FINAL REPORT

Cougar Creek Flood Risk Mapping Study

March 1994

prepared for

Alberta Environmental Protection River Engineering Branch

prepared by

CH2M HILL Engineering Ltd.

CGY\25182\999.R

Certification

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PROFESSIONAL ENGINEER ALBERTA Jennifer C. Sharp 94/03/08	PERMIT TO PRACTICE CH2M HILL ENGINEERING LTD. Signature Date 94/03/08 PERMIT NUMBER: P 2558 The Association of Professional Engineers, Geologists and Geophysicists of Alberta
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Executive Summary

The Cougar Creek Flood Risk Mapping Study was conducted as part of the Canada-Alberta Flood Damage Reduction Program, and as an addition to the Canmore Flood Risk Mapping Study. This study deals with only surface flooding caused by basin runoff and does not consider potential flooding effects from groundwater or sediment and debris accumulation.

Cougar Creek is a steep mountainous channel, that typically has its highest flows during spring runoff. Floods have been reported in 1948, 1956, 1967, 1974, 1980, and 1990. The creek is usually dry in winter and thus ice formation and ice jamming are of little concern. The creek is ungauged, and flood frequency estimates were made by Alberta Environmental Protection, Hydrology Branch, using a regional frequency analysis of nearby basins with similar characteristics. The drainage basin is typical for a mountainous area with an incised channel in the upper reach opening onto an alluvial fan in the Bow River Valley. The basin has extensive tree cover and an area of approximately 44 km^2, with a total elevation difference across the basin of approximately 1450 m. The study reach is essentially from the Bow River to the upstream end of the alluvial fan and is approximately 3 km in length. For most of the reach, the creek flows in a constructed trapezoidal channel with riprap bank armoring.

Water surface profiles were calculated using the HEC-2 model developed by the U.S. Army Corps of Engineers. Since no reliable high water levels were available for the reach, direct calibration of the model was not possible. Model sensitivity does indicate, however, that the HEC-2 program can be used to accurately predict the water levels for floods up to and including the 1:100-year return period flood. The 1:100-year flood risk limit is shown on a 1:5000 scale orthophoto mosaic with a topographic overlay with one metre contour intervals.

The flood risk map shows that the 1:100-year flood would be contained within the existing channel and would not affect any of the residential or developed areas adjacent to Cougar Creek.

Although this study does not specifically deal with sediment transport, it is known that considerable aggradation and degradation of the channel bed has occurred over the years. The Town of Canmore has set up a monitoring and maintenance program to prevent excessive sediment accumulation in the creek, which may result in higher water surface elevations than predicted by the analysis.

Contents

Section 1
Introduction

Purpose

This study is being carried out as part of the Canmore Flood Risk Mapping Study initiated under the Canada-Alberta Flood Damage Reduction Program. The purpose of the study is to compute water surface profiles for the 1:100-year, 1:50-year, and 1:10-year floods for Cougar Creek, and to prepare a flood risk map based on the 1:100-year flood profile.

Background

Cougar Creek is a tributary creek to the Bow River and is located in the southeast corner of Canmore. It is a steep mountain creek that originates in the Fairholm range east of Canmore and has a drainage basin of approximately 44 km^2. The drainage basin has extensive tree cover and has an elevation difference of approximately 1450 m. In the lower reaches, the creek is directed through culverts under three highway crossings at Elk Run Boulevard, the Trans Canada Highway, and Highway 1A, and a culvert under the CP railroad tracks. The total study reach is approximately 3 km in length. Figure 1 shows the study location.

History of Flooding

Cougar Creek typically has its highest flows during spring runoff in May and June. In the winter the creek is usually dry, so ice formation and jamming is of little concern.

Historical evidence indicates that characteristic flash floods occur at Cougar Creek approximately every 8 to 10 years. Flood events have been reported in 1948, 1956, 1967, 1974, 1980, and 1990. The large flood in 1967 washed out the bridge abutments of the existing Trans Canada Highway. Newspaper reports indicated 70,000 to 80,000 cubic yards (53 500 m^3 to 61 200 m^3) were pushed through the 40-foot (12.2-m) span, although the basis for this information is unknown.

In May 1990, flooding caused failure of the Cougar Creek Dam. The 10 m high rockfill dam had been constructed in 1981 to control sediment from the upper watershed. The report by Alberta Environmental Protection (AEP, formerly Alberta Environment) on the Cougar Creek Dam failure (1991) estimates the inflow rate in the hour before the dam failure to be 13 m^3/s, and the dam at the time of failure contained approximately 35 000 m^3 of water. According to reports of the dam failure, the destruction of the dam was rapid. The flow rate of the resulting flood wave is not known accurately but is estimated to be considerably greater than the 1:100-year design flow.

The dam failure caused major erosion of the creek to occur. The culverts under the Trans Canada Highway, Highway 1A, and the CP railroad tracks were either partly or wholly filled

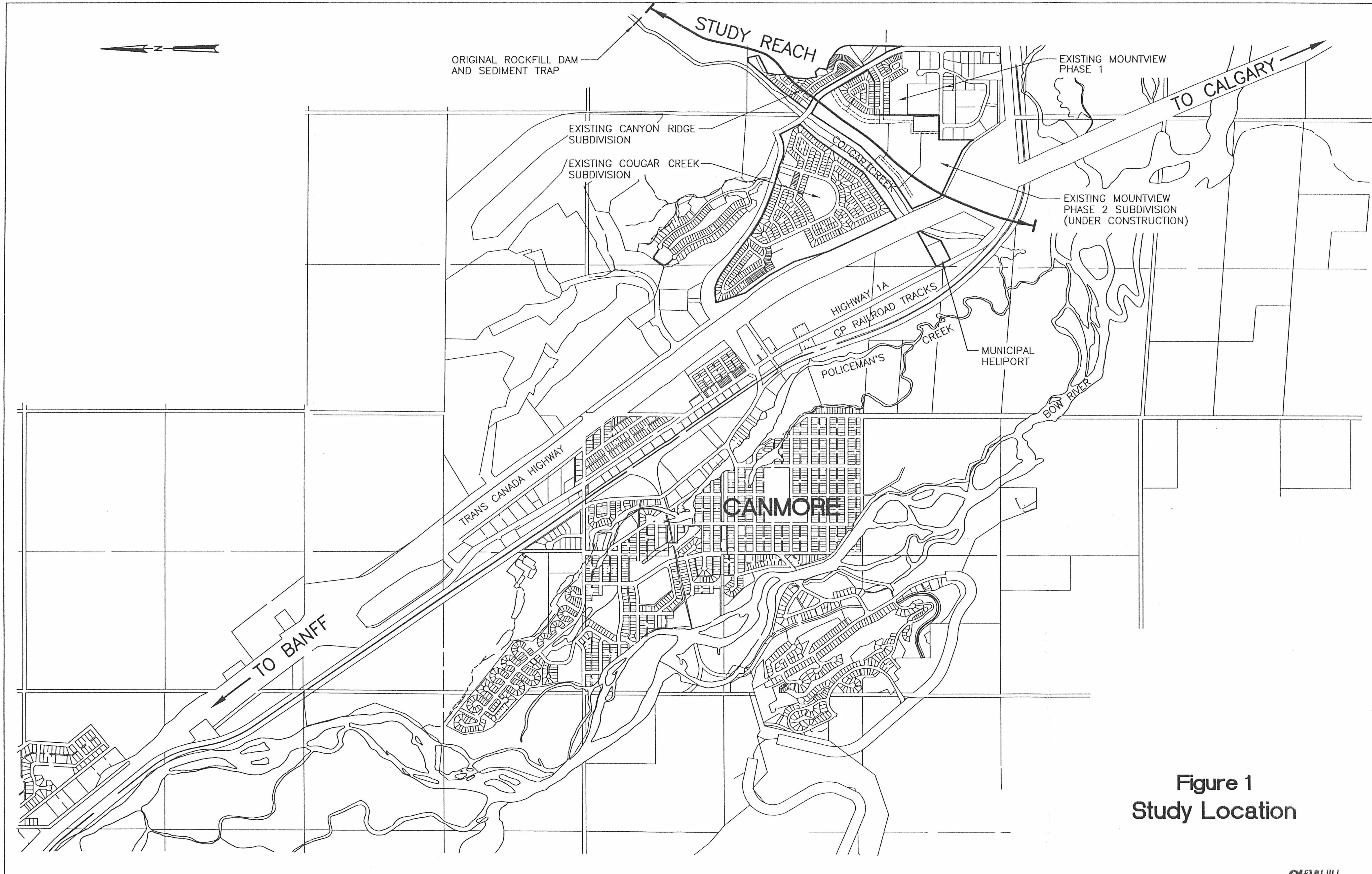

Figure 1
Study Location

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\CIVIL\CGY25182\5182C001 94/02/14 2 P.S. 1=20 with sediment resulting in overtopping of the culvert structures, flows across the highways, and a partial washout of the CP railroad tracks.

Flood Protection Work

As the Town of Canmore expanded in the mid 1970s, development began on the alluvial fan on the east side of the Trans Canada highway at the downstream end of Cougar Creek. With the imminent development of the Cougar Creek residential subdivision and Elk Run industrial subdivision in 1980, Alberta Housing Corporation (AHC) and AEP initiated studies of Cougar Creek to assess the need and extent for stabilization work of the creek channel. In 1981, AHC completed construction of a permeable rockfill dam upstream of any development, which was intended to act as a sediment trap to prevent downstream deposition of material washed down during flash floods. Following construction, ownership was transferred to the Town of Canmore and a licence to operate issued to the Town. In addition, both sides of the creek between the Trans Canada Highway and the proposed Elk Run Boulevard were to be shaped and armored with riprap to contain the creek adjacent to the subdivisions. These works were completed in mid-1981 as development of the subdivisions got started.

Downstream of the Trans Canada Highway, the creek was regraded and shaped and native material pushed to the side to form dykes. No imported riprap material was placed, however, except around the highway culverts.

More recent developments adjacent to the creek include Canyon Ridge, a new subdivision upstream of Elk Run Boulevard, and Mountview Phase II, a subdivision between Elk Run Boulevard and the Trans Canada Highway, currently under construction. The locations of the existing developments are shown on Figure 1.

To allow development of the Canyon Ridge and Mountview Phase II subdivisions, as well as to protect existing developments, the following remedial measures have been carried out in the creek:

- Placed 425 m of riprap on the right bank upstream of Elk Run Boulevard
- Placed 500 m of riprap on the left bank upstream of Elk Run Boulevard
- Repaired riprap between Elk Run Boulevard and the Trans Canada Highway damaged during the 1990 dam break flood
- Constructed a berm between the Trans Canada Highway and Highway 1A to protect the heliport; placed 150 m of riprap on curve of right bank from location of existing riprap downstream of the Trans Canada Highway culverts
- Placed 10 m of riprap in the creek bed downstream of Elk Run Boulevard, upstream of the Trans Canada Highway and upstream and downstream of Highway 1A

Section 2
Hydrology

Cougar Creek is an ungauged runoff creek with a drainage area of about 44.1 km^2 to the confluence with the Bow River.

In preparation for the Canmore Flood Risk Mapping Study, AEP Hydrology Branch updated the flood frequency estimates for Cougar Creek by carrying out a regional analysis (Alberta Environment, 1990). In the vicinity of Canmore, there are six gauged creeks or rivers that were considered suitable for describing regional runoff characteristics. A frequency analysis of the mean annual instantaneous discharge was carried out and the ratio of peak discharge to mean annual discharge was estimated from the recorded streamflow data. The following equation describes the estimated mean annual instantaneous flood for the region:

$$Q_{MAF} = 0.180684\ (A)^{0.95435}$$

where: Q_{MAF} is the mean annual flood (m^3/s)
A is the drainage area (km^2)

The estimated ratios of peak discharge to mean annual discharge were then applied to the above equation to compute the various return period flood flows. Table 1 lists the computed flood frequency estimates for Cougar Creek.

Table 1
Cougar Creek Flood Frequency Estimates

Return Period	Annual Maximum Instantaneous Discharge (m^3/s)
100	19.30
50	17.00
25	14.60
10	11.50
5	9.10
2	5.74

In addition, AEP directed that coincident peaks between the Bow River and Cougar Creek should be assumed for floodplain delineation and Bow River water surface elevations.

Section 3
Hydraulic Analysis

Channel Characteristics

Cougar Creek is a steep mountain creek that originally spread out onto a wide alluvial fan in the Bow River valley. In recent times, the creek has been constrained in a constructed channel through the fan to prevent erratic channel formation and more predictably define the flow path to the Bow River. The creek has an average slope of about 4 percent through the study area, which essentially is from the Bow River to the upstream end of the alluvial fan. The creek is steepest at the upstream end with decreasing slope as it flows downstream. The creek flows under three road crossings at Elk Run Boulevard, the Trans Canada Highway, and Highway 1A, and also under the CP railroad tracks just south of Highway 1A. About 200 m south of the CPR tracks, Cougar Creek ends in a confluence with Policeman's Creek which then joins the Bow River. Interestingly, the available flow area through each of the crossings decreases in the downstream direction. This is probably a reflection of the increasing knowledge of the creek's flooding characteristics as each successive crossing moved upstream from the earliest crossing by the CPR. Elk Run Boulevard crossing is a corrugated steel multiplate arch culvert 6.36 m high by 9.62 m wide by 25 m long with a slope of 4.8 percent. The Trans Canada Highway crossing consists of 3 concrete box culverts each 2.68 m high by 2.44 m wide by 63.9 m long with a slope of 3.6 percent. Highway 1A crossing also has 3 concrete box culverts each 2.11 m high by 2.44 m wide by 19.7 m long with a slope of 1.8 percent. Similarly, the CPR crossing has 3 concrete box culverts each 1.51 m high by 2.98 m wide by 5.8 m long with a slope of 1.2 percent.

At the upstream end of the creek the channel flows through an incised valley and then into an area that is on part of the alluvial fan just upstream from Elk Run Boulevard. The creek grade is fairly steep through this section and averages approximately 4.7 percent. The material in the creek in this section is mainly gravel and cobbles with a few boulders. A high constructed bank exists on both sides of the creek and is over 5 m high. Both sides of the creek are bordered by high natural escarpments. The new Canyon Ridge subdivision is located on the left side of the downstream stretch of this reach. Future residential development is planned in the longer term for the other side of the creek. As a safety buffer to accommodate any localized erosion, no development is allowed to encroach closer than 25 m to either creek bank. Two metre high armoring has been extended from Elk Run Boulevard to the upstream end of the Canyon Ridge subdivision.

Between Elk Run Boulevard and the Trans Canada Highway the creek is fairly straight and has 3 to 4 m high banks with 2 m high armoring on each side. On the right side of the creek is the existing Cougar Creek subdivision, and on the left side is the Mountview Phase II subdivision, currently under construction. The creek grade through this section is also fairly steep (average slope 4.0 percent). This reach also has a 25 m wide buffer strip on each bank.

The creek makes a slight curve to the south just downstream of the Trans Canada Highway. The average slope in the section between the Trans Canada Highway and Highway 1A is

The new berm constructed between the Trans Canada Highway and Highway 1A was not added to the HEC-2 cross sections, since the computed water surface elevations were below the existing banks.

No reliable data is available for high water levels or recorded flood flows. Thus it is not possible to calibrate Manning's 'n' for the channel. Similarly, there is no discharge-rating curve for Cougar Creek. As mentioned in the previous section, flood flows derived from the regional analysis conducted by the Hydrology Branch of AEP were used in the analysis.

Hydraulic Parameters

Several hydraulic parameters are required in HEC-2 to compute the water surface profiles. These include:

- Definition of culverts/bridges
- Expansion and contraction coefficients
- Manning's 'n' coefficient

The four culverts along Cougar Creek were input using the HEC-2 normal bridge routine. This method was selected as the most appropriate, since in the 1:100-year flood all culverts operate with free surface flow, and the geometry of the Elk Run Boulevard arch culvert and other box culverts could be accurately defined. The special bridge method was not used since the culvert must be represented by a trapezoidal opening and also weir flow and pressure flow were known not to exist in the 1:100-year flood. The new special culvert routine was also not used since this method is only applicable for subcritical flow.

Typical expansion and contraction coefficients for a natural channel are 0.1 and 0.3 respectively (U.S. Army Corps of Engineers, 1990). These values were selected for the natural channel reach of Cougar Creek. At culverts, more abrupt transitions occur and the expansion and contraction coefficients are typically increased to account for the higher hydraulic losses. Thus the expansion and contraction coefficients for each culvert were changed to 0.6 and 0.8 respectively. Again, these values are defined as typical by the HEC-2 User's Manual.

Since there are no data available to calibrate the Manning's 'n' of the channel, a typical 'n' value was selected from the available literature and visual inspection. Chow's *Open Channel Hydraulics* (1959) indicates that for a mountain stream with steep banks, no vegetation in the channel and a bottom of gravel, cobbles and a few boulders, a Manning's 'n' of 0.04 is appropriate. This was selected for the base case run for the calculation of water surface profiles. The sensitivity of water surface profiles to changes in Manning's 'n' is discussed in a later section.

The computed headwater depth at Highway 1A is 1.37 m, higher than the HEC-2 computed water depth of 0.89 m (critical depth). The subcritical water depth at this location was thus selected. At the CPR culverts, the computed headwater depth is 1.19 m, again higher than the HEC-2 computed water depth of 0.79 m (critical depth). The subcritical water surface profile at this location was also selected as being more representative of actual conditions. The supercritical water surface profile predicted by HEC-2 at the TransCanada Highway culverts was accepted without any adjustment.

The 1:50-year HEC-2 computed profile showed a similar subcritical condition at the culverts. Again we performed manual calculations for the culverts, and selected the resulting subcritical water surface profiles. In the 1:10-year HEC-2 computed profile the model computes supercritical flow at every cross section.

The computed HEC-2 water surface elevations at the downstream section of Cougar Creek were compared to the flood risk limits of the Bow River at Cross Section 8 of the Canmore Flood Risk Mapping Study (W-E-R AGRA Ltd., 1993). As mentioned in the AEP Hydrology Branch frequency analysis, coincident peaks between the Bow River and Cougar Creek were to be assumed. In each of the 1:100-, 1:50-, and 1:10-year flood frequencies, the water surface elevations at the most downstream cross section of Cougar Creek (Cross Section 1) are influenced by the respective flood risk limits for the Bow River. The water surface elevation computed in the Cougar Creek analysis at Cross Section 2 for each profile (1:100-, 1:50-, and 1:10-year) is marginally higher than the flood risk elevation for the Bow River at Cross Section 1. Thus the backwater effect is minimal and does not extend back to Cross Section 2.

Figure 2 shows the computed water surface profile for the 1:100-year flood. For clarity, the 1:50-year and 1:10-year profiles are not shown as they are very close to the 1:100-year profile. Table 2 indicates the final computed water surface profiles for the 1:100-, 1:50-, and 1:10-year flood frequencies.

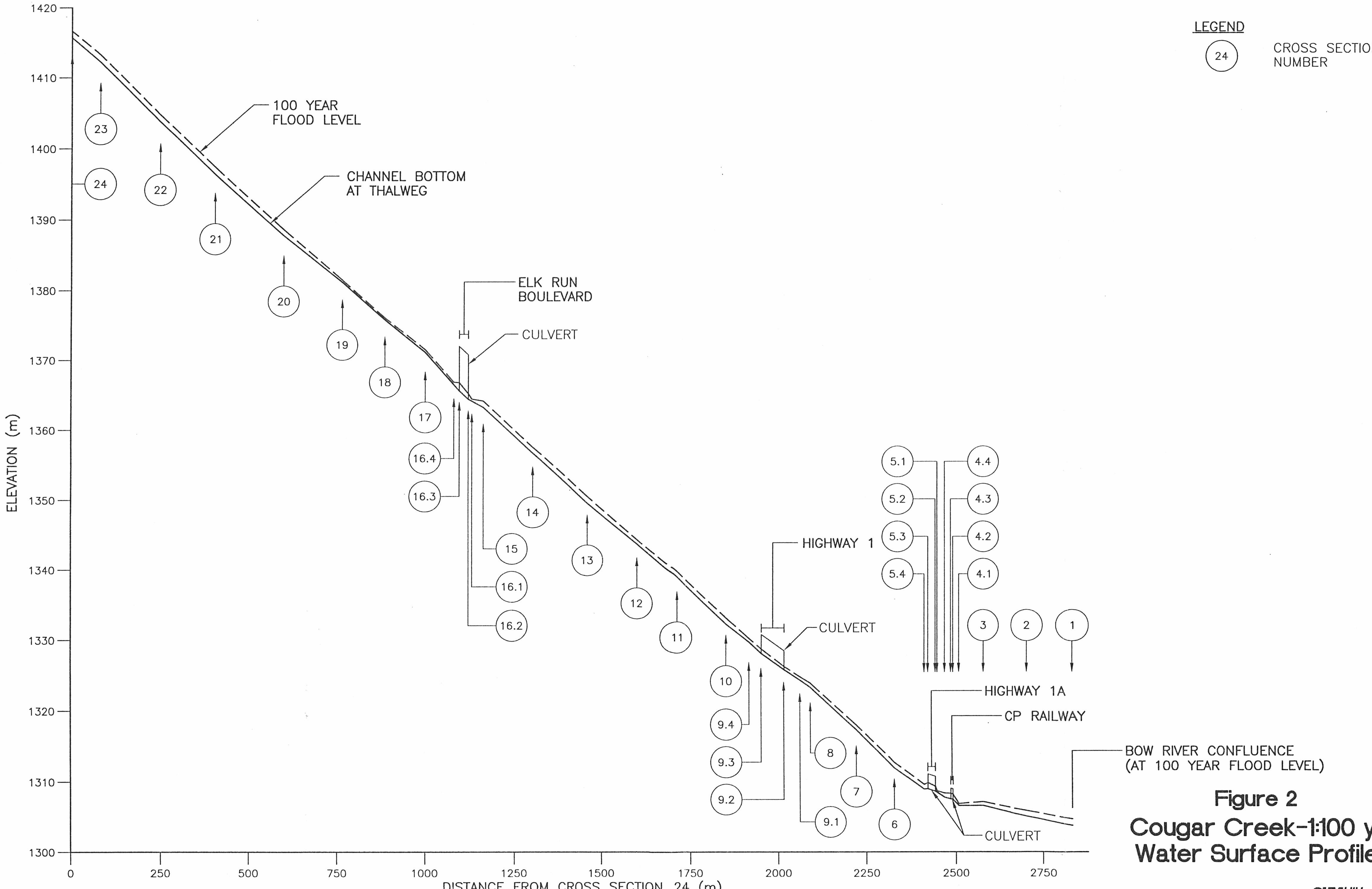

Figure 2
Cougar Creek-1:100 yr Water Surface Profile

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Table 2
Computed Water Surface Elevations

Cross Section	Distance (m)	1:100-year Profile	1:50-year Profile	1:10-year Profile
24	0	1416.64	1416.59	1416.47
23	80	1413.27	1413.24	1413.12
22	247	1404.74	1404.71	1404.56
21	404	1397.41	1397.37	1397.26
20	599	1388.61	1388.57	1388.46
19	766	1381.49	1381.47	1381.40
18	888	1376.11	1376.09	1376.03
17	1002	1371.54	1371.51	1371.44
16.4	1082	1366.88	1366.86	1366.78
16.3	1097	1366.82[1]	1366.74[1]	1366.52
16.2	1122	1365.25	1365.19	1365.03
16.1	1132	1364.47	1364.45	1364.40
15	1164	1364.18[1]	1364.12[1]	1363.97
14	1304	1357.57	1357.54	1357.46
13	1461	1350.54	1350.49	1350.39
12	1601	1344.37	1344.30	1344.24
11	1711	1339.83	1339.81	1339.69
10	1853	1333.18	1333.15	1333.04
9.4	1918	1330.28	1330.25	1330.17
9.3	1953	1328.79	1328.71	1328.57
9.2	2017	1326.32	1326.28	1326.18
9.1	2062	1324.87	1324.85	1324.80
8	2092	1323.97	1323.92[1]	1323.83
7	2222	1318.06	1318.03	1317.93
6	2329	1312.78	1312.74	1312.63
5.4	2414	1310.36[2]	1310.23[2]	1309.44
5.3	2424	1310.36[2]	1310.23[2]	1309.62
5.2	2444	1309.35	1309.29	1309.11
5.1	2449	1308.74[2]	1308.69	1308.64
4.4	2469	1308.74[2]	1308.64[2]	1308.23
4.3	2486	1308.74[2]	1308.64[2]	1308.11
4.2	2492	1308.21	1308.15	1307.99
4.1	2509	1306.88	1306.86	1306.80
3	2579	1307.15[1]	1307.10[1]	1306.99
2	2704	1305.86	1305.82	1305.65
1	2829	1305.83[3]	1305.73[3]	1305.38[3]

Notes:
1. Critical depth computed by HEC-2
2. Water surface elevation computed by hand calculation
3. 1:100-yr flood level at the Bow River (computer by others)

intervals is approximately plus or minus 0.5 m. Thus the calculated water surface elevations can confidently be used for mapping purposes.

Table 4
Model Sensitivity to Variation in Manning's n

Change of Manning's n from Base Simulation	Absolute Difference in Water Levels (m)		
	Min	Max	Mean
+30%	0.00	0.11	0.05
+10%	0.00	0.04	0.02
0%	0.00	0.00	0.00
-10%	0.00	0.05	0.02
-30%	0.00	0.12	0.06

1:100-year Flood Risk

The computed 1:100-year water surface elevation is contained entirely within the banks of Cougar Creek. Thus no flooding of the overbanks is expected. The 1:100-year flood risk limits for Cougar Creek are indicated on Drawing 5182-20201 attached at the end of this report. The flood risk map shows that the 1:100-year flood would not affect any of the residential or developed areas along Cougar Creek.

Although sediment transport is not a part of this study, sediment and debris accumulation in the creek could be a potential flooding problem if it caused overtopping of the armoring or blockage of the culverts. As outlined in a previous study (CH2M HILL Engineering Ltd., 1993), the 1:100-year flow could still pass through the culverts even with deposition of the predicted 1:100-year sediment volumes in the channel.

Section 4
Works Cited

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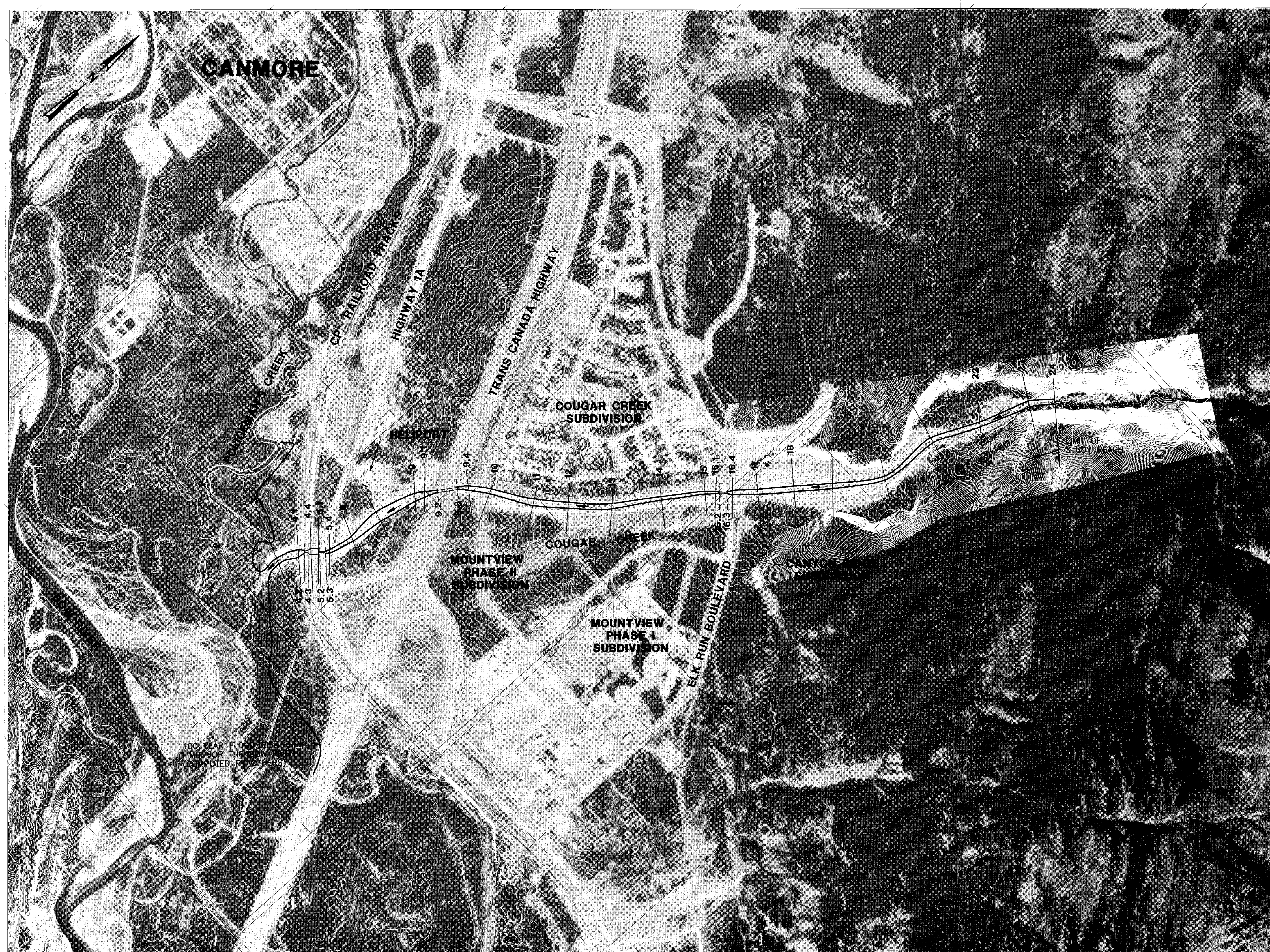

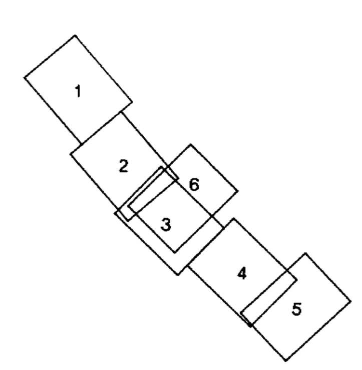

SCALE 1:5 000

metres 0 100 200 300 400 500 600 metres
feet 0 100 500 1,000 1,500 2,000 feet

Projection: 3° Transverse Mercator, Scale factor 0.9999 at Reference Meridian 114°

Contour interval: 1 METRE

Elevations: in metres above mean sea level, North American Datum, 1927

metre contour

metre index contour

Depression contour

750.5 Spot height in metres

Canada-Alberta
FLOOD
DAMAGE
REDUCTION
PROGRAM

Environment Canada / Environnement Canada

Alberta ENVIRONMENT

VERIFY SCALES

BAR IS 20mm LONG ON ORIGINAL DRAWING.

0 20

IF NOT 20mm ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

1:100 YEAR COMPUTED WATER SURFACE ELEVATION

CROSS SECTION NUMBER	DISTANCE FROM XS 24 (m)	WATER LEVEL (m)
24	0	1416.64
23	80	1413.27
22	247	1404.74
21	404	1397.41
20	599	1388.61
19	766	1381.49
18	888	1376.11
17	1002	1371.54
16.4	1082	1366.88
16.3	1097	1366.82
16.2	1122	1365.25
16.1	1132	1364.47
15	1164	1364.18
14	1304	1357.57
13	1461	1350.54
12	1601	1344.37
11	1711	1339.83
10	1853	1333.18
9.4	1918	1330.28
9.3	1953	1328.79
9.2	2017	1326.32
9.1	2062	1324.87
8	2092	1323.97
7	2222	1318.06
6	2329	1312.78
5.4	2414	1310.36
5.3	2424	1310.36
5.2	2444	1309.35
5.1	2449	1308.74
4.4	2469	1308.74
4.3	2486	1308.74
4.2	2492	1308.21
4.1	2509	1306.88
3	2579	1307.15
2	2704	1305.86
1	2829	1305.83

NOTES

1. BASE MAPS WERE PROVIDED BY ALBERTA ENVIRONMENTAL PROTECTION.
2. BOW RIVER FLOOD RISK LIMITS DETERMINED BY OTHERS.

LEGEND

- 1:100 YEAR FLOOD RISK LIMIT
- 2 — CROSS SECTION NUMBER AND LOCATION
- 5.1 ---- SUPPLEMENTARY CROSS SECTION NUMBER AND LOCATION
- CULVERT LOCATION
- FLOW DIRECTION

NO.	DATE	REVISIONS	BY	CHK'D	APPROVED

CH2M HILL
Calgary, Alberta

PERMIT

ENGINEER

COUGAR CREEK
FLOOD RISK MAPPING STUDY

FLOOD RISK MAP FOR THE 100 YEAR FLOOD

DATE 94/01/04	SCALE 1:5000	PROJECT NO. CGY25182	DRAWING NO. 5182–20201
DRAWN HAN	REV. NO. △		

94/01/07 CIVIL\CGY25182\5182C003 C.P. 2 P.S. 1=5