BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

Environmental Research and Technology Inc. - Air Quality and Climatic Effects of the Proposed Hat Creek Project Report - Appendix E - Climatic Assessment - April 1978.

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Air quality and climatic effects of the proposed Hat Creek project

Appendix E
Climatic assessment

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E1.0 INTRODUCTION

This Appendix documents an investigation of climate in south-central British Columbia. In particular, the weather of the region surrounding B.C. Hydro's proposed Hat Creek Project and the potential for climatic alterations due to the Project coal mine, power plant, and associated facilities were examined.

A survey of climate serves two major purposes in the context of an Environmental Report for a new facility, such as the Hat Creek Project. First, an assessment of the magnitude and severity of potential impacts requires baseline information describing conditions without the Project. In addition, air quality analysis must include consideration of characteristic local winds and atmospheric dispersion potential. Meteorological statistics are routinely employed in mathematical modeling studies to estimate the behavior of stack plumes, cooling tower effluent, and fugitive dust emissions due to mining.

A thorough review of available meteorological data was completed to provide a description of regional (Section E3.0) and local (Section E4.0) climatic patterns. Data sources used in this analysis are identified in Section E2.0. An extensive literature survey provided most of the information regarding possible climatic impacts of the proposed Project. Wherever possible, quantitative estimates of the magnitude and geographical extent of such effects were formulated on the basis of documentation in the literature and expected operating characteristics of the mine and power plant. The results of this analysis are presented in Section E5.0. The many references used in the climatic assessment are listed in Section E6.0.

E2.0 DATA SOURCES

True climatic averages of meteorological parameters should be determined on the basis of consistent records maintained over long periods. A five-to-ten-year data base is normally considered the minimum period to establish climatological averages, although a 30-to-40-year record is desirable in terms of averaging highly variable parameters (like annual snowfall or thunderstorm frequency), or to obtain extreme values (e.g., maximum and minimum temperatures). In regions where topographical features limit the types of flow that can occur, surface wind measurements taken over only a year or so may be adequate to define characteristic wind field patterns for purposes of environmental assessment.

The analysis of regional climatology presented in this study is based primarily on long-term data from the records and periodic reports produced by the Climatological Service Division of Atmospheric Environment Service (AES) of Canada, and the U.S. Naval Weather Service World-Wide Airfield Summaries (Vol IV).[1] The two periodic AES publications utilized are the Canadian Weather Review[2] and the Monthly Record: Meteorological Observations in Canada.[3] These data are supplemented for detailed examination of climate near the proposed Hat Creek Project site by one year of hourly information obtained from the network of weather stations operated in the vicinity of the Hat Creek site by B.C. Hydro. Each of the eight mechanical stations in the network records continuous measurements of wind speed, wind direction, temperature and relative humidity. In addition to the 1975 data from the mechanical weather stations, B.C. Hydro provided AES meteorological data on magnetic tapes. These include hourly surface observations at Ashcroft (1966-1971), Kamloops (1974-1975), and Lytton (1974-1975), as well as upper air radiosonde observations (RAOB) for Vernon and Prince George, B.C.

Other climatic information incorporated by this analysis were obtained from the reference texts: The Climate of Canada[4], The Earth's Problem Climates[5], and the Climatological Atlas of Canada[6], as well as an unpublished AES report "Mixing Heights, Wind Speeds and Air Pollution Potential for Canada."[7]

The investigation of local climate made use of results from field measurement programs sponsored by B.C. Hydro and performed by the MEP Company.[8,9] These studies provided information regarding the vertical structure of winds and temperature over the Hat Creek Valley.

Figure E2-1 indicates the relative locations of the weather stations that provided data for use in the regional climatology study. Figure E2-2 shows the positions of the stations in the immediate Hat Creek Valley area. Table E2-1 lists all the meteorological observation stations used as data sources in the present study. The distance, direction and elevation of each station with respect to the proposed power plant site, as well as the time period corresponding to the data utilized in this study, are presented in this table.

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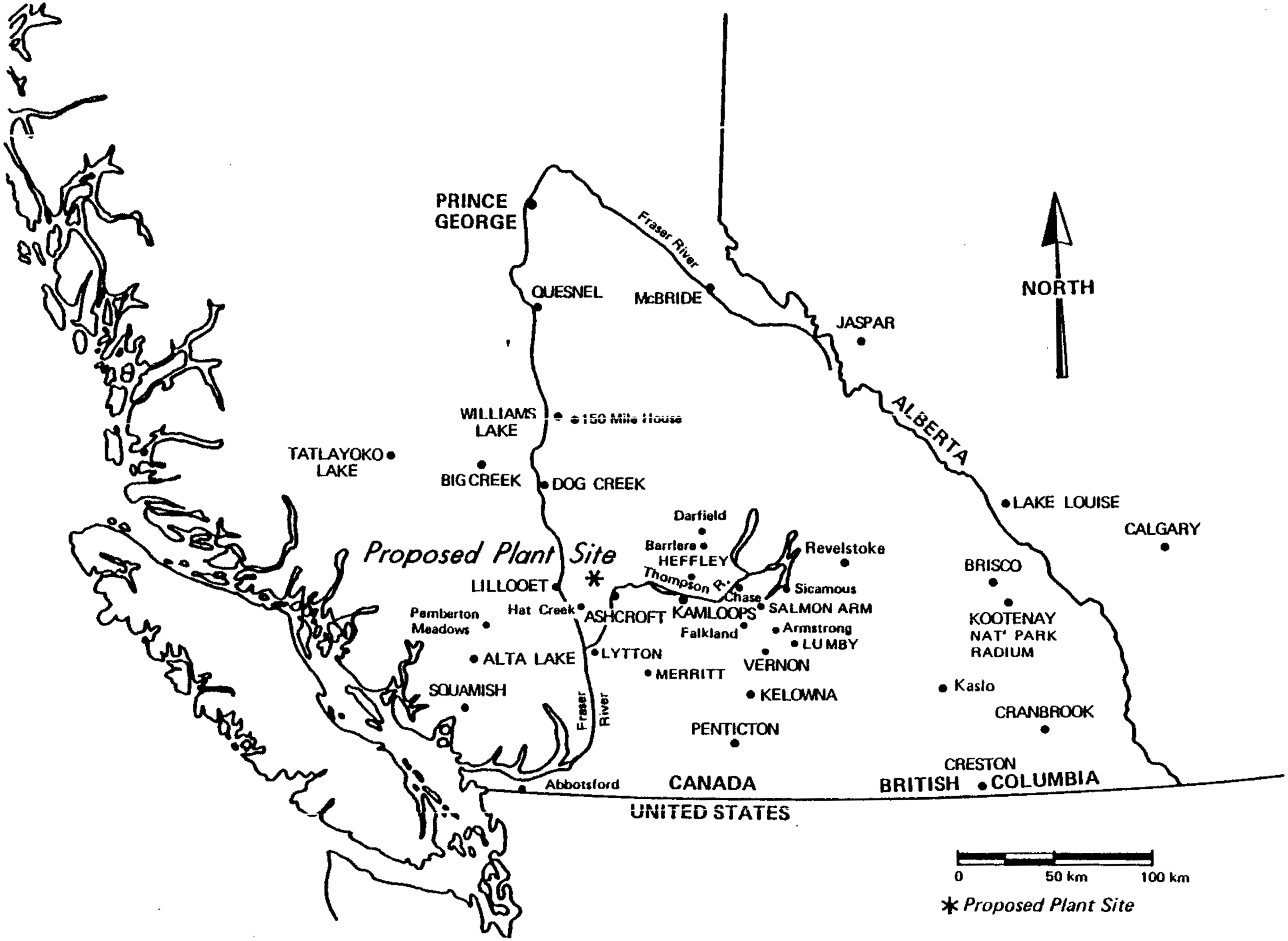


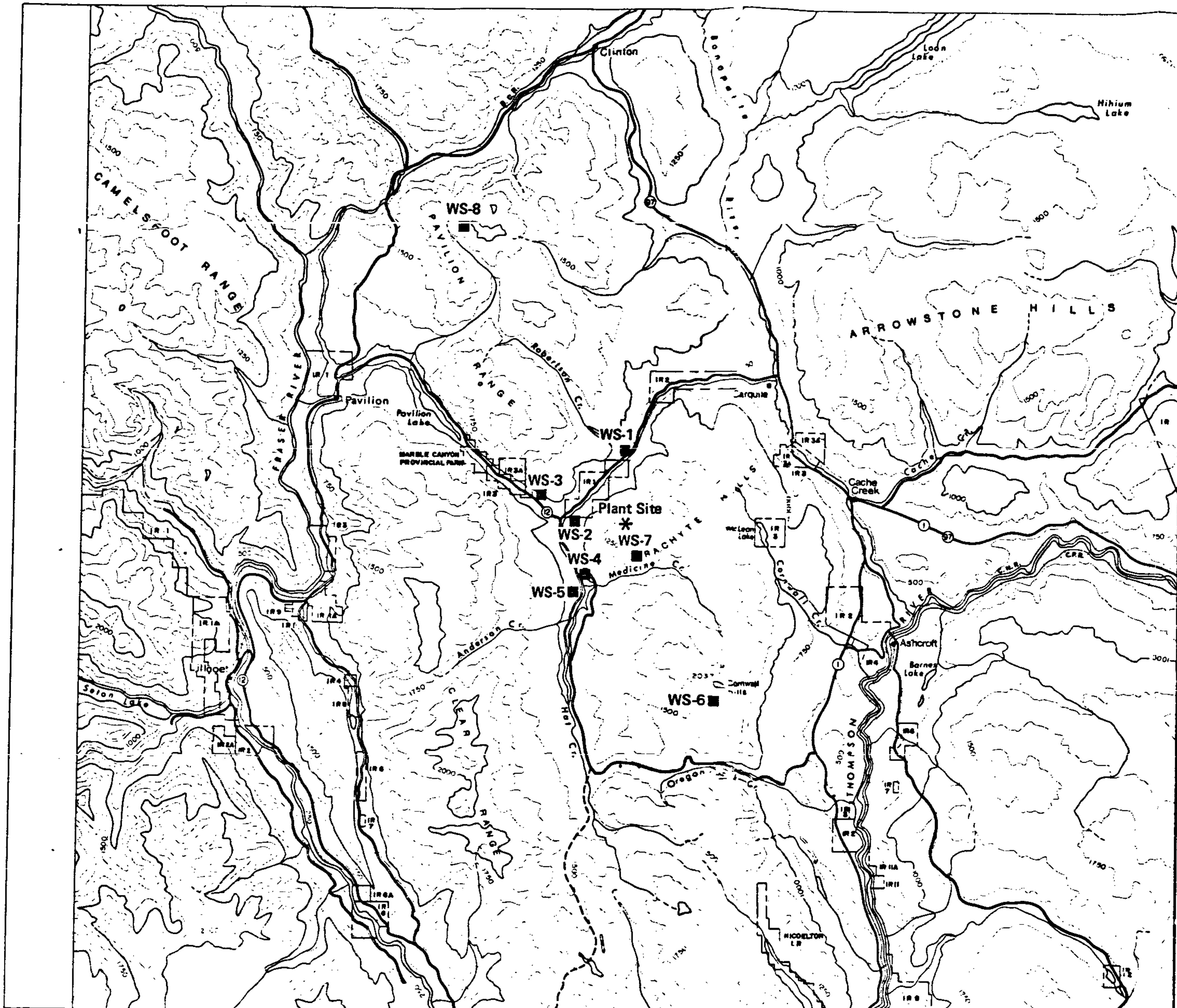
Figure E2-1 Map of Hat Creek Valley with Locations of the AES Meteorological Stations

TABLE E2-1

LOCATIONS OF METEOROLOGICAL OBSERVATION STATIONS
RELATIVE TO PROPOSED GENERATING STATION SITE AT HARRY LAKE

Station	Elevation (m MSL)	Direction from Site	Distance (km)
B.C. Hydro Mechanical Weather Stations			
WS 1	762	NNW	6.4
WS 2	823	W	6.4
WS 3	853	W	8.0
WS 4	945	WSW	4.8
WS 5	1006	WSW	6.4
WS 6	2012	SSE	11.2
WS 7	1402	N	1.4
WS 8	2042	NW	25.6
Atmospheric Environment Service Observation Stations			
Surface:			
Alta Lake	668	SW	12
Ashcroft*	336	ESE	18
Dog Creek	655	NNW	96
Kamloops**	378	E	77
Kelowna	418	SE	166
Lytton**	259	S	54
Penticton	341	SE	176
Squamish*	6	SW	154
Williams Lake	942	NNW	141
Upper Air (RAOB)			
Prince George	677	NNW	352
Vernon	555	ESE	160

*Wind data obtained through B.C. Hydro
**Complete observations obtained through B.C. Hydro



SCALE - 1:250,000

CONTOUR INTERVAL - 250 METRES

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY HAT CREEK PROJECT

DETAILED ENVIRONMENTAL STUDIES

Figure E2-2 Meteorological Network in the Vicinity of the Hat Creek Project

E3.0 REGIONAL CLIMATOLOGY

E3.1 EFFECTS OF TERRAIN

The rugged, mountainous terrain that characterizes much of British Columbia is an important factor influencing the types and geographic distribution of climatic patterns within the Province. Major orographic features modify air mass properties associated with large-scale pressure systems and divert ground-level flows to conform with the directions of mountain valleys. The Pacific Coast Range to the west and the Monashee Range of the Rocky Mountains to the east are the topographical features of greatest significance in terms of regional climate in south-central British Columbia.

The Coast Range, with peaks extending to 3000 m (10,000 ft), effectively prevents the intrusion of mild, humid air from the Pacific Ocean into the interior of the Province. As the prevailing westerlies flow up the slopes of these mountains, the maritime air is cooled, causing condensation and precipitation. The presence of the Coast Range is thus responsible for the marked differences between the mild, damp climate along the coast and the dryer, 'continental' weather of the southern interior. Similarly, the Rocky Mountains create another area of relatively high precipitation to the east of the Hat Creek area. Both the Coast Range and the Rocky Mountains act to block lower-level flows associated with major circulations aloft.

Upper-level winds (e.g., at 500 mb or about 550 m above sea level) are controlled by global-scale pressure/circulation systems, and generally flow from west to east over British Columbia. This zonal flow is modulated by north-south (meridianal) currents created by differential heating between equator and pole. The amplitudes of these waves are greatest during the spring and fall at the latitude of Hat Creek, and this is reflected at the surface by the maximum frequency of cyclones (low pressure systems) and anticyclones (high pressure systems) during these seasons. In winter, the 'storm track' moves to an average latitude south of the Project area; in the summer, storms take a more northerly path.

At lower levels in the atmosphere (e.g., at 850 mb or about 1500 m above sea level), winds over the region are slowed by the frictional drag of the high terrain, and the wind directions are different from those above the terrain in the free air stream. Where topographic features penetrate the flow field, winds are forced to conform to the alignment of the terrain. The relatively small magnitude of the prevailing westerlies at 500 mb (an average speed of 10 to 16 mps) and lower elevations results in frequent channeling of the wind flow near the surface by the predominantly north-south mountain valley systems. The differences between wind patterns at the 500 mb and 850 mb levels at Vernon, B.C. are evident upon examination of Table E3-1. The shifting of the prevailing direction toward the south and the diminished speeds at the lower level reflect the influence of terrain.

The Hat Creek region is part of the larger Thompson Plateau which separates the two major mountain systems. Despite its designation as a plateau, this region is characterized by significant terrain features due to erosion by large rivers such as the Fraser and Thompson and smaller ones like Hat Creek. The topography of the Hat Creek Valley and surrounding areas is depicted in Figure E2-2. The valley floor varies in elevation from about 1067 m (3500 ft) at Upper Hat Creek to approximately 487 m (1600 ft) near the towns of Carquile and Cache Creek and approximately 336 m (1100 ft) near Ashcroft. Surrounding ridges and peaks in the Trachyte Hills (to the east) and Cornwall Hills (to the south) reach elevations of 1554 m (5100 ft) and 2012 m (6600 ft), respectively. To the north of the Project area, peaks of the Marble Range reach a maximum elevation of 2073 m (6800 ft), while the highest points of the Clear Range to the west have elevations between 2195 m (7200 ft) and 2377 m (7800 ft). As will be seen in later sections, terrain effects are important in terms of both regional and local climatology.

E3.2 SYNOPTIC-SCALE WINDS

The migrations and relative locations of major synoptic-scale pressure systems are primarily responsible for seasonal variations in the large-scale wind flow patterns over British Columbia. For the region of interest

TABLE E3-1

WIND DIRECTION AND MEAN SPEEDS FOR SEVERAL LEVELS AT VERNON, B.C.*

Frequency of Occurrence of Wind Direction by Level

Wind Direction	Winter 500mb	Winter 850mb	Winter Surface	Spring 500mb	Spring 850mb	Spring Surface	Summer 500mb	Summer 850mb	Summer Surface	Fall 500mb	Fall 850mb	Fall Surface
N	5	6	23	16	17	21	4	11	28	7	17	21
NNE	2	5	16	6	7	14	2	7	11	6	4	9
NE	0	3	14	3	7	10	1	4	8	2	5	7
ENE	2	2	2	1	2	4	2	5	5	1	1	6
E	1	3	6	5	2	8	4	7	4	0	1	5
ESE	0	1	5	1	2	2	2	1	3	0	2	4
SE	0	8	18	2	7	14	0	2	12	1	7	21
SSE	1	13	14	5	8	15	5	3	15	1	7	14
S	5	19	22	9	13	12	9	9	18	6	35	20
SSW	5	24	14	15	20	6	17	16	12	5	23	17
SW	11	28	10	17	16	23	25	27	25	8	23	19
WSW	11	17	5	22	17	10	34	34	11	18	12	8
W	16	10	13	16	9	17	23	12	15	26	7	3
WNW	16	7	1	18	10	13	19	12	6	20	5	6
NW	9	14	4	13	17	4	18	15	6	19	12	4
NNW	2	11	5	10	22	8	7	13	3	11	12	10
Calm	1	2	8	1	1	3	1	2	2	0	4	6
Monthly Mean Wind Speeds (mps)												
Mean Wind Speed	11.2	5.1	2.7	12.6	4.5	3.9	13.3	3.9	3.4	13.8	7.6	4.5

*Radiosonde Data: AES (1975)

in this study, the systems of primary importance are: the semi-permanent high pressure center over the northern Pacific; the low pressure system near the Aleutian Islands; and the continental ridge of high pressure that forms over Alaska in winter.

By mid-winter the Pacific high pressure system has receded to its most southerly position. Steered by an upper-level trough of low-pressure, most major storms pass south of the Hat Creek area. At 850 mb the prevailing wind direction over the region is southwesterly. Surface winds are channelled by the Fraser River Valley and flow over the interior plateau from the south to southwest. Examination of observations at the Vernon Station (Table E3-1) reveals the importance of local effects on ground-level winds. Typically, the flow at Vernon associated with synoptic conditions is reinforced by mesoscale flows during the day, and counteracted at night by a northerly drainage flow.

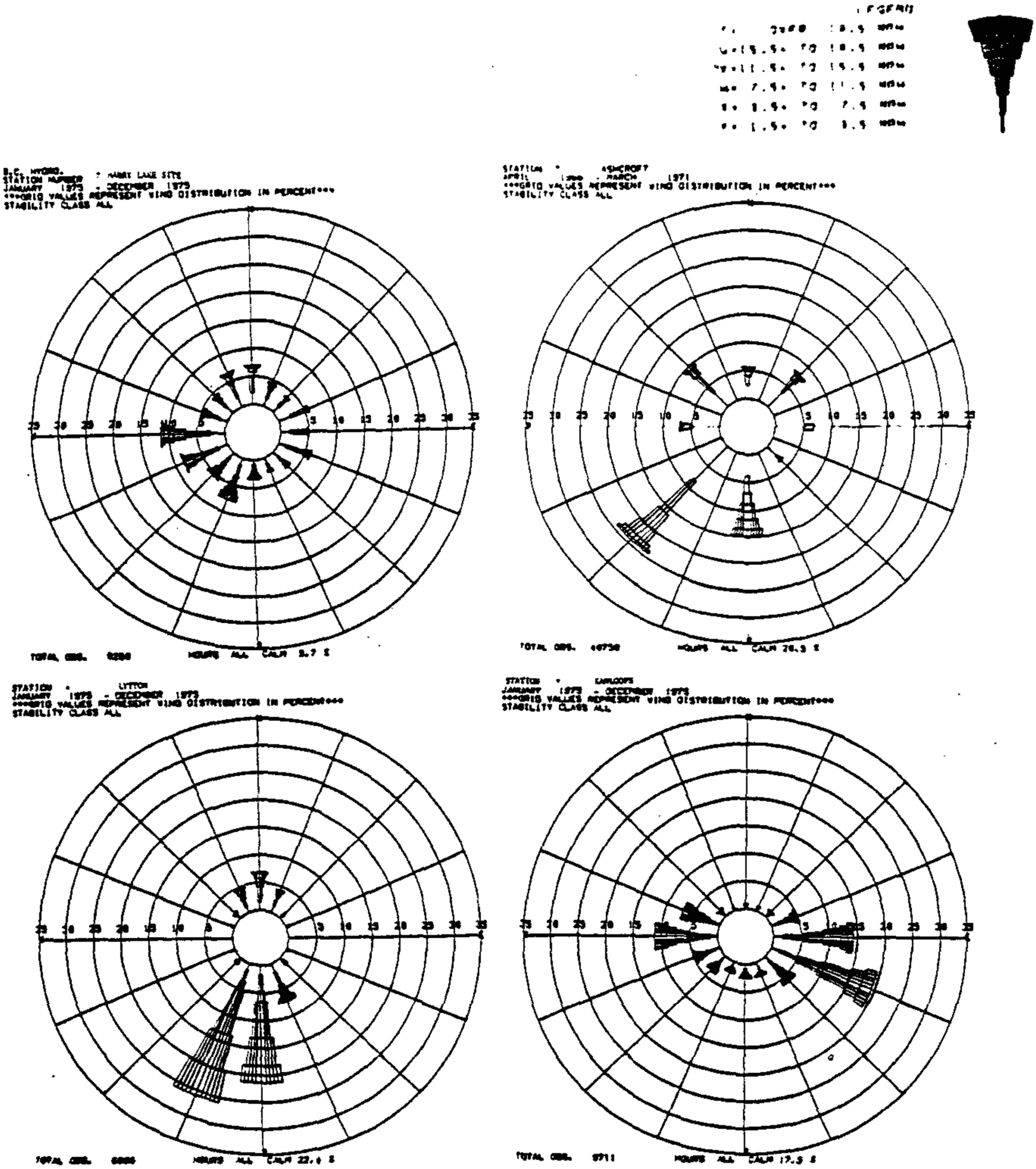
During the transition to spring, the stream of Pacific cyclones weakens and advances northward. The Alaskan ridge moves toward the east, causing a more frequent northerly component in the upper and lower-level flows. At 500 mb, wind direction varies with the passage of storm centers, but is predominantly from the southwest to northeast. Average speed at this level is about 13 mps. Nearer the surface, e.g., at 850 mb, winds are more aligned with the north-south orientation of interior mountain valleys and slightly weaker than during the winter.

Considerable weakening and retreat of the Arctic high pressure ridge takes place in the summer months. Simultaneously, the semi-permanent Pacific high pressure center builds up about 1600 km (1,000 miles) off the Oregon coast at a latitude of approximately 43°N. Westerly winds dominate the upper-air flow pattern over southern British Columbia, and the track of Pacific storms migrates to its most northerly position (about 54°N) by late July. During this season, the upper-air waves have their minimum amplitudes, generating only occasional weak cyclonic disturbances at the surface. Low-level winds are generally light, and, under the influence of the persistent Pacific high, are mainly from the north or northwest. The winds at 850 mb are, on the average, about one-third as strong as those at 500 mb. Occasionally, the Pacific high will drift to the west or south, causing light southwesterly winds to be channelled through the Fraser River gap in the Coast Range.

Synoptic-scale winds during summer tend to be decoupled from observed flows at ground level, due to local effects (primarily, mountain-valley circulations) that are intensified by strong solar heating. At Vernon (see Table E3-1) the strong northerly and southerly surface wind components clearly reflect the orientation of the valley at this station. As demonstrated in Section E4.1, frequency distributions of ground-level winds throughout the study region demonstrate the strong influence of terrain-induced flows during the summer.

Fall, like spring, is a period of transition between the weak westerlies of summer and the stronger westerlies of winter. As the Pacific high weakens and retreats toward the south, the storm track passes over the Hat Creek area, producing fairly frequent perturbations in the wind flow. Mean winds at 500 mb and 850 mb are between northwest and southwest. Average speeds of these levels are about 14 mps and 8 mps, respectively. Maximum surface winds are recorded during this season at locations such as Vernon, where the orientation of its valley enhances the coupling of surface and upper-level flows.

Surface wind measurements from the B.C. Hydro weather station network in the vicinity of the Project site are presently available for one year (1975). For this reason it is of interest to compare wind roses obtained from data acquired at other stations in the study region with longer data records. Figure E3-1 is a presentation of annual wind roses for AES stations at Ashcroft, Lytton, and Kamloops as well as B.C. Hydro Station 7 (Harry Lake). The locations of these stations are shown in



*Source: Atmospheric Environment Service Data

Figure E3-1 Annual Wind Roses for Harry Lake Site, Ashcroft, Lytton, and Kamloops, B.C.

Figures E2-1 and E2-2. Clearly, predominant wind directions at each site are determined primarily by the orientation of local terrain features.

In general, orographically induced flows are characterized by low wind speeds; highest speeds occur when local flow is coupled with upper-level winds. Except for this speed enhancement effect, the predominant influence of local circulations and topographic channeling makes it difficult to infer major climatic flow patterns from these surface data. A comparison of wind roses illustrates the fact that the applicability of data from one of the long-term stations to a description of winds in the Hat Creek Valley area is governed more by the specific nature and orientation of topographical features near the station than by proximity to the Project site. For this reason, the on-site surface wind data collected by B.C. Hydro, supplemented by upper-air data from Vernon, are essential to the documentation of local flow near Hat Creek (see Section E4.1). At least in this case, a relatively short local data record from the mechanical weather stations provides a more representative understanding of long-term circulation patterns than a much longer record at any station removed from the Hat Creek Valley area even at Ashcroft, only 18 km from Harry Lake.

All the weather stations in the valley locations report relatively high frequencies (about 10% or more--see Table E3-2) of calm conditions. In this analysis, 'calm' refers to any wind speed less than 0.67 mps (1.5 mph), since at many standard observation stations, wind instruments do not operate reliably below this threshold. Table E3-2 summarizes seasonal and annual frequencies of calm at Ashcroft, Kamloops, and Lytton as well as valley and hilltop stations of the Hat Creek network. In valleys sheltered from southerly synoptic flow, the winter season is especially characterized by a high rate of calm conditions - about 35% of the time in the Hat Creek Valley.

TABLE E3-2

FREQUENCY (%) OF CALMS IN HAT CREEK REGION*

	Frequency** of Calms				
Station	Annual	Winter	Spring	Summer	Fall
Ashcroft (Apr 1966-Mar 71)	20.46	35.38	12.57	9.76	23.86
Kamloops (Jan 1974-Dec 75)	18.10	21.40	17.50	17.39	17.63
Lytton (Jan 1974-Dec 75)	21.43	30.99	14.11	8.18	32.76
Mechanical Sites 1-5 (Jan 1975-Dec 75)	22.53	34.79	21.10	15.07	22.47
Mechanical Sites 6 and 8 (Jan 1975-Dec 75)	0.81	0.66	1.29	0.30	1.35
Harry Lake Site Mechanical Site 7 (Jan 1975-Dec 75)	9.66	17.78	12.45	4.65	3.49

*Source: Analysis of AES data for Ashcroft, Kamloops, and Lytton; analysis of B.C. Hydro data for all mechanical station sites.

**The annual frequency does not necessarily equal the average of the seasonal frequencies because of periods of missing data in any one season.

E3.3 PRECIPITATION

Isopleths of mean annual and seasonal precipitation amounts throughout the study region are displayed in Figures E3-2 through E3-6. The isopleths were developed from 20-year averages at 34 AES stations. As evidenced by the figures, the southern interior of the Province is quite dry, with mean annual precipitation amounts from about 25 to 50 cm per year. The sharp gradients near the Coast Range demonstrate the efficiency with which these mountains block the intrusion of moist air to the inland region. Precipitation in the southern interior is rather evenly distributed over the four seasons. In the winter, most precipitation is in the form of snow. Spring and autumn snowfalls occur primarily at the higher elevations as a consequence of the migratory cyclonic systems passing through the region during these seasons. During the summer, thunderstorms account for most of the rain. Although locally heavy rains can occur, thunderstorm activity is generally scattered and of short duration.

Table E3-3 indicates seasonal and annual averages of total precipitation and thunderstorm frequencies at eight stations nearest the proposed Hat Creek Project site. Snowfall statistics for the same observation locations are listed in Table E3-4. The greatest 24-hour rainfall and snowfall for each of the eight stations are listed in Table E3-5. Peak 24-hour rainfall rates have been recorded in the summer and fall seasons because of thunderstorm activity. Snow is rare during the summer. Only Dog Creek and Lytton received measurable snowfall in June, July or August. In general, similar precipitation patterns occur at stations with similar elevations and topographic characteristics.

E3.4 TEMPERATURE

Due to the presence of the Coast Range, south-central British Columbia is characterized by a typically continental climate. Without the moderating influence of the ocean, regions with continental climates experience large diurnal and seasonal temperature variations. Isopleths of mean annual and seasonal temperatures are plotted on Figures E3-7 through E3-11. Normal and extreme temperature statistics for stations in the more immediate vicinity of Hat Creek are listed in Tables E3-6 through E3-8.

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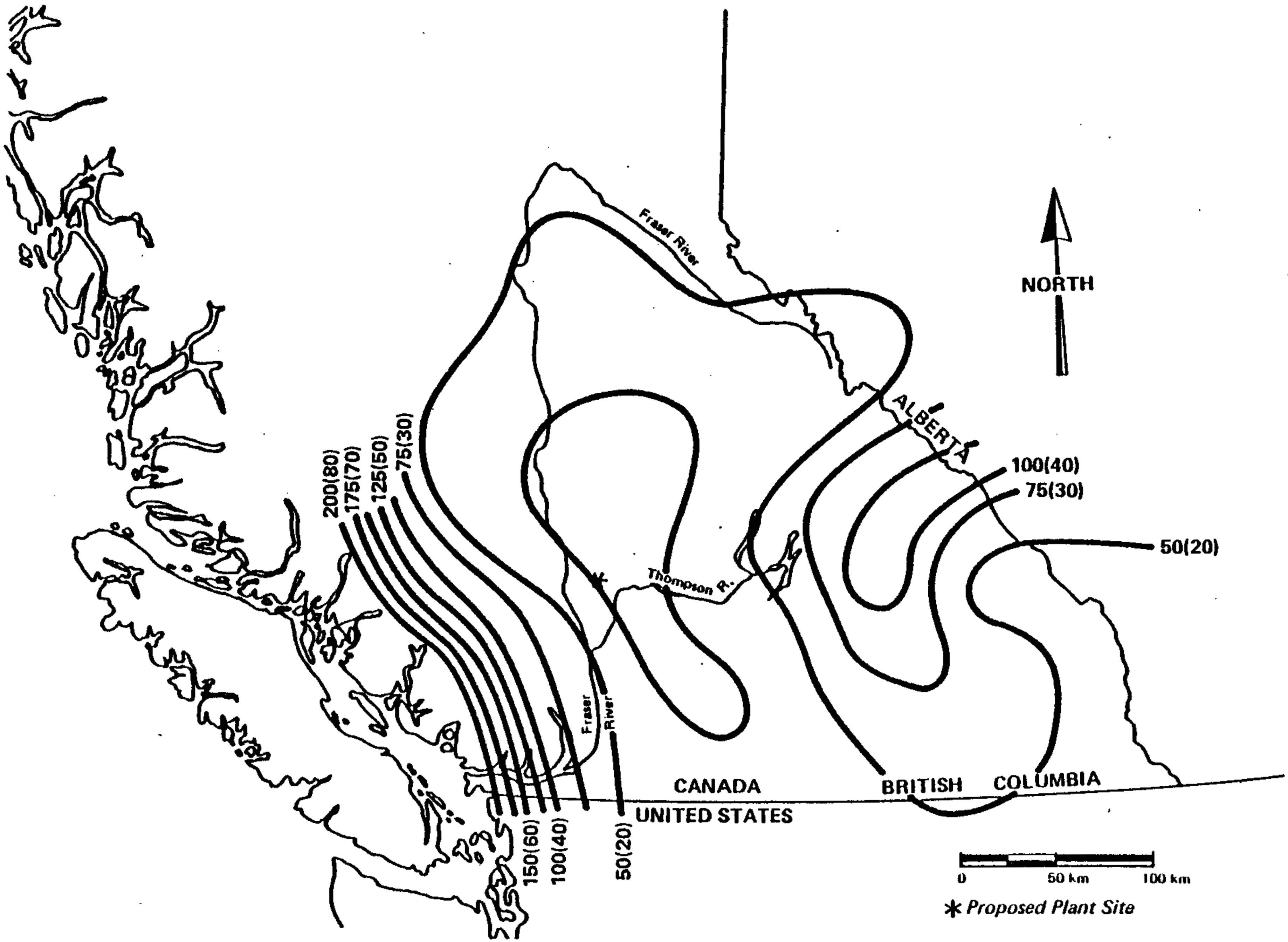

Figure E3-2 Hat Creek Region Mean Annual Precipitation [cm (inches)]

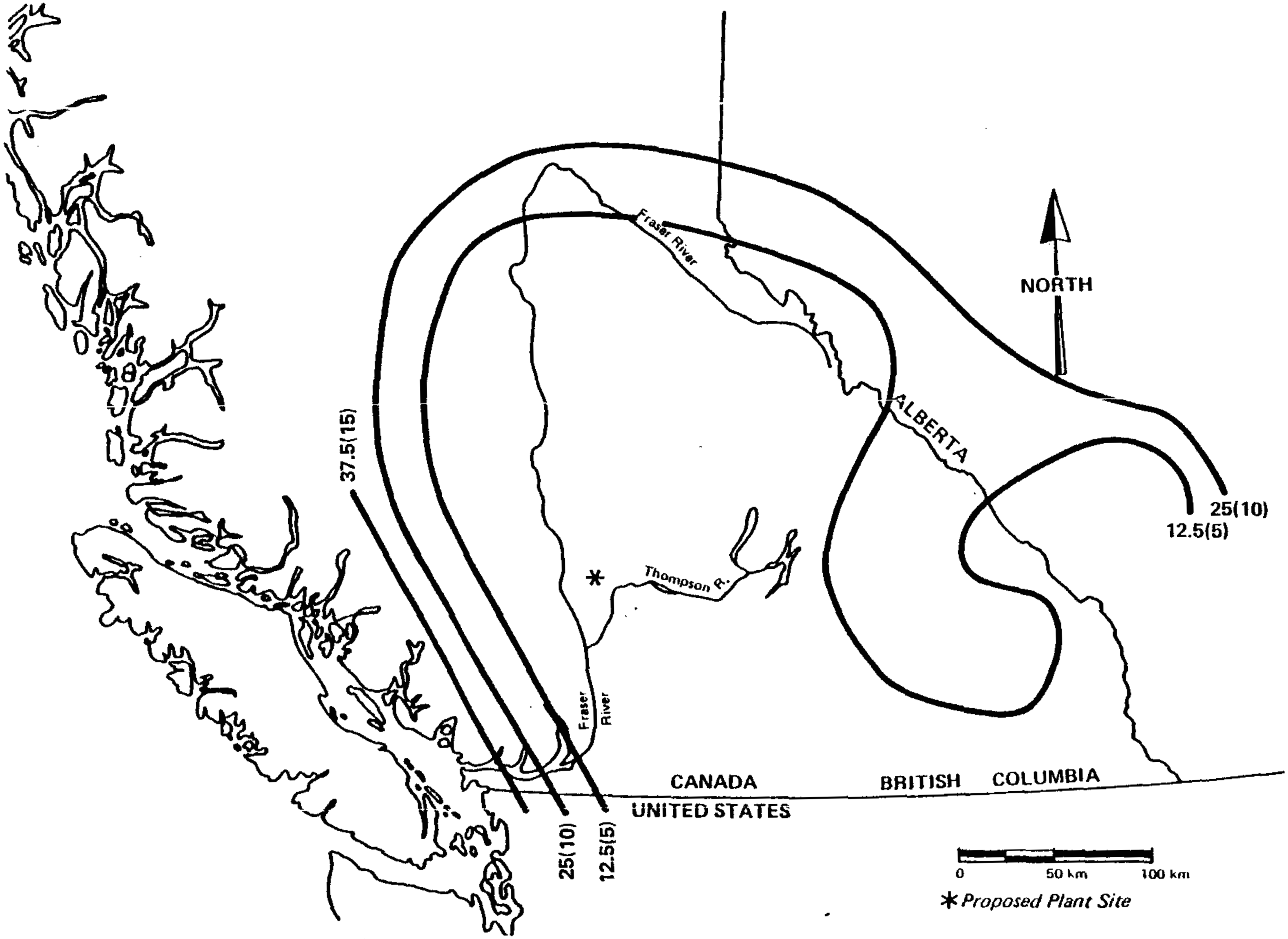

Figure E3-3 Hat Creek Region Mean Spring Precipitation [cm (inches)]

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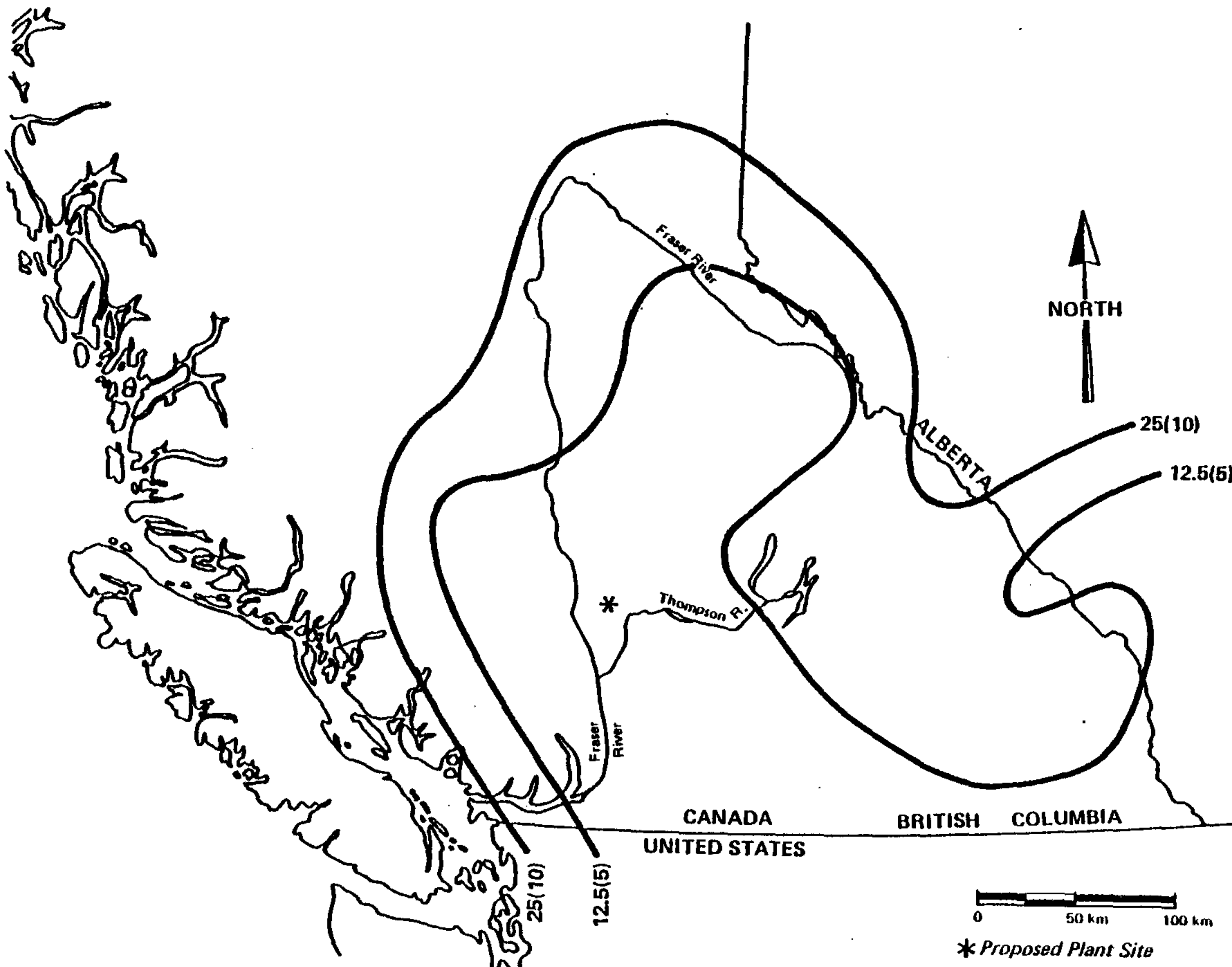

Figure E3-4 Hat Creek Region Mean Summer Precipitation [cm (inches)]

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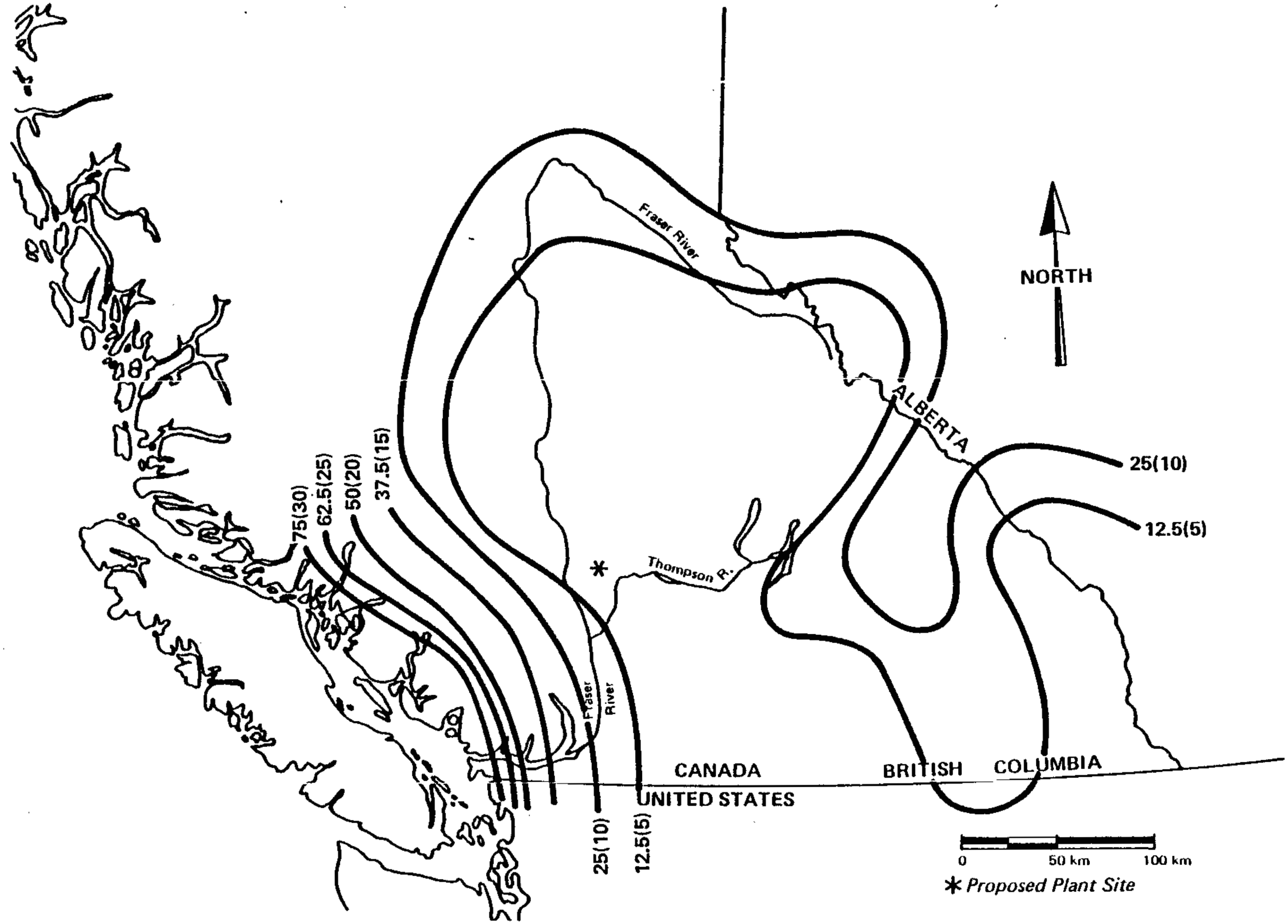

Figure E3-5 Hat Creek Region Mean Autumn Precipitation [cm (inches)]

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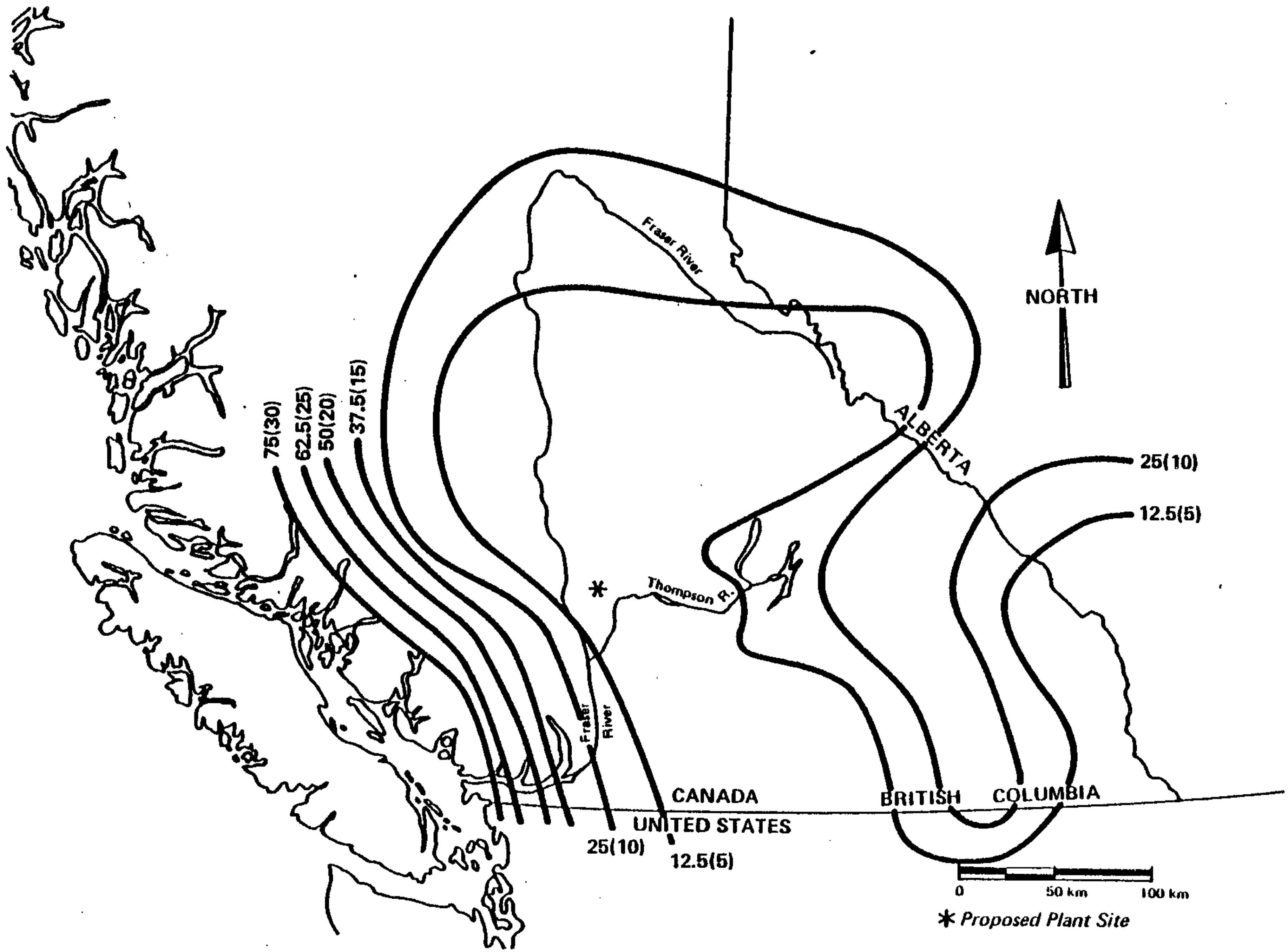


Figure E3-6 Hat Creek Region Mean Winter Precipitation [cm (inches)]

TABLE E4-1(a)

DIURNAL VARIATION IN SEASONAL MEAN RELATIVE HUMIDITY IN THE HAT CREEK REGION

(Winter)

Hour	Kamloops	Lytton	H.C. Mechanical 1	H.C. Mechanical 2	H.C. Mechanical 3
	%	%	%	%	%
01	69.1	999.0	74.5	75.7	77.1
02	69.9	999.0	74.6	75.5	77.9
03	70.1	999.0	75.4	75.5	78.3
04	70.3	999.0	75.5	75.4	78.2
05	69.9	79.7	75.4	75.5	78.1
06	69.4	79.9	75.6	75.5	77.9
07	69.2	79.6	75.9	75.6	78.3
08	68.9	79.5	74.8	74.4	78.3
09	68.8	79.0	66.9	71.6	75.8
10	67.5	77.3	55.8	65.9	71.5
11	65.6	76.4	49.7	58.6	63.8
12	64.8	72.6	45.4	53.0	58.5
13	63.2	70.5	43.5	49.2	57.2
14	62.6	68.5	43.8	48.3	57.6
15	62.7	66.5	44.3	49.5	60.0
16	62.9	68.2	48.9	54.3	61.7
17	63.9	69.3	57.7	60.9	65.9
18	65.2	72.0	65.6	66.8	70.6
19	65.4	72.9	70.1	70.3	73.8
20	67.0	74.2	72.3	72.7	75.7
21	67.8	74.8	73.7	73.5	76.7
22	68.5	76.1	74.8	74.6	77.6
23	68.4	76.7	75.0	75.3	77.9
24	68.8	999.0	75.2	75.6	78.2

Note: 999.0 means missing data.

area stations differ markedly in temperature from Kamloops and Lytton (see Table E3-6). During the most frequent fog-formation periods (i.e., early mornings in winter), the Hat Creek Valley stations (Nos. 1-5) average 5° to 10°C colder than Kamloops and Lytton, while Harry Lake is 2° to 6°C warmer. For this reason, when compared to the Kamloops and Lytton conditions, fog and its associated visibility restrictions can be expected more often in the Hat Creek Valley and less often at the ridge sites.

Table E4-2 (derived from Tables E3-11 and E3-12) lists frequency distributions of visible range limits observed at Kamloops and Lytton during winter (December 1974-February 1975). Visibilities less than 3.2 km (2 miles) occurred 5.6% and 3.9% of the time, respectively, at those stations. The corresponding figure for the lower Hat Creek Valley would be significantly higher, perhaps as high as 8% to 10%. Upper Valley sites should yield similar visibility distributions to those found at Kamloops and Lytton. Ridge sites (e.g., Harry Lake) would experience less frequent visibility restrictions in winter (probably less than 3% occurrence of visibilities less than 3.2 km).

E4.6 SOLAR RADIATION

Although no solar radiation sensors have been in operation in or near the Hat Creek Valley, estimates of seasonal and annual insolation can be obtained using data from nearby AES stations (Section E3.6).

E4.7 MIXING DEPTHS

The Hat Creek Valley and vicinity experience persistent ground-based inversions during early morning hours, as a result of downward settling of cold air. When nights are cloudy or winds vigorous, the inversions are weaker or absent. The inversion can be as deep as 500 m in the spring and up to 1000 m in the early autumn. When insolation is sufficiently strong, a shallow mixing layer forms near the surface. This layer extends upward into the inversion as the heating continues.

as 'continental'. Mean daily maximum and minimum temperatures are 11°C and -4°C. On the basis of comparisons with data from other stations in the region, a slightly warmer mean temperature is anticipated on the ridge near the proposed power plant site (see Table E3-6).

E4.4 HUMIDITY

The B.C. Hydro mechanical weather stations provide the only source of on-site humidity data for the present analysis. Table E4-1 lists seasonal mean relative humidities for each hour of the day at the eight stations. The tabulated values represent a one-year period. For comparison, corresponding humidities at Kamloops and Lytton are also included. Diurnal ranges of relative humidity are extremely large at Lower Valley Stations (Nos. 1-3), averaging about 40% during the spring and summer, about 30% in the fall, and 20% to 25% in winter. The ridge sites (Nos. 6-8) are generally less humid at night, but similar to the valley stations during the day.

E4.5 VISIBILITY

As was mentioned in Section E3.6, restricted visibility in the study region occurs infrequently, with most such events taking place in the fall and winter months. The major causes of restricted visibility are low-lying fog, particularly radiation fog, and slash burning. Radiation fog forms when air near the surface is cooled sufficiently to reach the dew point. In the Hat Creek area, such fogs occur most frequently in winter (coldest temperatures and low wind speeds), during early morning hours (4 AM is the hour of most frequent fog occurrence), and in low-lying areas. Restrictions to visibility because of radiation fog occur more frequently in the Hat Creek Valley than at the more elevated Harry Lake site.

Visibility data are not available for stations within the valley itself, although a visibility sensor was installed by B.C. Hydro in the fall of 1977. The nearest monitors are in Kamloops and Lytton. The Hat Creek

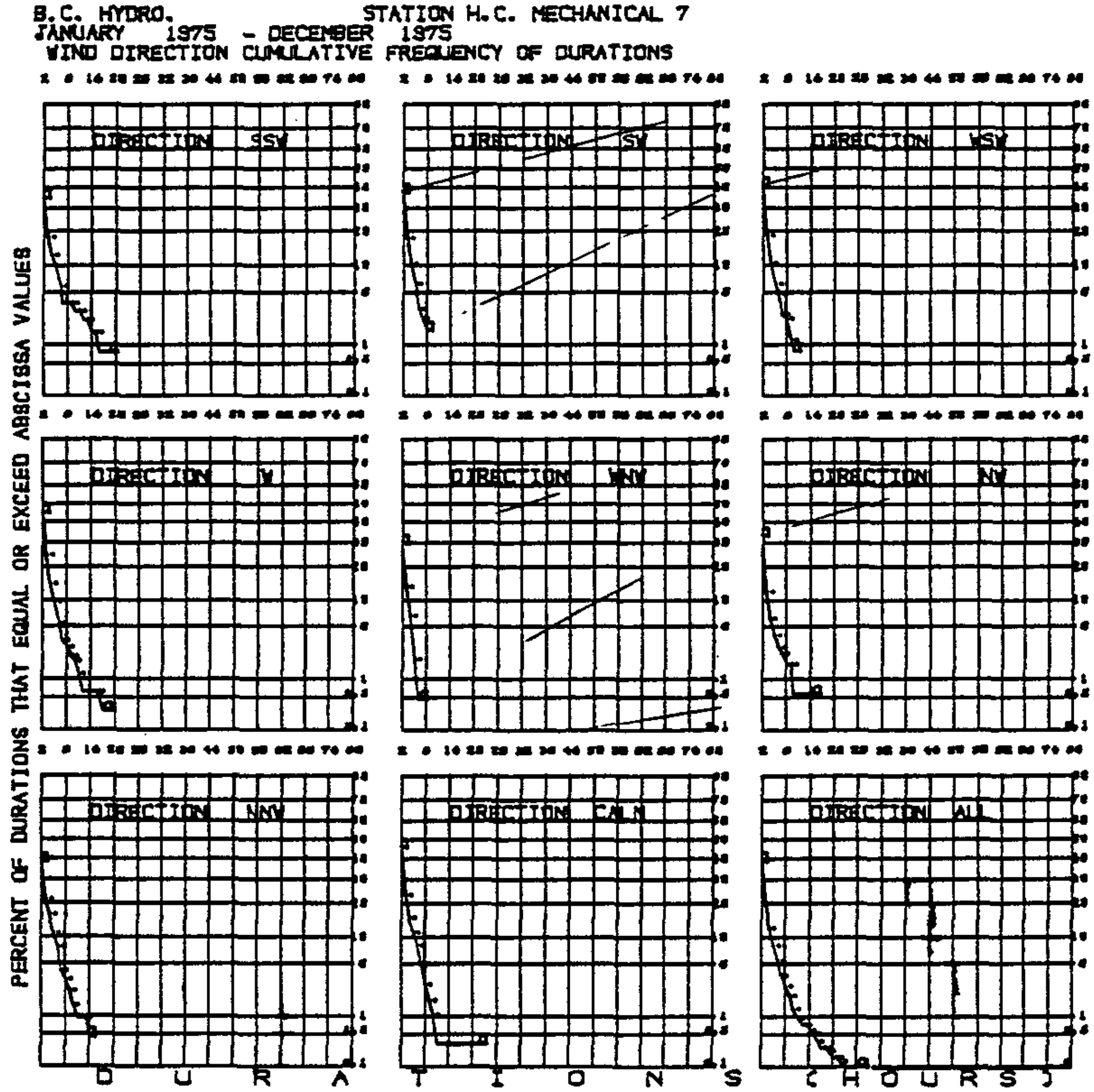


Figure E4-6 (Continued)

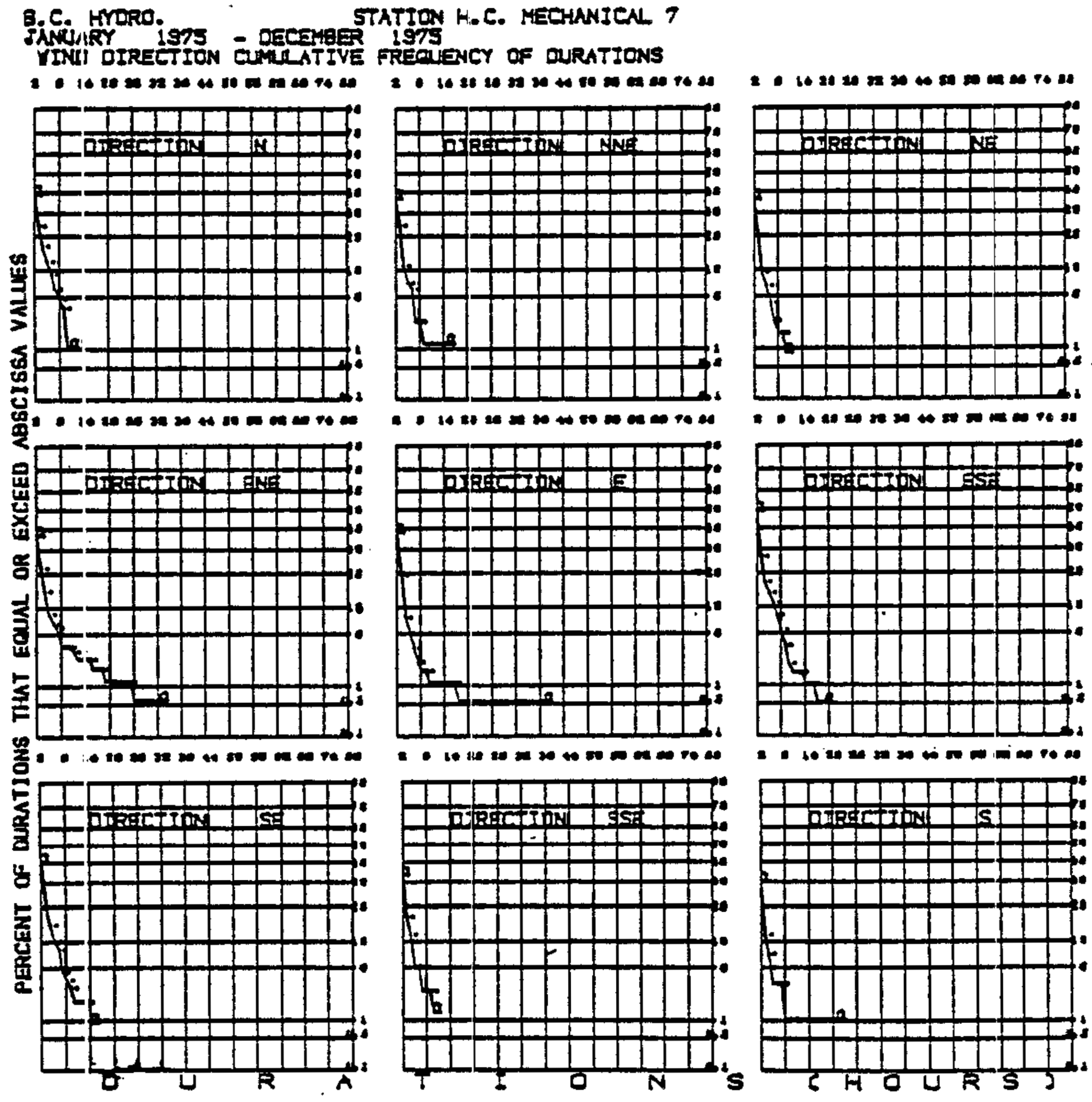


Figure E4-6 Plots of Wind Direction Persistence Versus Frequency for Station 7, Harry Lake Site

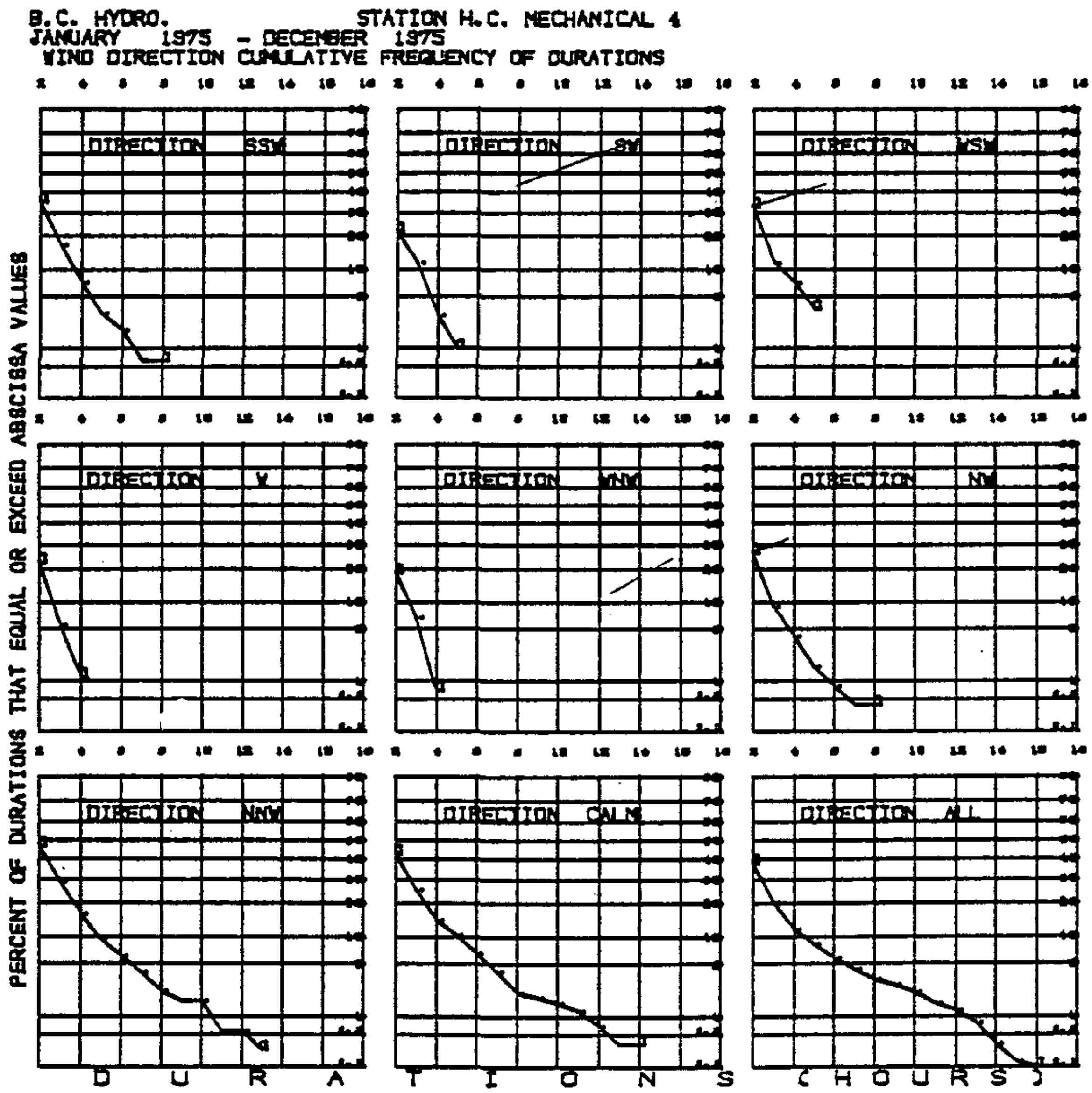


Figure E4-5 (Continued)

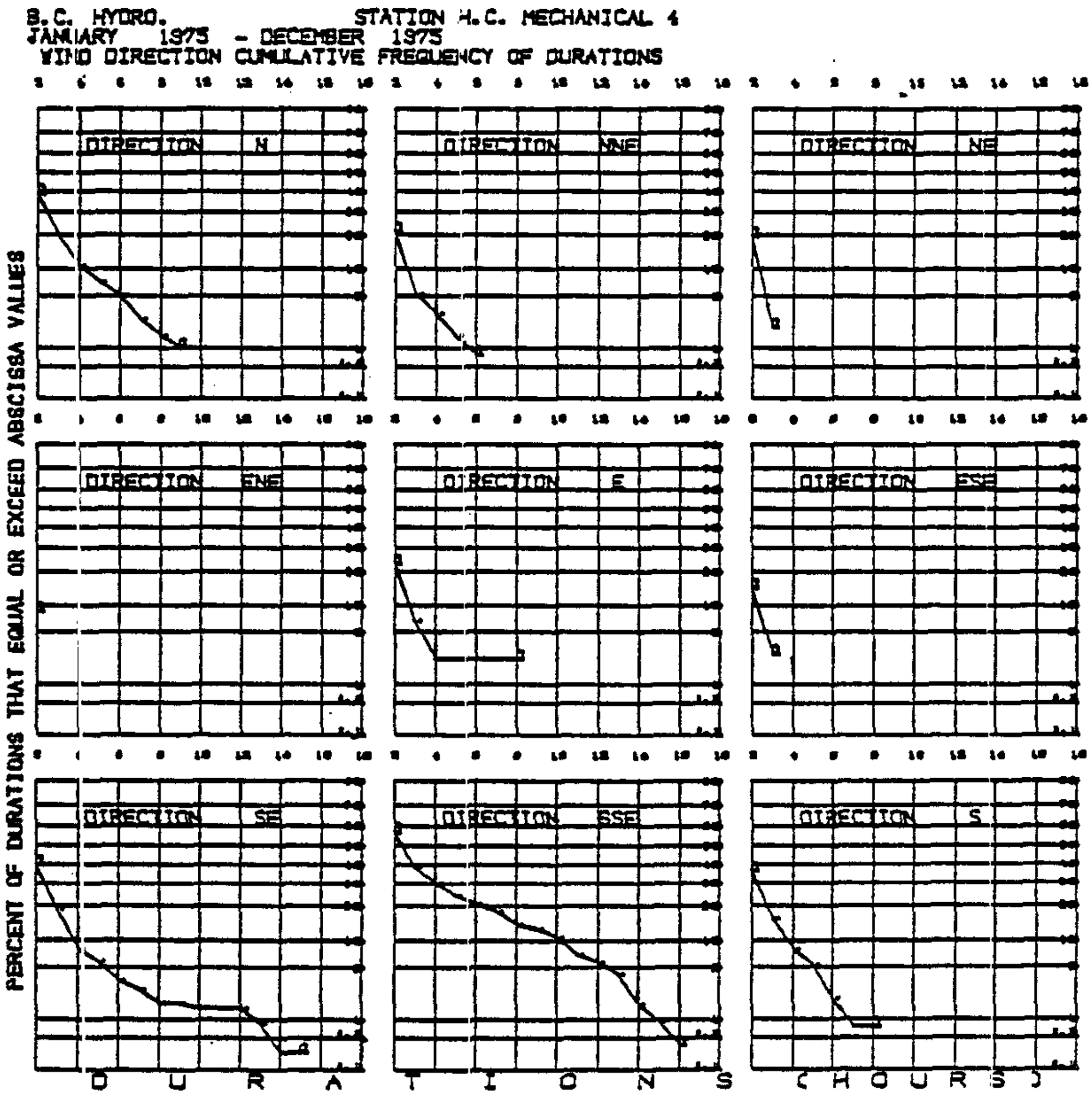


Figure E4-5 Plots of Wind Direction Persistence Versus Frequency for Station 4, Mine Site

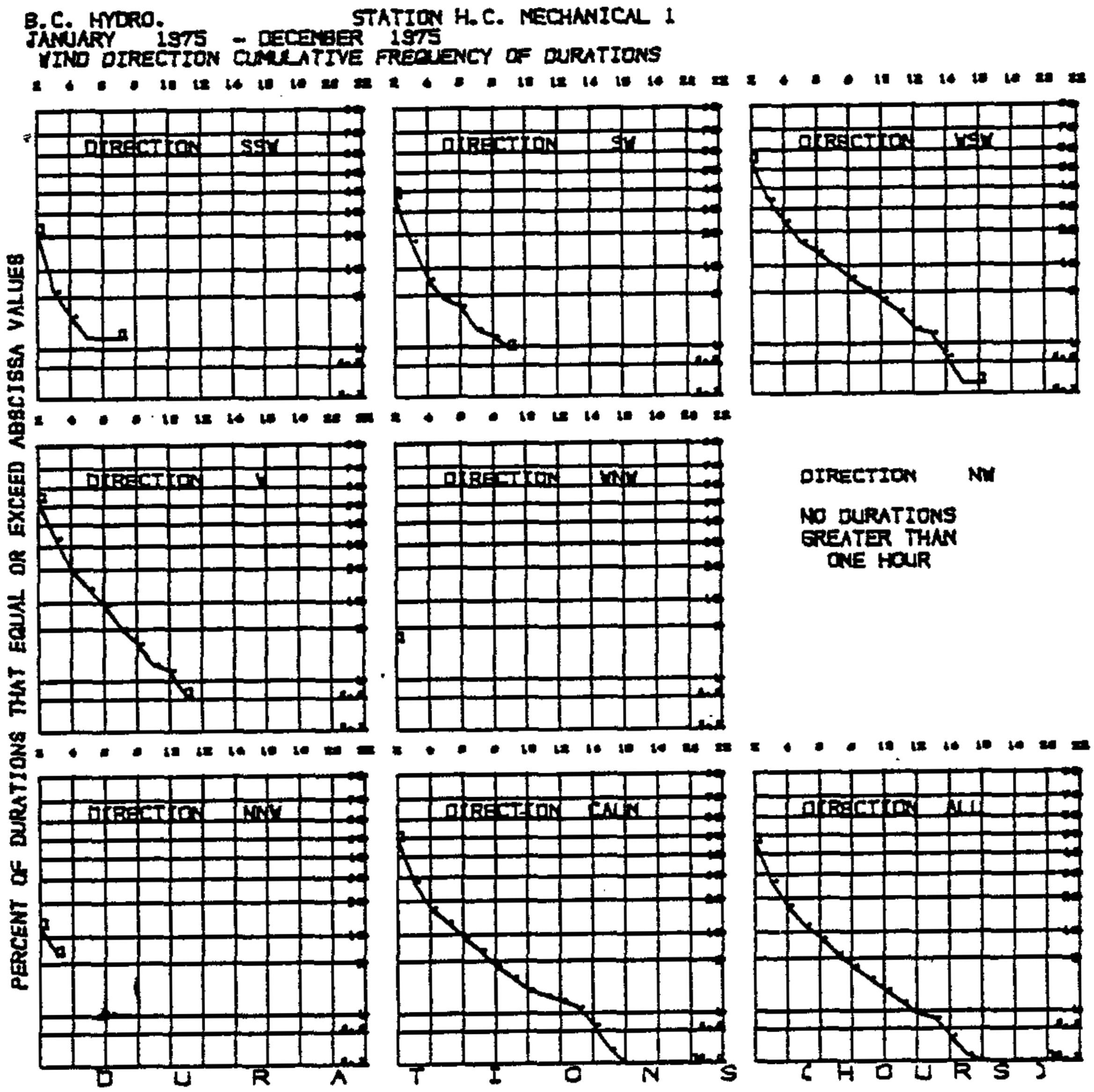


Figure E4-4 (Continued)

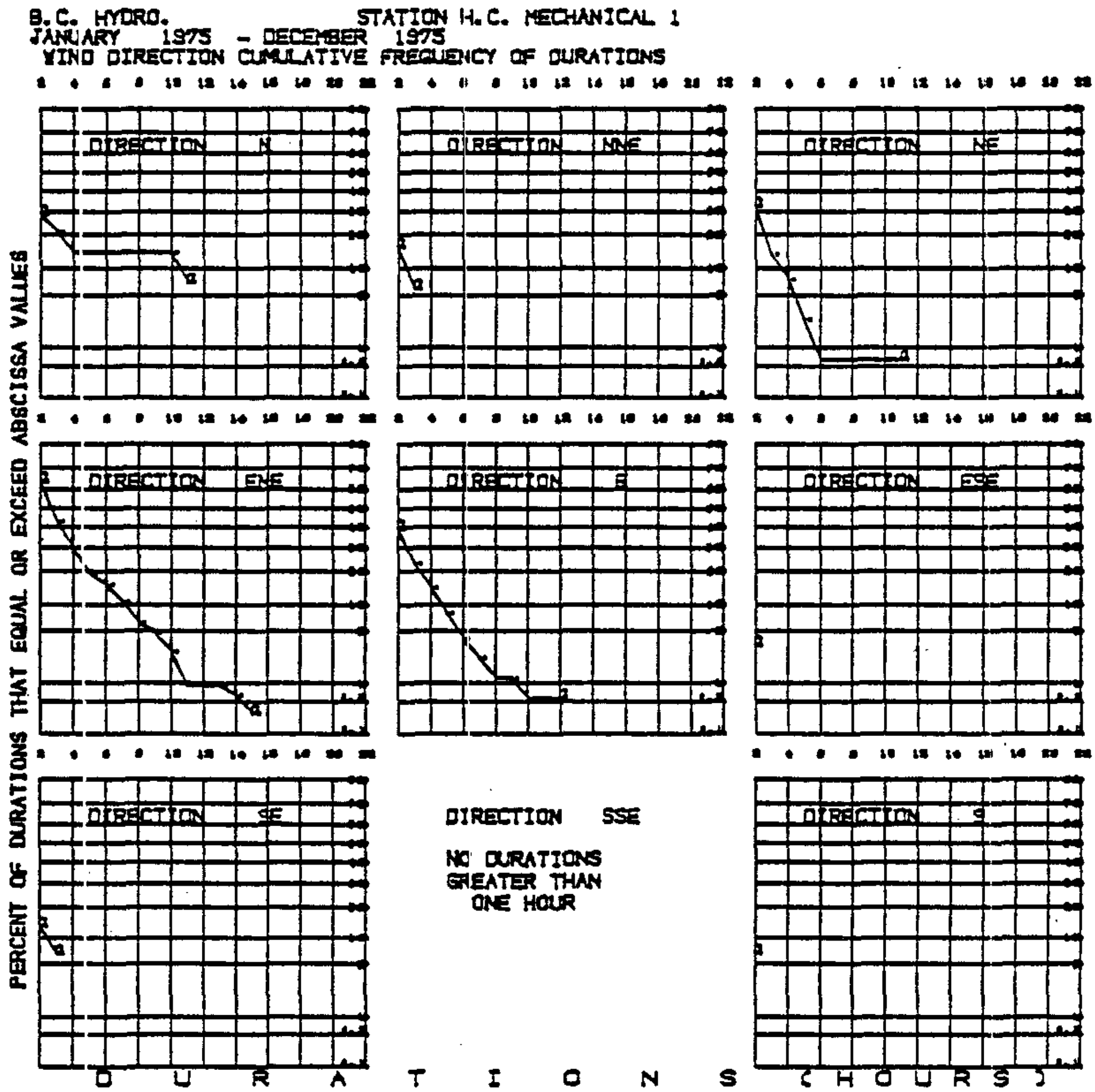


Figure E4-4 Plots of Wind Direction Persistence Versus Frequency for Station 1, Lower Hat Creek Valley winds at three levels above the valley floor are depicted. In the absence of a strong synoptic-scale flow, winds in the valley usually behave much as illustrated. When a regional wind is channeled into the valley, it may enhance, dominate or counteract the thermal circulation, depending on its speed and direction.

Cumulative frequency plots of directional persistence in the Lower Valley (Station 1), Upper Valley (Station 4), and at Harry Lake (Station 7) are presented in Figures E4-4 through E4-6. From these plots it is evident that calms and winds along the axis of the valley floor are the most persistent at valley locations, but periods with persistent direction for more than 16 hours are rare.

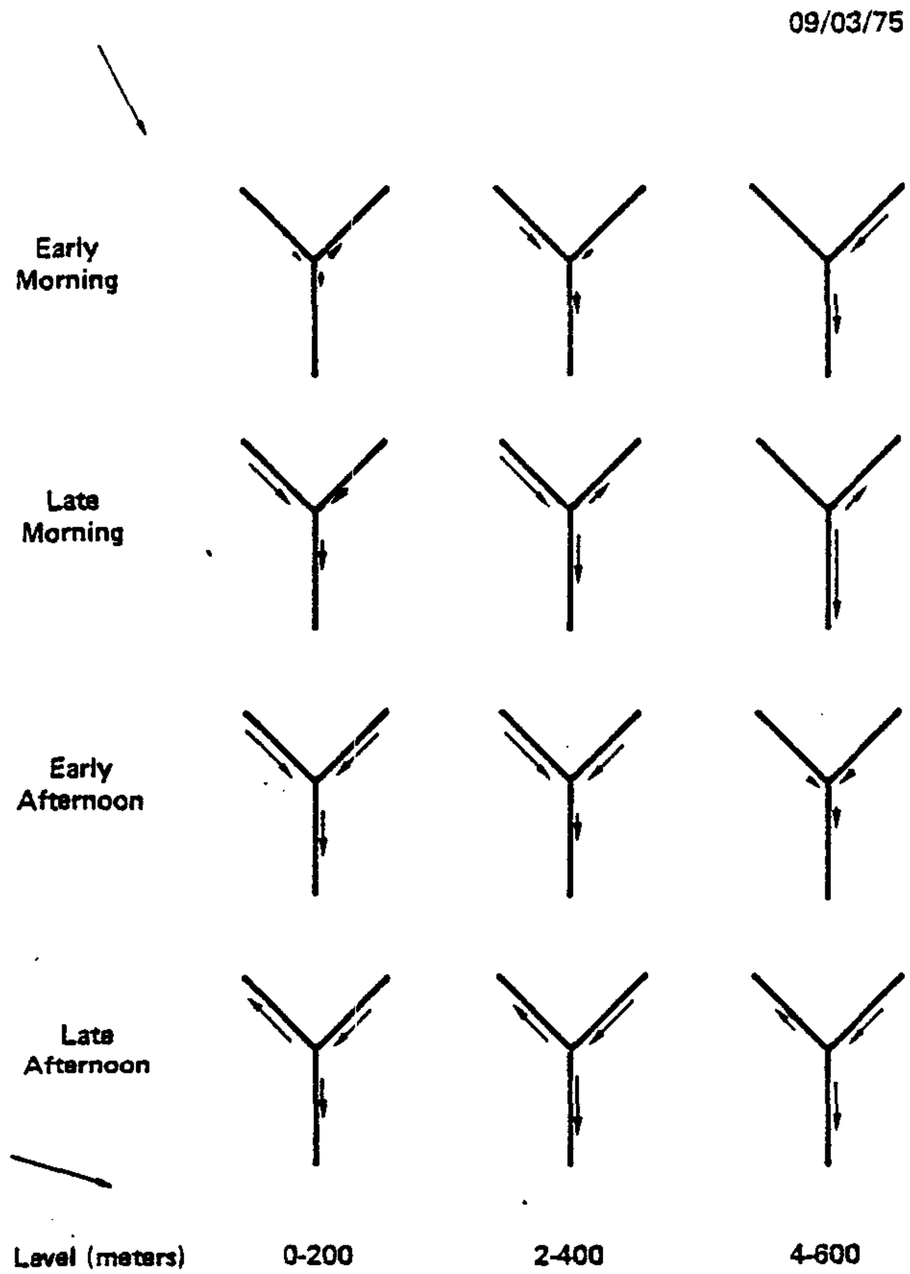
E4.2 PRECIPITATION

Precipitation measurements have been conducted continuously at the Hat Creek Climate Station in the Upper Valley for 15 years. The average total annual precipitation at this location is 31.6 cm. This total is distributed almost evenly over the year, with a slight maximum in winter. As noted in Section E3.3, precipitation amounts are similar for locations at similar elevations. Assuming a similar distribution for Harry Lake, it is expected that average total precipitation near the Harry Lake power plant site will be slightly more than the 40 cm recorded at Williams Lake (see Table E3-3).

Annual snowfall in the Hat Creek Valley averages approximately 130 cm; about 60% of this total is measured during the winter. Estimated snowfall at Harry Lake is about 250 cm, with somewhat larger contributions during the spring and fall seasons than are expected in the valley.

E4.3 TEMPERATURE

Mean annual temperature in the Hat Creek Valley is 3.2°C. Absolute maximum and minimum recorded values are 34°C and -43°C, respectively. Clearly, the area near the proposed Project site is aptly characterized



Notes: Lower center vector represents Hat Creek Valley. Upper left and upper right vectors represent adjoining west and east valleys. The two vectors in the left column represent the synoptic winds during the early morning and late afternoon.

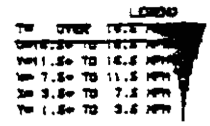
Figure E4-3 Wind Flow in the Hat Creek Valley and Adjoining East and West Valleys at Three Vertical Levels for Four Diurnal Periods, September 3, 1975

The figures presented in this section adequately characterize the annual average and annual diurnal distribution of winds taken at locations representative of the thermal plant (Harry Lake) and the coal mine (Station 5) - see Figure E4-2. The day-night variation in wind speed and direction at Harry Lake is small. The Harry Lake data indicate relatively light winds (typically 2 mps) and little orographic influence. The annual and diurnal wind roses show the influence of synoptic scale north-northwesterly, westerly and general southwesterly winds. On the other hand, the data collected at Station 4 show the dominance of the valley circulation. Although the winds in the valley are generally light, occasional strong southwest winds occur when the drainage flow reinforces the synoptic flow. Nighttime winds are predominantly from the south-southwest, a manifestation of the drainage flow, while daytime conditions generate upslope and channeled winds.

The wind rose figures depict the frequency distribution of wind speed for each station and indicate that strong winds (above 18.5 mph) are infrequent. This is especially true for the valley station. Only the Cornwall Hills (Station 6) and Pavillion Mountains (Station 8) sensors recorded significantly high winds (see Figure E4-1). At the Cornwall Hills, strong south-southwest winds were observed about 3.5% of the time; at the Pavillion Mountains, strong southwest winds were recorded about 3% of the time. As an additional illustration of strong winds, a list of the frequency of winds in specified wind speed (in knots) categories* measured at Kamloops for each month during 1963-1972 follows: Jan 39-46 0.7%; Feb 39-46 0.4%; Mar 32-38 0.6%; Apr 32-38 0.2%; May 32-38 0.3%; June 25-31 4.8%; July 34-46 0.1%; Aug 32-38 0.1%; Sept 32-38 0.2%; Oct 32-38 0.3%; Nov 32-38 0.6%; and Dec 39-46 0.1%.

Figure E4-3 demonstrates a typical diurnal flow pattern in the Hat Creek Valley. This figure is taken from a report by the MEP Company. Average

*The upper limit of each category represents the maximum possible wind speed for that month.



B.C. HYDRO.
STATION NUMBER H.C. MECHANICAL 7
JANUARY 1975 - DECEMBER 1975
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT
STABILITY CLASS ALL

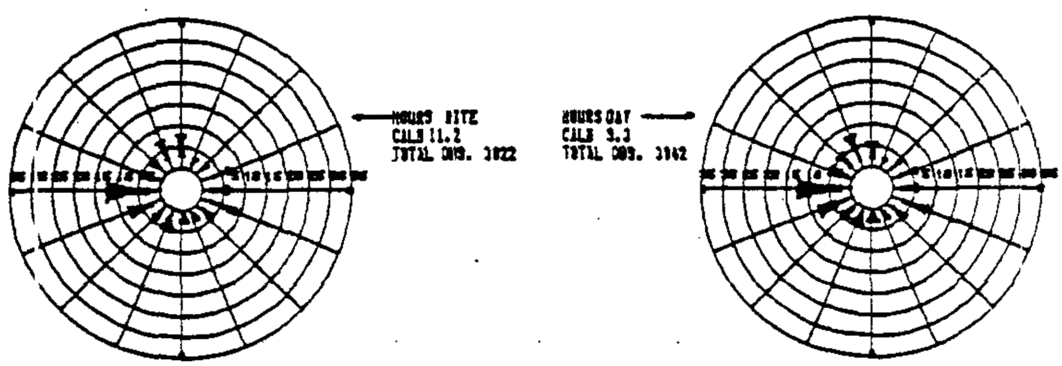


Figure E4-2 (Continued) (Station 7)

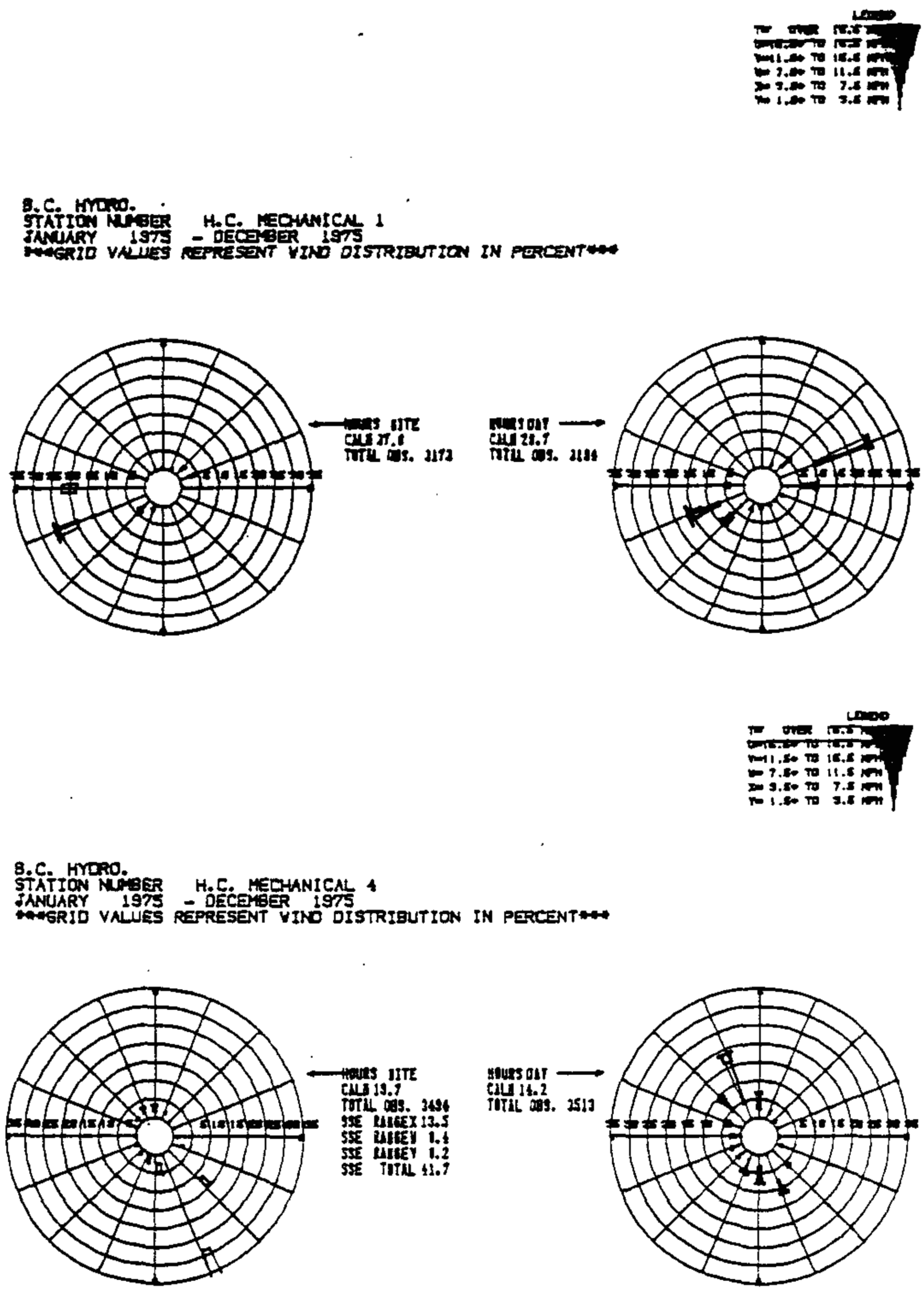


Figure E4-2 Annual Day/Night Wind Roses for Lower Hat Creek Valley (Stations 1 and 4)

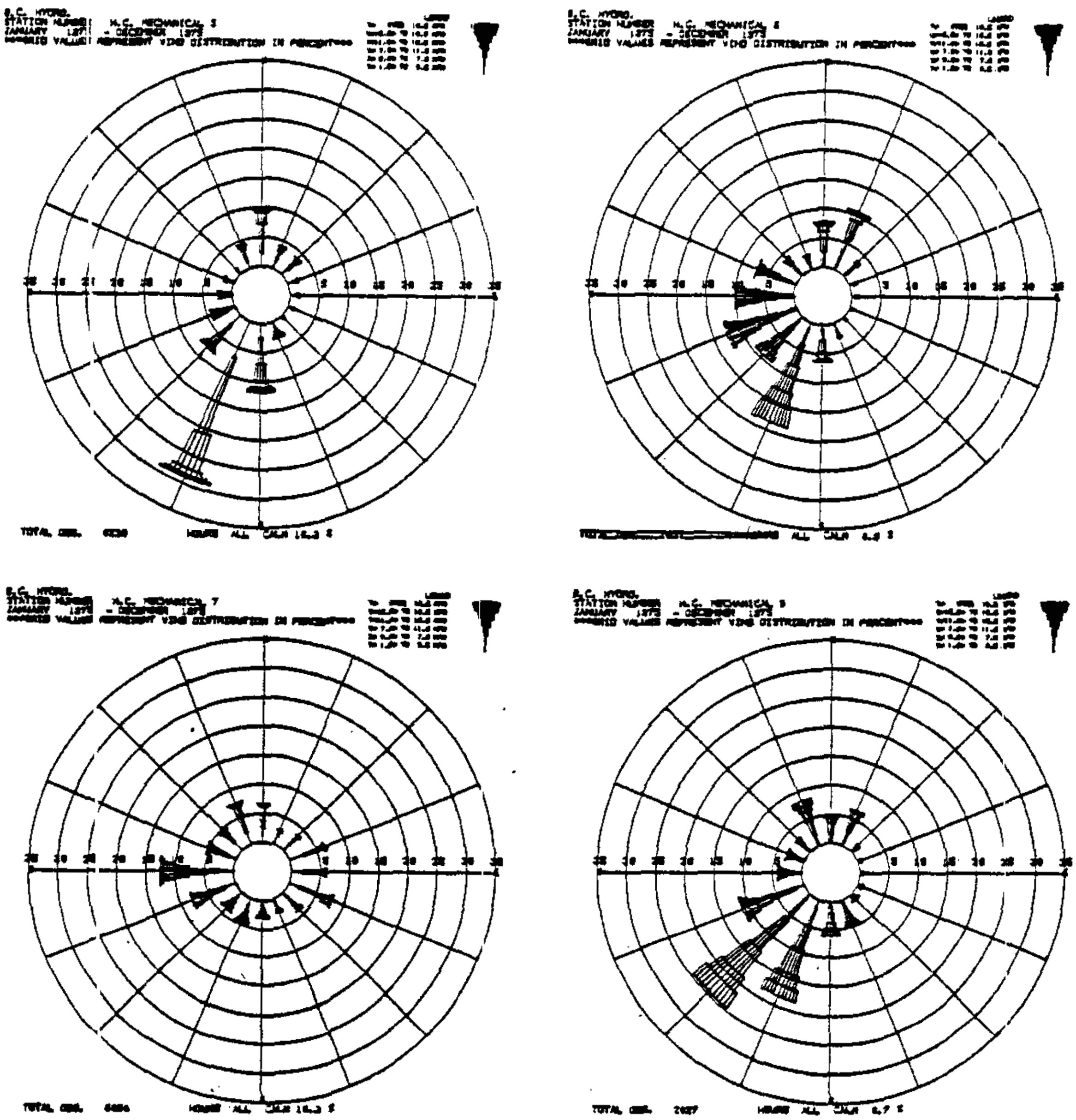


Figure E4-1 (Continued)

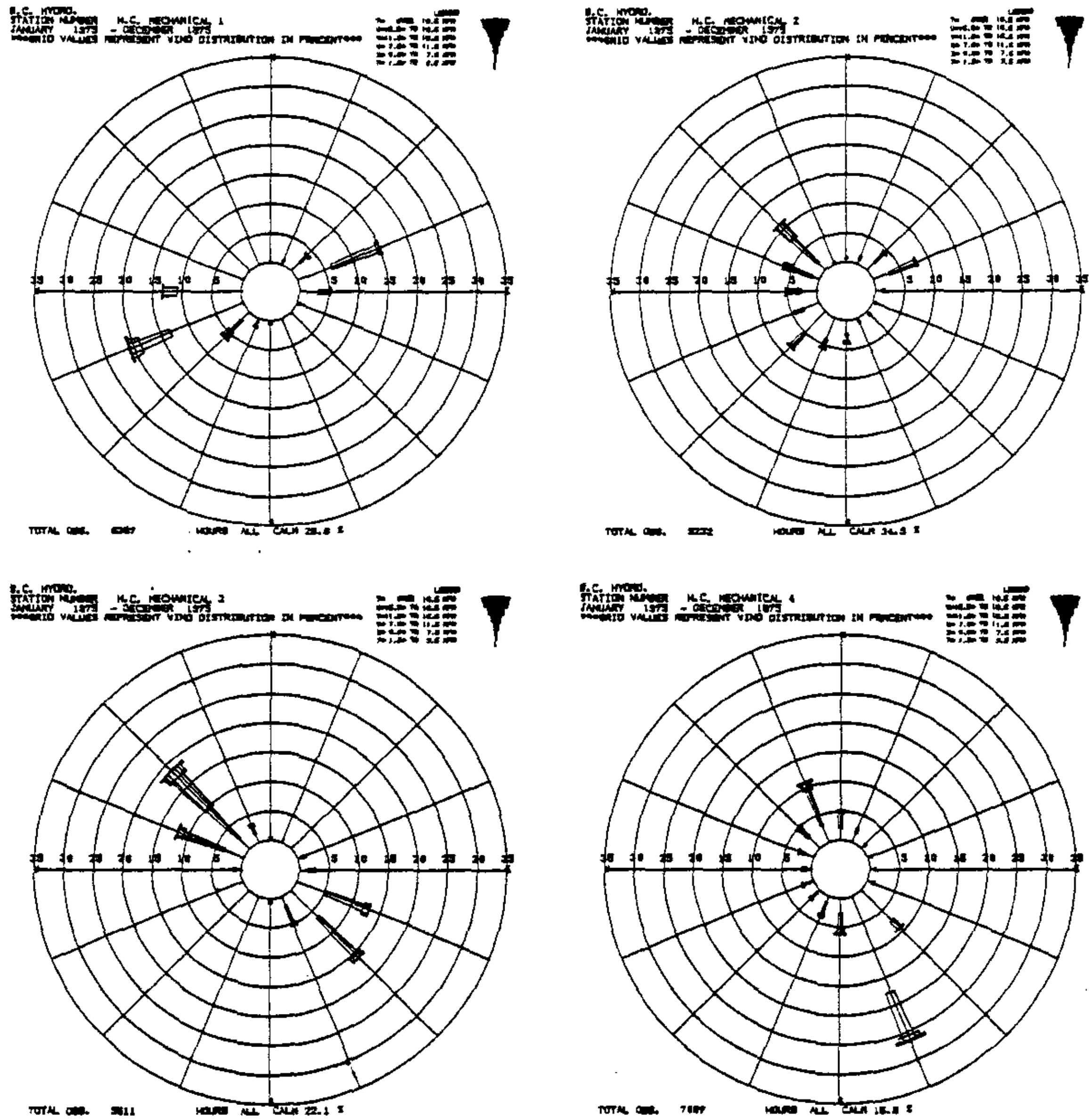


Figure E4-1 Annual Wind Roses for All Hours at Eight Mechanical Weather Stations since only on-site measurements provide realistic data for this purpose, it is recommended that this analysis be repeated when information representing a time period of three years or more becomes available.

E4.1 LOCAL WINDS

Annual wind roses (the frequency distribution of wind speed and direction) for the eight B.C. Hydro weather stations are presented in Figure E4-1. The importance of terrain channeling and local mountain/valley circulations is immediately apparent from the large differences in wind statistics for stations separated by only a few kilometers. It is possible to infer the orientation of terrain at each of the valley stations (Nos. 1-5) from the directions and speeds of the prevailing winds. Only the stations at higher elevation (Nos. 6-8) show evidence of the frequent southerly and westerly flows associated with large-scale pressure systems over the region. These ridge stations report the highest frequency of high wind speed conditions; valley locations often experience calms (see Table E3-2).

Diurnal flow patterns at three stations (Nos. 1, 4, and 7) are displayed by means of separate daytime (6 AM to 6 PM) and nocturnal wind roses in Figure E4-2. Stations 1 and 4 provide data indicative of conditions within the Lower and Upper Valleys, respectively; Station 7 is near Harry Lake about 2 km south of the power plant site. Significant variations are evident in the day/night patterns at the valley stations. These differences are characteristic of locations influenced by mountain/valley circulations. Calm conditions (wind speed less than 0.67 mps) dominate during nighttime hours. Otherwise, winds tend to conform to the orientation of the valley at each site. Daytime winds at the lower elevations are generally upslope and slightly stronger. The diurnal variation at the ridge site (Station 7), the location most representative of the thermal plant, is much less pronounced, reflecting more the frequent influence of synoptic winds at this less sheltered location.

E4.0 LOCAL CLIMATOLOGY - THE HAT CREEK PROJECT SITE

As discussed in Section E2.0 and elsewhere, wind speed, wind direction, temperature and relative humidity have been measured continuously since late 1974 by B.C. Hydro at each of eight mechanical weather stations in and around the Hat Creek Valley. The locations of these stations with respect to local topographic features and to the proposed sites of the coal mine and power plant are indicated in Figure E2-2. At the time of this study, data representing only one year (1975) of meteorological measurements were available for analysis. Normally, a longer record of weather data is required to establish climatological patterns. However, due to the complex topography of the southern interior of B.C., the representativeness of data from other locations in the study region must be carefully evaluated.

The results of analyses discussed in Section E3.3 through E3.5 indicate that precipitation, temperature and humidity patterns depend primarily on elevation and location with respect to nearby terrain features. Visibility, cloudiness and solar insolation appear to be fairly uniform over the study region (Sections E3.6 and E3.7). Thus, characteristic patterns for these parameters at Hat Creek may be inferred from long-term station data with reasonable certainty. On the other hand, local wind circulations in the region are uniquely determined by the nature and orientation of terrain features near the measurement stations. Low-level winds in the immediate vicinity of the proposed Project site cannot be determined with confidence on the basis of data acquired at stations with other topographic characteristics. For this reason, wind data derived from the B.C. Hydro network and other on-site field studies are considered more appropriate for purposes of identifying local flow characteristics. The relatively short duration of the data record available from the mechanical weather stations is less important for winds than for other variables in a location like Hat Creek, where topography defines and limits the types of flow that can occur. However,

TABLE E3-16

MEAN AFTERNOON MIXING DEPTHS FOR
SOUTHERN BRITISH COLUMBIA (1965-69)*

	Mean Mixing Depth (m)			
Season	Port Hardy (coastal station)	Prince George	Spokane, Wash.	Hat Creek Valley Vicinity**
Winter	400	350	400	350
Spring	<1000	1600	1300	1400
Summer	800	1800	2250	1800
Fall	400	750	950	750
Annual	650	1100	1350	1100

*Source: Portelli (1976).
**Interpolated from Portelli (1976) graphs.

TABLE E3-17

VENTILATION COEFFICIENTS FOR
SOUTHERN BRITISH COLUMBIA (1965-1969)*

	Mean Ventilation Coefficients (m^2/sec)			
Season	Port Hardy (coastal station)	Prince George	Spokane, Wash.	Hat Creek Valley Vicinity**
Winter	<3,000	2,000	∿3,000	<3,000
Spring	<3,000	4,500	6,000	4,500
Summer	4,000	8,500	12,500	8,500
Fall	<3,000	4,500	6,000	4,500

*Source: Portelli (1976)
**Interpolated from Portelli (1976) graphs.

analysis: Prince George, Port Hardy, and Spokane, Washington. Table E3-16 presents the results for the three upper-air observation stations and Hat Creek Valley. Mixing depths for the valley were estimated by interpolation from Portelli's isopleths[12] and are included in the table. The method used to calculate the tabulated values does not include consideration of terrain effects that can affect the true mixing depth in a region of complex topography. It is also important to note that contaminants released above the mixing height (e.g., from a tall stack) will not result in appreciable ambient concentrations below this level, since the inversion acts to inhibit downward as well as upward dispersion.

A crude measure of the potential for adverse air quality in a region is indicated by characteristic values of the so-called 'ventilation coefficient.' This parameter is defined simply as the product of the mixing depth and the concurrent average wind speed. According to Gross,[13] a ventilation coefficient less than 6,000 m^2/sec is associated with potentially high contaminant concentrations. Table E3-17 lists seasonal and annual mean ventilation indices for the three upper-air stations nearest the Project area and for Hat Creek Valley. An annual average value of 6,000 to 7,000 was recommended by Portelli for the section of the Fraser River Valley between Prince George and Hope, B.C. Nearly all of Canada was found to have a winter ventilation coefficient below 6,000 m^2/sec. Winter values below 3,000 m^2/sec are estimated for all stations listed in Table E3-17.

The Atmospheric Environment Service has not yet verified that the ventilation index criterion used in the United States is valid in Canada. A pollution potential forecast method appropriate for Canada is presently under development.

TABLE E3-15

TOTAL HOURS OF BRIGHT SUNSHINE IN THE HAT CREEK REGION*

Station	Number of Hours of Sunshine **				
	Annual	Winter	Spring	Summer	Fall
Kamloops	2,080	217	574	895	394
Kelowna	2,088	160	574	903	451
Lytton	1,990	185	607	829	369
Penticton	2,076	174	599	880	423
Williams Lake	2,168	251	621	912	384

*3-1/2 year average, (1972-1975)
**Bright sunshine hours defined as hours when solar intensity is strong enough to produce a reading on a pyronometer.

Source: Canadian Weather Review

TABLE E3-13

ANNUAL CLOUD COVER STATISTICS FOR KAMLOOPS AND LYTTON
(1974-1975)

KAMLOOPS Upper Limit of Interval (tenths of sky covered)	KAMLOOPS Percent Occurrence	KAMLOOPS Cumulative Percent	LYTTON Upper Limit of Interval (tenths of sky covered)	LYTTON Percent Occurrence	LYTTON Cumulative Percent
0	12.834	12.834	0	14.763	14.763
1	6.859	19.692	1	6.341	21.104
2	5.688	25.380	2	5.059	26.163
3	5.498	30.821	3	4.659	30.823
4	4.442	35.264	4	3.903	34.725
5	3.800	39.063	5	3.819	38.544
6	4.689	43.752	6	4.463	43.007
7	6.445	50.198	7	5.633	48.641
8	9.631	59.829	8	7.378	56.019
9	13.293	73.122	9	16.165	72.183
10	26,878	100.000	10	27.817	100.000

*Source: Analysis of AES data

TABLE E3-14

ANNUAL CLOUD CEILING STATISTICS FOR KAMLOOPS AND LYTTON
(1974-1975)

KAMLOOPS Upper Limit of Ceiling Height Interval (100's of feet)	KAMLOOPS Percent Occurrence	KAMLOOPS Cumulative Percent	LYTTON Upper Limit of Ceiling Height Interval (100's of feet)	LYTTON Percent Occurrence	LYTTON Cumulative Percent
0	0.029	0.029	0	0.112	0.112
29	5.912	5.940	20	5.788	5.900
40	4.023	9.964	40	8.772	14.672
60	9.241	19.204	60	8.856	23.529
80	8.816	28.020	80	7.266	30.795
100	8.569	36.590	100	5.872	36.666
120	5.504	42.094	120	2.845	39.511
140	2.101	44.194	140	1.184	40.695
160	1.527	45.721	160	1.177	41.872
180	0.316	46.037	180	0.694	42.566
200	1.119	47.156	200	1.920	44.486
220	1.314	48.470	220	1.338	45.824
240	0.316	48.786	240	0.764	46.588
260	2.221	51.007	260	1.345	47.933
280	0.080	51.066	280	0.084	48.017
300	0.264	51.352	300	0.021	48.038
	48.648	100.000		51.962	100.000

*Source: Analysis of AES data

Although the Kamloops and Lytton visibility data indicate relatively infrequent restrictions to visibility, slash burning by the forest industry during the autumn has caused visibility reductions in and near the Hat Creek Valley. Slash burning can reduce the visibility to less than 8 km and occasionally to about 1.0 km or less.

E3.7 CLOUD COVER AND SOLAR INSOLATION

Cloudy skies are common in the southern interior of British Columbia. While the region is generally quite dry, the presence of numerous rivers and lakes and the orographic lifting of low-level flows over the mountains produce clouds covering at least half the sky about 60% of the time. Tables E3-13 and E3-14 are statistical summaries of cloud cover and ceiling observations taken at Kamloops and Lytton during a two-year period. Frequency distributions of both parameters for the two stations are quite similar. Middle and high clouds occur most often; ceilings less than 1800 m (6,000 ft) above the ground were reported less than 10% of the time.

Table E3-15 lists seasonal and annual average hours of recorded bright sunshine at five locations. About 2,000 hours of bright sunshine per year are reported throughout the region. Winter is the cloudiest season; summer the least cloudy. It should be noted that the great differences between summer and winter sunshine hours are partly attributable to the fact that summer days are substantially longer than winter days at the latitude of the study region (48° - 50°N).

E3.8 MIXING DEPTHS AND VENTILATION COEFFICIENTS

Mixing depth may be defined as the height of the atmospheric layer nearest the ground through which significant dilution of air contaminants can occur. The larger the value of this parameter, the greater the volume available for dispersal of the contaminants. The top of the mixing layer corresponds to the base of stable atmospheric layers or inversions. Following the methods of Holzworth[10] and Munn,[11] Portelli[12] has computed mean seasonal and annual mixing depths throughout Canada. Three stations in the general vicinity of Hat Creek are included in this

TABLE E3-11

SEASONAL FREQUENCY DISTRIBUTION OF VISIBLE RANGE LIMITS (MILES) FOR KAMLOOPS (1974-1975)

December 1974 - February 1975

Upper Limit of Interval	Percent Occurrence	Cumulative Percent
0.0	2.663	2.663
1.000	3.010	5.673
2.000	1.505	7.176
3.000	1.852	9.030
4.000	1.667	10.697
≥ 5.000	89.303	100.000

Number of Values = 4319

March 1974 - May 1975

Upper Limit of Interval	Percent Occurrence	Cumulative Percent
0.0	0.159	0.159
1.000	0.113	0.272
2.000	0.068	0.340
3.000	0.136	0.476
4.000	0.136	0.611
≥ 5.000	99.369	100.000

Number of Values = 4416

June 1974 - August 1975

Upper Limit of Interval	Percent Occurrence	Cumulative Percent
0.0	0.0	0.0
1.000	0.0	0.0
2.000	0.0	0.0
3.000	0.0	0.0
4.000	0.0	0.0
≥ 5.000	100.000	100.000

Number of Values = 4416

September 1974 - November 1975

Upper Limit of Interval	Percent Occurrence	Cumulative Percent
0.0	0.281	0.281
1.000	0.421	0.702
2.000	0.234	0.936
3.000	0.117	1.053
4.000	0.164	1.217
≥ 5.000	98.783	100.000

Number of Values = 4272

*Source: Analysis of AES data

TABLE E3-12

SEASONAL FREQUENCY DISTRIBUTION OF VISIBLE RANGE LIMITS (MILES) FOR LYTTON (1974-1975)

December 1974 - February 1975

Upper Limit of Interval	Percent Occurrence	Cumulative Percent
0.0	1.911	1.911
1.000	1.965	3.876
2.000	1.050	4.926
3.000	2.826	7.752
4.000	1.373	9.125
7.000	90.875	100.000

Number of Values = 3715

March 1974 - May 1975

Upper Limit of Interval	Percent Occurrence	Cumulative Percent
0.0	0.326	0.326
1.000	0.299	0.625
2.000	0.109	0.734
3.000	0.408	1.142
4.000	0.353	1.495
7.000	98.505	100.000

Number of Values = 3679

June 1974 - August 1975

Upper Limit of Interval	Percent Occurrence	Cumulative Percent
0.0	0.086	0.086
1.000	0.0	0.086
2.000	0.0	0.086
3.000	0.0	0.086
4.000	0.114	0.200
7.000	99.800	100.000

Number of Values = 3496

September 1974 - November 1975

Upper Limit of Interval	Percent Occurrence	Cumulative Percent
0.0	2.218	2.218
1.000	0.769	2.986
2.000	0.355	3.341
3.000	1.538	4.879
4.000	0.828	5.707
7.000	94.293	100.000

Number of Values = 3382

*Source: Analysis of AES data

TABLE E3-9

DEW POINT AND RELATIVE HUMIDITY IN THE HAT CREEK REGION*

	Mean Dew Point (°C) per Station					
Season	Ashcroft	Dog Creek	Kamloops	Kelowna	Lytton	Penticton
Winter	-10.9	-10.0	-6.3	-4.3	-4.3	-4.3
Spring	0.6	-1.8	1.7	1.5	2.8	1.5
Summer	7.8	7.4	10.0	10.5	10.0	10.5
Fall	1.3	0.0	3.3	4.1	4.4	4.0
Annual	0.2	-1.1	2.2	2.9	3.2	2.9
	Mean Relative Humidity (%) per Station					
Winter	83.7	82.7	79.3	79.3	82.0	79.3
Spring	57.7	61.7	57.7	61.3	61.0	61.3
Summer	49.0	62.3	53.7	60.0	50.7	60.0
Fall	66.3	73.0	71.7	71.3	72.0	71.3
Annual	64.2	69.9	65.6	68.0	66.4	68.0
Period of Record (yrs)	6	6	10	10	6	10

*Source: World-wide Airfield Summaries, USNWS (1967)

TABLE E3-10

OBSERVATIONS OF LIMITED VISIBILITY IN THE HAT CREEK REGION

Number** of Observations of Limited Visual Range (miles)*

Location	1973 0.0-0.8 km (0-1/2 mi)	1973 1-8 km (5/8-5 mi)	1974 0-0.8 km (0-1/2 mi)	1974 1-8 km (5/8-5 mi)	1975 0-0.8 km (0-1/2 mi)	1975 1-8 km (5/8-5 mi)
1. Kamloops						
Winter	2	22	6	37	7	46
Spring	1	1	1	2	7	0
Summer	0	0	0	0	0	1
Fall	2	19	0	4	0	7
2. Kelowna						
Winter	8	25	2	32	6	30
Spring	0	3	1	7	0	8
Summer	0	0	0	0	0	0
Fall	4	22	0	8	1	7
3. Lytton						
Winter	3	13	1	39	3	34
Spring	1	2	0	3	1	10
Summer	0	0	0	2	1	1
Fall	1	24	16	17	0	15
4. Penticton						
Winter	0	12	1	15	3	38
Spring	0	1	0	1	1	7
Summer	0	0	0	0	0	0
Fall	1	16	0	4	1	4
5. Williams Lake						
Winter	6	28	8	44	8	53
Spring	3	14	1	16	2	14
Summer	3	7	0	5	1	11
Fall	12	46	11	29	4	26

Source: *Monthly Record, AES (1973-5)

**Possible number of observations each year: Winter = 360, Spring = 368, Summer = 368, Fall = 364

Comparisons of seasonal average temperatures show that summer averages exceed winter by 20°C or more. Diurnal ranges are also significant. During the summer, maximum temperatures exceed minimum values by 14-17°C; in the winter the range is 5-10°C. As with precipitation, stations with similar elevations usually exhibit similar temperature characteristics.

Throughout the region, the first frost usually occurs in late September or early October and frost continues through early March. The number of frost-free days ranges from approximately 60 to 140. On the average, stations on hillsides tend to have longer frost-free seasons than nearby stations in valley locations.

E3.5 HUMIDITY

Mean dewpoint temperatures and relative humidities for selected stations in the Hat Creek region are presented in Table E3-9. Seasonal ranges of dewpoint are similar to those for temperature. Relative humidity values indicate little variation among stations. Spring and summer are significantly drier than fall and winter.

E3.6 VISIBILITY

Table E3-10 is a statistical summary of visibility observations taken at the weather stations nearest Hat Creek. The table represents a three-year data collection period comprising four observations per day at each of the five stations. More detailed data based on hourly observations over two years at Kamloops and Lytton are presented in Tables E3-11 and E3-12.

Visibilities of less than 1.6 km (1 mile) are rare in this area (less than 6% of the time at Kamloops and less than 4% of the time at Lytton). At all stations, highest frequencies of reduced visibility occur during fall and winter. The majority of observations with severe visibility restrictions occurred during the early morning hours. The significant variability from year to year demonstrates the desirability of long data records to establish truly 'climatic' patterns.

TABLE E3-8

CLIMATOLOGICAL AVERAGES OF DAILY TEMPERATURE RANGES IN THE HAT CREEK REGION*

Mean Maximum/Minimum Temperatures (°C)

Month	Ashcroft	Dog Creek	Hat Creek	Kamloops	Kelowna	Lytton	Penticton
December	-1/-8	-2/-9	-3/-13	1/-5	1/-4	1/-5	2/-3
January	-4/-13	-6/-12	-5/-17	-2/-9	-1/-7	-1/-6	0/-6
February	1/-8	-3/-10	1/-12	1/-7	2/-7	4/-4	3/-5
March	7/-3	3/-5	4/-14	9/-2	8/-2	11/1	10/-1
April	14/2	10/0	11/-3	17/3	14/1	18/4	16/2
May	22/7	17/4	17/2	22/8	20/6	23/8	21/6
June	23/10	18/8	20/4	25/11	23/9	25/12	25/9
July	28/12	23/10	24/6	29/13	27/12	29/14	29/12
August	27/12	21/8	23/6	28/12	26/11	29/	27/11
September	23/7	17/6	19/2	22/8	20/7	23/10	19/2
October	13/2	9/-4	11/-2	13/3	13/2	15/6	15/3
November	4/-3	0/-7	2/-9	5/-1	6/-1	7/0	7/-1
Annual	13/2	9/-1	11/-4	14/3	13/2	15/4	15/3
Period of Record (yrs)	9	6	7	61	40	13	32

*Source: World-wide Airfield Summaries, USNWS (1967)

TABLE E3-6

NORMAL TEMPERATURES IN THE HAT CREEK REGION*

Seasonal and Annual Mean Temperature (°C)

Season	Hat Creek	Kamloops	Kelowna	Lytton	Penticton	Williams Lake
Winter	-18.3	-3.3	-3.5	-0.9	-0.9	-7.2
Spring	3.7	8.5	7.4	10.2	7.6	4.1
Summer	13.8	19.6	17.6	20.7	18.9	14.6
Fall	3.2	8.3	7.0	10.0	8.9	4.4
Annual	0.6	8.3	7.1	10.0	8.6	4.0

*Source: Canadian Weather Review, AES (1974)

TABLE E3-7

SEASONAL EXTREME TEMPERATURES IN THE HAT CREEK REGION*

Season	Ashcroft	Dog Creek	Hat Creek	Kamloops	Kelowna	Lytton	Penticton
			Absolute Maximum Temperature (°C)				
Winter	15.0	13.3	13.3	17.8	17.2	18.3	17.8
Spring	35.0	30.0	27.8	37.8	33.9	40.0	34.4
Summer	38.9	34.4	34.4	41.7	38.9	44.4	40.6
Fall	33.9	28.9	31.1	35.0	33.9	36.1	34.4
Annual	38.9	34.4	34.4	41.7	38.9	44.4	40.6
			Absolute Minimum Temperature (°C)				
Winter	-37.2	-40.6	-42.8	-38.3	-31.1	-31.7	-26.7
Spring	-29.4	-35.6	-27.8	-25.0	-22.2	-21.1	-17.8
Summer	1.1	1.7	- 3.3	0.6	- 1.1	4.4	3.3
Fall	-25.0	-31.1	-30.0	-30.0	-22.8	-17.8	-18.9
Annual	-37.2	-40.6	-42.8	-38.3	-31.1	-31.7	-26.7
Period of Record (yrs)	20	10	7	65	60	40	50

*Source: World-wide Summaries, USNWS (1967)

804284

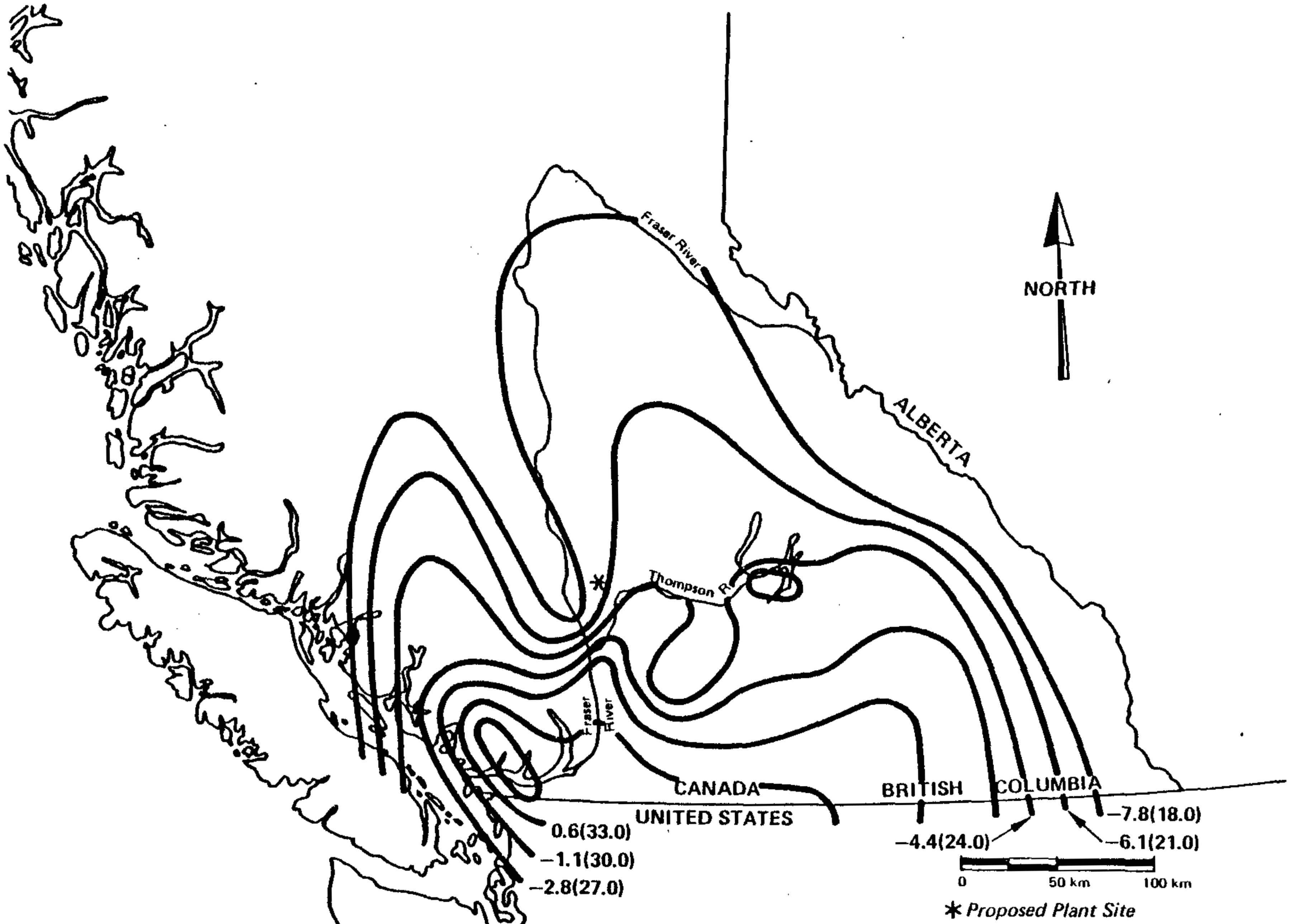


Figure E3-11 Hat Creek Region Mean Winter Temperature [°C (°F)]

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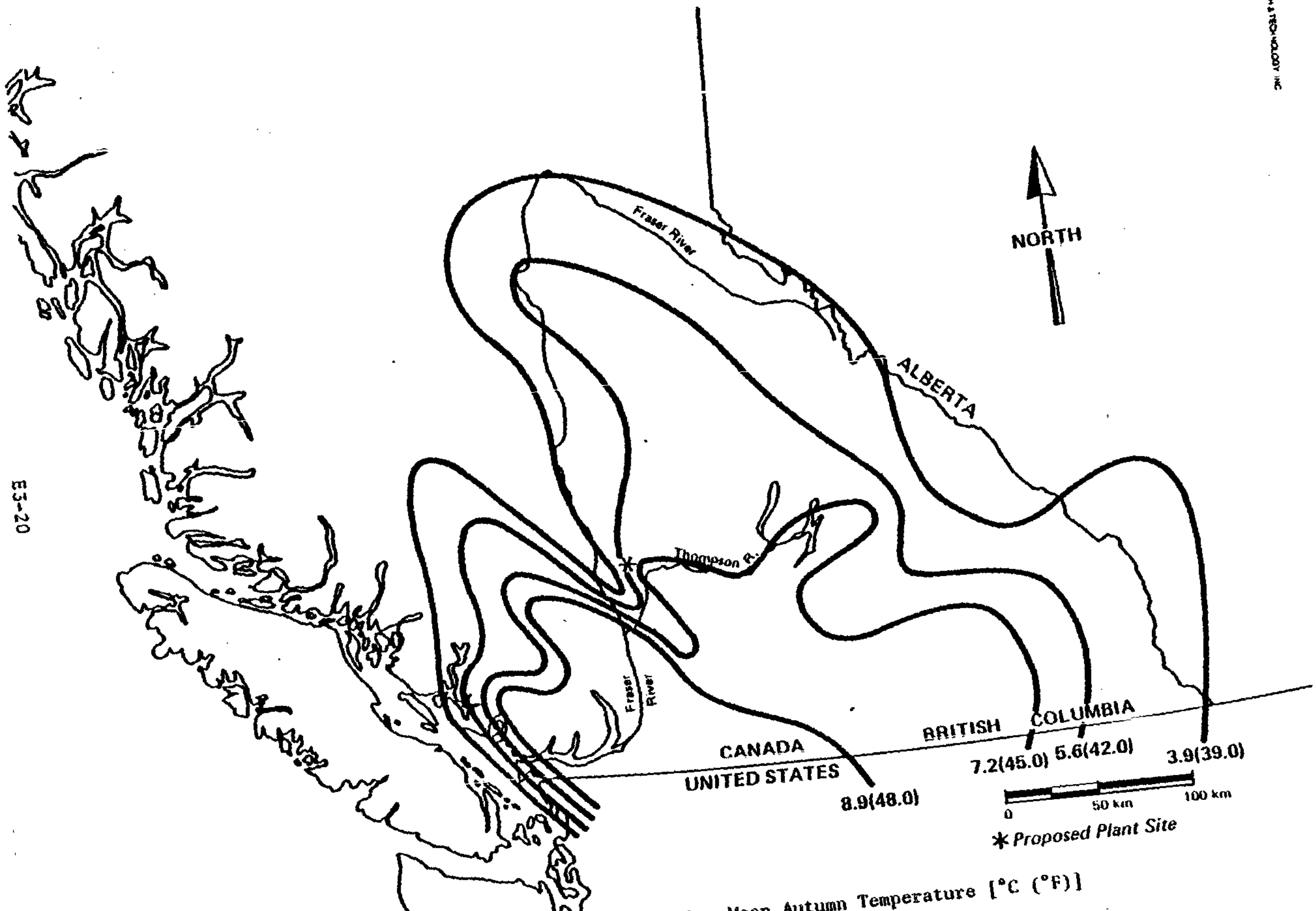


Figure E3-10 Hat Creek Region Mean Autumn Temperature [°C (°F)]

804286

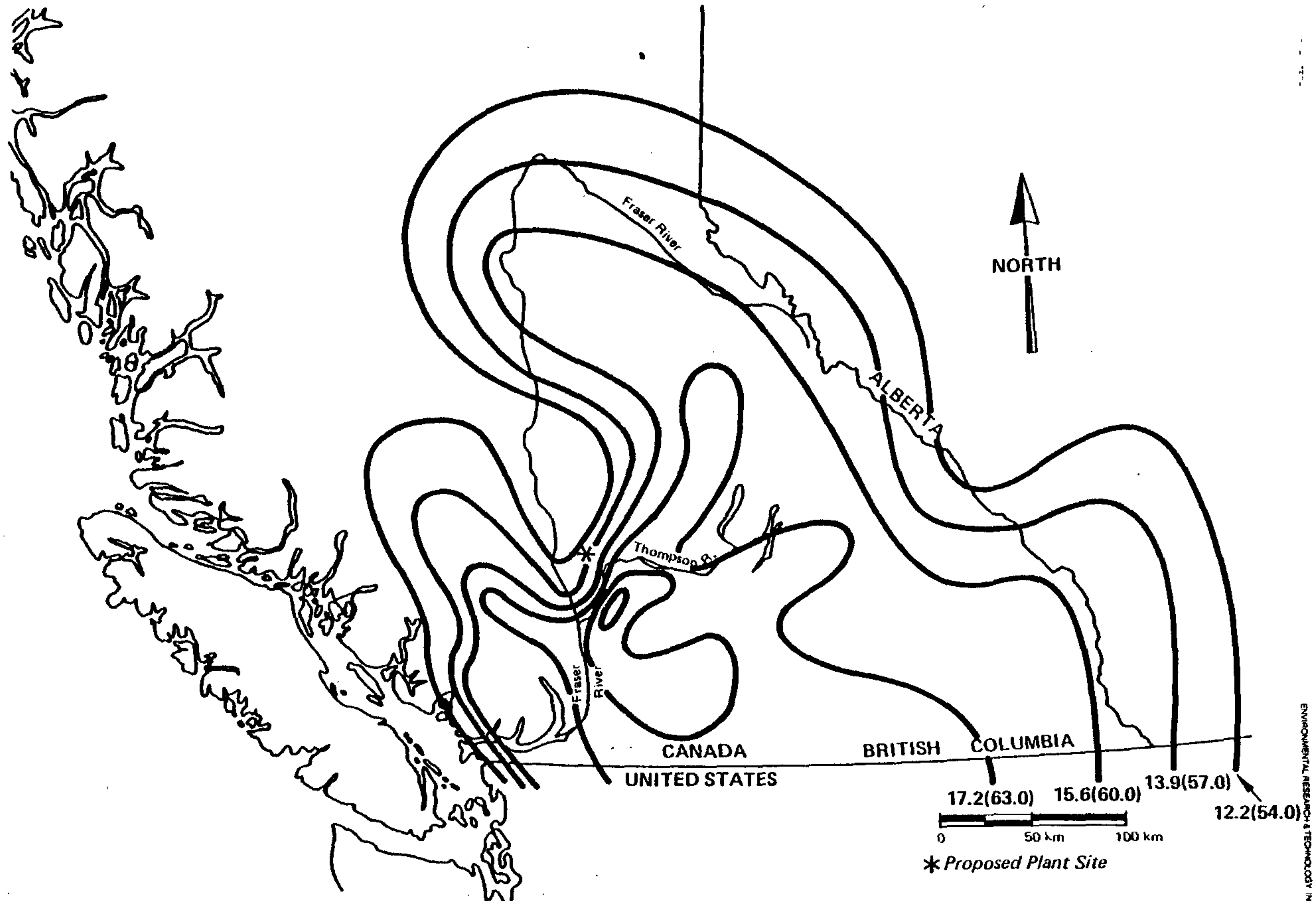


Figure E3-9 Hat Creek Region Mean Summer Temperature [°C (°F)]

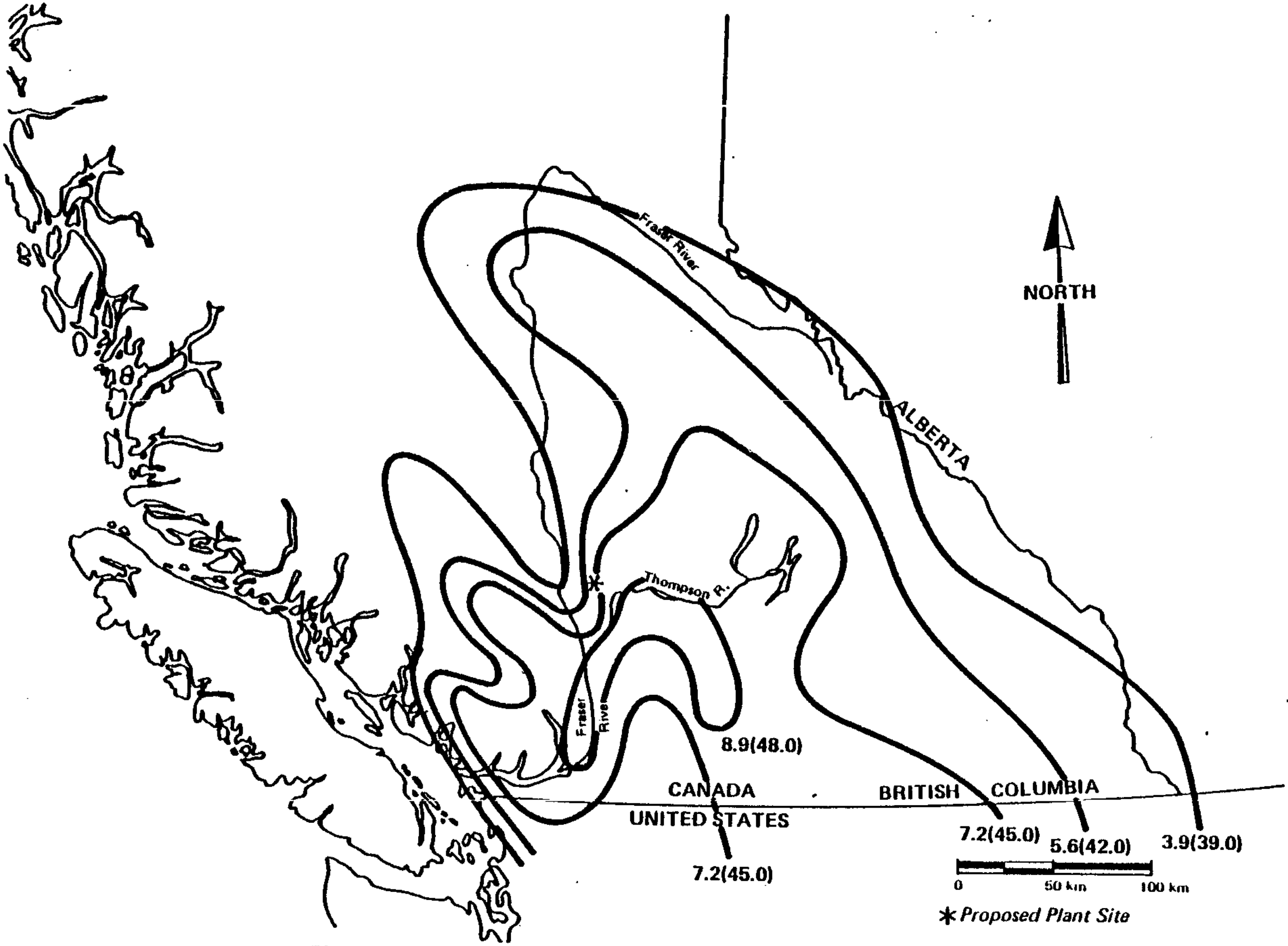


Figure E3-8 Hat Creek Region Mean Spring Temperature [°C (°F)]

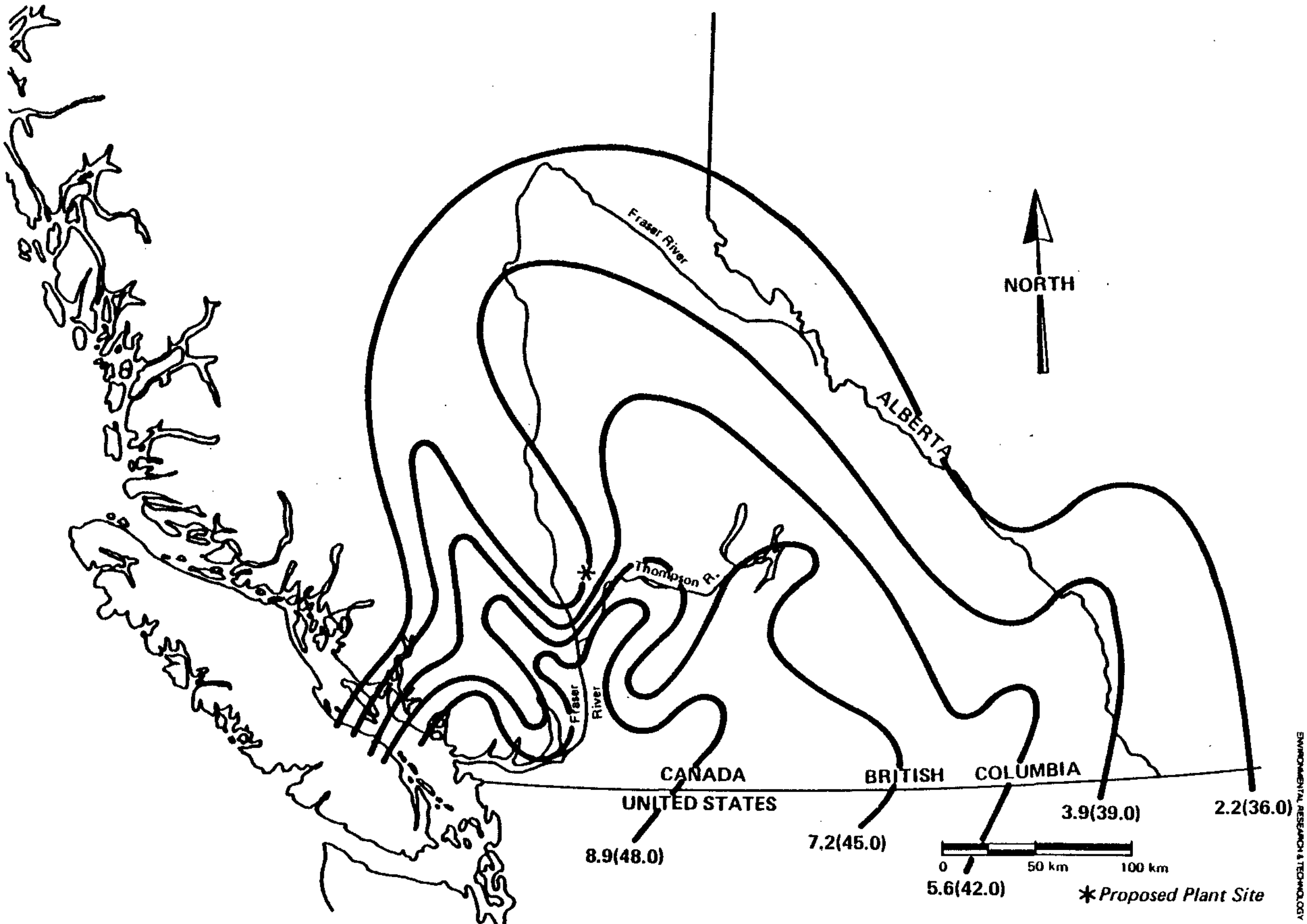


Figure E3-7 Hat Creek Region Mean Annual Temperature [°C (°F)]

TABLE E3-4

SNOWFALL IN THE HAT CREEK REGION

Mean Snowfall (cm) per Station

Month/Season	Ashcroft	Dog Creek	Hat Creek	Kamloops	Kelowna	Lytton	Penticton	Williams Lake**
December	18.8	31.5	31.0	20.3	27.9	45.0	18.0	42.4
January	27.9	22.3	36.8	22.9	27.1	36.1	18.3	66.5
February	16.2	29.0	15.7	15.2	16.2	17.0	11.4	38.4
Winter	62.9	82.8	83.5	58.4	71.2	98.1	47.7	147.3
March	4.6	23.4	10.1	2.5	8.1	5.6	6.3	24.7
April	1.3	14.2	8.1	1.3	0.3	0.8	0.0	5.3
May	0.0	2.3	3.8	1.3	0.0	0.0	0.0	2.5
Spring	5.9	39.9	22.0	5.1	8.4	6.4	6.3	32.5
June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
August	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Summer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	0.0	0.0	0.5	1.3	0.0	0.0	0.0	0.0
October	2.3	0.8	3.8	1.3	0.8	0.3	0.5	4.3
November	10.7	7.9	23.3	32.3	10.2	7.1	6.3	52.3
Fall	13.0	8.7	27.6	34.9	11.0	7.4	6.8	56.6
Annual	81.8	131.4	132.9	98.4	90.6	111.9	60.8	236.4
Days with Snowfall > 1.5 in.	6.1	12.4		5.5	7.0	9.0	4.4	***
Period of Record (yrs)	9	6	14	73	40	22	32	4

*Source: World-wide Airfield Summaries, USNWS (1967)
**Source: Monthly Record, AES (1972-1975)
***Williams Lake data not available

TABLE E3-5

GREATEST RAINFALL (CM) AND SNOWFALL (CM) IN A 24-HOUR PERIOD*

Season	Ashcroft	Dog Creek	Hat Creek	Kamloops	Kelowna	Lytton	Penticton	Williams Lake
Rainfall (cm)								
Winter	2.18	0.94	1.02	5.69	6.35	6.99	1.85	1.57
Spring	2.26	2.11	1.65	2.54	3.30	3.10	2.97	2.03
Summer	3.94	3.07	3.89	4.22	4.19	2.49	3.28	3.43
Fall	4.45	4.70	2.67	1.80	2.92	7.67	4.45	3.77
Snowfall (cm)								
Winter	31.8	41.9	42.4	33.0	47.0	66.0	22.1	42.7
Spring	12.7	25.4	11.9	12.7	30.5	21.6	06.4	17.0
Summer	00.0	00.5	00.0	00.0	00.0	00.0	00.0	00.0
Fall	13.2	22.1	19.1	20.3	20.8	28.2	12.7	19.1

*Source: Canadian Normals - Precipitation (1941-1970)
**Trace amount

TABLE E3-3

TOTAL PRECIPITATION IN THE HAT CREEK REGION*

Season	Ashcroft	Dog Creek	Hat Creek	Kamloops	Kelowna	Lytton	Penticton	Williams Lake**
			Mean Total Precipitation (cm) per Station					
Winter	7.1	8.9	9.1	6.8	9.4	14.2	7.2	9.6
Spring	3.5	5.3	5.3	4.3	5.5	6.2	6.1	6.7
Summer	7.5	13.2	9.7	8.6	7.4	5.5	7.3	15.1
Fall	5.8	7.3	7.5	6.1	8.6	10.8	7.0	8.9
Annual	23.9	34.7	31.6	25.8	30.9	36.7	27.6	40.3
			Frequency (days) of Precipitation > 0.25 cm (0.1 in)					
Winter	9.1	11.7	27.0	8.6	11.8	21.9	9.1	28.0
Spring	4.3	6.0	18.0	5.3	6.9	7.7	7.7	16.8
Summer	9.3	15.5	22.0	10.2	9.1	7.0	8.9	16.5
Fall	8.1	7.8	21.0	8.4	10.3	11.6	9.1	20.3
Annual	30.8	41.0	88.0	32.5	38.1	48.2	34.8	81.6
			Thunderstorm Frequency (days) per Station					
Winter	0	0	***	0	0	0	0	***
Spring	2	2	***	1	2	0	2	***
Summer	5	8	***	6	12	2	12	***
Fall	0	0	***	1	1	0	1	***
Annual	7	10	***	8	15	2	15	***
Period of Record (yrs)	9	6	7	73	40	22	32	4

*Source: World-Wide Airfield Summaries, USNWS (1967)
**Source: Monthly Record, AES (1972-1975)
***Williams Lake data not available

TABLE E4-1(a) (Continued)

DIURNAL VARIATION IN SEASONAL MEAN RELATIVE HUMIDITY IN THE HAT CREEK REGION

(Winter)

Hour	H.C. Mechanical 4	H.C. Mechanical 5	H.C. Mechanical 6	H.C. Mechanical 7	H.C. Mechanical 8
	I	I	I	I	I
01	76.9	65.4	999.0	77.0	81.0
02	76.6	65.2	999.0	77.1	81.4
03	76.9	65.5	999.0	77.6	78.8
04	76.8	65.5	999.0	77.6	79.9
05	76.1	65.4	999.0	77.3	80.6
06	75.0	65.1	999.0	76.7	80.7
07	74.6	65.0	999.0	76.7	80.7
08	74.6	65.0	999.0	76.9	80.2
09	73.6	65.0	999.0	76.6	79.5
10	69.3	64.1	999.0	73.5	77.7
11	61.9	61.0	999.0	69.4	76.7
12	55.0	56.3	999.0	64.8	75.8
13	50.7	52.8	999.0	61.4	74.3
14	48.0	51.1	999.0	59.6	72.9
15	47.3	51.1	999.0	60.5	72.1
16	48.6	52.2	999.0	63.0	73.4
17	34.0	54.8	999.0	67.8	76.6
18	61.9	57.8	999.0	72.3	78.4
19	67.8	60.4	999.0	75.1	80.0
20	71.6	62.2	999.0	76.3	81.5
21	74.3	63.5	999.0	76.8	81.6
22	76.0	64.6	999.0	77.3	81.3
23	77.0	64.9	999.0	77.2	80.9
24	77.2	65.3	999.0	77.1	80.9

TABLE E4-1(b)

DIURNAL VARIATION IN SEASONAL MEAN RELATIVE HUMIDITY IN THE HAT CREEK REGION

(Spring)

Hour	Kamloops	Lytton	H.C. Mechanical 1	H.C. Mechanical 2	H.C. Mechanical 3
	I	I	I	I	I
01	61.8	999.0	73.4	73.5	76.4
02	62.9	999.0	74.7	74.0	77.0
03	64.7	999.0	75.9	74.6	77.9
04	66.3	999.0	77.5	75.3	77.9
05	66.8	73.0	78.2	75.7	78.9
06	68.4	73.4	79.0	77.1	78.5
07	67.4	74.3	78.2	75.5	76.8
08	63.9	72.5	75.7	69.0	71.8
09	59.5	68.1	64.0	60.5	62.8
10	55.6	62.1	54.8	52.7	54.2
11	51.0	55.8	47.9	46.2	46.2
12	47.6	50.4	42.4	40.8	40.9
13	43.9	45.6	37.8	37.4	37.1
14	40.9	41.6	35.1	34.3	34.7
15	39.1	40.0	33.1	31.8	33.3
16	38.4	39.6	31.6	31.2	34.3
17	38.2	40.2	31.8	32.8	39.0
18	39.9	42.9	33.9	37.4	47.3
19	42.4	45.7	40.1	46.4	55.7
20	46.6	49.7	49.1	55.0	61.5
21	50.0	53.2	58.0	60.7	67.2
22	53.3	56.2	64.3	66.1	71.6
23	56.7	58.5	68.0	69.6	73.7
24	59.2	999.0	70.6	72.0	75.7

TABLE E4-1(b) (Continued)

DIURNAL VARIATION IN SEASONAL MEAN RELATIVE HUMIDITY IN THE HAT CREEK REGION (Spring)

Hour	H.C. Mechanical 4	H.C. Mechanical 5	H.C. Mechanical 6	H.C. Mechanical 7	H.C. Mechanical 8
	I	I	I	I	I
01	69.8	66.1	69.0	65.8	73.8
02	71.4	67.9	68.0	67.3	76.0
03	72.9	68.7	69.2	69.1	77.9
04	73.8	69.7	70.9	70.3	75.2
05	74.6	70.6	72.3	71.1	77.8
06	75.5	71.5	73.2	71.9	78.0
07	75.0	70.8	73.9	71.3	77.9
08	68.7	66.8	73.2	68.2	75.6
09	58.4	61.0	72.1	63.0	71.8
10	50.3	55.7	70.9	57.7	66.0
11	41.6	48.1	65.4	52.3	60.9
12	35.2	42.2	62.0	47.5	58.4
13	31.2	38.9	59.8	44.4	51.7
14	28.4	36.4	58.2	42.5	50.1
15	26.7	36.3	55.5	41.4	49.4
16	27.0	36.2	56.4	42.0	53.6
17	29.6	38.4	57.9	45.1	60.8
18	46.8	42.0	60.8	49.8	66.6
19	44.0	47.2	66.9	54.0	68.7
20	51.8	51.3	68.7	56.7	69.8
21	56.7	56.0	69.6	59.3	70.7
22	61.0	59.1	70.0	61.7	73.3
23	65.2	62.1	69.7	63.3	72.9
24	67.8	64.1	69.6	64.7	72.1

TABLE E4-1(c)

DIURNAL VARIATION IN SEASONAL MEAN RELATIVE HUMIDITY IN THE HAT CREEK REGION

(Summer)

Hour	Kamloops	Lytton	H.C. Mechanical 1	H.C. Mechanical 2	H.C. Mechanical 3
	I	I	I	I	I
01	58.6	999.0	75.9	75.3	76.8
02	62.2	999.0	78.6	78.2	79.3
03	65.2	999.0	81.0	79.9	81.2
04	67.0	999.0	82.4	81.6	82.4
05	68.8	67.0	83.7	81.6	83.2
06	69.6	69.4	83.8	78.6	83.8
07	67.3	70.1	79.4	72.3	80.2
08	63.1	67.4	71.5	64.4	73.3
09	58.3	61.8	63.9	56.8	64.6
10	53.5	56.0	55.7	50.6	57.9
11	49.2	51.8	48.9	46.0	52.0
12	44.9	46.6	45.0	43.2	47.8
13	41.2	42.9	41.7	41.4	45.3
14	38.0	40.7	39.3	40.2	42.9
15	36.6	38.2	38.6	39.0	40.9
16	36.6	37.3	37.7	38.1	39.8
17	35.9	37.7	37.9	38.5	40.2
18	36.8	38.4	40.0	40.3	41.3
19	38.8	39.9	43.4	44.6	44.2
20	41.9	43.5	49.1	49.6	49.0
21	45.7	47.5	56.3	55.5	56.0
22	48.4	50.3	63.3	62.5	62.8
23	52.5	53.2	68.6	68.0	68.2
24	55.4	999.0	73.0	72.2	72.8

TABLE E4-1(c) (Continued)

DIURNAL VARIATION IN SEASONAL MEAN RELATIVE HUMIDITY IN THE HAT CREEK REGION

(Summer)

Hour	H.C. Mechanical 4	H.C. Mechanical 5	H.C. Mechanical 6	H.C. Mechanical 7	H.C. Mechanical 8
	I	I	I	I	I
01	73.0	60.0	71.9	68.6	70.0
02	76.3	62.3	73.6	69.6	70.4
03	78.5	64.1	74.2	70.7	71.8
04	80.0	65.9	75.0	72.4	71.6
05	80.9	67.6	74.8	72.9	72.0
06	81.3	68.5	75.0	72.9	70.1
07	79.2	68.7	75.5	72.8	68.8
08	72.3	65.5	73.9	69.2	66.9
09	63.5	60.4	71.6	66.4	66.2
10	56.5	55.9	69.8	61.6	63.0
11	50.7	50.6	69.9	58.2	59.6
12	46.0	46.3	68.9	55.4	58.4
13	44.4	44.1	66.3	54.5	57.6
14	42.3	41.5	62.5	51.5	55.2
15	40.1	39.8	61.1	50.3	54.9
16	39.0	37.7	60.2	49.8	54.6
17	39.1	37.6	58.2	49.3	54.8
18	40.4	37.6	58.9	50.1	55.3
19	42.8	39.2	59.7	51.8	57.4
20	47.9	42.0	61.8	56.7	60.6
21	53.5	46.3	63.6	60.4	63.3
22	60.1	50.7	66.6	62.8	65.6
23	65.1	54.3	69.0	64.8	67.4
24	69.6	57.4	70.4	67.6	69.0

TABLE E4-1(d)

DIURNAL VARIATION IN SEASONAL MEAN RELATIVE HUMIDITY IN THE HAT CREEK REGION

(Fall)

Hour	Kamloops	Lytton	H.C. Mechanical 1	H.C. Mechanical 2	H.C. Mechanical 3
	I	I	I	I	I
01	64.1	999.0	75.6	75.8	80.1
02	65.4	999.0	77.0	75.5	81.5
03	66.1	999.0	78.1	75.6	82.5
04	67.7	999.0	79.0	76.2	82.9
05	68.9	79.1	80.1	77.0	83.5
06	69.7	79.8	80.4	77.3	83.3
07	70.0	80.6	80.6	77.3	83.2
08	68.9	80.8	80.5	77.0	83.0
09	64.6	79.0	76.5	76.0	81.6
10	61.4	74.7	69.5	69.4	75.9
11	57.7	70.3	60.0	60.6	65.9
12	54.0	65.7	53.7	54.4	58.2
13	50.4	62.2	48.5	48.8	53.2
14	47.3	59.2	45.2	47.4	49.5
15	45.6	57.6	42.2	47.4	47.8
16	45.3	58.0	42.4	47.1	48.4
17	46.3	59.0	45.5	50.6	50.4
18	47.5	61.5	49.6	54.3	54.3
19	50.3	63.8	54.1	60.9	60.1
20	52.5	66.1	60.7	65.4	65.6
21	55.2	67.8	65.6	68.5	70.4
22	57.7	70.3	68.7	70.7	73.6
23	60.4	71.6	71.4	73.0	75.7
24	62.6	999.0	73.5	76.0	78.2

TABLE E4-1(d) (Continued)

DIURNAL VARIATION IN SEASONAL MEAN RELATIVE
HUMIDITY IN THE HAT CREEK REGION
(Fall)

Hour	H.C. Mechanical 4	H.C. Mechanical 5	H.C. Mechanical 6	H.C. Mechanical 7	H.C. Mechanical 8
	I	I	I	I	I
01	74.8	54.7	85.4	65.7	75.5
02	75.7	55.7	84.8	65.2	77.3
03	76.7	57.2	85.0	64.9	78.5
04	77.6	58.1	85.0	65.9	78.6
05	78.2	58.8	84.2	66.1	78.9
06	78.9	59.8	84.0	66.2	80.6
07	79.0	60.5	83.5	66.7	81.3
08	78.6	61.6	82.4	67.3	80.8
09	76.2	62.1	80.3	66.4	78.8
10	67.8	60.3	78.0	65.7	76.3
11	59.9	55.3	77.9	63.5	73.7
12	53.8	50.5	77.3	60.2	70.8
13	49.6	45.9	78.7	58.9	65.8
14	46.1	42.2	77.2	55.9	65.9
15	45.4	40.5	76.8	56.0	60.7
16	46.4	39.7	76.7	57.5	59.6
17	49.5	39.6	79.1	61.2	57.3
18	53.0	40.5	80.0	62.2	57.7
19	56.7	41.7	81.2	63.3	60.4
20	61.9	44.3	82.1	65.1	64.5
21	66.4	47.1	83.1	66.0	68.2
22	69.4	49.9	84.6	66.3	70.2
23	71.5	51.7	84.7	66.3	71.8
24	73.7	53.6	85.7	65.4	73.8

Toward late afternoon, the mixing height begins to decrease, ultimately giving way to a ground-based inversion again. Depending upon the degree of heating at the surface, the morning inversion may persist throughout the day (as an elevated inversion layer overlying a surface-based mixed layer), or it may be completely eroded by the growing mixing layer.

Table E4-3 lists sequential inversion depths measured during two field monitoring programs in the Hat Creek Valley by MEP.[8,9] Most days studied were characterized by morning surface inversions, generally disappearing by afternoon. Among the four cases with day-long inversions, three occurred during the March field program, when insolation is weaker than in summer months. Site 1 in Table E4-3 was located in the Lower Valley, while Site 4 was in the Upper Valley.

Figure E4-7 shows four successive vertical temperature profiles obtained during the MEP study on September 5, 1975, above Hat Creek Valley. During early morning hours, a surface-based inversion occurred, extending upward to 200 m. By late morning (1112 PDT), a superadiabatic layer was seen near the surface, while slightly stable conditions occurred aloft. Late afternoon (1602 PDT) is similar to late morning, except that the lapse rate above the surface superadiabatic layer had become more nearly adiabatic. Finally, by early evening (1857 PDT), the low-level temperature inversion had begun to reestablish itself.

TABLE E4-2

FREQUENCY DISTRIBUTION OF VISIBLE RANGE LIMITS FOR
KAMLOOPS AND LYTTON, B.C.
(1974-1975)

	Visible Range (mi)	Percent Occurence	Cumulative Percent
Kamloops	0-1	2.7	2.6
	1-2	3.0	5.6
	2-3	1.5	7.1
	3-4	1.9	9.0
	4-5	1.7	10.7
	5+	89.1	100.0
Lytton	0-1	1.9	1.9
	1-2	2.0	3.9
	2-3	1.1	5.0
	3-4	2.8	7.8
	4-5	1.4	9.2
	5+	90.8	100.0

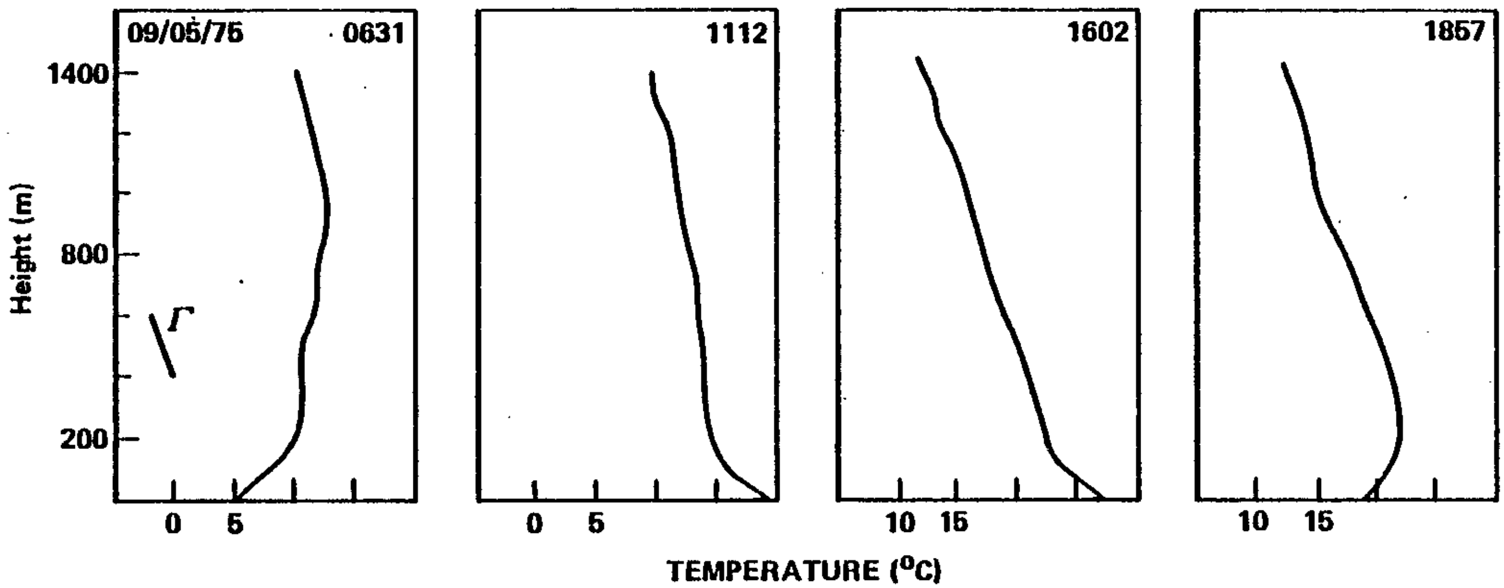
TABLE E4-3

VERTICAL TEMPERATURE STRUCTURE IN THE HAT CREEK VALLEY*

	Depth of Surface Inversion and/or Isothermal Layer (m)			
	Site 1		Site 4	
Date (1975)	0600-0900**	1400-1700	0600-0900	1400-1700
March 3	90	0	-	-
4	285	0	135	0
5	440	110	225	0
6	606	0	269	0
7	324	90	231	0
8	0	0	151	0
9	0	0	0	0
10	0	0	0	0
11	810	0	253	0
August 31	70		357	
September 1	251	0	161	0
2	175	0	257	0
3	0	0	0	0
4	841	0	182	0
5	388	0	563	0
6	-	-	660	115
7	-	-	435	0

*Source: *Short-term minisonde studies* by MEP Co. (Weisman 1975, 1976).

**Local time of day.



Notes: The time of the sounding is given in the upper right corner of each panel. An adiabatic lapse rate, Γ, which is indicative of neutral stability conditions, is a decrease of 0.98 °C per 100 m.

Figure E4-7 Vertical Temperature Profiles in the Hat Creek Valley, September 5, 1975

E5.0 CLIMATIC ALTERATIONS EXPECTED FROM THE HAT CREEK PROJECT

E5.1 OVERVIEW

Most of man's industrial activities generate waste heat and moisture and often gaseous and particulate contaminants that are released to the atmosphere. There is no question that these wastes have changed local or urban climates and there is considerable controversy over whether anthropogenic wastes are causing climatic changes on a global scale. With the continuing demand for energy and accelerating consumption of fossil fuels, there is a need to assess potential climatic alterations caused by new sources of heat, moisture and atmospheric contaminants.

The impact of the proposed Hat Creek Project has been addressed in terms of three spatial scales: global (greater than 1000 km), meso and synoptic (5-1000 km) and local (less than 5 km). The following material represents the product of a literature survey, an examination of field measurement programs, and an analysis of the existing climate to determine, at least qualitatively, the potential for climatic alterations associated with the Hat Creek Project. Although there have been few theoretical or measurement studies to determine the climatic effects of individual coal-fired electric generating facilities, it can be concluded that the Hat Creek Project will not significantly alter the climate. There may, however, be some minor effects restricted to within the immediate environs (generally within 0.5 km) of the Hat Creek facilities. In addition, the Project will produce restrictions to visibility, especially on the local scale because of mining operations and to some extent on local and regional scales because of the thermal plant stack and cooling tower plumes. Table E5-1 summarizes the expected impacts. It must be emphasized that these projected impacts are generally minor. In particular, any enhancement of precipitation will occur in highly localized regions and will total approximately 1% on an annual basis. Any snowfall from an elevated cooling tower plume would add no more than 2.5 cm of snow on the ground at any one time. Any decrease in available sunlight because

TABLE ES-1

PROJECTED POTENTIAL CLIMATIC EFFECTS OF THE HAT CREEK PROJECT

Impact	Area of Impact	Cause
Slight Enhancement (approximately one percent on an annual basis) of precipitation	Within 50 km of the Hat Creek Project	Waste Heat and Moisture from Cooling Towers, Particulate Matter from Hat Creek Facility
Fogging	Within 600 m of the Cooling Towers	Plumes from Mechanical Draft* Cooling Towers
Fogging	Within 2-5 km of the Make-up Water Reservoir and Ash Pond	Evaporation of Water
Icing	Within 600 m of the Cooling Towers	Plumes from Rectangular Mechanical Draft* Cooling Towers
Slight Reduction of Snow Cover	Within 500 m of the Cooling Towers	Plumes from Mechanical Draft* Cooling Towers
Slight Cooling (Annual Average Temperature) in Hat Creek Valley	Within the environs of the mining operations	Fugitive Emissions Associated with Mining Activities
Reductions in Visibility	Near the mine and within the general project region	Fugitive Emissions and Sulphates and Nitrates Produced in the Power Plant Plume

*B.C. Hydro now plans to use two natural draft cooling towers to service the facility. These will not produce any fogging, icing, or reduction in snow cover.

Note: These potential climatic effects are minor. Agriculture in the area will not be affected by any minor environmental consequences of the Project.

of dust produced by mining operations will be limited to the project area. No measurable changes in temperature will occur elsewhere. B.C. Hydro now plans to use two natural draft cooling towers to service the facility. These cooling towers will produce no fogging or icing at ground level and will not affect the snow cover. If mechanical draft cooling towers are utilized at Hat Creek, any increases in fogging or icing or changes in the snow cover (by the warm cooling tower plume) will be restricted to within about 0.5 km of the towers and be confined within the Project boundaries.

Fogging will definitely be produced by the make-up water reservoir and the ash pond. Fog produced by these facilities could persist for several days during the months October through March. Significant reductions in visibility are expected near the mining operations. Slight reductions in visibility will be caused by sulfates formed by the transformation of sulfur dioxide (SO_2) in the power plant plume. Agricultural activities will not be affected by any environmental consequences of the Project. A discussion of the global climate is given in Section E5.2, and the regional (meso and synoptic scales) and local climates are examined in Section E5.3.

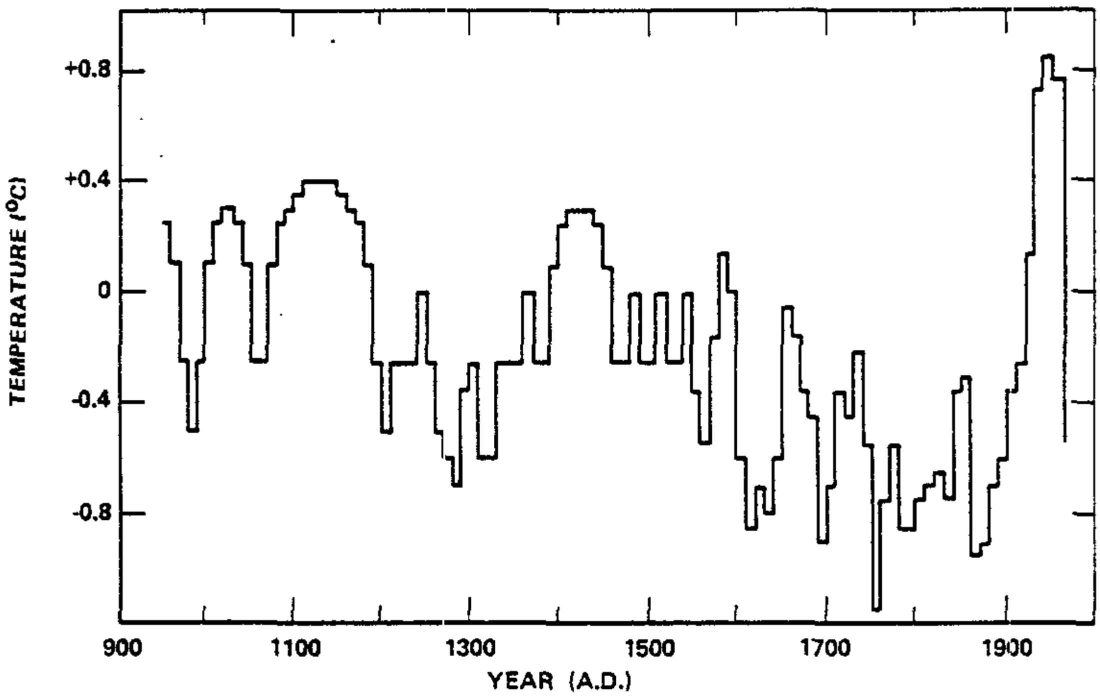
E5.2 GLOBAL EFFECTS

(a) General Discussion

In recent years, several scientists have expressed suspicions that man's activities will affect and have affected the global climate. However, of the various aspects of man-induced climatic changes which have been studied, global-scale impacts remain the least understood due to the lack of understanding of the complex relationships and feedback mechanisms between atmospheric dynamics and chemistry and other factors, and primarily to the paucity of information in the current large-scale meteorological-climatological data base. Strong differences in opinion among the various researchers characterize many aspects of the global impact question. For example, many scientists have expressed concern that the large increases in carbon dioxide (CO_2) and particulate matter released into the atmosphere in recent decades from anthropogenic sources will significantly alter the temperature structure of the atmosphere, and a recent committee, sponsored by the U.S. National Academy of Sciences,[14] suggests that industrial nations carefully decide whether to continue reliance on fossil fuels because of the possible climatic consequences. Lansburg,[15] however, believes the effects of anthropogenic contaminant emissions on temperature cannot be distinguished from the high variability that has characterized mean temperatures in the past. Figure E5-1, for example, shows ten-year average Icelandic temperature variations over the past 1000 years constructed by Bergthorsson[16] from historic records of the extent and duration of sea ice. Predicted temperature changes attributed to CO_2 and particulate buildups (Rasool and Schneider,[17] and Bryson[18]) fall well within the long-term variations shown in Figure E5-1.

Nevertheless, Bryson,[18] Lovelock,[19] and others have stated that recent worldwide temperature declines* may have been caused in large part by man's activities. By limiting incoming solar radiation, it is contended,

*The average global surface temperature rose between about 1880 and 1940 and has declined since that time.



Note: Taken from Berthorsson,[16] who constructed the records of the extent and duration of sea ice.

Figure E5-1 Temperature Variations in Iceland particulates and other contaminants may reduce surface temperatures to such a degree that major climatic effects such as the initiation of an ice age or the poleward movement of agricultural regions may be produced. As a result of the continuing debate and widespread uncertainty that surround global climate studies, an assessment of the impact of any individual source is speculative.

To put into perspective the magnitude of atmospheric discharges from the Hat Creek Project as compared to the global climate, a discussion of the global energy balance and general circulation is given below, followed by a review of postulated effects of individual sources. A discussion of the chemical composition of the stratosphere is then presented.

(b) Large-Scale Energy Balance in the Atmosphere

In a general sense, the atmosphere can be described as a heat engine driven by radiation from the sun. General circulation (i.e., large-scale mean flow) results from the uneven distribution of heating and cooling caused by the earth's spheroid shape: equatorial areas, exposed almost directly to the sun's radiation, serve as a net <u>source</u> of heat; polar regions, on the other hand, receive solar radiation more obliquely, resulting in a lower net heating per unit area and with the loss of terrestrial radiation act as a net <u>sink</u> of heat. This differential heating results in a net poleward transfer of sensible and latent heat, and when combined with the rotation of the earth, a basic circulation pattern (Figure E5-2, reprinted from Williamson[20]) develops. In each hemisphere, three primary circulation patterns occur: the low-latitude easterly trade winds, mid-latitude westerly winds and the polar easterly flow. At the confluences of the cells, narrow bands of intense wind flow (the subtropical and polar jet streams) are found.

Bryson[18] identifies four variables which influence this circulation pattern. These are: (1) the intensity of sunlight reaching the top of

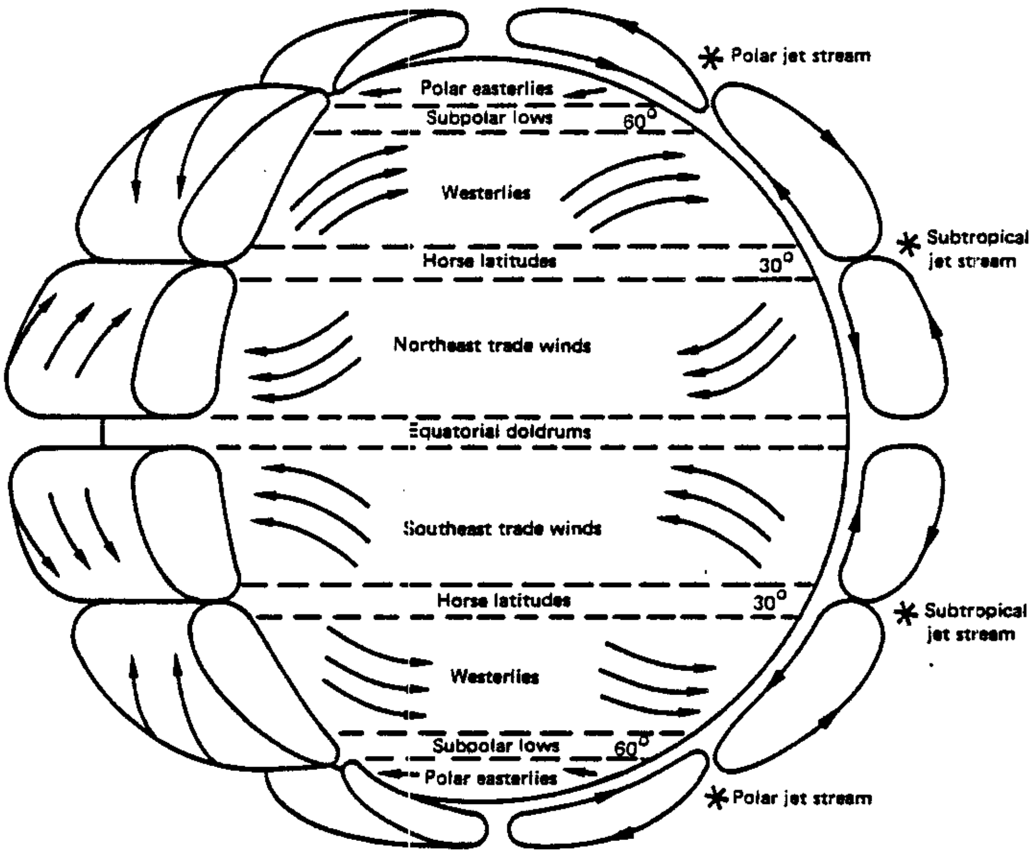


Figure E5-2 Global Circulation Pattern (Reprinted from Williamson[20]) the atmosphere; (2) the transmittance of the atmosphere as modified by processes not internal to the atmosphere; (3) the albedo (the ratio of solar radiation reflected and scattered by the earth and atmosphere, e.g., snow, ice, clouds, to the radiation incident upon them) of the earth-atmosphere system; and (4) the greenhouse control of infrared radiation from the earth by gas and particulate concentrations. Bryson[19] claims that incoming solar radiation is the only parameter which is essentially constant.* However, Lamb[21] believes that this too might vary. Knox and MacCracken[22] refer to the energy balance system as one that is delicately balanced by these variables.

Changes in any of the four variables above could have significant impacts. Thoroddson[23] and Bryson[18] refer to drastic effects that slight solar radiation changes may induce in Iceland. For example, Bryson predicts that a reduction in the mean annual Icelandic temperature by 2.4°C could produce a 40-day (25%) reduction in the growing season.**

Air pollutants generated by worldwide fossil fuel combustion may have an effect on two of the sensitive parameters (2 and 4 above) that govern the global atmospheric energy budget. Of particular concern are gaseous compounds of carbon, nitrogen, and sulfur, and suspended particulate matter, heat, and moisture. As an example, it has been speculated that CO_2 affects the greenhouse control of terrestrial radiation in the energy budget of the atmosphere. Of all the contaminants emitted in combustion processes, CO_2 is released in by far the greatest amount, an estimated 1.6×10^{11} tonnes globally in 1965 (Williamson[20]); of this total, about 10% is anthropogenic. Although this has led to statements hypothesizing significant temperature increases, actual temperatures

*The top of the atmosphere receives 1.95 $cal/cm^2/sec$ of direct solar radiation. Some investigators have postulated that changes in this solar constant may have been the real cause of climatic change throughout the history of the atmosphere.

**On the other hand, Lansberg speculates that a reduction of 2°C in the worldwide average temperature would not produce drastic effects.

have decreased in recent years (e.g., Figure E5-1). This latter anomaly may be the result of increased particulate or dust loading in the lower atmosphere causing increased reflection and absorption and, thus, reduced transmittance of solar radiation through the atmosphere.

Particulates, as mentioned above, reduce the surface solar radiation flux by reflecting or absorbing incoming radiation. Sulfates and nitrates, formed by oxidation of sulfur- and nitrogen-containing compounds, are believed to limit solar radiation in much the same way as particulate matter. Photochemical smog, which has become a serious air pollution problem in many parts of the industrialized world, produces a fine aerosol as a secondary pollutant, thus further reducing insolation at the surface.[20] In short, these contaminants may reduce the transmittance of sunlight through the atmosphere. It is not expected that anthropogenic emissions will affect the solar constant or the earth's albedo on a global scale.[18] However, man's activities have certainly affected the albedo on smaller scales, e.g., urban areas. Charney[24] has also suggested anthropogenic modifications of the albedo near the major deserts with a subsequent increase in their extent.

(c) Impacts of Individual Large Sources

Historically, little attention has been given to analysis of global impacts of individual anthropogenic sources of heat, moisture, and contaminants into the atmosphere; most studies have involved the effects of worldwide emissions. Recently, however, with increasing concern for future energy supplies, new, large sources of power production have been considered. The potential effects of 'energy parks' and other similar complexes have been studied by Hanna and Gifford,[25] Koenig et al.,[26] NRC[27] and Moore.[28] Such plants would generate upwards of 50,000 Mw of usable electric power. Assuming 33% efficiency, more than 100,000 Mw of waste energy would be released into the atmosphere. This latter figure represents about 2% of current worldwide man-emitted energy, and is particularly important since it is concentrated in a very small area.

The B.C. Hydro plant, however, would have more than an order of magnitude less generating capacity than would such an 'energy park'. Assuming that 4000 Mw of energy are lost to the atmosphere,* and using the Weinberg and Hammond[29] estimates of a total anthropogenic energy release of 4.9×10^6 Mw in 1970 and predicted 4×10^8 Mw in the year 2000, it appears that the proposed plant would generate about 0.1% of total 1970 anthropogenic production energy and 0.001% of 2000 A.D. projections. Compared to natural thermal radiation emitted by the earth, however, these values are very small. Since about 10^{11} Mw are emitted over the entire earth surface,[20] it is clear that the influence of the B.C. Hydro heat emissions upon the global energy balance would be negligible.

The B.C. Hydro thermal plant will emit approximately 79.2×10^3 tonnes of SO_2 yearly and about 9.7×10^3 tonnes of particulate matter.** Worldwide yearly emissions[30] of these contaminants are about 200×10^6 tonnes SO_2 about about 1000×10^6 tonnes particulate matter. The anthropogenic contribution to the particulate emissions burden is about 300×10^6 tonnes. Since the thermal generating station will fire low sulfur coal and employ efficient electrostatic precipitators to control particulate emissions and since its contributions to worldwide SO_2 and particle emissions are minute fractions (0.0004 and 9.7×10^{-6}) of the total global emissions burden, it is not expected that the Hat Creek Project will affect the global climate in any significant manner. Similarly, the rejection of moisture from the cooling towers to the atmosphere would contribute only negligibly to global water vapor and would not cause any change in the global climate.

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*Based on an initial generation of 2000 Mw and an approximate generating station efficiency of 33%.

**Mining activities will produce another 2400 tonnes of particulates during the year of peak activity. These particles can be represented as a ground-level release, and because of the local topography and climate, will not be significantly entrained into large-scale flow patterns.

(d) Chemical Composition of the Stratosphere

The vertical structure of the atmosphere consists of a series of nearly spherical layers, each characterized by a distinctive vertical temperature distribution. Figure E5-3 illustrates a temperature sounding taken at Fort Churchill, Canada and the international reference atmosphere.[31] The lowest atmospheric layer is called the troposphere and is characterized by decreasing temperature with height. This layer contains about 80% of the total atmospheric mass and almost all weather phenomena. Complex horizontal and vertical motions occur in the layer and large vertical overturnings are frequent. The depth of the troposphere varies with season and latitude. In the tropics, it averages about 17 km and over the poles in summer, about 8 to 10 km.

The thermally stable layer above the troposphere is called the stratosphere and extends to a height of about 50 km. At this height, the temperature is comparable to that of the earth's surface. Because of its stability, vertical motions are suppressed; however, horizontal motions develop and in the winter stratosphere there is often an easterly jet stream.

Without the protective chemistry of this layer, life on earth would not exist. The sparse oxygen molecules in the stratosphere readily absorb the intense ultraviolet wavelengths of the solar spectrum. The result is that an oxygen molecule (O_2) dissociates into atomic oxygen (O). These oxygen atoms then recombine with O_2 and any available third molecule to form ozone (O_3). Ozone is very unstable in sunlight; long wavelengths of light quickly break it down into O_2 and O. Thus, the amount of ozone in the stratosphere depends on the net balance between the production and destruction reactions.

The region between 25 and 35 km above the earth is the primary area where ozone production exceeds destruction.[32] The maximum ozone concentration occurs around 30 km and is on the order of 10 ppm.[33] Temperatures at this level are higher because of the absorption of

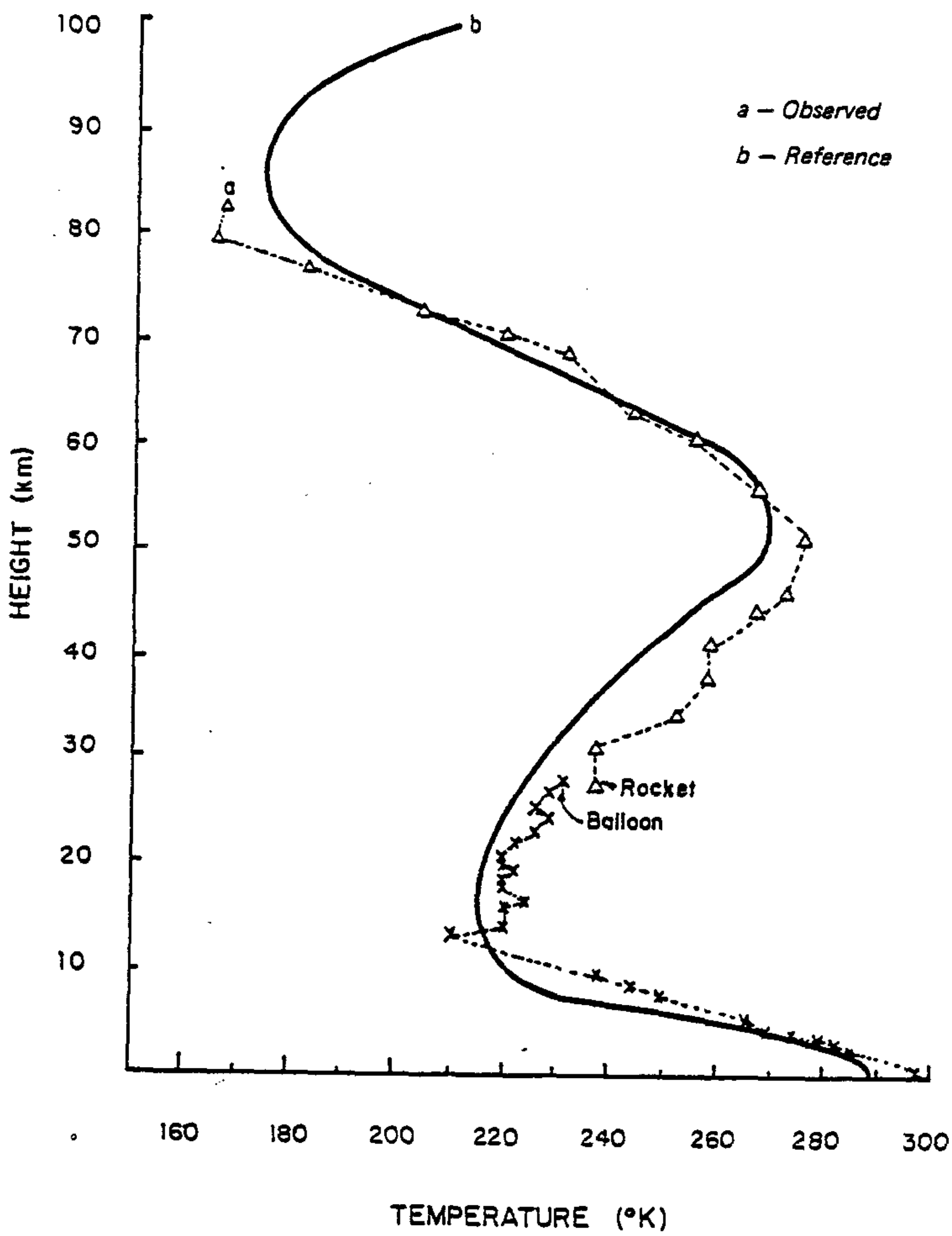

Figure E5-3 Temperature as a Function of Height
(a) Observed at Fort Churchill, Canada, on July 23, 1957 2330 CST
(b) International Refernce Atmosphere, Redrawn from Reference 31

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ultraviolet solar radiation. Large natural variations in concentration occur seasonally depending on solar activity and the stratospheric radiation balance.

Man may alter stratospheric photochemical reactions by either of two processes--the radiation balance or chemical reactions. For example, injection of water vapor or particulates into the stratosphere will reduce the available radiation for ozone production. Also, chemical compounds such as nitrogen oxides and hydrocarbons can tie up atomic oxygen also causing depletion of ozone. Tremendous vertical transports are required for surface emissions to reach altitudes as high as 25 km. For example, updrafts and downdrafts in large thunderstorms, severe storms and hurricanes have been hypothesized as a possible mechanism for the exchange of air between the troposphere and stratosphere.[34]

Another transport mechanism is also possible, as exemplified by the presence of chlorofluorocarbons in the stratosphere. These compounds, used as spray can propellants and refrigerants, are poorly removed from the troposphere because of their extreme chemical stability. Thus, because of their light atomic weights, they gradually diffuse and reach stratospheric altitudes where they are capable of reacting with ozone in the presence of ultraviolet light.[35] There are, then, two mechanisms that could transport contaminants from the lower troposphere to the stratosphere: (1) vertical updrafts in thunderstorms and hurricanes, and (2) slow diffusion associated with very large-scale, low-frequency vertical turbulence accompanying synoptic or even larger scale meteorological events.

The thermal plant contaminants will be emitted from a tall stack and will undergo a further rise because of the buoyancy of the stack gases. A typical* equilibrium height of the contaminants will be 2000 m MSL. Although it is recognized that the probability is non-zero, but small, over the lifetime of the Hat Creek facility, the occurrence of a

*Based on a ground-level wind speed of 2 m/sec.

thunderstorm in the vicinity of the plume with sufficient vertical updrafts to carry the contaminants to the stratosphere would not be frequent enough to effect appreciable alternations of the photochemical balance of the stratosphere. Thermal plant contaminant emissions are readily removed from the atmosphere. The particles and gases undergo chemical reactions and are washed out or rained out in precipitation. They are readily deposited when the plume reaches ground level. It must be concluded that residence time of particles, gases and aerosols that result from point source emissions are sufficiently short to preclude their transport by large-scale vertical motions from the troposphere to the stratosphere.

ES.3 REGIONAL AND LOCAL CLIMATIC IMPACTS

(a) Overview

Few studies have thoroughly considered the impacts of large single industrial facilities upon regional-scale climatic characteristics. As in the case of global scale effects, mesoscale meteorology and climatology and their modification by man's activities are poorly understood and cannot be assessed or predicted with certainty. Nevertheless, it is possible, at least in a qualitative sense, to describe the influence that a single large power plant, such as the proposed Hat Creek facility, might exert upon the surrounding area. In particular, the effects of the proposed Project on the regional and local energy balance, precipitation, temperature structure, fogging, icing, and winds are discussed.

(b) Energy Balance

The energy park models of Hanna and Gifford,[25] and Moore[28] caution that the regional effects from postulated 50,000 Mw power plants may influence regional climatic phenomena. For example, Moore theorizes that a power plant designed to serve the state of New York (a 50,000 Mw plant) may have profound effects on climatic patterns within a 10-mile region. On the other hand, power plants an order of magnitude smaller in size are not expected to significantly alter the regional or local energy balance.

Comparisons of expected effects of wet cooling towers and stack heat emissions with geophysical processes, such as thunderstorm production or rainfall enhancement, require data on the total energy released and the ambient humidity conditions at the point of release. The total energy released by a storm, the product of the energy flux (watts/m^2) and the area covered by the storm, may be determined by considering the latent heat released as a function of the precipitation rate, or by considering the kinetic energy production of the storm.

Available estimates for the energy production of major atmospheric processes (Table ES-2) indicate that a thunderstorm produces about 10^{10} watts of kinetic energy over an approximate area of $10^8 m^2$, or about 100 watts/m^2. The release of latent heat with a rainfall rate of 1 cm/30 min for such a storm equals about 5×10^{11} watts, fifty times as much as the kinetic energy. Operating at full load, the Hat Creek facility is expected to release about 4000 Mw of waste heat. Although the initial production per unit area is large, by the time the plume has expanded so that its cross-sectional area is comparable to that of a thunderstorm, the expansion has reduced the energy flux (40 w/m^2) to less than 40% of the kinetic energy flux and less than 0.8%* of the latent heat release in a small thunderstorm. Thus, because the initial energy flux of the thermal facility is within a small area, the facility may produce enough concentrated energy to initiate convection activity or cloudiness, especially if the atmosphere contains a large amount of moisture and is unstable. Because the energy gradually dissipates over a large area and becomes small as compared to material geophysical processes, the thermal facility is not expected to affect the local or regional atmospheric energy balance.

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*4×10^9 W divided by 5×10^{11} W.

TABLE ES-2

ENERGY PRODUCTION OF SOME ATMOSPHERIC PROCESSES
(ADAPTED FROM HANNA, 1971)

Process	Area Influenced by Atmospheric Process	Energy Production	Production Per Unit Area
	Natural Processes		
Tornado Kinetic Energy (K.E.) Production	$10^4 m^2$	$10^8 W$	$10^4 W/m^2$
Thunderstorm			
(K.E.) Production	$10^8 m^2$	$10^{10} W$	$10^2 W/m^2$
Latent Energy Production	$10^8 m^2$	$5 \times 10^{11} W$	$5 \times 10^3 W/m^2$
Total Energy Production	$10^8 m^2$	$5.1 \times 10^{11} W$	$5.1 \times 10^3 W/m^2$
Great Lakes Snow squall latent heat release (4 cm snow in 1 hr.)	$10^{10} m^2$	$10^{13} W$	$10^3 W/m^2$
Cyclone latent heat release (1 cm rain per day)	$10^{12} m^2$	$2 \times 10^{14} W$	$2 \times 10^2 W/m^2$
Solar Energy Flux	$5 \times 10^{14} m^2$	$1.75 \times 10^{17} W$	$3.5 \times 10^2 W/m^2$
	Anthropogenic Processes		
Energy Park	$10^8 m^2$	$10^{11} W$	$10^3 W/m^2$
2,000 MW Power Plant (33% efficiency)	$10^8 m^2$	$4 \times 10^9 W$	$4 \times 10^1 W/m^2$

Total release of latent heat (in addition to the 4000 Mw waste heat) emitted to the atmosphere can only occur when the plume water vapor condenses and does not re-evaporate in entrained air that is dryer than the saturation mixing ratio of the plume. The ambient conditions required for maximum latent heat energy release would most frequently occur near precipitating clouds, or near clouds just on the threshold of producing precipitation. This latter factor makes it very difficult to ascertain the differential effect of a cooling tower plume upon precipitation.

Table E5-3 (reprinted from Huff[36]) lists the relative magnitude of heat-moisture liberated from two cooling towers (equivalent to a 2200 Mw plant) and that ingested by medium-sized shower clouds and large thunderstorm clouds. Comparing cooling tower output with thunderstorm input, we see that the latent heat of water vapor from the cooling tower plume only supplies 0.1% of the total energy needed to fuel a thunderstorm.

Although the initial flux of waste heat rejected from the Hat Creek thermal plant would be relatively large, atmospheric diffusion and transport would reduce the concentration of energy to levels much smaller than atmospheric storms when the plume dimensions are comparable to the size of the areas affected by these storms. In short, it is not expected that the Hat Creek project would significantly alter the regional or local energy budget but the heat wastes could act to initiate additional clouds or even initiate precipitation (see below).

(c) Precipitation Enhancement

Increases in precipitation downwind of a thermal power plant could occur because of three mechanisms: (1) condensed water vapor directly from a cooling tower; (2) the initiation of precipitation because of the interaction of the cooling tower plume with natural clouds; and (3) emitted particulate matter acting as condensation nuclei. Few studies have attempted to quantify the potential effects of these mechanisms on downwind precipitation patterns. Although a number of researchers have

TABLE ES-3

RELATIVE MAGNITUDE (TONNES/SEC) OF HEAT/MOISTURE OUTPUT FROM COOLING TOWERS* AND STORM CLOUD INGESTION

	Two Cooling Towers Output	Typical Medium-Sized Shower Cloud	Typical Large Thunderstrom Cloud
Air	30	1,650	165,000
Evaporated Water	2	8	1,650

*Developed by Huff[27] based on the utilization of two natural draft cooling towers at the Zion nuclear plant (2200 Mw) in Illinois. It should be noted that cooling towers have not been constructed to service this facility.

reported light drizzles in the vicinity of towers,[37,38,39,40,41,42] no comprehensive analysis has yet been conducted to define and assess augmentation of natural precipitation[43] that could occur because of emissions of heat, moisture and particulate matter. It should be noted that noticeable drizzle has been virtually eliminated as an effect of cooling towers by utilizing highly efficient drift eliminators. Based on a theoretical study of the potential effects of cooling tower plumes on downwind precipitation, Huff[36] found that under steady, light rain conditions, the condensation of water vapor in the plume cloud from a 2200 Mw plant near Lake Michigan led to small increases in local rainfall (a trace amount within a few hundred meters of the plant). On a regional scale, the addition was found to be negligible.

Martin[41] describes his observations at a power plant with a large natural draft cooling tower (NDCT) complex (eight towers) at Radcliffe, England. At full load, about 400 kg/sec of evaporated water are released into the atmosphere. Particulate matter is also released from the power plant stack. According to Martin, no significant regional precipitation enhancement can be discerned in the area, particularly since the plant lies in an area of high variability of precipitation total and intensity.

Stockham[44] investigated climatological precipitation statistics at several locations in the vicinity of the Keystone, Pennsylvania coal-fired power plant. These data included precipitation measurements before and after operation of the plant and its natural draft cooling towers. No significant differences in precipitation were observed after commencement of operation at the Keystone facility. It should be noted the emission rate of particulate matter is larger at Keystone than is proposed for the Hat Creek station.

Following the procedure of Huff,[36] we can examine the potential water vapor output of the B.C. Hydro facility and attempt to quantify its effect on the precipitation of the region. As much as 109,000 metric tons of evaporated water could be discharged to the atmosphere per day from the plant; assuming that all of this vapor were condensed (clearly an overestimate) and deposited as rainfall (the first mechanism described above) over a distance of 100 miles and within a 45° sector, the annual increase in precipitation would be only 0.15 inches, or about 1% of the mean total for the Hat Creek region. In actuality, any increase will be much less than this, since a rather small fraction of the water vapor is expected to condense. Some documentation of cooling tower plume induced snowfalls can be found in recent literature. Culkowski[37] reports an observed snowfall in Oak Ridge, Tennessee. He theorized that the snow was related to the release of vapor from the Oak Ridge Gaseous Diffusion Plant. This vapor froze around ferro-manganese dust emitted from a plant 18 miles away. The snow was deposited 3 to 5 km downwind from the cooling tower with some snowflakes as large as one-fourth of an inch.

Agee[40] also presented evidence of a locally induced snowfall in Lafayette, Indiana. The heaviest snowfall, approximately one-fourth inch, was observed around a power plant. On this day, January 11, 1971, a cold front which had passed through northern Indiana the day before, was retreating across Lafayette as a weak warm front. Some precipitation was associated with the frontal zone. However, because of the snowfall pattern Agee argued that the snowfall was locally induced.

More recently, Kramer et al.[45] reported that during the winter of 1975-1976, nearly one inch of very light fluffy snow fell from the plumes of the large natural draft cooling towers associated with the American Electric Power Services Corporation Amos Plant in Charleston, West Virginia. The authors report that this snow was not falling from natural clouds. In fact, snow from the tower plumes was observed to fall before, during and after natural snowfalls. This snowfall was recorded between 13 km and 43 km from the plant.

The actual conditions required for induced snow are not well known. Kramer et al.[45] state that the observations recorded to date have indicated that these induced snowfalls have been associated with: (1) low ambient air temperature (less than -12°C); (2) relatively stable diffusion conditions at plume height, and (3) a sufficiently large source of water vapor.

Huff[36] and Bergeron[46] seem to believe that it is most likely that the effect of the plume upon snow systems would be to act as a feeder cloud. This cloud (the plume) would merely augment snow falling in its environs. Therefore, they feel the snowfall would be dependent upon the duration and the intensity of the synoptic snowfall. In conclusion, the moisture and particulate matter emitted from the proposed thermal plant will not significantly alter local or regional rainfall amounts, although it could initiate cloudiness or precipitation. The cooling tower plume, however, could help initiate or cause additional convective clouds on occasion. Since the meteorological conditions associated with snowfall from cooling tower plumes do occur near Hat Creek, it is likely that the cooling tower will infrequently augment snowfall by as much as 2.5 cm. Since the increased snowfall will occur only under the plume, it should not, however, significantly alter the total amount of snowfall for the region. The output of released water and vapor from cooling towers is too insignificant to alter synoptic scale snowfalls. In fact, Hanna and Gifford[25] in their recent comprehensive review of the possible meteorological effects of energy parks do not even mention snowfall augmentation.

(d) Thermal Alteration

An alteration of the temperature structure near the ground could occur by either of two mechanisms: (1) the release of hot cooling tower and stack plumes and their subsequent dispersion to ground level, and (2) the reduction of solar radiation incident at the ground by the aerosols in the stack plume, by visible cooling tower plumes, and by fugitive dust emissions from mining activities. The dispersion of the stack plume to ground level occurs relatively slowly during normal meteorological conditions unless the plume were to impinge upon nearby terrain whose elevation is comparable to the height of the plume. The cooling tower plumes would also reach ground level relatively slowly if round mechanical or natural draft cooling towers are used at the facility. If rectangular mechanical draft towers are used, then the plumes will be brought to the ground almost immediately during high winds. Plume fumigation conditions would also tend to bring both stack and cooling tower plumes to the ground more quickly than during 'normal' meteorological conditions.

To assess the effect of the hot plume on ambient temperatures, the model COOLTOWR was applied to estimate plume centerline temperature excess as a function of downwind distance from the cooling towers. The results for a system of two natural draft* towers are summarized below. This temperature excess represents the temperature increase that would occur in a small volume of air near ground level that would cover a horizontal area roughly equal to the horizontal dimension of a bank of mechanical draft cooling towers. Only with mechanical draft towers would any temperature increase occur at ground level. The temperature excess would only persist as long as the plume remained at ground level at a specific location. Note that this excess is essentially eliminated within 500 m from the towers.

*Since plumes from elevated natural draft towers mix with ambient air more slowly than those from other types of towers, temperature excesses in the table represent a worst case.

Temperature difference (°C) between the plume and the environment	Downwind distance from heat release (in meters)
20.00	124
10.00	143
5.00	168
1.00	218
0.50	298
0.10	436
<0.01	500

Ambient conditions 10.2°C = Temperature
6 m/sec = Wind speed
90% = Relative humidity

Plumes from tall power plant stacks will achieve thermal equilibrium before reaching ground level. Downwash from rectangular or round mechanical draft cooling towers is the only mechanism by which temperatures at the ground could be altered. If these towers were used, downwash could result in a small reduction in snow cover within a few hundred meters of the towers. This reduction would occur because of the heating of the air near the ground.

The aerosols contained in the stack plume and the visible cooling tower plumes are not expected to reduce areawide incident solar radiation in any significant way, although visibility will be reduced by the plume and fugitive dust emissions from the mine. The Hat Creek facility will utilize modern, efficient electrostatic precipitators to collect most of the particulate matter before it enters the atmosphere. The particles that are released will be sufficiently small in size so as not to attenuate insolation radically. The precipitator will be designed to limit particulate emissions to a maximum of 0.23 grams/m^3 (0.1 grains/SCF). This plume will be slightly visible. However, the natural variability of wind direction and the relatively narrow horizontal extent of the plume will preclude any significant reduction in sunlight at the ground. Appendix D describes the effects of alternative cooling tower systems and provides estimates of the number of hours of visible plumes for each system. For example, two natural draft cooling towers will produce only 271 hours with visible plumes at the point of maximum shadowing during the winter season (Figure D3-10). The location of maximum shadowing is within 0.5 km of the cooling towers. Outside a radius of about 2 km, no more than 20 hours of visible plumes overhead are expected at any point. Considering that some of these hours will be at night and that visible plumes often occur during periods of natural cloudiness, this, then, represents an insignificant reduction in insolation.

Mining activities associated with the Hat Creek Project are expected to generate approximately 2,462 tonnes per year of fugitive dust emissions during the period of peak activity. These emissions will cause a peak annual average TSP concentration of about 260 $\mu g/m^3$. This peak will be limited in extent to the immediate area around the open pit. Outside an approximate 3 km radius, values decrease to about 60 $\mu g/m^3$. The maximum value will reduce the amount of direct sunlight reaching the ground in the Hat Creek Valley in the immediate vicinity of the mine. Since dust particles do not absorb longwave terrestrial radiation, there could be a slight cooling in the valley in the immediate environs of the mine on an annual basis[50] because of the mining activities. However, this cooling would certainly be small compared to the natural variability in annual average temperatures and is not expected to affect agriculture in any significant way. No measurable effect on temperature will occur outside the mining area. In summary, the following conclusions can be made in regard to the potential effects of the Hat Creek Project on the temperature distribution in its environs.

- The stack and cooling tower plumes will not affect the temperature structure.
- If rectangular mechanical draft cooling towers are used at the facility, there could be a slight reduction of snow cover within an approximate 0.5 km radius of the towers.
- The stack and cooling tower plumes will not significantly alter areawide incident solar radiation, although the power plant plume and fugitive emissions will reduce visibility.

- Mining activities will produce fugitive dust emissions which will reduce the intensity of direct solar radiation and may cause a slight cooling in the environs of the mine in the Hat Creek Valley.

(e) Relative Humidity

The principal Hat Creek facilities that will add moisture to the atmosphere include: (1) the cooling towers, (2) the make-up water reservoir, and (3) the ash disposal area. Details of the impact of the cooling towers are given in Appendix C. If the preferred natural draft cooling towers are utilized, little change in the ground-level relative humidity is expected because the vapor plumes will remain elevated until the plume relative humidity decreases to the ambient background humidity. The expected hours of visible plumes (see Figure D3-6) are indicative of the effect of the cooling tower on relative humidity at the height of the plume (e.g., 300-500 m above ground). The cooling tower plume will be visible about 40 hours per year within an approximate 2 km radius of the cooling towers, which means the rejected moisture will increase the relative humidity by 5 to 15% during these 40 hours at the plume height.

To illustrate the general impact of the cooling tower water vapor emissions on relative humidity the following simple calculations were performed based on adverse and typical meteorological conditions. The typical daily emission rate of water vapor is 5.3×10^7 kg/day. If it is assumed this water is contained within a volume defined by an average wind speed of 0.5 m/sec, a mixing height of 200 m, and a wind direction sector of 22.5 degrees,* then the cooling tower would add approximately 0.72 g of water per kg of air. During the winter a dew point of -10.9°C (see Table E3-9) would give a water mixing ratio of approximately 2 g of water per kg of air. If the ambient temperature is -7.0°C, then the relative humidity would be increased from 71% to 97% in the mixing

*This assumes the wind persists from the same direction at a speed of 0.5 m/sec for 24 hours.

volume. If this mixing volume is defined by a more typical 2 m/sec average wind speed, then the added water would be 0.05 g per kg of air. Table E5-4 depicts the effect of the cooling towers for several meteorological conditions. It must be emphasized that the impact will be limited to the defined mixing volume. No impact would occur at any other location.

Typical evaporation rates from the make-up reservoir and the ash disposal area are 3.67×10^5 kg/day and 3.36×10^6 kg/day. Frequently, the water vapor evaporated from the reservoir and ash pond will disperse in a diurnal valley circulation. To simulate this effect, the water vapor is assumed to be dispersed throughout a volume defined by a mixing height of 50 m and a uniform downwind extent defined by a 5 km radius around the two moisture sources.* The added moisture would increase the atmospheric water vapor mixing ratio by 0.95 g water per kg of air. Table E5-5 lists the impact of this increase for selected meteorological conditions. Increases in relative humidity to 100% can be expected on cold days. It is likely that the ash pond and reservoir will produce fog that could persist for several days during the late fall, winter and early spring months. A substantial change in the microclimate around these facilities can be expected.

(f) Fogging and Icing

Appendix D discusses in detail the environmental effects of four alternative cooling tower systems. Computer model calculations indicate the potential for 915 hours of fogging per year and about 170 hours of icing per year for the rectangular mechanical draft towers. These impacts will be limited to within 600 m of the cooling towers. Some ground-level fogging (29 hours per year), but no significant icing, is predicted

*This assumes meteorological condition is somewhat adverse although little transport of the water vapor can be expected during stagnant meteorological conditions.

TABLE ES-4

EFFECT OF COOLING TOWER WATER VAPOR EMISSIONS ON LOCAL ATMOSPHERIC WATER MIXING RATIO AND RELATIVE HUMIDITY

Windspeed (m/sec)	Temperature (°C)	Dewpoint (°C)	Mixing Ratio (g/kg)	Increased Mixing Ratio (g/kg)	Relative Humidity (%)	Increased Relative Humidity (%)
0.5	-7.0	-10.9	2.0	2.72	71	97
0.5	3.7	0.6	5.0	5.72	75	85
0.5	13.8	7.8	8.5	9.22	70	76
0.5	3.2	1.3	5.5	6.22	92	100
2.0	-7.0	-10.9	2.0	2.05	71	73
2.0	3.7	0.6	5.0	5.05	75	75
2.0	13.8	7.8	8.5	8.55	70	70
2.0	3.2	1.3	5.5	5.55	92	93

TABLE ES-5

EFFECT OF RESERVOIR AND ASH POND WATER VAPOR EVAPORATION ON LOCAL ATMOSPHERIC WATER MIXING RATIO AND RELATIVE HUMIDITY

Temperature (°C)	Dewpoint (°C)	Mixing Ratio (g/kg)	Increased Mixing Ratio (g/kg)	Relative Humidity (%)	Increased Relative Humidity (%)
-7.0	-10.9	2.0	2.95	71	100
3.7	0.6	5.0	5.95	75	89
13.8	7.8	8.5	9.45	70	77
3.2	1.3	5.5	6.45	92	100

for the round mechanical draft towers. No localized fogging or icing is predicted for either of the two natural draft tower options (the preferred cooling system) examined in this study.

(g) Visibility

Visibility and visual range are two parameters that are potentially affected by emissions of atmospheric contaminants. Visibility, as applied in this report, refers to the clarity with which an object stands out from its surroundings; visual range is the distance at which an ideal black object can just be seen against the horizon.

In the western part of North America there are many areas located great distances from large sources of anthropogenic aerosols. In these areas, visibility and visual range are largely determined by light scattering by particulate matter and aerosols from natural sources. Thiuller et al.[52] have computed that the visual range for such locations can be greater than 160 km. For such locations, a small absolute increase in light-scattering particles could greatly affect the visibility of objects in the area of an observer.

The remainder of this section discusses the potential effects of the proposed Hat Creek Project on visibility on a local scale and visibility on a regional scale.

Henry[53] has applied the linear system theory of visual acuity to visibility reduction by aerosols (see Appendix B, Modeling Methodology). His approach is based upon the assumption that the eye-brain system is nearly linear in its response to light stimulus and that all objects can be defined in terms of Fourier combinations of sinusoidal light patterns given in cycles per angular degree. This approach leads to the result that as the integrated mass concentration increases, the smallest discernible sinusoidal frequency of an object decreases. Hence, the visual detail of the object is obscured.

Before discussing visual effects it is important to discuss one meteorological variable which has a great effect on atmospheric visibility, namely, relative humidity. Many particles in the atmosphere are deliquescent while others are hygroscopic. In both cases the particle size increases with increasing relative humidity. Covert et al.[54] examined the relative light scattering properties of various atmospheric aerosols for relative humidities ranging from 20 to 100%. In all cases they found a dramatic increase in light scattering for relative humidities greater than 70%. Thuiller et al.[52] also found that for the same aerosol mass distributions, the visual range dropped from 20 miles at a relative humidity of less than 40% to a range of 10 miles when the relative humidity exceeded 70%. Their conclusion was that visual range was not necessarily indicative of total aerosol mass concentration at relative humidities of greater than 70%. The implications of relative humidity effects will be discussed in the following section.

(i) Visibility Effects of Mining Operations on the Local Scale

Emissions, other than those from the cooling towers, which may significantly affect visibility within 25 km of the Hat Creek Project are due to mining operations and to material discharged from the power plant stack. In light of the discussion of relative humidity in the previous section, visibility effects on the local and regional scales will be assessed for periods when the relative humidity is less than 70%. Using the best available humidity data from the B.C. Hydro monitoring station nearest the power plant site, the frequency of hours when the relative humidity is less than 70% for each month of 1976 is presented in Table E5-6.

TABLE E5-6

FREQUENCY OF HOURS WITH RELATIVE HUMIDITY LESS THAN 70%

Month	Frequency (%)
January	29.3
February	26.6
March	62.8
April	77.6
May	68.0
June	59.7
July	75.6
August	57.8
September	72.6
October	58.8
November	57.8
December	27.3

Table E5-6 indicates that for the winter months (Dec-Jan) the visibility may be less than the annual average visibilities computed in this section more than 70% of the time. The results of Thuiller et al.[52] indicate that the visual range during high humidity periods may be only 50% of the values computed here.

Measurements near mining sources indicate that the mass median diameter of dust particles emitted from mining operations and other fugitive sources is from 10 to 50 μm. The major emissions from mining operations are in the form of silica dust. Background TSP concentrations have been measured at 5 sites in the Hat Creek Valley. The average annual concentration of TSP in the Indian Reserve 3 km north of the mine pit is approximately 20 $\mu g/m^3$ (based on data collected at sites 1 and 2; see Appendix A). For a background concentration of 20 $\mu g/m^3$, the light scattering coefficient (b) is $4.5 \times 10^{-5} m^{-1}$.

According to Henry,[55] the human eye-brain system is capable of distinguishing object sizes which correspond to spatial frequencies of 40 to 50 cycles/degree. Objects which are approximately 30 cycles/degree represent fine detail (the limb of a tree), while objects corresponding to 15 cycles/degree represent moderate detail (the trunk of a tree) and objects corresponding to 5 cycles/degree represent coarse detail (the tree itself). The visual ranges for 30, 15 and 5 cycles/degree correspond to no visibility reduction detected, moderate reduction and severe reduction respectively.

Henry suggests the visual ranges associated with the background concentration of 20 $\mu g/m^3$ are approximately 14.6, 36.0 and 54.0 km for objects of spatial frequencies of 30, 15 and 5 respectively. This indicates that at 14.6 km fine detail is discernible; at 36 km moderate detail is visible and at 54 km coarse detail is visible.

The annual average TSP concentration in the lower Hat Creek Valley near the southern boundary of the Indian Reserve located approximately 3 km north of the mine pit was computed to be about 60 $\mu g/m^3$ as a result of mining operations. Adding in the background concentration, the total is approximately 80 $\mu g/m^3$. For this concentration, the light scattering coefficient (b) is $1.8 \times 10^{-4} m^{-1}$. Assuming the total TSP increases from 20 $\mu g/m^3$ to 80 $\mu g/m^3$, the visual ranges for spatial frequencies 30, 15 and 5 are about 3.6, 9.0 and 13.5 km respectively. These are the visual ranges at which fine, moderate and coarse details can be discerned by an observer. More typical annual TSP values that are expected to occur in the Indian reserve because of mining operations are about 25 $\mu g/m^3$. This increase in TSP would result in a total concentration of 45 $\mu g/m^3$. This level would reduce the visual ranges for spatial frequencies 30, 15 and 5 to about 6.5, 16.0 and 24.0 km, respectively.

Comparing the visual ranges for background and mine-added TSP concentrations, one can deduce that an observer located at the southern tip of the reserve would only be able to discern moderate object detail due to mine-induced TSP concentrations at a distance of 29.0 km where he could distinguish fine detail when only background TSP concentrations were present. At other locations in the reserve the visual range of fine detail will be reduced from 14.6 km to 6.5 km, moderate detail from 36.0 km to 16.0 km and coarse detail from 54.0 km to 24.0 km.

(ii) Local Visibility Due to Power Plant Emissions

The power plant emissions can affect visibility on a local scale because of dispersed particulate matter and the opacity of the plume itself.

ERT has calculated that on an annual basis the maximum average TSP concentration within 25 km of the proposed power plant is approximately 1.2 $\mu g/m^3$ from particulate emissions from a 366-meter stack. This TSP concentration is negligible when compared with estimated background and mine-induced TSP levels. Therefore, visibility reduction due to particulate emissions from the power plant must be considered insignificant on an annual basis.

Significant sulfate and nitrate concentrations will not be produced by the power plant within 25 km of the stack. The question of light scattering and plume discoloration by NO_2 has been addressed by Latimer and Samuelsen[55] who used a plume concentration-visibility model that has been verified by comparing visibility degradation to observed NO_2 concentration data in power plant plumes. The results of their studies, based on this modeling approach, indicate that NO_2 levels have a very small effect on the visibility through individual power plant plumes.

Weir et al.[57] listed such factors as latitude, sun angle, plume color, particle density, distance of observer from stack, and meteorological conditions that affect observed power plant plume opacity. Their conclusion was that plume opacity observations are not necessarily indicative of mass emissions, although the U.S. Environmental Protection Agency has suggested that a particulate matter emission rate of 0.1 lb/MBtu heat input gives an opacity of about 20%. Based on an electrostatic precipitator efficiency of 99.7% and a particulate matter emission rate of 40,000 kg/day, the emission rate in terms of heat input is approximately 0.12 lb/MBtu. Considering that plume opacity is generally lower for high latitude power plants[57] and the rate of 0.10 lb/MBtu produces a low opacity, no significant visibility reduction is expected because of plume opacity. In any event, any restrictions to visibility because of opacity effects will be limited to within a few kilometers of the stack. At further downwind distances plume concentrations will be reduced to sufficiently low levels to preclude significant visibility degradation.

(iii) Visibility Effects on the Regional Scale

The contaminants expected to produce light scattering and affect visibility on a regional scale are TSP and sulfates. Although the power plant will also emit oxides of nitrogen, studies conducted in the midwestern United States indicate that nitrate formation in individual power plant plumes is not significant[58] and, therefore, nitrates will not significantly contribute to light scattering in the rural areas around the Hat Creek site.

ERT used a Gaussian plume dispersion model which incorporates the effects of contaminant chemical transformation and deposition in its computational scheme to compute surface concentrations of primary and secondary contaminants. Surface concentrations were computed by the model for an area bounded by two concentric arcs with radii of 25 km and 100 km.

On an annual basis, it has been computed that the incremental increase of both TSP and sulfates because of power plant emissions is approximately 0.10 $\mu g/m^3$. As previously mentioned, the background levels of TSP in the region of the Hat Creek Valley has been estimated to be 20 $\mu g/m^3$. It is anticipated that annually an increase of 0.10 $\mu g/m^3$ in TSP concentrations will not significantly alter the magnitude of TSP light scattering near the earth's surface.

At the height of the plume centerline (approximately 1400 m above the ground) the incremental annual increase in TSP levels is approximately 0.3 $\mu g/m^3$ for distances of 50 to 100 km from the plant site. Therefore, at the height of the plume it is not anticipated that particulates originating from the power plant will significantly affect visibility.

Trijonis et al.[59] performed linear regression analyses relating airport visibility measurements and contaminant mass concentrations for locations in the southwestern United States. They calculated that sulfates had a significant effect on visibility even though the mass concentration of sulfates was generally one order of magnitude smaller than TSP concentrations. These results were attributed to the smaller particle size of the sulfates and, hence, a greater scattering coefficient. In fact, they estimated that the scattering coefficient for sulfates is about one order of magnitude greater than the coefficient for particulates. However, care must be taken in interpreting results derived from a linear regression analysis. Such an approach assumes that only the variables in the regression equation significantly contribute to visibility reduction. The method also assumes that the variables are independent of each other. Finally, the visibility observations were taken at airport locations where the effects of aircraft emissions are probably present but unaccounted for in the analysis.

Assuming the research by Trijonis et al.[59] is applicable to the Hat Creek Project and realizing that the magnitude of light scattering due to sulfates could overestimate the visibility degradation, it is estimated that the contribution due to sulfates in the region is 5% of the light scattering due to background particulate concentrations. This conclusion was derived from the fact that the annual average sulfate concentrations are two orders of magnitude smaller than the background

TSP levels* (0.1 $\mu g/m^3$ vs. 40.0 $\mu g/m^3$) but the scattering coefficient of sulfates is estimated to be one order of magnitude larger than the TSP coefficient.

Adding the small contribution of particulate matter (0.2 $\mu g/m^3$), it is estimated that the annual average regional visibility will be reduced by a total of about 6.0% because of concentrations of TSP and sulfates that will be produced by the proposed power plant emissions.

(h) Wind Flow - Valley Drainage

Mountain valley circulation patterns result from differential heating distributions on both the floor of the valley and the slopes of the mountains. In broad terms, the winds are generally upslope during the day and drawn down the valley at night. The influence of the power plant on local wind circulation patterns can be expected to be minimal. Briggs[50] estimates that a power plant can alter the direction of flow only within a distance equivalent to its aerodynamic wake, or about 3 to 5 times its height. Wind speeds may differ slightly from ambient values within a distance of 30 plant heights. Any slight wind alterations will not adversely affect the environment.

*It was assumed that background sulfate levels were zero.

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