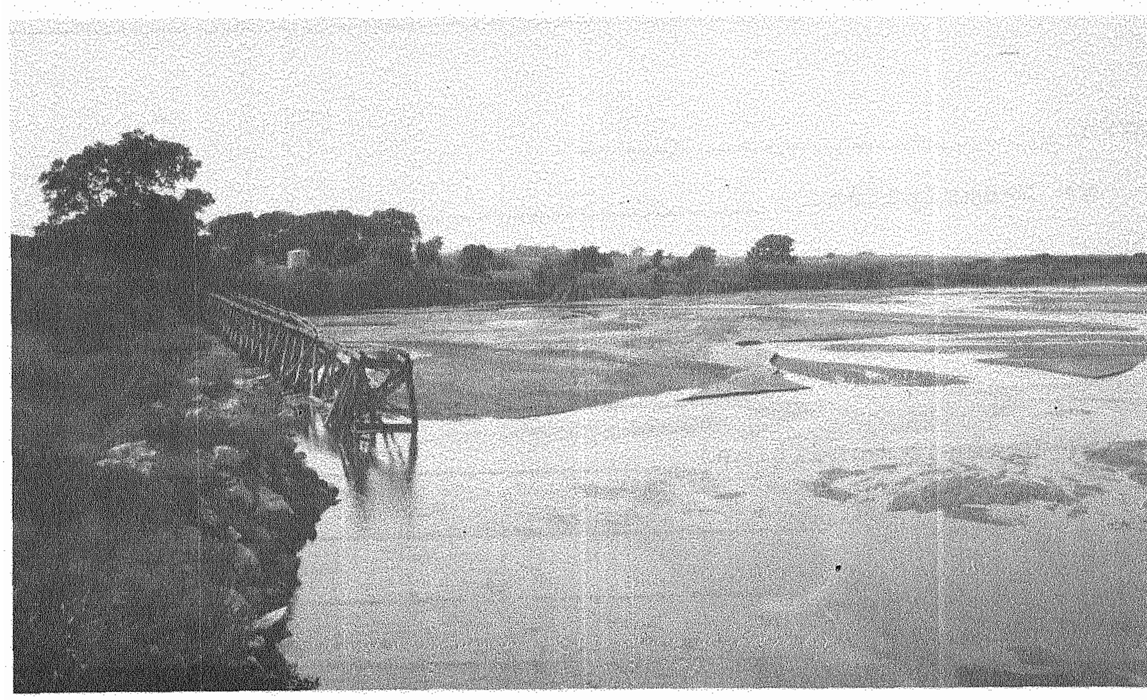
TYPE: ______

a) Description: ______

b) Present Condition: ______

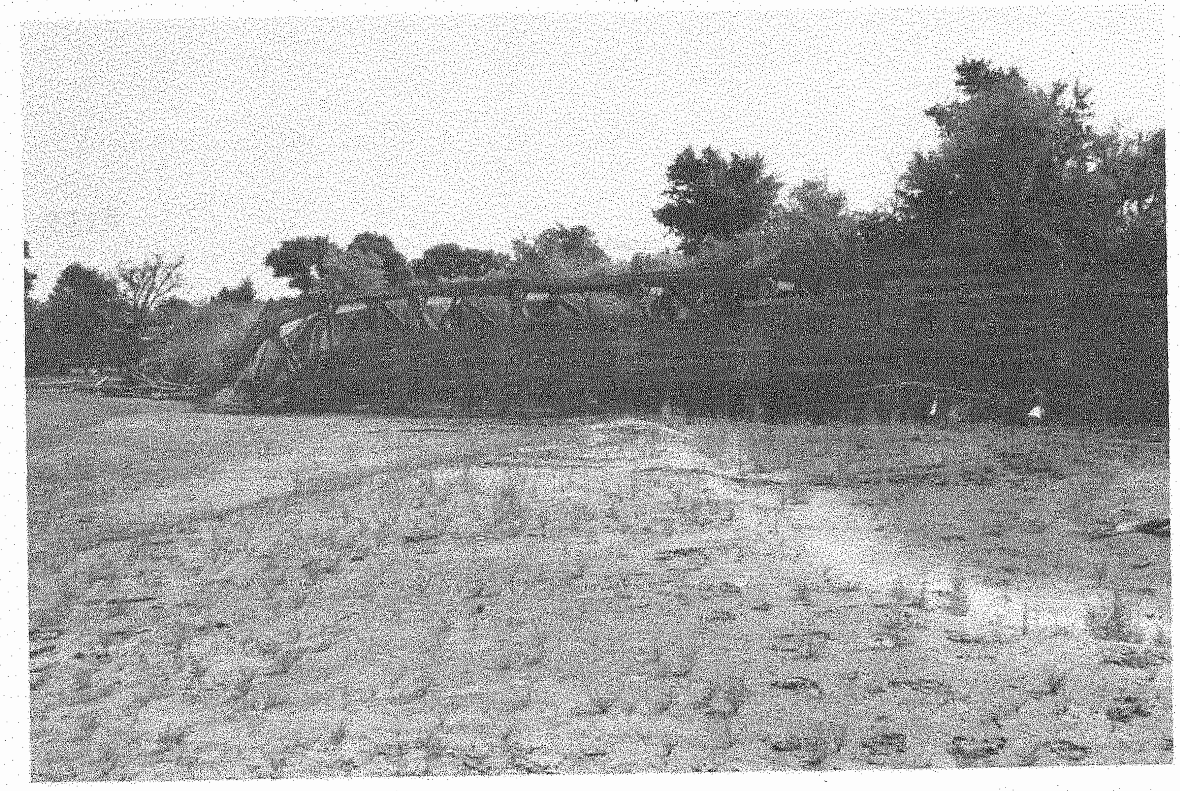
View of Bridge Abutment with Riprap

FIGURE 37a



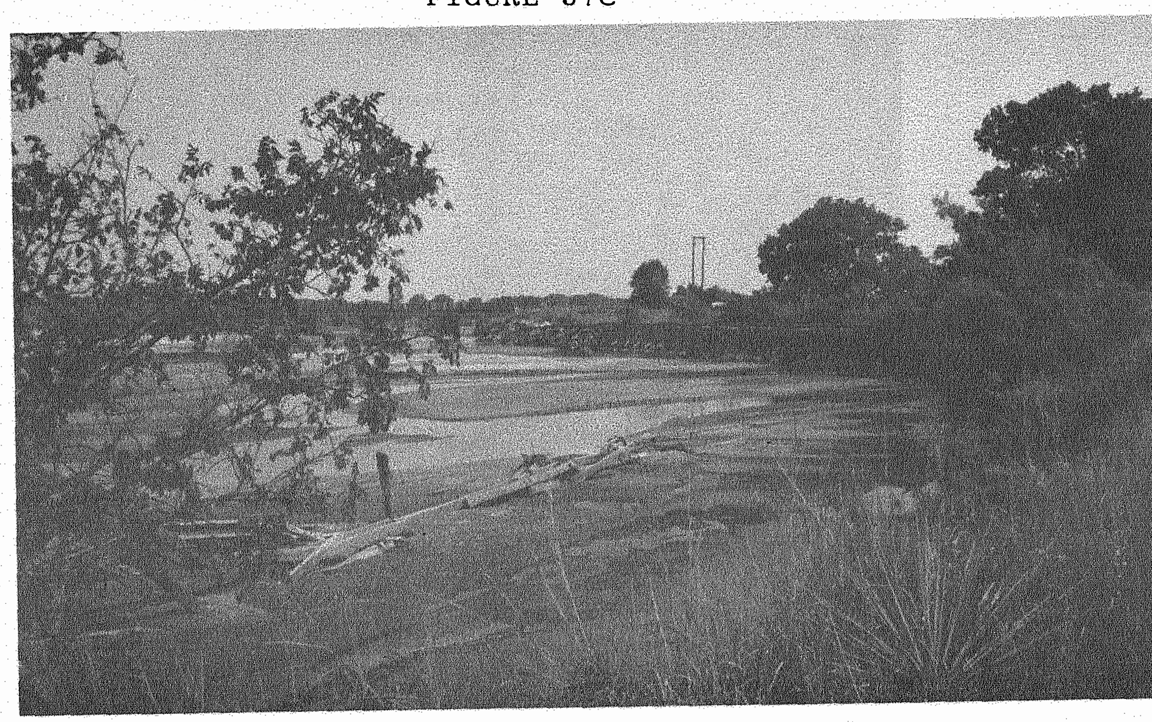
View of the Pile Diversion Field

FIGURE 37b



Pile Diversion with Missing Face Planks

FIGURE 37c



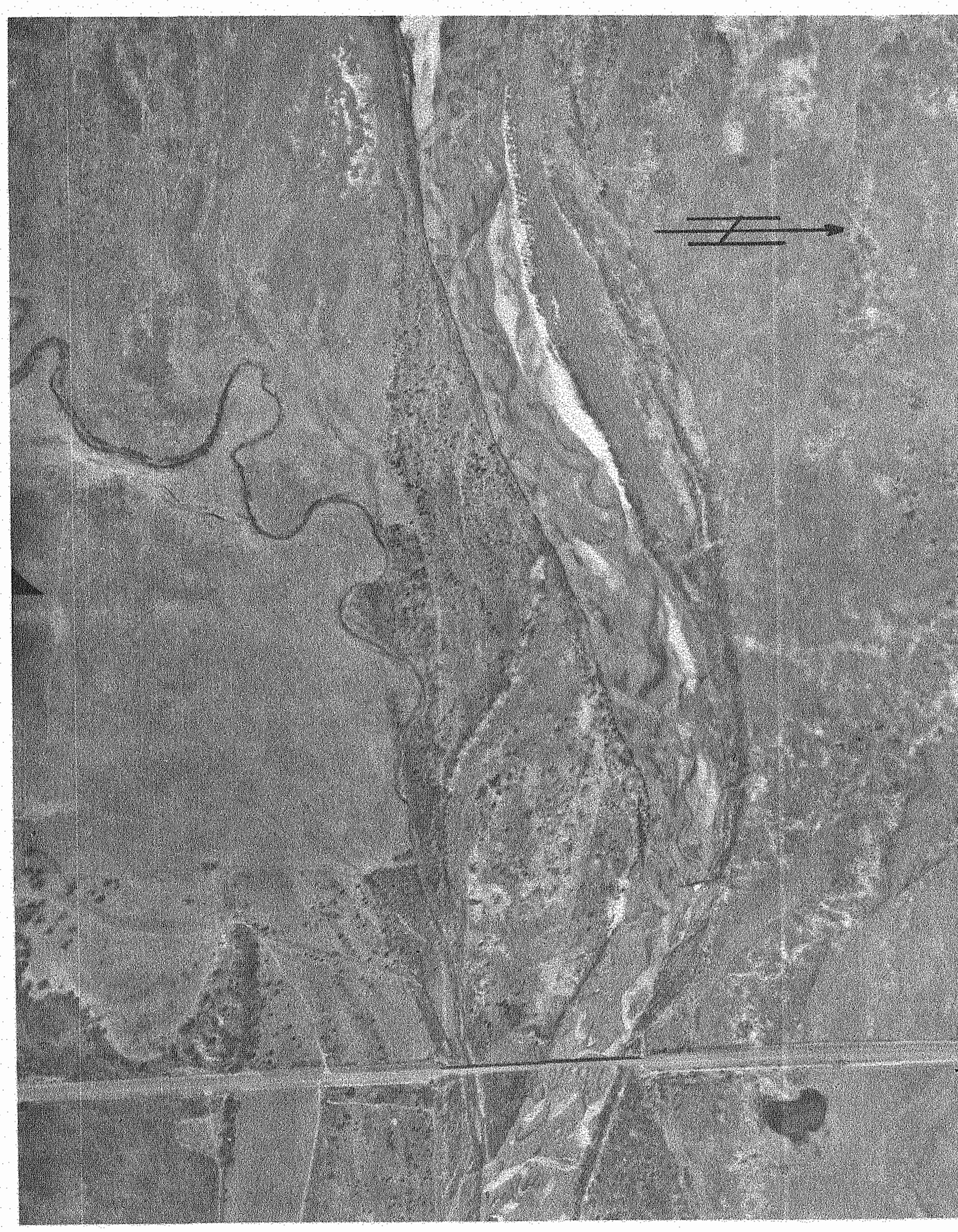
Another View of Damaged Pile Diversions

FIGURE 37d

CIMARRON RIVER - US281

Site No. 4

South of Waynoka (Woods County)



Scale: 1" = 1177'

1989 Site Aerial Photograph

FIGURE 38

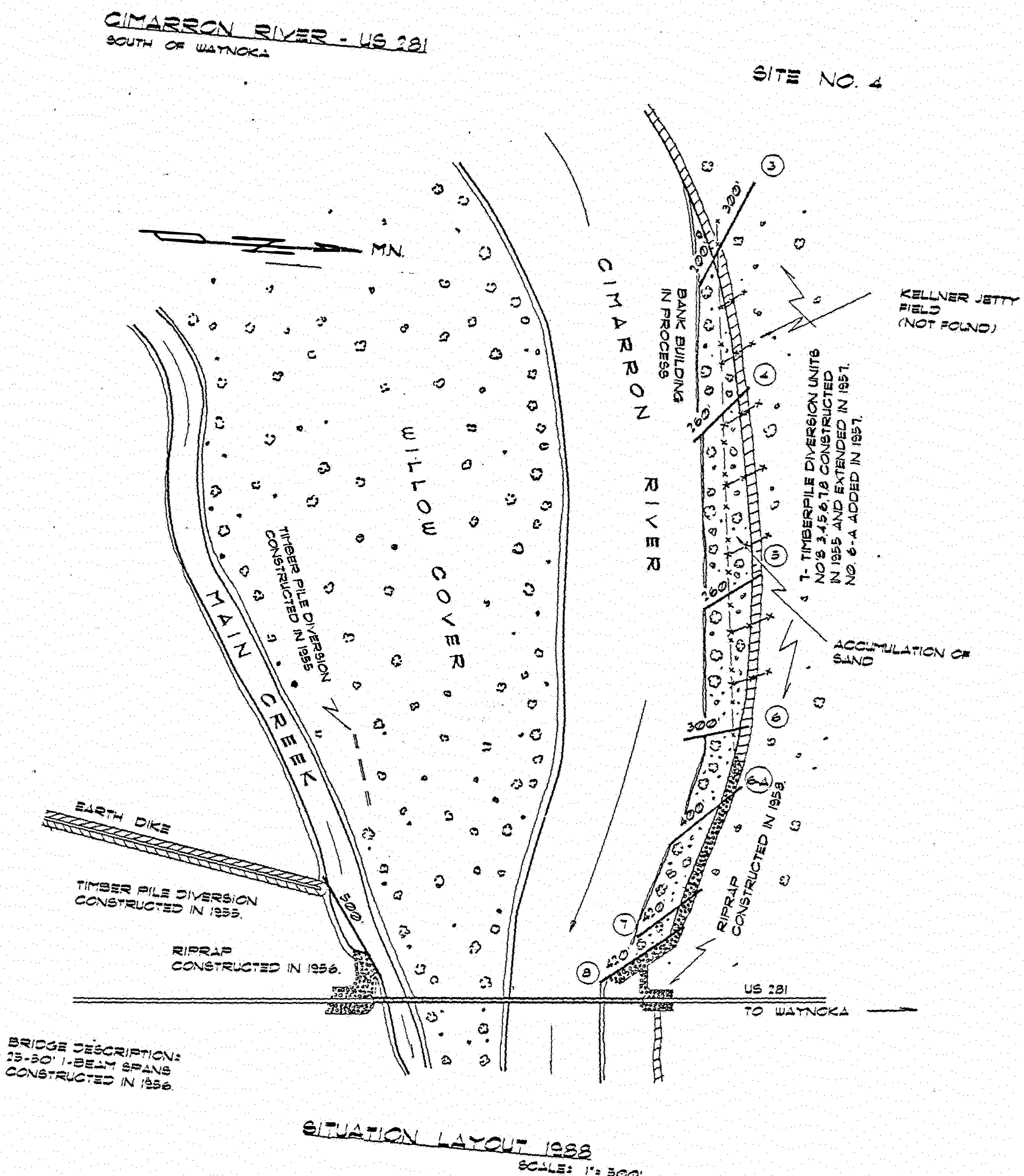

CIMARRON RIVER - US 281
SOUTH OF WATNOKA
SITE NO. 4
M.N.
KELLNER JETTY FIELD (NOT FOUND)
BANK BUILDING IN PROCESS
CIMARRON RIVER
WILLOW COVER
MAIN CREEK
TIMBER PILE DIVERSION CONSTRUCTED IN 1955
T- TIMBERPILE DIVERSION UNITS NO'S 3,4,5,6,7,8 CONSTRUCTED IN 1955 AND EXTENDED IN 1957. NO. 6-A ADDED IN 1957.
ACCUMULATION OF SAND
EARTH DIKE
TIMBER PILE DIVERSION CONSTRUCTED IN 1955.
RIPRAP CONSTRUCTED IN 1956.
RIPRAP CONSTRUCTED IN 1958
US 281
TO WATNOKA
BRIDGE DESCRIPTION: 25-50' I-BEAM SPANS CONSTRUCTED IN 1956.
SITUATION LAYOUT 1988
SCALE: 1"= 300'

FIGURE 39

CIMARRON RIVER - US281 Site No. 4
South of Waynoka (Woods County)

Bridge and Site Data:

The bridge structure in place was constructed in 1956 and consists of twenty five, 50 ft I-Beam spans. The river banks are of alluvial nature and very silty with low plasticity. The riverbed shows signs of extensive sand deposition evidenced by the presence of extensive sandbars. The flood plain is extensive and shallow and the bridge structure seems to span a very large portion of it. There is a tributary that flows parallel to the river at the bridge site. The floodplain seems to be densely covered with stunted vegetation of willows and other shrubs. The radius of the meander loop of the Cimarron river at this point is large.

History of Stabilizing Procedures:

About 1950, before the new bridge was constructed, Kellner jetties were constructed to protect the northern banks of the river from riverine attack. In 1955, the present bridge structure was constructed and along with it two pile diversions were erected on the southern bank, and six pile diversions were constructed on the northern bank. The 1957 flood created the need to repair the diversions on the northern bank, and also a new diversion structure was added. In 1958, riprap was added along the damaged sections of the northern banks. Extensive riprap can be found on both the northern and the southern bridge abutments. An earth dike can be located near the pile diversion adjoining the southern bridge abutment.

Site Evaluation:

The Cimarron river has numerous sandbars primarily due to a dominant low water velocity and large silt load. The southern part of the flood plain has an extensive sandbar, which is densely covered by low shrubs and other types of vegetation. In 1968 a part of the river flowed through a channel in this sandbar. This channel joined a creek flowing parallel to the river and it directly attacked the southern bank. Two pile diversions were erected on the channel and one on the creek next to the bridge abutment. As of now, the old channel seems to be vegetated over and is difficult to locate. As for the tributary, it has moved northward and no longer seems to be attacking the bridge abutment. The northern abutment shows heavy riprapping at the abutment, which seems to be in very good condition. Seven pile diversions were constructed on the northern bank. Comparison of the 1968 and 1989 aerial photographs show that the pile diversions were effective in shifting the river more southward. All along this bank, the pile diversions have encouraged the growth of vegetation. The extreme upstream diversions are now no longer in contact with the river which is a clear indication that the river has definitely changed its course. Presently, the northern abutment of the bridge seems to be in no danger of being dangerously attacked by the river. The pile diversions have clearly reduced the radius of the meander loop of the river. This may give the river more erosive influence against the diversionary structures immediately upstream from the bridge. A wide scour pool can be observed around the first pile diversion upstream, and this may be the first observable action due to such a phenomena. This action can be confirmed only after the occurence of a major flood.

In conclusion it can be stated that this difficult site has been responsive to the stabilization procedures that have been applied. There does no seem to be any immediate danger at this site though a maintenance of the pile diversions would be helpful.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: AUGUST 8 - 1988 SITE NO.: 4

HIGHWAY NO.: US 281 COUNTY: WOODS

BRIDGE LOCATION: CIMARRON RIVER, SOUTH OF WAYNOKA

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1956

Span Description: 25, 50' I-BEAM SPANS

2) Yr. of constr.:

Span Description:

EMBANKMENT TYPE:

SLOPE: STEEP SLOPES AT THE EMBANKMENTS.

PROTECTION: RIPRAP AT THE EMBANKMENT

SPECIAL NOTES: DENSE VEGETAL COVER ON THE SAND BAR ADJOINING THE SOUTHERN BANK.

RIVER BANK:

SOIL NATURE: SANDY / SILTY VEGETATION: WILLOWS AND COTTONWOOD

COMMENTS:

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: PILE DIVERSIONS (NORTH BANK)

a) Description: 7 DIVERSIONS CONSTRUCTED IN 1955 to 1957 DIVERSIONS ARE NOT ANCHORED. CONSTRUCTED TO DIVERT WATER AWAY FROM THE BANK.

b) Present Condition: ALL THE DIVERSIONS ARE IN NEAR PERFECT CONDITION, AND ARE DOING AN EXCELLENT JOB IN DIVERTING THE FLOW

TYPE: KELLNER JETTIES (IN BETWEEN PILE DIVERSION)

a) Description: THESE KELLNER JETTIES WERE CONSTRUCTED IN BETWEEN PILE DIVERSIONS TO REDUCE FLOW OF WATER BETWEEN THESE STRUCTURES.

b) Present Condition: NONE OF THESE JETTIES ARE VISIBLE, POSSIBLY COVERED OR DESTROYED IN PREVIOUS FLOODS.

TYPE: RIPRAP (ON NOTHERN BANK)

a) Description: CONSTRUCTED IN 1958, TO PROTECT THE NOTHERN BRIDGE ABUTMENT FROM DIRECT ATTACK OF THE RIVER.

b) Present Condition: SEEMS TO BE IN NEAR PERFECT CONDITION IN 1989.

TYPE: PILE DIVERSION (SOUTHERN BANK)

a) Description: CONSTRUCTED IN 1955 AND 500' FT. IN LENGTH TO PROTECT SOUTHERN ABUTMENT FROM THE ATTACK OF THE PARALLEL CREEK.

b) Present Condition: THE CREEK IS NO LONGER IN CONTACT WITH THE PILE DIVERSION, DUE TO REALIGNMENT. THE DIVERSION IS OVERGROWN WITH WILLOWS AND SHRUBS.

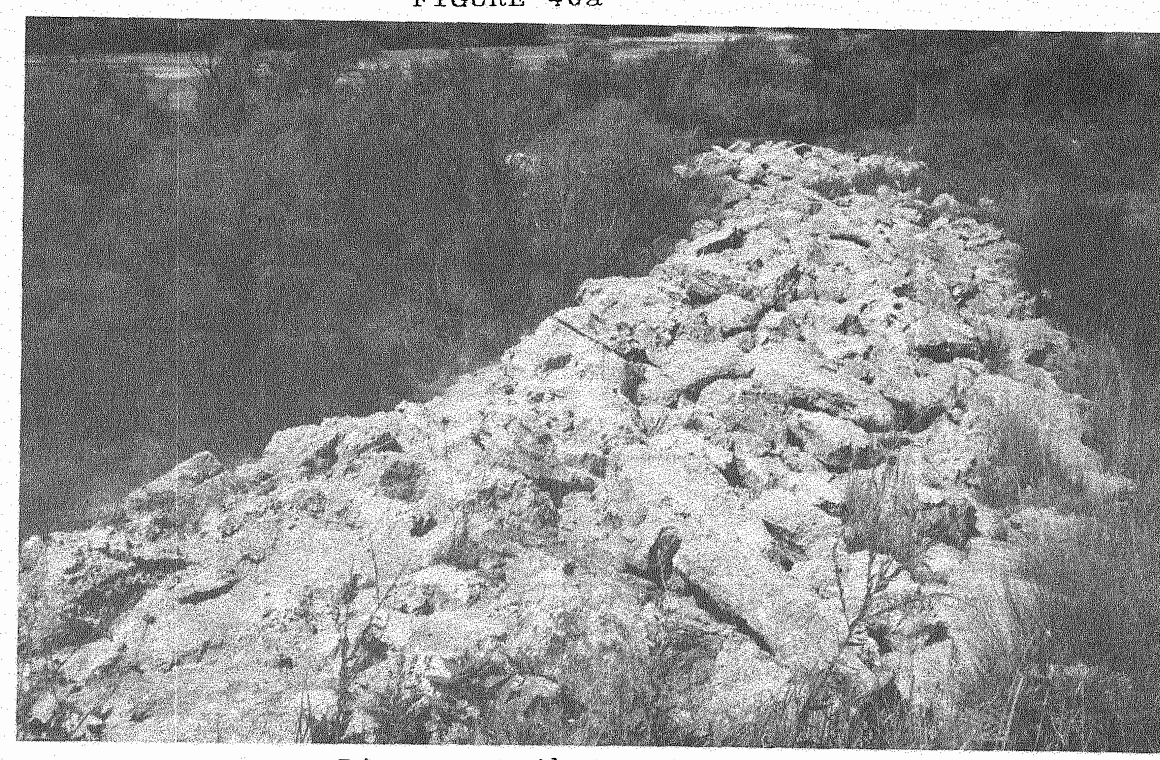
TYPE: PILE DIVERSION (IN MAIN CREEK)

a) Description: CONSTRUCTED IN 1955. AND [illegible]' IN LENGTH IN THE CIMARRON RIVER CREEK, TO DIVERT RIVER FLOW AWAY FROM ABUTMENT.

b) Present Condition: DENSELY COVERED WITH VEGETATION, AND NOT VISIBLE BY LAND. CREEK NO LONGER EXIST. ELIMINATING THE NEED FOR THIS STRUCTURE.

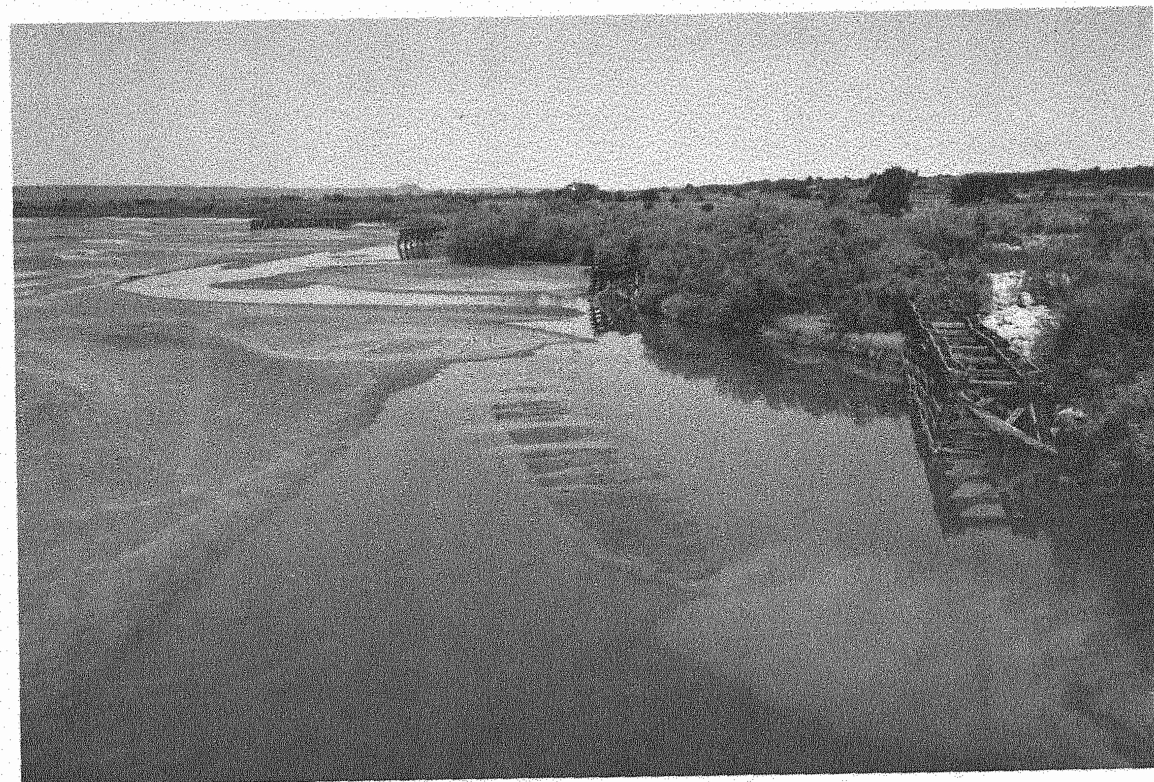
View of Bridge Site

FIGURE 40a



Riprap at Abutment

FIGURE 40b



View of Pile Diversion Field

FIGURE 40c

Bank Building Process in between Pile Diversions

FIGURE 40d

ARKANSAS RIVER - US 64
North of Bixby (Tulsa County)

Site No. 5

Scale: 1" = 1126'

1989 Site Aerial Photograph

FIGURE 41

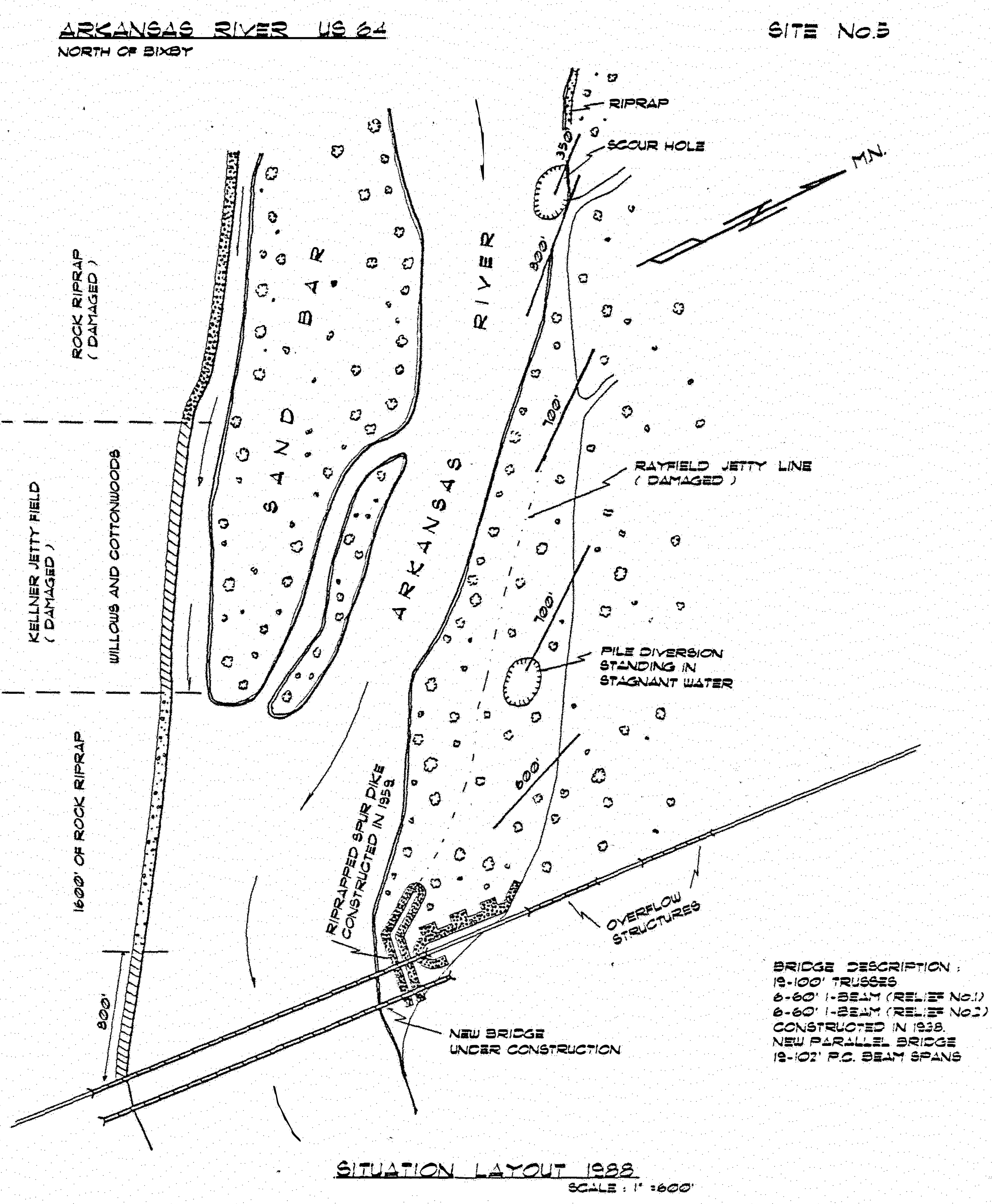

ARKANSAS RIVER US 64
NORTH OF BIXBY
SITE No.5
RIPRAP
SCOUR HOLE
350'
M.N.
ROCK RIPRAP (DAMAGED)
SAND BAR
RIVER
800'
700'
ARKANSAS
RAYFIELD JETTY LINE (DAMAGED)
KELLNER JETTY FIELD (DAMAGED)
WILLOWS AND COTTONWOODS
700'
PILE DIVERSION STANDING IN STAGNANT WATER
1600' OF ROCK RIPRAP
RIPRAPPED SPUR DIKE CONSTRUCTED IN 1959
600'
OVERFLOW STRUCTURES
800'
NEW BRIDGE UNDER CONSTRUCTION
BRIDGE DESCRIPTION :
19-100' TRUSSES
6-60' I-BEAM (RELIEF No.1)
6-60' I-BEAM (RELIEF No.2)
CONSTRUCTED IN 1938.
NEW PARALLEL BRIDGE
19-102' P.C. BEAM SPANS
SITUATION LAYOUT 1988
SCALE : 1" =600'

FIGURE 42

Bridge and Site Data:

The bridge structure in place was constructed in 1938. It consisted of nineteen, 100 ft trusses and six, 60 ft I-Beam spans. A new parallel structure was added to this in about 1987. The span of the bridge covers a good part of the stream and it absorbs a wide part of the meander pattern of the stream. A large accumulation of sand can be noticed on the river bed leading to large sandbars through which the river braids at low stages. The northern part of the riverbank shows a dense cover of willows and other vegetation. Downstream from the bridge structure extensive sandmining operations can be seen.

History of Stabilization Procedures:

Along with the construction of the bridge in 1938, a Kellner jetty field was constructed on the northeast bank. Another jetty field was constructed in 1948 on the southeast bank. Rock riprap can be seen on the north bank in broken segmented sections. The major stabilizing structures were constructed in 1959. This included replacement of the fill of the northern abutment with broken stone, and construction of a rock spur upstream of the north abutment. Five pile diversions were constructed on the north bank and they were anchored to the bank formed by the 1959 floods. North of the bridge are overflow structures, built along the path of the river in 1959.

Site Evaluation:

The Arkansas river agressively maintains a very wide flood plain. It is also a high discharge river. This site has once again proven the effectiveness of pile diversions as appropriate river training structures. Comparison of the 1968 and 1989 aerial photographs show no major changes in the meander pattern of the river. Another observation is that the river seems to have held its course and flows between well defined banks. There does not seem to be any sign of any concentrated attacks of the river on any particular bank or on the embankments. The river winds its way through enormous sandbars that have been deposited over time. The northern embankment seems to be adequately protected from river attacks by the spur dike as well as the riprap and rock spurs which forms a double line of defense.

The five pile diversions that have been constructed on the upstream northern banks seem to have been highly successful. Damage to a pile diversion can be an evidence of the effectiveness of the structure. This can be demonstrated by the fact that the three pile diversions that are immediately upstream of the bridge structure are in a bad state of deterioration. Most of the face planks are missing and there is noticeable structural failure. These three structures are also seen to be resting on high banks. This phenomenon can possibly be explained by the fact that they were erected right across the river channel of 1959, and a later flood acted on them in an effort to cut back into the channel. This action was effectively thwarted due to the proper location of the pile diversions. The other two pile diversions further upstream are in near perfect condition although they are in direct contact with the water line. This may be because they may have not been in the direct line of attack of the water. The sandbar that is present on the northern bank is about 10 ft high and provides additional protection.

An overall view of this site shows no major erosional problems at present. This may also due to the reduced water level in the river due to the presence of a dam further upstream of the bridge structure as well as irrigation and other water use pattern changes.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: NOV. 10, 1988 SITE NO.: 5

HIGHWAY NO.: US 64 COUNTY: TULSA

BRIDGE LOCATION: ARKANSAS RIVER, NORTH OF BIXBY

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1938

Span Description: 19 - 100' TRUSSES

6 - 60' I - BEAMS

6 - 60' I - BEAMS

2) Yr. of constr.: ______

Span Description: ______

EMBANKMENT TYPE:

SLOPE: MEDIUM SLOPING BANKS

PROTECTION: SPUR DIKE ON NORTHERN BANK

SPECIAL NOTES: VERY EXTENSIVE SAND BARS NEAR THE BRIDGE SITE.

RIVER BANK:

SOIL NATURE: SANDY VEGETATION: WILLOWS / COTTONWOODS

COMMENTS: ______

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: SPUR DIKE

a) Description: CONSTRUCTED IN 1959, ON THE NORTHERN ABUTMENT, TO CONTROL RIVER AT THAT POINT.

b) Present Condition: SPUR DIKE IS INTACT AND IS OVERGROWN WITH VEGETATION. SEEMS TO HAVE SERVED ITS PURPOSE SUCCESSFULLY.

TYPE: PILE DIVERSIONS

a) Description: 5 DIVERSIONS CONSTRUCTED IN 1959, ON THE NORTHERN BANK, TO DIVERT RIVER AWAY FROM THE NORTHERN BANK.

b) Present Condition: MOST OF THE DIVERSIONS ARE ON THE PRESENT HIGH BANK IN GOOD CONDITION (MANY OF THEM STANDING IN STAGNANT WATER.) THOSE IN CONTACT WITH THE WATER ARE ALSO IN FAIRLY GOOD CONDITION.

TYPE: RIPRAP AND ROCK SPURS (NEAR NORTHERN ABUTMENT)

a) Description: CONSTRUCTED IN 1959. TO PROTECT ABUTMENT AGAINST WASHOUT IN CASE OF A BIG FLOOD.

b) Present Condition: THIS STRUCTURE SEEMS TO BE IN PERFECT CONDITION.

TYPE: RIPRAP AND KELLNER JETTIES (ON THE SOUTHERN BANK)

a) Description: BUILT AROUND 1948 TO STABILIZE THE SOUTHERN BANK.

b) Present Condition: THERE SEEMS TO BE NO TRACES OF THESE STRUCTURES, AND ARE MOST PROBABLY DESTROYED.

TYPE: ______

a) Description: ______

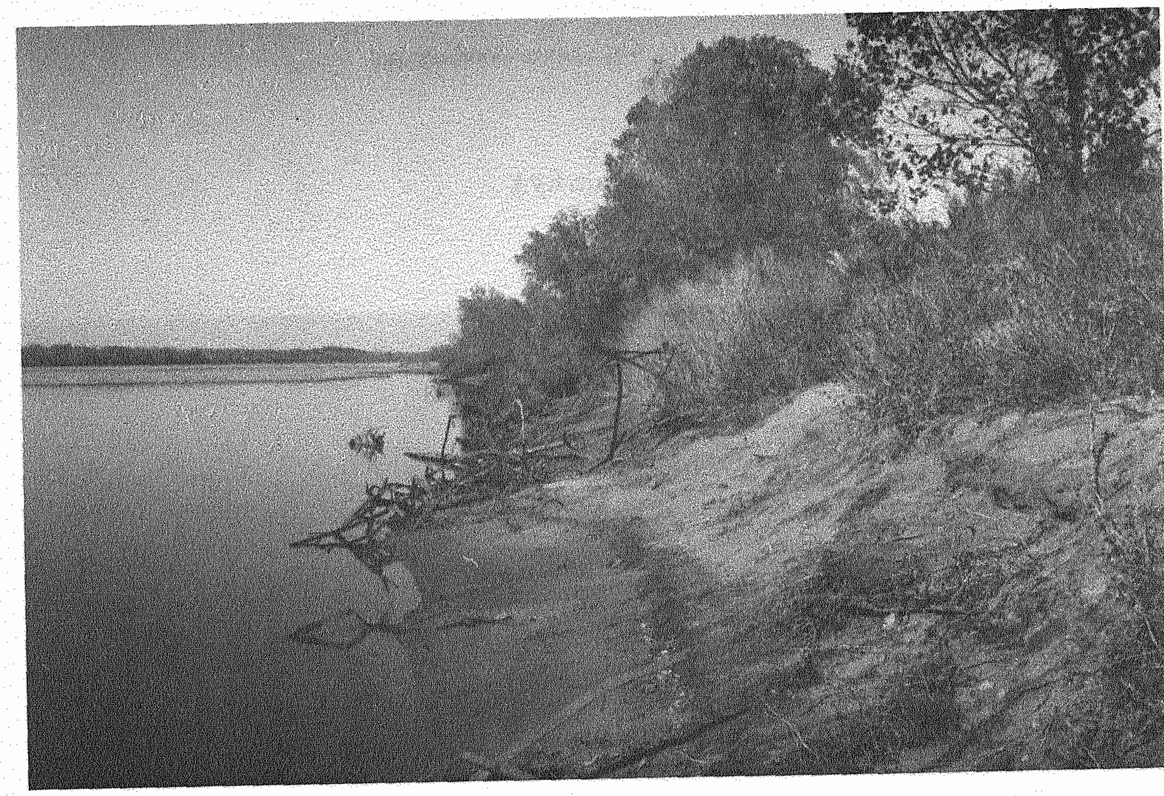
b) Present Condition: ______

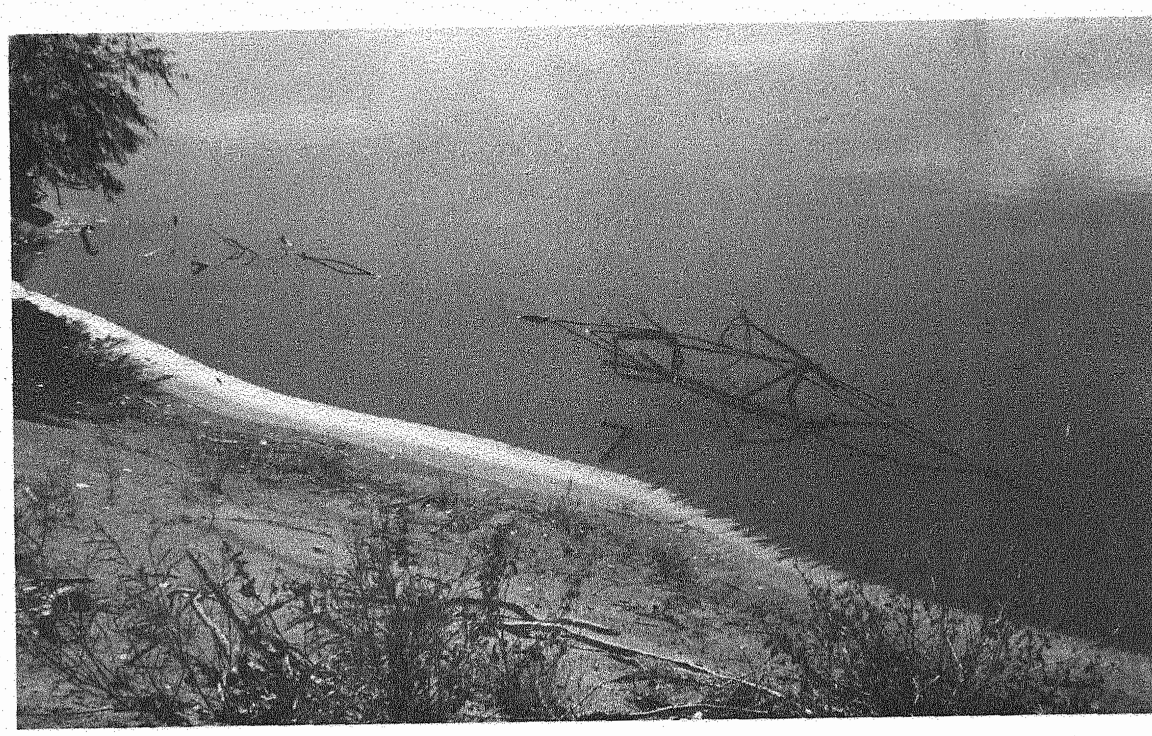
Pile Diversion standing in a Scour Pool

FIGURE 43a

Pile Diversion with Missing Surface Planks

FIGURE 43b





Damaged jetty fields

FIGURE 43c

NORTH CANADIAN RIVER - US281
South of Watonga (Blaine County)

Site No. 6

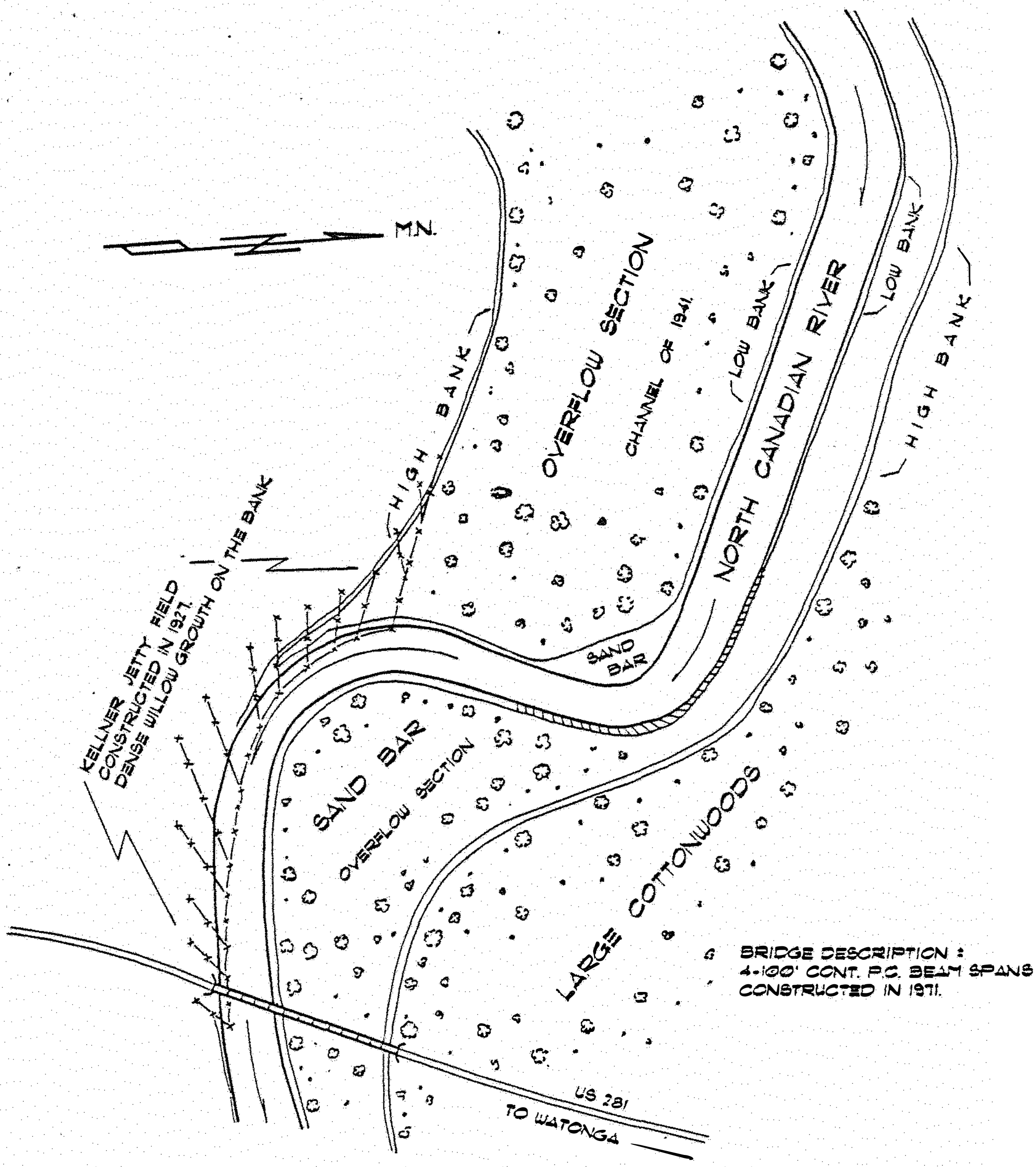
Scale: 1" = 1067'

1989 Site Aerial Photograph

FIGURE 44

NORTH CANADIAN RIVER US-281 SITE No. 6

SOUTH OF WATONGA



SITUATION LAYOUT 1988

SCALE: 1" = 300'

FIGURE 45

NORTH CANADIAN RIVER - US281 Site No. 6
South of Watonga (Blaine County)

Bridge and Site Data:

The old bridge at this site was constructed in 1924 and consisted of six, 75 ft trusses. In 1970 a new multilane bridge was constructed immediately upstream of the old bridge. The soil at the site seems to be clayey and erosion resistant. The North Canadian river has a high degree of sinuosity, but it has a history of high instantaneous volume and long time of duration. The sandbar on the northern bank is vegetated with tall willows and cottonwoods. It also constitutes the overflow section. The riverbanks are narrow and well defined.

History of Stabilization Procedures:

In 1927 a Kellner jetty field was constructed on the southwestern bank to prevent the erosive action of the river at this point. This was the only river training procedure adopted at this site. Riprap can be observed on both the abutments of the new bridge.

Site Evaluation:

As stated earlier, the only river training structure at this site, is a Kellner jetty field built on the southwestern bank. When the new bridge was built in 1970, care was taken not to disturb the jetty field insofar as possible. A clear line of the installed diversionary line of jetties can be seen in the river, though only remnants can be located. Most of the jetties have sunken into the sand, or have been damaged by riverine action. Comparison of the 1968 and 1989 aerial photographs show only negligible differences in the alignment of the river. All the jetties that are located on the high bank, are in near perfect condition. There does not seem to be any river attack on any of the abutments. The low volume and intensity of the North Canadian river is the primary reason for the negligible change in the river alignment. There are no signs of any bank formation activities in the jetty field. In the unlikely event of a high discharge flood, the steep south bank is vulnerable to massive erosion due to the loss of the jetty fields at its face.

The meander loop of the river which is situated further upstream, seems to have moved downstream, but right now no possible threat can be seen due to such an action.

In conclusion it can be stated that the site under consideration is one in which the river has been in a dormant state for a period of over sixty years. This however does not completely eliminate the possibility for a change in this scenario.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JAN. 6, 1989 SITE NO.: 6

HIGHWAY NO.: US 281 COUNTY: BLAINE

BRIDGE LOCATION: NORTH CANADIAN RIVER, SOUTH OF WATONGA.

STREAMFLOW: LOW WEATHER: COLD

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1924 (OLD STRUCTURE, NO LONGER EXIST.)

Span Description: 6, 75' TRUSSES

2) Yr. of constr.:

Span Description:

EMBANKMENT TYPE:

SLOPE: STEEP SLOPED EMBANKMENT

PROTECTION: RIPRAP ON BOTH APPROACH ABUTMENTS.

SPECIAL NOTES: NEW OVERFLOW BRIDGE STRUCTURE CONSTRUCTED ABOUT 600' SOUTH OF THE BRIDGE.

RIVER BANK:

SOIL NATURE: SANDY VEGETATION: SHRUB

COMMENTS: NARROW RIVER WITH VEGETATION ON BOTH BANKS.

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: KELLNER JETTY FIELD

a) Description: CONSTRUCTED IN 1927. TO PREVENT THE RIVER LOOP FROM PUSHING SOUTHWARDS.

b) Present Condition: MOST OF THE JETTIES ARE BADLY DAMAGED EXCEPT FOR THOSE SITTING ON THE HIGH SOUTHERN BANK. THE JETTY LINE IN THE RIVER HAVE MOSTLY SUNKEN INTO THE SAND. THE UPSTREAM MEANDER LOOP HAS PUSHED TOWARDS THE ROADWAY, BUT IS NO CAUSE FOR IMMEDIATE CONCERN.

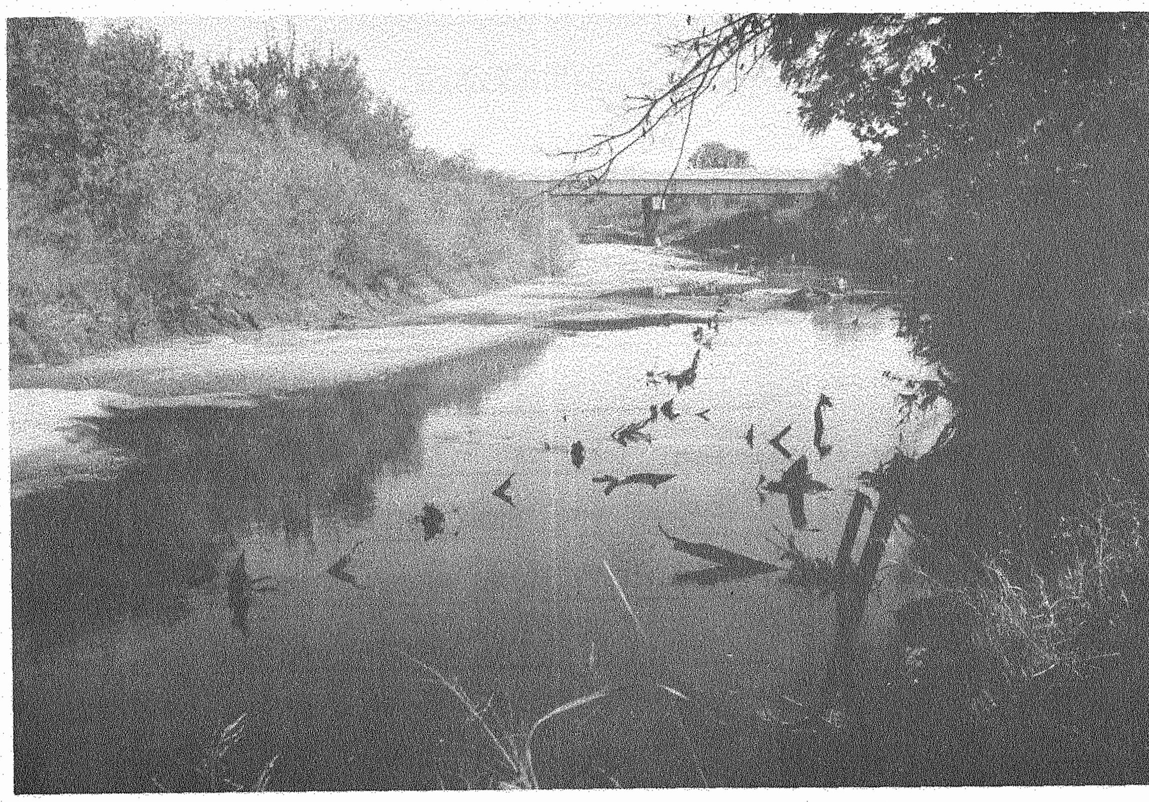
TYPE: ______

a) Description: ______

b) Present Condition: ______

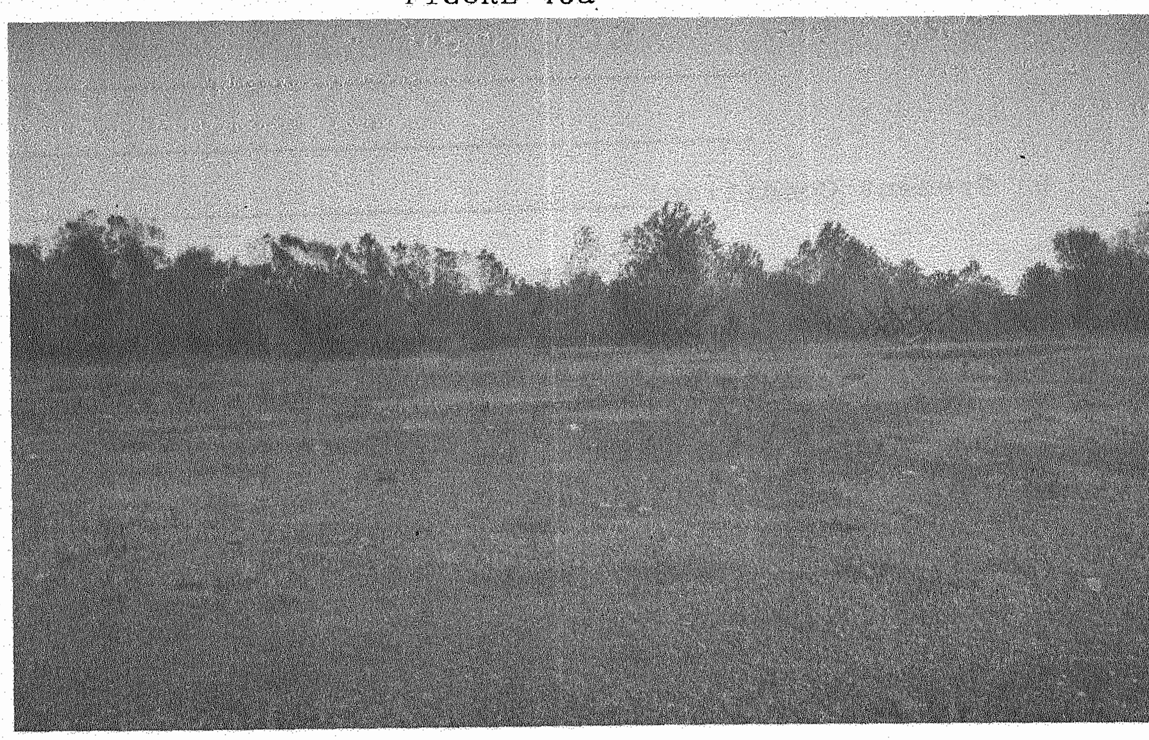
TYPE: ______

a) Description: ______



View of Bridge and Jetty field

FIGURE 46a

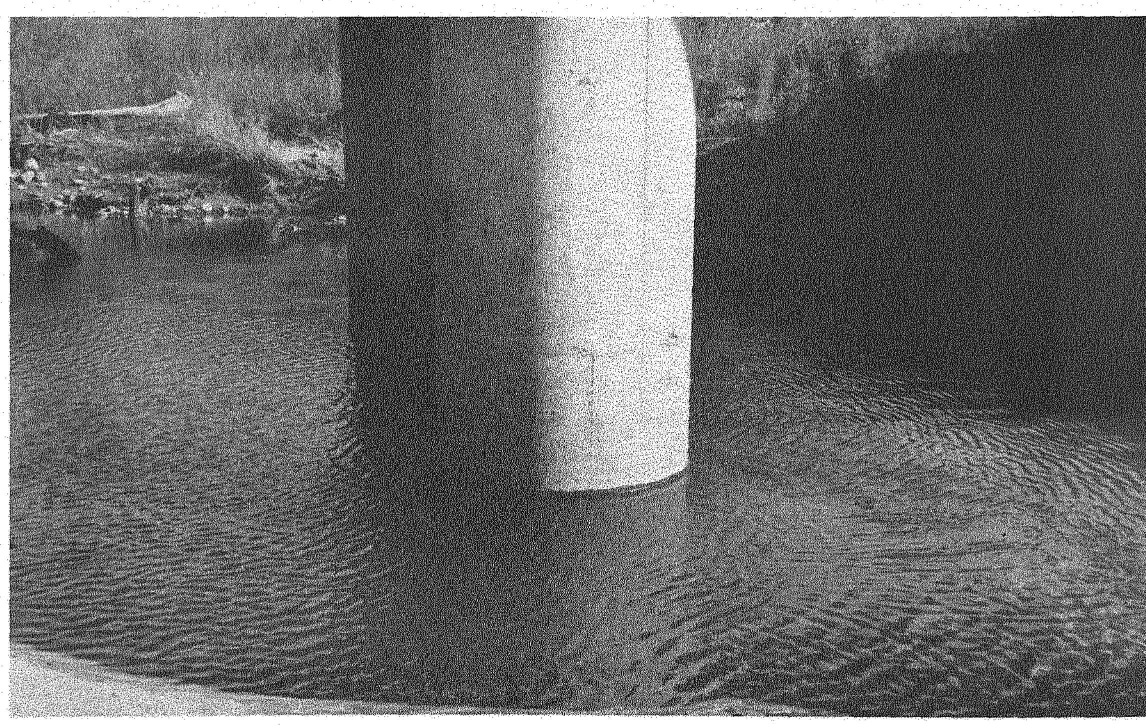


View in a Kellner Jetty Field

FIGURE 46b

Upstream View of the River

FIGURE 46c



Bridge Pier in a Scour Pool

FIGURE 46d

SOUTH CANADIAN RIVER - US281

East of Bridgeport (Caddo County)

Site No. 7

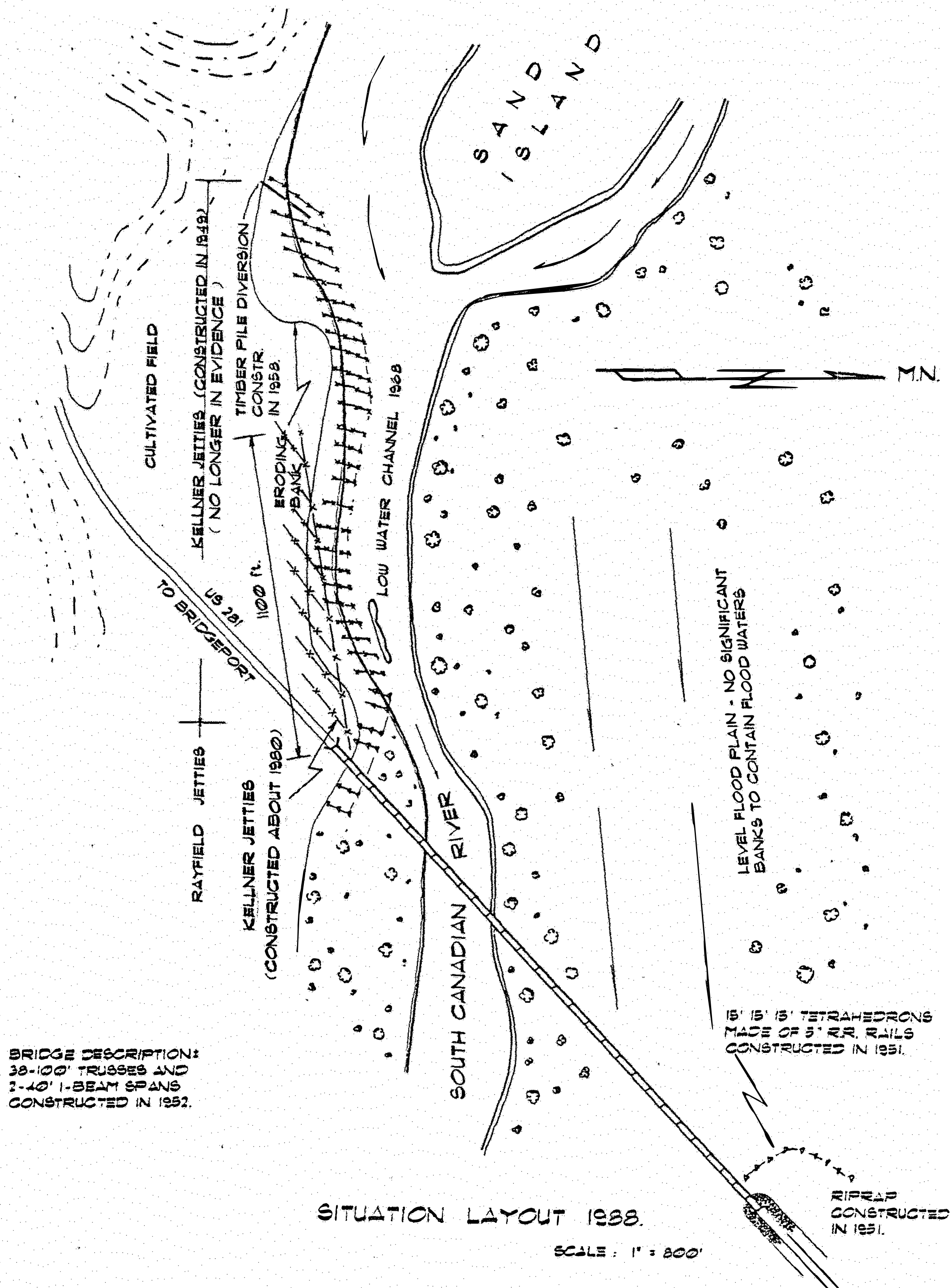
Scale: 1" = 1158'

1989 Site Aerial Photograph

FIGURE 47

SOUTH CANADIAN RIVER US 281
EAST OF BRIDGEPORT

SITE No. 7



SITUATION LAYOUT 1988.

SCALE : 1" = 800'

FIGURE 48

SOUTH CANADIAN RIVER - US281 Site No. 7
East of Bridgeport (Caddo County)

Bridge and Site Data:

The bridge structure in place was built in 1932. It is about 3080 ft in length which seems to cover the wide floodplain of the South Canadian river. The structure consists of thirty eight, 100 ft trusses and two, 40 ft I-Beam spans. The river is flowing close to the southern bank of the floodplain and is attacking that bank. Most of the river training structures are located on the southern bank.

History of Stabilization Procedures:

About 4150 ft of Kellner jetties with backups were constructed in 1935 to discourage erosion of the southern bank. In 1939 this jetty field was extended by about 1332 ft due to severe cutting around the jetty field. In 1949 another 2700 ft of jetties were constructed because the river moved about 400 ft southward, cutting through the previously established jetty fields. The flood of 1951 cut behind the jetty field on the southern bank, and damaged the northern road approach. At the same time 850 ft of Kellner jetties were also installed on the southern bank, riprap and about 720 ft of 15 ft by 15 ft by 15 ft steel tetrahetrons were placed around the northern road approach abutment. Another major flood in 1957 prompted the building of 8 pile diversions to rebuild the damaged southern bank. In 1964 the Borger,Texas dam was constructed which has generally tended to keep the waters in the South Canadian under control.

In about 1980, the Kellner jetty field was reconstructed again on the southern bank to retard a severe erosion point progressing downstream and endangering the roadway approach.

Site Evaluation:

The following comments can be made about the river site and the stabilization structures:

1) The northern road approach along with its riprap and steel tetrahedron protection structures seems to be in near perfect condition. There seems to be no attack of the river on the northern bank.

2) The river in spite of its reduced water levels seems to be actively attacking the southern bank, upstream from the bridge. Comparison of the 1968 and 1989 aerial photographs show a change in the meander pattern just upstream of the bridge. All of the pile diversions installed in 1957 seem to have been destroyed except for one which is in a badly deteriorated state. The river is attacking the base of the jetty field in an attempt to cut behind the field. Since this is relatively far upstream from the bridge, there does not seem to be any cause for immediate concern. However, immediately downstream from this point of attack the river seems to have altered its meander pattern and is moving into the floodplain. If the jetty field holds out against the cutting action of the river, then this change in meander pattern may be further emphasized. If such an action occurs then harm may be sustained. This might arise from the fact that the angle of attack of the river at the southern abutment may increase making it more vulnerable to damage. Though this is just a possibility, it basically depends upon the action of the river to cut behind the jetty field. This

phenomenon has to be kept under further observation in order to predict the next action of the river.

3) All the Kellner and Rayfield jetties installed in the jetty field seems to be in fairly good condition and do not seem to need immediate maintenance.

On the whole the situation on this river site seems to be acceptable and any possibility of river channel shift does not seem to be impending. Continued surveillance is suggested before any specific recommendations be made for this site.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: NOV. 3, 1988 SITE NO.: 7

HIGHWAY NO.: US 281 COUNTY: CADDO

BRIDGE LOCATION: SOUTH CANADIAN RIVER, EAST OF BRIDGE PORT

STREAMFLOW: LOW WEATHER: COOL

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1932

Span Description: 38, - 100' TRUSSES

2, - 40' TRUSSES

2) Yr. of constr.: ____

Span Description: ____

EMBANKMENT TYPE:

SLOPE: MEDIUM SLOPED BANKS.

PROTECTION: NORTHERN BANKS ARE RIPRAPPED.

SPECIAL NOTES: THERE IS AN EXTENSIVE FLOOD PLAIN ON THE NORTHERN PART OF THE RIVER.

RIVER BANK:

SOIL NATURE: SANDY / SILTY VEGETATION: SHRUBS

COMMENTS: THE EMBANKMENTS ARE IN NO DANGER OF DIRECT RIVER ATTACK.

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: RAYFIELD JETTIES

a) Description: CONSTRUCTED IN 1949. TO DIVERT SOUTHERN ABUTMENT FROM POSSIBLE RIVER ATTACK.

b) Present Condition: THESE STRUCTURES ARE IN NEAR PERFECT CONDITION.

TYPE: KELLNER JETTIES

a) Description: CONSTRUCTED IN 1949, TO PREVENT MEANDER INTO THE SOUTHERN BANK. REBUILT IN ABOUT 1980.

b) Present Condition: THESE STRUCTURES ARE ALSO IN NEAR PERFECT CONDITION. EXCEPT THE WESTERNMOST PARTS OF IT. MOST OF THESE STRUCTURES ARE NO LONGER IN USE (DIRECT) DUE TO THE REVERSAL IN THE MEANDER LOOP OF THE RIVER

TYPE: PILE DIVERSIONS

a) Description: THREE CONSTRUCTED IN 1958. TO PREVENT THE CUTTING OF THE RIVER INTO THE BANK.

b) Present Condition: ONLY ONE OF THESE DIVERSIONS IS LEFT. AND IT IS IN A BADLY DAMAGED CONDITION. THE RIVER IS CUTTING INTO THE BANK AT THIS POINT. BUT DOWNSTREAM, THE RIVER HAS CHANGED ITS MEANDER PATTERN, PROBABLY DUE TO THE EFFECTIVENESS OF THE KELLNER JETTIES.

TYPE: TETRAHEDRON STRUCTURES.

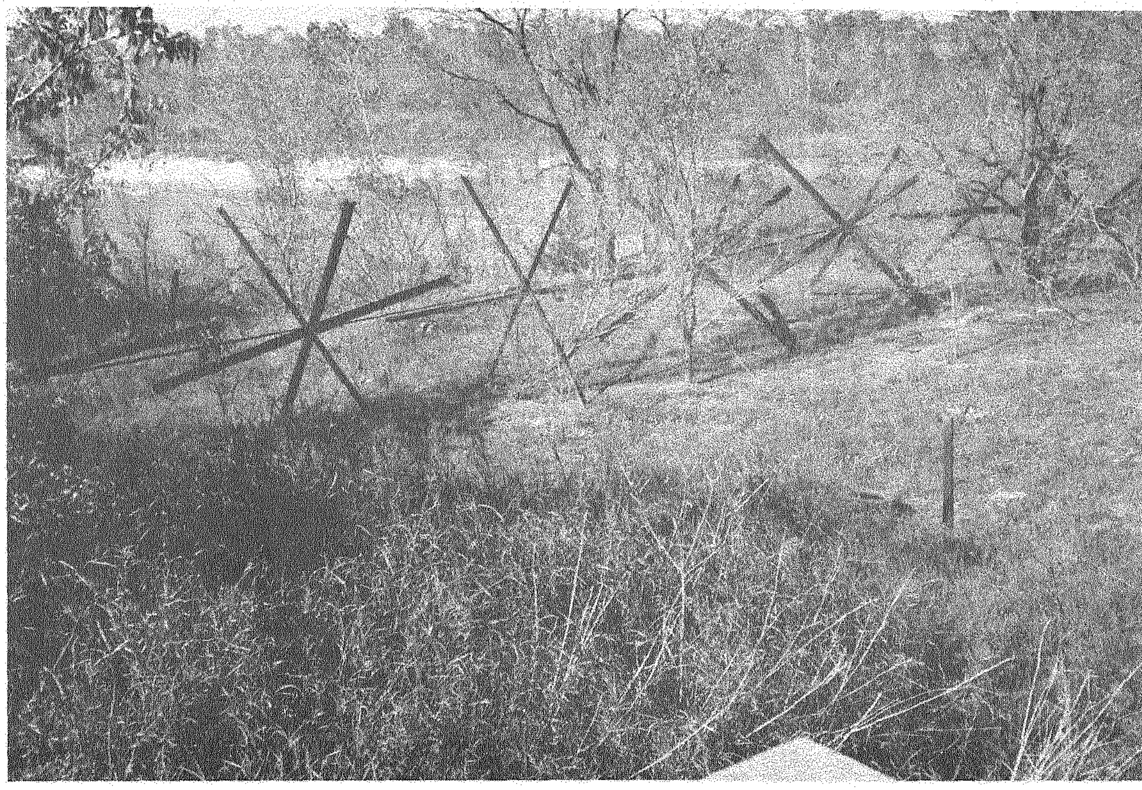
a) Description: CONSTRUCTED IN 1951, THEY ARE 15' x 15' x 15' TETRAHEDRON, CHAINED TOGETHER TO PROTECT THE NOTHERN EMBANKMENT. THE RIVER IS NO LONGER IN CONTACT WITH THIS STRUCTURE.

b) Present Condition: THESE STRUCTURES ARE IN NEAR PERFECT CONDITION.

TYPE: RIPRAP (ON NORTHERN ABUTMENT)

a) Description: THIS WAS PLACED IN 1951 TO PROTECT THE EMBANKMENT OF THE ROAD APPROACH.

b) Present Condition: THE RIPRAP IS IN NEAR PERFECT CONDITION.



View of Kellner Jetties on South Bank

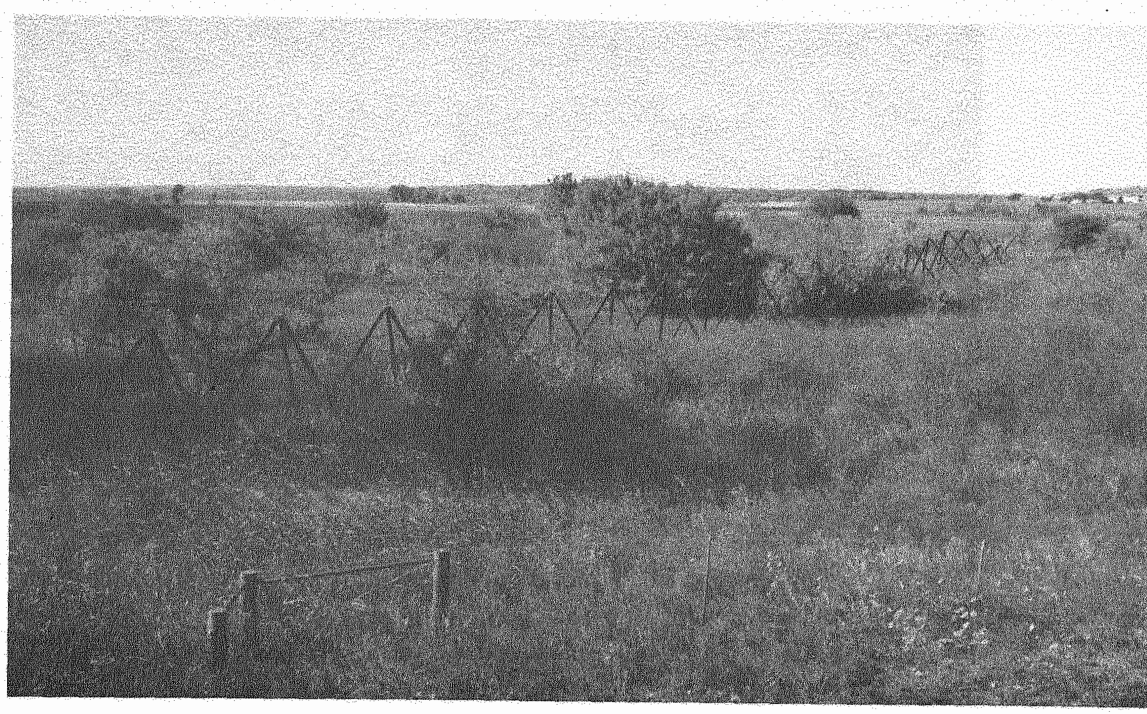
FIGURE 49a

View of Kellner Jetty Field

FIGURE 49b

View of Eroding South Bank (Upstream)

FIGURE 49c



View of Tetrahedron Field on North Bank

FIGURE 49d

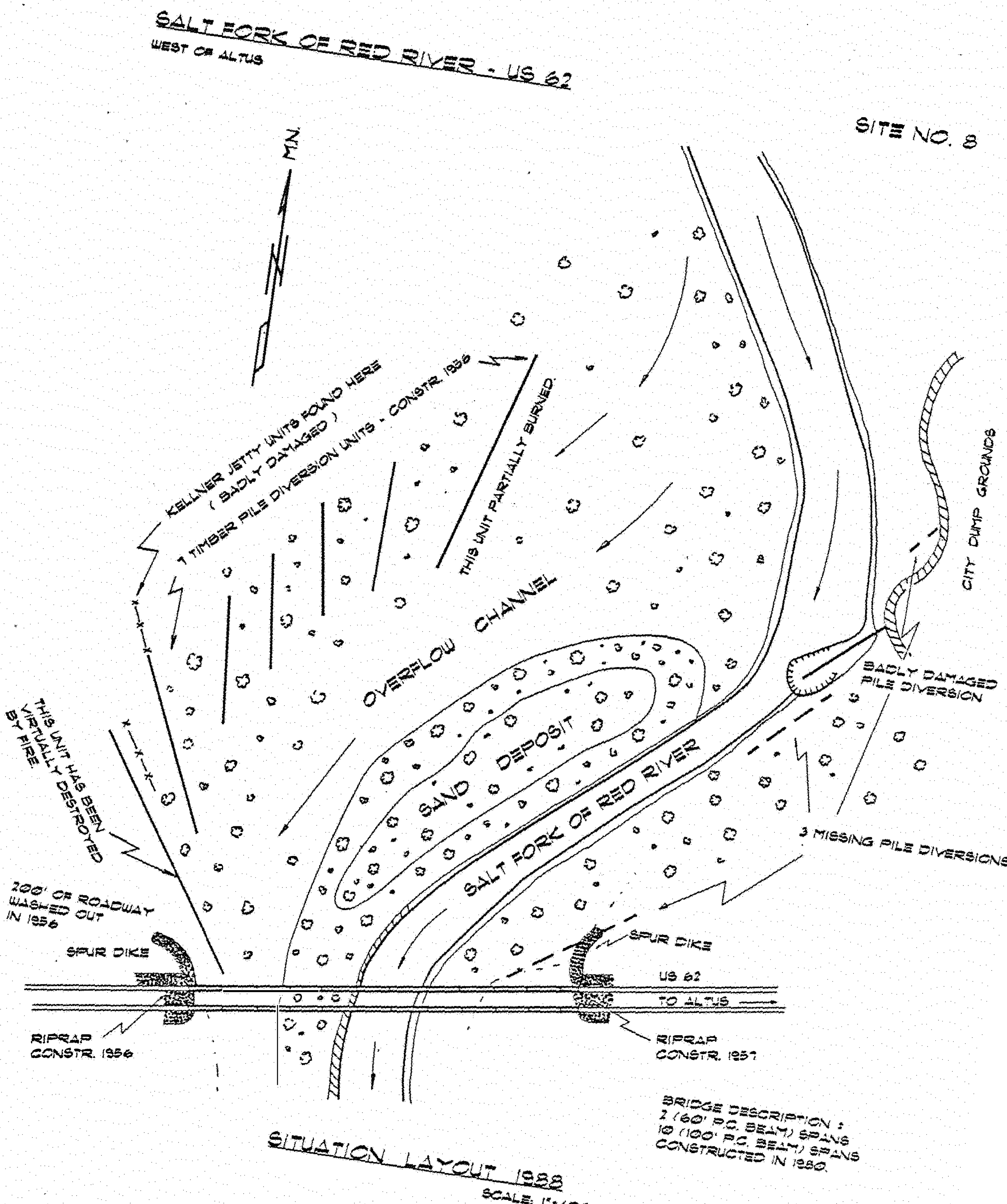
SALT FORK OF THE RED RIVER - US62
West of Altus (Jackson County)

Site No. 8

Scale: 1" = 1195'

1989 Site Aerial Photograph

FIGURE 50



SALT FORK OF RED RIVER - US 62
WEST OF ALTUS
SITE NO. 8
M.N.
KELLNER JETTY UNITS FOUND HERE
(BADLY DAMAGED)
7 TIMBER PILE DIVERSION UNITS - CONSTR. 1956
THIS UNIT PARTIALLY BURNED
OVERFLOW CHANNEL
SAND DEPOSIT
SALT FORK OF RED RIVER
CITY DUMP GROUNDS
BADLY DAMAGED PILE DIVERSION
3 MISSING PILE DIVERSIONS
THIS UNIT HAS BEEN VIRTUALLY DESTROYED BY FIRE
200' OF ROADWAY WASHED OUT IN 1956
SPUR DIKE
SPUR DIKE
US 62
TO ALTUS
RIPRAP CONSTR. 1956
RIPRAP CONSTR. 1957
BRIDGE DESCRIPTION :
2 (60' P.C. BEAM) SPANS
10 (100' P.C. BEAM) SPANS
CONSTRUCTED IN 1980.
SITUATION LAYOUT 1988
SCALE: 1"=400'

FIGURE 51

SALT FORK OF THE RED RIVER - US62 Site No.8
West of Altus (Jackson County)

Bridge and Site Data:

A new bridge of state-of-the art technology has been constructed in 1980 at this site. It consisted of two, 60 ft spans, four, 100 ft spans and six, 100 ft spans made of prestressed concrete. The old bridge was constructed in 1936, and it consisted of eleven, 100 ft trusses. The new bridge structure consists of twin structures and it spans a little more eastward when compared to the old bridge. The Red River locally flows through agricultural land with silty soils. The river bed is wide at this site, and has shallow banks. Site visits show that the banks are made of loose erodible soils. At present there is an massive sandbar deposit just upstream from the bridge structure and it is thickly vegetated with tall trees.

History of Stabilization Procedures:

In 1936 when the old bridge was built, 1950 ft of mainline and 14 backup Kellner jetties were installed on the northwest bank to align the concave bank immediately upstream from the western abutment. In 1939, after a major flood, another 3600 ft of jetties were installed at the same position. Then the flood of 1956 washed out nearly 200 ft of the west embankment which prompted the placement of nearly 300 ft of riprap on the western abutment. Seven pile diversions were also constructed at the site of the jetty field on the northwestern bank in an effort to appropriately direct the flow of the river under the bridge. The 1957 flood eroded the northeastern bank and damaged the eastern abutment. About 200 ft of riprap was constructed on the eastern abutment. Simultaneously four pile diversions were completed on the northeastern bank. After the construction of the new bridge in about 1980 no further structures have been constructed other than the placement of two massive spur dikes at both the bridge abutments.

Site Evaluation:

The Salt Fork of the Red River flows through plains which are basically agricultural. The natural vegetation in the area is basically small shrubs and other stunted plants. The soil in the area is silty and the river has a low debris content, which is deemed to be the major reason for the failure of the Kellner jetty field. The river is on a flat grade and subjected to only periodic flooding.

The river, at this time, is a shallow alluvial stream. There is an extensive sandbar which is shallow deposited in the river bed just upstream of the bridge structure. This sandbar is extensively vegetated. The area is being used as pasture, is fenced, and livestock are in this area. A major flood might make the water flow on both sides of the sandbar and even through it. This may result in possible river attack on both the abutments. The seven pile diversions constructed on the northwestern bank are at present no longer in contact with the river. Most of them are destroyed, even though traces of them are still visible in various forms. The Kellner jetty field at this position is no longer in existence and is either destroyed or covered by silt. These diversionary structures have not contributed significantly to bank building which is evident from the negligible difference in elevation on the river bed and the surrounding farmland.

Of the four pile diversions located on the northeastern bank only one could be located. This one was in direct contact with the river. It can be said that this no longer serves the function of a pile diversion due to its condition. Only a few surface planks can be seen, with only the framework still in position. As of now, only the riprap which has been placed with the newly constructed bridge is in good condition.

In conclusion it can be stated that most of the bank protection structures are inactive. This is in part due to the long, dry, dormant state of the river. In case of a major flood, none of the installed structures except for the riprap on both the abutments will be effective to train the river under the bridge due to the present poor state of deterioration or condition. This site should be closely monitored and immediately inspected in the event of a major flood. The new lengthened double span structure provides more flow area and will have great integrity and expected long survival life.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: AUG. 9, 1988 SITE NO.: 8

HIGHWAY NO.: US 62 COUNTY: JACKSON

BRIDGE LOCATION: SALT FORK OF RED RIVER, WEST OF ALTUS

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1936 (OLD BRIDGE)

Span Description: 11 - 100' TRUSSES

2) Yr. of constr.: 1980

Span Description: 2 (60' P.C. BEAM SPANS)
10 (100' P.C. BEAM SPANS)

EMBANKMENT TYPE:

SLOPE: VERY LOW BANK, AND SMALL SLOPE

PROTECTION: RIPRAP PROTECTION ON BOTH EMBANKMENTS.

SPECIAL NOTES: THE BRIDGE HAS A LOW CLEARENCE FROM THE STREAMBANK.

RIVER BANK:

SOIL NATURE: SILTY VEGETATION: SHRUBS

COMMENTS: EXTENSIVE SAND BAR IN THE RIVER.

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: ROCK RIPRAP (ON BOTH ABUTMENTS)

a) Description: EXTENSIVE HEAVY ROCK RIPRAP ARE PLACED ON BOTH ABUTMENTS TO PREVENT RIVER ATTACK. CONSTRUCTED IN 1970.

b) Present Condition: THE ROCK RIPRAP SEEM TO BE IN GOOD CONDITION.

TYPE: 7 PILE DIVERSIONS

a) Description: BUILT IN 1956 ON THE WESTERN BANK TO DIVERT THE RIVER FLOW UNDER THE BRIDGE.

b) Present Condition: MOST OF THEM ARE IN A VERY BAD STATE OF DETERIORATION, AND SOME OF THEM ARE BURNT

TYPE: 4 PILE DIVERSIONS

a) Description: BUILT IN 1957 ON THE EASTERN BANK. TO PROTECT THE EASTERN ABUTMENT, AND TO DIVERT THE RIVER UNDER THE BRIDGE.

b) Present Condition: ONLY ONE PILE DIVERSION IN CONTACT WITH THE RIVER WAS LOCATED, AND IT WAS IN A BAD STATE OF DETERIORATION, WITH MOST SURFACE PLANKS MISSING.

TYPE: KELLNER JETTIES

a) Description: CONSTRUCTED IN 1939, TO BUILD A BANK LINE ON THE ERODING WESTERN BANK.

b) Present Condition: NO TRACES OF THE JETTY FIELD CAN BE FOUND.

TYPE: ______

a) Description: ______

b) Present Condition: ______

Overgrown Damaged Pile Diversion

FIGURE 52a

Pile Diversion with few Surface Planks

FIGURE 52b

NORTH FORK OF THE RED RIVER - SH 5 Site No. 9
West of Tipton (Jackson/Tillman County)

Scale: 1" = 1108'

1989 Site Aerial Photograph

FIGURE 53

NORTH FORK OF RED RIVER - SH 5
WEST OF TIPTON

SITE NO. 9

BRIDGE DESCRIPTION :
50' I-BEAM
2(400' I-BEAM)
50' I-BEAM
CONSTRUCTED IN 1954.

SITUATION LAYOUT 1988
SCALE 1" = 310'

FIGURE 54

NORTH FORK OF THE RED RIVER - SH 5 Site No. 9

West of Tipton (Jackson/Tillman County)

Bridge and Site Data:

The original bridge site no longer exists due to the realignment of SH 5 about one mile downstream. The original old bridge was constructed in about 1927, and the structure rested on timber piles. It consisted of twenty one, 29 ft spans, to a total length of 609 ft. The North Fork of the Red River is similar to the Salt Fork of the Red River in soil type, and vegetation. This river carries a low sediment and debris load. The new structure was built in 1954 along a new alignment about one mile downstream from the old structure.

History of Stabilization Procedures:

The old 1927 bridge site was a source of constant problems. The river would attack both of the bridge abutments so that there was a constant need to repair the damage or to lengthen the bridge structure at both abutments. A Kellner jetty field of about 1200 ft in length was constructed extending upstream from the western abutment. There are no records of any other diversionary/stabilization structures which may have been constructed at this site.

Site Analysis:

From the information available at this site the old bridge location was indeed a difficult one. The new structure which is located about one mile downstream appears to have a much better site. The summer 1988 site visits evidenced no signs of either the old bridge or the Kellner jetties which were said to have been installed on the western bank about 1942. The 1989 aerial photograph shows the new bridge site location is nearly in perfect alignment with the river. The new site was well chosen. The are no visible signs of river training structures at this new site. Indeed, they are not necessary at such a perfect site. The new bridge seems to be functioning well with the riverine environment. This can further be attributed due to the presence of well defined, mature river banks. Also the bridge abutments extend well into overbank areas and are protected. The river at this site is narrow and straight. The bridge has been designed with adequate clearance to pass a large flood, and the structure spans virtually the entire floodplain.

The river site is relatively new, and the general riverine condition is apparently stable and in a mature regime. It is unlikely that the upstream configuration of the river is apt to change. Downstream from the bridge, the river is a maze of old and new braids. The bridge is well sited and no changes are recommended. Perhaps, the best river crossing is the one where no bank stabilization is required. This is, however, rarely possible.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: AUGUST 9, 1988 SITE NO.: 9

HIGHWAY NO.: SH 5 COUNTY: JACKSON / TILLMAN

BRIDGE LOCATION: NORTH FORK OF THE RED RIVER, WEST OF TIPTON

STREAMFLOW: MEDIUM WEATHER: WARM

BRIDGE(S) ON SITE: (NEW BRIDGE SITE)

1) Yr. of constr.: 1954

Span Description: 50' I - BEAM

2(400' I-BEAM)

50' I - BEAM

2) Yr. of constr.: ____________

Span Description: ____________

EMBANKMENT TYPE:

SLOPE: STEEP

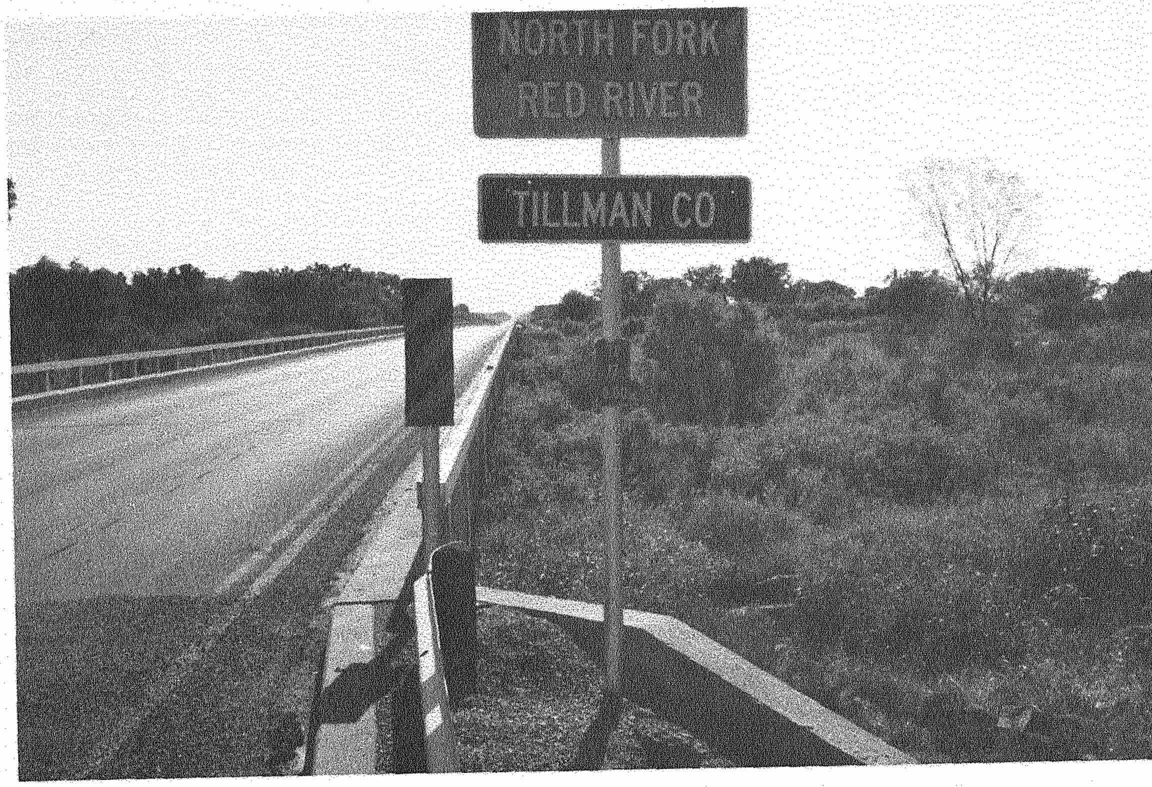
PROTECTION: RIPRAP

SPECIAL NOTES: THE BRIDGE STRUCTURE IS NEARLY NORMAL TO THE RIVER

RIVER BANK:

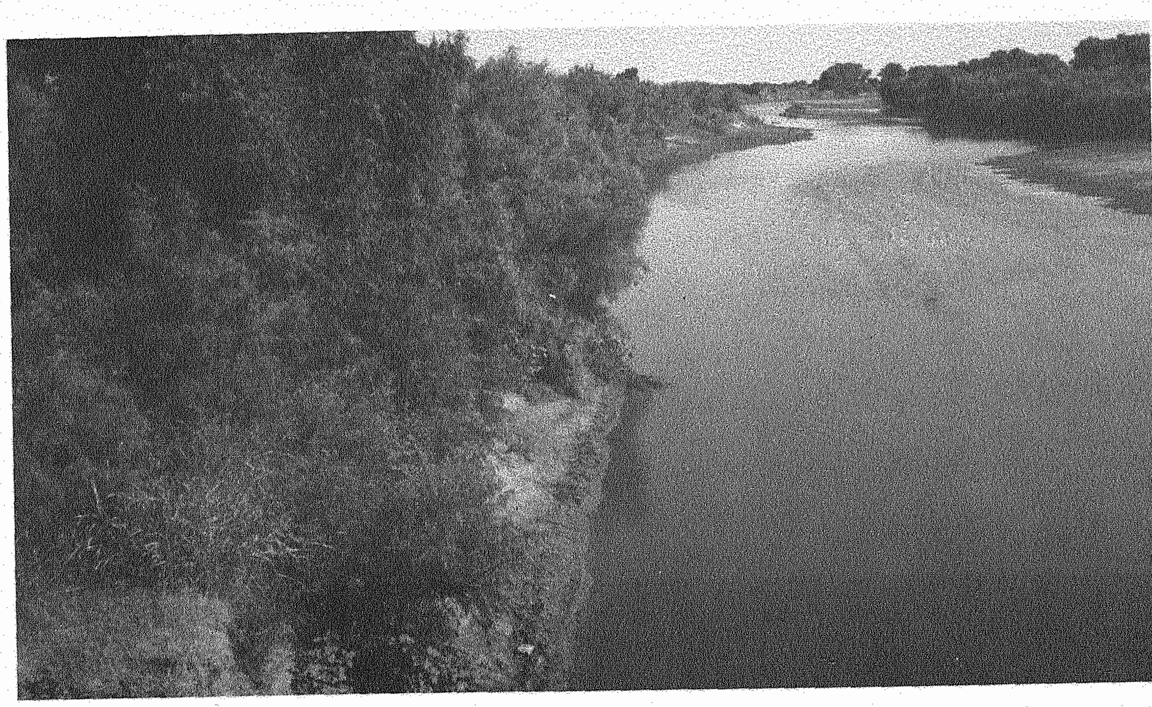
SOIL NATURE: CLAYEY VEGETATION: WILLOWS

COMMENTS: NO STABILIZATION STRUCTURES AT THIS SITE



View of the Bridge Site

FIGURE 55a



Steep Upstream West Bank

FIGURE 55b

WASHITA RIVER - SH 76 Site No. 10
South of Lindsay (Garvin County)

Scale: 1" = 1360'

1989 Site Aerial Photograph

FIGURE 56

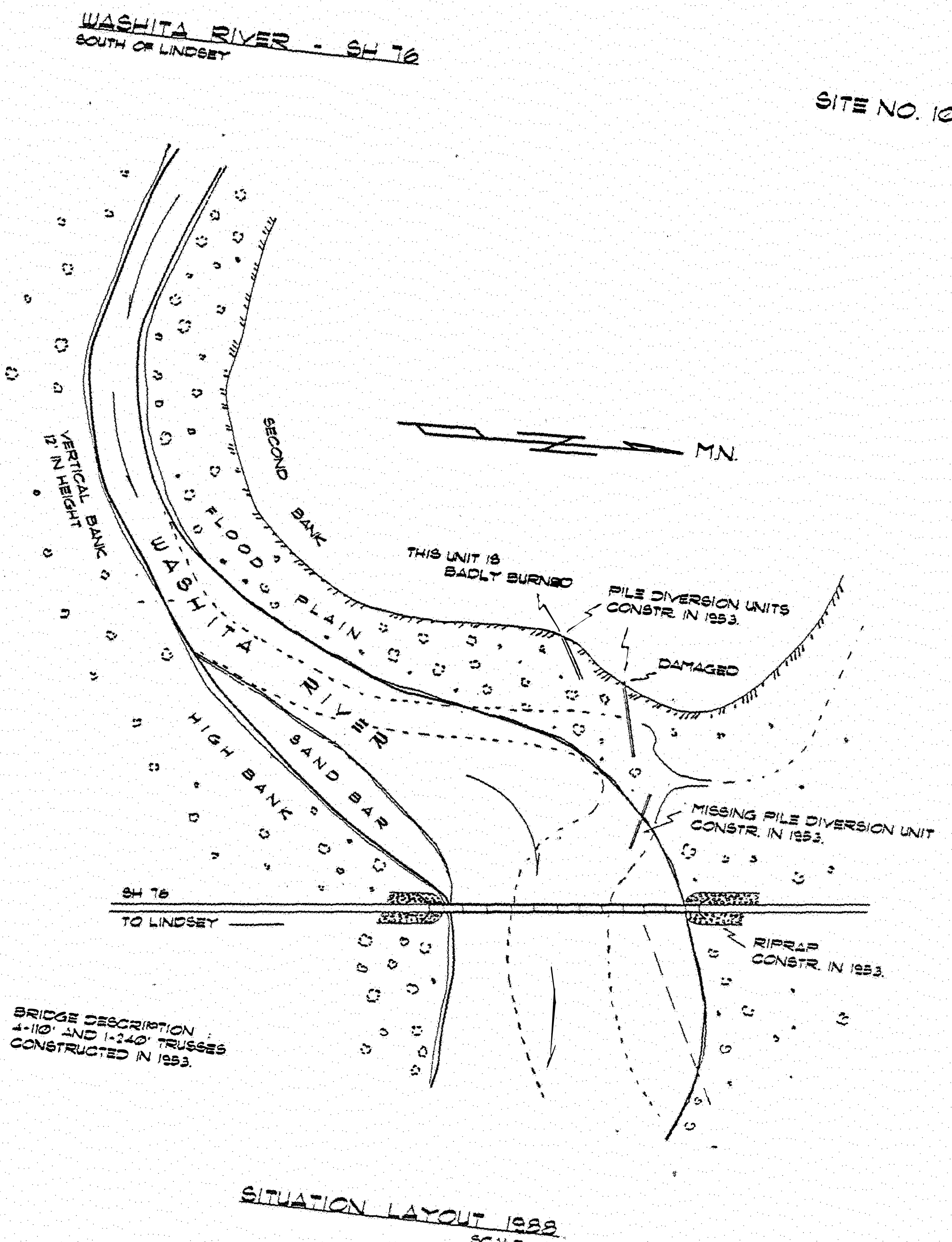

WASHITA RIVER - SH 76
SOUTH OF LINDSEY
SITE NO. 10
M.N.
SECOND BANK
VERTICAL BANK
12 IN HEIGHT
FLOOD PLAIN
WASHITA RIVER
THIS UNIT IS
BADLY BURNED
PILE DIVERSION UNITS
CONSTR. IN 1953.
DAMAGED
HIGH BANK
SAND BAR
MISSING PILE DIVERSION UNIT
CONSTR. IN 1953.
SH 76
TO LINDSEY
RIPRAP
CONSTR. IN 1953.
BRIDGE DESCRIPTION
4-110' AND 1-240' TRUSSES
CONSTRUCTED IN 1953.
SITUATION LAYOUT 1988
SCALE : 1" = 300'

FIGURE 57

WASHITA RIVER - SH 76 Site No. 10
South of Lindsay (Garvin County)

Bridge and Site Data:

The present bridge structure was built in 1953 and consists of four, 110 ft trusses and one, 240 ft truss. The site is located on the Washita River which has a known history of active meander loops, steep eroding banks and dynamic rise/fall characteristics. Both upstream and downstream from this site, the land is used for agricultural purposes. The river at this site has always had an active meander loop process which attacks both the north and south bridge abutments.

History of Stabilization Procedures:

The bridge was installed at this site in 1953, and 3 pile diversions were constructed on the northwest bank to keep the channel under the bridge. At the same time riprap was placed on both the abutments to prevent direct attack of the river. After the flood of 1957, all three pile diversions suffered extensive damage. Riprap was constructed behind the first pile diversion in 1957, immediately upstream from the bridge structure.

In 1988 plans were made for the excavation of a new channel to divert the flow of the river under the bridge. A Kellner jetty field was also planned consisting of about 1500 ft of mainline jetties and about 16 backup retardance lines. This plan has not yet been implemented.

Site Evaluation:

This site is an excellent example whereby the course of a river was substantially altered in a relatively short time of about twenty years. On the northwestern bank, only one of the three pile diversions is still standing. The second pile diversion is almost burned to the ground. The last pile diversion could not be located and is assumed destroyed. The pile diversion that is immediately upstream from the bridge structure is now located on high ground and is no longer in contact with the river.

Aerial photographs of the site of 1968 and 1989 show distinctly different river configurations, immediately upstream and even further upstream. In 1953, it was reported that the river turned through a 105 degree angle immediately upstream from the bridge structure. This scenario has changed completely. The river no longer makes a sharp angle turn, but has oriented itself to flow more northeasterly toward the bridge. Considering this situation, it can be deduced that the three erected pile diversions were completely effective in their application. The river has been actively eroding the upstream south bank, while depositing extensively on the north bank. This was at least partially what was desired by the placement of the pile diversions. The river now directly attacks the north bridge abutment. Traces of the old riprap placed at the north bank can be found, but it surely will not hold against the new, concentrated flood ravages of the Washita. The downstream eastern bank of the river has been eroding actively and considerable agricultural land has been lost as a result.

Site visits indicate that the river is also attacking the southern abutment. The river has substantially pushed its meander loop toward the roadway, south of the bridge structure. There has been an extensive deposition of debris near the bridge piers. This may prompt the use of a Kellner jetty field for the control of the river. But experience has shown on many different river sites that Kellner jetties have been used effectively on the Washita.

In conclusion it can be stated that the Washita River has not reached a mature state at this site, and is now in a state of continuous change. More observation of this site is needed for specific reccomendations. Immediately, the two problems that should be addressed are the movement of the river eastward, and the simultaneously endangering the south highway approach and the river attack on the northern bridge abutment.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JULY 29, 1988 SITE NO.: 10

HIGHWAY NO.: SH 76 COUNTY: GARVIN

BRIDGE LOCATION: WASHITA RIVER, SOUTH OF LINDSEY

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1953

Span Description: 4 - 110' TRUSSES

1 - 240' TRUSS

2) Yr. of constr.: ____

Span Description: ____

EMBANKMENT TYPE:

SLOPE: STEEP

PROTECTION: BOTH ABUTMENTS FACED WITH RIPRAP.

SPECIAL NOTES: MASSIVE EROSION ON BOTH BANK

RIVER BANK:

SOIL NATURE: CLAYEY VEGETATION: SHRUBS

COMMENTS: AGRICULTURAL LAND ALL AROUND.

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: 3 PILE DIVERSIONS

a) Description: CONSTRUCTED IN 1953 TO PROTECT THE NORTHERN BANK.

b) Present Condition: ONE PILE DIVERSION IS BADLY DAMAGED. ONE IS MISSING AND ONE IS BURNT DOWN.

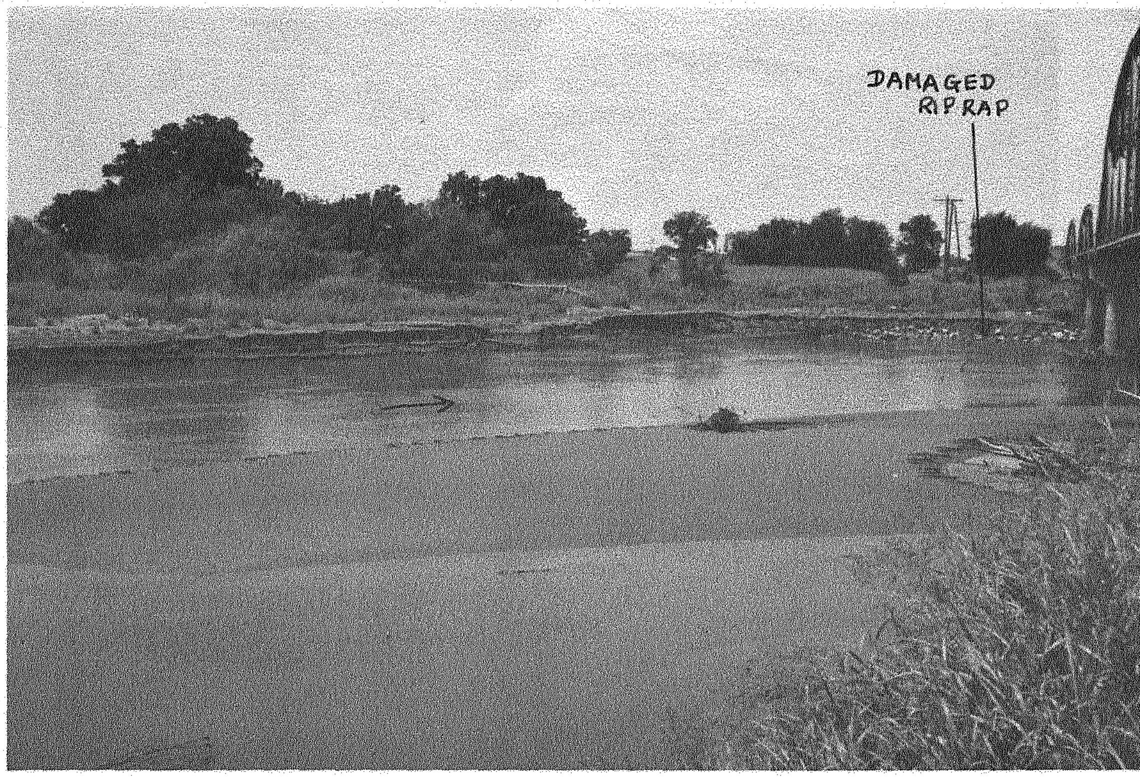
TYPE: RIPRAP

a) Description: PLACED ON BOTH ABUTMENTS TO PROTECT IT FROM EROSION.

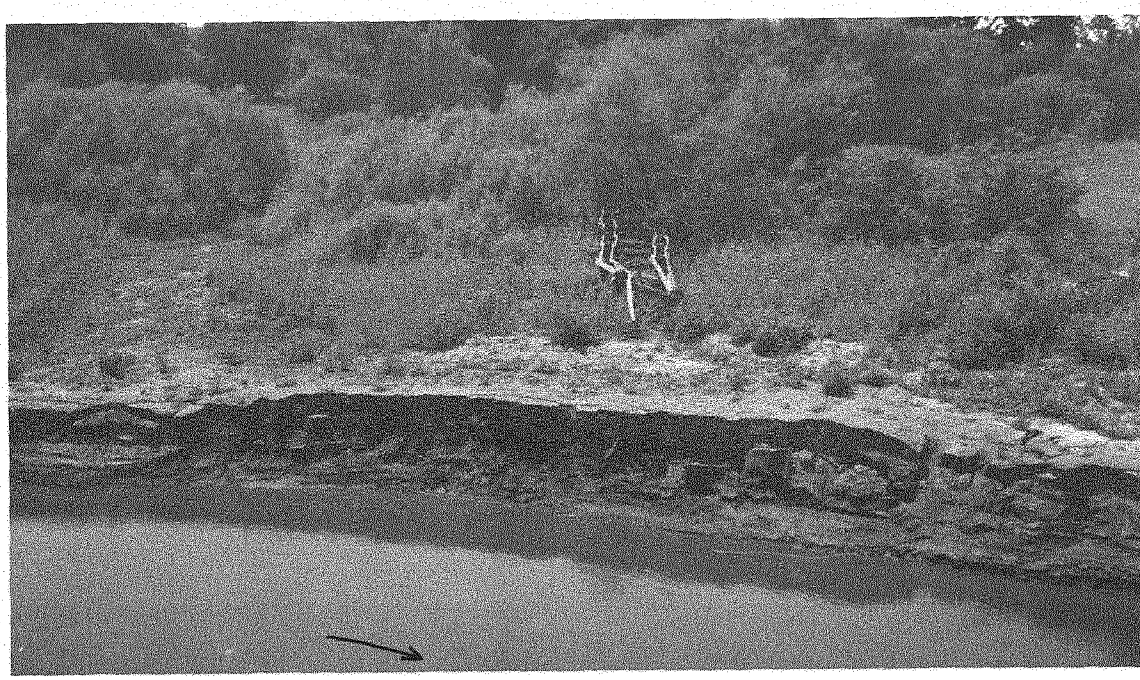
b) Present Condition: DAMAGE IS PREVALENT ON BOTH BANKS.

TYPE:

a) Description:

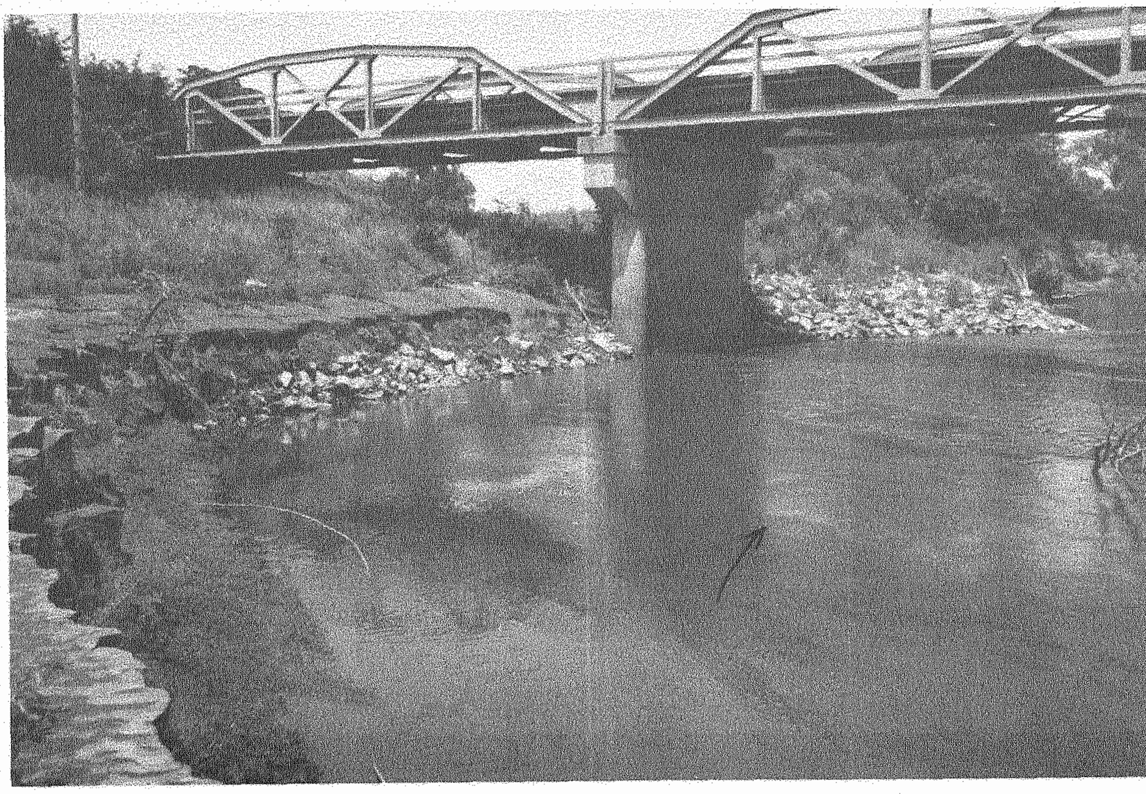


Bridge and Eroding Concave Bank



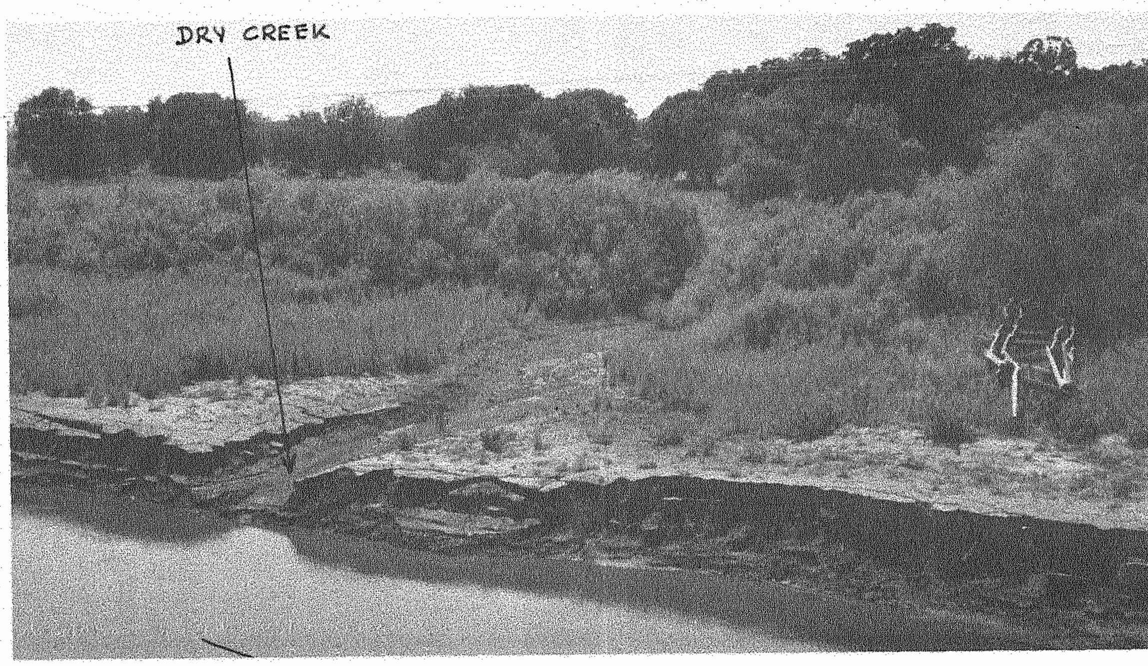
View of Damaged Pile Diversion from Bridge

FIGURE 58b



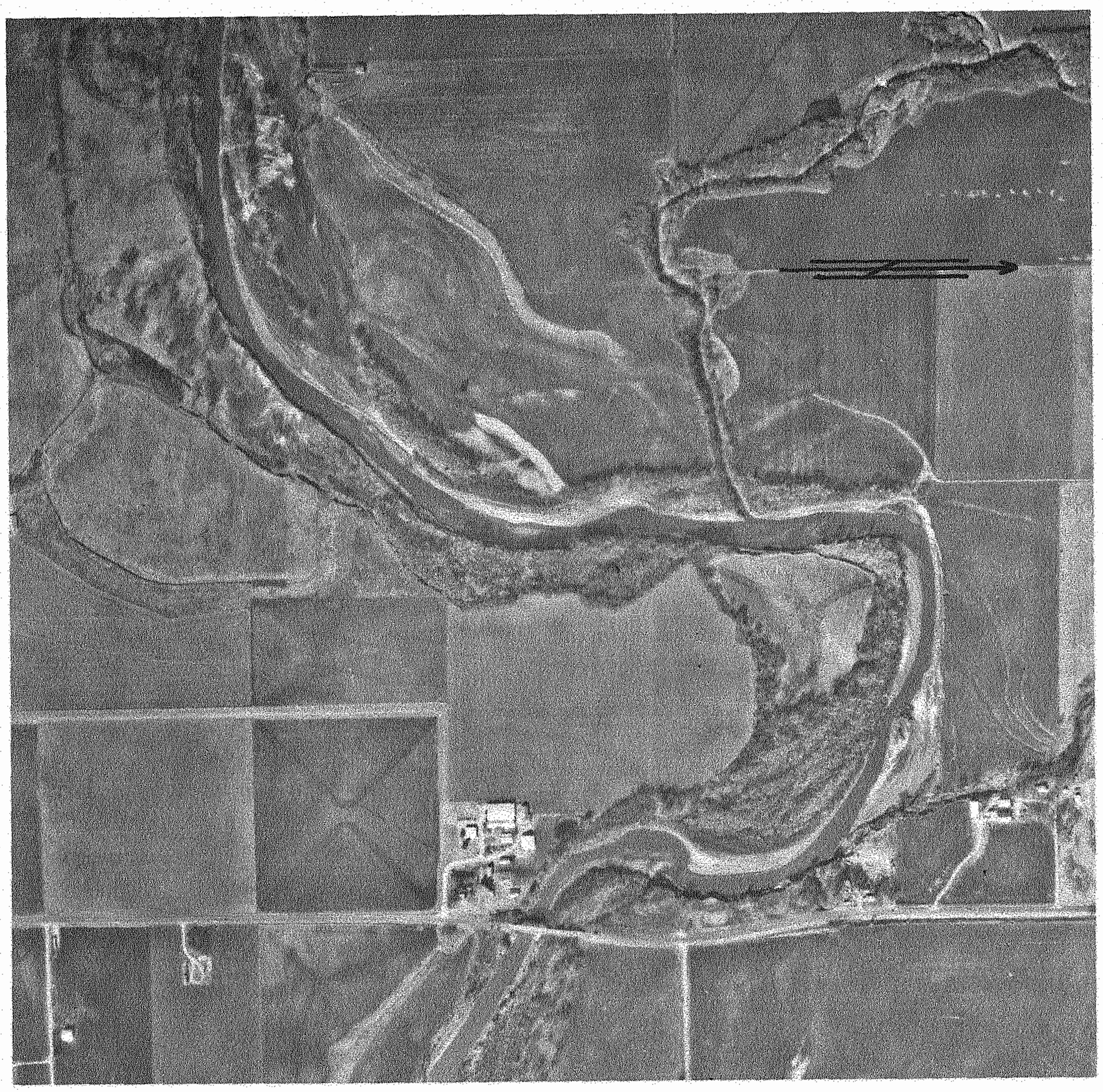
Damaged Riprap on North Bank

FIGURE 58c



Creek Running into the Washita

FIGURE 58d



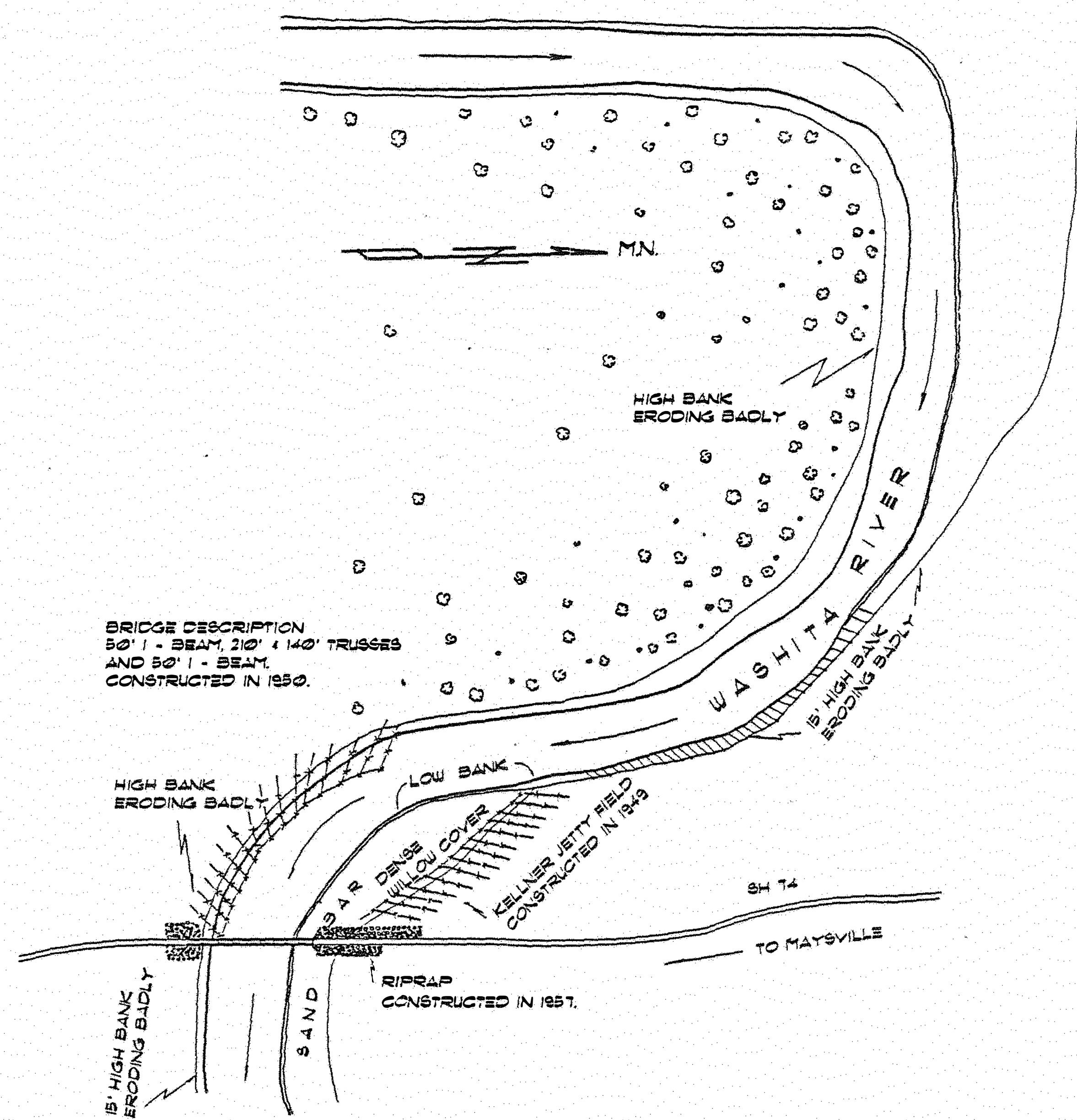
Scale: 1" = 1200'

1989 Site Aerial Photograph

FIGURE 59

WASHITA RIVER SH 74 SITE No. 11

NORTH OF MAYSVILLE



SITUATION LAYOUT 1988

SCALE: 1" = 400'

FIGURE 60

WASHITA RIVER - SH74 Site No. 11
North of Maysville (Garvin County)

Bridge and Site Data:

The present bridge structure was built in 1950 and has two, 50 ft I-Beam spans and 210 ft and 140 ft trusses. It is located on the Washita river near Maysville and is the location of an active meander loop. The banks of the river are steep at this site and nearly vertical. Upstream banks show signs of active erosion.

History of Stabilization Procedures:

A large flood on the Washita in 1949 resulted in the washout of the old bridge which was present at that time. The new, present, bridge structure was built in 1950 slightly downstream from the original location. On both the banks Kellner jetty fields were placed to limit erosion and to promote the growth of vegetation on the banks. Both northern and southern abutments were heavily riprapped to minimize the erosion there. At this site, as well as other sites on the Washita, Kellner jetties have proven to be successful in bank protection due to the high content of silt and debris in the water.

Site Evaluation:

Some of the major observations at the site are as follows:

1) The southern bank which is the concave bank is showing signs of active erosion. The Kellner jetties seem to be limited in effectiveness on this bank because of it's steep nature. Moreover most of the jetties are destroyed or in a very bad state of disrepair. It has been observed that the jetties were effective in holding the bank together due to the observance

of a widening of the channel immediately upstream of the jetty field. This may be an attempt of the river to cut behind the jetty field, but at present it is difficult to confirm.

2) At the place where the river seems to cut behind the jetty field, steep banks are observed. Old automobile bodies have been dumped at this location, possibly by local farmers, to prevent any further erosion, but this method has been clearly seen to be ineffective, generally.

3) The southern bridge abutment seems to be under at least a modified attack of the river, and there seems to be a loss of riprap and bank weakening behind the first set of bridge piers. 4) The Kellner jetty field that has been placed on the northern bank upstream of the bridge seems to have functioned well and has encouraged the growth of significant vegetation. This can be explained because of the high debris and silt content of the Washita. The upstream end of this jetty field is severely damaged and needs maintenance and repair.

5) There is an apparent possibility of the river cutting behind the jetty field on the northern bank. This can be clearly seen in the 1989 aerial photograph.

6) A comparision of the 1960 aerial photograph with the 1989 aerial photograph also clearly elucidates the danger of the embankment being hazarded. This hazard is stimulated because of a small tributary which unfortunately enters right at this place. In 1970 the concave bank, about 1500 to 2000 ft upstream, was moving towards the roadway and was at a distance of about 500 ft from it. The 1989 photograph shows a clear, major movement toward the road and the river can be estimated at about 300 ft from the roadway. A set of Kellner jetties placed further upstream (about 2000

ft from the bridge) would seem to be the most likely solution for the present situation. The banks along the river at this position are steep and show signs of active erosion. Other forms of river training might also be investigated for this site because Kellner jetties may not be entirely sufficient to prevent the erosion of the steep banks. The Palisade technique of "ERCON" Corporation seem applicable.

One of the many ways to prevent erosion of the badly eroding northern bank can be to place heavy riprap on the concave bank after grading the slope. In conclusion it can be stated that this site needs to be under surveillance in the event of a major flood.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JULY 30th 1988 SITE NO.: 11

HIGHWAY NO.: SH 74 COUNTY: GARVIN

BRIDGE LOCATION:

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1950

Span Description: 50' I-BEAM

210' & 140' TRUSSES

50' I-BEAM

2) Yr. of constr.:

Span Description:

EMBANKMENT TYPE:

SLOPE: STEEP ON BOTH BANKS

PROTECTION: HEAVY RIPRAP ON ROADWAY APPROACHES BOTH NORTH AND SOUTH.

SPECIAL NOTES: SOUTHERN EMBANKMENT IN DIRECT CONTACT WITH THE RIVER.

RIVER BANK:

SOIL NATURE: SILTY AND CLAY VEGETATION: TALL WILLOWS

COMMENTS: MODERATE DIFFICULTY IN ACCESS.

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: RIPRAP AT EMBANKMENTS (CONSTRUCTED IN 1957)

a) Description: BOTH THE NORTHERN AND SOUTHERN EMBANKMENTS ARE HEAVILY RIPRAPPED.

b) Present Condition: THE SOUTHERN EMBANKMENT RIPRAP UNDER RIVER ATTACK IN POOR CONDITION, NORTHERN RIPRAP NEAR PERFECT.

TYPE: KELLNER JETTIES (NORTHERN) CONSTRUCTED IN 1949.

a) Description: JETTIES ARE IN NEAR PERFECT CONDITION. AND INGROWN WITH WILLOWS, EXCEPT FOR THE RIPSTREAM SECTION WHICH IS BADLY DAMAGED.

b) Present Condition: UPSTREAM JETTIES IN NEED OF SAME REPAIR AND MAINTANENCE.

TYPE: KELLNER JETTIES (SOUTHERN BANK) CONSTRUCTED IN 1949.

a) Description: THESE JETTIES ARE LOCATED IN THE STEEP SOUTHERN BANK, WHICH IS BADLY ERODING.

b) Present Condition: BADLY DAMAGED, AND NEEDS REPAIR TO PREVENT MORE EROSION OF THE BANK.

TYPE: ________________

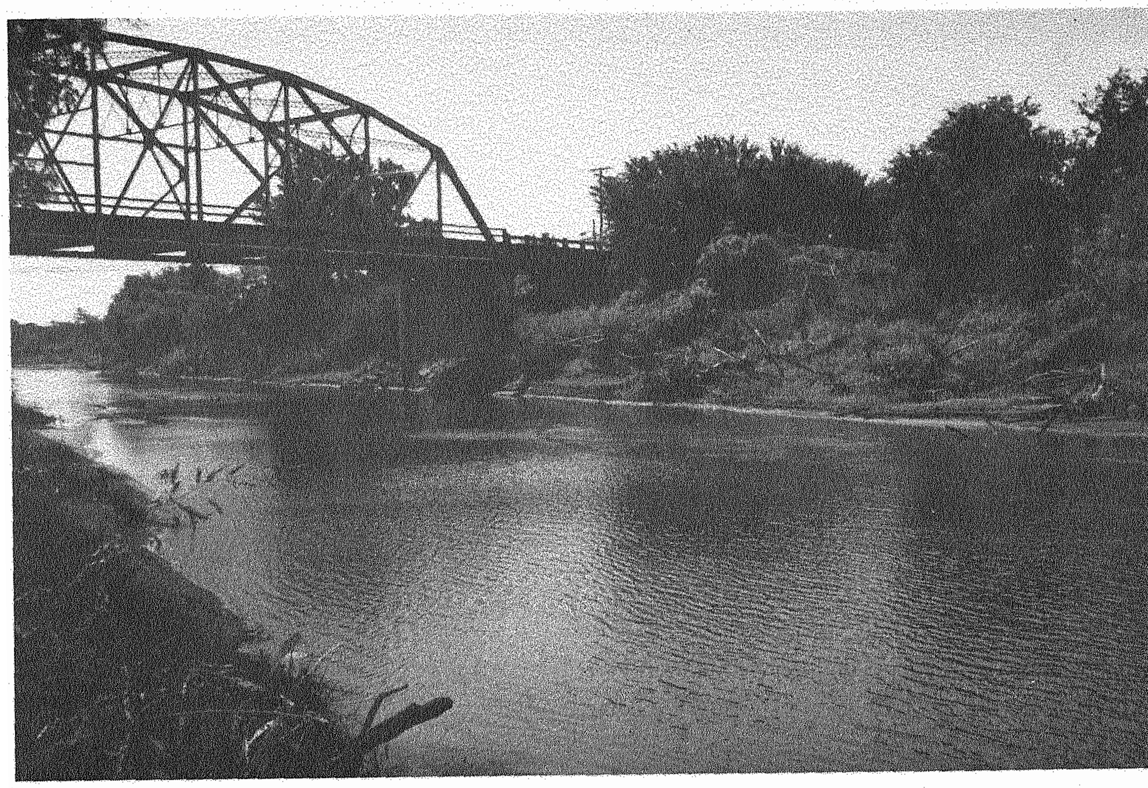
a) Description: ________________

b) Present Condition: ________________

TYPE: ________________

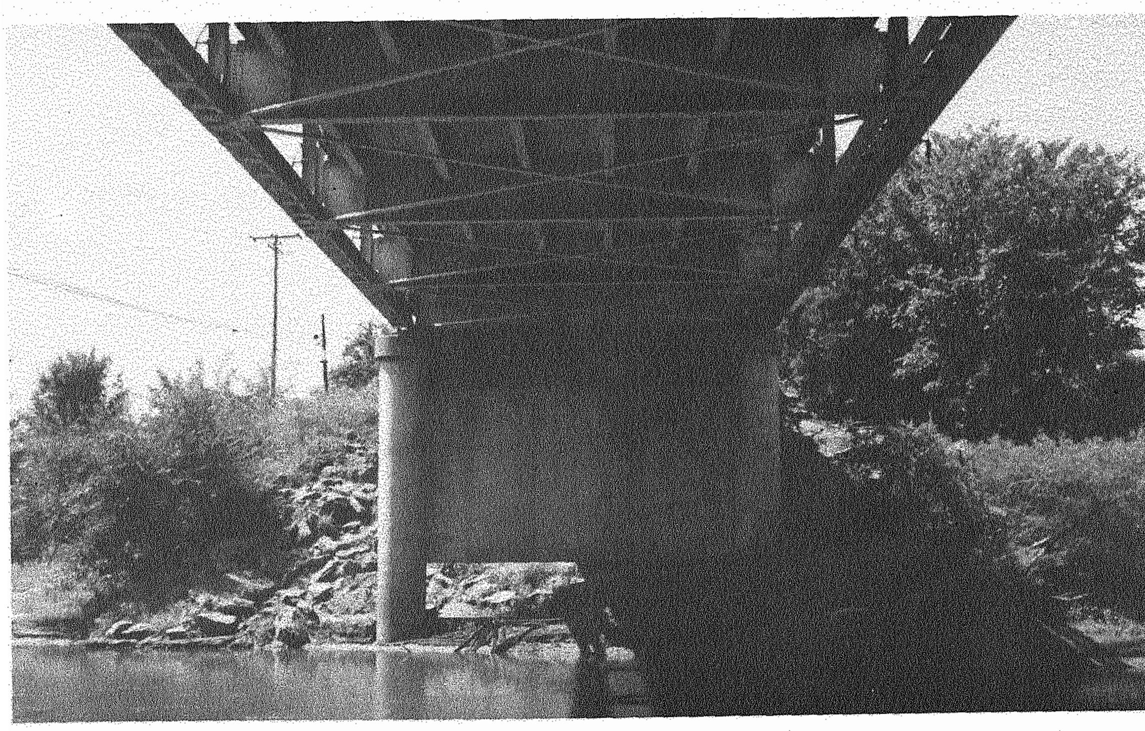
a) Description: ________________

b) Present Condition: ________________



View of the Bridge Pier

FIGURE 61a



View of the Attacked South Bank

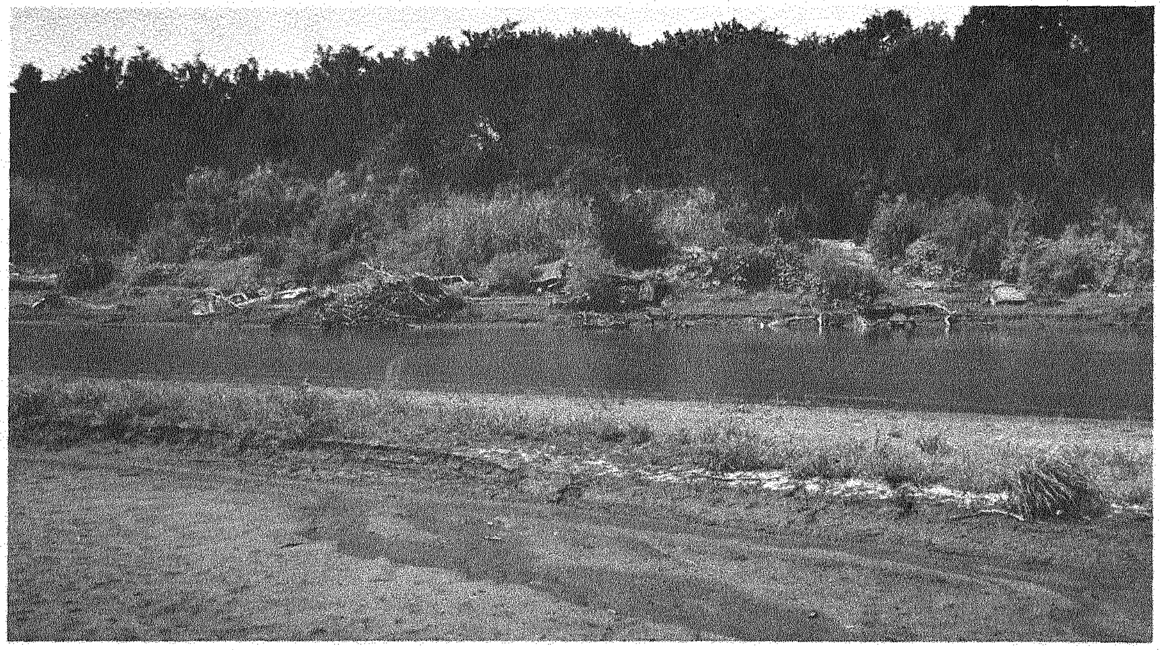
FIGURE 61b

Views of the Damaged Kellner Jetty Field

FIGURE 61c

Kellner Jetty Field on North Bank

FIGURE 61d



Car Bodies Used as an Erosion Control Measure

FIGURE 61e

CIMARRON RIVER SH 33 — Site No. 12

North of Coyle (Logan County)

Scale: 1" = 1173'

1989 Site Aerial Photograph

FIGURE 62

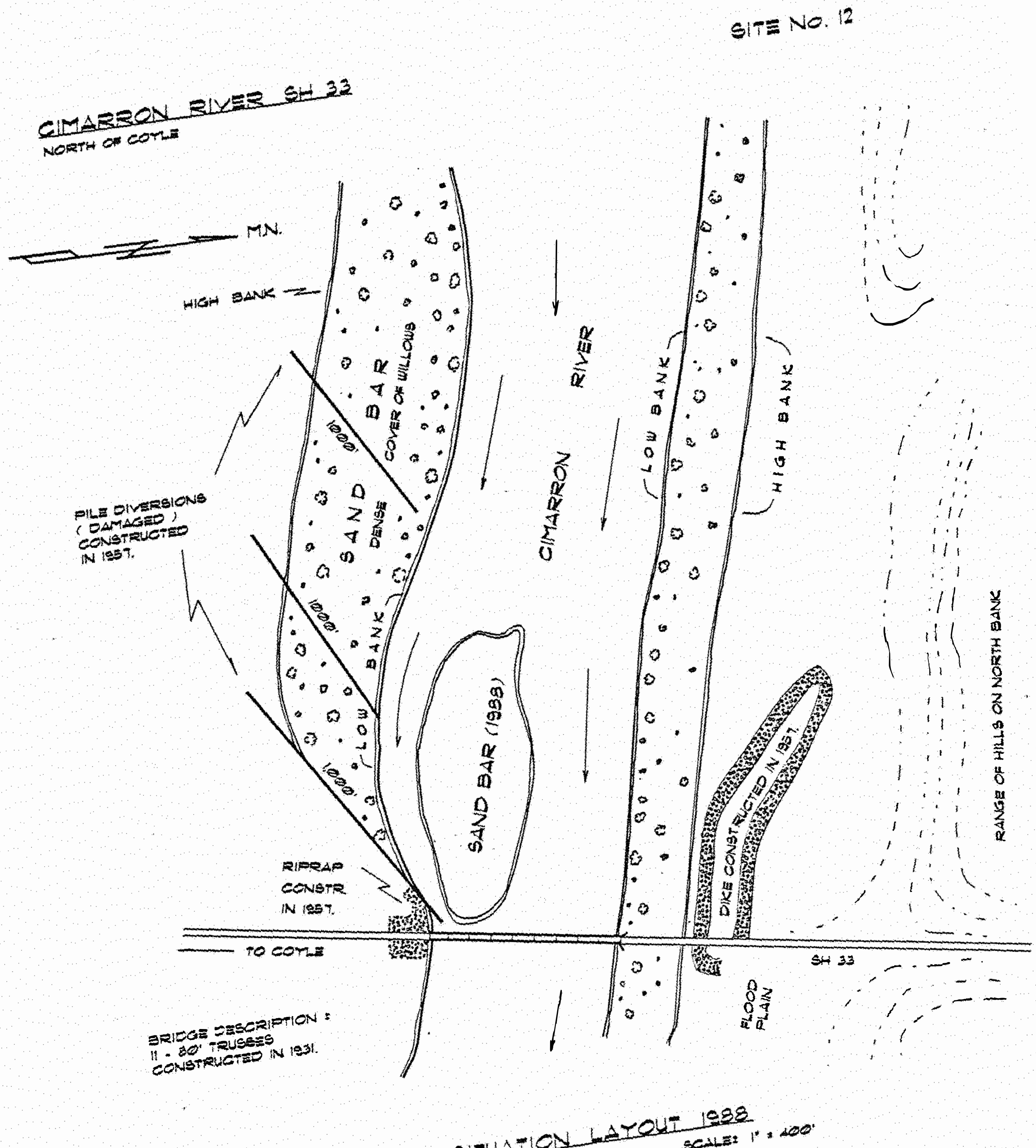

SITE No. 12
CIMARRON RIVER SH 33
NORTH OF COYLE
M.N.
HIGH BANK
SAND BAR
DENSE
COVER OF WILLOWS
1000'
1000'
1000'
PILE DIVERSIONS
(DAMAGED)
CONSTRUCTED
IN 1957.
LOW BANK
CIMARRON RIVER
SAND BAR (1988)
LOW BANK
HIGH BANK
DIKE CONSTRUCTED IN 1957.
RANGE OF HILLS ON NORTH BANK
RIPRAP
CONSTR.
IN 1957.
TO COYLE
SH 33
FLOOD
PLAIN
BRIDGE DESCRIPTION :
11 - 80' TRUSSES
CONSTRUCTED IN 1931.
SITUATION LAYOUT 1988
SCALE: 1" = 400'

FIGURE 63

CIMARRON RIVER SH 33 Site No. 12

North of Coyle (Logan County)

Bridge and Site Data:

The present bridge structure was built in 1931, and has eleven, 80 ft trusses. It is located on the Cimarron River near Coyle and is oriented near normal to the flow. The river at this point is fairly straight and quite wide. The river banks have a medium slope and are densely overgrown with vegetation. Both the northern and southern abutments are heavily riprapped and the river bed shows extensive deposition of sandbars.

History of Stabilization Procedures:

In 1944, 2300 ft of riprap was placed on the southern bank which was about 8 ft in height. In the year 1957 a major plan to stabilize the river was undertaken. A high discharge flood earlier that year had washed away nearly 300 ft of the roadway south of the bridge. The structures erected were :

1) A spur dike nearly 1000 ft long oriented upstream from the bridge. This structure is nearly 12 ft high and has a riprap facing of nearly 3 ft in thickness.

2) Riprap placed on both the northern and southern abutments.

3) Three pile diversions placed on the southwest bank, each about 1000 ft in length. One end of the first unit was tied down to the riprap of the southern abutment and the other end was anchored 150 ft into the southern bank.

4) A new bridge is being planned about one mile upstream due to the poor alignment of the existing bridge. If the embankment is raised at this site, the backwater effect at Coyle will be raised. This site will be immediately

abandoned after the new bridge is constructed.

Site Evaluation:

One factor that is immediately noted in the evaluation of this site is that the relatively narrow bridge is situated on a wide flood plain. Ever since the installation of the bridge in 1931, the river has been constantly eroding the southern bank. In 1944 riprap was placed on the southern bank which contributed very little to the stabilization of the bank. The major effort came in 1957 by the installation of the 3 pile diversions. Looking at aerial photographs of 1938, 1956, 1968 and 1989 it can be generally stated that the river has maintained its course without any noticeable changes in the meander pattern. The only observable change is the erosion of the southern bank just upstream of the bridge. The 3 diversions have contributed significantly to the reduction of this problem. It cannot be stated that the river no longer attacks the bank. This can be inferred from the presence of wide scour holes around the diversions, cutting of the river behind the first diversion, and damaged face planks. There is a wide sandbar in front of the diversions, but it is not wide enough to prevent the water from attacking the southern bank. The section of the second pile diversion in contact with the river is in a bad state of deterioration, and the third pile diversion is no longer in contact with the river. The spur dike at the northern abutment is in good condition and does not seem to need any repair. It is heavily overgrown with vegetation. The riprap on the northern bank seems to be in satisfactory condition, but the base of the riprap on the southern bank is being attacked and needs maintenance. On the whole it can be stated that the river at this site seems to be quite stable and the stabilization structures seem to have done their job well. There does not seem to be any reason for immediate maintenance at this site. In the event that the bridge structure is replaced, consideration should be given to a new alignment.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JULY 25th 1988 SITE NO.: 12

HIGHWAY NO.: SH 33 COUNTY: LOGAN

BRIDGE LOCATION: CIMARRON RIVER, NORTH OF COYLE.

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1931

Span Description: 11, 80' TRUSSES

2) Yr. of constr.:

Span Description:

EMBANKMENT TYPE:

SLOPE: MEDIUM SLOPES, SOUTHERN BANK, 10' HEIGHT BANK, ON NORTH

PROTECTION: RIPRAP ON BOTH EMBANKMENT

SPECIAL NOTES:

RIVER BANK:

SOIL NATURE: SILTY / CLAYEY VEGETATION: SHRUBS

COMMENTS: BIG SAND BAR DEPOSITION ON THE SOUTHERN BANK.

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: PILE DIVERSIONS

a) Description: 3 DIVERSIONS CONSTRUCTED IN 1957. TO PREVENT RIVER ATTACK ON THE SOUTHERN BANK.

b) Present Condition: PILE DIVERSION SHOW DECAY DUE TO THE EFFECT OF WATER. THE RIVER SEEMS TO BE ATTACKING THE OPPOSITE BANK, BUT DUE TO THE EXTENSIVE FLOOD PLAIN, IT IS OF NO IMMEDIATE CONCERN.

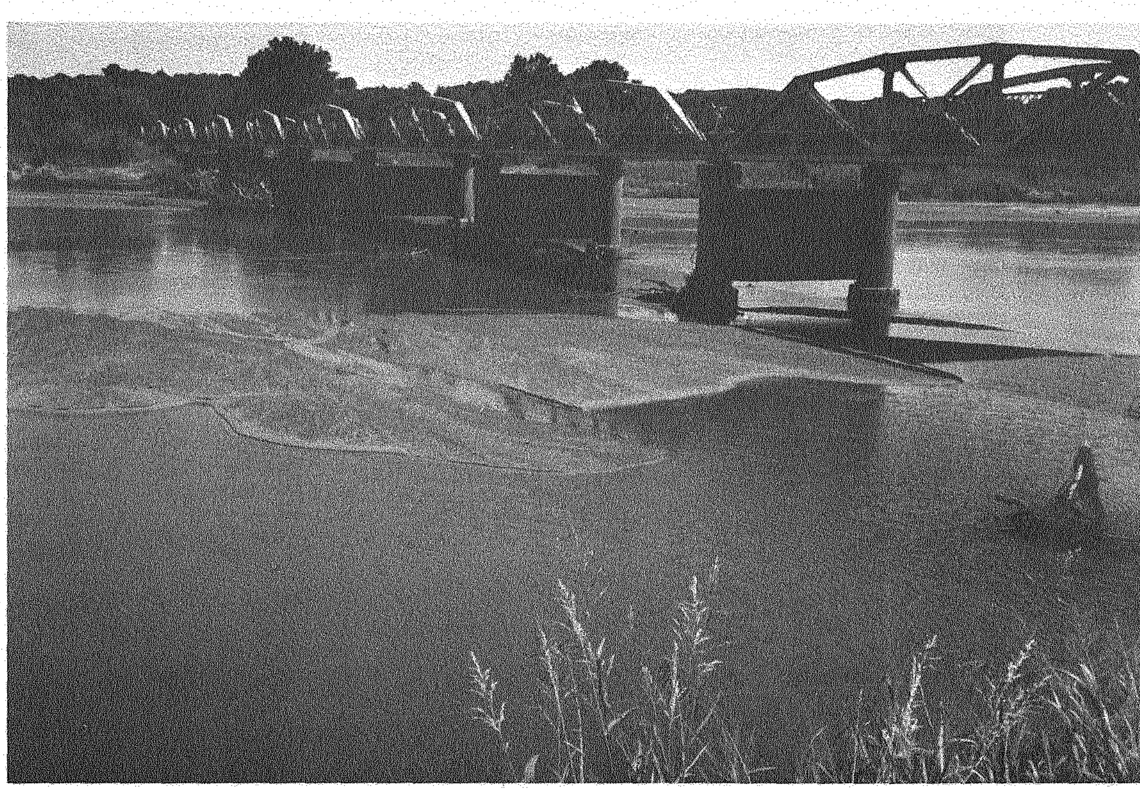
TYPE: SPUR DIKE

a) Description: CONSTRUCTED ON NORTHERN ABUTMENT IN 1957. 12' IN HEIGHT, AND FACED WITH RIPRAP.

b) Present Condition: THE DIKE SEEMS TO BE IN PERFECT CONDITION.

TYPE:

a) Description:

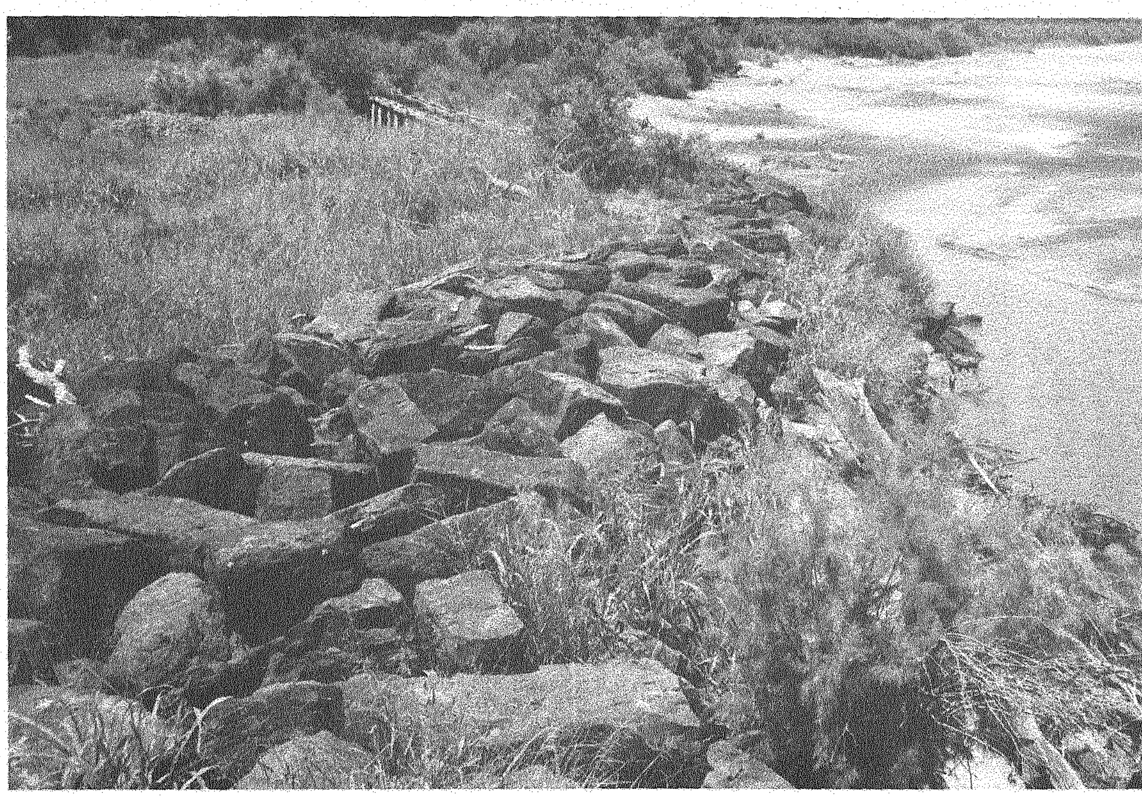


Log Jams on Bridge Piers

FIGURE 64a

Sandbar in the River

FIGURE 64b



Riprap on the Southern Abutment

FIGURE 64c

Second Pile Diversion in a Deteriorated Condition

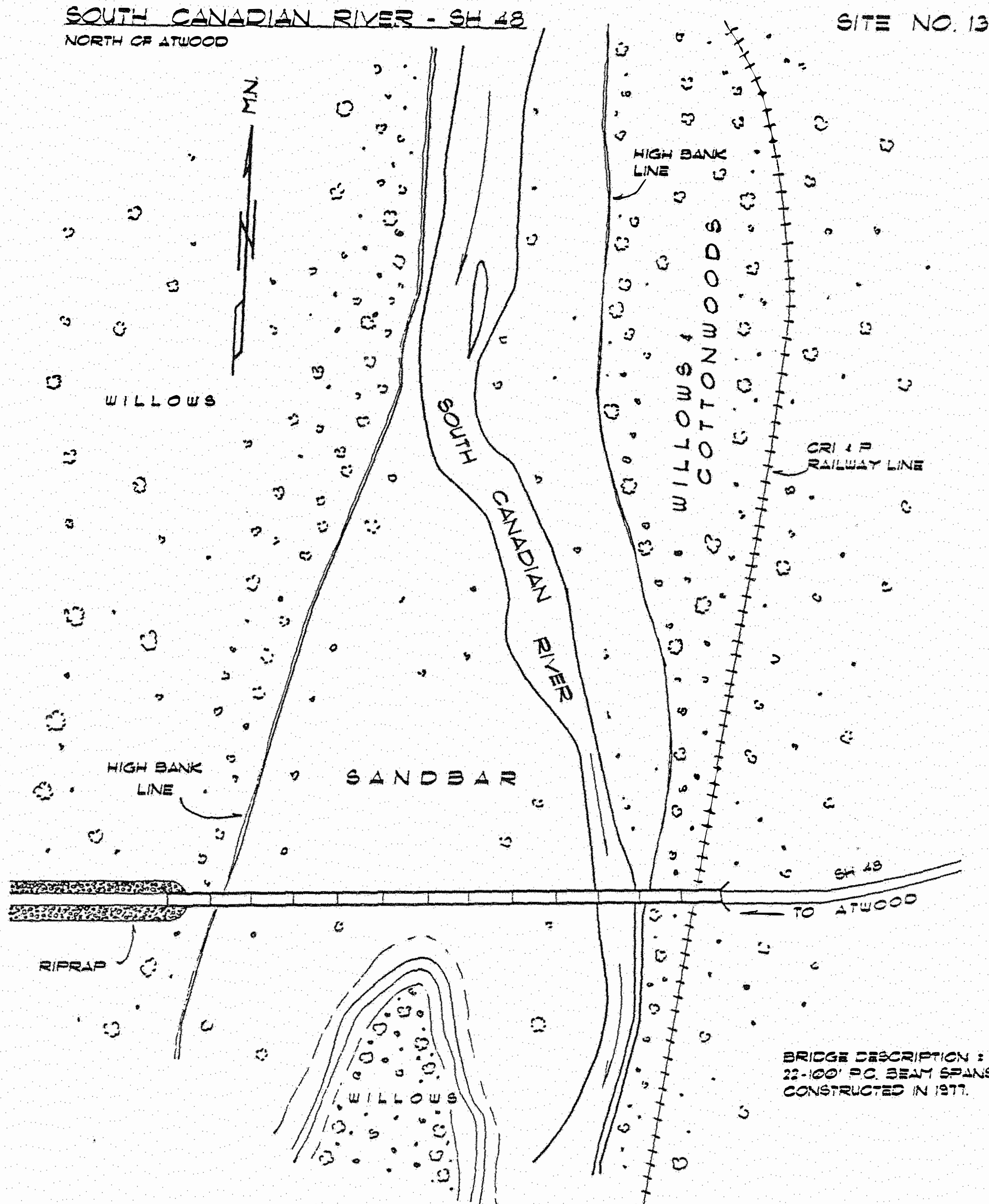
FIGURE 64d

SOUTH CANADIAN RIVER -SH 48 Site No. 13
North of Atwood (Hughes County)

Scale: 1" = 1173'

1989 Site Aerial Photograph

FIGURE 65



SITUATION LAYOUT 1988.

SCALE 1" = 611'

FIGURE 66

SOUTH CANADIAN RIVER -SH 48 Site No. 13

North of Atwood (Hughes County)

Bridge and Site Data:

The old bridge was constructed in 1928 and was composed of three, Bailey trusses, one each of a 150 ft and 130 ft trusses, and one, 40 ft I-Beam span. The bridge had a normal intersection to the stream, with the road approach running parallel to the river and making a 90 degree turn at the bridge site. This bridge site no longer exists and a new bridge site is located about a mile downstream with a completely new alignment. The old location of the bridge had been a problem site with massive embank failure and bridge failures. The old bridge structure is an ideal example of an improper, or poor alignment coupled with a small bridge and the problems this create.

History of Stabilizing Procedures:

Large river discharges between 1941 to 1960 had the southern abutment failing which lead to the construction of five pile diversions and about 1000 ft of tree retards. In 1957 the river cut around these diversions and this lead to the construction of five more diversions and an addition of about 100 ft to each of the diversions present. In 1959 two more diversion were constructed. Later that year, the river scoured around many of the diversions and riprap had to be placed at the site. The flood of 1960 caused massive mudslides and bank failures, and also the washing out of the bridge. In about 1970, it was decided that the problems associated with this site were due to improper location of the bridge, and a new location was selected which was further downstream and at a better alignment.

Site Analysis:

The bridge at the new location about one mile downstream seems to be a much better alignment than the older one. There seems to be no stabilizing structures at this site as indicated by field visits. Riprap is present on both the embankments. As of now the site seems to be functioning in the manner expected. There does not seem to be any need for additional river training structures as the situation stands. The site has to withstand many more hydrologic events before any more recommendations can be made.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: NOV. 11, 1988 SITE NO.: 13

HIGHWAY NO.: SH 48 COUNTY: HUGHES

BRIDGE LOCATION: SOUTH CANADIAN RIVER, NORTH OF ATWOOD

STREAMFLOW: MEDIUM / LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1928 (OLD BRIDGE NO LONGER EXISTS)

Span Description: 3, 150' BAILEY TRUSSES
1, 150' TRUSS
1, 130' TRUSS ; 1, 40' I-BEAM.

2) Yr. of constr.: 1977

Span Description: 22 - 100' P.C. BEAM SPANS

EMBANKMENT TYPE:

SLOPE: STEEP

PROTECTION: RIPRAP

SPECIAL NOTES: THE PRESENT SITE IS ONE MILE D/S FROM THE ORIGINAL SITE.

RIVER BANK:

SOIL NATURE: SILTY VEGETATION: WILLOWS

COMMENTS: NEW BRIDGE IS IN MUCH BETTER LOCATION THAN OLD ONE. THE APPROACH IS LONG AND STRAIGHT. NO PROBLEMS ARE ANTICIPATED. NO PROTECTIVE STRUCTURES AT THIS SITE.

Upstream View of the River

Figure 67a

Downstream View of the River

Figure 67b

NORTH CANADIAN RIVER - SH 84
North of Dustin (Okfuskee County)

Site No. 14

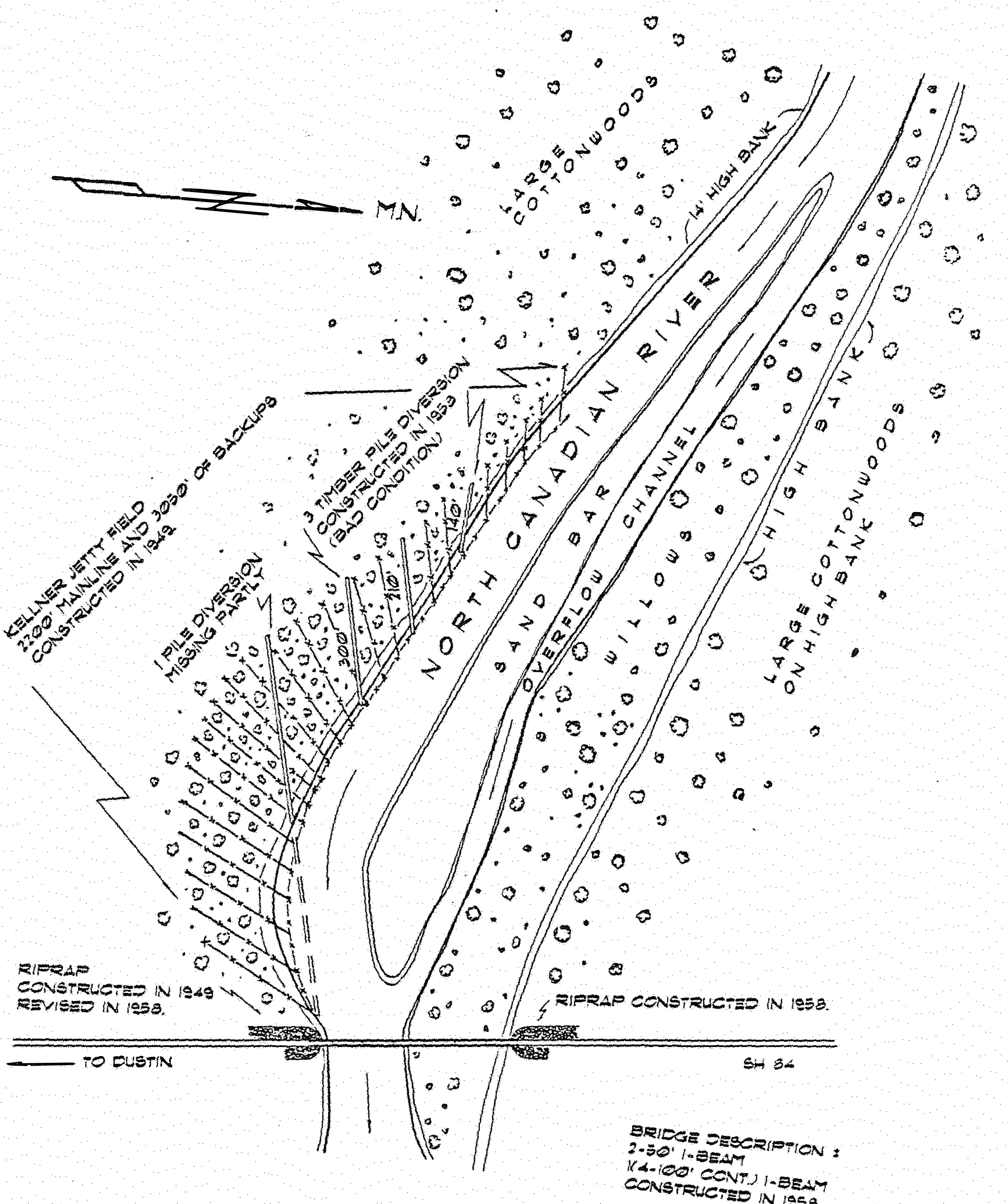
Scale: 1" = 1143'

1989 Site Aerial Photograph

FIGURE 68

NORTH CANADIAN RIVER SH 84
NORTH OF DUSTIN

SITE No. 14



SITUATION LAYOUT 1988
SCALE : 1" = 300'

FIGURE 69

NORTH CANADIAN RIVER - SH 84 — Site No. 14

North of Dustin (Okfuskee County)

Bridge and Site Data:

The bridge structure in place was constructed in 1958. It consists of two, 50 ft I-Beam spans, and four spans of 100 ft continuous I-Beams. The North Canadian at this point is relatively narrow and is relatively straight with no large dominant meander loops. The absence of a meander pattern at the bridge site may be solely because of the presence of the bridge. The vegetation at this site are mainly large cottonwoods trees.

History of Stabilization Procedures:

The old bridge of 1949 was a problem site with the North Canadian constantly attacking the southern bank. At this place Kellner jetties were installed (nearly 2200 ft of mainline and 3050 ft of backups) to discourage damaging action of the river. Riprap was also placed on the southern abutment of the bridge. The flood of 1958 demonstrated that Kellner jetties were not successful at this site. Most of the jetties that were erected are no longer observable and only remnants of the structures can be observed behind the pile diversions.

In 1958 a new superior bridge was built, and four pile diversions were erected on the southern bank instead of jetties. The length of the pile diversions were 800 ft, 300 ft, 210 ft, and 140 ft the lengths decreasing upwards. The riprap on the southern abutment was repaired and extended further upstream. Riprap was also placed on the northern abutment.

Site Evaluation:

This is the case of a site that has not responded well to stabilization procedures with the use of Kellner jetties but has responded favorably to the use of pile diversions. Sites visits have shown that only one of the installed jetties (the one nearest to the bridge) is in contact with the water. All the others are deeply embedded in silt. This observance should be enough to state that the diversions have functioned as designed and intended. The first pile diversion however needs repair.

Comparison of the 1968 and the 1989 aerial photographs have revealed that the pile diversions seem to be functioning effectively against the eroding action of the river. The places where the river seemed to have been cutting into the bank in 1968 now have a very active vegetal cover, mainly cottonwoods.

There is a small cutting behind the first pile diversion but this is no cause for immediate concern due to the presence of a thick layer of riprap on the bank. At the bridge site the river seems to be pushing towards the northern cutbanks, or abutments. This may be evaluated after a major hydrologic event for further evaluation. The combination of the Kellner jetties and the pile diversions seem to be an effective tool for controlling rivers with a large meander loop radius.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JAN. 6, 1989 SITE NO.: 14

HIGHWAY NO.: SH 84 COUNTY: OKFUSKEE

BRIDGE LOCATION: NORTH CANADIAN RIVER, NORTH OF DUSTIN

STREAMFLOW: MEDIUM WEATHER: COOL

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1958

Span Description: 2, 50' I-BEAMS
4, 100' CONTINUOUS I-BEAMS

2) Yr. of constr.: ______

Span Description: ______

EMBANKMENT TYPE:

SLOPE: STEEP SLOPES ON THE EMBANKMENTS

PROTECTION: BOTH EMBANKMENTS ARE PROTECTED BY RIPRAP.

SPECIAL NOTES: ______

RIVER BANK:

SOIL NATURE: CLAYEY VEGETATION: WILLOWS

COMMENTS: ______

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: RIPRAP (ON BOTH ABUTMENTS)

a) Description: INSTALLED IN 1958, ON BOTH BANK TO PROTECT THE BRIDGE APPROACHES.

b) Present Condition: SOUTHERN ABUTMENT IN DIRECT CONTACT WITH THE RIVER AND MAY NEED SOME REPAIR.

TYPE: KELLNER JETTIES

a) Description: CONSTRUCTED IN 1949, 2200' OF MAINLINE AND 3050' OF BACKUPS, BUILT TO PROTECT THE SOUTHERN BANK.

b) Present Condition: THE JETTIES ABOVE THE WATERLINE, SEEMS TO BE IN PERFECT CONDITION, WHILE THOSE IN CONTACT WITH THE WATER ARE IN A SERIOUS STATE OF DETERIORATION.

TYPE: PILE DIVERSIONS

a) Description: 4 STRUCTURES, CONSTRUCTED IN 1958, TO DIVERT THE RIVER AWAY FROM THE BANK

b) Present Condition: ALL THE DIVERSIONS EXCEPT THE ONE NEAREST THE BRIDGE, AND ON THE BANK AND HAVE SILTED IN AROUND 400' OF THE FIRST DIVERSION IS DESTROYED.

TYPE: ____________________

a) Description: ____________________

b) Present Condition: ____________________

TYPE: ____________________

a) Description: ____________________

b) Present Condition: ____________________

View of Damaged Pile Diversion

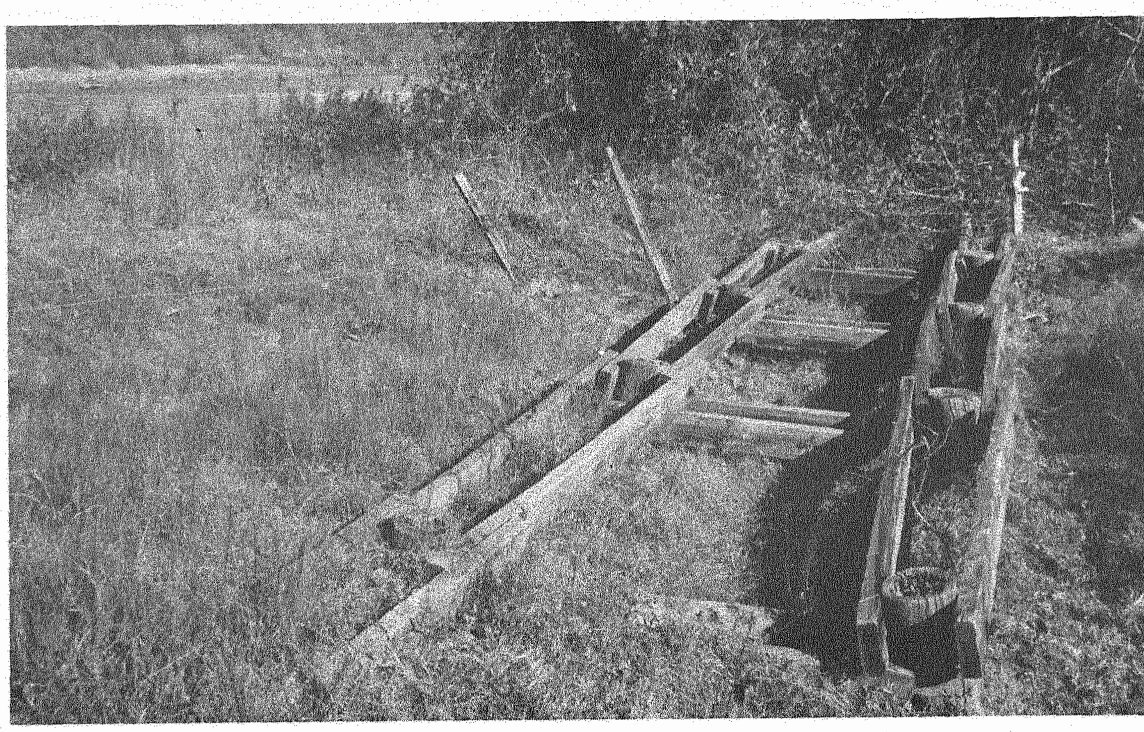
FIGURE 70a

Exposed Deadman of Kellner Jetty Field

FIGURE 70b

Damaged Jetty Field

FIGURE 70c



A Buried Pile Diversion

FIGURE 70d

SOUTH CANADIAN RIVER SH 2
North of Whitefield (Muskogee County)

Site No. 15

Scale: 1" = 1196'

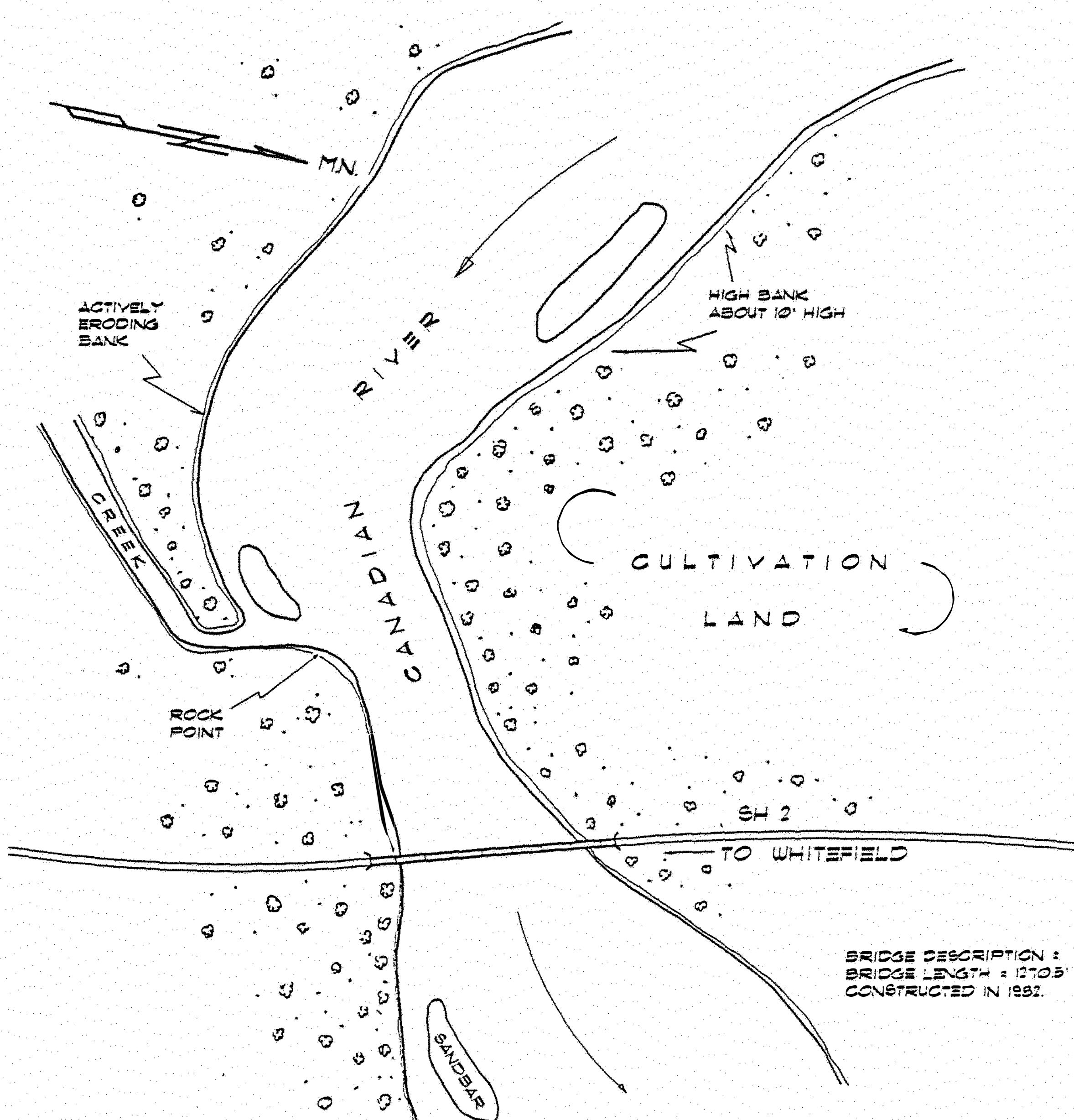
1989 Site Aerial Photograph

FIGURE 71

CANADIAN RIVER - SH 2

NORTH OF WHITEFIELD

SITE NO. 15



SITUATION LAYOUT 1988

SCALE 1" = 847'

FIGURE 72

SOUTH CANADIAN RIVER SH 2 Site No. 15
North of Whitefield (Muskogee County)

Bridge and Site Data:

The old bridge structure at this site was built in 1922, and it consisted of four, 212 ft steel truss spans. The bridge on the Canadian River at this site has been replaced by a new concrete bridge which is located slightly downstream from the old structure. The southern abutment of the bridge is located on a rock outcrop, and has remained stable. The river has been attacking the south bank repeatedly, only to be retarded by the rock outcrop. In its efforts to establish a meander loop, there have been many instances where the river has attacked the northern bank. The land on both sides of the river is cultivable and subjected to various degrees of erosion.

History of Stabilization Procedures:

A major stabilization project was performed at this site was in 1948, when a flood in 1947 caused an unexpected change in channel configuration which resulted in the river moving north at the bridge site washing out about 750 ft of the northern bridge approach. This included the construction of three pile diversions to move the river back into its original channel. The diversions had facings which were composed of a single line of fallen trees tied together. Further upstream, tree retards were placed to prevent the erosion of a concave bank.

Site Analysis:

This is a site to illustrate the complex nature of a meandering river and its related unpredictability. In 1947 a channel cut through the north abutment washing out nearly 750 ft of the approach embankment. The main stabilization procedures at this site came after this event. In about early 1949, the Canadian once again returned to its earlier channel. There were many theories for this movement but the real reason may never be realized. The new bridge was constructed slightly downstream of the old structure and seems to be in a good alignment. None of the old diversionary or other structures could be found at this site. About three miles upstream of the bridge site four hardpoints could be located. This is thought to be constructed by local farmers to prevent erosion of cultivable land. The southern bank seems to be in no danger in spite of the constant attack of river. This is due to the presence of a rock point at this place on which the abutment rests.

This site may be more mature due to Eufaula Reservoir being built just upstream.

Right now, there seems to be no problem with the site. This does not however guarantee the safety of the site. The Canadian had once changed its course attacking a very unexpected location, and there is no reason to believe why such a phenomenon should not reccur. This is however no cause for immediate concern, only a reminder to be ready for the unexpected.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: NOV. 3, 1988 SITE NO.: 15

HIGHWAY NO.: SH2 COUNTY: MUSKOGEE

BRIDGE LOCATION: CANADIAN RIVER, NORTH OF WHITEFIELD

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1982

Span Description: BRIDGE LENGTH = 1270.5'

2) Yr. of constr.: ______

Span Description: ______

EMBANKMENT TYPE:

SLOPE: STEEP

PROTECTION: RIPRAP

SPECIAL NOTES: THE RIPRAP IS IN FAIRLY GOOD CONDITION.

RIVER BANK:

SOIL NATURE: CLAYEY VEGETATION: WILLOWS

COMMENTS: NO EVIDENCE OF PREVIOUSLY INSTALLED PROTECTIVE STRUCTURES.

View of the Bridge Site

FIGURE 73a

Damaged Riprap at Bridge Abutment

FIGURE 73b

Riprap on the Upstream Bank

FIGURE 73c

Upstream View of the River

FIGURE 73d

NORTH CANADIAN RIVER - SH 3 Site No. 16
East of Shawnee (Pottawatomie County)

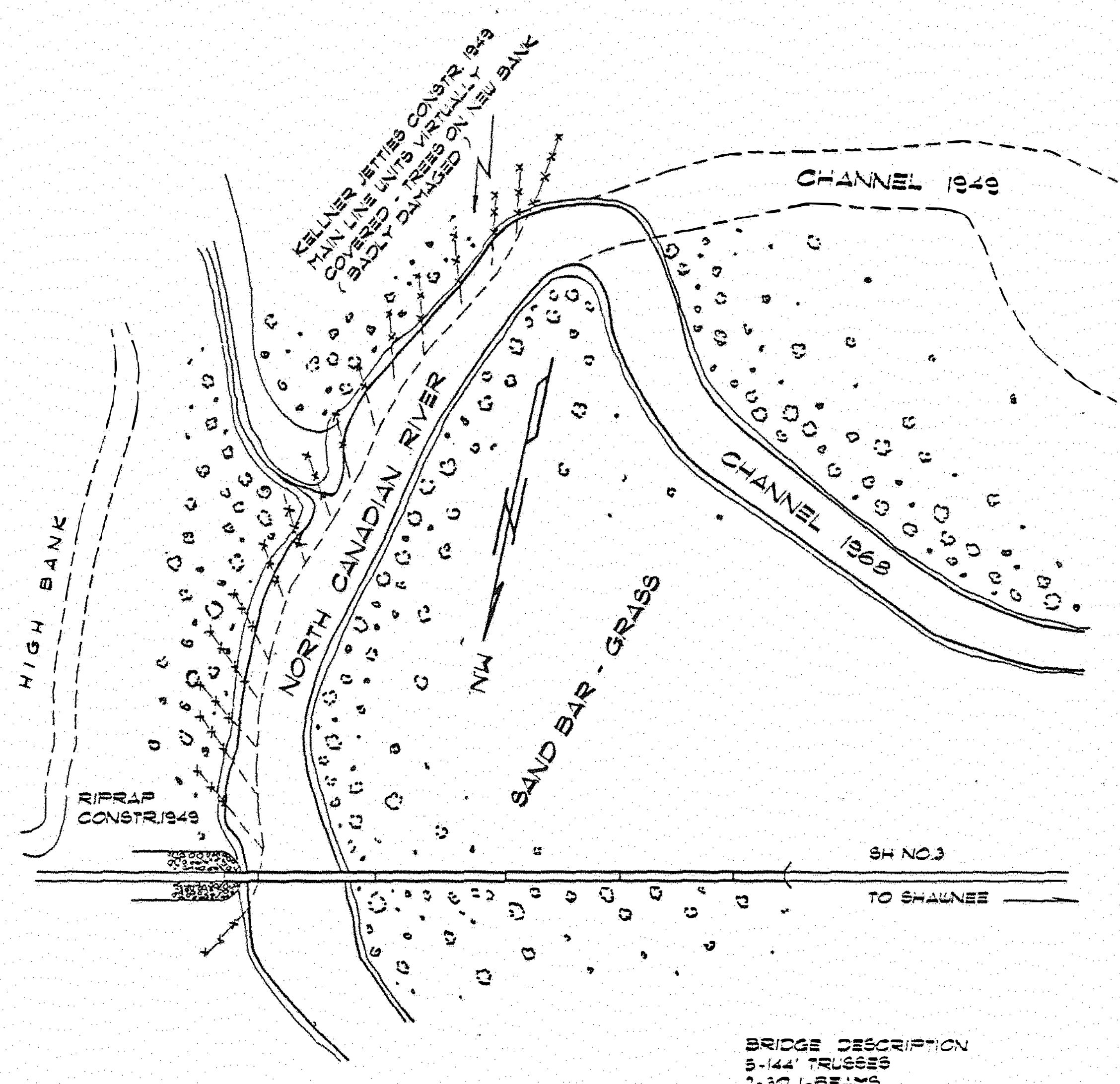
Scale: 1" = 1040'

1989 Site Aerial Photograph

FIGURE 74

NORTH CANADIAN RIVER - SH NO. 3
EAST OF SHAWNEE

SITE NO. 16



SITUATION LAYOUT
SCALE 1"=200'

FIGURE 75

NORTH CANADIAN RIVER - SH 3 Site No. 16
East of Shawnee (Pottawatomie County)

Bridge and Site Data:

The old bridge structure on the site consisted of five, 144 ft trusses and two, 30 ft I-Beam spans. In 1975, a new concrete bridge was constructed on the same location. The North Canadian is very sinuous in nature and the diversion of its waters to Oklahoma City and the construction of an upstream barrage at Canton has sufficiently reduced its potential for large instantaneous discharge and, dynamic rise/fall characteristics. The vegetation on both the banks are medium height willows and other shrubs. The soil in the area shows a small clayey content.

History of Stabilization Procedures:

The flood of 1949 attacked nearly 1400 ft of the southeastern bank. This prompted the installation of a Kellner jetty field (nearly 1350 ft of main line and 15 rows of backups) along the southeastern bank. Riprap was also placed on the abutment of the eastern bank (about 100 ft both upstream and downstream). After the installation of the new bridge in 1975 no additional protective structures were installed, except for the riprap which was placed on the eastern bank.

Site Evaluation:

As pointed out by Keeley (9), the North Canadian river has been reduced in potential high flow after the diversion of its water and the construction of an upstream barrage at Canton. Comparison between the 1968 and the 1989 aerial photographs show no change in the river meander pattern, in its sinuousity or its attack on the bank. Remnants of the old jetty field built at the waterline can be seen, but in a highly deteriorated condition. Most of the backup jetties, especially those on the high bank seem to be in perfect condition. There is absolutely no change in the river configuration even further upstream. The river is a dormant state. Since the new bridge spans further eastward compared to the old structure, fear of attack of the eastern abutment has also been eliminated.

Summarily, the maturity of the river due to the construction of the bridge, and other stabilizing activity, has been achieved at this site. The original volatile nature of the river is clearly seen in aerial photographs. The long straight approach to the bridge is excellent evidence of good River Training practice.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JAN. 6, 1989 SITE NO.: 16

HIGHWAY NO.: SH16 COUNTY: POTTOWATOMIE

BRIDGE LOCATION: NORTH CANADIAN RIVER. EAST OF SHAWNEE

STREAMFLOW: LOW WEATHER: COOL

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1975

Span Description: 5 - 144' I-BEAMS
2 - 30' I-BEAMS

2) Yr. of constr.: ______

Span Description: ______

EMBANKMENT TYPE:

SLOPE: STEEP

PROTECTION: RIPRAP

SPECIAL NOTES: EAST ABUTMENT IN CONTACT WITH THE RIVER.

RIVER BANK:

SOIL NATURE: SILTY VEGETATION: WILLOWS

COMMENTS: VERY LOW WATER FLOW

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: KELLNER JETTIES

a) Description: CONSTRUCTED IN 1949 ON THE EASTERN BANK, TO PREVENT EROSION ON THAT BANK.

b) Present Condition: MOST JETTIES IN CONTACT WITH THE RIVER ARE IN A BAD CONDITION, WHILE THOSE ON THE HIGH BANK ARE IN NEAR GOOD CONDITION. VERY LITTLE BANK BUILDING ACTIVITY.

TYPE: __________

a) Description: __________

b) Present Condition: __________

TYPE: __________

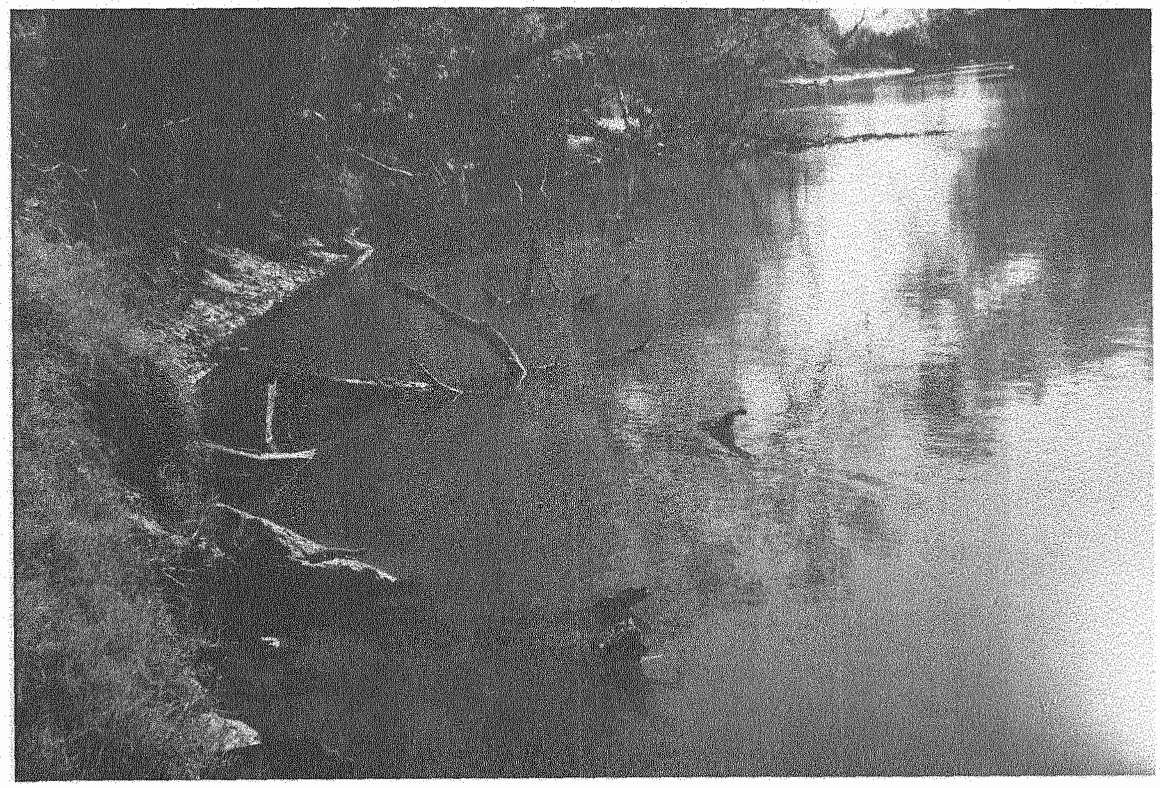
a) Description: __________

Riprap At Bridge Abutment

FIGURE 76a

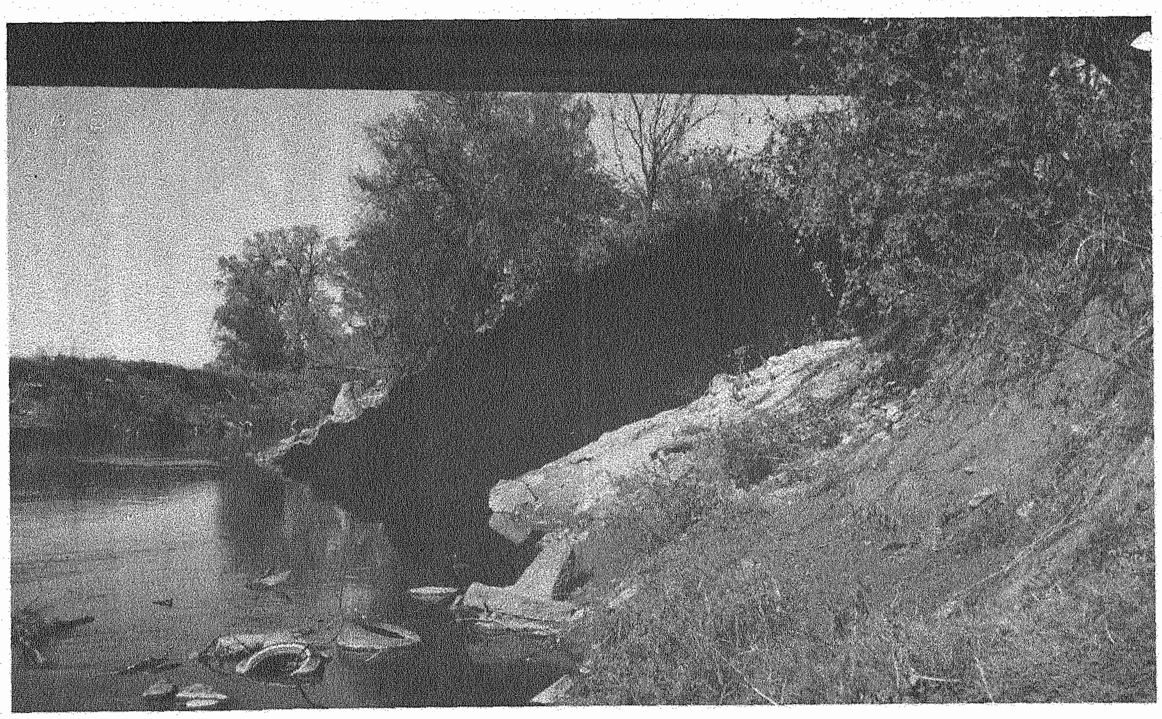
Overgrown Kellner Jetty Field

FIGURE 76b



Damaged Kellner Jetty Field

FIGURE 76c



Remnants of Old Bridge

FIGURE 76d

Scale: 1" = 1067'

1989 Site Aerial Photograph

FIGURE 77

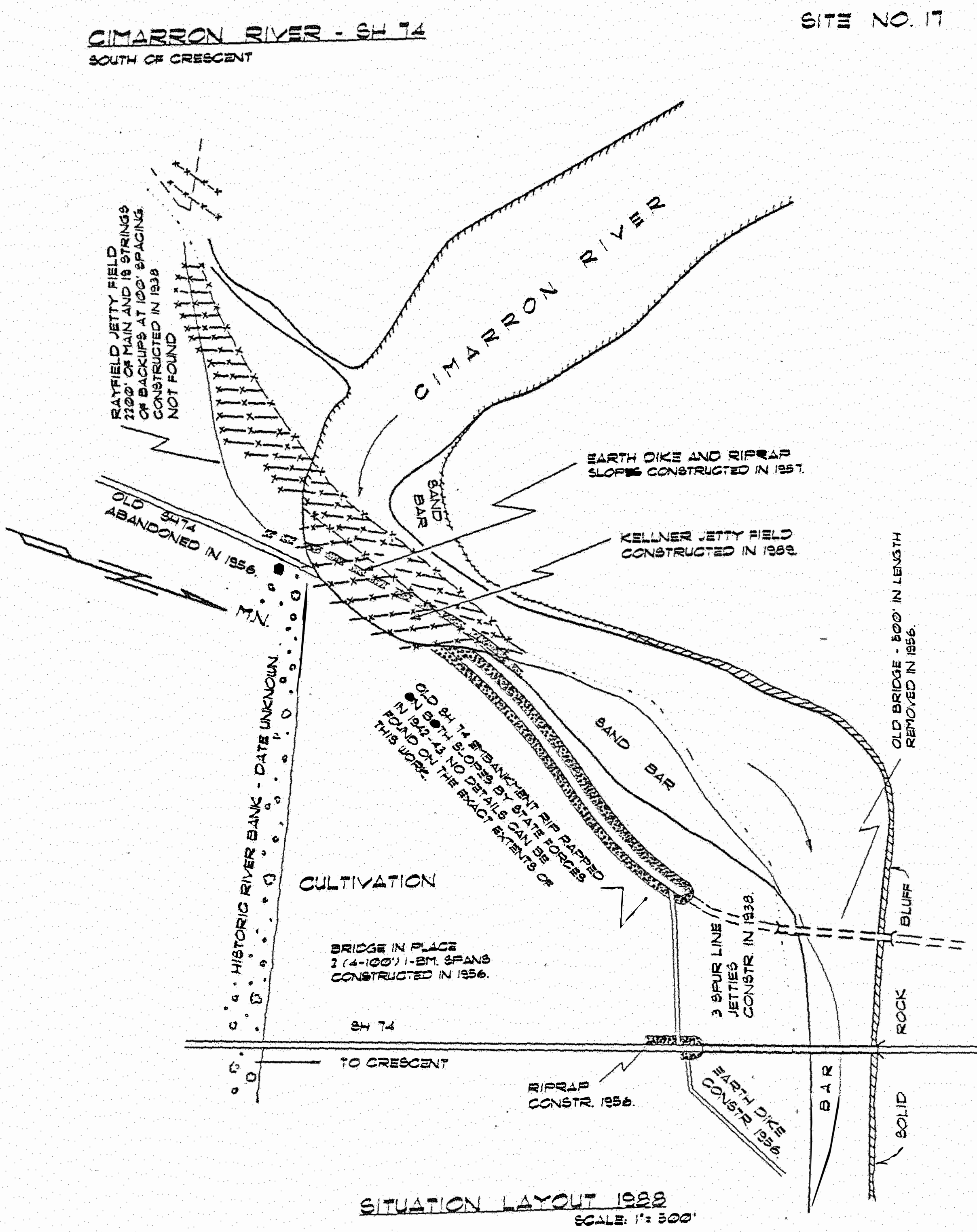

CIMARRON RIVER - SH 74
SOUTH OF CRESCENT
SITE NO. 17
CIMARRON RIVER
RAYFIELD JETTY FIELD 2200' OF MAIN AND 18 STRINGS OF BACKUPS AT 100' SPACING. CONSTRUCTED IN 1938 NOT FOUND
EARTH DIKE AND RIPRAP SLOPES CONSTRUCTED IN 1957.
SAND BAR
KELLNER JETTY FIELD CONSTRUCTED IN 1988.
OLD SH 74 ABANDONED IN 1956.
M.N.
HISTORIC RIVER BANK - DATE UNKNOWN.
OLD SH 74 EMBANKMENT RIP RAPPED ON BOTH SLOPES BY STATE FORCES IN 1942-43. NO DETAILS CAN BE FOUND ON THE EXACT EXTENTS OF THIS WORK.
SAND BAR
OLD BRIDGE - 800' IN LENGTH REMOVED IN 1956.
CULTIVATION
BLUFF
BRIDGE IN PLACE
3 (4-100') I-BM. SPANS
CONSTRUCTED IN 1956.
3 SPUR LINE JETTIES CONSTR. IN 1938.
SH 74
ROCK
TO CRESCENT
RIPRAP CONSTR. 1956.
EARTH DIKE CONSTR. 1956.
BAR
SOLID
SITUATION LAYOUT 1988
SCALE: 1"= 500'

FIGURE 78

CIMARRON RIVER - SH 74 — Site No. 17

South of Crescent (Logan County)

Bridge and Site Data:

The bridge structure found at this site was built in 1957. It consists of two sets of four, 100 ft long I-Beam spans. The north abutment of the bridge is situated on a rock outcrop which extends for a long distance both upstream and downstream. The Cimarron river flows in a braided pattern and the streambed shows extensive deposition of sand, but these sandbars are not high enough to disturb the path of flow of water in situations of high flows. The flood plain of the river is extensive and the bridge spans only a small section of it.

History of Stabilization Procedures:

In 1937, 2200 ft of Rayfield jetties were constructed, upstream from the southern bank in an effort to reduce the angle of impact of the river and to stabilize the river parallel to the old SH 74. In 1943, about 1600 ft of the old road embankment was riprapped to protect it from damage. In 1957 a new bridge was built along a new alignment. It was constructed downstream from the old structure and was a better orientation than the old one. An earth dike was constructed and riprapped on both faces. This dike has become an integral part of the embankment of the old roadway. Extensive riprap was constructed on the southern embankment which has an elevation of about 952 ft. The northern abutment apparently needed no bank protection work due to the fact that it was founded on an extensive rock outcrop foundation. Towards the end of 1988, plans for extensive bank protection of the southern bank were completed. Two viable alternatives were available and they were the construction of a Kellner jetty field and the building of a dike (as an extension to the old one already present) all the way from the bridge structure to the length of nearly 3000 ft upstream. Finally a Kellner jetty field was installed which consisted of 1600 ft of mainline jetties, and 16 lines of backups. Construction of this jetty field was constructed in early 1989.

<u>Site Evaluation:</u>

Comparison of the 1968 aerial photograph to the one taken in 1989 reveals a general trend of the Cimarron River to push the principal meander loop further downstream. It can be clearly seen that the southern edge of the river has moved more eastward, and the river is in contact with the riprapped dike which was originally the embankment of the old SH 74. The northern banks of the river at this site have no erosion problems due to the presence of a solid rock outcrop. This might conceivably lend itself as a problem to the bridge integrity in that the north directed river flow might produce a rebounding current which could cause some problems downstream. The 1989 aerial photographs show that the southern bank is no longer convex and extensive concavity of the bank shows the magnitude of the erosional forces acting on it. The riprapped abutment of the old SH74 shows signs of decay, and is being continuously attacked. The southern embankment that was once not in contact with the water is now under attack of the river. The main action that presently holds the southern bank is the massive, extensive riprap that has been placed on it. As of now the river seems to be generally contained between the two abutments, and it is likely that it will be for the forseeable future. Notice should be paid to the bridge piers that might be subject to extensive scouring due to the confined status of the river. The jetty field installed in 1989 on the southern bank, may be a solution to the problems present at that site. The jetty field must be confronted by some major floods to find its effectiveness at that site.

In conclusion, there is little that can be done to the site other than to keep the southern banks riprapped and protected to reduce erosion, and to be sure that the southern bridge abutment is not left unprotected at any time.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JULY 25, 1988 SITE NO.: 17

HIGHWAY NO.: SH 74 COUNTY: LOGAN

BRIDGE LOCATION: CIMARRON RIVER, SOUTH OF CRESCENT

STREAMFLOW: LOW WEATHER: COOL

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1956

Span Description: 2 (4 - 100') I - BEAMS

2) Yr. of constr.: ______

Span Description: ______

EMBANKMENT TYPE:

SLOPE: STEEP

PROTECTION: MASSIVE ROCKS USED AS RIPRAP

SPECIAL NOTES: NORTHERN BANK IS A SOLID ROCK OUTCROP.

RIVER BANK:

SOIL NATURE: SILTY / SANDY VEGETATION: SPARSE

COMMENTS: OLD ROADWAY EMBANKMENT HAS BEEN CONVERTED INTO A PROTECTIVE STRUCTURE.

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: OLD EMBANKMENT (OF SH 74)

a) Description: IN 1943 THIS EMBANKMENT HAD BEEN RIPRAPPED TO ACT AS A PROTECTIVE STRUCTURE.

b) Present Condition: THE ABUTMENT HAS BEEN SERIOUSLY ERODED AND THE RIVER IS TRYING TO CUT BEHIND IT.

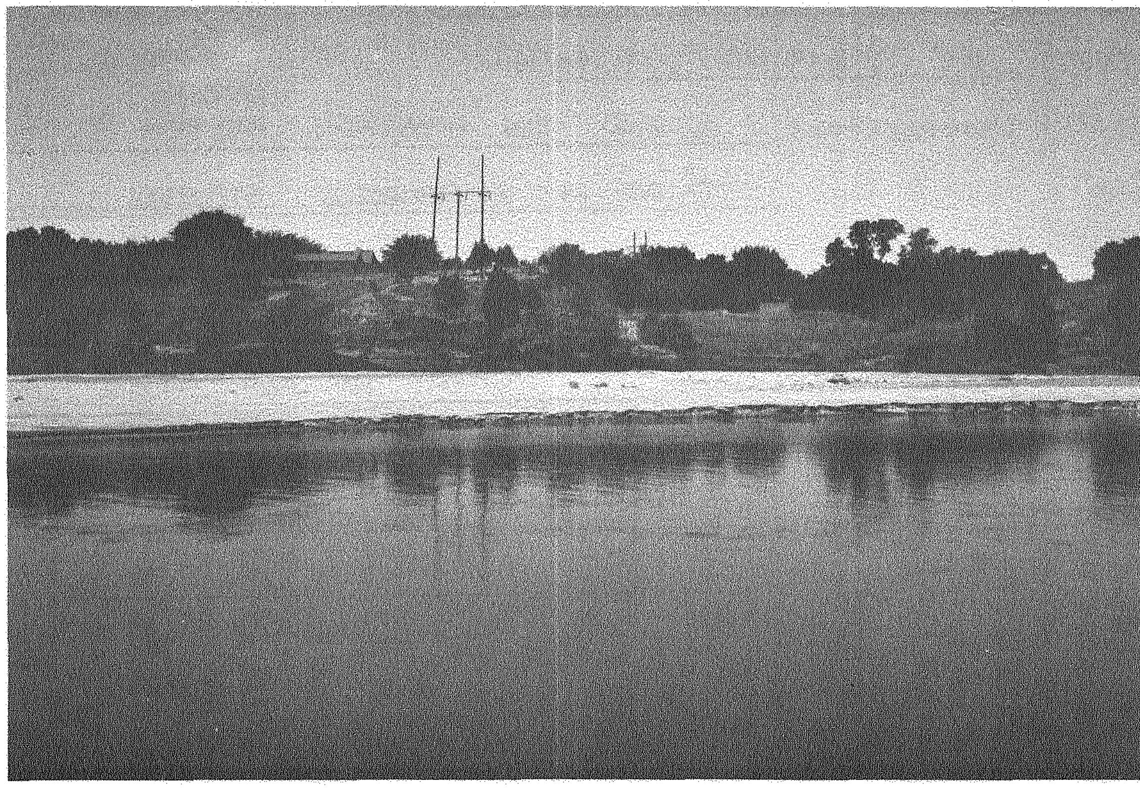
TYPE: RAYFIELD JETTY FIELD

a) Description: CONSTRUCTED IN 1938 TO PROTECT THE OLD SH 74.

b) Present Condition: THIS JETTY FIELD IS NO LONGER EXISTENT

TYPE: KELLNER JETTY FIELD

a) Description: CONSTRUCTED IN 1989 TO EXTENDING FROM THE BRIDGE STRUCTURE TO THE OLD RAYFIELD JETTY FIELD, TO PROTECT THE SOUTHERN BANK.

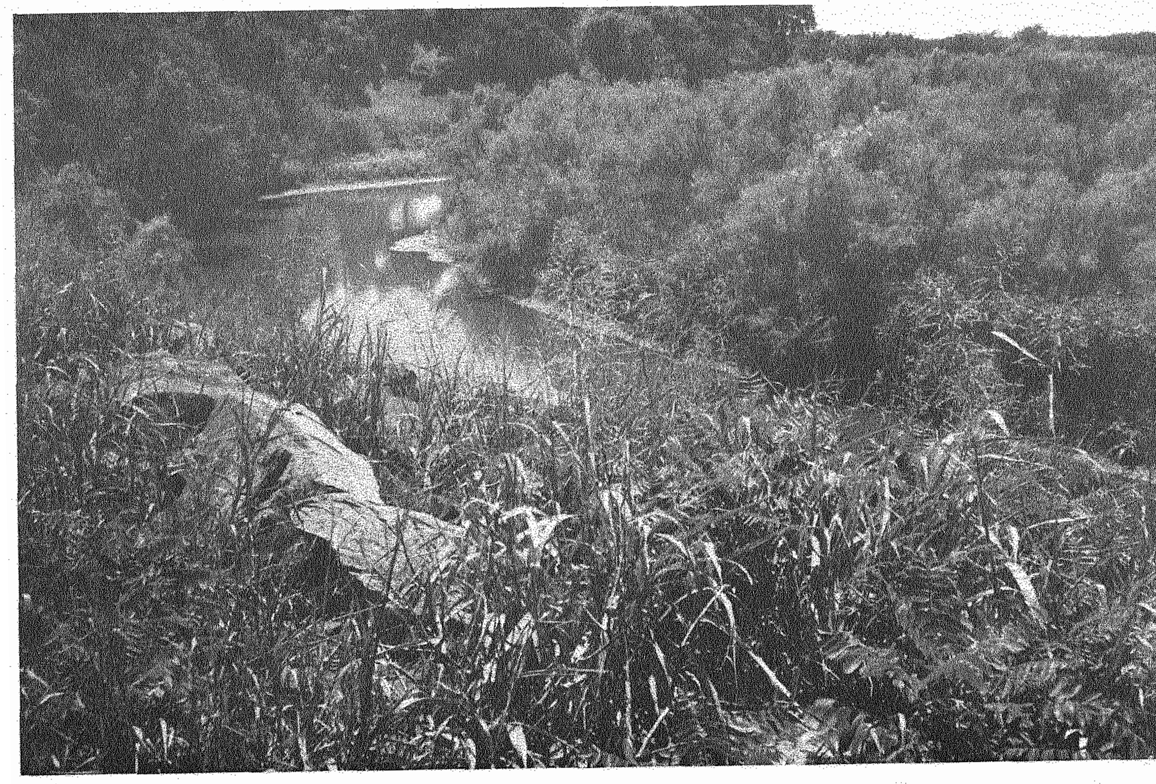


View of Sandbar and Rock Outcrop

FIGURE 79a

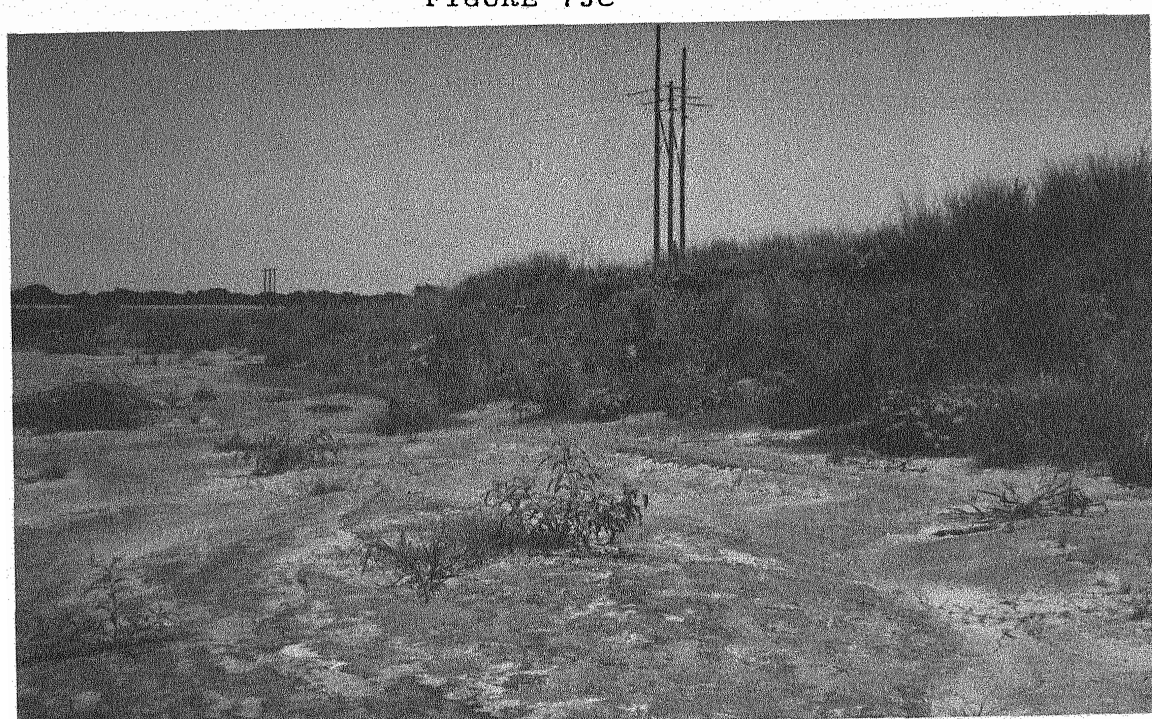
Dike with a Facing of Riprap

FIGURE 79b



Creek Flowing into the River

FIGURE 79c



Location of Newly Installed Jetty Field

FIGURE 79d

WASHITA RIVER - I 35 | Site No. 18

U/S of intersection of I 35 & US 77
South of Davis (Murray County)

Scale: 1" = 500'

1989 Site Aerial Photograph

FIGURE 80

SITE No. 18

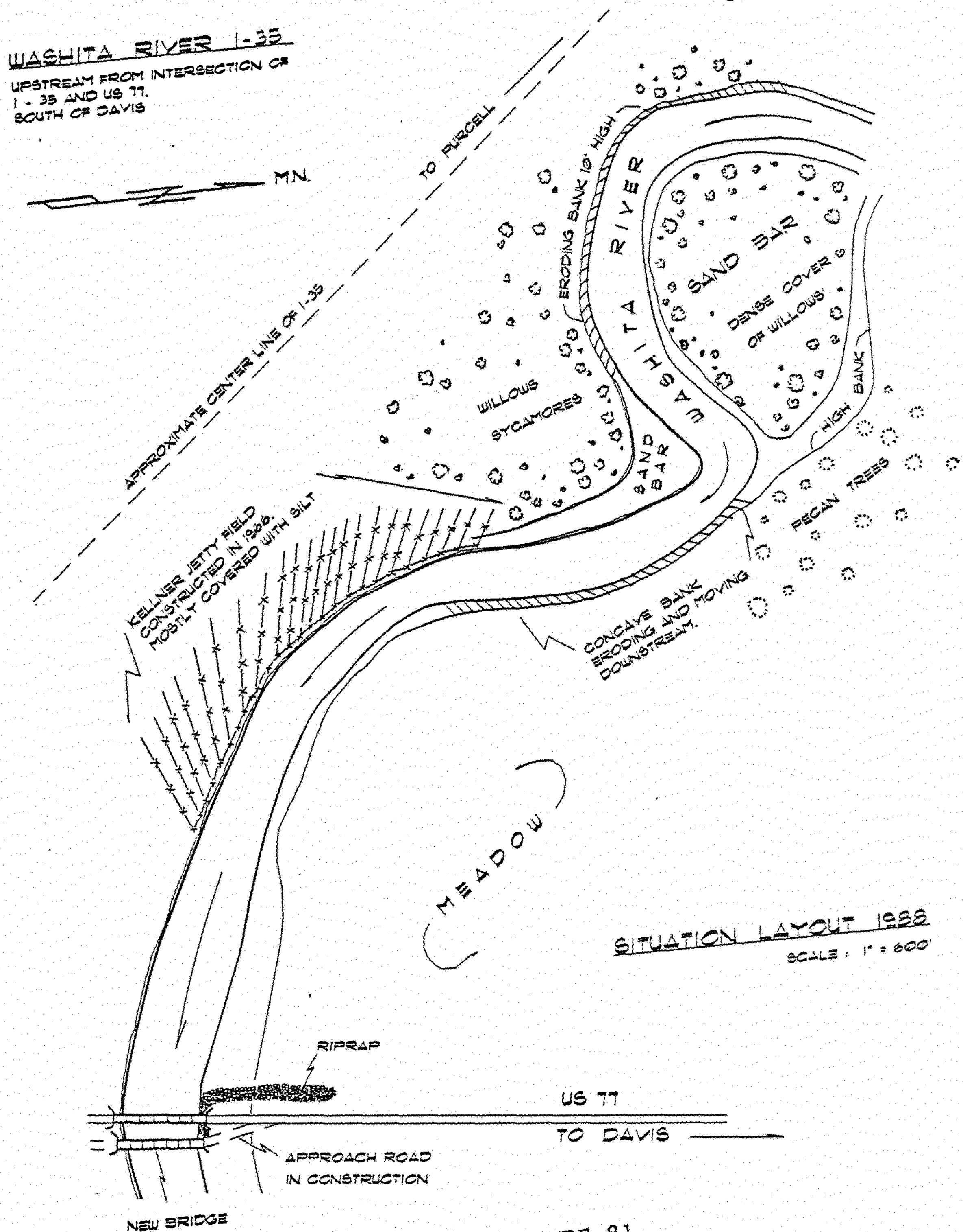


FIGURE 81

WASHITA RIVER - I 35 — Site No. 18

U/S of intersection of I 35 & US 77
South of Davis (Murray County)

Bridge and Site Data:

The site under consideration is the whole area upstream on the Washita from the intersection of US 77 to I-35. The two major factors under consideration are the protection of the twin bridge structure of US 77 across the Washita and the encroachment of the river on I-35 about a mile upstream of the bridge.

History of Stabilization Procedures:

This site has been under observation for a long time due to the presence of I-35. The two major stabilization techniques applied at the site were: the riprapping of the meander loop on the upstream of the bridge (in 1967) where there was a danger of the river encroaching on I-35 and, the construction of a Kellner jetty field (in 1966) to realign the river and hence protect the downstream bridge structure. Both of the abutments of the bridge on US77 are heavily riprapped.

Site Evaluation:

Site visits and study of the aerial photographs have made it possible to make the following observations:

1) The construction of the Kellner jetty field and the evacuated channel in 1966 on the southern bank was a definite success. This can be stated from the fact that the Kellner jetties have held the bank on which they have been placed very well. The jetty field is so densely covered with vegetation

(mainly willows) that access to the field is very difficult. Most of the jetties are buried deep in silt and in most cases only tips of the jetties can be seen. The old channel has filled up very well and thickly forested to discourage the river from flowing back in it's old channel. There is a deep creek that flows through the jetty field, but there seems to be only a very small liklehood that it will be flooded and possibly undermine the field.

2) Riprap was placed on the meander loop further upstream in 1967 to discourage the river from pushing toward I-35. No signs of the riprap could be found in 1988 and has it apparently been washed away in previous floods. Comparisons between the aerial photographs of 1964 and 1989 has shown that there is no significant movement of the river toward I-35, however, the meander loop has definitely become wider. Although site visits have shown that the river seems to be flowing generally on a stable channel configuration it must be noted that a major flood might push the river to the large loop. The bank all along this large loop is unprotected, except for the vegetation present there. The river is slowly, but surely working on this bank and is evident from large clumps of fallen trees all along the bank. Placement of riprap or the erection of retardance structures like jetty fields are the possible remedies to the situation.

3) There seem to be no sign of any distress on the abutments or the piers on the bridge on US77 and hence no forseeable threat to the structure.

Site No. 18 is a good case study of two different river training methods that have been used at the same site. The Kellner jetty field seems to have been a very successful operation compared to the riprap protection method. Some other method of training is needed at this site to complement the riprap. Since there is a good stretch of high ground between the river and I-35, the problem is not critical enough to warrant immediate attention, although eventually some work will be needed.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JULY 29th 1988 SITE NO.: 18

HIGHWAY NO.: I - 35 COUNTY: MURRAY COUNTY

BRIDGE LOCATION: U/S OF INTERSECTION OF I-35 AND US 77. SOUTH OF DAVIS

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.:

Span Description:

2) Yr. of constr.:

Span Description:

EMBANKMENT TYPE:

SLOPE: GENTLE

PROTECTION: RIPRAP

SPECIAL NOTES: HEAVILY RIPRAPED NORTHERN EMBANKMENT.

RIVER BANK:

SOIL NATURE:

VEGETATION: WILLOW AND COTTON WOOD.

COMMENTS: KELLNER FIELD HAS A VERY DIFFICULT ACCESS.

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: RIPRAP

a) Description: RIPRAP IS INSTALLED ON BOTH EMBANKMENTS, WITH THE NORTHERN BANK HEAVILY RIPRAPPED.

b) Present Condition: BOTH BANK RIPRAP SEEMS TO HAVE SUFFERED LITTLE DAMAGED.

TYPE: RIPRAP (2 Mi U/S)

a) Description: INSTALLED ON A 10' HIGH ERODING BANK TO PROTECT THE NEARBY I-35 FROM THE MEANDER LOOP.

b) Present Condition: ALL THE RIPRAP IS VIRTUALLY GONE, BUT THE RIVER MOVEMENT SEEMS TO HAVE STOPPED.

TYPE: KELLNER JETTY FIELD.

a) Description: BUILT IN 1966, ON THE OLD CHANNEL BED, TO PREVENT ANY MEANDER OF THE RIVER AT THAT POINT.

b) Present Condition: KELLNER JETTY FIELD IS HEAVILY VEGETATED WITH WILLOWS & COTTON WOOD AND THE RIVER FLOWS PARALLEL TO THE FIELD.
EFFECTIVE IN THE REQUIRED PROTECTION.

TYPE: ______

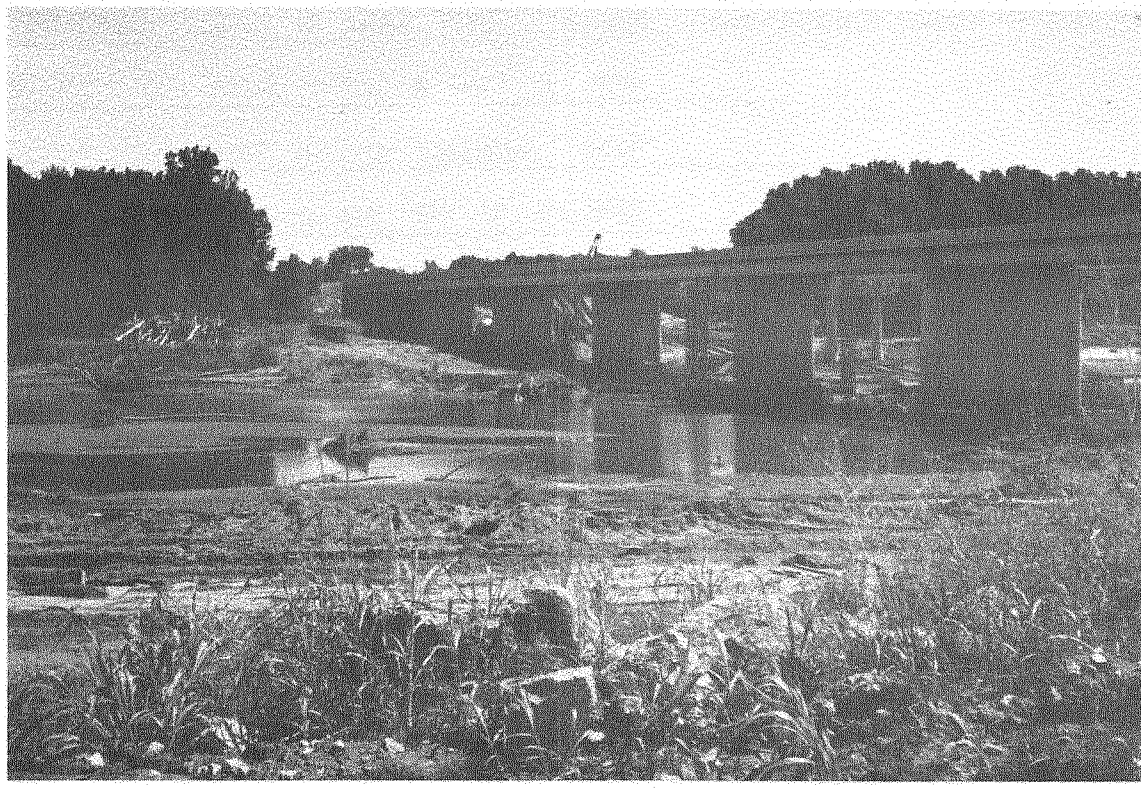
a) Description: ______

b) Present Condition: ______

TYPE: ______

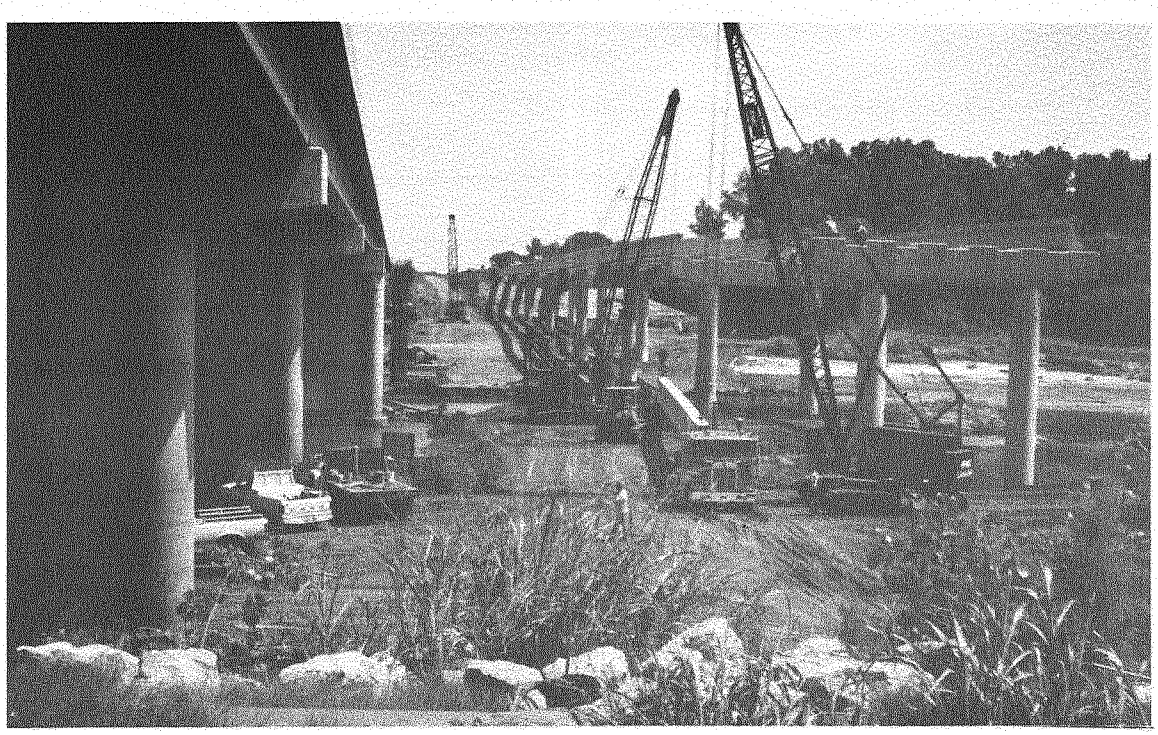
a) Description: ______

b) Present Condition: ______



View of Bridge Site

FIGURE 82a

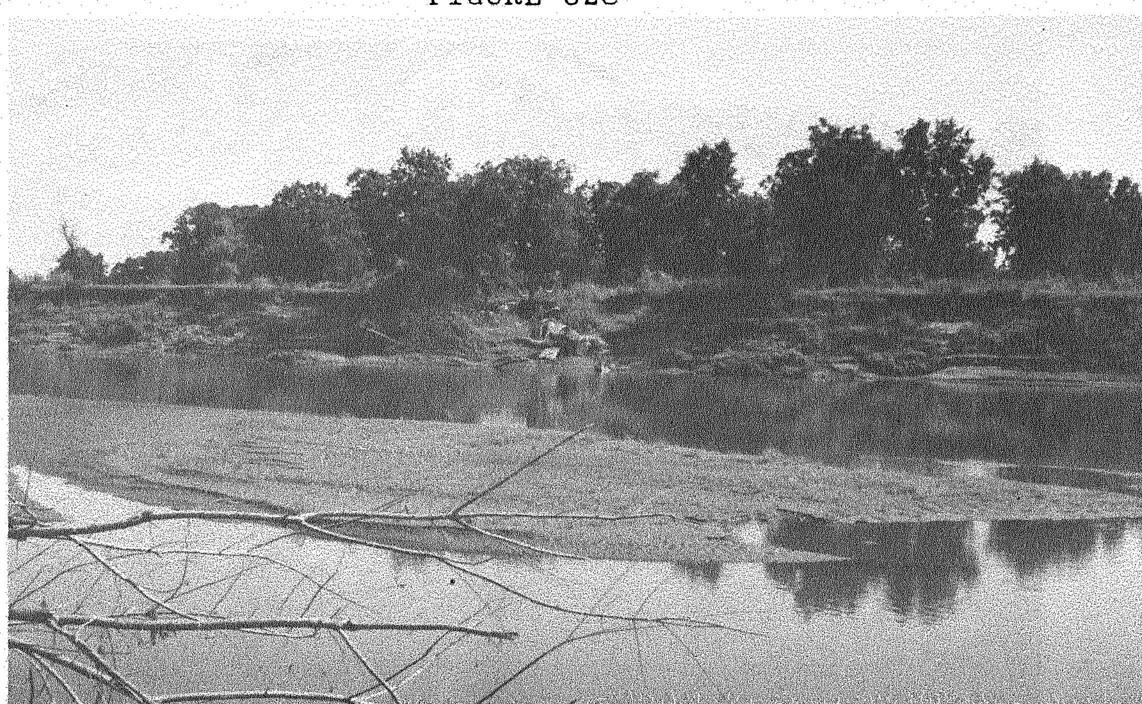


New Bridge Under Construction

FIGURE 82b

Densely Forested Jetty Field

FIGURE 82c



Car Bodies Used to Prevent Erosion

FIGURE 82d

Riprap on Abutment

FIGURE 82e

Erosion of Upstream Banks

FIGURE 82f

BEAVER RIVER - US283 Site No. 19

North of Laverne (Harper County)

Scale: 1" = 1200'

1989 Site Aerial Photograph

FIGURE 83

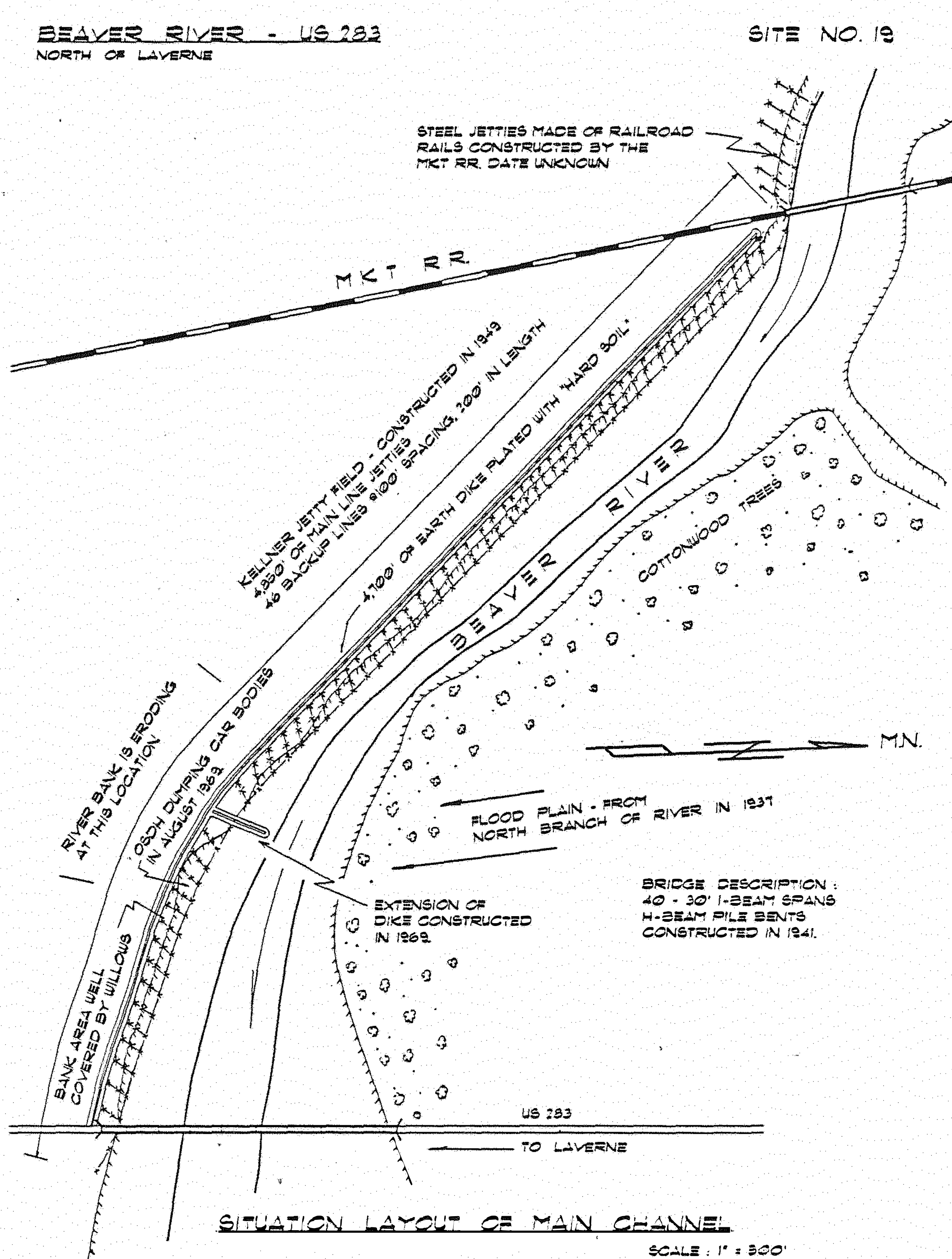

BEAVER RIVER - US 283
NORTH OF LAVERNE
SITE NO. 19
STEEL JETTIES MADE OF RAILROAD RAILS CONSTRUCTED BY THE MKT RR. DATE UNKNOWN
MKT RR.
KELLNER JETTY FIELD - CONSTRUCTED IN 1949
4,350' OF MAIN LINE JETTIES
46 BACKUP LINES @100' SPACING, 200' IN LENGTH
4,100' OF EARTH DIKE PLATED WITH "HARD SOIL"
BEAVER RIVER
COTTONWOOD TREES
RIVER BANK IS ERODING AT THIS LOCATION
ODH DUMPING CAR BODIES IN AUGUST 1969
M.N.
FLOOD PLAIN - FROM NORTH BRANCH OF RIVER IN 1937
EXTENSION OF DIKE CONSTRUCTED IN 1969
BRIDGE DESCRIPTION :
40 - 30' I-BEAM SPANS
H-BEAM PILE BENTS
CONSTRUCTED IN 1941.
BANK AREA WELL COVERED BY WILLOWS
US 283
TO LAVERNE
SITUATION LAYOUT OF MAIN CHANNEL
SCALE : 1" = 300'

FIGURE 84

BEAVER RIVER - US283 Site No. 19

North of Laverne (Harper County)

Bridge and Site Data:

The bridge structure, in place, was built in 1941, and it consists of forty, 30 ft I-Beam spans. The Beaver River on which the bridge is located can be considered a small stream. It flows through low agricultural land, and the vegetation in this area is not dense. The channel is generally narrow and shallow with the banks only a few feet high. This river becomes potentially dangerous during periods of high discharges when it attacks the southern bank. The soil in this area is generally silty, and there is only a negligible amount of drift load from the river.

History of Stabilization Procedures:

In 1938, Kellner jetty fields were constructed on the southern bank to repair the damage caused by a flood earlier that year. A new bridge was built in 1941, which was about 400 ft longer than the older one to take advantage of the higher bank on the northern end. A flood of 1946 moved the Beaver River about 200 ft nearer to the southern bank, for a length of about 1500 ft upstream. In 1949, 4900 ft of an 8 ft high earth dike and a Kellner jetty field consisting of about 4850 ft of mainline and 46 lines of backups about 200 ft' in length were installed upstream of the US 283, extending all the way up to the MKT Railroad Bridge located upstream. In 1969, there were still erosional problems of smaller magnitude at the site. The Oklahoma Department of Transportation made an extension of the dike already present. It was oriented perpendicular to the dike on site and about 1500 ft upstream from the bridge. Old car bodies were dumped on the dike to protect the dike from any direct attack of the river.

Site Evaluation:

As mentioned earlier the Beaver River is a small river by some standards, but it is known to have a damage-causing potential during times of heavy flooding. Though it could never be proven to be the only reason, a comparison of all the aerial photographs show this site to be a good example of a site that has responded well to river training methods. This may be also due to the weak nature of the river itself. Nevertheless, the installation of the earth dike and the Kellner jetties have effectively protected the south bank from the river attack.

The main problem at this site was the nature of the river itself. The Beaver river is a very shallow river which runs on an extensive low lying plain which is basically agricultural in nature. The abutments of the bridge are also not very high (about 5 feet above the river). To compound the problem even further, the river only had rare, but severe flooding problems.

The earth dike has proven to be effective in keeping the river from cutting into the southern bank. The river carries a very small amount of drift. This can be proven from the fact that although the Kellner jetties have been in place for about forty years, most of them are visible, and show only small signs of deterioration as compared to other sites where similar jetties are installed. The debris collected on the Kellner jacks is negligible, only consisting of small shrubs. The extension of the old earth dike into the river bed in about 1969, has effectively shifted the stream away from the southern bank. The river has moved northwards, far away from the southern bank. As the situation stands, neither of the banks are likely to be attacked, except in the case of a large, sustained flood. Even that should not be a matter of major concern due to the extensive span of the bridge.

In conclusion it can be stated, that river training techniques have worked well at this site. There is no immediate forseeable danger to the bridge, as of now. The alignment of the bridge seems to be favorable. The bridge may be due for replacement in the near future, but no additional stabilization measures may be required for this site.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: AUG. 8, 1988 SITE NO.: 19

HIGHWAY NO.: US 283 COUNTY: HARPER

BRIDGE LOCATION: BEAVER RIVER, NORTH OF LAVERNE

STREAMFLOW: LOW WEATHER: COOL

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1941

Span Description: 40 - 30' I-BEAMS
H-BEAM PILE BENTS

2) Yr. of constr.:

Span Description:

EMBANKMENT TYPE:

SLOPE: GENTLE

PROTECTION:

SPECIAL NOTES: THERE IS VERY LITTLE DIFFERENCE IN ELEVATION BETWEEN THE SURROUNDING LAND

RIVER BANK:

SOIL NATURE: SILTY VEGETATION: SHRUBS

COMMENTS:

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: EARTH DIKE

a) Description: BUILT IN 1949 TO PREVENT THE RIVER FROM CUTTING THE SOUTH ABUTMENT.

b) Present Condition: THE DIKE IS IN FAIRLY GOOD CONDITION. AN EXTENSION OF THIS DIKE WAS MADE IN 1969.

TYPE: KELLNER JETTY FIELD

a) Description: CONSTRUCTED IN 1949, TO ENCOURAGE BANK BUILDING ALONG THE EARTH DIKE.

b) Present Condition: MOST KELLNER JETTIES ARE IN GOOD CONDITION, AND THERE IS VERY LITTLE DRIFT WOOD PRESENT.

TYPE: OLD CAR BODIES

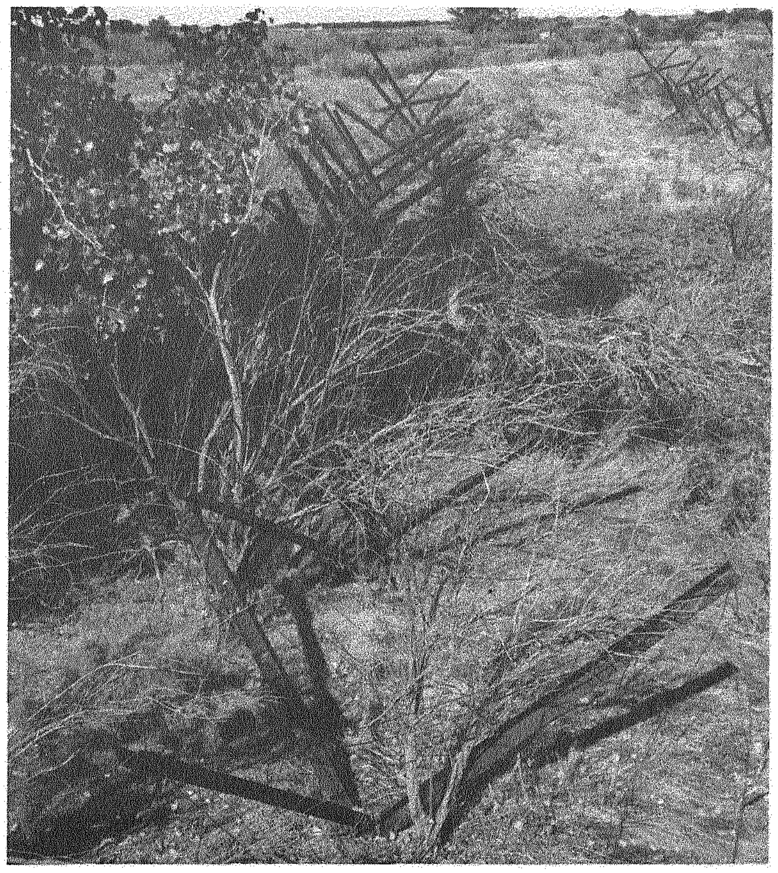
a) Description: DUMPED BY OSHD TO PROTECT THE EARTH DIKE, THEY SEEM TO BE IN GOOD CONDITION.

View of Bridge Site

FIGURE 85a

Car Bodies for Bank Protection

FIGURE 85b



Views of Jetty Field

FIGURE 85c

WASHITA RIVER - I 35
Southwest of Paoli (Garvin County)

Site No. 20

Scale: 1" =1152'

1989 Site Aerial Photograph

FIGURE 86

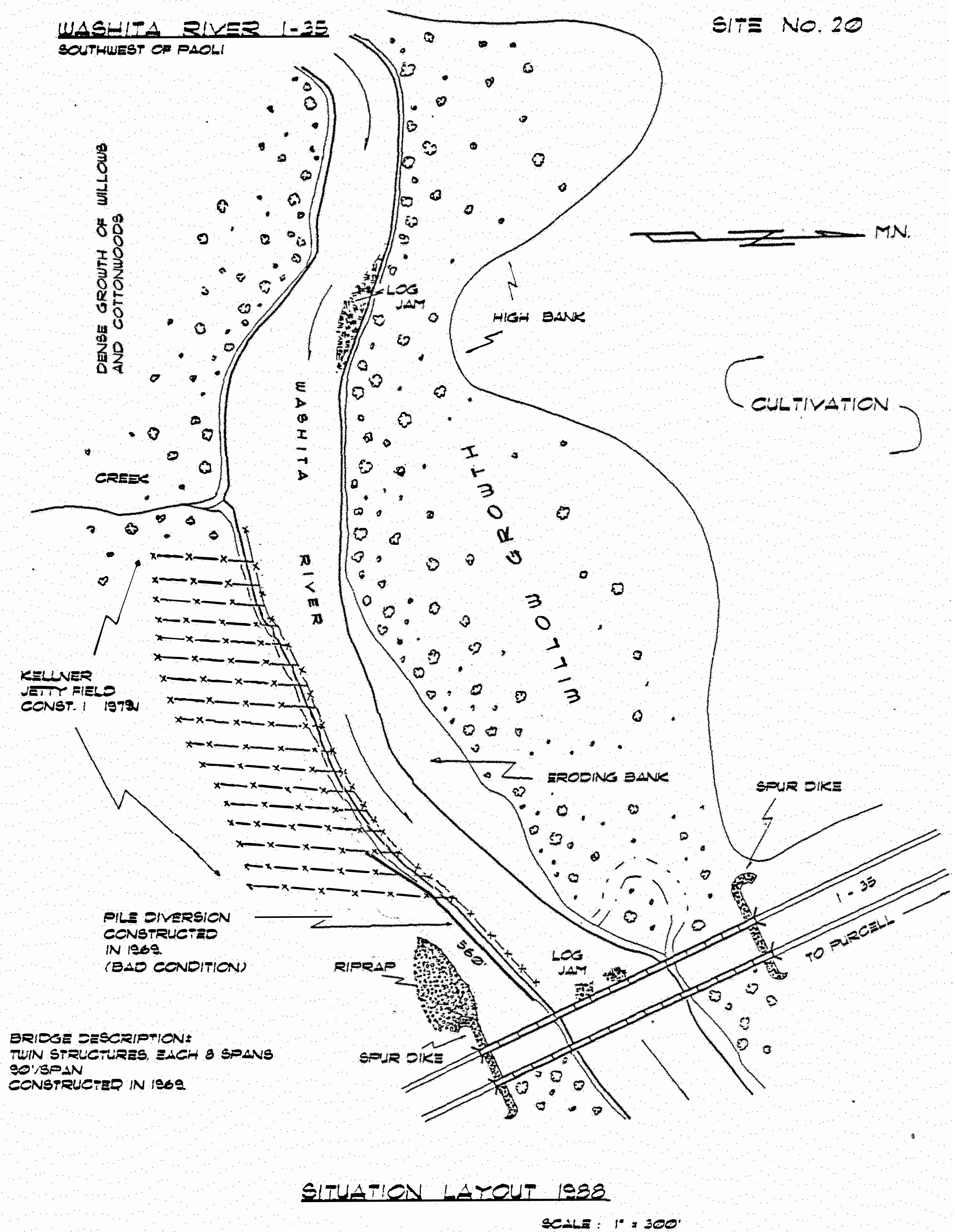

WASHITA RIVER I-35
SOUTHWEST OF PAOLI
SITE No. 20
M.N.
DENSE GROWTH OF WILLOWS AND COTTONWOODS
LOG JAM
HIGH BANK
CULTIVATION
WASHITA
CREEK
RIVER
WILLOW GROWTH
KELLNER JETTY FIELD CONST. I 1973
ERODING BANK
SPUR DIKE
1-35
TO PURCELL
PILE DIVERSION CONSTRUCTED IN 1969. (BAD CONDITION)
560'
LOG JAM
RIPRAP
SPUR DIKE
BRIDGE DESCRIPTION:
TWIN STRUCTURES, EACH 8 SPANS
90'/SPAN
CONSTRUCTED IN 1969.
SITUATION LAYOUT 1988
SCALE: 1" = 300'

FIGURE 87

WASHITA RIVER - I 35 Site No. 20

Southwest of Paoli (Garvin County)

Bridge and Site Data:

The bridge structure, in place, was constructed in 1969, an consists of a twin structure composed of eight, 90 ft spans each. It is constructed across the Washita which is very sinuous in nature and is characterized be steep eroding banks. The soil is generally cohesive in nature. The waters have a high drift and silt content, which makes the use of Kellner jetties ideal for such conditions. Both banks have characteristic growth of tall willows, and both sides of the river are mainly in use for cultivation purposes.

History of Stabilization Procedures:

In 1969, a pile diversion was constructed along the southern bank which was anchored into the bank about 500 ft upstream from the bridge structure, and extended all the way to the bridge. This was done as a part of preventive maintenance during the bridge construction phase. A flood later that year caused significant erosion behind the pile diversion in an effort to cut behind it. To prevent any further erosion about 350 ft of riprap was placed along the eroding bank. After 1971 there was noticeable river induced erosion at the pile diversion and the riprap on the banks. A Kellner jetty field was constructed to a upstream to the bridge structure in an effort to prevent the cutting action of the river behind the pile diversion on the southern bank. It consists of about 1300 ft of mainline jetties and 17 rows of backup diversion units. The pile unit is situated within the jetty field.

Site Evaluation:

River stabilization efforts along the Washita provide interesting challenges. The Washita attacks both the banks alternately due to its high degree of sinuosity. The problem bank on this site is the southern bank. The pile diversion on this bank is in a highly deteriorated state. There is a significant loss of face planks of this structure. There are almost no signs of the riprap placed along the southern bank. The Kellner jetties in contact with the water are in bad condition. They exhibit more evidence of destruction than settlement into the river bed. The jetties on the high bank seem to be in good condition and are covered with shrub type vegetation.

Comparison of the 1968 and the 1989 aerial photographs reveal considerable change at this river site. The Kellner jetties that were constructed to prevent bank erosion have shown no signs of bank growth. The have functioned simply to hold the bank together. Little, or no, vegetal growth or major silt deposition has been observed in between the jetties at the water line. Extensive debris seems to have been accumulated on the jetties but they seem to be damaging the jetties rather than encouraging deposition. If there are any further efforts in river training at this site, it should be kept in mind that a stronger form of permeable bank protection is needed here. Another observation at this site is that the steep bank situated north of the Kellner jetty field has shown massive erosional problems. This can be possibly due to the currents that were diverted by the Kellner jetties. From the aerial photographs it is deemed likely that a major flood will initiate concentrated attacks on both the river banks and bridge abutments. Large amounts of drift wood have been accumulated on the bridge piers which have caused the formation of large scour holes around the piers. There have been massive erosion problems downstream from the bridge, where the river of 1989 is nearly twice as wide as the river of 1969. The river has formed an island downstream from the bridge and the flow has moved to a dominant path on the south fork of the island.

Intensive observation has to be kept on this site due to the erratic nature of the Washita river and the everchanging site conditions. There will be an absolute necessity of a large river training construction project to be performed at this site. Since 1982, there have been several large floods on the Washita. From about 1957 until 1982, there was a long period of dry conditions and general low flow sequences. The greatest flood of record at this site was on, or about June 1, 1987. It is likely that much of the damage that now exists was recieved during this five year period.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JUNE 17th, 1988 SITE NO.: 20

HIGHWAY NO.: I 35 COUNTY: GARVIN

BRIDGE LOCATION: WASHITA RIVER, SOUTHWEST OF PAOLI

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1969

Span Description: TWIN STRUCTURES

8 SPANS OF 90'

2) Yr. of constr.:

Span Description:

EMBANKMENT TYPE:

SLOPE: STEEP EMBANKMENT SLOPES

PROTECTION: RIPRAP AND SPUR DIKE

SPECIAL NOTES:

RIVER BANK:

SOIL NATURE: CLAYEY VEGETATION: WILLOWS AND SHRUBS

COMMENTS:

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: PILE DIVERSION

a) Description: CONSTRUCTED IN 1969, 560' IN LENGTH, TO PREVENT RIVER PUSHING INTO THE SOUTHERN EMBANKMENT.

b) Present Condition: THE DIVERSION IS STEEL IN PLACE, BUT HAS SHOW SIGNS OF DECAY AND NEEDS SOME LOST SURFACE PLANKING. THE DIVERSION IS IN NEED OF REPAIR OR ALTERNATIVE REPLACEMENT.

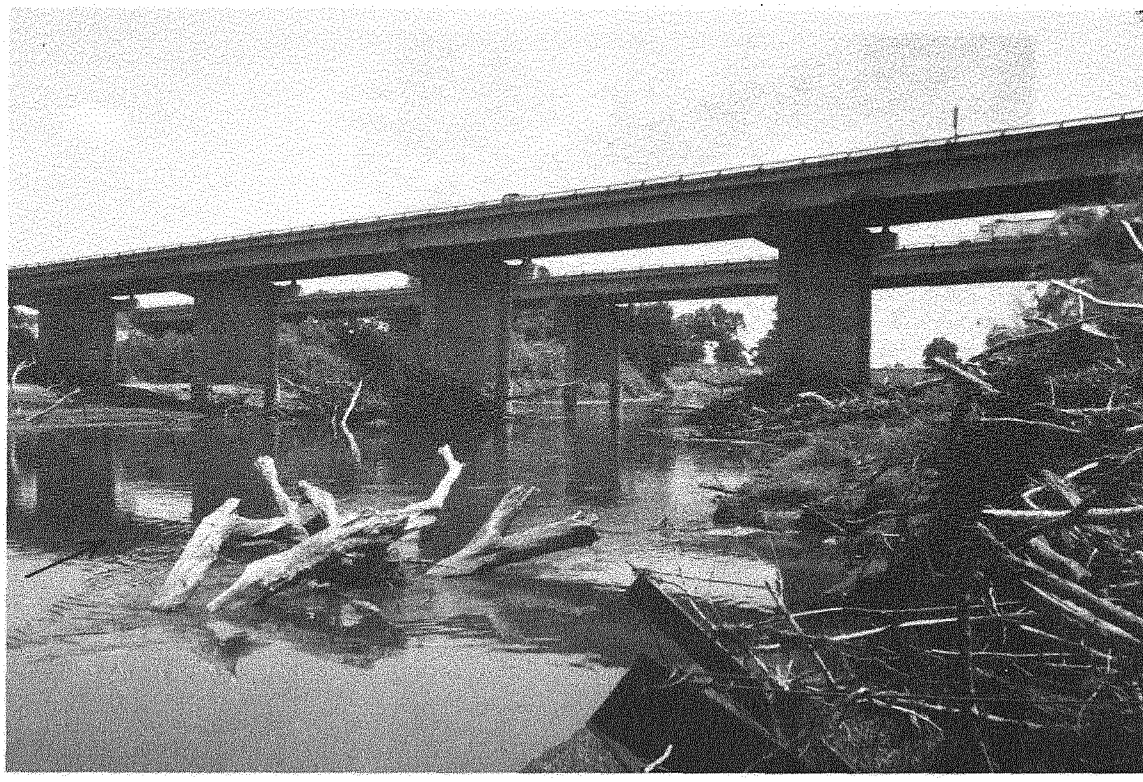
TYPE: KELLNER JETTIES

a) Description: CONSTRUCTED IN ON THE SOUTHERN BANK, ALONG PILE DIVERSION AND WESTWARDS.

b) Present Condition: ALL JETTIES ARE IN FAIRLY GOOD CONDITION EXCEPT FOR THOSE IN DIRECT CONTACT WITH THE WATER, WHICH NEED REPAIR, OR HAVE SUNK IN THE SAND.

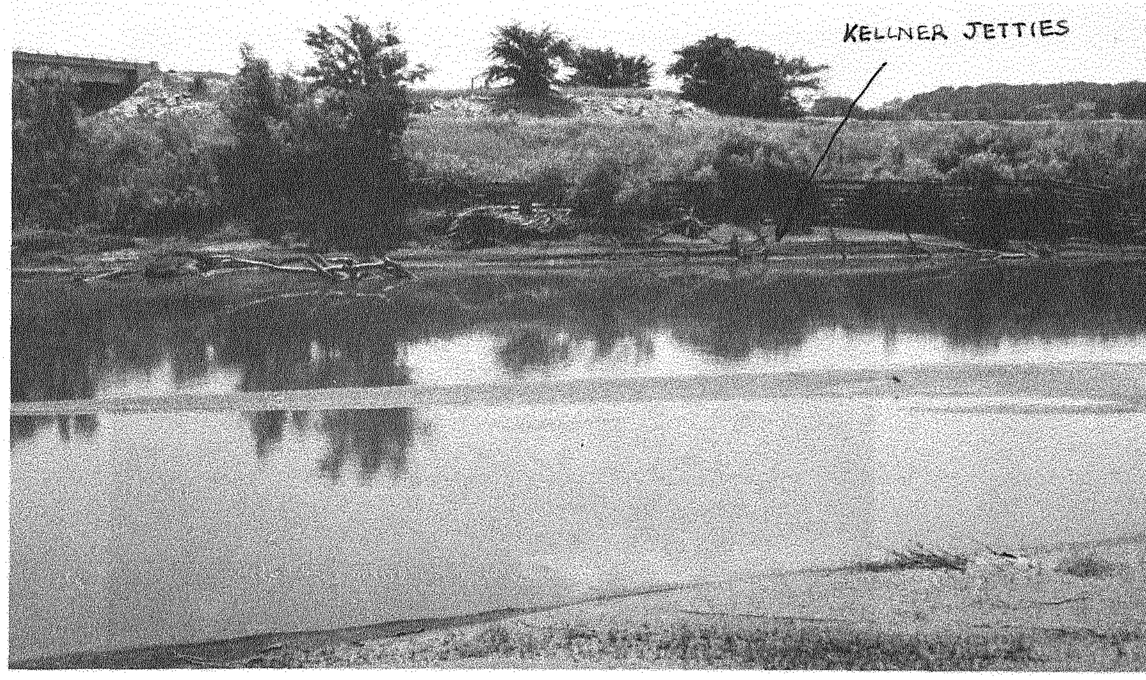
TYPE:

a) Description:



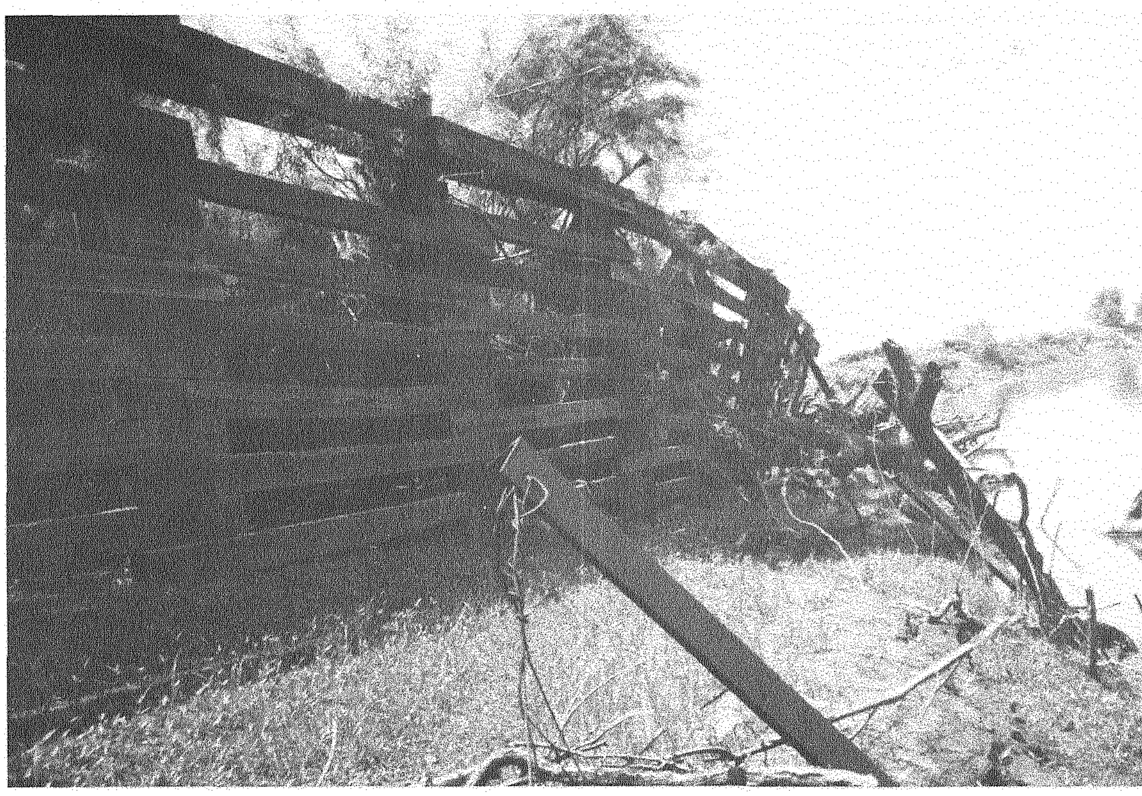
Log Jam at Bridge Piers

FIGURE 88a



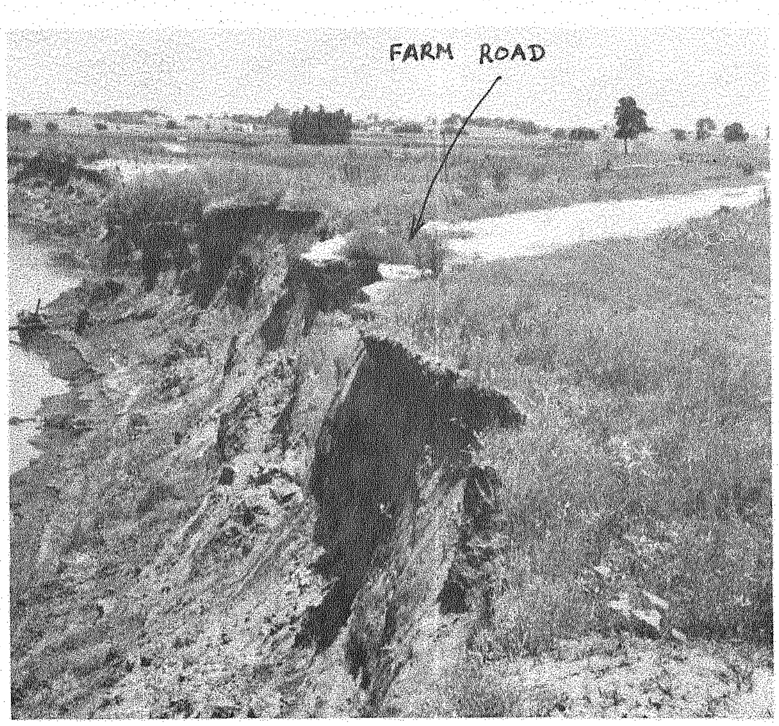
Damaged Pile Diversion

FIGURE 88b



Closeup of Pile Diversion

FIGURE 88c



Badly Eroding High Bank

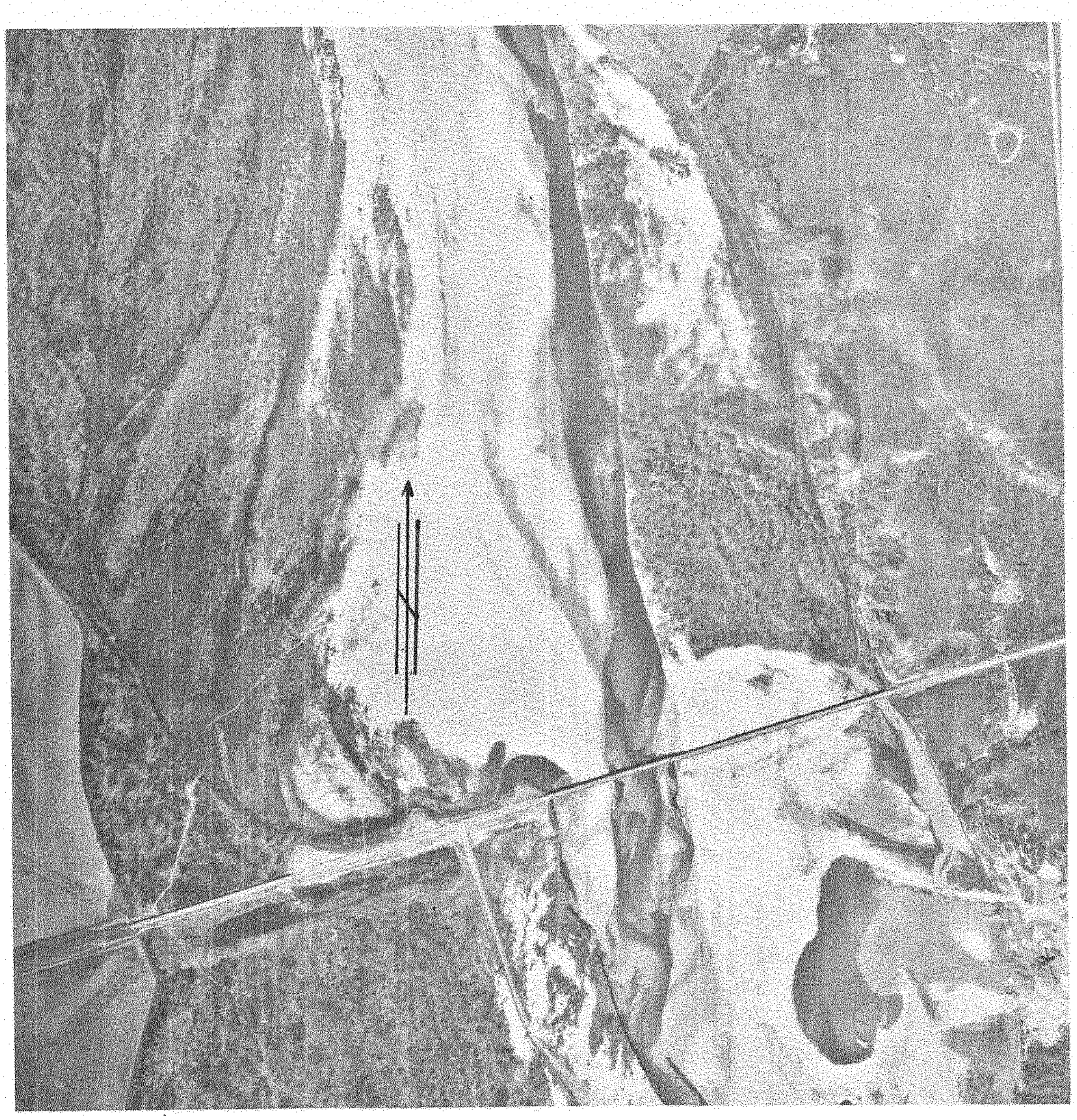
FIGURE 88d

Views of Jetty Field

FIGURE 88e

RED RIVER SH 79 | Site No. 21

West of Waurika (Clay/Jefferson County)



Scale : 1" = 1132'

1989 Site Aerial Photograph

FIGURE 89

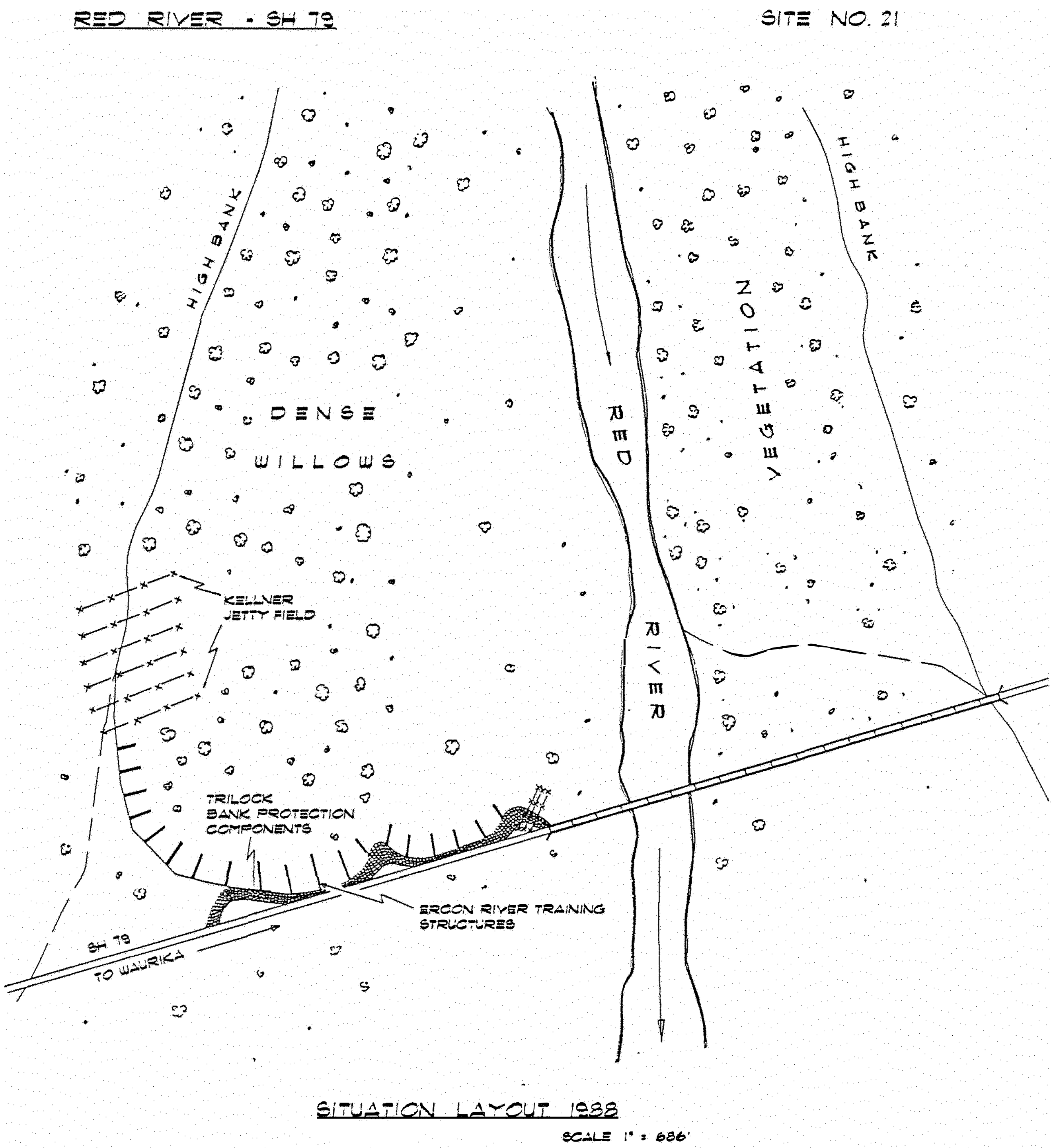

RED RIVER - SH 79
SITE NO. 21
HIGH BANK
DENSE
WILLOWS
RED
RIVER
VEGETATION
HIGH BANK
KELLNER
JETTY FIELD
TRILOCK
BANK PROTECTION
COMPONENTS
ERCON RIVER TRAINING
STRUCTURES
SH 79
TO WAURIKA
SITUATION LAYOUT 1988
SCALE 1" = 686'

FIGURE 90

RED RIVER SH 79 Site No. 21

West of Waurika (Clay/Jefferson County)

Bridge and Site Data:

The present bridge structure spans the Red River at the border of Oklahoma and Texas. At this site the Red River has an extensive flood plain and is attacking the bridge structure at both the eastern and western abutments. To the west of the principal bridge span there is an overflow structure, which is one of the possible routes of the river in case of a severe flood. The soil in this region is clayey, and the vegetation in this area is basically stunted shrubs. In conditions of low flow, the river flows centrally under the bridge, far away from the bridge abutments.

History of Stabilization Procedures:

The 1989 aerial photograph, and the topographical maps of the area clearly show the braiding of the river current to establish a meander loop at this site. The riverine efforts have formed a large concave bank at the western abutment. The presence of the highway approach at this point has prevented the river from pushing further southward. At this point, the river has directed itself on to the eastern bank, causing massive erosion near the eastern abutment. There are many diversionary and protective structure at this site. Wooden fence panels are located at the upstream west bank which were erected by "Hold That River", to create a zone of low velocity flow to encourage deposition and to promote bank building. A Kellner jetty field is located west of the wood panel structures that achieves the same effect. The approach abutment has been armored with precast interlocking concrete blocks to further prevent erosion of the bank.

Site Analysis:

This site is one which has notorious erosional problems. The pattern of the scouring of the banks by the river indicates many points of high stress. The bridge structure is located on a flood plain which is quite extensive and a small bridge which spans only a section of it. Most of the wood panels on the wooden jetty structure built by "Hold That River" are missing. Presently, isolated piles which once held the wood panels together are still found standing. Only traces of the jetty field can be located and those are in a high state of deterioration. The concrete bank paving structure at the site was found, more or less, intact.

The riverine site conditions make the future of the bridge perhaps tenuous. When the bridge has to be rebuilt at some future time, perhaps a longer structure should be sought, and supplementry additional overflow structures should be planned, which spans the entire floodplain. At this site the diversionary and bank building structures that have been installed, are performing exactly as intended. However, the river has moved to the east and the long approach filament is straight. Most likely the causes of nature have produced the desirable present result that hopefully will be sustained. The small stretch of abutment which holds the approach road between the overflow structure and the bridge is essentially a small island in the river. The last major flood showed direct attack on this area, but the abutment resisted it well. This can be attributed to the presence of a strong layer of clay found in that area. This part is certain to be attacked by the river in case of a major flood. The Oklahoma side of the river is braided but shows evidence of maturity. The Texas side of the river has benefited by the maturity imposed by the bridge. The downstream side of the river sustains a sand mining operation, which is deemed to be beneficial. The operator might be encouraged to mine sand scientifically as set out by Harp and Laguros (26) in 1980.

Building additional structures for river training or bank protection at this point, will likely buy more time until a cost effective solution can be determined. This site needs constant observation to prevent the surprises that will surely be posed by the river anytime in the future.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JAN. 4, 1989 SITE NO.: 21

HIGHWAY NO.: SH 79 COUNTY: CLAY / JEFFERSON

BRIDGE LOCATION: RED RIVER, WEST OF WAURIKA.

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1939

Span Description:

2) Yr. of constr.:

Span Description:

EMBANKMENT TYPE:

SLOPE: STEEP

PROTECTION: RIPRAP ON BOTH ABUTMENTS

SPECIAL NOTES: THE BRIDGE SPANS AN EXTENSIVE FLOOD PLAIN

RIVER BANK:

SOIL NATURE: CLAYEY VEGETATION: SHRUBS

COMMENTS:

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: PERMEABLE TIMBER JETTY

a) Description: THIS IS LOCATED ON THE TEXAS SIDE. THE LAST OCCASION IT WAS RIPRAPPED WAS IN 1983.

b) Present Condition: MOST OF THE WOODEN PANELS HAVE DISAPPEARED OR IN A BAD STATE OF DETERIORATION. MOST OF THE STEEL JETTIES ARE STILL STANDING.

TYPE: TRILOCK BLOCK

a) Description: PLACED IN 1983 TO PREVENT THE TOP SOIL ON THE BANKS FROM EROSION.

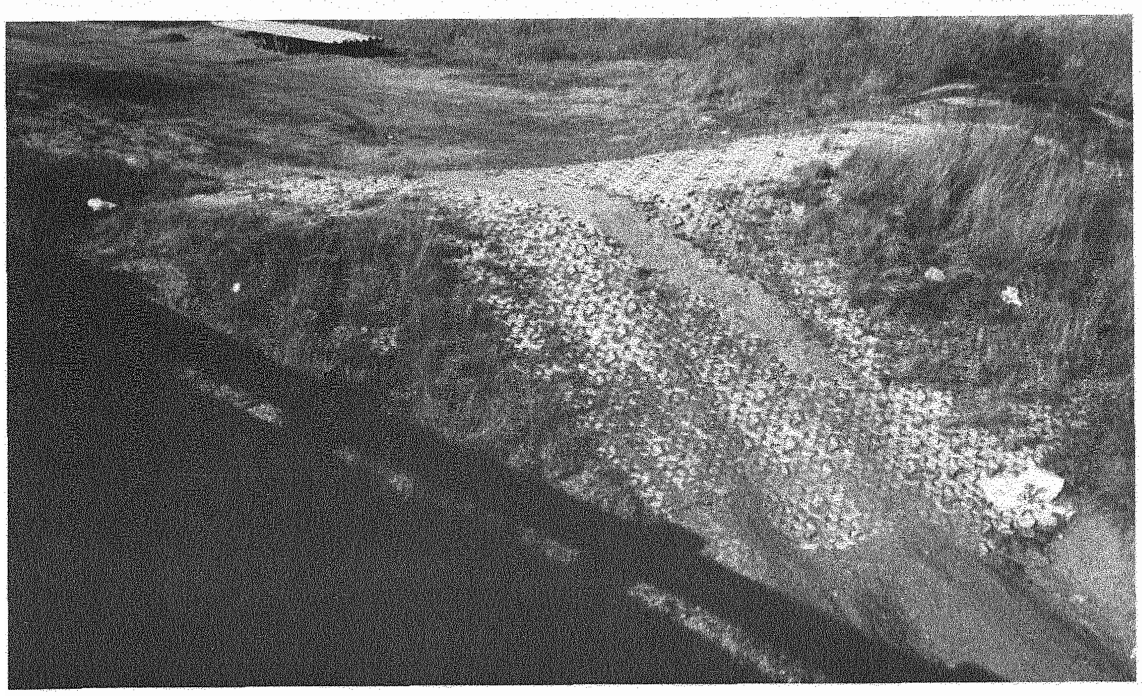
b) Present Condition: AT MOST PLACES THEY SEEM TO BE IN FAIRLY GOOD CONDITION, BUT IN SOME PLACES THE TRILOCK BLANKET HAVE BEEN STRIPPED.

TYPE: KELLNER JETTY FIELDS

a) Description: THESE STRUCTURES ARE MOSTLY DAMAGED WITH VERY FEW OF THEM STILL STANDING.

Massive Riprap Along the Highway

FIGURE 91a



View of TRILOCK Bank Protection Mattress

FIGURE 91b

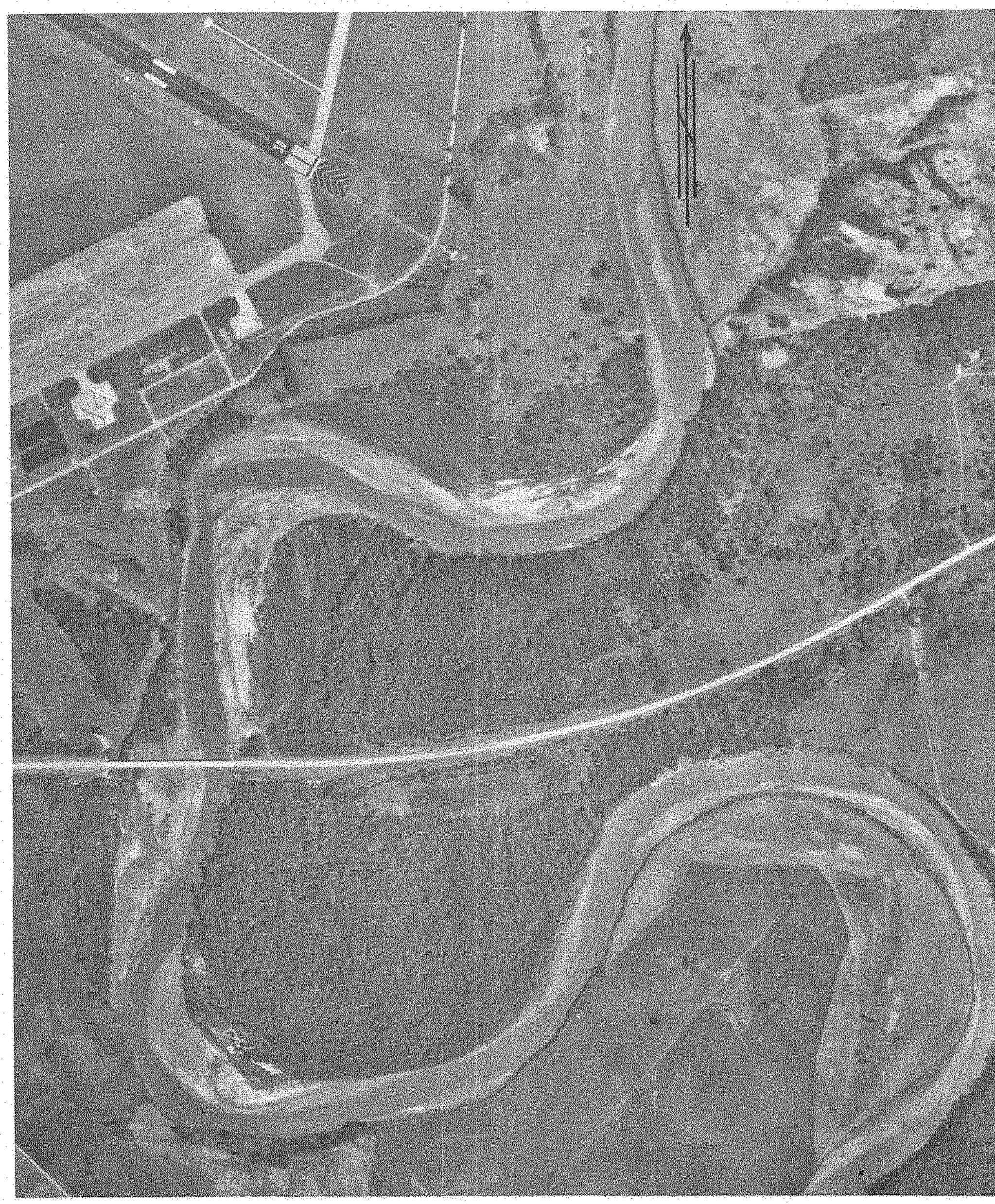
Henson Type Fence Structure

FIGURE 91c

Kellner Jetty Field

FIGURE 91d

WASHITA RIVER SH 53 Site No. 22
East of Gene Autry (Carter County)



Scale: 1" = 1164'

1989 Site Aerial Photograph

FIGURE 92

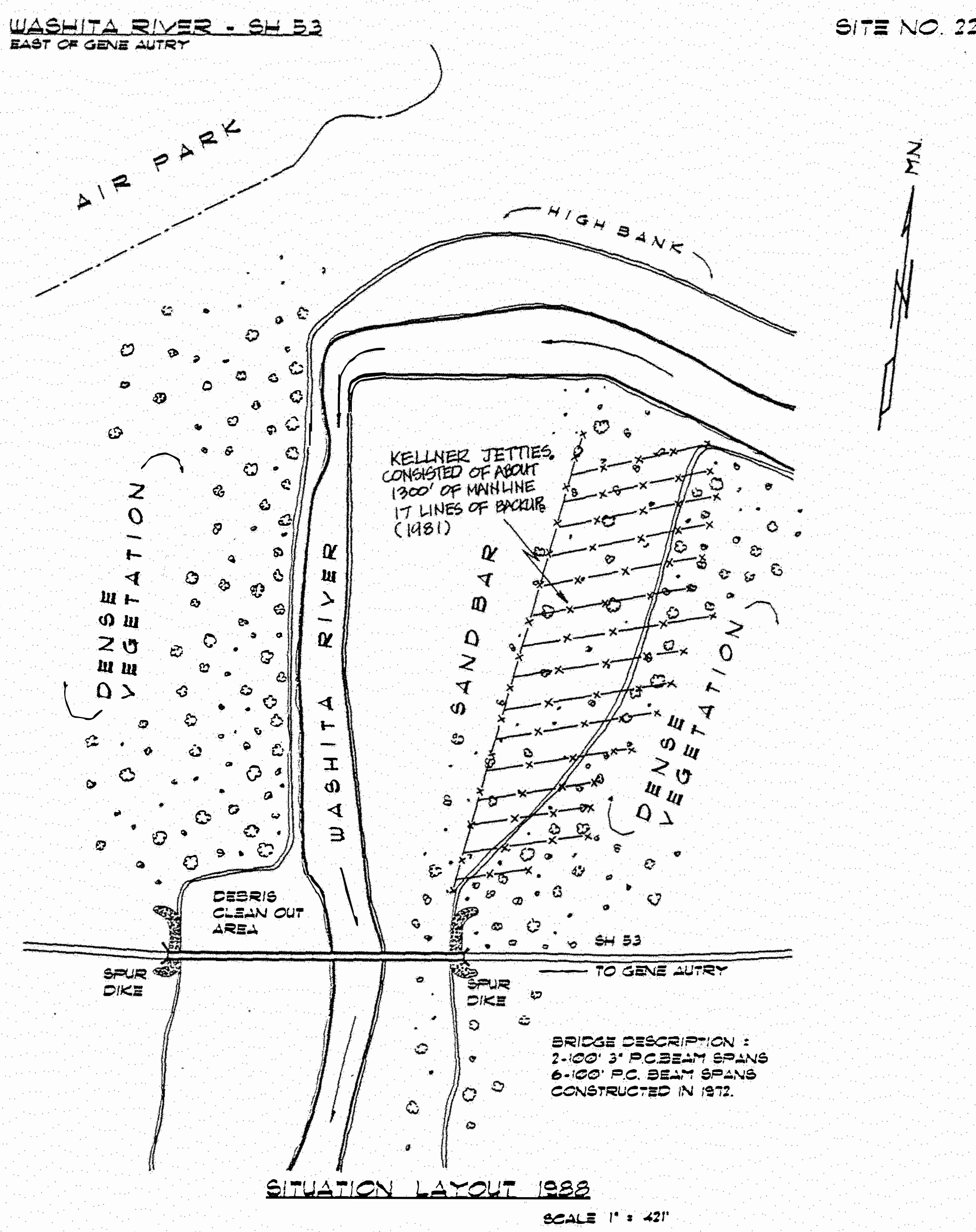

WASHITA RIVER - SH 53
EAST OF GENE AUTRY
SITE NO. 22
AIR PARK
HIGH BANK
MN
KELLNER JETTIES CONSISTED OF ABOUT 1300' OF MAINLINE 17 LINES OF BACKUP (1981)
DENSE VEGETATION
WASHITA RIVER
SAND BAR
DENSE VEGETATION
DEBRIS CLEAN OUT AREA
SPUR DIKE
SH 53
TO GENE AUTRY
SPUR DIKE
BRIDGE DESCRIPTION :
2-100' 3" P.C.BEAM SPANS
6-100' P.C. BEAM SPANS
CONSTRUCTED IN 1972.
SITUATION LAYOUT 1988
SCALE 1" = 421'

FIGURE 93

WASHITA RIVER SH 53 Site No. 22

East of Gene Autry (Carter County)

Bridge and Site Data:

The bridge in place has seven spans and is located on the Washita which is well known for its sinuous nature, steep banks, and low radius meander loops. The soil in this region is silty with traces of clay being a typical pattern all along the Washita. The western part of the river at the site shows an extensive low sand bar with no vegetation. At this site, similar to the other sites along the Washita there are massive logjam accumulations. There is evidence of a recent logjam cleanup at the west portion of the bridge.

History of Stabilization Procedures:

The first effort to stabilize the bank was in 1981 when a Kellner jetty field was constructed consisting of about 1300 ft of mainline jacks and 17 lines of backup diversion units. In 1983 a flume and dike was built on the eastern bank. On both the bridge abutments massive spur dikes are present which are continuously repaired and maintained. These spur dikes were about 20 ft in height. The spur dikes are faced with massive riprap. These spur dikes were constructed to protect the bridge structure from the constant working of the Washita against both the abutments. Presently, the river is in direct contact with the eastern spurdike. The western abutment is further away from the active river filament. There are no traces of the Kellner jetty field at this point of time.

Site Analysis:

The aerial photograph of 1989 show the clear indication of the Washita attacking the eastern bank, the primary reason for which the spur dike was built. Presently, the river seems to be causing no damage to the dike or the bridge structure itself. Although most unlikely at this time, there is always a possibility that during periods of high flows, the river may move into the old channel now located east of the river and may attack the roadway behind the spur dike. Although the river may attack behind the dike, this is only minimum reason for concern in view of the elevation of the roadway approaches that are significantly higher than the stream bed.

No further conclusions or recommendations are apparent this site. The recent spur dike construction at the site was the proper countermeasure. Further observation is needed to comment any further on the site.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: MARCH 3, 1989 SITE NO.: 22

HIGHWAY NO.: SH 53 COUNTY: CARTER

BRIDGE LOCATION: WASHITA RIVER, EAST OF GENE AUTRY

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1972

Span Description: 2, 100' 3" P. C. BEAMS

6, 100' P. C. BEAMS

2) Yr. of constr.: ______

Span Description: ______

EMBANKMENT TYPE:

SLOPE: STEEP

PROTECTION: SPUR DIKE, WITH MASSIVE RIPRAP

SPECIAL NOTES: ______

RIVER BANK:

SOIL NATURE: SILTY VEGETATION: WILLOWS

COMMENTS: ______

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: KELLNER JETTY FIELD

a) Description: CONSTRUCTED IN ABOUT 1981. IT CONSISTED OF ABOUT 1300' OF MAINLINE, AND 17 LINES OF BACKUP DIVERSION UNITS.

b) Present Condition: NOT ONE OF THE KELLNER JETTIES CAN BE LOCATED.

TYPE: SPUR DIKE

a) Description: CONSTRUCTED IN 1972, AND RIPRAPPED IN 1983, WITH RIPRAP

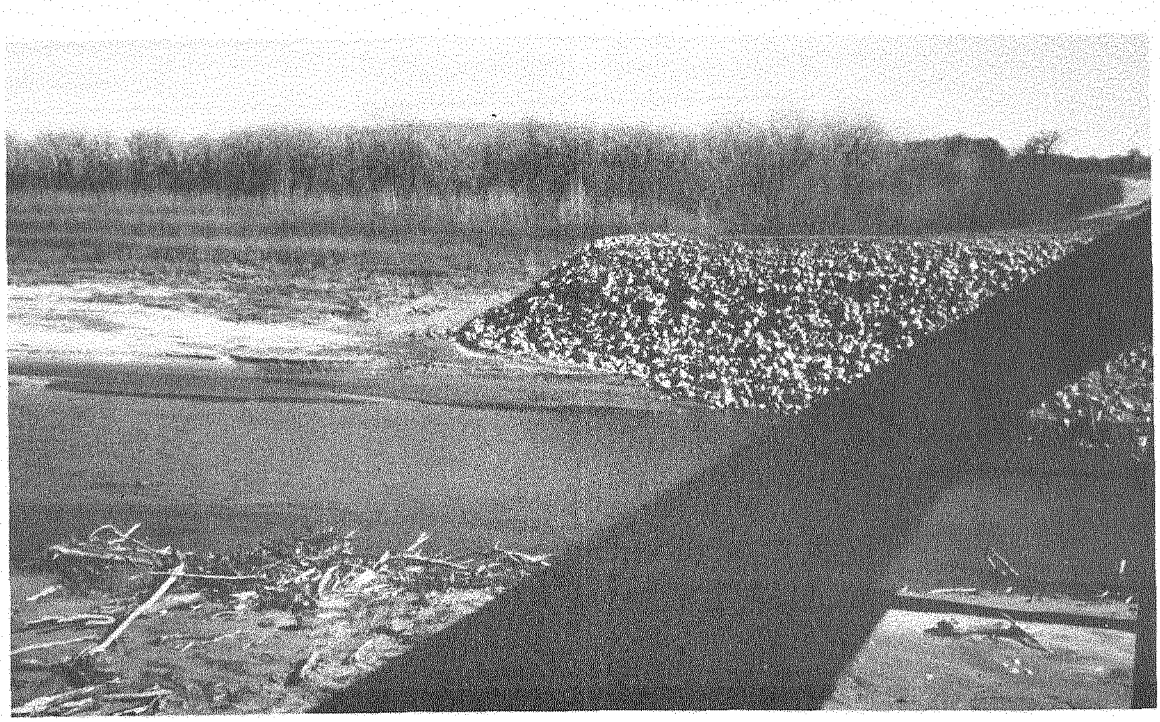
b) Present Condition: THE SPUR DIKE SEEMS TO BE IN A FAIRLY GOOD CONDITION.

TYPE: ______

a) Description: ______

Upstream View of the Washita

FIGURE 94a



Riprap faced Spur Dike

FIGURE 94b

Views of Old Kellner Jetty Field

(No Longer Existent)

FIGURE 94c

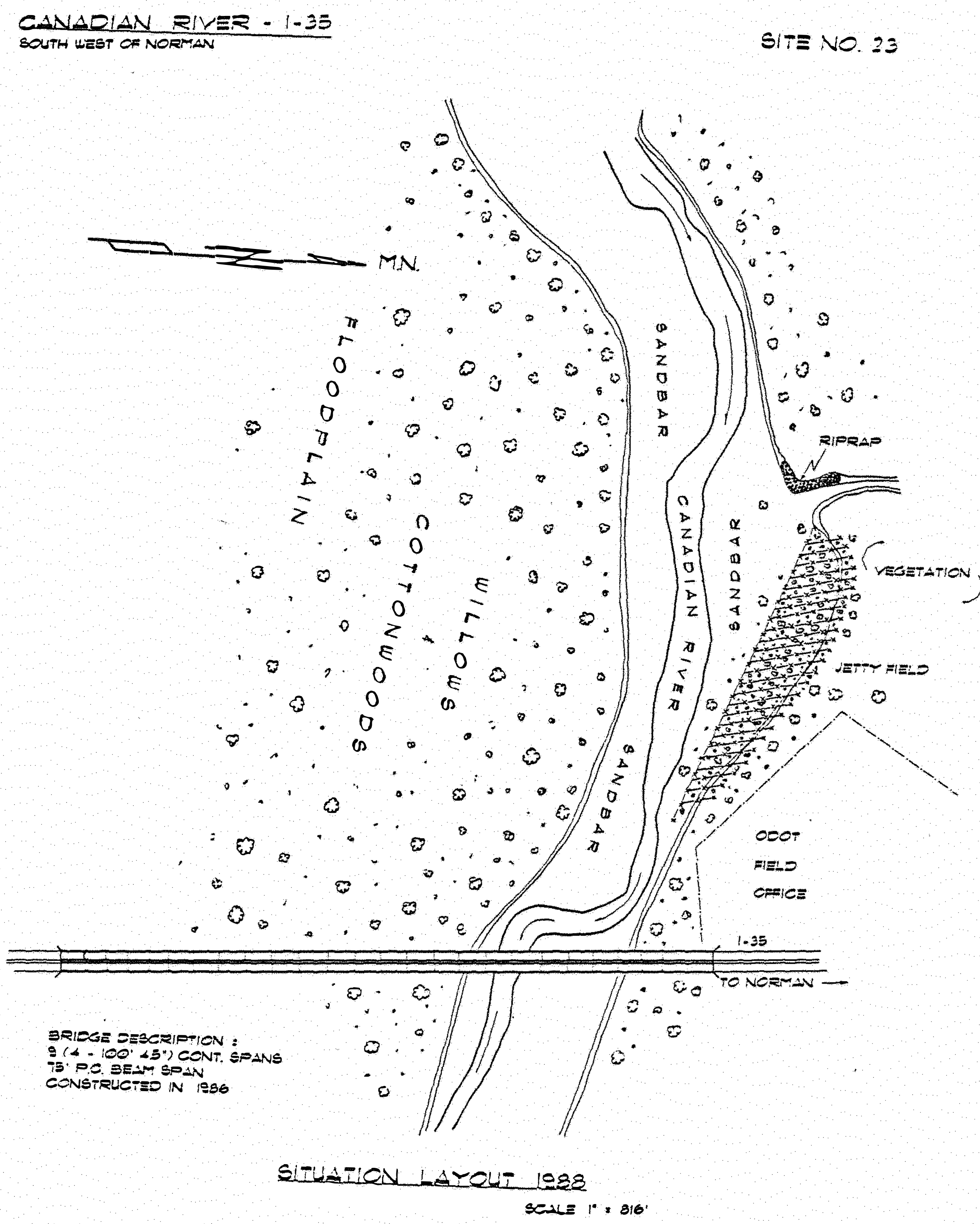
CANADIAN RIVER I-35 Site No. 23

Southwest of Norman (Cleveland/McClain County)

Scale: 1" = 1176'

1989 Site Aerial Photograph

FIGURE 95



CANADIAN RIVER - I-35
SOUTH WEST OF NORMAN
SITE NO. 23
M.N.
FLOODPLAIN
COTTONWOODS
WILLOWS
SANDBAR
CANADIAN RIVER
SANDBAR
SANDBAR
RIPRAP
VEGETATION
JETTY FIELD
ODOT
FIELD
OFFICE
I-35
TO NORMAN
BRIDGE DESCRIPTION :
3 (4 - 100' 45") CONT. SPANS
75' P.C. BEAM SPAN
CONSTRUCTED IN 1986
SITUATION LAYOUT 1988
SCALE 1" = 816'

FIGURE 96

CANADIAN RIVER I-35 Site No. 23
Southwest of Norman (Cleveland/Mcclain County)

Bridge and Site Data:

The present bridge structure newly was built in 1988. The bridge spans the Canadian River and it is long enough to cover a very wide flood plain. The town of Norman is situated on its northern bank. Since 1982 the Canadian River has flooded often.

The soil in this region is a mixture of silt and clay which is erosion resistant. The surrounding areas are low lying and becomes flooded whenever the water level in the river rises sufficiently.

A problem of stability on the north bank has existed for about a decade, and underground water lines have been exposed several times. Concurrently, the north bridge abutment is subject to riverine hazards.

History of Stabilization Procedures:

Although the flood plain of the Canadian is wide at this site, the river is now flowing close to the northern bank. For a long distance upstream, the river is eroding the northern bank. Careful observation reveals that the northern bank is not eroded evenly, but is attacked at certain places, which are possibly the pockets of replaced banks, and poorly compacted replacement cutbanks. For about 1000 ft upstream of the bridge is an extensive, constant erosive action.

In 1989, an extensive Kellner jetty field was designed and constructed in conjunction with the city of Norman. It consisted of 2000 ft of mainline jetties and 21 lines of backup jetties. The main purpose of this jetty field was bank reestablishment. The diversion of the main flow was the secondary objective. West of the jetty field there is a small creek that flows into the river.

Nearly 150 ft of the bank was riprapped with a riprap facing of about 24 in. thickness.

Site Analysis:

The Canadian river is a large river with an extensive flood plain. The river has a large drift load which is mainly silt. The debris content of the river is relatively small as compared to the Washita.

The Kellner jetty field may well be the ideal bank protection method at this site. Silt deposition in the jetty field may encourage rapid bank re-establishment, and the presence of relatively increased amount of debris should be a positive feature in the maintenance of the integrity of the jetty field.

Only time will fully reveal the effectiveness of the jetty field, but present conditions warrant the construction of the new structure. As a diversionary structure, a Kellner jetty field is usually inadequate. The exact behavior of any jetty field can be determined only after a series of major flood events where it will be directly exposed to currents of high velocity, and the deposition of a large amount of silt.

This Kellner jetty field will be an ideal site to continuously learn more about the functioning of a jetty field. The Kellner jetty field was completed in the spring of 1989 and its construction was monitored from delivery of materials to final completion. The river upstream fro mthis site has meandered greatly and the dynamic effects of recent times, since 1982, provide an ideal test site in a volatile scenario.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: MARCH 30, 1989 SITE NO.: 23

HIGHWAY NO.: I - 35 COUNTY: CLEVELAND / McCLAIN

BRIDGE LOCATION: CANADIAN RIVER, S.W. OF NORMAN

STREAMFLOW: LOW WEATHER: WARM

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1986

Span Description: 9 (4 - 100' 45") CONT. SPANS

75' P.C. BEAM

2) Yr. of constr.:

Span Description:

EMBANKMENT TYPE:

SLOPE: MEDIUM

PROTECTION: RIPRAP

SPECIAL NOTES: THE BRIDGE SPANS AN EXTENSIVE FLOOD PLAIN.

RIVER BANK:

SOIL NATURE: SILTY / CLAYEY VEGETATION: WILLOWS

COMMENTS:

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: KELLNER JETTY FIELD

a) Description: INSTALLED IN 1989, CONSISTS OF:

2000' MAINLINE JETTY

21 LINES OF BACKUP JETTIES

b) Present Condition:

TYPE: RIPRAP (150')

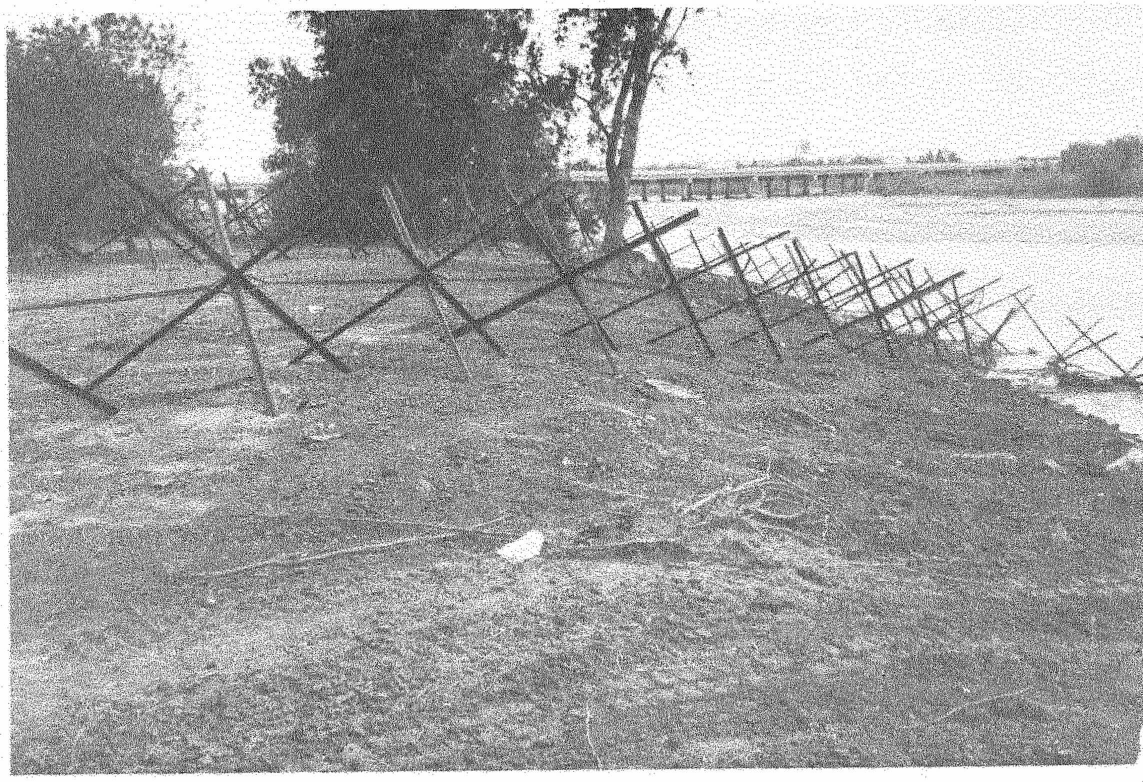
a) Description: CONSTRUCTED IN 1989,

AT THE UPSTREAM END OF THE JETTY FIELD.

b) Present Condition:

TYPE:

a) Description:

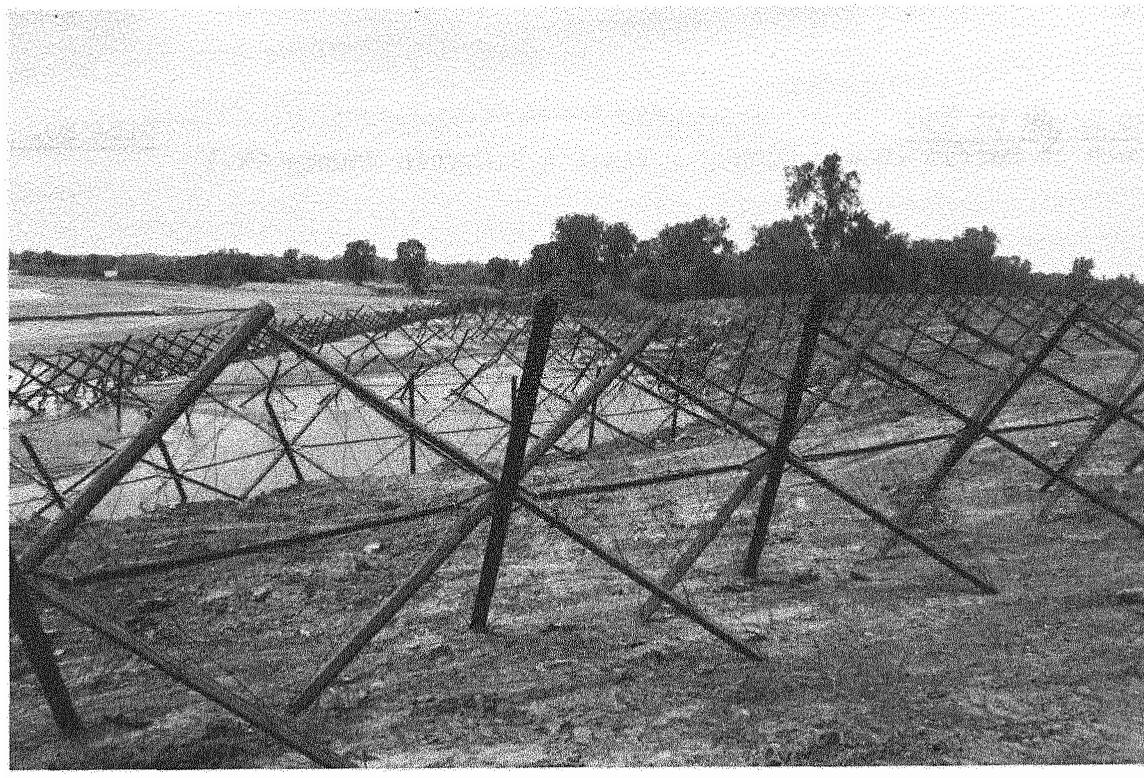


View of Bridge from Jetty Field

FIGURE 97a

View of Mainline Jetty With Pile Anchor

FIGURE 97b



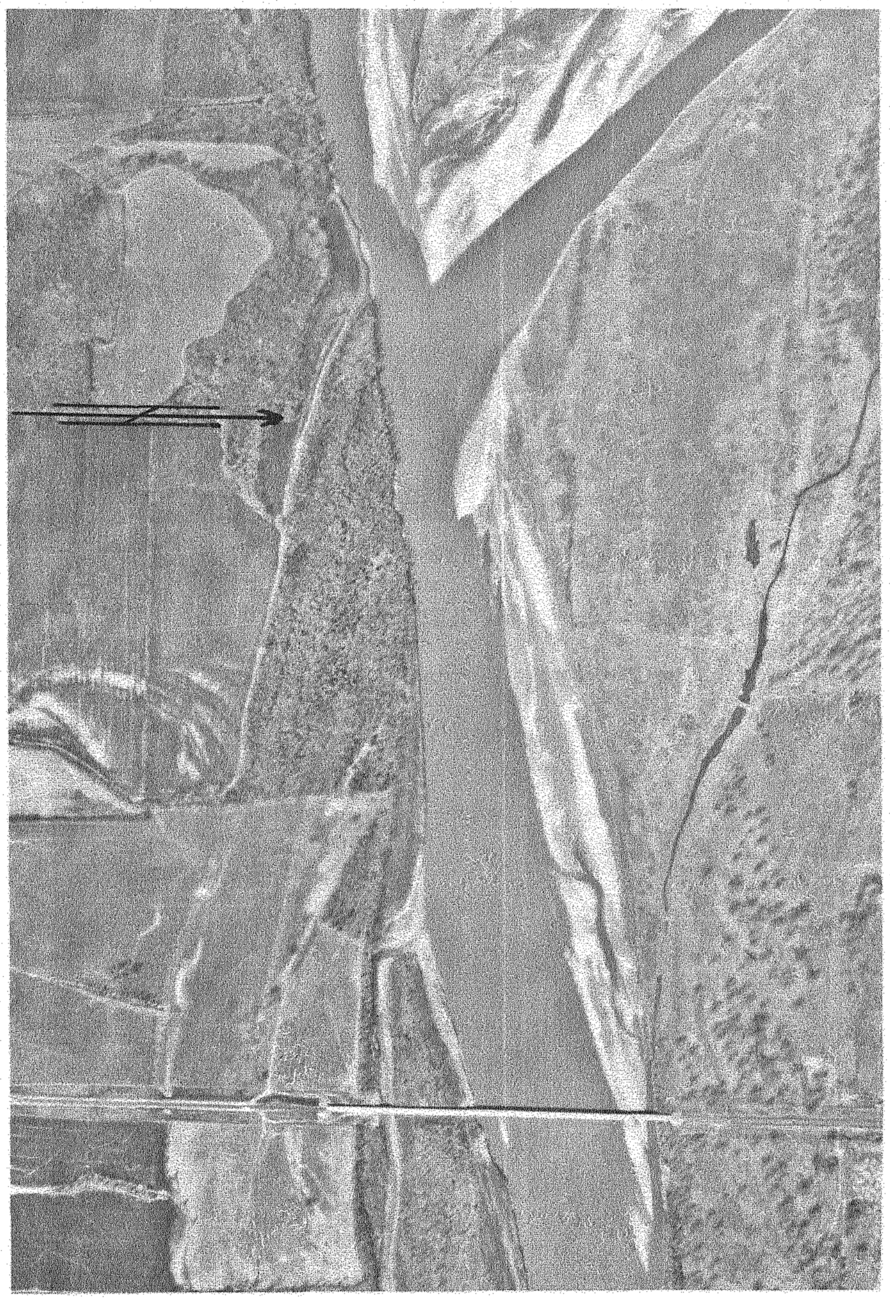
View of Kellner Jetty Field

FIGURE 97c

Riprap at Upstream End of Jetty Field

FIGURE 97d

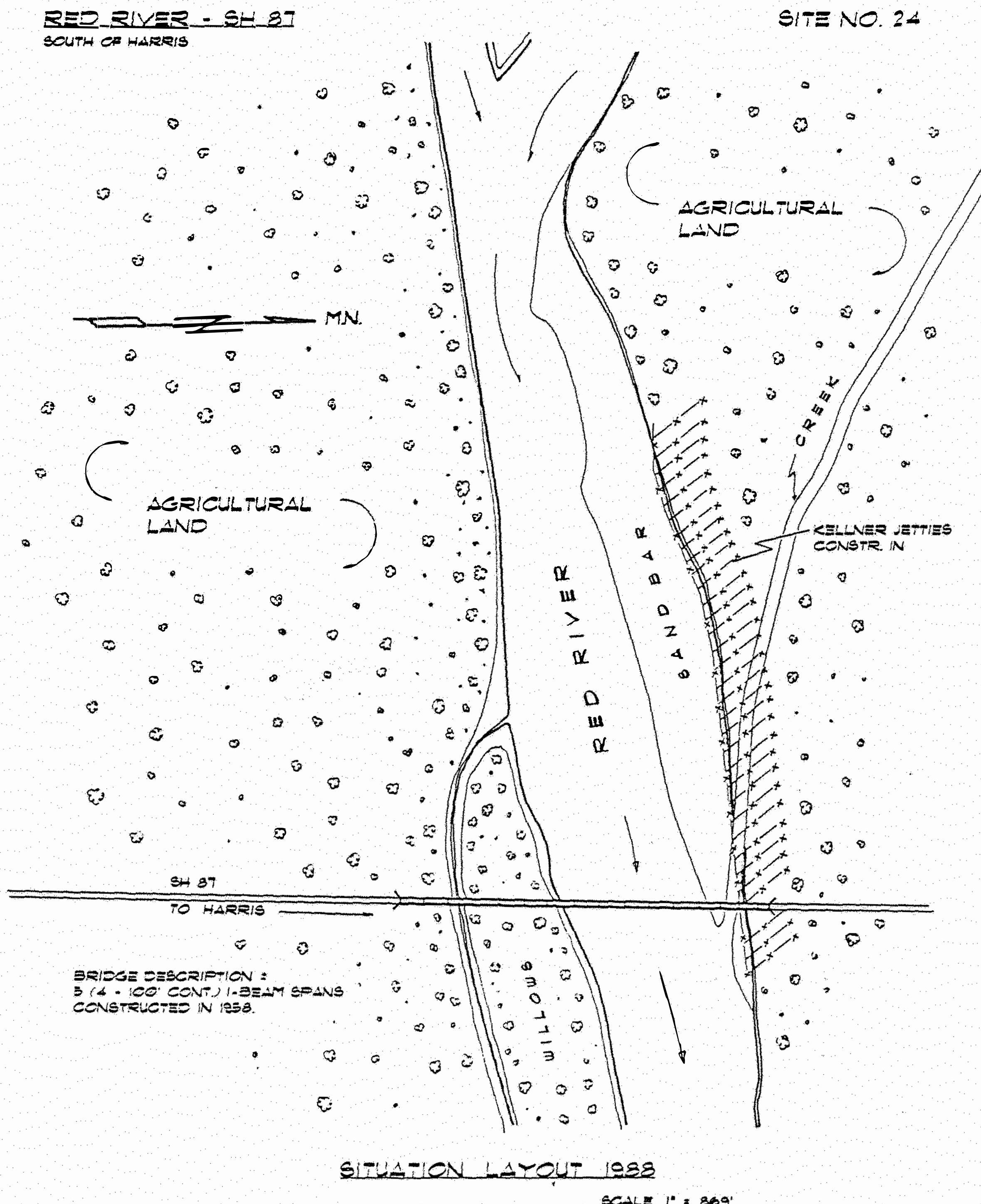
RED RIVER US 259 Site No. 24
South of Harris (Bowie County , Texas & McCurtin County Ok.)



Scale: 1" = 1146'

1989 Site Aerial Photograph

FIGURE 98



RED RIVER - SH 87
SOUTH OF HARRIS
SITE NO. 24
AGRICULTURAL LAND
M.N.
AGRICULTURAL LAND
CREEK
KELLNER JETTIES CONSTR. IN
SAND BAR
RED RIVER
SH 87
TO HARRIS
WILLOWS
BRIDGE DESCRIPTION :
3 (4 - 100' CONT.) I-BEAM SPANS
CONSTRUCTED IN 1958.
SITUATION LAYOUT 1988
SCALE 1" = 869'

FIGURE 99

RED RIVER SH 87 Site No. 24

South of Harris (Okfuskee County)

Bridge and Site Data:

The present bridge structure was built in 1958. It is a concrete structure made of prestressed concrete spanning a length of 2007 ft. The bridge spans the Red River at the Oklahoma-Texas border. The Red River at this site has an extensive floodplain of which the bridge spans a large part. The soil in the area is basically clayey in nature and the vegetation in this area generally consists of stunted shrubs. The southern bank however, seems to have a tall but rare vegetative cover. The Red river has relatively straight approaches, with large meander loops. The river has scarred the area extensively with oxbow lakes, abandoned channels, etc. The river has low debris load but extensive deposition of sandbars can be seen all along the river.

History of Stabilization Procedures:

Approximately eighteen years after the bridge was built, a Kellner jetty field was constructed along the northern river bank to stabilize about 2500 ft of raw bank. At that time, the bank was verticle and caving badly. This was a cooperative project with the Corps of Engineers. It consisted a mainline jetty of about 3000 ft in length and 81 lines of backup retardance lines. Most of the jetty field was located on the upstream section from the bridge. A few jacks can also be seen slightly downstream from the bridge. This Kellner jetty field seems to be the only river training device that seem to have been erected at this site. Both bridge abutments seem to be well protected from river attacks by the placement of a combination of riprap and concrete paving at the abutments.

<u>Site Analysis:</u>

This site is an excellent example which shows that the change in the course or the intensity of flow of the river can sometimes be beneficial to the bridge site and serve as a protecting factor. In this case the Kellner jetty field was erected on the northern bank to combact the erosional problems there due to lake releases causing sudden bank full flows then receding rapidly. The jetties were placed to cause a more gentle riverbank slope.

Right now, the most of the Kellner jetties are found behind an extensive bar, and not in contact with the river. This cannot be fully attributed to the effectiveness of the Kellner jetty field, which can be explained by the fact that there is not a single instance where a Kellner jetty field has caused such external deposition and bank building.

The possible explanation to this phenomenon lies further upstream from the bridge. Study of the aerial photograph and topographical maps of the area have revealed that upstream from the bridge the river forks into northern and southern forks along the massive sandbar. Initially the northern bank just upstream from the bridge was under attack possibly due to a larger discharge in the southern fork which directly eroded the northern bank. Possible changes in the meandering pattern of the river upstream of the fork may have resulted in more flow now in the northern fork. Now the river immediately upstream from the bridge attacks the southern bank while depositing extensively on the northern bank. This is the most feasible explanation of the presence of the extensive sand bar. Another explanation can be that the deposition of the bar was initiated by the jetty field which directed the flow to the south.

This may give insight to the fact that in some cases, river training at bridge sites can be better implemented by studying meander patterns further upstream from the site. On the whole, as of now, the site seems to be in excellent condition without any forseeable danger to the bridge structure. Presently, the river is attacking the southern bank, but this is no cause for concern due to a strong stable southern bank.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JAN. 4, 1989 SITE NO.: 24

HIGHWAY NO.: SH 87 COUNTY: OKFUSKEE

BRIDGE LOCATION: RED RIVER, SOUTH OF H.ARRIS

STREAMFLOW: LOW WEATHER: COOL

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1958

Span Description: 5 (4-100' CONT.D) I-BEAM

2) Yr. of constr.: ____

Span Description: ____

EMBANKMENT TYPE:

SLOPE: STEEP

PROTECTION: ____

SPECIAL NOTES: SPANS AN EXTENSIVE PART OF THE FLOOD PLAIN.

RIVER BANK:

SOIL NATURE: CLAYEY VEGETATION: SHRUBS

COMMENTS: EXTENSIVE FLAT LANDS ON BOTH SIDES OF THE RIVER

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: KELLNER JETTY FIELD

a) Description: CONSTRUCTED IN ABOUT 1960. IT CONSISTED OF 3000' MAINLINE, 81' LINES OF BACKUP RETARD STRUCTURE. THE JETTY FIELD EXTENDS DOWNSTREAM FROM THE BRIDGE.

b) Present Condition: THE JETTY FIELD IS IN A FAIRLY GOOD CONDITION AND IT IS NOT IN DIRECT CONTACT WITH THE RIVER.

TYPE: ______________________

a) Description: ______________________

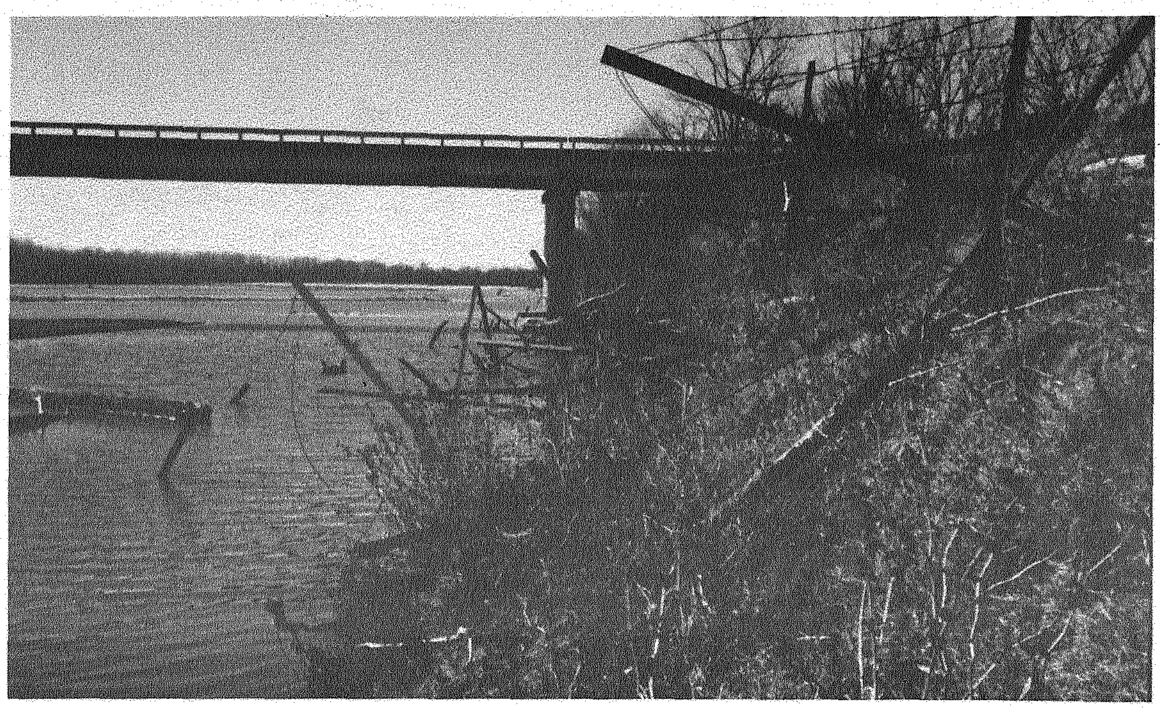
b) Present Condition: ______________________

TYPE: ______________________

a) Description: ______________________

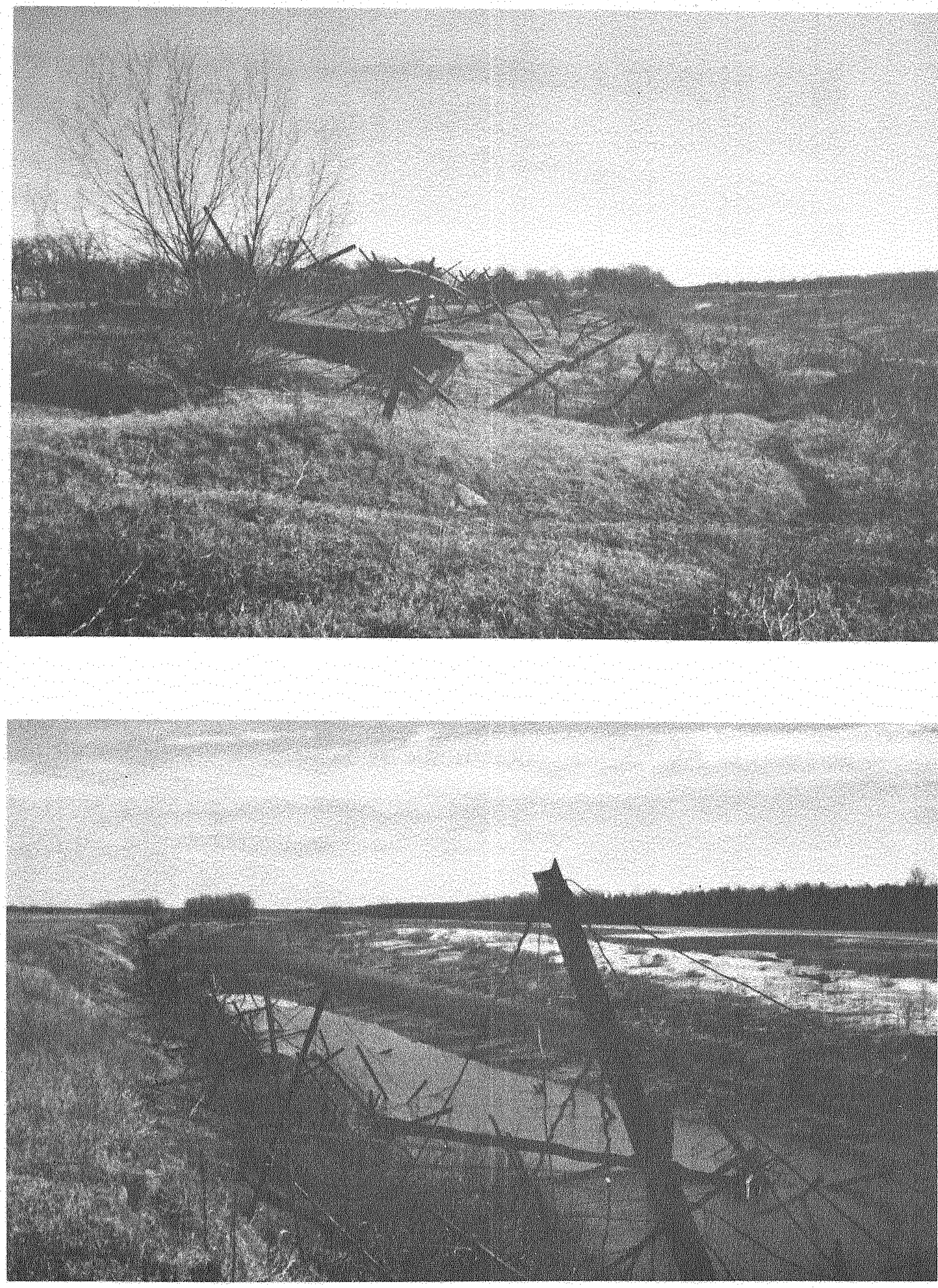
Jetty Field Upstream of Bridge

FIGURE 100a



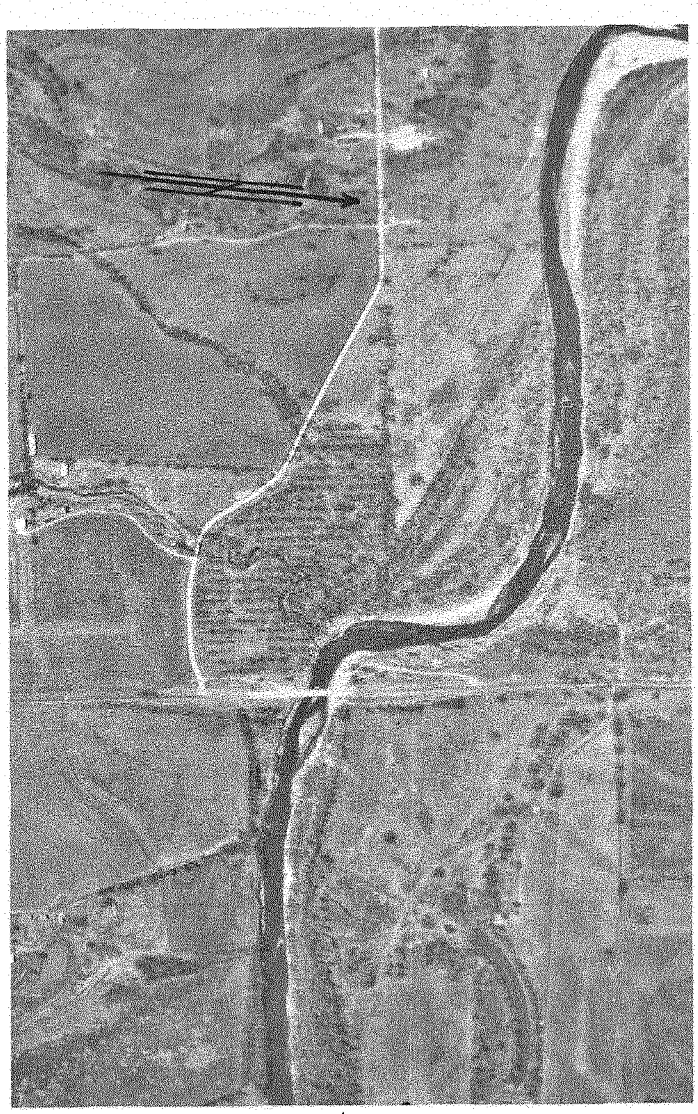
Jetty Field Downstream Of Bridge

FIGURE 100b



Views of Jetty Fields

FIGURE 100c



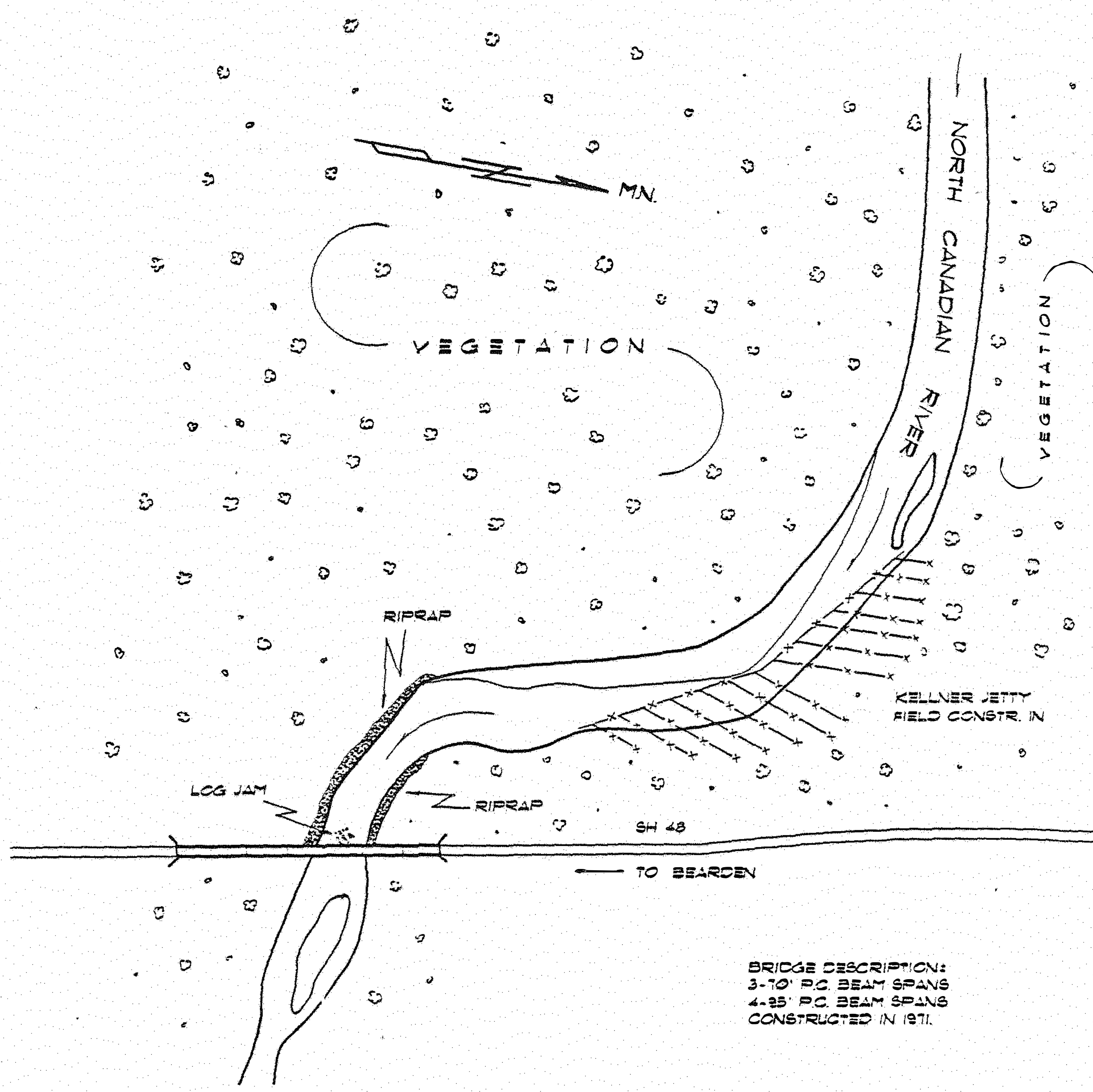
Scale: 1" = 1180'

1989 Site Aerial Photograph

FIGURE 101

NORTH CANADIAN RIVER - SH 48
NORTH OF BEARDEN

SITE NO.23



SITUATION LAYOUT 1988

SCALE 1" = 347'

FIGURE 102

NORTH CANADIAN RIVER - SH 48 Site No.25

North of Bearden (McCurtain/Bowie County)

Bridge and Site Data:

The present bridge structure is situated on the North Canadian River which is a meandering stream of considerable sinuosity. The stream has become less dangerous as far as bridge structure protection is concerned, due to the presence of upstream impoundment structures. These structures have reduced the river to the dimensions of a stream. The soil in this area is not highly erosible, and the river carries only a moderate amount of drift load.

History of Stabilization Procedures:

This is the case of a site in which bank protection devices were installed to prevent an upstream meander loop from moving eastward and hence endangering the highway approach. On the northern bank, west of the highway, the river had been encroaching on the land separating the highway from the approach road, and hence endangering the highway. A Kellner jetty field was installed at this concave bank in 1985, in an effort to discourage this action and to help in bank building. Nearly 1500 ft of mainline jetties were installed, and 14 backup retardance jetties were installed. At the upstream end of the jetty field, stone riprap was placed on the bank to prevent any occurences of the river cutting behind the jetty field. About 500 ft of riprap was placed on the northern bank and 550 ft of riprap was placed on the southern bank at about the same time. The bridge abutments seems to be quite safe from the river attacks since the bridge seems to span a considerable amount of the floodplains.

Site Evaluation:

This site is a good example of the reasonable success of jetty fields in helping the process of bank building. the 1989 aerial photographs clearly show the extent that the jetties have reestablished the bank. There is a reasonable amount of sediment and debris deposition which have collected in the jetty field and helped in bank protection.

From a pessimistic point of view, most of the jacks in contact with the river are submerged in sand, or are in a bad state of deterioration. Another observation is that though the bank building process has been successful, the new bank which has been built is a very low on and can be submerged easily in case of high flows. Also the sand bar has been formed at the site which once again can let the water flow behind it which can erode the bank.

On the other hand, considering the low low flow conditions of the river due to upstream impoundments, the bank may not be exposed to high discharges, which may inhibit the erosion process. As of now, the site does not seem to be in need for any new bank protection structures.

STREAMBANK STABILIZATION STRUCTURES

FIELD SURVEY

SURVEY DATE: JAN. 6, 1989 SITE NO.: 25

HIGHWAY NO.: SH 48 COUNTY: McCURTAIN / BOWIE

BRIDGE LOCATION: NORTH CANADIAN RIVER, NORTH OF BEARDEN

STREAMFLOW: LOW WEATHER: COLD

BRIDGE(S) ON SITE:

1) Yr. of constr.: 1971

   Span Description: 3 - 70' P. C. BEAM SPANS
   4 - 95' P. C. BEAM SPANS

2) Yr. of constr.: ________

   Span Description: ________

EMBANKMENT TYPE:

SLOPE: STEEP

PROTECTION: RIPRAP

SPECIAL NOTES: RIVER DOES NOT TOUCH ANY EMBANKMENT IN LOW FLOW CONDITION.

RIVER BANK:

SOIL NATURE: CLAYEY VEGETATION: SHRUBS

COMMENTS: ________

DESCRIPTION OF PROTECTION STRUCTURES:

TYPE: KELLNER JETEY FIIELD

a) Description: CONSTRUCTED IN 1985

1500' MAINLINE JETTIES

14 BACKUP JETTIES

b) Present Condition: THE KELLNER JETTY FIELD IS IN A DAMAGED CONDITION, BUT IT HAS EFFECTIVELY PREVENTED DAMAGE TO THE BANK.

TYPE: RIPRAP

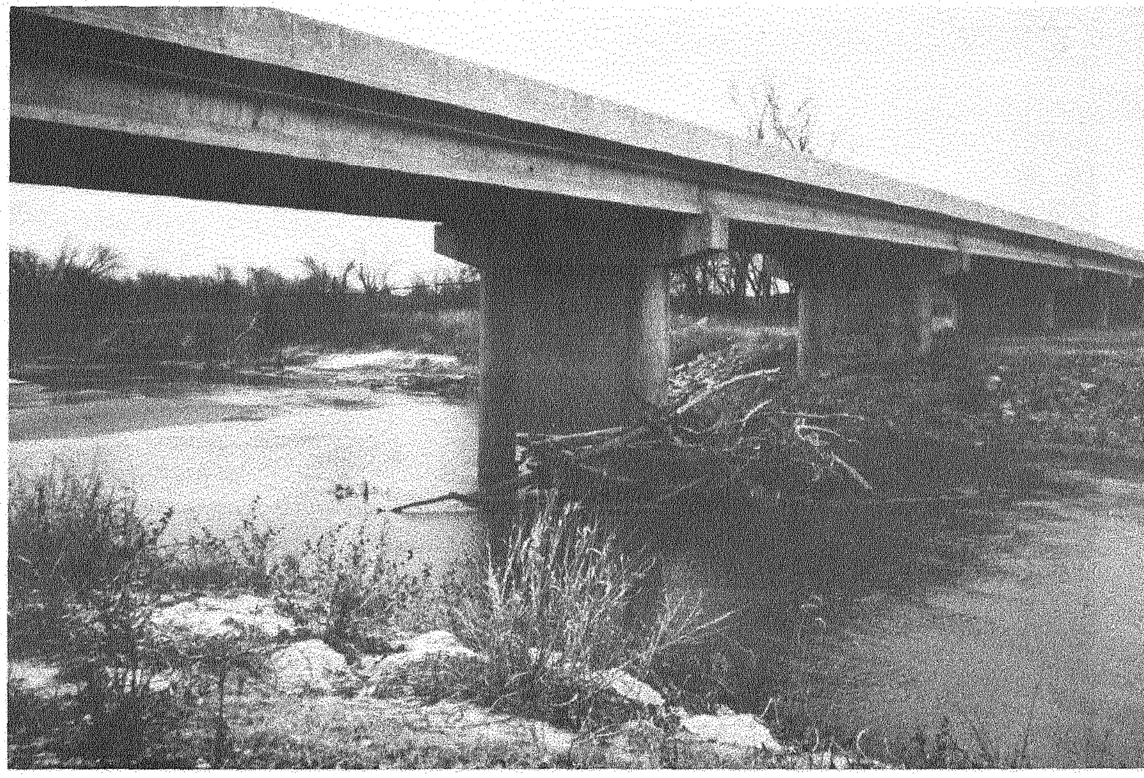
a) Description: 500' ON NORTHERN BANK

550' ON SOUTHERN BANK

b) Present Condition: RIPRAP ON BOTH BANKS ARE IN A DAMAGED CONDITION.

TYPE: ______

a) Description: ______

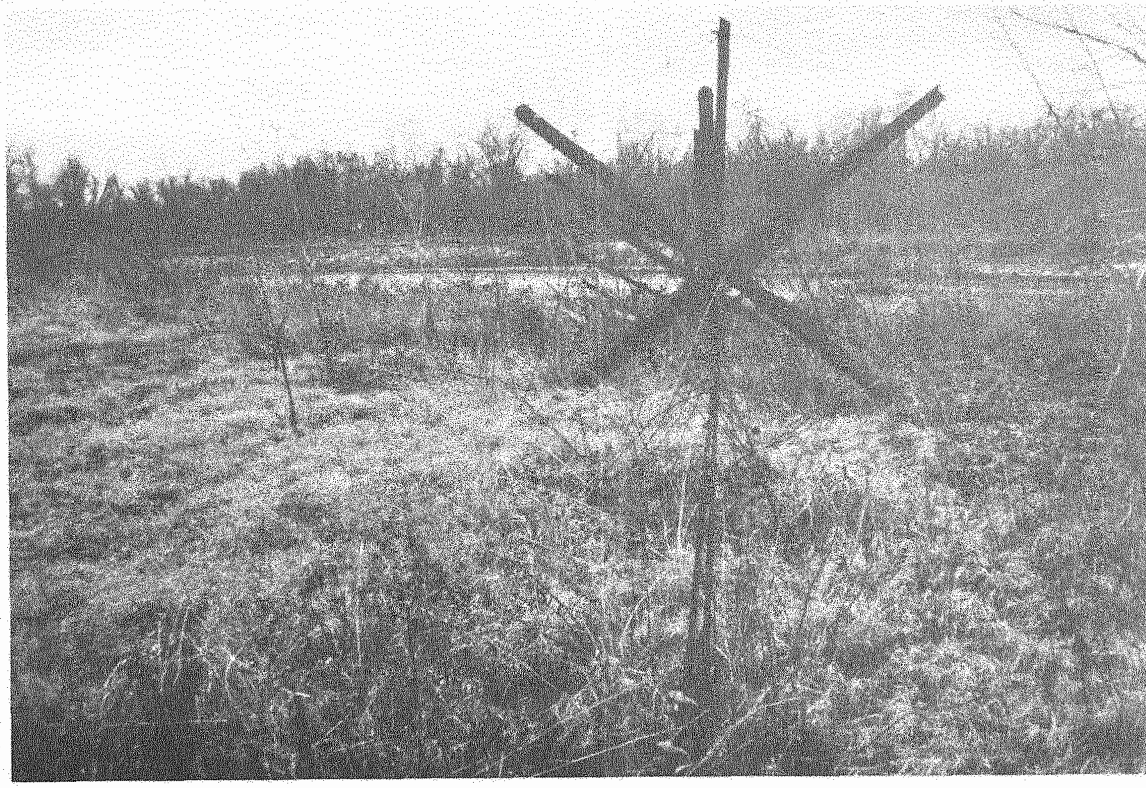


Log Jam at Bridge Piers

FIGURE 103a

Upstream View form Bridge

FIGURE 103b



Views of the Jetty Field

FIGURE 103c

CHAPTER VI

RECOMMENDATIONS

The Oklahoma Department Of Transportation has to maintain about six thousand bridges. Only twenty five bridge sites have been studied in this project. However, the twenty five sites that were studied covered most of the major rivers in Oklahoma and many trouble spots. Hence those can be considered representative samples of major bank stabilization and river control problems. On the basis of the information which is presented herein, the following recommendations can be made:

1) Presently, river stabilization procedures involve the protection of a limited stretch of bank which is under attack. This may be cost effective in some places but may not be the solution in other places. In cases of bridge sites that are about two to three thousand feet downstream from the fork of a river, it may be justifiable to study the intensity of flow through both the forks to consider the degree of protection required on both of the river banks. Site No. 24 is a clear example of the south fork

of the Red River which became weaker than the north fork, hence causing a change in the river flow. This resulted in the attack of the river on the southern bank, when it was previously attacking the northern bank.

2) It is not cost effective to find a permanent solution to river erosion problems. It is best to consider the stabilizing of a river site for the active life span of the bridge structure, say, about fifty years. This can be noted due to the fact that in course of time the river may naturally meander to such a position that a site which was considered stable in prior years has become unstable in later years and no amount of stabilization may seem to rectify the problems at the site. Sometimes, it may be the best policy to realign the highway, in case a new bridge is to be constructed at troublesome bridge sites. Site No. 9 may be taken as an example of such a site.

3) It has been noticed that bridges located on large rock outcrops seem to have erosional problems on the bank across the rock outcrop. This is apparently due to the rebounding effect of the water off the rock outcrop, which in many cases results in the erosion of the opposite bank, especially downstream. Another reason could be the tremendous velocity generated due to confinement, and the volume of discharge in case of sudden floods. Site No.17 at Crescent may be an example of such type of action, where the presence of a rock outcrop on the north bank may have been the cause for the erosional problems on the southern bank. Site No.15 at Whitefield may be another example of a site which had similar problems.

4) At many of the Oklahoma sites, pile diversions have observed to be quite effective in diverting the river to a path directly under the bridge structure and hence encouraging bank protection. Recently the use of pile

diversions has been limited due to the high cost of construction and installation.

5) The use of Kellner jetty fields has had extensive application in the State of Oklahoma. Riprap has also been used extensively statewide for bank protection applications. However, it has been noticed that few single countermeasures are ever fully effective in its intended bank protection capacity. More research must be done to design a structure, or a configuration of structures to improve the effectiveness of all structures. This can be theorized by taking into consideration the following factors:

a) Kellner jetties are effective in inducing deposition, but not as effective in diverting flows away from the banks. Moreover, Kellner jetties are not found to be absolutely effective in the case of rivers like the Washita, where, due to the large volume of the debris, there is sometimes destruction of the jacks before they can effectively reduce the velocity of the water and hence induce deposition.

b) Pile diversions are effective in diverting river flows, but are not usually effective in the bank building process.

c) Rock riprap is only used for bank protection and offers no role in diverting the flow, or in the bank building process.

A rational approach may well be to use the advantage of any one structure, and to counteract its disadvantages using other structures that are available. Research should be continued on the configuration of the bank protection structures to best achieve this effect. In the case of the State of Oklahoma, especially on the Washita a scenario to accomplish this could be as follows:

i) The bank that requires protection could be given a moderate layer of riprap to protect the soil on the bank from washout.

ii) A Kellner jetty field could be then erected on the site as the principal structure and bank forming device.

iii) On the upstream end of the Kellner jetty field, a proper, highly permeable pile diversion (preferably without any surface planking) could be constructed. The primary objective of this diversion will be to divert the main flow away from the Kellner jetty field and to provide a barrier to prevent large debris from destroying the Kellner jacks. This sort of pile diversion will effectively help in the function of the jetty field in inducing deposition and forming a bank. This pile diversion should be so designed to be able to resist large overturning moments due to the action of the water, and also due to the debris collected on it. The piles must be embedded deeply enough to resist the effect of scour. Periodic maintenance is a must for the effectiveness of the whole system.

iv) The portion of the bank where the pile diversion is anchored should be extensively riprapped to prevent the action of the river from cutting behind the pile diversion.

This system should effectively incorporate the best features of the three widely used bank protection structures. More research must be done to determine the orientation of the pile diversion and the jetty field to find the optimum conditions for the maximum length of bank protection.

6) In the State of Oklahoma, the river that needs the most training is the Washita which is known for its considerable sinuosity, high water velocities, and large drift loads. Regular clearance of excessive drift from bank protection structures is a must for their long useful life.

7) In the case of installation of structures such as pile diversions, right of way must be obtained for maintenance purposes. This is because pile diversions, unlike jetty fields, do not get covered up by silt, and are exposed to the river attacks for a very long period of time. Maintenance is essential to keep the structures effective for longer periods of time.

8) In cases of structures like pile diversions, where the main purpose of which is to deflect river currents away from the bank, face planks should be given vertical flexibility, similar to the one developed by "ERCON". This is essential to reduce the effect of erosion problems caused by water currents passing under these structures through scour holes.

Such currents are one of the main factors which prevent effective bank building on banks protected by pile diversions.

9) A well defined program should be developed for a scheduled monitoring of bank protection structures, especially after high flood periods. This is especially important for sites which have proven to be trouble spots. Major damages should be immediately be repaired to prevent any further worsening of the situation.

10) Kellner jacks are used extensively for bank protection in Oklahoma. The use of more durable materials for building jacks may increase the length of useful life of these jetties.

11) A statistically based strict inspection procedure may be recommended to identify damage as soon as it occurs, especially after major floods.

12) Riverbank protection and river training is a constant process. Once a protective structure is installed, periodic maintenance as well as constant monitoring, is a must to ensure the effectiveness of the project. A well documented, maintenance schedule can insure successful projects.

CHAPTER VII

CONCLUSIONS

1. This report "Effectiveness Of Riverbank Protection And River Control In Oklahoma", covers extensively all the twenty five designated sites under consideration. The first twenty sites were those originally covered by the Keeley Report (9), and the last five sites were specifically selected for analysis in this study. It covers many of the river training and bank stabilization methods, now in use or in stages of development, in the extensive literature survey that was conducted. The latest state-of-the-art information on bank stabilization and river training techniques has been provided.

2. Bank erosion is a complex phenomenon that has still not yet been completely understood. The meandering of a river and its erosional and depositional characteristics are a function of many parameters many of which are still not well understood.

3. Efforts were made to develop an Expert System on river training and bank stabilization to give a near definite solution to the erosional problems using well known rules, and heuristics. The system was designed to recommend an appropriate river training structure that could be used at a site, given the characterisitics of that site. This effort lead to complex problems due to the very nature of the problem and was not within the scope of this project.

4. The present state-of-the-art techniques in river training offers no permanent solutions to riverine problems. Stabilization structures that work well at one site may not work well at other sites. Further, if an extensive river training technique is to be applied, it may not be cost effective. All cases of river training are site specific. The best solution to this problem may be to design protection systems that will last for the lifetime of the bridge structure to be protected, say about fifty years, and to derive the maximum advantage it offers.

5. Older bank protection methods like riprap, Kellner jetties, pile diversions, and spur dikes have experienced extensive application in Oklahoma. They have varying degrees of success depending upon site specific conditions. The newer river sites have not generally been subjected to the application of pile diversions, mainly due to the high costs associated with the erection of such a structure, and the short life they generally exhibit.

6. Other methods of river training like Bulkheads, Cribs, etc. have not found extensive application in Oklahoma, again mainly due to high costs. Another reason could be because most of the banks of the Oklahoma rivers are quite shallow, and such structures are usually used in rivers with relatively high banks.

7. Newer methods of river training such as Palisades and Vanes have been applied at test sites across the United States by commercial entities such as "ERCON", and the Iowa Hydraulic Research Institute. The effectiveness of these structures need to be further studied to prove its application potential.

8. River stabilization structures are usually applied just upstream from the structure to be protected. This element mostly reduces the manifestation of detrimental effects any further downstream than the protected structure itself. Therefore, the liability of well intended countermeasures is virtually eliminated. As a general statement of fact, bank stabilization projects not performed upstream from hydraulic structures have proven to be qualitatively viable, but quantatively uncertain. This is true for a variety of reasons: hydrological uncertainity, land use patterns, upstream controls, etc. Considering all these factors, bank stabilization applications must necessarily be practiced by governmental agencies like the ODOT.

9. New bridge structures that are to be built should be aligned to absorb most of the predicted meandering characteristics of the river for a period of at least fifty years, which is approximately the useful life of a bridge.

10. Effects of upstream discharge control measures on the stream flow should be considered to determine the necessary stability of the installed river training structures.

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