Kathryn Flood Damage Reduction Study

North Dakota State Water Commission
SWC Project No. 1264
February 1987

KATHRYN

FLOOD DAMAGE REDUCTION

STUDY

February, 1987

North Dakota State Water Commission
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INTRODUCTION

In a January 6, 1987 letter, the Barnes County Water Resource Board requested technical assistance from the North Dakota State Water Commission in studying the flood problem at the City of Kathryn. As shown in Figure 1, Kathryn is located in southeastern Barnes County, approximately 16 miles south of Valley City.

Specifically, the Board was interested in improving the channel conditions of Spring Creek near the downstream end of the city. Vegetative growth and sediment has further decreased the limited capacity of the channel.

Information used for this study included the following: the 1980 Flood Insurance Study for the City of Kathryn, the 1986 planning report prepared by the Soil Conservation Service, entitled: "Kathryn Flood Prevention, South Central Dakota RC&D," 7 1/2 minute USGS quadrangle maps, and discussions with the Barnes County Road Department. Additional cross-sections were obtained by the State Water Commission survey crew on January 13 and 14, 1987. These were added to the existing cross-sections obtained from the previous studies.

Several alternative channel improvements were looked at for this study. A hydraulic analysis was performed to determine the affects of each alternative. The results of that analysis and a cost estimate of each alternative is provided within this report.

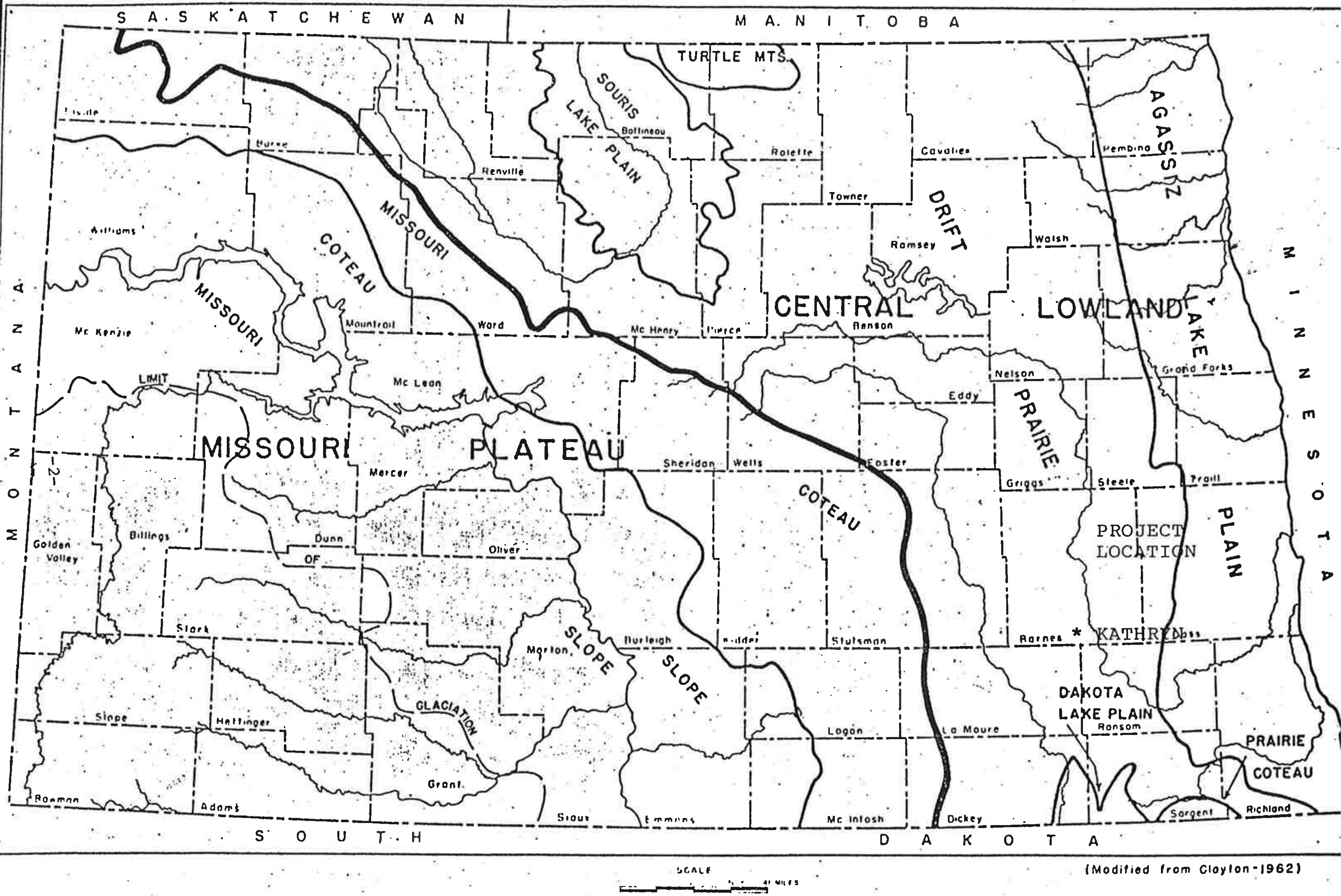

FIGURE 1 - General Location

STATEMENT OF PROBLEM

Spring Creek, with a channel length of approximately 23.5 miles, flows southeasterly through Kathryn before entering the Sheyenne River, approximately 1 1/2 miles further downstream. At Kathryn, Spring Creek has a total drainage area of approximately 73 square miles. About 63 square miles of this is considered to be contributing area. Clausen Springs Dam is located upstream on Spring Creek. This structure has limited flood storage capability and so has little affect on the peak flows of major floods.

Between June 26 and July 2, 1975, a rainfall ranging between 2 and 12 inches occurred in the watershed. A peak flow of approximately 1500 cubic feet per second (cfs) caused flood damage in Kathryn. (Figures 2-4 are photos taken of that event.)

Plate 1 shows the channel alignment and cross-section locations within Kathryn. According to previous studies, at least 13 buildings in Kathryn appear to be located within the 100-year floodplain. Seepage may also cause problems to other buildings. Some buildings are located close to the channel, restricting possible channel widening.

A fairly steep slope exists on the channel through Kathryn. High velocities, possibly causing erosion, exist in certain areas. Sediment and vegetation appear to be building up in the channel near the lower end of the city. The channel slopes in the wrong direction for a short distance both upstream and downstream of the bridge on the school road.

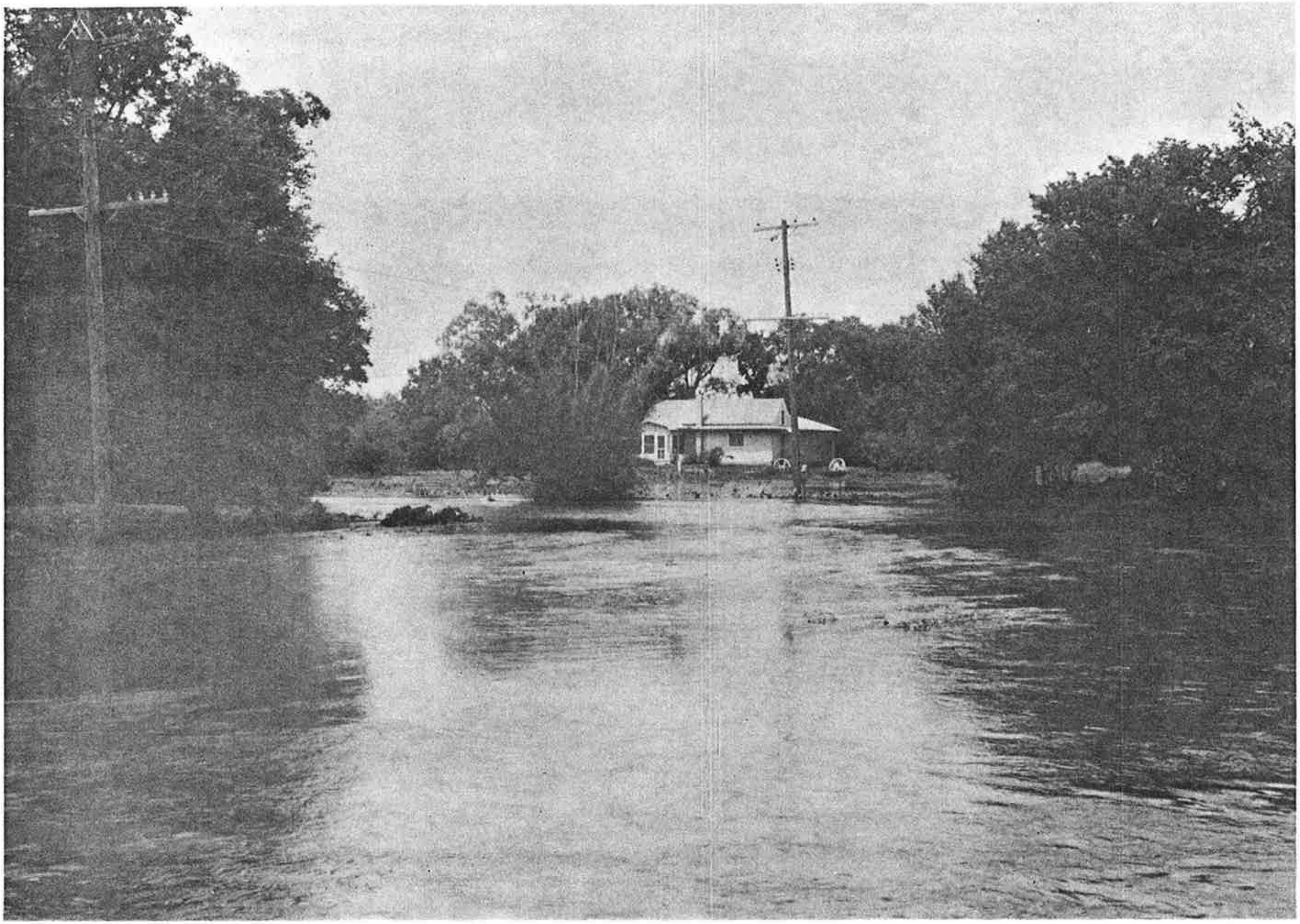

FIGURE 2 - Looking west from bridge on 2nd Street

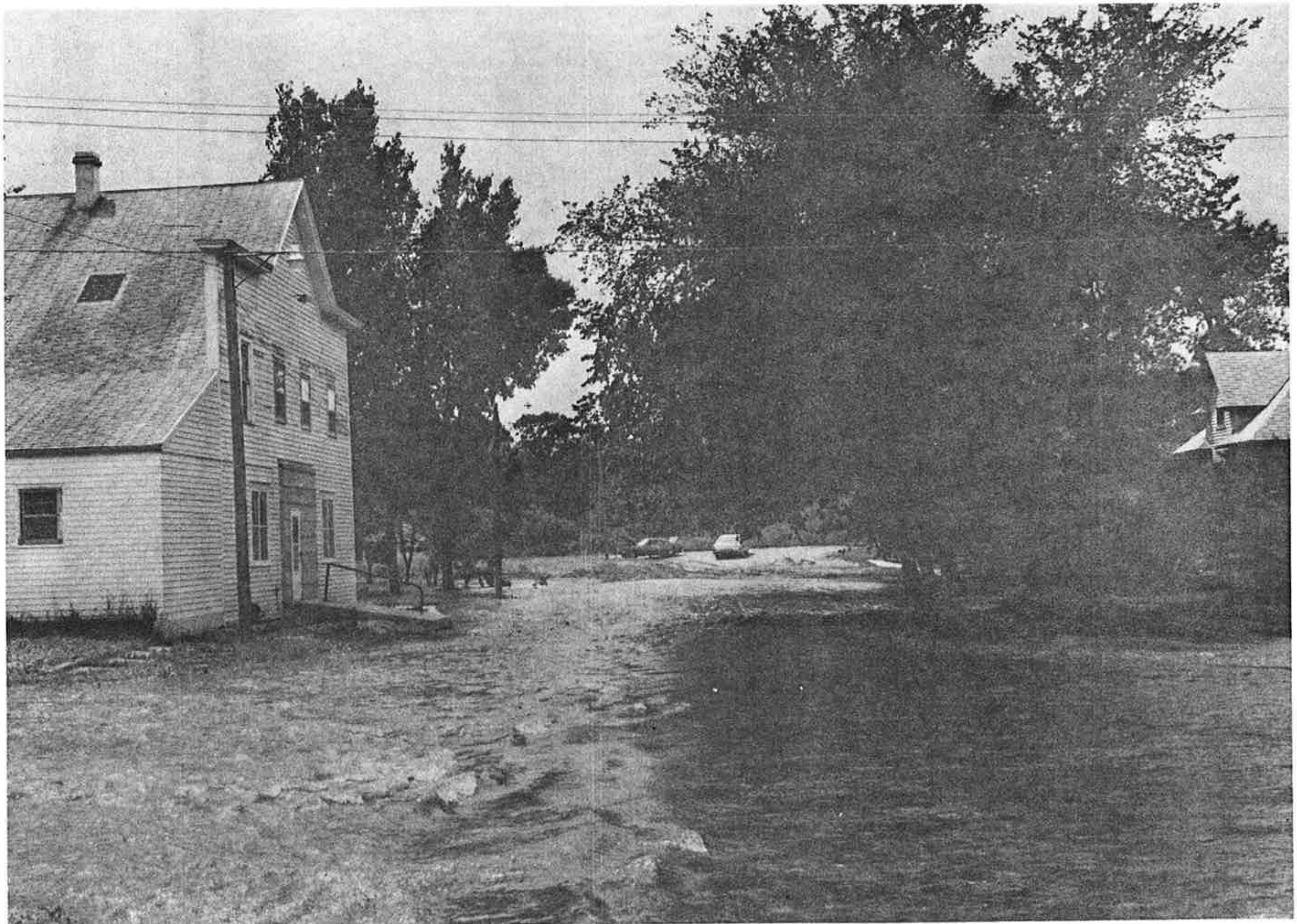

FIGURE 3 - Looking south from bridge on 2nd Street

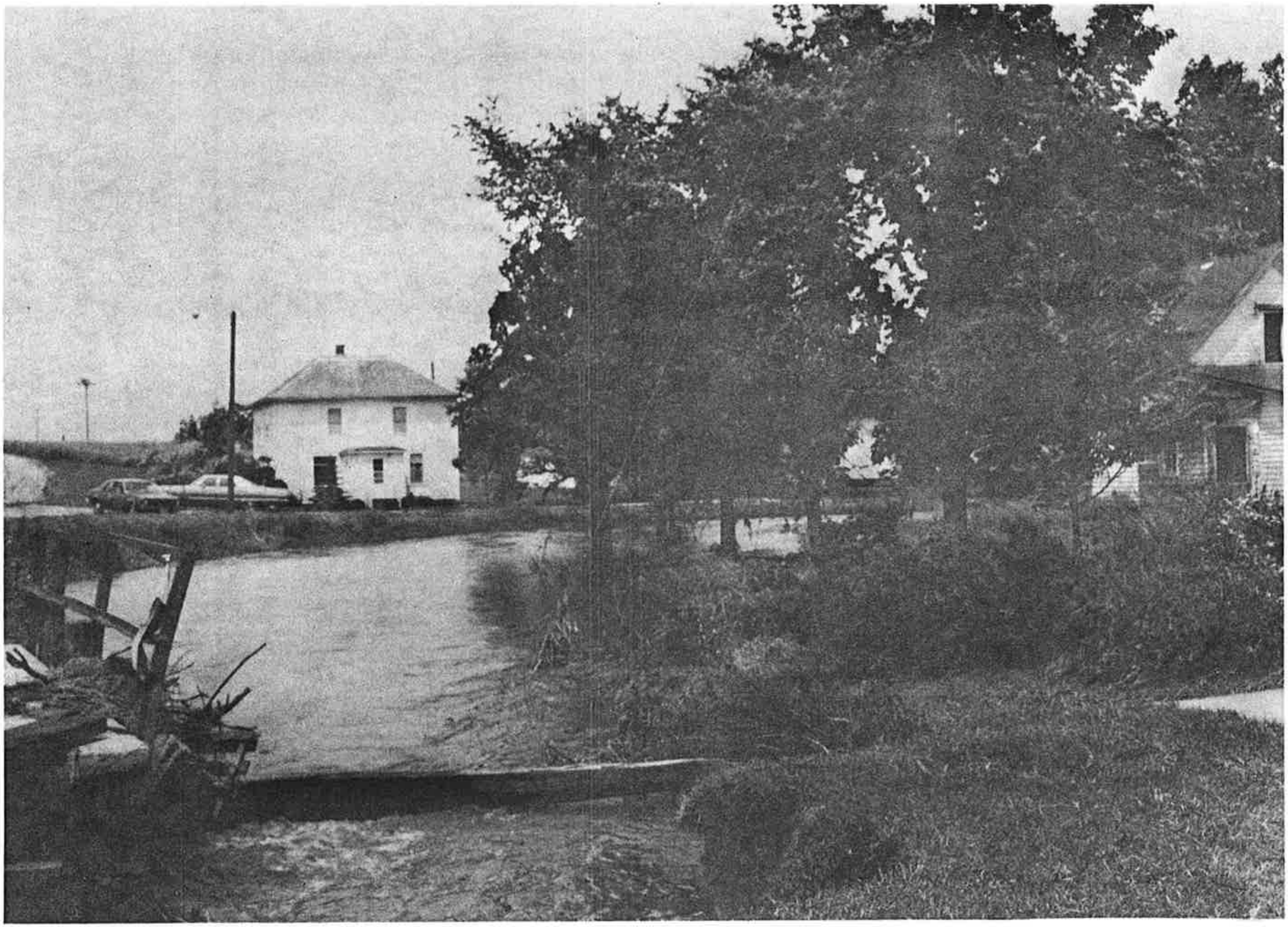

FIGURE 4 - Looking northwest from bridge on Main Street

HYDROLOGY AND HYDRAULICS

Prior studies had determined the following flows for the corresponding frequency event:

Event	Flow (cfs)
10-year	660
25-year	910
50-year	1150
100-year	1450

For purposes of the channel design, a flow of 1500 cfs was used. The Corps of Engineers HEC-2 computer model was used to analyze the existing channel conditions and the effects of any possible improvements. Most of the channel cross-sections inserted into this model were obtained from previous studies. The additional cross-sections obtained by the State Water Commission were located at the downstream end of Kathryn. This is the area that the Board is most interest in improving. The results obtained should be considered preliminary in nature.

ALTERNATIVES

Various flows were looked at when studying the alternatives. Unless stated otherwise, all discussion on the water conditions refers to the design flow of 1500 cfs.

Six alternatives are presented for review. Alternative 1 consists of maintaining the channel in good condition. Alternative 2 consists of channel excavation starting 735 feet downstream of the bridge on the school road and continuing 300 feet upstream of the bridge. Essentially, the channel bottom would be restored to the level to remove the sediment near the bridge. Alternative 3 is exactly the same as Alternative 2, but extends 1,000 feet further upstream. Channel improvements proposed for Alternative 4 starts 540 feet further downstream but ends at the same upstream location as Alternative 2. The channel bottom would be lower than the elevation proposed for Alternative 2, matching the lowest elevation on the existing channel. Alternative 5 includes the channel improvements proposed for Alternative 4 and also proceeds 1,000 feet further upstream. The upstream end would be at the same location as proposed for Alternative 3. Alternative 6 consists of improving the channel through the entire city limits of Kathryn.

Velocities within areas of the existing channel are high enough to cause erosion problems. At cross-section 7.0, velocities exceed 7 feet per second, at a flow of 1500 cfs. Erosion is evident for a short section within this area. The velocity does not decrease much for smaller rates of flow. By improving the downstream conditions, velocities may be increased further upstream. The increase in velocity would not continue for an extended distance upstream of the improved area, as the flow conditions gradually return to the original conditions. Except possibly for Alternative 5, any noted increase in velocity upstream of the channel improvements did not seem significant. This problem should be looked into further before the project is constructed.

The junction between the existing channel and the improved channel is another area where high velocities could develop. A smooth transition area, gradually increasing the channel dimensions from the existing condition to the improved condition, is necessary to prevent unstable flow conditions.

For all alternatives, it was assumed that the spoil material could be spread on both sides of the channel for the area below the bridge on the school road. The dimensions of the proposed channel are 20-foot bottom width and 4H:1V side slopes. Some alternatives include dikes. In these cases, a berm of at least 10 feet should remain between the edge of the channel and the toe of the dike. For the area upstream of the bridge, all the material should be deposited on the left side of the channel. for Alternative 3, the spoil material upstream of the bridge is recommended to be compacted to form a dike. Within this area, water could then be contained closer to the channel and further away from any buildings. The right bank should not be filled in, allowing it to act as an overflow area during extremely high flows.

In preparing cost estimates for all alternatives, it was assumed that black dirt would be stripped from the construction area and respread over the completed area. From prior discussions, excavation was assumed to be done by dragline or backhoe. Water conditions may make this necessary. It may be possible to remove the material with a dozer or other equipment, although some dewatering may be necessary.

For Alternatives 2 and 3, rock riprap was felt to be required below the bridge on the school road. The velocity through the bridge was calculated to be around 12 fps for these alternatives. This is slightly lower than the velocity calculated to occur under existing conditions. Velocities at the bridge would also be very high with Alternatives 4 and 5. Erosion protection is provided with the proposed bridge improvements for these alternatives.

The three existing bridges within the study area are not adequate to handle the design flow. The limited cross-sectional area of the opening causes a stage increase on the upstream side of the structure. Although not stated as a separate alternative, conditions would be much improved if these bridges were replaced or removed. Plate 2 shows the decrease in water elevation if the bridges were not in place. The bridge on the school road is not as critical, although still not adequate, because the buildings upstream of the bridge are a fair distance from the channel.

If acceptable to the community, any of these structures could be replaced by low water crossings. This could be a cheaper alternative than replacing them with new bridges of sufficient waterway opening.

A water line apparently is buried within the vicinity of the bridge on main street. The exact location should be obtained before any excavation of the area, or modification to this bridge is attempted.

Alternative 1

This alternative consists of maintaining the channel in good operating condition. The channel vegetation would be controlled, possibly by mowing. Brush and other obstructions would be removed from the channel.

For the most part, the channel conditions within the city limits, are in relatively good condition. An 'n' value, channel roughness, of 0.040 was used for the existing conditions. This value was reduced to 0.035 to determine the affects of this alternative.

For the more frequent floods, this alternative would reduce the water elevation by up to 0.2 feet. Floods larger than the 10-year event start to break out of the channel and onto the unimproved overbank area. Therefore, the decrease in water elevation would become less than 0.2 feet, as the magnitude of the flood increased.

This alternative alone would not cause any significant reduction in flood damage. It is recommended, however, that proper channel maintenance should be incorporated with any channel improvement. An average annual cost of $250 is estimated for this alternative.

Alternative 2

A thick vegetative growth is present both upstream and downstream of the bridge on the roadway to the school. Also, and perhaps because of this, it appears that sediment has been deposited in this area. The channel slopes in the wrong direction for a short distance just upstream of the bridge, with a similar condition located downstream of the bridge.

According to the information provided through the Barnes County Road Department, the bridge on the school road was replaced after the 1975 flood. It was designed with the channel bottom 10 feet below the low beam of the bridge. If the channel were to be deepened below this elevation, horizontal supports would be necessary for the bridge.

The 10-foot clearance below the bridge would be maintained for this alternative. The proposed channel bottom, along with the new water elevation, is shown on Plate 3.

The water elevation at cross-section 4.0 would be reduced by about 2.8 feet, at a flow of 1500 cfs. Proceeding upstream, the water elevation would eventually approach the water elevation determined from existing conditions. Under the proposed condition, the channel at cross-section 4.0 could contain the entire flow of a 25-year event. The channel at cross-section 5.0 could contain a 10-year event, while a 10-year event would break out of the channel at cross-section 5.5. The width of flooding would be reduced along the channel reach where the elevation would be reduced. The buildings that are closest to the channel, between cross-section 4.0 and 5.5 would benefit from this alternative. It would appear that buildings 21 and 24, as number on Plate 2, would be removed from the design floodplain.

As shown in Table 1, approximately 9,000 cubic yards of excavation would be required for this alternative. The total cost, not including cost to obtain fee title or easements to land, are estimated to be $32,000.

Table 1 - Preliminary Cost Estimate
Alternative 2

Item	Quantity	Unit	Unit Price	Total
Mobilization		L.S.	$5,000.00	$ 5,000.00
Stripping, Stockpiling and Spreading Topsoil	17,500	S.Y.	0.20	3,500.00
Excavation	6,000	C.Y.	1.50	9,000.00
Rock Riprap	70	C.Y.	30.00	2,100.00
Rock Riprap Filter	35	C.Y.	12.00	420.00
Seeding	5	Acres	350.00	1,750.00
	Subtotal			$21,770.00
	Contingencies			4,620.00
	Engineering			3,500.00
	Contract Administration			2,200.00
	TOTAL			$32,000.00

Note: This amount does not include cost to acquire fee title or easements for land.

Alternative 3

This alternative is identical to Alternative 2 except that the excavation continues from cross-section 4.0 to cross-section 6.0, as shown on Plate 4. Therefore, benefits due to flood elevation reduction are extended further upstream. A 25-year event could be contained within the channel at cross-section 4.0, 50-year event at cross-section 5.0, nearly a 25-year event at cross-section 5.5, and less than a 10-year event at cross-section 6.0. The design flood would not extend as far beyond its banks and towards the town within this area. Without considering any dikes, the distance the water would extend from the left bank would be reduced by 185 feet at cross-section 4.0, 50 feet at cross-section 5.0, 155 feet at cross-section 5.5, and 95 feet at cross-section 6.0. Buildings apparently removed from the design floodplain would include buildings 21, 24 and 25, as shown on Plate 1.

This alternative would increase the velocity of flow in the area around cross-section 7.0, by about 0.6 feet per second. This is the area that appears to have velocities capable of causing erosion under existing conditions. Before this alternative was to be constructed, that potential problem area should be investigated more thoroughly.

Approximately 14,000 CY of excavation would be required for this alternative. Although the buildings between cross-sections 4.0 and 6.0 appear to be removed from the design flood area, they could possibly still be affected by groundwater. To reduce the likelihood of this occurring, the spoil material that would be placed along the left bank could be formed into a dike. Water would be contained closer to the channel and further away from the buildings. To do this properly, compaction of the dike would be required. The dike would also have to be tied into high ground. As shown in Table 2, the total cost for this alternative, including the dike, is estimated to be $68,000. This does not include the cost to acquire fee title and easements to land.

Until the improvement is extended further upstream, the 0.3% slope is recommended from cross-sections 4.0 to 6.0. This will minimize any increase in velocities further upstream. Some slight modifications may be necessary, if construction was later continued further upstream from this alternative. In order to obtain the required depth, the 0.3% slope from cross-section 4.0 to 6.0, may have to be changed at that time to a 0.2% slope. This would consist of a maximum cut of about 1.5 feet at cross-section 6.0, tapering off to no additional excavation at cross-section 4.0.

Table 2 - Preliminary Cost Estimate
Alternative 3

Item	Quantity	Unit	Unit Price	Total
Mobilization		L.S.	$5,000.00	$ 5,000.00
Stripping, Stockpiling and Spreading Topsoil	40,000	S.Y.	0.20	8,000.00
Excavation	14,000	C.Y.	1.50	21,000.00
Embankment	5,600	C.Y.	1.00	5,600.00
18-inch CMP	46	L.F.	10.00	460.00
Flap Gate	1	L.S.	400.00	400.00
Rock Riprap	70	C.Y.	30.00	2,100.00
Rock Riprap Filler	35	C.Y.	12.00	420.00
Seeding	10	Acres	350.00	3,500.00
	Subtotal			$46,480.00
	Contingencies			8,520.00
	Engineering			8,000.00
	Contract Administration			5,000.00
	TOTAL			$68,000.00

Note: This amount does not include cost to acquire fee title or easements for land.

Alternative 4

As shown in Plate 5, this alternative would start at cross-section 1.0 and continue upstream to cross-section 4.0. The channel elevations are identical, as proposed by the Soil Conservation Service within their report. This would require a deeper cut than proposed with Alternative 2. The cut would provide an 11.4-foot clearance below the bridge located on the school road. As stated by the consultant for the Barnes County Road Department, horizontal supports would be required if the cut provided a clearance of more than 10 feet below the low beam. A rough cost estimate to do this, would be between $10,000 to $15,000.

The water elevation for this proposal is also shown in Plate 5. The design flow can be completely contained within the channel at cross-section 4.0.

Upstream from that point, however, the results are nearly identical to that of Alternative 2.

A total of 13,000 CY of excavation is required for this alternative, as shown in Table 3. An estimated cost of $67,000, not including cost to obtain fee title or easements to land, was calculated for this alternative.

Table 3 - Preliminary Cost Estimate
Alternative 4

Item	Quantity	Unit	Unit Price	Total
Mobilization		L.S.	$ 5,000.00	$ 5,000.00
Stripping	29,000	S.Y.	0.20	5,800.00
Excavation	13,000	C.Y.	1.50	19,500.00
Bridge Improvements		L.S.	15,000.00	15,000.00
Seeding	7	Acres	350.00	2,450.00
	Subtotal			$47,750.00
	Contingencies			7,350.00
	Engineering			7,100.00
	Contract Administration			4,800.00
	TOTAL			$67,000.00

Note: This amount does not include cost to acquire fee title or easements for land.

Alternative 5

This is a continuation of Alternative 4. The excavation continued beyond cross-section 4.0 to cross-section 6.0. The proposed channel bottom and resulting water surface are shown in Plate 6. Extending upstream from the bridge, the entire design flow would be contained within the channel up to cross-section 5.0. Only 5 cfs is out of the left bank at cross-section 5.5. Upstream from the construction limit, the water elevation gradually approaches the water elevation encountered with the existing conditions. The 10-year event will overflow its banks at cross-section 6.0. Buildings 21, 24 and 26, appear to be removed from the design flood area.

This alternative will cause increased velocities between cross-section 6.0 and cross-section 7.0. The possible erosion problem is more serious with this alternative than with the other alternatives.

With 56,000 CY of excavation, this alternative is estimated to cost about $115,000, as shown in Table 4. This does not include the cost to acquire fee title and easements for land, or any required erosion protection between cross-section 6.0 and 7.0.

Table 4 - Preliminary Cost Estimate
Alternative 5

Item	Quantity	Unit	Unit Price	Total
Mobilization		L.S.	$ 5,000.00	$ 5,000.00
Stripping	56,000	S.Y.	0.20	11,200.00
Excavation	30,000	C.Y.	1.50	45,000.00
Bridge Improvements		L.S.	15,000.00	15,000.00
Seeding	14	Acres	350.00	4,900.00
	Subtotal			$ 81,100.00
	Contingencies			13,500.00
	Engineering			12,200.00
	Contract Administration			8,200.00
	TOTAL			$115,000.00

Alternative 6

This includes channel improvement through the entire limits of Kathryn. As discussed by the Soil Conservation Service in their report, 68,400 CY of excavation would be required. Another major expense of the project are the Reno mattresses. These are required to protect the channel. In these areas, the buildings are located very close to the channel. This restricts the possibility of excavating the channel to dimensions that would reduce the velocity to a level that would not require erosion protection.

This alternative would provide benefits from flood damage reduction for the entire City of Kathryn. The alternative was estimated to cost a total of $306,000, of which $50,000 was estimated for acquisition of easements and fee title.

This alternative is the complete project for the entire city. The city should consider providing this project in phases, as funds become available.

SUMMARY AND CONCLUSIONS

The Board had requested technical assistance from the State Water Commission in order to reduce the flood damages to the City of Kathryn. They wished to concentrate their efforts on improving the channel conditions at the downstream portion of the city. Sediment and steep slopes in the channel further reduce the capacity within this area.

Sources of information for the study included the following: 1980 Flood Insurance Study, the 1986 Kathryn Flood Prevention Planning Report prepared by the Soil Conservation Service; 7 1/2 minute quadrangle maps, additional cross-sections, and the Barnes County Road Department.

The HEC-2 computer program was used to analyze several alternatives of channel improvement. All results are preliminary in nature.

Six alternatives are presented in this report. Several of the alternatives were similar in that one alternative may have been an extension of another, or the channel bottom may be slightly deeper than another alternative. Alternative 6 consisted of the entire project through Kathryn. The Board apparently wished to concentrate on the lower end at this time. In seeking alternatives for the lower end, I attempted to find solutions that could possibly be continued upstream through the entire city. The lower portion could be considered Phase 1 of the entire project.

Dimensions of the channel for Alternatives 2 through 5, were a 20-foot bottom width and 4H:1V side slopes. Alternative 2 mainly removed the sediment from near the bridge and eliminated most of the adverse slopes. Alternatives 2 and 3, are identical except that the channel improvement for Alternative 3 extends further upstream. The elevation below the bridge on the school road was proposed to be excavated to the same elevation as the previously designed channel bottom, 10 feet below the low beam of the bridge. Channel improvements extended in both directions from the bridge.

Neither Alternative 2 or 3, can contain the entire flow of the larger floods within the channel. The water elevation would be reduced starting upstream of the bridge and continuing upstream to cross-section 7.0 for Alternative 2, and to cross-section 8.0 for Alternative 3. The reduction would become smaller as the distance upstream is increased. Two buildings would apparently be removed from the floodplain of the design flow for Alternative 2, while three buildings would be removed from the floodplain with Alternative 3. Estimated costs for the two alternatives was $32,000 and $68,000. This does not include the cost to acquire fee title or easements for land.

Alternatives 4 and 5, cover the same lengths as the previously mentioned alternatives, but at a lower elevation. The bottom elevations are similar to the downstream portion of the plan proposed by the Soil Conservation Service. The entire design flow can be contained within the improved sections of the channel. Alternative 4 would produce exactly the same water elevation upstream of cross-section 4.0 as Alternative 2 would. Two buildings would appear to be removed from the floodplain for the design flow with this alternative. Alternative 5 would provide a considerable reduction in water elevation throughout the length of the channel improvement. Upstream of that point, the elevation would gradually increase, until matching the existing water elevation around cross-section 7.0. Three buildings would appear to be removed from the floodplain with this alternative.

Additional horizontal supports are required for the bridge at the school road if either Alternative 4 or 5 is selected. The consultant for the Barnes County Road Department roughly estimated this to cost between $10,000 and $15,000. Excluding land costs, these alternatives are estimated to cost $67,000 and $115,000.

Both Alternatives 3 and 5 cause an increase in velocities upstream of the channel improvement area, near cross-section 7.0. The increase caused by Alternative 3 is very slight while that caused by Alternative 5 may be more severe. Even under existing conditions, the area near cross-section 7.0 encounters velocities that may cause erosion. Any additional increase in velocity could cause further problems.

Alternatives 2 and 4 provide identical results upstream of cross-section 4.0. This is where all the buildings are located. Therefore, the benefits received from either of these alternatives would be nearly identical.

Although Alternative 3 cannot contain the entire design flow within the improved channel, the water elevation is lowered enough to remove the buildings located between cross-section 4.0 and 6.0 from the floodplain. A dike could be constructed along the left bank between these cross-sections to contain the water within a limited area near the channel. This could reduce any possibility of encountering seepage problems within this area. In comparison, Alternative 5 could contain the entire flow within the channel through this area. The water elevation would be at a lower level, providing less chance of seepage problems.

Alternative 5 could easily tie into a continuation of the upstream project. Some slight modifications may be required to Alternative 3, for the project to be continued further upstream.

Alternative 1, continued maintenance of the channel, will ensure the best hydraulic conditions. This should be a part of any alternative.

It is recommended that the Board select either Alternative 2 or 3. Alternative 3 extends further upstream than Alternative 2. The decision between these two is based on the availability of funds.

The possibility of continuing the project through the remainder of the city should be pursued when funds become available. The entire project could be constructed in phases. Only when the entire project is completed will the city realize the most flood damage reduction.

Replacement or elimination of the bridges would also help to reduce the flood elevation. The limited area of the bridges cause the upstream water elevation to increase. A structure such as a low water crossing would not require such a stage increase.

PLATE I - Project Location

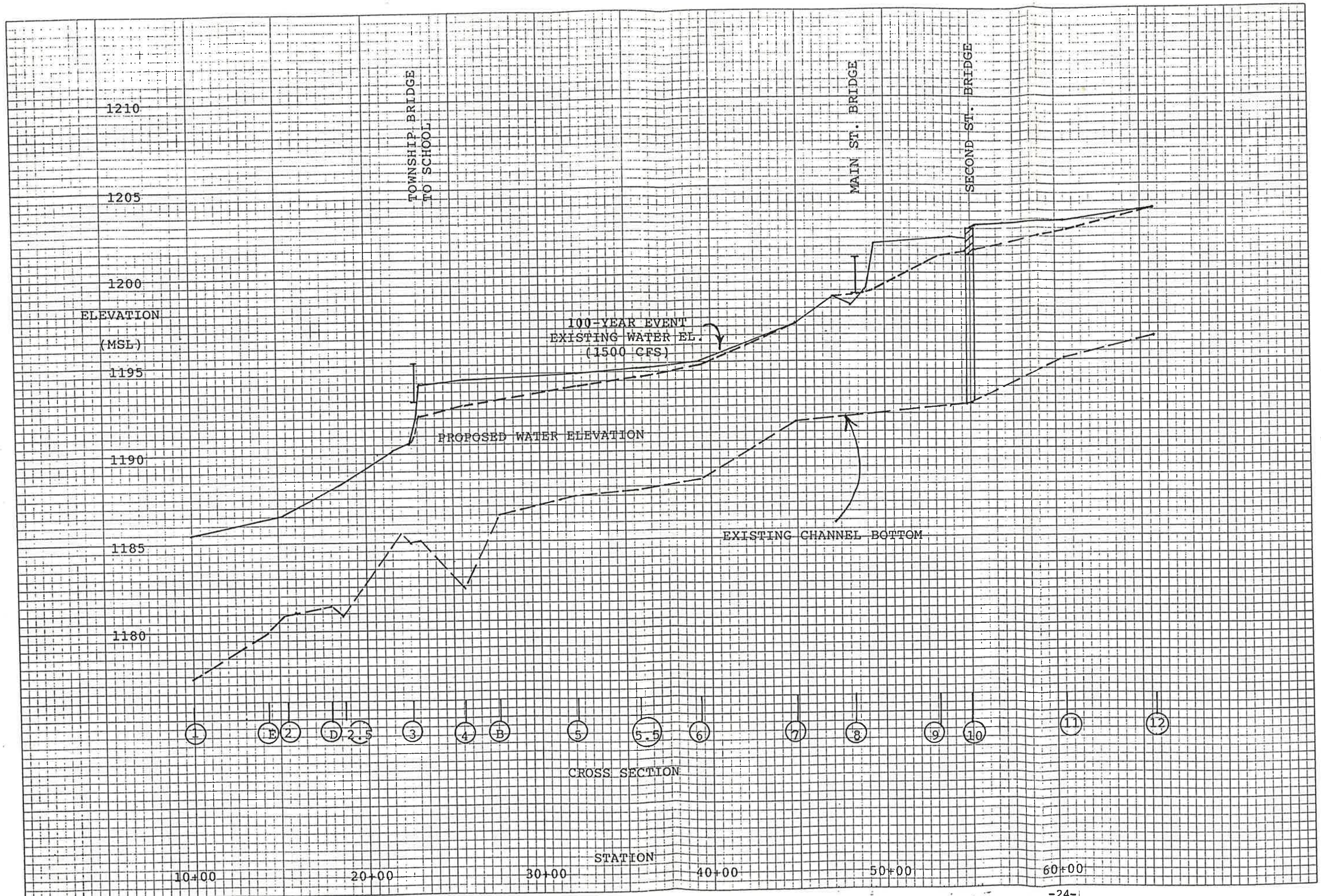

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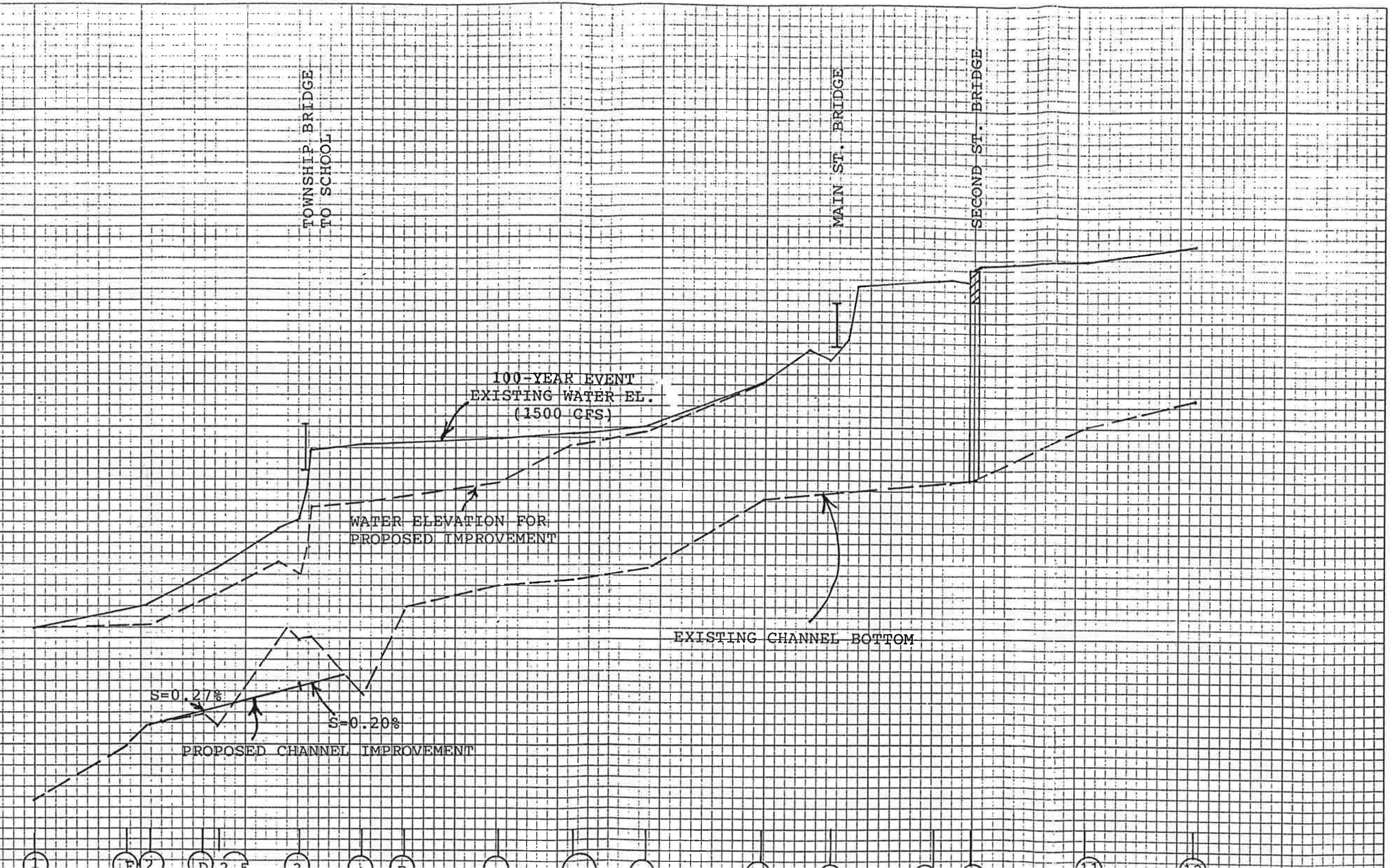
PLATE - BRIDGE REMOVAL

PLATE 2 - Bridge Removal


TOWNSHIP BRIDGE
TO SCHOOL
MAIN ST. BRIDGE
SECOND ST. BRIDGE
100-YEAR EVENT
EXISTING WATER EL.
(1500 CFS)
WATER ELEVATION FOR
PROPOSED IMPROVEMENT
EXISTING CHANNEL BOTTOM
S=0.27%
S=0.20%
PROPOSED CHANNEL IMPROVEMENT

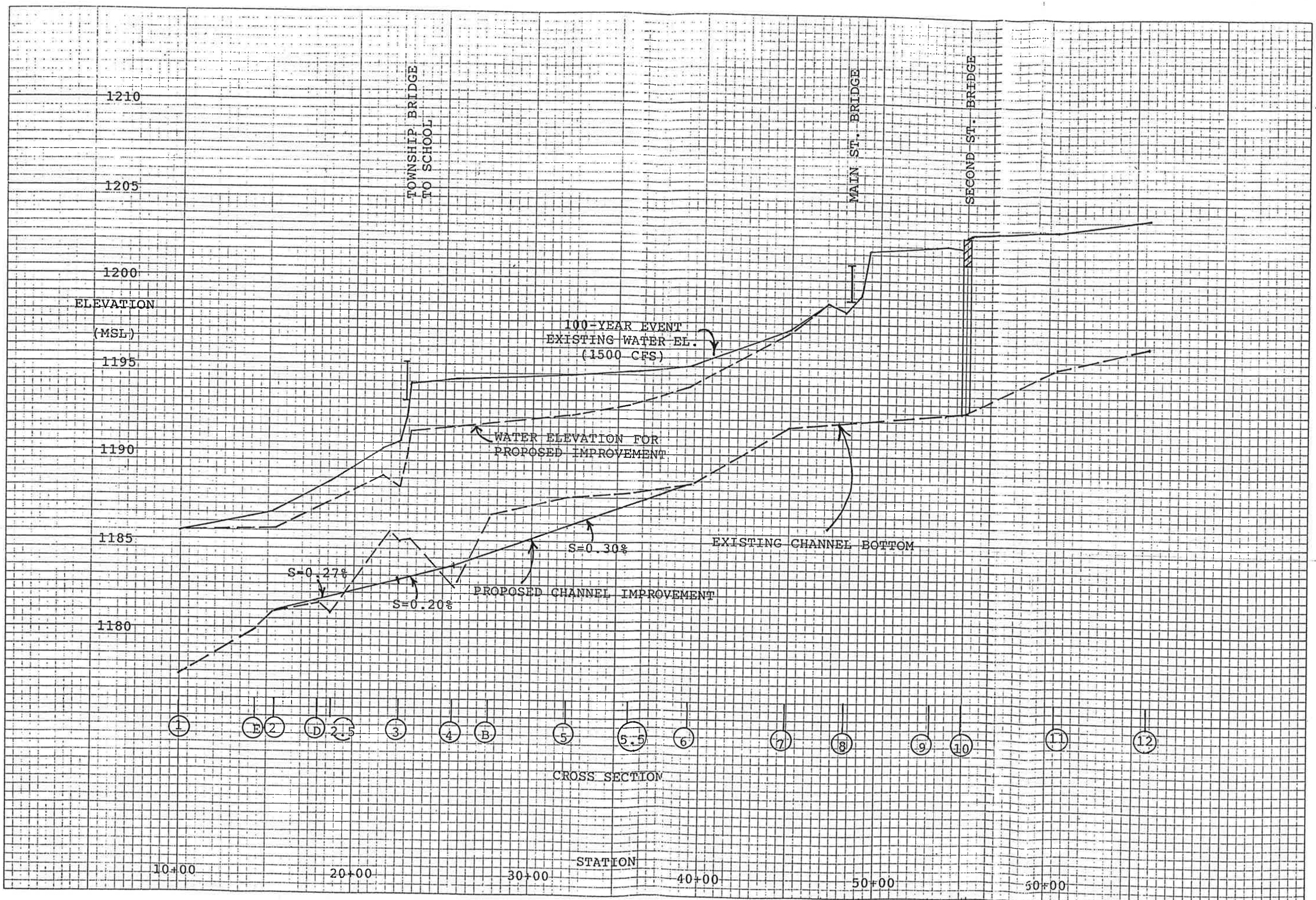


PLATE 4 - Alternative 3

PLATE 5 - Alternative 4

PLATE 6 - Alternative 5