DRAFT

A Review of Weather Station Networks in the Mountain Parks

A Report Prepared for Parks Canada

By

William Thompson
Consulting Meteorologist
Calgary, Alberta

November 21, 2005

Revised Nov 23/05

Executive Summary

A review of weather networks in the seven Mountain National Parks was conducted. The networks were examined on their ability to address needs in the following areas:

a) Aquatic, vegetation and wildlife studies or management
b) Forest fire management and avalanche control
c) Trend monitoring and climate change modeling, assessment and reporting
d) Climate information for visitors at information centres

Most of the stations were installed to meet Forest Fire Management and Avalanche Control activities and adequately meet those needs. There are not enough stations operated by Parks Canada to meet the needs of climate change assessments and its impacts on vegetation and wildlife. Several other organizations operate weather stations in the Parks. When the information from these stations is taken into consideration the network density is near adequate. A core network consisting of 25 existing stations operated by Parks Canada, three new stations and 26 stations operated by other agencies is recommended.

Weather information could be delivered to Park Visitors in a more efficient manner. Web cams are suggested as one means of providing current information. Negotiation with the Meteorological Service of Canada is required to improve the quality of weather forecasts.

The weather stations are not well maintained and the location and quality of data are in doubt. It will not be possible to conduct studies without a supply of good quality data. Priority should be given to improving maintenance and data handling activities.

Table of Contents

A Review of Weather Station Networks in the Mountain Parks

Prepared by Bill Thompson
Consulting Meteorologist
Calgary, Alberta

Introduction

Parks Canada has requested that the ability of the current climate and weather monitoring program in the seven Mountain Parks be assessed to meet the long-term monitoring needs of the Parks. In the event that the program is found to be inadequate it further requested that recommendations be made to overcome the deficiencies.

The following undertakes that task. It begins with a compilation of the factors generally considered in program planning, then determines the needs of the Parks, identifies stations in the existing networks, and then weighs the ability of those stations to meet the needs. It briefly examines the cooperative aspects of weather issues by examining the activities of national weather services. Other organizations are engaged in monitoring weather in and around the Parks. Their activities are also examined. Finally, the needs are balanced against the contributions of all organizations engaged in weather monitoring. The Report concludes with a set of recommendations.

The terms of reference specified that the existing network be evaluated on its ability to address needs in the following areas:

a) Aquatic, vegetation and wildlife studies or management
b) Forest fire management and avalanche control
c) Trend monitoring and climate change modeling, assessment and reporting
d) Climate information for visitors at information centres

The needs were to be determined in consultation with a number of specialists in each of the various Parks. Needs relating to highway maintenance, except for avalanche control, and air quality management were to be excluded

Parks Canada provided the location of weather stations and the instrumentation at each station. No provision was made to visit any of the stations though, as will be noted, the Consultant did inspect a few sites in connection with other activities.

Elements of Program Planning

A meteorological program consists of several components. Network design is an important one but the ability to support the program is equally important. Supporting components include: maintenance, standards, manufacturer's support, and technological expertise. A program should also undergo periodic review to determine if new

technologies such as those offered by remote sensing might replace conventional monitoring activities.

Network Design

Many approaches to network design exist. They range from the purely theoretical to the practical. At one extreme stations are distributed in a random manner using statistical theory. At the other stations are only at locations to meet a specific need such as, for example, avalanche control.

The practical approach is favoured here. However, it is necessary to understand the meaning of need. Forthcoming sections will outline needs identified by Parks staff and this review will focus on meeting those needs. However, there are other underlying needs that are not so obvious but yet necessary for long term planning.

The network should strive to improve our knowledge of local climates. The climate of the Parks is not well understood. Janz and Storr (1977) conducted the only examination of the climate in the Mountain Parks. It was confined to the four contiguous Parks; Banff, Jasper, Kootenay and Yoho. No climatological studies have been conducted for Waterton, Glacier or Mt Revelstoke National Parks.

There is also a need to provide feedback to atmospheric models. Atmospheric models describe the ongoing weather events and are the basis for weather prediction. The resolution of these models is increasing. The current generation of models has a resolution of 15 kilometres. This means that they are capable of identifying weather events as small as 15 km in breadth. This is approaching the scale where the influence of local mountain ranges on precipitation can be quantified. To achieve this capability information must be fed back from a network of similar scale. In other words the network should contain one station per 225 square kilometres on average.

Field Maintenance

Factors to be considered in the operation of a network are: installation, maintenance, power supply and communications. These factors consume a large portion of the budget when weather stations are installed at remote locations.

Standards

A frequently unrecognized aspect of operating a monitoring program is the compilation and management of data. Analysts and others conducting studies expect the data to be in a recognizable format and free of errors. Reformatting and error removal is time consuming and costly. Adhering to standard procedures all the way from the installation of the sensors to the delivery of the database will reduce the amount of erroneous data. Standards are required for:

- Sensor specifications

- The siting of the weather station
- The mounting of the sensors
- The monitoring of the sensors
- The coding and delivery of data
- The quality control procedures
- The coding and formatting of stored data

Manufacturer's Support

It is desirable from maintenance and data management perspectives to minimize the variety of equipment in use. The ability of the manufacturers to support to supply and support their products is an important factor in equipment selection.

Technological expertise

The installation, operation and maintenance of weather stations and associated equipment including data loggers and modems are detailed and complex. An inventory of sensors at each weather station must be maintained and updated, sensors calibrated, field equipment routinely checked for accuracy, and repairs made as necessary. These activities require special skills and should be performed by an individual possessing a good knowledge of instrumentation and electronics.

Data collection and management activities also tend to be complex. Software is required to reformat and display data. Data must be checked for accuracy and erroneous information either corrected or removed. The data must be submitted to an archive, and the archive must be maintained. Information contained in the archive should be readily available to a variety of users including those charged with preparing climatological statistics. Again it is desirable that these tasks be assigned to an individual with a good knowledge of data processing and computer technology.

Remote Sensing Capabilities

Remote sensing techniques are continually being introduced to monitor weather conditions. In some areas they reduce the reliance on weather stations. Weather radar, satellite imagery and lightning detection fall into this category. Unfortunately, the operation of all three is limited in mountainous terrain. The need for surface based observations will continue to exist in the Mountain Parks.

Needs

One or more staff members were interviewed in each of the seven Mountain Parks to determine the present and anticipated needs for weather information. Among these were attendants at three Information Centres. Staff members in the Calgary Regional Office and in Headquarters in Ottawa were also interviewed. Most of the interviews were conducted by telephone but a few were conducted in person. A summary of the comments follows.

Aquatic, vegetation and wildlife studies or management

Most of the comments related to studies as opposed to management. The impact of climate change was expressed as a concern. Vegetation boundaries are expected to shift upward due to warming. Fish and waterfowl populations are expected to be impacted as wetland areas respond to changes in runoff patterns from glaciers.

Studies tend to be of a correlation type in which changes are related to weather elements. The elements most often examined are air temperature, precipitation including snow depth and humidity. The behavioral changes tend to take place over a few days or weeks or longer so that a need for a high sampling rate for weather information is not required. Daily measurements would meet most requirements.

Typical studies undertaken included the migration habits of large mammals in Banff National Park and the foraging activities of woodland caribou in Mt. Revelstoke, Glacier and Jasper National Parks. The independent variable in the migration study was snowmelt and in the foraging study was snow depth.

Chemicals are used in highway clearing operations. They are released into streams during melt periods. The impact of the chemicals was not identified as a concern but was nevertheless taken into account in network design.

Forest Fire Management and Avalanche Control

Forest fire management and avalanche control have the greatest need for weather information. Both are seasonal activities. Forest fire management requires weather information during the summer season; avalanche warning/control during the winter season. Both need information in real time i.e. within a few minutes or hours of observation.

Forest Fire Management

Day to day activities conducted for forest fire management in the Parks are generally done in accordance with the Fire Weather Index (FWI) System, a procedure for monitoring fire danger conditions and a major component of the Canadian Forest Fire Danger Rating System. Most Provinces and the territories adhere to this System.

The FWI uses daily weather observations to estimate the moisture content of three different fuel classes. These in turn are used to generate a set of relative indicators of potential rate of fire spread, fire intensity, and fuel consumption.

The Fire Weather Index is started at the beginning of the season and updated daily as the season progresses. Each Unit collects noon time weather observations from the local weather stations. They are entered into a model that calculates the FWI at each station. The updated values are held in local storage where they become accessible by the

Regional and National Offices. They are distributed from these Offices to the Canadian Wildland Fire Information System where they are integrated into the national daily fire weather map. This map is used by managers at the local, regional and national levels to shift resources to the areas of greatest fire threat. The values also enter a database where they are available for climatological purposes.

The FWI System requires observed temperature, relative humidity, and wind speed at noon local standard time, as well as 24-hour precipitation. The System requires an unbroken record of daily weather. If a station fails to report or reports missing data, the missing values must be estimated.

While the Parks participate in the national data management system, the strategy for forest fire suppression in the Parks differs from that in most Provinces and Territories. The Provinces and Territories consider the forests a resource and take steps to combat a fire. The Parks view fire as a natural event. Thus the Parks will not necessarily take action to combat a fire unless it threatens a community, a transportation corridor or adjacent forest outside the Park.

The BC Ministry of Forests and Range (Forestry section) and the Alberta Forestry Service operate weather stations adjacent to the Parks. Agreements exist to exchange data at the local level. Nearly all of the weather stations used by the BC and Alberta BC Forest Services are manufactured by Forest Technology Systems (FTS). The stations were chosen because of their ease of programming and their portability.

Overall, the density of weather stations was felt to be adequate but a desire existed for better coverage at fringes of the Parks where a fire might spread onto Provincial lands. The Beaver Creek watershed in Glacier National Park is subject to lightning strikes and might also merit better coverage. Staff members outside the Units expressed some dissatisfaction with the communications system. The radios occasionally fail and prevent access to the data. When the failure occurs at a repeater station the data from more than one station is unavailable. The protocol for radio communication varies from Unit to Unit so that a variety of download procedures are required. Incompatibility with some versions of MS Windows was cited as another problem. A standardized system is preferred.

Only one weather station has existed in Mt Revelstoke National Park and its future seems to be in doubt. It was located in the Compound near Mile 1 and has been dismantled for the season. The Compound may close over winter so that the station cannot be returned to its usual location next year.

Avalanche Control

Each of the Units within the seven Parks conducts an avalanche program. The monitoring program in the Glacier Unit is more intense than in the other Units because of the importance of keeping the Trans Canada Highway clear.

All Units provide daily Avalanche Bulletins that advise hikers and others of the risk of avalanches over the forthcoming two days. The Bulletins are forwarded to the Canadian Avalanche Association in Revelstoke where they are posted on a web site for public view. The Bulletin from Glacier National Park is posted in the morning whereas the Bulletins from all other Units are posted in the afternoon. The Bulletins are also available on the web sites of the respective Parks

The Bulletins contain snow profile, forecast and observed weather information. In the LLYK Unit snow profiles are scheduled to be taken twice per week and an additional 2 to 3 more may be taken during the week depending on need. The atmospheric parameters of interest are temperature, humidity, wind and precipitation. The snow depth, time of year, and recent history of avalanches are also factors. Avalanche risk is determined partly on theory and partly on the experience of the forecaster.

In the Glacier Unit, nine weather stations will exist during the 2005-2006 snow season. The Illecillewaet and Perly Lake stations, which have been used for glacier monitoring in the past, will be shut down. In 2005 a new station, Mt. Abbott, was installed. An avalanche warning sensor exists at Cougar 6 but the location provides no weather information. The Heather Hill station is adjacent to the Trans Canada Highway and is equipped with conductivity and road temperature sensors to monitor highway conditions as well as to serve as an avalanche control station.

All stations are equipped with Campbell Scientific, Inc data loggers, VHF radios, and modems. The stations are polled at ten minute intervals. This is a high rate of data recovery and is undertaken to overcome a deficiency in the system which does not allow the remote stations to initiate contact with the base station. Some of the remote stations are equipped with avalanche sensors. By polling at ten minute intervals an avalanche is detected within not more than ten minutes of its occurrence.

Data are downloaded and stored on a local server. Records are held in-house and extend back to 1988. Manual checks are undertaken to remove errors. Service manuals exist for all sensors. Wiring diagrams have been prepared to standardize station configurations. Manuals containing programming and processing instructions for all sensors exist.

The Campbell Scientific, Inc. data loggers and radios are not current generation. Campbell Scientific, Inc. indicated that it would continue to repair the data loggers as long as parts are available. At present a good supply of parts exists. The situation is not the same with the radios. They are obsolete and the current generation radios are not fully compatible with the older data loggers. Various options to overcome the incompatibility are being examined.

The stored data have not been used for analysis purposes except for the calculation of a few statistics on snow depth.

Sites at Rogers Pass and Mt. Fidelity have been inspected by the Meteorological Service of Canada and found to meet its standards for climatological stations. Maximum and

minimum temperatures and precipitation are manually recorded each day and forwarded to the Meteorological Service of Canada. Apart from these two locations no data from any of the locations reaches the Meteorological Service of Canada for forecast or archival purposes. Security was cited as the reason for keeping the data in-house though overload of telephone lines, capacity of the server and interference with alarm systems were also identified as concerns. This situation may change as data from all stations will be forwarded to the Canadian Avalanche Centre where they become available to subscribers. The Meteorological Service of Canada is a subscriber.

Most of the stations are at or near the tree line and therefore subject to lightning strikes in summer. All are taken out of service except Mt. Fidelity during the summer season to prevent damage. The equipment at Mt. Fidelity is moved to a lower location and the station re-activated to assist in the fire weather program.

There are no weather stations used for avalanche purposes in Mt. Revelstoke National Park. Only one avalanche station operates in Waterton National Park.

Avalanche conditions develop differently in the Selkirks than they do in the Rockies. Avalanche conditions often set up within hours in the Selkirks whereas the set up period is of the order of a day in the Rockies. Thus hourly weather observations are required in the Selkirks whereas daily observations are adequate in the Rockies.

It was felt that a few more high-level weather stations could be used in the LLYK Unit otherwise the existing network was adequate.

Trend Monitoring and Climate Change

There were few comments on trend monitoring and climate change. Most related to the impacts on wildlife and vegetation addressed above. Other impacts must be speculated upon.

Scott and Suffling (2001) indicated that General Circulation Models point to temperature rises in the 5 to 7 Deg C range over the next 100 years. The models are not so clear on changes in precipitation amounts. However, with rising temperatures snowlines can be expected to rise, runoff can be expected to begin earlier, and the rain/snow balance at most locations will shift in favour of more rain. Glaciers will also be affected. Some may decrease; others may expand. The end result will be significant changes in the hydrological cycle.

The changes will produce secondary impacts. Possible impacts might include changes in soil stability. Species and ecosystems may be forced to migrate uphill forcing those whose climatic ranges are already limited to mountain tops to become extinct. Changes in the water supply to downstream users may result in changes in societal attitudes toward the operation of the Parks.

Climate change studies require meteorological data over a long time period. Existing networks operated by the Parks provide inadequate snow pack information to understand the mechanisms projected to take place in the hydrological cycle. It therefore seems prudent to monitor elements affecting the water balance so that informed decisions can be made as the impacts of climate change are felt.

Visitor Information

There are numerous visitors to the Parks each year. Sightseeing, hiking, camping and skiing are among many of the activities that draw visitors to the Parks. Weather is one of the most sought after pieces of information.

Weather information is provided by a number of means. These include Parks Canada operated web-sites, personal and telephone contact at Visitor Information Centres, and recorded telephone messages. The web sites provide direct links to a Meteorological Service of Canada website where weather forecasts and some current weather information exists. The Meteorological Service of Canada information is distributed to Visitor Information Centres where it is used by local staff to respond to visitor queries. It is also posted at some Centres for public view.

There are other sources of weather information. Weather information is contained in avalanche bulletins. Businesses, primarily ski resorts, operate their own weather stations and web cams. Their information is distributed to the media and posted on their own websites.

Attendants in Information Centres that were visited indicated that a lot of requests are received for current weather conditions. Many are for conditions at tourist sites but there are also many for up to date weather information on the highways especially when weather conditions are changing. Most callers seek sky and visibility information. The attendants indicated that they occasionally call other centres for current information.

Evaluation of the Parks Canada Network

In addition to the interviews with Parks staff, the Consultant undertook a number of steps to evaluate the performance of the existing Parks Canada network. Web sites for all of the Parks were examined. Trips were made by road through five of the Parks (Banff, Kootenay, Yoho, Glacier and Mt Revelstoke). The following weather stations were inspected: Kootenay West Entrance Administration Building, McLeod Meadows, Vermilion Crossing, Banff, Lake Louise, Wapta Lake, Boulder Creek, Yoho E-MAN, Golden Airport, and Rogers Pass. Available documentation on the network was also examined.

Overall, the hardware including the sensors, data loggers, towers and power supply are of good quality. Stations installed for a specific operation such as avalanche control and fire weather applications are for the most part well placed.

However, there are a number of shortcomings. Lack of maintenance exists in some of the Units. Cleaning and calibration of sensors is not regularly scheduled and some of the sites need maintenance. Both contribute to measurement errors. Calibration records for sensors are not always complete nor are records of sensor changes.

Station description sheets are not complete and are not regularly updated. Differences in co-ordinates and elevation exist for the same station in records held by the Units and by the Meteorological Service of Canada. This makes it difficult to determine whether one or more stations operate at the same location. Some stations operate under different names. For example, the hourly reporting station operated at Banff is called Banff by the Meteorological Service of Canada and Banff Indian Grounds by Parks Canada. Partnership agreements exist which are not documented. For example, there appears to be three partners in the station at Lake Louise.

The location of data from some stations seems to be in doubt. It is also not clear what steps were taken to prevent erroneous data from entering the databases.

All of the foregoing create major problems for analysts. Considerable effort will be expended locating data and removing errors.

Some of the stations are not well sited. For example, the temperature sensors at Kootenay West Gate Administration and Boulder Creek are located on walls or rooftops. Radiation from the walls or rooftops in such close proximity can easily result in an error of one degree in temperature, an error that would render the equipment unsuitable for trend monitoring purposes. At other locations the wind sensors are located below the tops of nearby trees and are subject to turbulent eddies.

There are a number of weather stations operated by other agencies within the Parks or near Park boundaries that measure parameters useful for Park applications. Some are very close to stations operated by Parks Canada creating the opportunity to share costs. For example, there are two stations at Bow Summit, two at Akamina and up to four stations on Mt. Fidelity. An example of cost sharing exists at Bow Summit where two stations exist and share the same precipitation gauge.

The real time weather information distributed to Park visitors is not always complete nor is it the most representative. The individual Park web sites provide weather information through a link to Environment Canada. For all of the Parks, except Glacier and Mt. Revelstoke, the link displays a forecast and current weather information. A link is not provided for Glacier and Mt. Revelstoke and therefore no weather information is available other than that contained in the seasonal Avalanche Bulletins. The current weather information presented on the links for the other Parks is not always the most representative nor does it provide the information desired. For example, the Wapta Lake station in Yoho National Park provides the current weather information for Kootenay National Park. No information is provided on cloud cover, visibility and precipitation which play a fairly important role in planning the daily activities of many visitors. The information provided at some Visitor Centres is not necessarily representative. For

example, weather information posted at the Radium Hot Springs Visitor Centre was found to display current information from the Cranbrook Airport.

Role of National Weather Services

The atmosphere over a given land area is not a closed system. Air is continually entering the upstream side and departing through the downstream side. The borders are porous. The air is a resource and must be managed collectively.

Using the Mountain Parks as an illustration, managers need to be concerned about the quality of air entering from upstream. Those downstream have not only to be concerned about the quality of the air leaving the Parks but also the quantity and quality of water in streams and rivers resulting from condensation of the water vapour lost in transit over the Parks. Thus a need exists to cooperate with jurisdictions both upstream and downstream. The need for cooperation extends beyond provincial borders. Rivers flowing from some of the Parks reach the United States. Conversely, pollutants emitted in southeast Asia reach western Canada.

Nearly all countries have a weather service charged with a variety of activities related to the management of the atmosphere including the responsibility for monitoring and forecasting weather conditions. Most belong to the World Meteorological Organization (WMO). The WMO is a UN body. It sets standards and procedures for atmospheric monitoring. It also provides a forum for addressing atmospheric issues.

Canada's national weather service is the Meteorological Service of Canada. It does not have complete responsibility for all atmospheric issues. For example, stream flow prediction and air pollution control are provincial responsibilities. However, it does have responsibility for weather prediction. It develops and runs global atmospheric models for this purpose. The models require weather observations as input. The Meteorological Service of Canada operates its own network of weather stations but must rely on other jurisdictions to supplement that network.

The model output is distributed to regional centres and to private companies where it is interpreted and tailored to meet specific applications. Regional Centres in Edmonton and Vancouver prepare forecasts for Alberta and BC, respectively.

Climatological data captured from local weather stations is fed back into the forecast system to improve performance. This happens in two ways. Firstly, the information allows the models to provide greater local detail. As an example, the information will indicate to the model that under certain circulation patterns the eastern slopes of the Rockies will be overcast and wet while interior valleys are cloud free. Secondly, forecasts are continually being verified. The more information that is fed back, the greater the opportunity to identify areas of poor performance. The atmospheric models are gradually increasing in accuracy. Their ability to identify local variations requires local input to keep pace.

Weather forecasts are important to the Parks and to agencies operating within the Parks. Precipitation forecasts, particularly those of snow, are used extensively by those clearing highways, preparing avalanche warnings and controlling avalanches, operating ski resorts, and clearing railroad tracks. Less apparent but equally important are aviation weather forecasts. Helicopter pilots flying on Parks contracts rely on them for flight planning. Low ceilings, poor visibility and extreme turbulence are critical factors to flight.

In summary, weather forecasting is a cooperative effort extending from the local to international level. The Parks must contribute to the effort to receive benefit in return.

Other Networks in and Near the Parks

Weather stations are operated by several agencies in and near the Parks. The locations of the stations operated by the various agencies are shown in Figures A1a, A1b and A1c of Appendix A. The equipment and operating details are shown in Table A1. Only stations lying within about 10 km of Park Boundaries are shown.

A few other stations exist that are operated by private companies and individuals. In most instances they record only maximum and minimum temperature and precipitation. They are not included.

Meteorological Service of Canada (MSC)

The Meteorological Service of Canada operates three stations within the Parks. These are Banff (Banff Indian Grounds), Jasper (Jasper Warden) and Waterton Park Gate (Crooked Creek). A fourth, Yoho (Wapta Lake), is jointly operated with Parks Canada. All are hourly reporting stations. The hourly data are fed into the national data collection system and are used for forecast purposes.

Data from a number of stations operated by other agencies also reach the Meteorological Service of Canada but they do not enter the forecast stream. These data are checked for quality and placed in the Meteorological Service of Canada archive where they become available for public use. The stations in and near the Parks having data that enter the archive are those displaying a Meteorological Service of Canada identification number in Table 1. Only data from 12 of the 33 stations solely operated by Parks Canada enter the MSC archive. Of the twelve most are located in the Parks in Alberta.

Not all precipitation data exist in the MSC archive. Data from snow pillows and snow courses are held by the Provinces owing to their mandate for the management of water resources.

Water Survey of Canada (WSC)

Water Survey of Canada operates a network of hydrometric stations across Canada. The primary purpose of these stations is to measure flow in rivers and water level in lakes.

Four stations exist in the Mountain Parks. The locations are the Athabasca River near Jasper, the Miette River near Jasper, the Bow River at Banff and the Kootenay River at Kootenay Crossing. A fifth exists close to the boundary of Glacier National Park on the Illecillewaet River at Greeley. Most of these stations are equipped with a data logger and either a telephone modem or GOES transmitter.

The data loggers have the capacity to monitor additional sensors such as those used to measure temperature, wind speed and direction, and humidity. For example, the Illecillewait and Bow River stations also measure air temperature. None of the other stations are equipped with sensors to measure atmospheric elements.

Stream flow stations are operated on a partnership basis. The Federal Government has the greatest interest in monitoring stream flow but other agencies also have an interest. The WSC acts as the lead agency and negotiates costs with partners. The Alberta Department of Environment, BC Ministry of Environment and BC Hydro are listed on its web site as partners. Parks Canada is not identified as a partner. Data from the stations can be found at http://scitech.pyr.ec.gc.ca/waterweb/selectProvince.asp.

BC Ministry of Environment

Two sections of the BC Ministry of Environment have responsibilities for the collection and management of weather data. One is the River Forecast Centre (RFC). It collects and interprets snow, meteorological and stream flow data to provide warnings and forecasts of stream and lake runoff conditions around the province. Most of the meteorological and stream flow data are collected by other agencies, but the RFC is the lead agency in the province for the collection, quality control, analysis and archival of snow data. It does not operate any stations directly in the Mountain Parks but it does receive data from stations operated by BC Hydro. It publishes the Snow Survey Bulletin (http://wlapwww.gov.bc.ca/rfc/river_forecast/bulletin_summer.htm). It also maintains an archive of snow pillow and snow course data.

The second section is the Air Protection Division. In conjunction with local air sheds it operates air quality monitoring stations. None of these stations are located in the Parks but stations do exist in the communities of Golden and Revelstoke.

BC Hydro

BC Hydro operates four stations within or very near the Parks. They are located at Floe Lake in Kootenay National Park, on Mt. Revelstoke near the boundary of Mt. Revelstoke National Park, and on Mt. Fidelity and Rogers Pass in Glacier National Park. Information from the stations is used to control the operation of reservoirs and estimate power generation.

All stations measure temperature and precipitation on an hourly basis. The stations at Floe Lake and on Mt. Revelstoke are equipped with snow pillows that are also monitored

on an hourly basis. Snow course surveys are conducted adjacent to the two snow pillows. They are conducted manually at the beginning of each of the winter months.

BC Hydro stations are equipped with GOES transmitters. The data are downloaded and posted at (http://www.bchydro.com/info/res_hydromet/res_hydromet9820.html) where they are held for 72 hours. After 72 hours the data are removed from the web site and submitted to an archive. Some manual and automated checking for errors is conducted prior to entry. The stored data are available on request. An agreement with the Meteorological Service of Canada does not exist and the data do not enter the Meteorological Service of Canada archive.

The precipitation gauges are a custom made standpipe/pressure transducer type.

BC Forestry

The Ministry of Forests Protection Program operates 214 hourly reporting weather stations throughout BC. None are located within the Mountain Parks but a number are fairly close to Park boundaries. The weather observations are used to support fire weather forecasting and to update Fire Weather Indices. The indices are forwarded for entry into to the Canadian Wildland Fire Information System.

FTS stations are used exclusively though not all are current generation. The Ministry is in the fourth year of a seven year replacement program. Data are recovered in real time by a variety of means. Most stations telemeter data via UHF radio but 67 stations are on meteorburst, 40 on landlines, 4 use Globalstar and one transmits via cell.

The data are transmitted to Protection headquarters, every hour from April through October and less frequently during the winter months. Data from the stations are synthesized and maps of temperature, humidity, precipitation and wind speed are produced daily and displayed on a web site. Parks Canada has access to data from individual stations through an interagency cooperative agreement. Past data are stored in Ministry facilities. The data base contains data as far back as 1970. All data from the stations are submitted to the archive by electronic means. Checks for errors are basic and consist of range checks and manual flagging of suspicious data. The data are made available to the Meteorological Service of Canada but are not archived by the Meteorological Service of Canada. Historical data would be made available on request.

Maintenance and some calibration are done in house. The balance of the calibration is performed by the Manufacturer. The field units are modular and repairs are often made in the field by swapping out parts. No field maintenance is performed over the winter, so sites that fail usually remain inoperative until the pre-season service has been completed.

Sites are selected to conform as nearly as possible to WMO siting criteria but difficulty is experienced in finding sites that meet the criteria for wind.

BC Ministry of Transportation

A Road Weather Information System is in operation on BC's Highways. This system collects road surface information and measures temperature, relative humidity, precipitation and wind speed and direction on towers adjacent to the highways. The information is used to support highway clearing operations. The System is part of a broader Road Weather Information Systems initiative. The initiative is a joint provincial, territorial, Transport Canada and Environment Canada program. As a condition of funding, provinces and territories are required to enter into a data-sharing agreement with Environment Canada.

ICBC in cooperation with Environment Canada and the BC Ministry of Transportation posts the data at http://www.weatheroffice.pyr.ec.gc.ca/icbctravelalert/dtables_e.html. No roadside stations exist in the Mountain Parks but there are stations near Park boundaries. Stations are located north of Invermere on Highway 95, east of Golden on Highway 1 at Top of Ten Mile, and east of Revelstoke on Highway 1 near Albert Canyon. A fourth station was observed on Highway 1 just east of the Glacier National Park boundary. It does not appear on the web site and its status is unknown.

Alberta Environment (AMOE)

Weather monitoring is conducted by the Water Management Division of the Alberta Ministry of Environment for various uses including the preparation of river and water advisories and warnings, water data, and water supply reports.

Several stations exist on the foothills and in the mountains including locations within Banff, Jasper, and Waterton National Parks. There are also two stations in the US Glacier National Park. The elements most commonly measured are temperature, total precipitation, and stream flow but some stations are equipped to measure humidity and wind speed and direction. Fischer-Porter precipitation gauges are most commonly to measure total precipitation but a few Pluvio gauges are also used. All are fitted with shields.

Snow pillows exist at a number of sites and snow courses are operated at a few others. Nearly all of the stations are equipped with GOES transmitters but a few transmit data via telephone landline. The majority of the stations equipped with GOES transmitters transmit data at one hour intervals. Precipitation is usually measured at fifteen minute intervals but held on site until the next available transmission. All telemetered data are posted on a web site and displayed for 72 hours. After 72 hours the oldest data are dropped off. The location of the stations and a record of recent and current data are available at: http://www3.gov.ab.ca/env/water/basins/basinform.cfm.
Data older than 72 hours enter a data base operated by Alberta Environment. The data are not subjected to rigorous quality control. They are available to outside users on request.

Alberta Environment has a number of technical staff responsible for selecting sites, taking field readings, and making repairs in the field. They also maintain and update

station description sheets and keep an inventory of equipment. Maintenance is conducted in-house but sensors are sent out to manufacturers or calibration shops for major repairs and calibration.

Not all stations conform to WMO siting standards. For example, stations located in heavy snowfall areas are mounted on platforms to prevent temperature sensors from becoming snow covered.

About 140 air quality stations are operated in Alberta. None collect weather information in the Parks or near Park boundaries but some passive monitors are located within the Parks.

Alberta Sustainable Resource Development (ASRD)

The Forest Protection Division of ASRD collects weather observations to support its fire suppression operations. It also operates a network of Storage precipitation gauges to measure seasonal precipitation.

The weather observation network extends over the forested areas of the Province including areas adjoining Banff, Jasper and Waterton National Parks. Most of the weather observations are taken at Lookout Towers. The Towers are staffed during the summer months. The observations are made twice daily, at 6AM and 1PM, by the Tower operator. They are transmitted by radio to the Forecast Centre where weather forecasts are prepared to support fire suppression operations. The weather is also observed at about 48 other locations using FTS automatic weather stations. Slightly over half of these stations transmit data via cell phone and the remainder via the Globalstar communications system. Observations are made hourly but downloaded three times per day except in fire situations to reduce communications costs.

Elements measured are temperature, dew point, precipitation, and wind speed and direction. The stations operate from April to November though a few operate year round. Data from the stations are posted at http://www3.gov.ab.ca/srd/wildfires/fpd/w_wfo.cfm. The data are forwarded to the Meteorological Service of Canada where they are entered into the national archive and are available online.

A network of Sacramento Storage gauges was installed by the Eastern Rockies Forest Conservation Board between about 1950 and 1970. This Organization was phased out about 1974 and the responsibility for operating the Storage Gauge network was transferred to the Forest Protection Division. The gauges in the network are simple standpipes which are visited and the contents measured twice per year; once in the spring and once in the fall. They are then emptied and recharged. Thus only measure seasonal precipitation is measured. They are not equipped with shields. Some of the gauges are located within Banff and Jasper National Parks.

The gauges are becoming obsolete as more and more real time reporting precipitation gauges are installed. However, they provide useful information on moisture reserves. The data are held by the Forest Protection Division and can be obtained without charge.

US Department of Agriculture

Two real time reporting stations exist in the US Glacier National Park within a few kilometres of Waterton National Park. Both are part of the SNOTEL (SNOwpack TELemetry) network. The data are used for forecasting and management of water supplies. The stations are Flattop Mountain and Many Glacier. The Natural Resources Conservation Service (NRCS) of the US Department of Agriculture installs, operates, and maintains the network.

SNOTEL uses meteor burst communications technology to collect from the stations. The stations are battery powered with solar cell recharge.

Data are posted at http://www.wcc.nrcs.usda.gov/snotel/Montana/montana.html. They are also available on the Alberta Environment web site.

Other

Nav Canada

NAV CANADA is a private corporation that owns and operates Canada's civil air navigation service (ANS). It provides air traffic control, flight information, weather briefings, and other services to the aviation community. Hourly reporting weather stations are operated on the Golden and Revelstoke Airports. These are the only weather stations providing cloud cover and visibility information between Springbank, Alberta and the Okanagan Valley. A weather station is also operated at the Cranbrook Airport to aid flights over southern BC.

Research Organizations

Research projects are conducted in the Parks. Weather stations are set up to obtain weather information for some of these projects. One of the longest standing projects is a program operated on Peyto Glacier under Canada's Glacier-Climate Observing System. Weather stations have been operated for various periods. The data are logged on site and the data recovered at periodic intervals. Historical data are held by various researchers. The records are often incomplete owing to failure of the loggers under the harsh environmental conditions. The stations are one of the few sources of solar and terrestrial radiation measurements in the Parks.

Radiation measurements are also made in conjunction with avalanche research being conducted in Glacier National Park

Among other known projects is a seven weather station network in Waterton National Park. The stations form a transect with the objective of measuring local climate variations.

Weather data have also been collected in a Project near Sunwapta aimed at studying permafrost.

Alberta Transportation

A Road Weather Information System is being installed on Alberta Highways under the same program used in BC. The installation has been slower to get under way. A contract was issued in the summer of 2005 to Telvent, a European company. About 75 weather stations will be installed and some of these will likely be near Park boundaries. Some of the hardware is in place but the system is not yet operating. It is not known how the data will be made available.

Communication Systems

Radio is the method most commonly used to telemeter data from the weather stations located in the Parks. It serves the purpose fairly well but occasional failures were noted. These resulted in the inability to recover data in real time. Also the present configuration of data recovery was found unwieldy.

Other communications system exist which can be used to telemeter data. They are provided here with brief comments. The comments do not provide a complete assessment and further investigation is recommended before committing to any of the systems.

Land line Telephone

Data is already being used to acquire data from some of the stations. It provides an inexpensive means of obtaining data. Unfortunately, few of the locations are served by telephone.

Cell Phone

Cell phone also provides an inexpensive means of recovering data. Again cell coverage is poor or non-existent in large parts of the Parks. Expansion of cell coverage is expected but it is not certain that it will extend to remote sections of the Parks.

Satellite Phone

Satellite phone service provides complete coverage. The disadvantage is higher cost.

Geostationary Operational Environmental Satellite (GOES)

The GOES Data Collection System (DCS) is a relay system used to collect information from earth-based data collection platforms (DCPs). Weather stations can be and often are

integrated into the DCPs. The platforms transmit an electronic signal, containing the observed sensor data, at predefined wavelengths and times. A transponder on board the satellite detects this signal, and then rebroadcasts it so that it can be picked up by the ground equipment at the Wallops Command and Data Acquisition (CDA) station in Wallops Island, Virginia. Data can be retrieved from the CDA by normal communications.

The GOES system is used extensively by BC Hydro, the WSC and the Meteorological Service of Canada.

Meteorburst

A meteor burst communications system uses ionized meteor trails as a means of radio signal propagation. Satellites are not involved. These trails exist in the 80 to 120 km region of the earth's atmosphere. They allow radio signals to be reflected between a remote station and a master station. The height of the trails allows over-the-horizon communication at distances up to 2000 km. The ionized trails exist for only from a few milliseconds to a few seconds so that communication is intermittent. Nevertheless, a sufficient number of trails exist so that on average more than 95 percent of transmissions are completed within five minutes of scheduled delivery times.

This type of system is used for the SNOTEL network in the northwest US and has been used by BC Hydro on international applications. The Mountain Parks lie within range of a master station of a commercial meteorburst system operating in Washington State. That system provides archival as well as data delivery services.

Assessment

The total area of all seven Parks is 22,352 square kilometers. Parks Canada operates 35 stations alone or in partnership with other agencies in these Parks giving a density of one weather station per 638 square kilometers. When the 36 stations operated by other agencies in the Parks are included the density drops to one station per 315 square kilometers. This is slightly greater than that required to match the resolution of forecast models but is acceptable. The sensors on the stations are of high quality. The data loggers are not current generation but perform satisfactorily. The manuals and documentation held in the Glacier Mt. Revelstoke Unit are exemplary.

Deficiencies do exist in the overall meteorological program. Many of the stations in the network are not well maintained. The sites are in need of upkeep. Records of ownership, calibration and maintenance are in doubt. The whereabouts and quality of historical data from some locations are also in doubt. The major cause of the deficiency is the lack of technical staff dedicated to equipment maintenance and data management on a long term basis.

The direction to be taken on upgrading the program requires that some philosophical questions be addressed. Foremost is the need for a decision on the extent of cooperation

to exist with other agencies engaged in meteorological activities in and near the Parks. If the decision is taken to operate independently then Parks Canada must be prepared to install, operate and maintain its own network. It will also need to collect data, remove errors from those data, create and maintain an archive, and provide its own forecast services.

Much is to be gained by working cooperatively with the other agencies. Indeed all agencies engaged in weather monitoring in the Parks would benefit from some form cooperative working arrangement. Parks Canada would benefit from the site inspection, data checking and archival, and forecast services of the MSC. It would also benefit from similar services provided by the Alberta and BC governments with respect to precipitation data, particularly snowfall measurements. All parties would benefit from agreements to consolidate the number of stations operating in close proximity to one another.

Key to a cooperative effort is the relationship with the Meteorological Service of Canada. The delivery of forecast and observed weather in the Parks can be improved. The improvements depend on the provision of data from weather stations. At present the only hourly reporting weather stations entering the forecast system are Waterton, Banff, Jasper and Yoho. Parks Canada operates others but the data do not reach the MSC either because they do not meet MSC standards, because of incompatibility of the communications systems or for security reasons. There are also issues within the MSC that need to be addressed. The inspection and archival services appear to differ between the Prairie and Pacific Regions. For example, there is a greater proportion of stations from Alberta entering the archive than from BC. There is also a question of the degree to which the MSC is capable of providing services. There is a growing number of networks in Canada. There is also a growing realization that duplication of effort exists. As an example, the Alberta MOE has already commissioned a project to identify overlap in networks operating in the Province.

The standards for exposure of sensors at weather stations in mountain locations need some relaxation. WMO standards specify that temperature be measured on metre above the surface. At many sites the snow depth exceeds one metre and the sensors become submerged. Use of an adjustable mounting platform is not practical because of the power requirements. An alternate standard is required and should be negotiated between all parties sharing data in mountain locations.

It is not feasible to install a network that will capture small-scale events such as thunderstorms and local winds. A more practical approach is to establish a core network of high quality stations to capture events on a broader scale and over a long period of time. The data from these stations would serve as baseline data. The needs for detailed local climate information could be served by installing additional stations on a short term basis. The detail could then be derived by developing relationships between the short term stations and the core stations.

Additional information will be required to address the requirements outlined in each of the special needs areas.

Snow depth information required for investigations relating to declining caribou populations and the migratory behaviour of large mammals is available from two sources. One is from snow courses. Snow course measurements are usually made at the beginning of the month, from late fall until late spring. Five to ten snow cores are taken each course location depending on the Operator. The depth of snow in each core is recorded. The second is by use of an acoustic or sonic gauge. These are operated at weather stations and make use of a downward looking beam to keep track of the advancing height of the snow pack. The sonic gauge provides a near continuous record whereas measurements from snow courses are only available at monthly intervals. On the other hand the sonic gauge only measures snow depth at one point whereas multiple points are measured at snow courses. If the site for the sonic gauge is not well chosen the snow can easily be redistributed by wind.

The study aimed at investigating the migratory behaviour of mammals indicated that a snow melt model was being used to estimate snow depth. Most snow melt models require measurements of solar radiation as an input. Often such measurements are unavailable and a combination of temperature and cloud cover is used as a substitute. There are hardly any measurements of cloud cover in the Parks so that it is not possible to insert a substitute. Solar radiation sensors exist and direct measurements can be made. They are relatively inexpensive and easily interfaced with existing data loggers. The information could also be used for future studies on plant growth even though a need for such studies was not identified. Vegetative growth is driven by the availability of solar radiation.

Operational needs, such as those required for forest fire management and avalanche control can be met with special stations which fall outside the core network. Those required for forest fire management do not necessarily need to meet the standards of the core network. Although the stations do not have to meet the standards it should be noted that siting remains important. The calculations used in the FWI assume an open wind measurement.

The measurements required for avalanche control also do not have to be precise. In practice, however, the conditions to which the sensors, cabling, and electronic equipment will be exposed are such that only durable equipment will perform. Durable sensors tend to be accurate. Although the Avalanche Bulletins are presently prepared by subjective means, it is expected in time that models will play a greater role in their preparation. The models, like snow models, will require radiation information.

The information provided to Park visitors also does not have to be precise but it should be current and would benefit from measurements of cloud cover and visibility. Web cams are a suitable means of providing this information. Web cams exist that will interface with the data loggers currently in use. Information collected for tourism would have little historical value and would not have to be saved.

Trend monitoring, particularly those aspects aimed at addressing climate change, will impose the greatest demands on the network. Temperature and precipitation are the elements of greatest importance. Temperature sensors must be accurate and they must be well maintained to identify changes of this magnitude. Shields are a big part of temperature measurement. If they are not properly cleaned they alone can introduce errors approaching one degree in magnitude. Precipitation sensors must not only be able to accurately measure precipitation amounts but they must be able to discriminate between snow and rain to identify changes in runoff patterns. This is not a simple task. Conventional precipitation gauges simply measure total precipitation. They need to be augmented with other sensors to identify snow accumulation and ablation. Snow pillows are best suited for this purpose. Stream flow measurements will also provide information on the timing of the spring melt.

Recommendations

It is recommended that Parks Canada:

- *Hire or contract one or more technical specialists to install and maintain weather stations and manage data.*

An instrument/electronic specialist is required to overcome deficiencies in maintenance and to provide continuity to the observing program. A data management technician is required to collect data, remove errors and manage a data base.

- *Promote the development of a forum involving all organizations operating weather stations in and adjoining the Parks for the purpose of promoting standards on the installation and operation of stations, monitoring procedures, data exchange, and data storage.*
-

Data exchange is in the interest of all parties. Parks Canada does not operate snow courses and snow pillows. It stands to benefit from these data. Operating costs could be reduced by consolidating the operation of adjacent stations.

- *Meet separately with the Meteorological Service of Canada (both Alberta and BC Regions) to improve the quality and quantity of forecast and observed weather information displayed on web sites and at visitor centres.*

More and better information can be supplied to visitors than is currently available. Forecasts are required for Glacier and Mt. Revelstoke National Parks. Current weather observations should be provided for Kootenay, Glacier and Mt. Revelstoke National Parks.

- *Meet with the a representative of Canada's Glacier-Climate Observing System to offer technical services for maintaining weather stations at its Peyto Glacier location in return for records of weather data.*

Instruments operated by the Glacier-Climate Observing System include solar and net radiation sensors. Information provided by these sensors is important for climate change studies related to melt rates, runoff and changes in snow pack characteristics. It also has indirect benefits for plant and animal studies.

- *Conduct a cost-benefit analysis on communications systems available to telemeter data.*

Alternate methods of communications may provide a more reliable and efficient means of delivering data from remote weather stations.

- *Evaluate the policy on the distribution of data from Parks Canada weather stations.*

Only a portion of the weather data observed at Parks Canada weather stations is reaching the forecast stream. Weather forecasts would be improved if all data were made available.

- *Create a core network of high quality, long term weather stations. The network should be made up of 25 existing stations operated by Parks Canada, three new stations and 26 stations operated by other agencies. The locations of the stations are shown in Figures 1a, 1b and 1c. Parameters to be recorded at each station are shown in Table 1.*

The stations have been selected to provide a balance of high and low elevation locations. Existing stations have been used to the extent possible since recorded weather information already exists. The new sites provide coverage in areas that are data deficient. Most cooperative stations bring important snow information that Parks Canada does not have but others provide coverage in areas of poor coverage. Solar radiation sensors are additions to a number of Parks Canada stations. Information provided by these sensors is expected to be important for future studies relating to snow melt, plant growth and avalanche control.

- *Establish a high quality database to store data from the core stations. A quality control program will be required to check the data and remove errors prior to entry. Priority should be given to temperature and precipitation data.*

Research studies, climate change studies and preparation of climatological reports require records of error-free, accurate data in a standardized format. Otherwise, the costs of data preparation are passed on to investigators. Temperature and precipitation are the most important for the majority of applications and priority should be given to ensuring their accuracy and availability.

- *Sites for fire management and avalanche control should be selected by staff charged with the responsibility for managing these activities. However, all stations should use a common communication system. It is not necessary for the stations used for fire management hardware to meet the performance standards of*

stations used in the core network but care should be given to siting and maintenance.

- *Adopt the manuals and documents used for programming data loggers and interfacing components in Glacier National Park as a guideline for weather stations in all Units.*

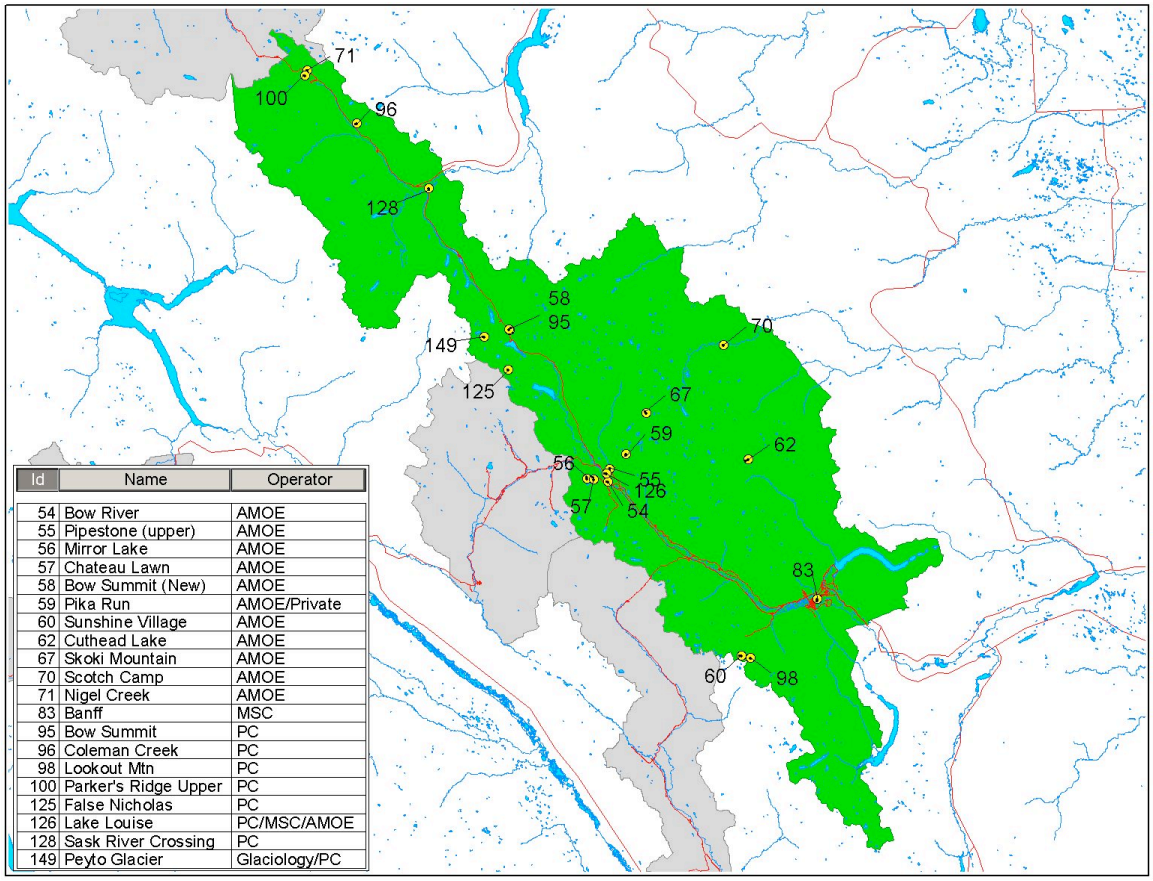
These manuals were drafted in consultation with the MSC and conform to many of the procedures used by the MSC. Their used would help maintain conformity. They would also help reduce errors created by improper programming and interfacing of sensors.

- *Install Web cams in Waterton Village, Lake Louise near the Lake, the Ice fields and Rogers Pass.*

Web cams provide up to date and easily interpreted information on sky condition, visibility and precipitation. The sites are believed to be those where the greatest demand for current weather conditions exist.

- *Install alarm equipped rain gauges in valleys upstream of any campgrounds and populated areas.*

Flooding was not identified as a need but this item is included as a precaution. Thunderstorms can produce severe local flooding and rock slides in mountain valleys leading to loss of life. The proposed network will not capture phenomena on the scale of thunderstorms.



Id	Name	Operator
54	Bow River	AMOE
55	Pipestone (upper)	AMOE
56	Mirror Lake	AMOE
57	Chateau Lawn	AMOE
58	Bow Summit (New)	AMOE
59	Pika Run	AMOE/Private
60	Sunshine Village	AMOE
62	Cuthead Lake	AMOE
67	Skoki Mountain	AMOE
70	Scotch Camp	AMOE
71	Nigel Creek	AMOE
83	Banff	MSC
95	Bow Summit	PC
96	Coleman Creek	PC
98	Lookout Mtn	PC
100	Parker's Ridge Upper	PC
125	False Nicholas	PC
126	Lake Louise	PC/MSC/AMOE
128	Sask River Crossing	PC
149	Peyto Glacier	Glaciology/PC

Figure 1a – Locations of stations proposed for the Core Network in Banff National Park

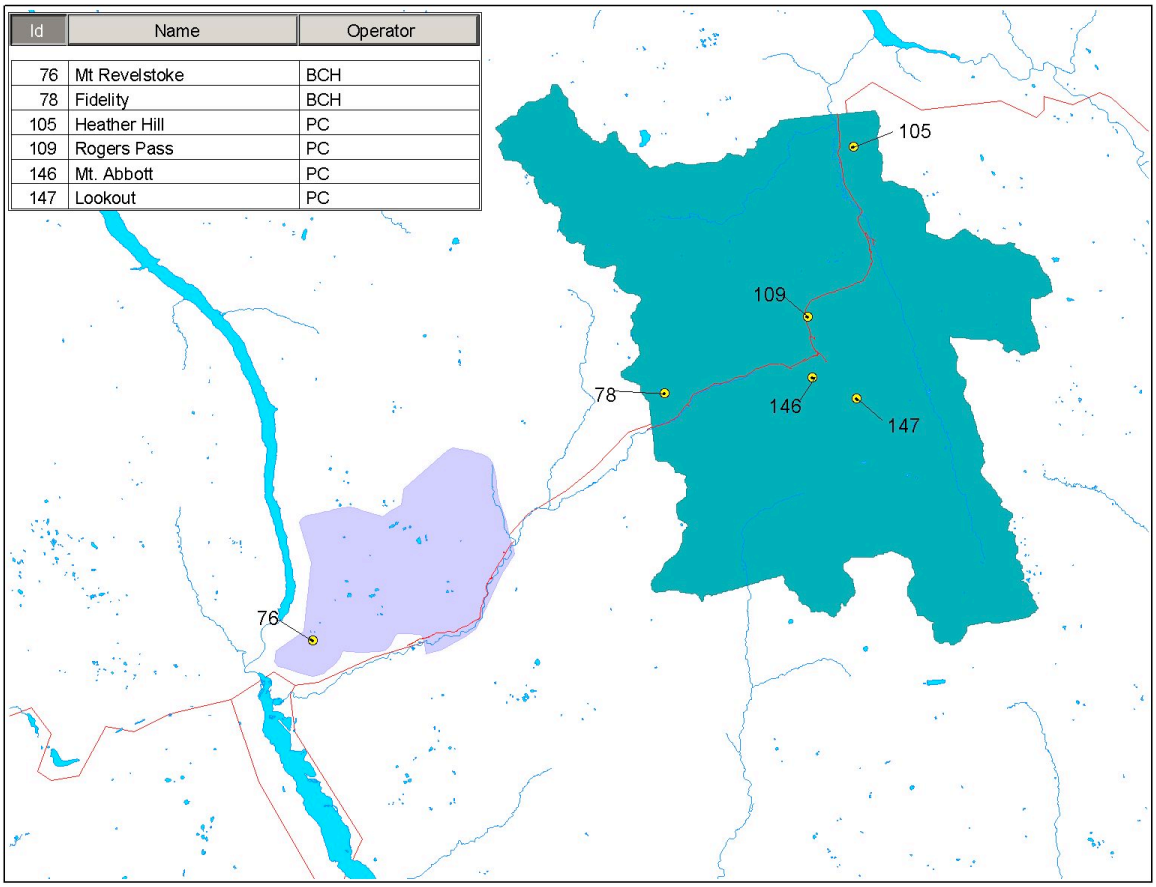
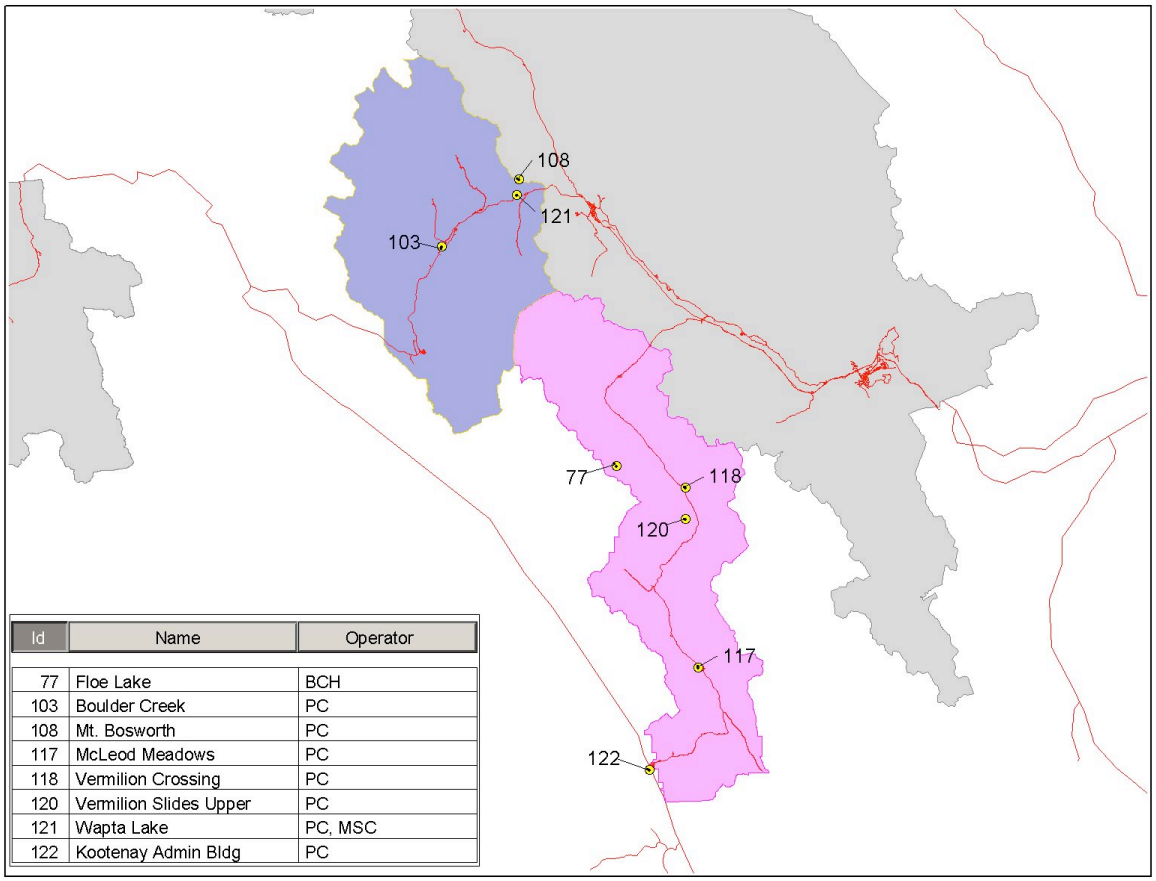
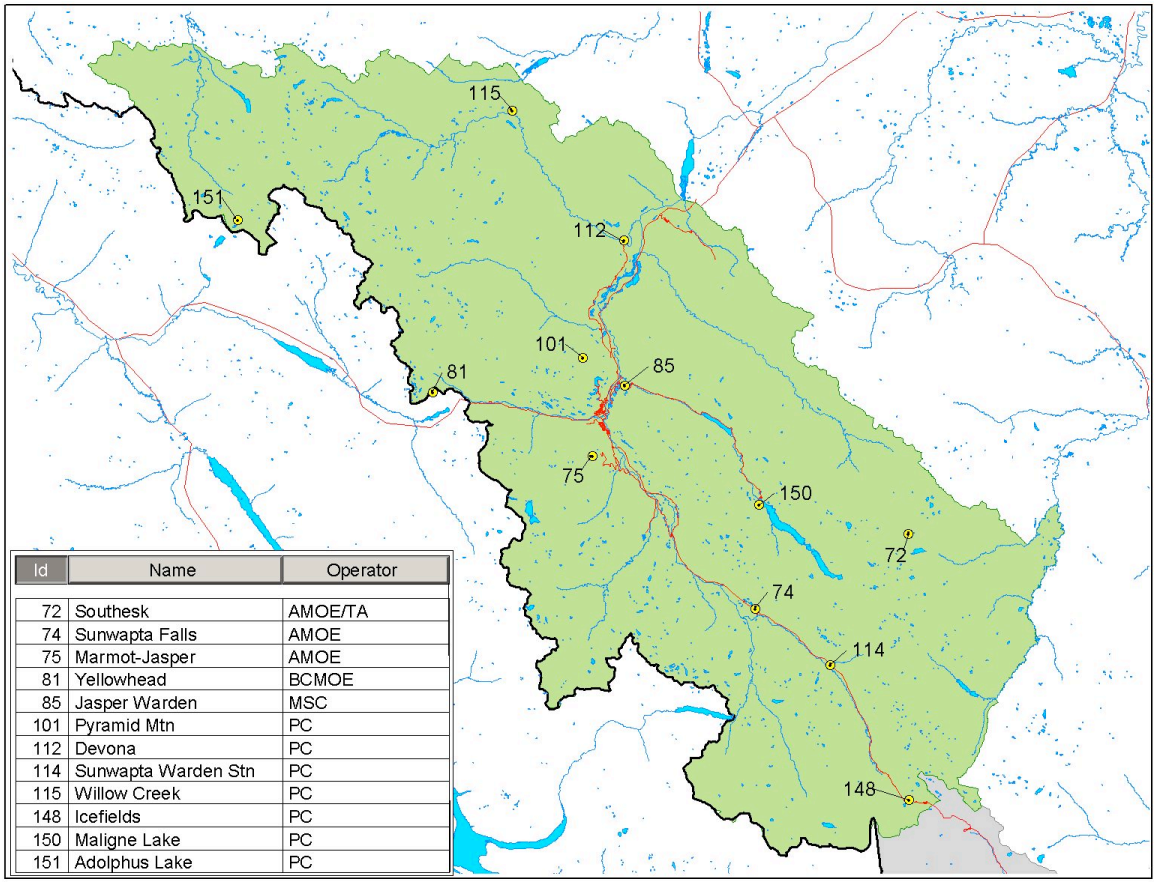


Figure 1b – Locations of stations proposed for the Core Network in Revelstoke/ Glacier National Parks



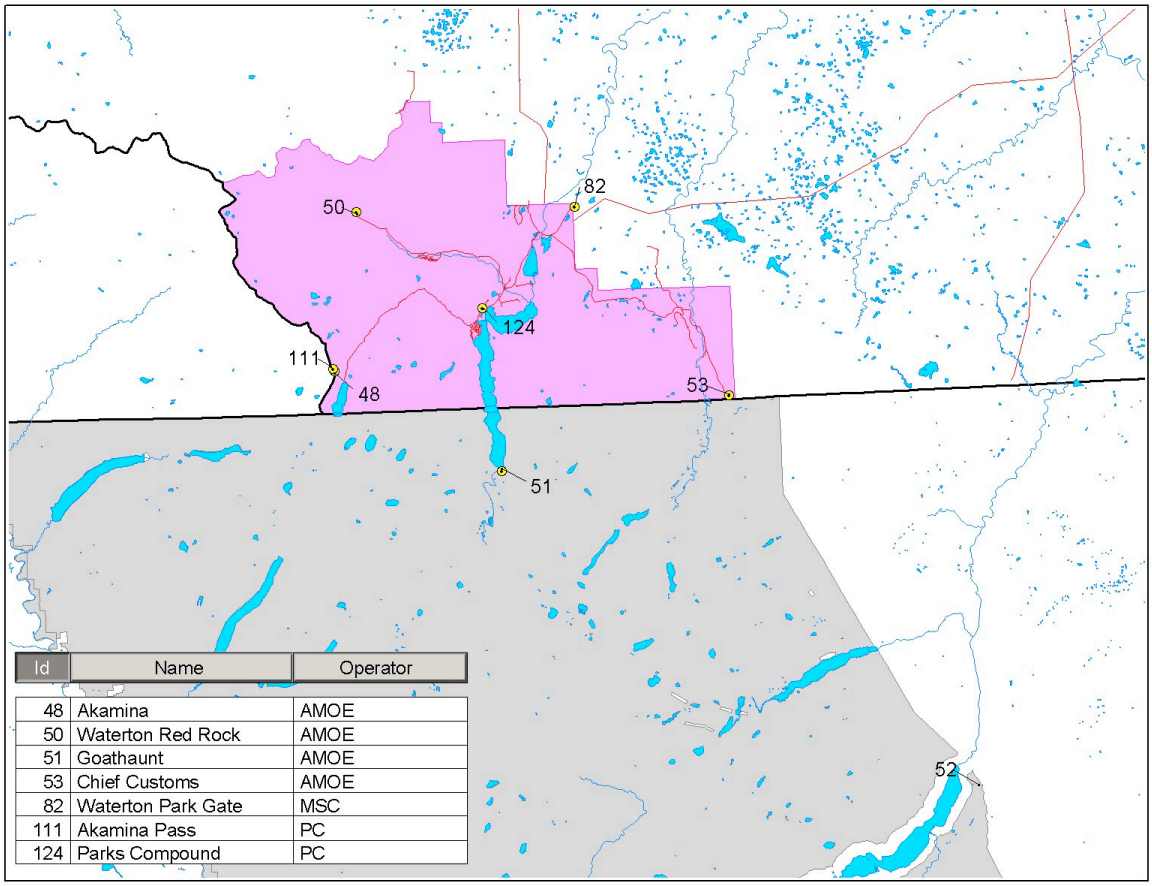
Id	Name	Operator
77	Floe Lake	BCH
103	Boulder Creek	PC
108	Mt. Bosworth	PC
117	McLeod Meadows	PC
118	Vermilion Crossing	PC
120	Vermilion Slides Upper	PC
121	Wapta Lake	PC, MSC
122	Kootenay Admin Bldg	PC

Figure 1c – Locations of stations proposed for the Core Network in Kootenay and Yoho National Parks



Id	Name	Operator
72	Southesk	AMOE/TA
74	Sunwapta Falls	AMOE
75	Marmot-Jasper	AMOE
81	Yellowhead	BCMOE
85	Jasper Warden	MSC
101	Pyramid Mtn	PC
112	Devona	PC
114	Sunwapta Warden Stn	PC
115	Willow Creek	PC
148	Icefields	PC
150	Maligne Lake	PC
151	Adolphus Lake	PC

Figure 1d – Locations of stations proposed for the Core Network in Jasper National Park.



Id	Name	Operator
48	Akamina	AMOE
50	Waterton Red Rock	AMOE
51	Goathaunt	AMOE
53	Chief Customs	AMOE
82	Waterton Park Gate	MSC
111	Akamina Pass	PC
124	Parks Compound	PC

Figure 1e – Locations of stations proposed for the Core Network in Waterton National Park.

Table 1 – List of Proposed Stations for Core Network showing existing sensors and upgrades.

			Latitude			Longitude								Snow			
Name	Operator	Park	Deg	Min	Sec	Deg	Min	Sec	Elev	Temp	Pcpn	Hum	Wind	Course	Pillow	Depth	Radiation
Bow Summit	PC	B	51	42	3	116	28	6	2960	x	x	x	x			sonic	U
Coleman Creek	PC	B	52	5	32	116	55	48	1390	x	x	x	x			sonic	
False Nicholas	PC	B	51	37	32	116	28	22	2640	x	x	x	x				U
Lookout Mtn	PC	B	51	4	29	115	45	11	2220	x	x	x	x				
Parker's Ridge Upper	PC	B	52	10	58	117	5	21	2080	x	x	x	x				
Pyramid Mtn	PC	B	52	57	46	118	8	3	2200	x	x	x	x				
Sask River Crossing	PC	B	51	58	9	116	42	39	2040	x	x	x	x				U
Sunshine Village	PC	B	51	4	43	115	46	38	2720	x	x	x	x			sonic	U
Boulder Creek	PC	G	51	22	20	116	31	11	1990	x	x	x	x				U
Fidelity	PC	G	51	14	9	117	42	10	2040	x	x	x	x				
Heather Hill	PC	G	51	26	19	117	27	33	2225	x	x	x	x			pole	U
Mt. Bosworth	PC	G	51	28	4	116	20	33	950	x	x	x	x				
Rogers Pass	PC	G	51	18	2	117	30	59	1870	x	x	x	x				
Akamina Pass	PC	J	49	1	43	114	3	22	1160	x	x	x	x				
Devona	PC	J	53	9	41	118	1	25	1960		x		x				U
Sunwapta Warden Stn	PC	J	52	27	0	117	26	24	1540	x	x	x	x			sonic	
Willow Creek	PC	J	53	22	39	118	20	36	1580	x	x	x	x				
McLeod Meadows	PC	K	50	46	7	115	57	1	1370	x	x	x	x				U
Vermilion Crossing	PC	K	51	1	30	115	58	26	2400	x	x	x	x			sonic	
Vermilion Slides Upr	PC	K	50	58	48	115	58	30	2040	x	x	x	x				
Wapta Lake	PC, MSC	K	51	26	43	116	20	53	980	x	x	x	x				U
Parks Compound	PC	W	49	3	54	113	54	11	1625		x		x				
Lake Louise	PC/ MSC/ AMOE	Y	51	25	40	116	10	41	1640	x	x	x	x			sonic	

Kootenay Admin	PC	W	50	37	25	116	3	46	1280	x	x		x				U

U denotes upgrade

New Stations

Mt Revelstoke	PC	MR	51	5		118	0			x	FP(S)	x	x			sonic	x
Icefields	PC	J	52	13	21	117	13	21		x	FP(S)	x	x				
Malign e Lk	PC	J	52	43	9	117	38	27		x	FP(S)	x	x				x
Adolphus Lk	PC	J	53	10	52	119	6	29		x	FP(S)	x	x				

Cooperative Stations

Akamina	AMOE	W	49	1	38	114	3	11	1761	x	FP(S)	x	x		x		
Waterton Red Rock	AMOE	W	49	7	55	114	1	35	1524	x	FP(S)	x					
Goathaunt	AMOE	GNP/ US	48	57	24	113	53	25	1280	x	PI(S)	x	x				
Chief Customs	AMOE		49	0	1	113	39	30	1690	x	FP(S)					sonic	
Bow River	AMOE	B	51	25	0	116	11	0	1580					x			
Pipestone (upper)	AMOE	B	51	26	0	116	10	0	1615					x			
Mirror Lake	AMOE	B	51	25	0	116	14	0	2030					x			
Chateau Lawn	AMOE	B	51	25	0	116	13	0	1740					x			
Bow Summit	AMOE	B	51	42	0	116	28	0	2080	x	FP(S)						
Pika Run	AMOE/ Priv	B	51	27	47	116	7	4	2240	x	FP(S)					sonic	
Sunshine Village	AMOE	B	51	5	0	115	47	0	2230	x	PI(S)				x		
Cuthead Lake	AMOE	B	51	27	0	115	45	0	2180	x	FP(S)						
Three Isle Lake	AMOE		50	37	53	115	16	46	2160	x	FP(S)	x	x		x		
Skoki Mountain	AMOE	B	51	32	26	116	3	23	2040	x	FP(S)				x		
Scotch Camp	AMOE	B	51	40	0	115	49	10	1737	x	FP(S)						
Nigel Creek	AMOE	B	52	11	32	117	4	56	1920					x			
Southesk	AMOE/ TA	J	52	40	15	117	13	32	2045	x	FP(S)						
Sunwapta Falls	AMOE	J	52	32	36	117	38	53	1400					x			
Marmot-Jasper	AMOE	J	52	48	24	118	5	22	1830					x			

Waterton Park Gate	MSC	W	49	7		113	48		1296	x	x	x	x				
Banff	MSC	B	51	11		115	33		1397	x	x	x	x				
Jasper Warden	MSC	J	52	55		118	1		1020	x	x	x	x				
Yellowhead	BCMOE		52	54		118	33		860						x		
Mt Revelstoke	BCH	MR	51	2		118	9		1830		x	SRG			x		
Floe Lake	BCH	K	51	3		116	8		2090		x	SRG			x		
Peyto Glacier	Glaciology	B	51	41	16	116	32	39									x

Abbreviations

AFS - Alberta Forestry Service

AMOE - Alberta Ministry of Environment (Water)

BC MOE - BC Ministry of Environment (Water)

BCH - BC Hydro

MSC - Meteorological Service of Canada

MSR - BC Ministry of Forests and Range (Forestry)

PC - Parks Canada

TA - Transalta

FP - Fischer Porter Precipitation Gauge

FP(S) - Fischer Porter Precipitation Gauge with Shield

PI - Pluvio Precipitation Gauge

PI (S) - Pluvio Precipitation Gauge with Shield

TB - Tipping Bucket Rain Gauge

Sonic - Sonic or Acoustic Snow Gauge

SRG - Standard Rain Gauge

SWE - snow water equivalent

B - Banff National Park

G - Glacier National Park

GNP(US) - Glacier National Park (United States)

J - Jasper National Park

K - Kootenay National Park

MR - Mount Revelstoke National Park

W - Waterton Lakes National Park

Y - Yoho National Park

References

Janz, B. and D. Storr, 1977: The Climate of the Contiguous Mountain Parks. Project Report No. 30, Applications and Consultation Division, Meteorological Applications Branch. Prepared for Parks Canada by the Atmospheric Environment Service, Environment Canada

Environment Canada, 2005. Climate Station Catalogue. Environment Canada, Meteorological Service of Canada, on-line data base at http://www.msc-smc.ec.gc.ca/climate/ station_catalogue/index_e.cfm.

D. Scott and R. Suffling (eds). 2000. Climate Change and Canada's National Parks. Environment Canada, Toronto. Cat. No. En56-155 / 2000E.

Bibliography

Alexander, M.E.; Stocks, B.J.; Lawson, B.D , 1996: The Canadian Forest Fire Danger Rating System. Natural Resources Canada (available online at http://fire.cfs.nrcan.gc.ca/research/environment/cffdrs/cffdrs_e.htm)

B. Jones, D. Scott, E. Barrow, N. Wun. 2003. Climate Change Scenarios for Canada's National Parks: A Users Manual. Parks Canada Technical Reports in Ecosystem Science Series. Parks Canada, Ottawa, Canada.

B.S. Lee,1995: The Canadian Wildland Fire Information System. Natural Resources Canada. (available online at http://cwfis.cfs.nrcan.gc.ca/en/index_e.php*)*

Meteorological Service of Canada, 2001: Siting Standards for Meteorological Observing Sites. Meteorological Service of Canada STDS 2 – 2001, Meteorological Service of Canada, Environment Canada

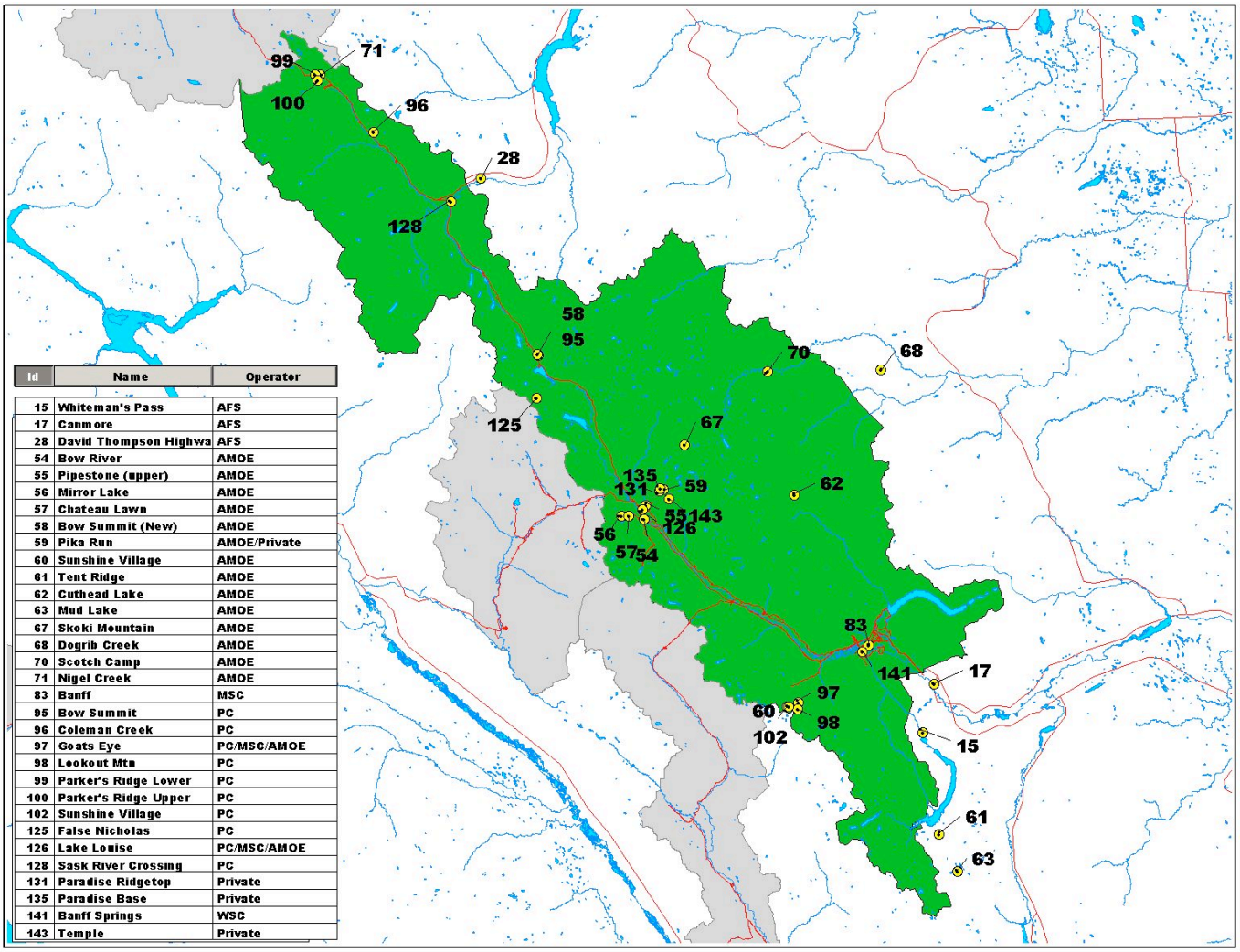
NOAA, 2001: NOAA News Online (Story 688) -The Big Thompson Flood, available online at http://www.noaanews.noaa.gov/stories/s688.htm

D. Scott and C. Lemieux. 2003. Vegetation Response to Climate Change: Implications for Canada's Conservation Lands. Parks Canada Technical Reports in Ecosystem Science Series. Parks Canada, Ottawa, Canada.

Welch, D.M. 2002. Atmospheric Science and Air Issues in Canada's National Parks, 2001. Parks Canada Ecosystem Monitoring and Data Reports No.7

APPENDIX A

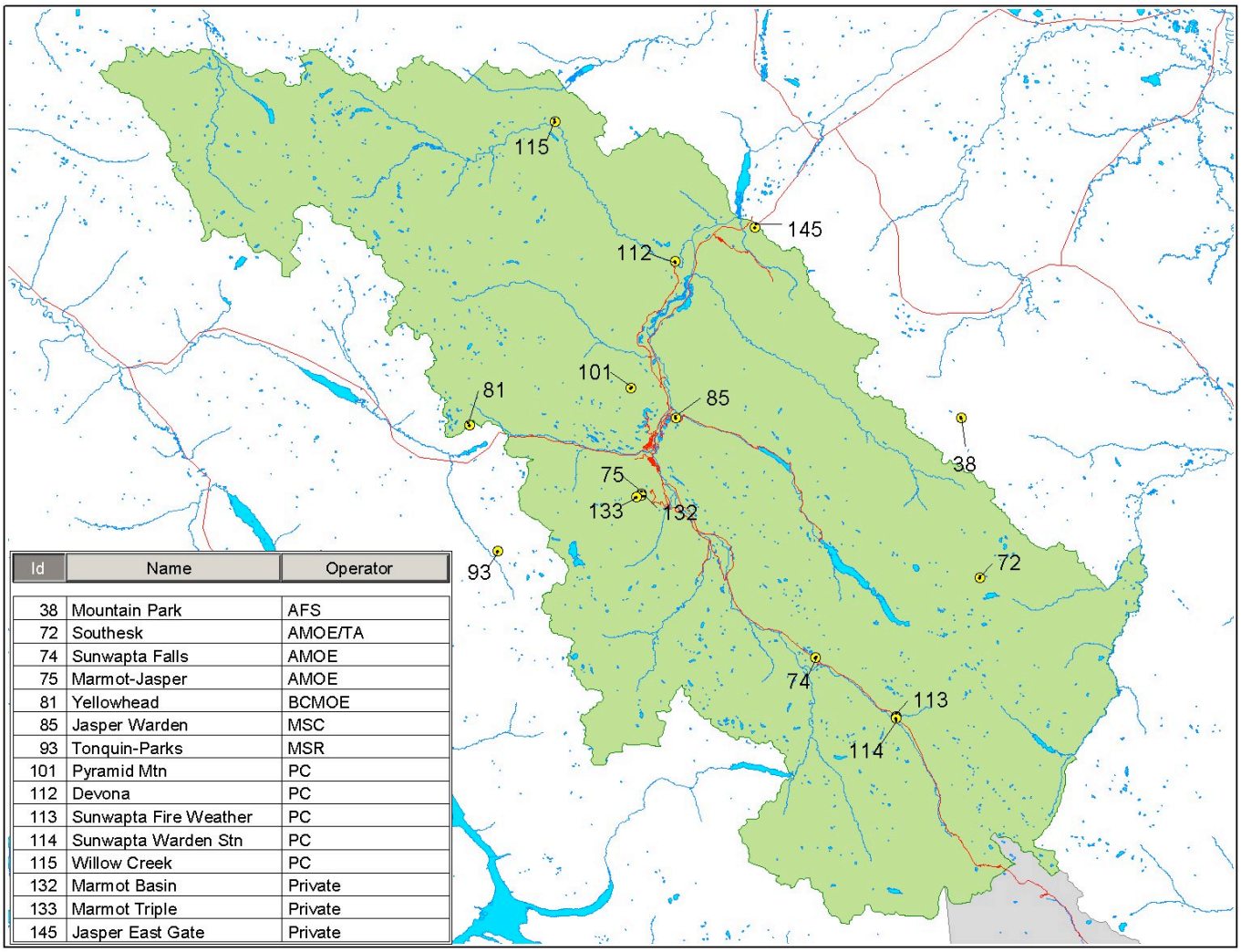
Existing Stations In and Near the Mountain Parks



Id	Name	Operator
15	Whiteman's Pass	AFS
17	Canmore	AFS
28	David Thompson Highwa	AFS
54	Bow River	AMOE
55	Pipestone (upper)	AMOE
56	Mirror Lake	AMOE
57	Chateau Lawn	AMOE
58	Bow Summit (New)	AMOE
59	Pika Run	AMOE/Private
60	Sunshine Village	AMOE
61	Tent Ridge	AMOE
62	Cuthead Lake	AMOE
63	Mud Lake	AMOE
67	Skoki Mountain	AMOE
68	Dogrib Creek	AMOE
70	Scotch Camp	AMOE
71	Nigel Creek	AMOE
83	Banff	MSC
95	Bow Summit	PC
96	Coleman Creek	PC
97	Goats Eye	PC/MSC/AMOE
98	Lookout Mtn	PC
99	Parker's Ridge Lower	PC
100	Parker's Ridge Upper	PC
102	Sunshine Village	PC
125	False Nicholas	PC
126	Lake Louise	PC/MSC/AMOE
128	Sask River Crossing	PC
131	Paradise Ridgetop	Private
135	Paradise Base	Private
141	Banff Springs	WSC
143	Temple	Private

Figure A1a – Locations of Weather Stations operating in and near Banff National Park.

DRAFT



Id	Name	Operator
38	Mountain Park	AFS
72	Southesk	AMOE/TA
74	Sunwapta Falls	AMOE
75	Marmot-Jasper	AMOE
81	Yellowhead	BCMOE
85	Jasper Warden	MSC
93	Tonquin-Parks	MSR
101	Pyramid Mtn	PC
112	Devona	PC
113	Sunwapta Fire Weather	PC
114	Sunwapta Warden Stn	PC
115	Willow Creek	PC
132	Marmot Basin	Private
133	Marmot Triple	Private
145	Jasper East Gate	Private

Figure A1b – Locations of Weather Stations currently operating in and near Jasper National Park.

DRAFT

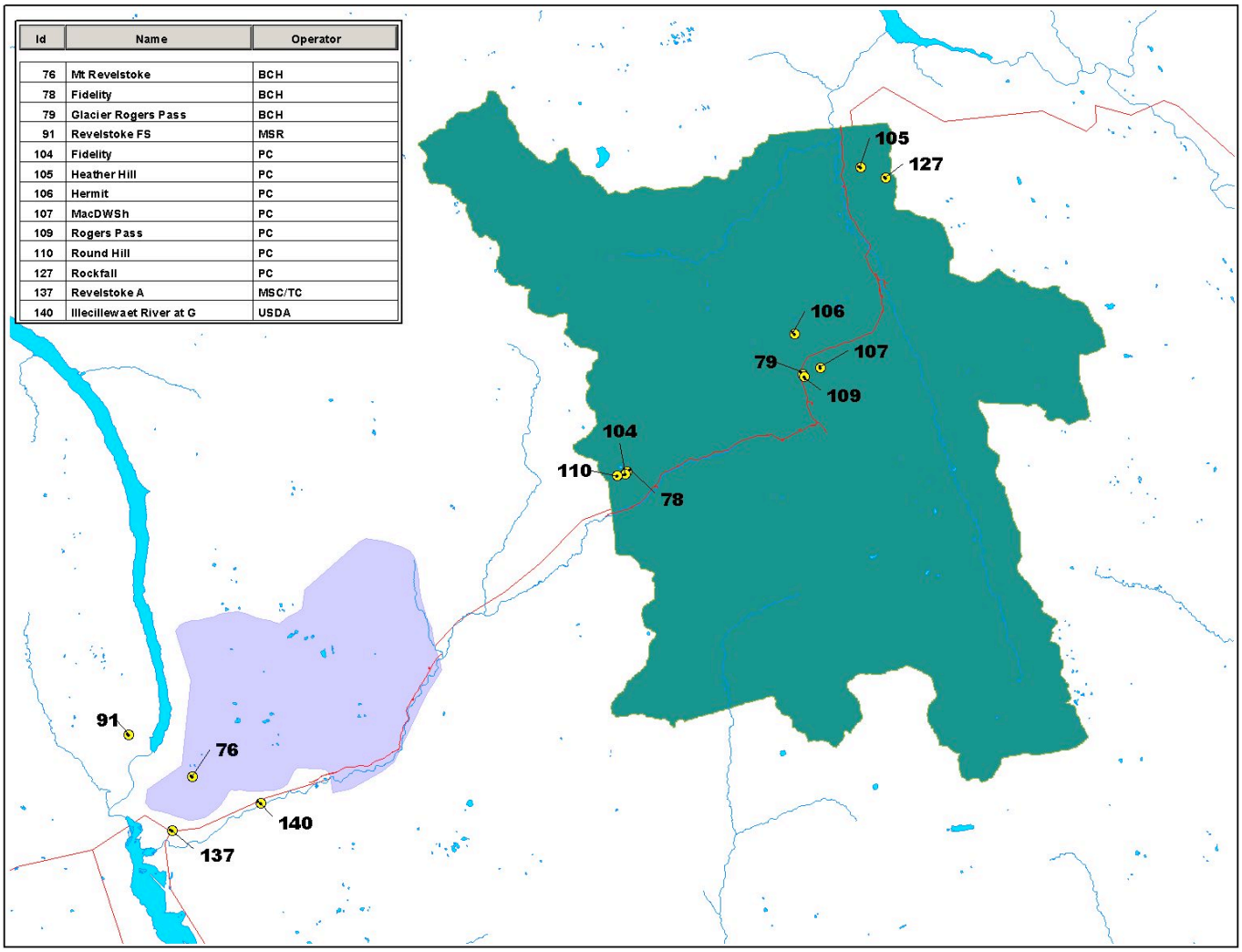
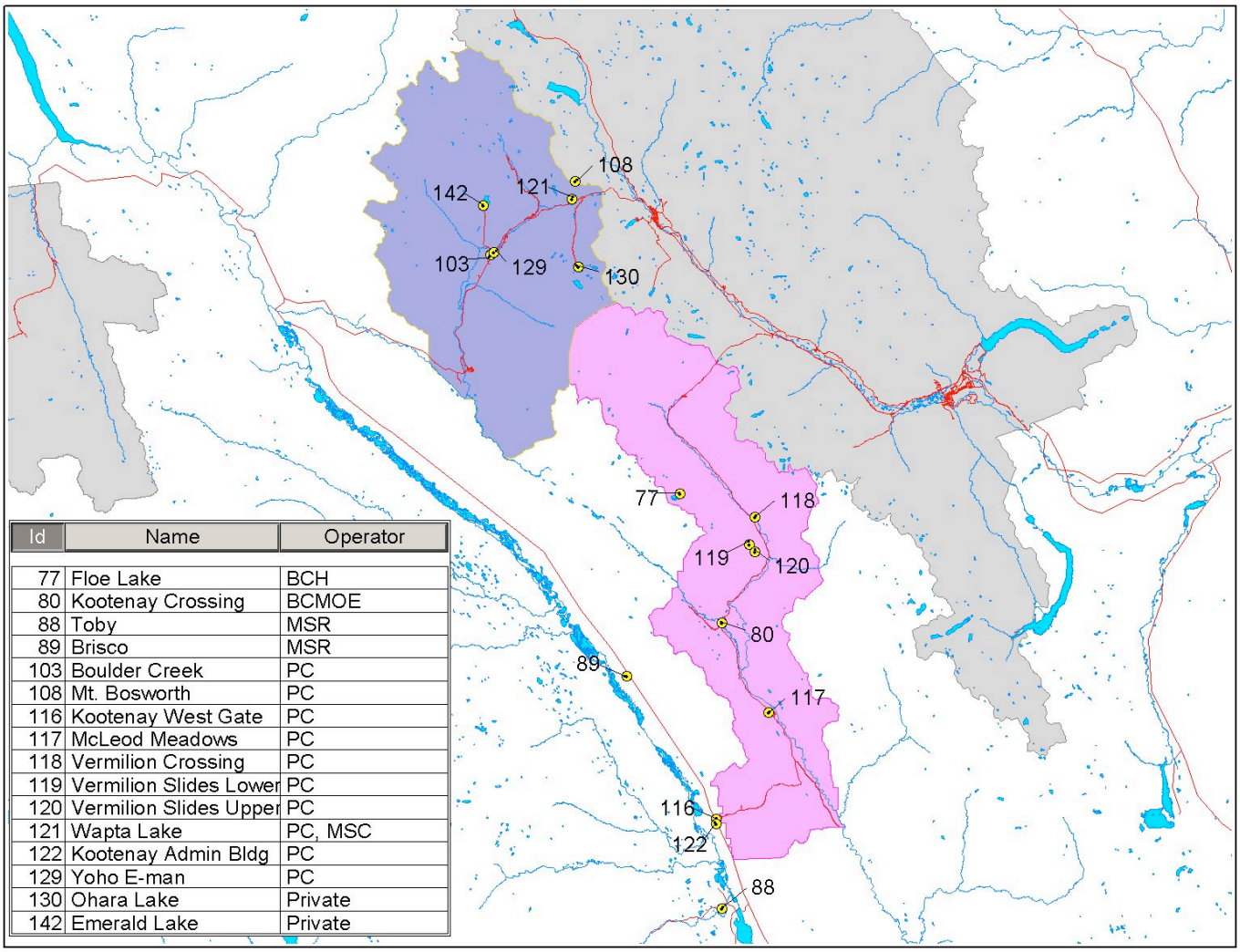


Figure A1c – Locations of Weather Stations currently operating in and near Revelstoke/ Glacier National Parks

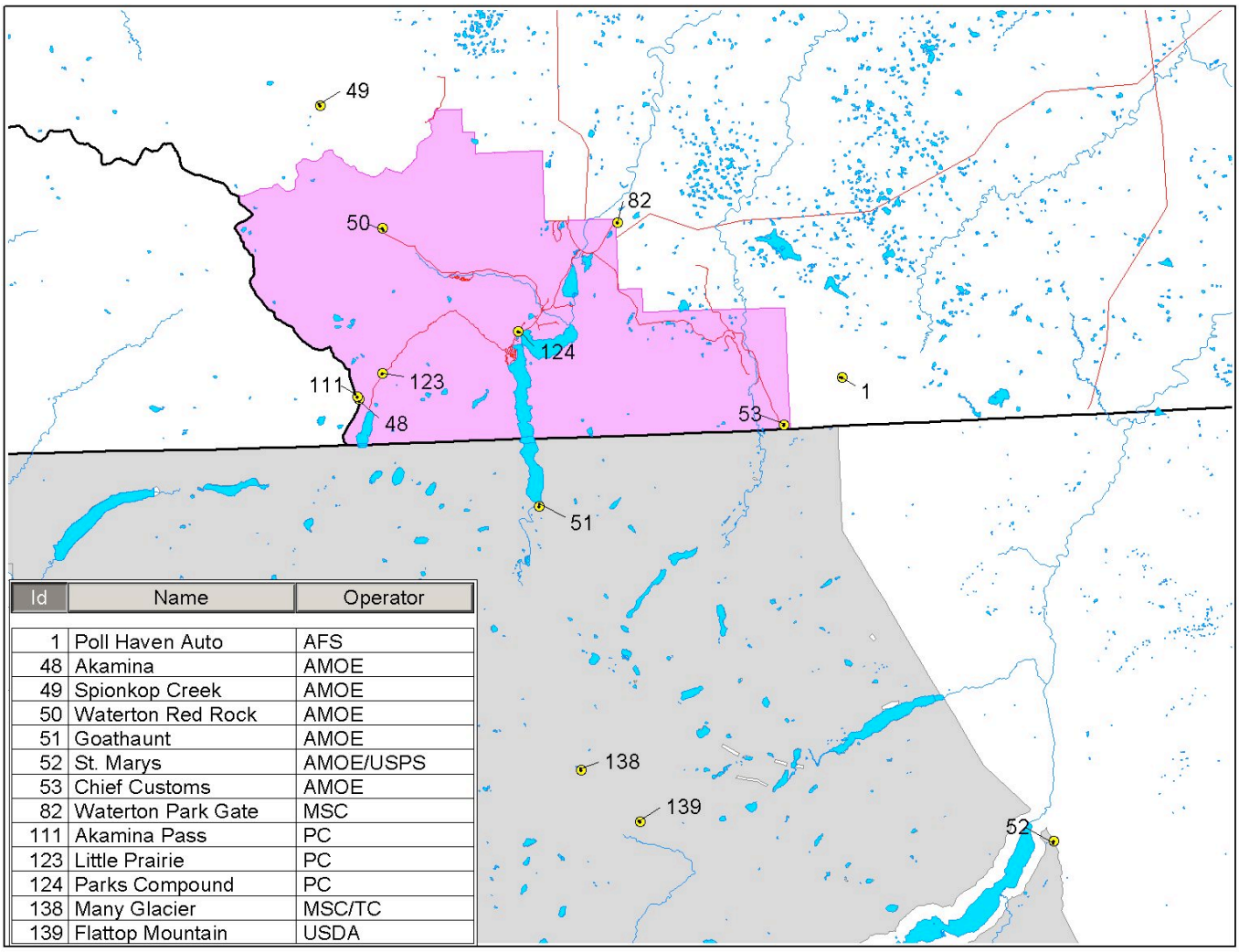
DRAFT



Id	Name	Operator
77	Floe Lake	BCH
80	Kootenay Crossing	BCMOE
88	Toby	MSR
89	Brisco	MSR
103	Boulder Creek	PC
108	Mt. Bosworth	PC
116	Kootenay West Gate	PC
117	McLeod Meadows	PC
118	Vermilion Crossing	PC
119	Vermilion Slides Lower	PC
120	Vermilion Slides Upper	PC
121	Wapta Lake	PC, MSC
122	Kootenay Admin Bldg	PC
129	Yoho E-man	PC
130	Ohara Lake	Private
142	Emerald Lake	Private

Figure A1d – Locations of Weather Stations currently operating in and near Yoho / Kootenay National Parks

DRAFT



Id	Name	Operator
1	Poll Haven Auto	AFS
48	Akamina	AMOE
49	Spionkop Creek	AMOE
50	Waterton Red Rock	AMOE
51	Goathaunt	AMOE
52	St. Marys	AMOE/USPS
53	Chief Customs	AMOE
82	Waterton Park Gate	MSC
111	Akamina Pass	PC
123	Little Prairie	PC
124	Parks Compound	PC
138	Many Glacier	MSC/TC
139	Flattop Mountain	USDA

Figure A1e – Locations of Weather Stations currently operating in and near Waterton National Park

DRAFT

Table A1 – Weather Stations Operating in and near the Mountain Parks

Stn No.	Operator ID	MSC ID	Station Name	Operator	Use	Park	Lat Deg	Min	Sec	Long Deg	Min	Sec	Elev	Freq	Comm	Power	Dur'n	Temp	Pcpn	Hdty	Wind	Snow
1	C3	3E+06	Poll Haven Auto	AFS	F		49	1	41	113	36	7	1615	H			SM	x	SRG			
2	C2	3E+06	Castle Auto	AFS	F		49	20	56	114	17	50	1360	H			SM	x	SRG			
3	A01		Castle RS	AFS	F		49	23	32	114	20	13	1387	TD	V	N	SM	x	SRG			Bd
4	CB	3E+06	Carbondale	AFS	F		49	25	53	114	21	28	1807	TD	V	N	SM	x	SRG			Bd
5	A11		Goat Creek	AFS	F		49	28	55	114	34	26	1859	TD	V	N	SM	x	SRG			Bd
6	G02		Mist Creek	AFS	F		50	31	5	114	50	53	1753	TD	V	N	SM	x	SRG			Bd
7	JM		Junction Mountain	AFS	F		50	33	55	114	38	53	2241	TD	V	N	SM	x	SRG			Bd
8	H02		Sheep River	AFS	F		50	35	50	114	47	31	1768	TD	V	N	SM	x	SRG			Bd
9	K02		Kananaskis Lakes	AFS	F		50	38	27	115	6	29	1676	TD	V	N	SM	x	SRG			Bd
10	B5		Peter Lougheed Park	AFS	F		50	42	49	115	7	9	1622	H			SM	x	SRG			
11	B7		Elbow Auto	AFS	F		50	54	18	114	41	28	1413	H			SM	x	SRG			
12	K07		Kananaskis Boundary	AFS	F		50	55	29	115	7	26	1509	TD	V	N	SM	x	SRG			Bd
13	B4		Kananaski Boundary Auto	AFS	F		50	55	40	115	7	24	1464	H			SM	x	SRG			
14	MS	3E+06	Moose Mountain	AFS	F		50	56	20	114	50	13	2431	TD	V	N	SM	x	SRG			Bd
15	K08		Whitemans Pass	AFS	F		51	1	42	115	24	18	1676	TD	V	N	SM	x	SRG			Bd
16	BP	3E+06	Barrier Lake	AFS	F		51	2	53	115	4	44	2021	TD	V	N	SM	x	SRG			Bd
17	K01		Canmore	AFS	F		51	6	48	115	22	12	1326	TD	V	N	SM	x	SRG			Bd
18	MH	3E+06	Mockingbird Hill	AFS	F		51	25	29	115	4	15	1907	TD	V	N	SM	x	SRG			Bd
19	L02		Mockingbird LO	AFS	F		51	25	32	115	4	19	1905	TD	V	N	SM	x	SRG			Bd
20	L03		Harold creek	AFS	F		51	28	30	114	52	44	1356	TD	V	N	SM	x	SRG			Bd
21	B3	3E+06	Ya Ha Tinda Auto	AFS	F		51	39	17	115	21	45	1479	H			SM	x	SRG			
22	M01		Red Deer RS	AFS	F		51	39	19	115	14	20	1433	TD	V	N	SM	x	SRG			Bd
23	M02		Blue Hill LO	AFS	F		51	42	16	115	13	26	1951	TD	V	N	SM	x	SRG			Bd
24	BH	3E+06	Blue Hill	AFS	F		51	42	18	115	13	25	1987	TD	V	N	SM	x	SRG			Bd
25	L05		Burnt Timber LO	AFS	F		51	51	38	115	36	43	2012	TD	V	N	SM	x	SRG			Bd
26	R1	3E+06	Clearwater Auto	AFS	F		51	59	15	115	14	24	1280	H			SM	x	SRG			
27	N01		Clearwater RS	AFS	F		51	59	15	115	14	24	1280	TD	V	N	SM	x	SRG			Bd

28	P06		David Thompson Highway	AFS	F		52	0	39	116	37	37	1372	TD	V	N	SM	x	SRG			Bd
29	P04		Kootenay Plains	AFS	F		52	3	44	116	24	47	1372	TD	V	N	SM	x	SRG			Bd
30	R4		Kootenay Plains Auto	AFS	F		52	3	44	116	24	46	1294	H			SM	x	SRG			
31	CE	30516F5	Cline	AFS	F		52	10	41	116	24	40	2050	TD	V	N	SM	x	SRG			Bd
32	O03		North Ram Summit	AFS	F		52	20	34	116	4	12	1676	TD	V	N	SM	x	SRG			Bd
33	BY	3E+06	Baldy	AFS	F		52	31	54	116	7	31	2082	TD	V	N	SM	x	SRG			Bd
34	P03		Shunda-Baldy	AFS	F		52	32	24	116	7	52	2083	TD	V	N	SM	x	SRG			Bd
35	P02		Chungo Creek	AFS	F		52	45	9	116	26	10	1372	TD	V	N	SM	x	SRG			Bd
36	BT	3E+06	Blackstone	AFS	F		52	46	27	116	19	49	1576	TD	V	N	SM	x	SRG			Bd
37	GF	3E+06	Grave Flats	AFS	F		52	53	16	116	59	27	2076	TD	V	N	SM	x	SRG			Bd
38	U01		Mountain Park	AFS	F		52	55	16	117	16	30	1798	TD	V	N	SM	x	SRG			Bd
39	Q03		Owl Creek	AFS	F		52	56	41	116	6	25	1158	TD	V	N	SM	x	SRG			Bd
40	W-F		Wampus F	AFS	F		53	6	5	117	18	47	1475	TD	V	N	SM	x	SRG			Bd
41	U03		Warden Creek	AFS	F		53	13	34	117	34	1	1433	TD	V	N	SM	x	SRG			Bd
42	YH	3E+06	Yellowhead	AFS	F		53	14	11	117	8	25	1477	TD	V	N	SM	x	SRG			Bd
43	U04		Felton Creek	AFS	F		53	16	11	117	12	4	1213	TD	V	N	SM	x	SRG			Bd
44	E4	306A009	Hinton Auto	AFS	F		53	24	2	117	34	42	1012	H			SM	x	SRG			
45	AT	3E+06	Athabasca	AFS	F		53	24	30	117	47	7	1582	TD	V	N	SM	x	SRG			Bd
46	E2	3E+06	Schwartz Creek Auto	AFS	F		53	25	28	116	31	30	958	H			SM	x	SRG			
47	U12		Schwartz Creek	AFS	F		53	25	39	116	30	7	922	TD	V	N	SM	x	SRG			Bd
48	05AD803	30500FR	Akamina	AMOE		W	49	1	38	114	3	11	1761	15	G	S		x	FP(S)	x	x	Plw
49	05AD804		Spionkop Creek	AMOE			49	12	33	114	4	50	1860	15				x	FP(S)			
50	05AD805	3E+06	Waterton Red Rock	AMOE		W	49	7	55	114	1	35	1524	15	G	S		x	FP(S)	x		
51	05AD806		Goathaunt	AMOE		G (US)	48	57	24	113	53	25	1280	15	G	S		x	PI(S)	x	x	
52	05AE818		St. Marys	AMOE/USPS		G (US)	48	44	11	113	25	28	1390	15	G	S		x	FP			
53	05AE819		Chief Customs	AMOE			49	0	1	113	39	30	1690	H	G	S		x	FP(S)			Snc
54	05BA801		Bow River	AMOE		B	51	25	0	116	11	0	1580	M	Rep	N						Crs
55	05BA802		Pipestone (upper)	AMOE		B	51	26	0	116	10	0	1615	M	Rep	N						Crs
56	05BA806		Mirror Lake	AMOE		B	51	25	0	116	14	0	2030	M	Rep	N						Crs
57	05BA808		Chateau Lawn	AMOE		B	51	25	0	116	13	0	1740	M	Rep	N						Crs
58	05BA813	3050PPF	Bow Summit	AMOE		B	51	42	0	116	28	0	2080	15	G	S		x	FP(S)			

DRAFT

59	05BA815		Pika Run	AMOE/Private		B	51	27	47	116	7	4	2240	15	T	S		x	FP(S)			Snc
60	05BB803		Sunshine Village	AMOE		B	51	5	0	115	47	0	2230	15	G	S		x	Pl(S)			Plw
61	05BC801		Tent Ridge	AMOE			50	51	0	115	22	0	2025	M	Rep	N						Crs
62	05BD801	3051R51	Cuthead Lake	AMOE		B	51	27	0	115	45	0	2180	15	G	S		x	FP(S)			
63	05BF821		Mud Lake	AMOE			50	47	0	115	19	0	1910	M	Rep	N						Crs
64	05BF824		Three Isle Lake	AMOE			50	37	53	115	16	46	2160	15	G	S		x	FP(S)	x	x	Plw
65	05BJ805		Little Elbow Summit	AMOE			50	49	20	114	59	20	2120	H	G	S		x	FP(S)	x	x	Plw
66	05BL802		Highwood Summit (Bush)	AMOE			50	36	0	114	59	0	2210	M	Rep	N						Crs
67	05CA805	3E+06	Skoki Mountain	AMOE		B	51	32	26	116	3	23	2040	15	G	S		x	FP(S)			Plw
68	05CA808	305B09K	Dogrib Creek	AMOE			51	39	59	115	30	7	2020	15	G	S		x	FP(S)			
69	05CA812	3E+06	Scalp Creek	AMOE			51	47	53	115	39	8	2040	15	G	S		x	FP(S)			
70	05CA813	3E+06	Scotch Camp	AMOE		B	51	40	0	115	49	10	1737	15	G	S		x	FP(S)			
71	05DA804		Nigel Creek	AMOE		B	52	11	32	117	4	56	1920	M	Rep	N						Crs
72	05DD804	3E+06	Southesk	AMOE/TA		J	52	40	15	117	13	32	2045	15	G	S		x	FP(S)			
73	05DD805	3E+06	Job Creek	AMOE/TA			52	22	19	116	46	44	2005	15	G	S		x	FP(S)			
74	07AA802		Sunwapta Falls	AMOE		J	52	32	36	117	38	53	1400	M	Rep	N						Crs
75	07AA803		Marmot-Jasper	AMOE		J	52	48	24	118	5	22	1830	M	Rep	N						Crs
76	2AO6P		Mt Revelstoke	BCH		MR	51	2		118	9		1830	H	G	S		x	SRG			Plw
77	2C14P		Floe Lake	BCH		K	51	3		116	8		2090	H	G	S		x	SRG			Plw
78			Fidelity	BCH		G	51	14	14	117	42	4	1800	H	G	S		x	SRG			
79			Glacier Rogers Pass	BCH		G	51	18	8	117	31	5	1210	H	G	S		x	SRG			
80			Kootenay Crossing	BCMOE		K	50	53	10	116	2	35	1220					x				
81	1AO1P		Yellowhead	BCMOE			52	54		118	33		860	H								Plw
82	WGM	3E+06	Waterton Park Gate	MSC		W	49	7	46	113	48	20	1296	H				x	SRG	x		x
83		3E+06	Banff	MSC		B	51	11		115	33		1397	H				x	SRG	x	x	x
84	WXA	3E+06	Bow Valley Auto	MSC			51	4		115	4		1298	H	T			x		x	x	
85		3E+06	Jasper Warden	MSC		J	52	55		118	1		1020	H				x	SRG	x	x	x
86			Flathead 2	MSR	F		49	4	15	114	32	14	1311	H		S		x	SRG	x	x	
87			Palliser	MSR	F		50	29	24	115	39	29	1100	H		S		x	SRG	x	x	
88			Toby	MSR	F		50	30	46	116	3	9	894	H		S		x	SRG	x	x	
89			Brisco	MSR	F		50	49	10	116	14	41	930	H		S		x	SRG	x	x	
90			Marion	MSR	F		51	2	32	116	21	50	1300	H		S		x	SRG	x	x	

DRAFT

91			Revelstoke FS	MSR	F		51	3	37	118	13	2	400	H		S		x	SRG	x	x	
92			Blaeberry	MSR	F		51	26	9	117	3	25	861	H		S		x	SRG	x	x	
93			Tonquin-Parks	MSR	F		52	42	10	118	28	12	1667	H		S		x	SRG	x	x	
94			Holmes	MSR	F		53	20	44	119	42	48	1179	H		S		x	SRG	x	x	
95		305A002	Bow Summit	PC	A	B	51	42	3	116	28	7	2040	H	R	S		x	FP	x	x	
96			Coleman Creek	PC	F	B	52	5	32	116	55	48	2080	H	R	S		x	x	x	x		x
97		3E+06	Goats Eye	PC/MSC/AMOE	F, A	B	51	5	9	115	44	58	2480	H	T		Wr	x		x	x	
98		305A003	Lookout Mtn	PC	F, A	B	51	4	29	115	45	11	2720	H	R	S		x	SRG	x		x
99		3E+06	Parker's Ridge Lwr	PC		B	52	11	36	117	5	50	2200				Wr	x		x			x
100		3E+06	Parker's Ridge Upr	PC		B	52	10	58	117	5	21	2520	H	R	S		x		x	x		
101			Pyramid Mtn	PC		J	52	57	46	118	8	3	1960										
102		3E+06	Sunshine Village	PC		B	51	4	43	115	46	38	220					x	x	x			x
103			Boulder Creek	PC	A	Y	51	22	20	116	31	11	1280	H				x	x	x	x		
104			Fidelity	PC	A	G	51	14	9	117	42	10	1870	10	R	S	Wr	x	S'pipe	x	x		Snc
105			Heather Hill	PC	A	G	51	26	19	117	27	33	950		R	S	Wr	x		x			Pole
106			Hermit	PC	A	G	51	19	43	117	31	35	1990		R		Wr	x	S'pipe	x	x		
107			MacDWSh	PC	A	G	51	18	23	117	29	58	1710		R		Wr	x		x	x		
108			Mt. Bosworth	PC	A	Y	51	28	4	116	20	33	2640	H	R	S		x		x		x	
109			Rogers Pass	PC	A	G	51	18	2	117	30	59	1360	H	R			x	S'pipe	x	x		
110			Round Hill	PC	A	G	51	14	4	117	42	40	2040	H	R			x		x	x		
111		3E+06	Akamina Pass	PC		W	49	1	43	114	3	22	1676										
112		3E+06	Devona	PC		J	53	9	41	118	1	25	1960						x	Sr only	x	x	
113		3E+06	Sunwapta Fire Weather	PC	F	J	52	27	10	117	26	24	1540	H		S		x		x	x	x	x
114		3E+06	Sunwapta Warden Stn	PC	F	J	52	27	0	117	26	24	1540	D				x		x	x		Depth, SWE
115		306GE70	Willow Creek	PC		J	53	22	39	118	20	36	1160					x	x	x	x		
116		1E+06	Kootenay West Gate	PC		K	50	37	48	116	3	42	940	D	Rep			x	SRG				
117			McLeod Meadows	PC	F, A	K	50	46	7	115	57	1	1140	H	R	S		x	TB	x	x		
118			Vermilion Crossing	PC	A	K	51	1	30	115	58	26	1280	H	R	S		x	S'pipe	x	x		Depth
119			Vermilion Slides Lwr	PC	A	K	50	59	23	115	59	11	2040	H	R	S	Wr	x	x	x	x		Depth
120			Vermilion Slides Upr	PC	A	K	50	58	48	115	58	30	2400	H	R	S		x		x		x	

DRAFT

121	WYL	11790J1	Wapta Lake	PC, MSC		Y	51	26	43	116	20	53	1640	H	T			x	FP(S)	x		x	Snc
122			Kootenay Admin Bldg	PC	F	K	50	37	25	116	3	46	980					x	TB		x	x	
123			Little Prairie	PC	A	W	49	2	33	114	1	54	1625				Wr						
124			Parks Compound	PC	F	W	49	3	54	113	54	11	1280				Sr						
125		3E+06	False Nicholas	PC	A	B	51	37	32	116	28	23	2960					x		x	x		
126		3E+06	Lake Louise	PC/MSC/ AMOE	F, A	B	51	25	40	116	10	41	1560	H	T			x	FP, TB	x	x		Snc
127			Rockfall	PC	F	G	51	25	53	117	25	57	2225		R	S	Wr	x	TB	x		x	Snc
128		3E+06	Sask River Crossing	PC	F, A	B	51	58	9	116	42	39	1390					x	x	x	x		
129			Yoho E-man	PC		Y	51	22	34	116	30	49	1280					x			x		
130		117R00H	Ohara Lake	Private		Y	51	21	23	116	20	10	2120				Intmt	x	x				Depth
131			Paradise Ridgetop	Private		B	51	27	33	116	7	50	2520				Wr	x					
132		305421B	Marmot Basin	Private		J	52	47	41	118	6	8	2072	D				x	x				x
133		3E+06	Marmot Triple	Private		J	52	47	29	118	6	52	2072	D			Sr	x					x
134				Private		J	52	42		118	7		2290	D									
135																							
136			Golden A	MSC/TC		B																	
137	YRV	1E+06	Revelstoke A	MSC/TC	Avn		50	57		118	10		785	H				x	SRG	x	x	x	
138	13a27s		Many Glacier	USDA		G (US)	48	47	49	113	40	12	1541	H					x SWE				Depth
139	13a19s		Flattop Mountain	USDA		G (US)	48	47	49	113	40	12	1921	H				x	SWE				Depth
140	08ND013		Illecillewaet River at Greeley	WSC			51	0	49	118	4	57						x	x				
141		3E+06	Banff Springs	Private		B	51	10	19	115	34	11	1370	D			Sr	x	SRG				
142		117R00G	Emerald Lake	Private		Y	51	26	15	116	32	8	1303	D			Intmt	x	SRG				
143		3056LPA	Temple	Private		B	51	26	46	116	6	10	1891	D				x	x				
144																							
145		3E+06	Jasper East Gate	Private		J	53	13	0	117	49	0	1003	D				x	SRG				
146			Mt. Abbott	PC		AG	51	15	4	117	30	37						x	x		x	x	
147			Lookout	PC		AG	51	14	3	117	27	10	2490					x	TB		x	x	

Abbreviations

Operators

AFS - Alberta Forestry Service

AMOE - Alberta Ministry of Environment (Water)
BC MOE - BC Ministry of Environment (Water)

BCH - BC Hydro

MSC - Meteorological Service of Canada
MSR - BC Ministry of Forests and Range (Forestry)

PC - Parks Canada
TA - Transalta

Pcpn - Precipitation
FP - Fischer Porter Precipitation Gauge

FP(S) - Fischer Porter Precipitation Gauge with Shield

PI - Pluvio Precipitation Gauge
PI (S) - Pluvio Precipitation Gauge with Shield
TB - Tipping Bucket Rain Gauge

Sonic - Sonic or Acoustic Snow Gauge

SRG - Standard Rain Gauge

SWE - snow water equivalent

Parks
B - Banff National Park
G - Glacier National Park

GNP(US) - Glacier National Park (United States)
J - Jasper National Park

K - Kootenay National Park
MR - Mount Revelstoke National Park
W - Waterton Lakes National Park
Y - Yoho National Park

Freq – Frequency of Observation

10 – 10 min

15 – 15 min

H – Hourly

TD – Twice Daily

D - Daily

Comm – Communication

V - Voice

G – GOES

R – Report

R – Radio
T - Telephone

Power

N – None

S –Solar

Dur – Duration
Sm – Summer

Wr – Winter

Intmt - Intermittent

Snow

Bd – Board
Crs – Course
Plw – Pillow