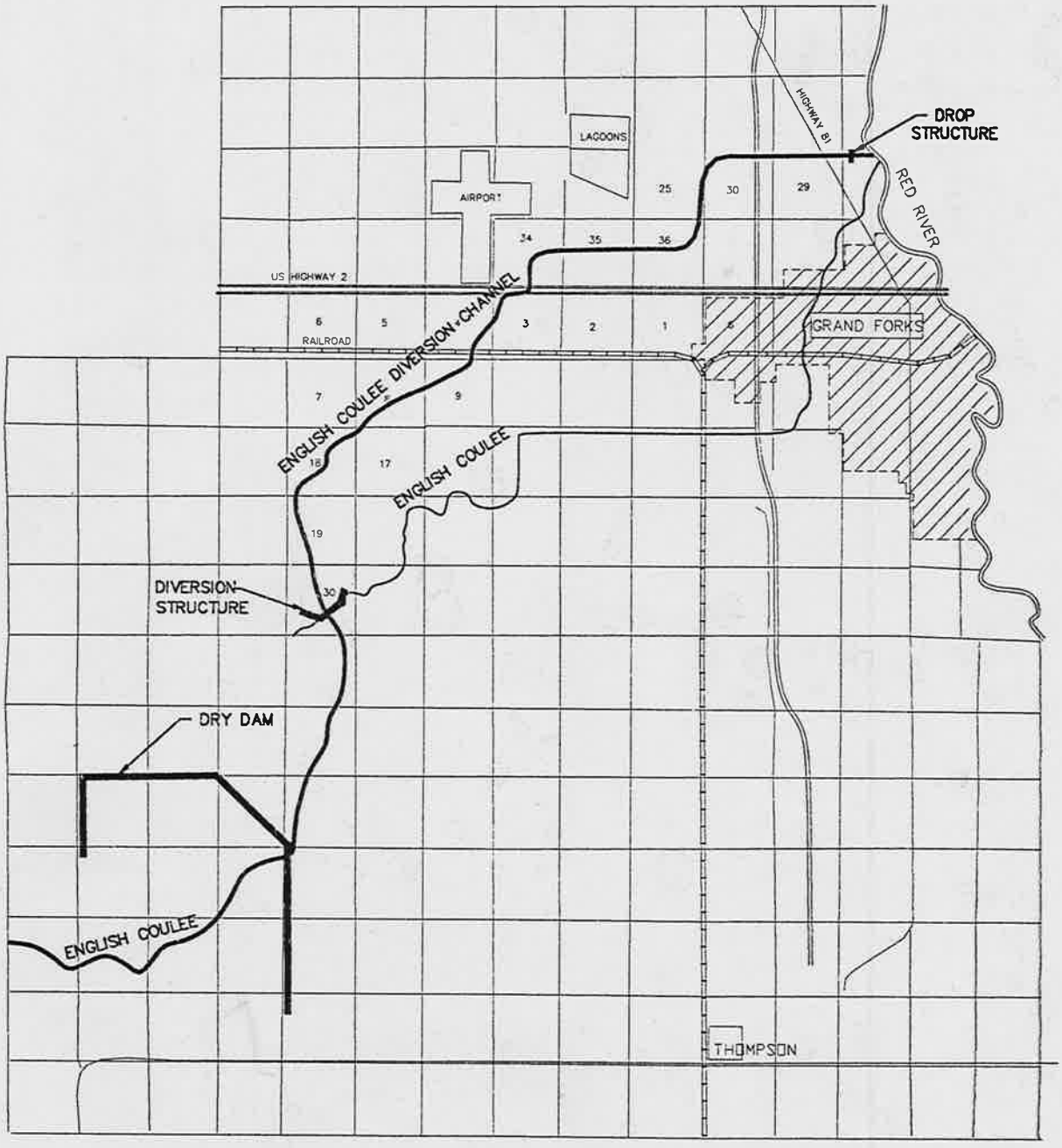
HYDRAULIC ANALYSIS

ENGLISH COULEE DIVERSION

SWC # 1351

GRAND FORKS COUNTY



NORTH DAKOTA
STATE WATER COMMISSION

SEPTEMBER 1994

PRELIMINARY ENGINEERING REPORT

English Coulee Diversion

SWC Project #1351

September 1994

North Dakota State Water Commission
900 East Boulevard
Bismarck, North Dakota 58505-0850

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I. INTRODUCTION

Study Objectives:

A hydraulic analysis of the English Coulee Diversion Channel was completed in order to certify that the diversion channel would meet federal floodplain requirements. The channel certification was also required for a map revision of the Flood Insurance Rate Map (FIRM) of the floodplain along the English Coulee in Grand Forks.

In order to meet federal requirements, the 100-year profile must either be at, or below natural ground, or if the profile is above natural ground, the channel dikes must be certified to contain the profile with 2 feet of freeboard.

Location:

The project area is located in eastern North Dakota, near the city of Grand Forks, in Grand Forks County. The diversion channel is one part of a flood control project to reduce flooding along English Coulee in Grand Forks. The project was completed in 1990, and consists of a dam and diversion structure constructed by the Soil Conservation Service (SCS), and the diversion channel constructed by the ND State Water Commission (Commission) in 1984 (Figure 1).

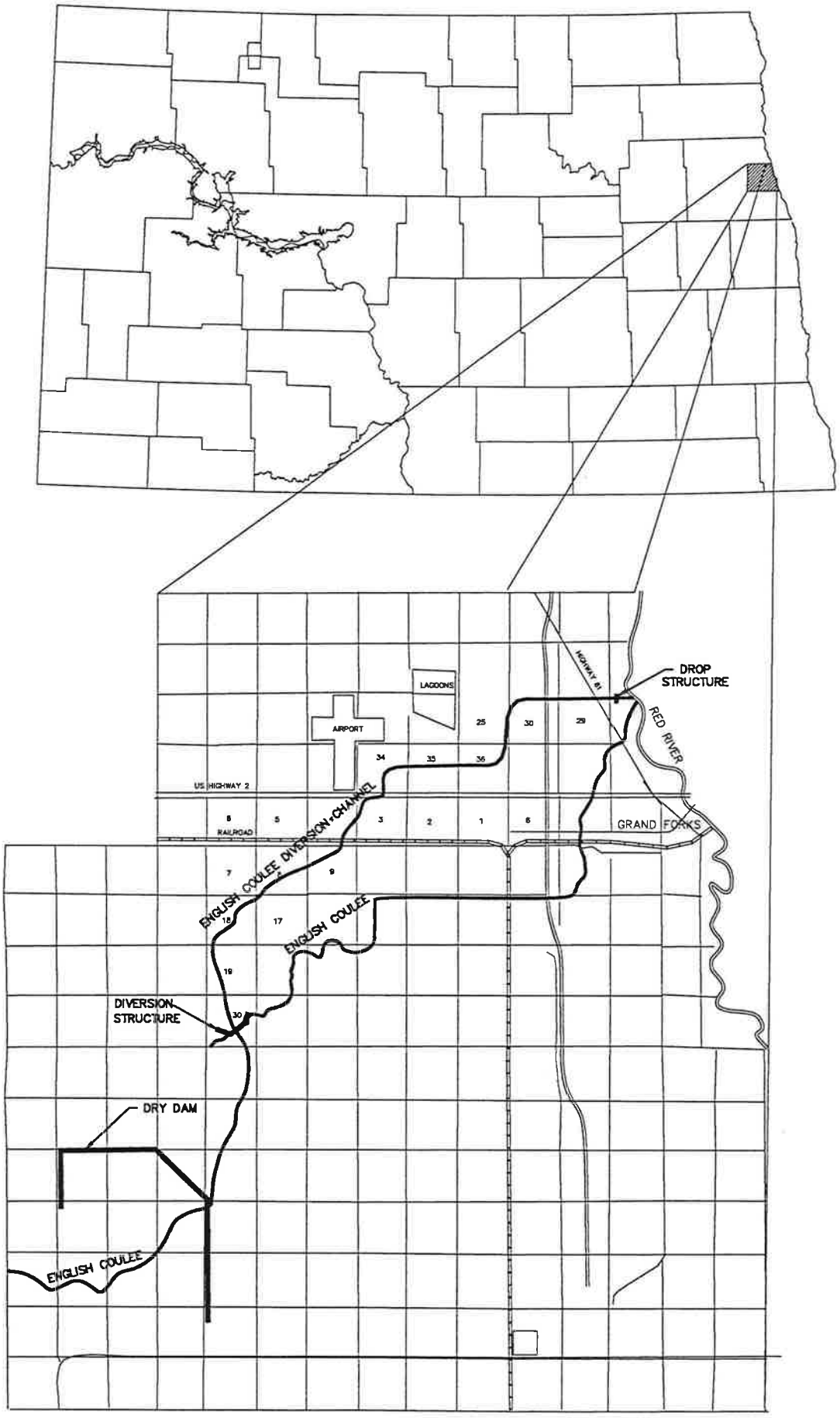

Figure 1

LOCATION MAP

Site Description:

The diversion channel is approximately 13 miles in length. The channel starts in the NW¼ of Section 28, Township 151 North, Range 50 West, and extends upstream to the diversion structure located in the NE¼ of Section 30, Township 151 North, Range 51 West. The construction of the diversion channel was done in two phases. Phase I extends from the Red River upstream approximately 6 miles to US Highway 2, and follows the alignment of Drain 18 approximately 4 miles upstream of the Red River, the remaining 2 miles is a constructed channel. Phase II extends from U.S. Highway 2, upstream approximately 7 miles to the diversion structure. The work consisted of channel construction, dike construction, construction of channel crossing, including placement of rock riprap at existing crossings for erosion control and installing culverts for local drainage.

The first 4 miles of the channel follows the alignment of what used to be Drain #18. The channel over this reach is an earthen channel with a 40-foot bottom width and 4:1 side slopes. The majority of the channel is below natural ground, but a dike was constructed along two sections. The first section extends 0.75 miles from I-29 in the NE¼ of Section 30, Township 152 North, Range 50 West, to the northwest corner of Section 30, Township 152 North, Range 50 West.

The dike along the south side of the drain is approximately 2 feet high, with 4:1 side slopes and an 8-foot top width. The second section of dike work was along a 1/2-mile section extending from the northeast corner of Section 36, Township 152

North, Range 51 West, to the southeast corner NE¼ of the same section. The dike work was only along the west side of the drain and consisted of a dike 2 feet high, 4:1 side slopes, and an 8-foot top width. The next 2 miles of the channel is a constructed channel, with a 16-foot bottom width and 4:1 side slopes. The majority of the channel is below natural ground.

The remaining 6 miles of channel involved the deepening of an existing drain. Work on this reach also included constructing road crossings, dike construction, and installing culverts for local drainage. The channel over this reach is an earthen channel with a 12-foot bottom width and 4:1 side slopes. The first 4 miles of this reach included construction of a dike approximately 3 feet high along both sides of the channel. The channel is below natural ground for the remaining 2 miles of this reach.

II. PROCEDURES

The HEC-2 computer model was used in the hydraulic analysis of the diversion channel. The HEC-2 model was developed by the US Army Corps of Engineers. The model calculates the water surface profiles based on the cross-sectional shape and distance between cross-sections, the channel slope, the channel roughness, and the flow.

The HEC-2 computer model was used to generate the 100-year water surface profile for the English Coulee Diversion Channel. The profile is calculated proceeding upstream, extending from the confluence of the diversion channel and the Red River upstream to the diversion structure.

The model consists of four reaches. Reach 1 extends approximately 3.5 miles from the confluence with the Red River upstream to the southeast corner NE¼ of Section 36, Township 152 North, Range 52 West. Reach 2 extends approximately 3 miles upstream from the end of Reach 1 to the northeast corner NE¼ of Section 3, Township 151 North, Range 51 West, immediately south of US Highway 2. The third reach starts at the termination of Reach 2, extending 5 miles upstream to the SW¼ of Section 18, Township 151 North, Range 51 West. The final reach, Reach 3b, extends from the end of Reach 3, upstream to the diversion structure located in the NE¼ of Section 30, Township 151 North, Range 51 West (Figure 2).

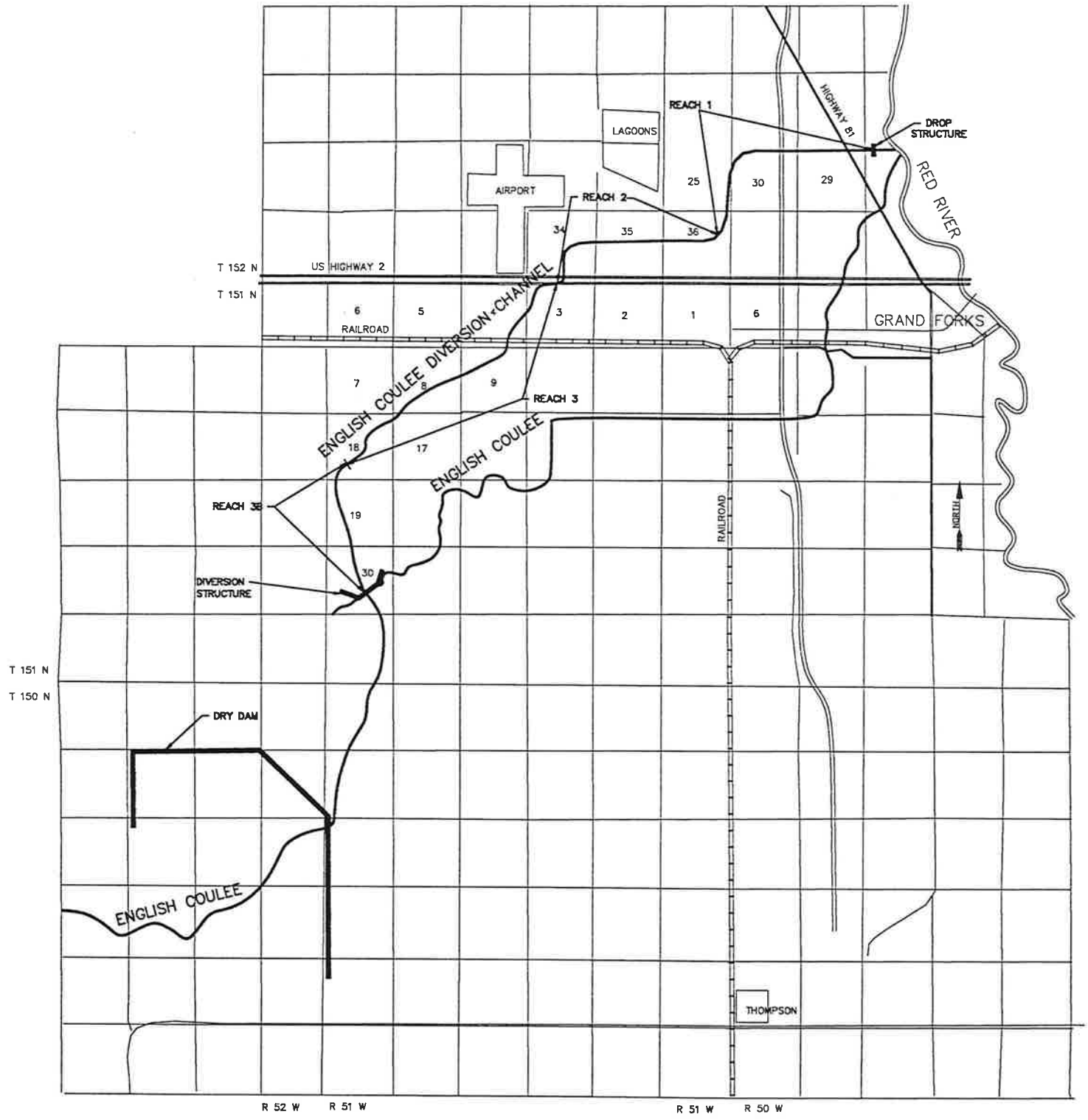

Figure 2 - Map Showing Channel
Alignment and Reaches Used in HEC-2 Model

Cross-Sections:

The information for the cross-sections in the model was obtained from two sources. The SCS conducted a survey on Drain #18 in 1979. This information was used to define the cross-sections in Reach 1. The modifications to the existing channel in Reach 1 were obtained from Water Commission "as-built" plans for Phase I. The cross-sections for Reaches 2, 3, and 3b, were input from Water Commission as-built surveys of Phases I and II. The HEC-2 cross-sections are identified on the plan and profile sheets for Phases I and II. The reach lengths were obtained directly from the cross-section data. The cross-sections used in the model can be found in Appendix A.

Channel Roughness:

Manning's roughness coefficient was calculated using the following equation: **N=(Nb + N1 + N2 + N3 + N4) * M:** where Nb=base value; N1=correction for surface irregularities; N2=variations in shape and size of cross-section; N3=value for obstructions; N4=value for vegetation; and M=factor for meandering.

The base value for the channel was assumed as 0.025 (channel constructed in firm soil). The channel is uniform in cross-section, with unobstructed flow and very little vegetation growing in the channel; therefore, the values assigned for N1, N2, N3, and N4 were 0, 0, 0, and 0.005, respectively. The factor for meandering was assumed to be 1; therefore, the resultant manning's "n" used in the model is 0.030. The following photos are representative of channel conditions (Figure 3).

Photo 1 - Showing Typical Channel Condition of Upper Reach of English Coulee Diversion

Photo 2 - Showing Typical Channel Condition of Lower Reach of English Cooulee Diversion

Figure 3 - Representative Photos of
Channel Condition of English Coulee Diversion

Design Flow:

The flows used in the model were developed by the SCS. The initial design flows were calculated assuming concurrent peaks. Table 3A gives the initial design flows. During the study, a question was raised on the validity of assuming concurrent peaks, when it is likely, based on timing, the peak flows from the uncontrolled drainage area downstream of the dam would be gone prior to the peak flow from the dam. The Water Commission and SCS discussed this issue and decided neglecting the timing was overly conservative and unrealistic. However, both agreed a detailed hydrologic study of the entire basin would require a great deal of time and was not justified. The SCS did develop a hydrologic model for the uncontrolled drainage area (approximately 8 square miles) between the dam and the diversion structure downstream. The results reduced the peak flow at the diversion structure by 144 cfs from 1104 cfs, the original design flow, to 960 cfs. Based on this, the original design flows downstream of the diversion structure were reduced by 144 cfs. The following table gives discharges used in the model.

Table 1 - Discharge Versus Cross-Section
Design Discharges Less SCS Adjustment

Reach	HEC-2 Cross-Section	Station	Discharge
1	70	73+00	1382
	5467	86+13	1346
	6146	65+13	1306
	6831	50+13	1272
2	106.9	506+85	1272
	1854.4	454+81	1256
	4201.8	399+99	1234
	5948.5	346+70	1132
3	162	358+72	1132
	3385.2	283+09	1043
	6166.9	164+17	960

TABLE 3A - STRUCTURAL DATA
FLOODWAY -
ENGLISH COULEE WATERSHED, NORTH DAKOTA

Reach	Station	Drainage Area 2/ sq. mi.	Design Capacity 3/ cu.ft./sec.	Water Surface Elev. ft.-msl.	Hydraulic Gradient 4/ ft./ft.	Existing Channel Data 1/ Gradient ft./ft.	Wetted Perimeter ft.	Cross Section Area sq. ft.	"n" value Aged	"n" value As Built	Velocities ft./sec. Aged	Velocities ft./sec. As Built	Excavation Volume - 1,000 cu. yds.	Type of Work 5/	Existing Channel Type 6/	Present Flow 7/ Conditi
1	700+00			821.4												
		82.9	1526		0.0017	0.0013	97	386	0.040	-	3.96	-	-	V	M(1968)	E
	697+00			821.9												
		82.9	1526		0.0017	0.0005	128	775	0.040	-	1.97	-	-	VI	M(1965)	E
	667+00			827.1												
		82.9	1526		0.0004	0.0007	119	684	0.040	-	2.23			VI	M(1965)	E
	638+00			828.2												
		82.9	1526		0.0008	0.0003	337	980	0.040	-	1.56	-	-	VI	M(1965)	E
	607+00			830.7												
		82.9	1526		0.0004	0.0006	116	739	0.040	-	2.07	-	-	VI	M(1965)	E
	570+00			832.1												
		80.9	1490		0.0003	0.0006	129	718	0.040	-	2.02	-	-	VI	M(1965)	E
	537+00			833.1												
		79.9	1416		0.0004	0.0003	121	677	0.040	-	2.09	-	-	VI	M(1965)	E
	513+00			834.1												

1/ Existing channel varies 40 to 50 foot bottom, 4:1 minimum side slopes, Vegetation established.

2/ Total drainage area, 57.1 square miles controlled by dam.

3/ Peak discharge, uncontrolled drainage area plus peak outflow from dam.

4/ Includes effects of bridge head losses at design discharge.

5/ V - Stabilization of localized area, present capacity adequate.
VI - Present floodway capacity adequate, no work planned.

6/ M() - Manmade or previously modified, () is approximate date of original construction.

7/ E - Ephemeral, flows only during periods of surface runoff, otherwise dry.

TABLE - 3 TORA A

FLOODWAY -

ENGLISH COULEE WATERSHED, NORTH DAKOTA

Reach	Station	Drainage 1/ Area sq. mi.	Design Capacity 2/ cu.ft./sec.	Water Surface Elev. ft.-msl.	Hydraulic Gradient 3/ ft./ft.	Floodway Dimension: Bottom Gradient ft./ft.	Bottom Width ft.	Bottom Elevation ft.-msl.	Side-Slopes	"n" value: As Aged	"n" value: As Built	Velocities ft./sec.: As Aged	Velocities ft./sec.: As Built	Excavation: Volume - 1,000 cu. yds.	Type of Work 4/	Existing Floodway: Type 5/	Present Flow 6/ Condition
II	513+00			834.1													
		79.9	1416		0.0005	0.0003	16		4:1	0.035	0.025	2.59	3.04	151,300	I	-	-
	454+32			836.8				827.0									
		78.9	1378		0.0004	0.0003	16		4:1	0.035	0.025	2.41	3.01	70,600	I	-	-
	400+00			838.7				828.6									
		78.9	1378		0.0003	0.0003	16		4:1	0.035	0.025	2.40	3.02	141,400	I	-	-
	346+27			840.4				830.2									
III	372+18			842.4				831.3									
		76.9	1276		0.0002	0.0006	12		4:1	0.035	0.025	2.46	2.70	22,600	II	M(1977)	E
	324+72			844.0				834.0									
		76.9	1276		0.0004	0.0006	12		4:1	0.035	0.025	2.72	3.16	16,600	II	M(1977)	E
	292+96			845.4				835.9									
		72.6	1187		0.0004	0.0005	12		4:1	0.035	0.025	2.64	3.28	17,100	II	M(1977)	E
	241+32			847.7				838.5									
		72.6	1187		0.0005	0.0006	12		4:1	0.035	0.025	2.88	3.63	29,700	II	M(1977)	E
	173+88			851.3				842.5									
					0.0005	0.0005	12		4:1	0.035	0.025	2.69	3.45	22,400	II	M(1977)	E
	120+00			854.0				845.2									
		69.1	1104		0.0005	0.0005	12		4:1	0.035	0.025	2.70	3.46	9,100	II	M(1977)	E
	99+63			855.0				846.2									
	99+63d/s Equals 188+92u/s																
	188+92			855.0				846.2									
		69.1	1104		0.0006	0.0006	12		4:1	0.035	0.025	2.85	3.40	21,000	II	M(1977)	E
	104+19			859.8				851.3									

1/ Total drainage area, 57.1 square miles controlled by dam.

2/ Peak discharge, uncontrolled drainage area plus peak outflow from dam.

3/ Includes effects of bridge head losses at design discharge.

4/ I - Establishment of new floodway, none existing presently.
II - Enlargement of existing floodway.

5/ M() - Manmade or previously modified, () is approximate date of original construction.

6/ E - Ephemeral, flows only during periods of surface runoff, otherwise dry.

Starting Water Surface:

The model started at the most downstream point, the drop structure at Sta. 73+00. The first step was to determine if the drop structure was affected by backwater from the Red River, i.e., free overfall versus submerged weir flow. The downstream starting water elevation assumed a 2-year event on the Red River (personal communications Terry Carlson, SCS, and Dean Weiland, CPS Engineering). The 2-year flow on the Red River is approximately 20,100 cfs, as stated in the "Techniques for Estimating Peak-Flow Frequency Relation for North Dakota Streams," USGS WRI 92-4020. The corresponding stage is approximately 811.5 msl, as taken from the rating curve for the Grand Forks gauge. The sill of the drop structure is at 815.5 msl; therefore, submergence is not a factor and the model was started at critical depth, water surface elevation 819.63 msl.

III. RESULTS

The results indicate the 100-year profile from the drop structure upstream to US Highway 2 (Reaches 1 and 2) is at or below natural ground, with the exception of the cross-section immediately upstream of the drop structure. However, if a breakout would occur in this location, the flow would be contained with no adverse impacts to Grand Forks.

The model indicates the profile is above natural ground and the dikes do not have the required 2 feet of freeboard, for approximately 4 miles upstream of US Highway 2 (Reach 3). The channel extends from the double 8' x 8' concrete box culverts at US Highway 2, northeast corner NW¼ of Section 3, Township 151 North, Range 51 West, upstream to the NE¼SW¼ of Section 8, Township 151 North, Range 51 West. Upstream from this section of channel to the diversion structure, the profile is contained within natural ground.

IV. PRELIMINARY DESIGN

Based on the results of the model, the channel certification could be accomplished by two primary means: 1) map the inundated area where the profile was above natural ground; or 2) certify the dikes by establishing the flow is contained with 2 feet of freeboard. The freeboard requirement can be met either by enlarging crossings to lower the profile to obtain 2 feet of freeboard, and/or adding fill to the dikes to obtain the freeboard.

A survey was conducted on the section of channel not meeting federal requirements. The purpose of the survey was to obtain topographical information for possible mapping of the area where the profile was above natural ground, and for use in calculating fill volumes. The survey was conducted in the summer of 1994, and included obtaining dike and ground elevations adjacent to the channel, elevations and type culverts at closure locations, elevations and type of culverts at road crossings, and road profiles. The plan view of the problem area can be seen in Plate 1.

The 100-year profile was plotted against natural ground elevations adjacent to the channel. The plot indicated the profile was above natural ground. Due to the flat topography, mapping the entire area of inundation would result in putting a large area in the 100-year floodplain. This option was not considered. Therefore, a combination of possible channel modifications to lower the profile and placement of fill to obtain the 2-foot freeboard were investigated.

Many possible combinations of channel modifications and fill requirements were considered before finding the option which was the least costly while meeting federal requirements. The recommended alternative is enlarging two field crossings and placement of approximately 20,000 CY of fill.

The first crossing is located in the NW¼ of Section 3, Township 151 North, Range 51 West. The crossing provides field access and consists of two 7'3" x 11'5" arch pipes. The present head loss across this structure is approximately 1-foot. The proposed modification calls for removing the arch pipes and construction of a low-head crossing, with the top of road approximately 5 feet above the channel bottom. This modification reduces the head loss to less than 0.1 of a foot.

The second crossing is located in the SE¼ of Section 151 North, Range 51 West. This crossing provides access to a feedlot and pasture, and like the first consists of two 7'3" x 11'5" arch pipes. The present head loss is approximately 1-foot. The proposed modification calls for relaying and the culverts removed from crossing one, increasing the number of pipes at this crossing to four. The modification reduces the head loss at this crossing to approximately 0.3 feet.

Modification at the crossing located on the section line between Sections 8 and 9, Township 151 North, Range 51 West, should be conducted since the freeboard is approximately 1-foot. The crossing is located in a swale on the township road, with two 7'3" x 11'5" arch pipes approximately 60 feet in length. The area can easily be

sandbagged to contain any possible breakouts; therefore, increasing the crossing was not considered necessary.

In addition to modifying crossings, fill is also required to increase the height of dikes in certain areas to obtain 2 feet of freeboard. The fill areas are identified on Plate 1, Appendix B.

A discharge sensitivity analysis was performed, assuming the modifications outlined above were performed. The analysis is to determine the approximate overland flow if there is a dike failure. The following table shows the results of the analysis.

Table 2 - Discharge Sensitivity Analysis
Overland Flow Versus Location

Station	Flow (cfs)
360+00 to 320+00	0-50
293+50 to 291+00	150
278+00 to 255+00	200-300
235+00 to 212+00	300

The results of the analysis indicate in the event of a complete failure of the dike system, overland flow would not present a major threat to increased flooding in Grand Forks, even though minor localized flooding would occur.

V. SUMMARY

A hydraulic analysis of the English Coulee Diversion Channel was conducted. The purpose was to certify the channel meets federal floodplain requirements. The certification is required to remove portions of the city of Grand Forks along the English Coulee from the 100-year floodplain.

The diversion channel is one phase of a three-phase project. The project includes a dry dam and diversion structure designed by the SCS, and the diversion channel designed by the Commission. The diversion channel functions as a bypass, diverting flood-flows away from the city of Grand Forks. The diversion channel is approximately 13 miles in length and extends from the Red River upstream to the diversion structure.

The first 4 miles of the diversion is an earthen channel with a 40-foot bottom width and 4:1 side slopes, with the majority of the channel below natural ground. The next 2 miles of the diversion is an earthen channel with a 16-foot bottom width and 4:1 side slopes, again the majority of the channel is below natural ground. The remaining 7 miles consisted of deepening an existing drain. The diversion over this reach has a 12-foot bottom with 4:1 side slopes. Dikes were constructed approximately 3 feet high along both sides of channel for the first 4 miles of this reach. The channel is below natural ground for the remaining 3 miles of this reach.

The hydraulic analysis indicates approximately 4 miles of the diversion channel does not meet federal floodplain requirements. The area starts at US Highway 2, and extends 4 miles upstream. The modifications required to bring the diversion channel into compliance with federal standards, includes modifying two field crossings and placement of about 20,000 CY of fill.

A sensitivity analysis was performed to determine overland flow in the event of a dike failure. The analysis was run assuming the two crossings were modified and the dikes were raised. The results indicate that overland flow would result in low velocity, localized flooding in the rural areas, but would not aggravate flooding in Grand Forks.

APPENDIX A

Cross Sections Used in HEC-2 Model

ENGLISH COULEE DIVERSION SWC #1351
CROSS-SECTIONS REACH 1

HEC-2 CROSS-SECTION	REACH LENGTH	SCS STATIONS	HIGHWAY SWC STATIONS	NOTES
70	0	700+00	73+00	DROP STRUCTURE @ RED RIVER
269	100	699+00	72+00	
397	200	697+00	70+00	
399	230	694+70	67+70	
493.7	100	693+70	66+70	
593.4	30	693+40	66+40	BRIDGE @ NE 1/4 29-152-50
693	40	693+00	66+00	
790	300	690+00	63+00	
887	300	687+00	60+00	
984	300	684+00	57+00	
1081	300	681+00	54+00	
1178	300	678+00	51+00	
1275	300	675+00	48+00	
1373	106	673+94	46+94	
1373.1	83	673+11	46+11	BRIDGE HWY 81 NE 1/4 29-152-50
1470	60	672+51	45+51	
1470.1	251	670+00	43+00	
1567	300	667+00	40+00	
1664	300	664+00	37+00	
1761	300	661+00	34+00	
1858	300	658+00	31+00	
1955	300	655+00	28+00	
2052	300	652+00	25+00	
2149	300	649+00	22+00	
2246	300	646+00	19+00	
2343	300	643+00	16+00	
2441.4	135	641+65	14+65	RR BRIDGE @ NW 1/4 29-152-50
2541.3	32	641+33	14+33	
2638.1	33	641+00	14+00	
2738	300	638+00	11+00	
2763.5	300	635+00	8+00	
2832	300	632+00	5+00	
2928.8	318	628+82	1+82	
2928.9	114	627+68	0+68	EQ. STA. 145+91 BK = 0+00 AHD
3126.1	168	626+00	144+91	DBL. 10X9 BOX CULVERTS I-29
3225.5	65	625+35	144+26	PHASE I STARTS IMMEDIATELY UPSTREAM OF
3324.9	64	624+71	143+62	I-29
3422	249	622+00	141+13	
3519	300	619+00	138+13	
3616	300	616+00	135+13	
3713	300	613+00	132+13	
3810	300	610+00	129+13	
3907	300	607+00	126+13	
4004	300	604+00	123+13	
4101	300	601+00	120+13	
4298	300	598+00	117+13	
4395	300	595+00	114+13	
4492	300	592+00	111+13	
4589	300	589+00	108+13	
4687.3	175	587+25	106+38	BRIDGE NW 1/4 30-152-50
4786.9	30	586+95	106+08	
4885	85	586+10	105+23	
4886	110	585+00	104+13	
4982	300	582+00	101+13	
5079	300	579+00	98+13	
5176	300	576+00	95+13	
5273	300	573+00	92+13	
5370	300	570+00	89+13	
5467	300	567+00	86+13	
5564	300	564+00	83+13	
5661	300	561+00	80+13	
5758	300	558+00	77+13	

ENGLISH COULEE DIVERSION SWC #1351
CROSS-SECTIONS REACH 1

HEC-2 CROSS-SECTION	REACH LENGTH	SCS STATIONS	HIGHWAY SWC STATIONS	NOTES
5855	300	555+00	74+13	
5952	300	552+00	71+13	
6049	300	549+00	68+13	
6146	300	546+00	65+13	
6243	300	543+00	62+13	
6340	300	540+00	59+13	
6437	300	537+00	56+13	
6534.5	247	534+53	53+66	TIMBER BOX CULVERTS NE 1/4 36-152-51
6633.9	61	533+92	53+05	
6731.1	60	533+32	52+45	
6831	232	531+00	50+13	
6928	300	528+00	47+13	
7025	300	525+00	44+13	
7124	100	524+00	43+13	
7223.7	30	523+70	42+83	RR BRIDGE NE 1/4 36-152-51
7323.5	25	523+45	42+58	
7422	145	522+00	41+13	
7519	300	519+00	38+13	
7618.9	120	517+80	36+93	FIELD CROSSING NE 1/4 36-152-51
7718.8	30	517+50	36+63	
7816	30	517+00	36+33	
7817	100	516+00	35+33	
7913	300	513+00	32+33	
8010	300	510+00	29+33	
8107.5	189	508+11	27+44	END REACH 1; START REACH 2

ENGLISH COULEE DIVERSION SWC #1351
CROSS-SECTIONS REACH 2

HEC-2 CROSS-SECTIONS	REACH LENGTHS	SWC STATIONS	NOTES
106.9	0	506+85	START REACH 2
203	385	503+00	
300	300	500+00	
397	300	497+00	
494	300	494+00	
591	300	491+00	
688	300	488+00	
785	300	485+00	
882	300	482+00	
979	300	479+00	
1076	300	476+00	
1173	300	473+00	
1174	300	470+00	
1267	300	467+00	
1364	300	464+00	
1461	300	461+00	
1558	300	458+00	
1559	107	456+93	
1754.6	100	455+93	
1854.4	112	454+81	14' X 24' STRUCTURAL ARCH PIPE (R VS. S) @ SE NE 1/4 35-152-51
1954.3	1	454+80	
2054.2	74	454+06	
2154.1	1	454+05	
2254	134	452+71	
2452	71	452+00	
2549	300	449+00	
2646	300	446+00	
2743	300	443+00	
2840	300	440+00	
2937	300	437+00	
3034	300	434+00	
3132	325	429+20	EQ. 431+15 BK. = 432+63 AHD.
3228	300	426+20	
3325	300	423+20	
3422	300	420+20	
3519	300	417+20	
3616	300	414+20	
3713	300	411+20	
3810	300	408+20	
3907	300	405+20	
4004	291	402+29	
4103.1	200	400+29	
4201.8	30	399+99	5 - 6' CMP'S @ SE NE1/4 34-152-51
4201.9	50	399+49	
4598	30	399+19	
4695	200	397+19	
4792	92	396+27	
4889	300	393+27	
4986	300	390+27	
5083	300	387+27	
5180	300	384+27	
5277	300	381+27	
5370	300	378+27	
5465	300	375+27	
5560	287	372+40	
5655	240	370+00	
5656	200	368+00	
5657	200	366+00	
5658	200	364+00	
5659	200	362+00	
5660	200	360+00	
5661	200	358+00	
5662	200	356+00	
5663	200	354+00	
5664	200	352+00	
5665	200	350+00	
5750.1	100	349+00	
5848.6	50	348+50	DOUBLE 8' X 8' BOX CULVERTS @ US HIGHWAY 2
5948.5	180	346+70	
6046.6	40	346+30	END REACH 2/PHASE I; START REACH3/PHASE II

ENGLISH COULEE DIVERSION SWC #1351
CROSS-SECTIONS REACH 3

HEC-2 CROSS-SECTIONS	REACH LENGTHS	SWC CENTERLINE STATIONS	NOTES
162	0	358+72	START REACH 3/PHASE II ENGLISH COULEE DIVERSION
258	200	356+72	
354	200	354+72	
450	200	352+72	
548.1	200	350+72	
647	200	348+72	
648	200	346+72	
649	200	344+72	
650	113	343+59	MODIFIED FIELD CROSSING NW 1/4 3-151-51
746.2	60	342+99	
845.9	38	342+61	
850.9	40	342+21	
945.5	95	341+26	
1044.8	62	340+64	
1142.5	108	339+56	
1143	209	337+47	
1144	185	335+62	
1145	200	333+62	
1331	200	331+62	
1332	200	329+62	
1333	223	327+39	
1425	194	325+45	
1426	200	323+45	
1427	199	321+46	
1428	195	319+51	
1519	185	317+66	
1618.3	200	315+66	
1717.2	90	314+76	SINGLE SPAN CONCRETE BRIDGE SW NW1/4 3-151-51
1816.5	34	314+42	
1916.3	170	312+72	
2011	185	310+87	
2012	214	308+73	
2013	200	306+73	
2105	198	304+75	
2106	199	302+76	
2200.2	200	300+76	
2201	200	298+76	
2202	200	296+76	
2398.4	70	296+06	FIELD CROSSING SE1/4 4-151-51; LOCATED IN EARL'S PASTURE
2498.1	15	295+91	
2597.7	116	294+75	
2693	176	292+99	
2792.8	198	291+01	
2793	128	289+73	
2891.2	70	289+03	MODIFIED EXISTING 2 - 7'X11' ARCH PIPES SE1/4 4-151-51
2990.5	38	288+65	
3090.1	30	288+35	
3187	203	286+32	
3188	174	284+58	
3285.4	131	283+27	RR BRIDGE SE1/4 4-151-51
3385.2	18	283+09	
3484.8	89	282+20	
3583.9	34	281+86	WOODEN TIMBER BRIDGE COUNTY ROAD SECS 4/9 151-51
3683.6	29	281+57	
3783.1	50	281+07	
3784	295	278+12	
3876	254	275+58	
3877	251	273+07	
3970	205	271+02	
3971	197	269+05	
3972	188	267+17	
3973	188	265+29	
4064	171	263+58	
4065	201	261+57	
4066	214	259+43	
4158	210	257+33	
4159	200	255+33	
4160	200	253+33	
4252	200	251+33	
4253	200	249+33	
4255	200	247+33	
4346	200	245+33	
4347	200	243+33	
4348	200	241+33	
4440	200	239+33	
4441	194	237+39	
4535.8	200	235+39	
4536	200	233+39	
4537	125	232+14	

ENGLISH COULEE DIVERSION SWC #1351
CROSS-SECTIONS REACH 3

HEC-2 CROSS-SECTIONS	REACH LENGTHS	SWC CENTERLINE STATIONS	NOTES
4634.2	64	231+50	2 - 7' X 11' ARCH PIPES SECS 8/9 151-51
4733.6	57	230+93	
4833.4	56	230+37	
4835	208	228+29	
4927	200	226+29	
4928	193	224+36	
4929	141	222+95	
5021	234	220+61	
5022	196	218+65	
5023	199	216+66	
5115	200	214+66	
5116	200	212+66	
5117	198	210+68	
5209	200	208+68	
5210	200	206+68	
5211	200	204+68	
5303	200	202+68	
5304	200	200+68	
5305	200	198+68	
5497	195	196+73	
5498	195	194+78	
5499	196	192+82	
5591	203	190+79	
5592	215	188+64	
5593	201	186+63	
5685	203	184+60	
5686	198	182+62	
5687	200	180+62	
5779	131	179+31	
5780	265	176+66	
5781	200	174+66	
5873	200	172+66	
5874	200	170+66	
5968.7	202	168+64	
5969	281	165+83	
6067.1	106	164+77	2 - 7' X 11' ARCH PIPES SECS 18/17 151-51
6166.9	60	164+17	
6266.5	68	163+49	
6267	95	162+54	
6361	130	161+24	
6362	234	158+90	
6363	227	156+63	
6455	188	154+75	
6456	200	152+75	
6457	201	150+74	
6549	200	148+74	
6550	191	146+83	
6551	317	143+66	
6641	189	141+77	
6642	200	139+77	
6643	200	137+77	
6735	200	135+77	
6736	202	133+75	
6737	200	131+75	
6829	229	129+46	
6830	231	127+15	
6831	198	125+17	
6923	200	123+17	
6924	200	121+17	
6925	200	119+17	
7017	200	117+17	
7018	195	115+22	
7019	155	113+67	
7020	107	112+60	
7110	200	110+60	
7111	198	108+62	

ENGLISH COULEE DIVERSION SWC #1351
CROSS-SECTIONS REACH 3B

HEC-2 CROSS-SECTIONS	REACH LENGTHS	SWC CENTERLINE STATIONS	NOTES
7111	0	108+65	START REACH 3B; PHASE II ENGLISH COULEE DIVERSION
7112	211	106+54	
7204	219	104+35	
7205	171	102+64	
7206	199	100+65	
7398	203	98+62	
7399	162	97+00	
7494	200	95+00	
7592.8	200	93+00	
7593	92	92+08	
7594	138	90+70	
7691.4	27	90+43	3 - 7' X 11' ARCH PIPES SECS 18/19 151-51
7790.8	62	89+81	
7890.4	31	89+50	
7891	245	87+05	
7892	205	85+00	
7984	195	83+05	
7985	312	79+93	
8078	230	77+63	
8079	200	75+63	
8080	195	73+68	
8081	123	72+45	
8171	203	70+42	
8172	189	68+53	
8173	198	66+55	
8265	200	64+55	
8266	201	62+54	
8267	197	60+57	
8359	200	58+57	
8360	200	56+57	
8361	199	54+58	
8453	204	52+54	
8454	200	50+54	
8455	200	48+54	
8547	196	46+58	
8548	200	44+58	
8549	200	42+58	
8641	199	40+59	
8642	200	38+59	
8643	175	36+84	
8735	145	35+39	
8838.8	128	34+11	2 - 7' X 11' ARCH PIPES SW1/4 19-151-51
8933.3	60	33+51	
9032.9	40	33+11	
9033	66	32+45	
9034	117	31+28	
9035	113	30+15	
9127	355	26+60	
9226.3	160	25+00	
9325.1	29	24+71	2 - 7' X 11' ARCH PIPES SECS NW 1/4 30-151-51
9424.7	32	24+39	
9524.3	89	23+50	
9525	192	21+58	
9618	182	19+76	
9619	181	17+95	
9620	204	15+91	
9621	197	13+94	
9712	201	11+93	
9810	200	9+93	
9811	93	9+00	
9818.5	55	8+45	2 - 7' X 11' ARCH PIPES NW1/4 30-151-51
9908.2	49	7+96	
9917.8	50	7+46	
9918	150	5+96	
9924.7	136	4+60	END PHASE II ENGLISH COULEE DIVERSION; REMAINING STATIONS FROM SCS
9925	162	2+98	START APPROACH TO DIVERSION STRUCTURE
9926	100	1+98	
9927	100	0+98	100 FEET DOWNSTREAM OF DIVERSION STRUCTURE

APPENDIX B

Plan View of Diversion Channel With Proposed Modifications