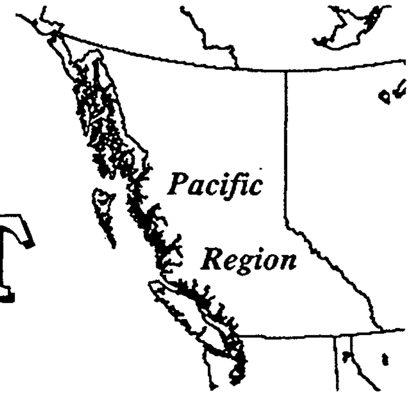
SCIENTIFIC SERVICES DIVISION

REPORT



TRANSBOUNDARY AIR POLLUTION CONCERNS

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for

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TRANSBOUNDARY AIR POLLUTION CONCERNS

Executive Summary:

This paper was prepared to address the benefits and detractions of "integrated monitoring" with a focus on air as the major medium. The area of interest is the transboundary region of British Columbia and the States of Washington, Idaho and Montana. With this goal in mind, the air pollution situation and the relevant meteorology of the transboundary region of British Columbia is reviewed.

The transboundary region of British Columbia is dominated by rugged mountains with deep valleys, the Fraser River valley and delta and the Pacific Ocean to the west. Air flow in the transboundary region of B.C. is controlled by these three factors. The deep valleys force the air to move north and south to and from British Columbia. These valleys define an airshed that includes the States of Washington, Idaho and Montana. Further west, the Fraser River Valley widens to form a well defined region where Washington State and British Columbia again share a common airshed. The air will often circulate within this small area moving pollution back and forth across the border which divides the airshed nearly in half. On a larger scale, storms will track through this transboundary region from the southwest. The movement of these weather systems provides a mechanism where air can be pulled northward from the Puget Sound area into the transboundary region. In a similar fashion, air from British Columbia can be swept southward by storms tracking over the area from the northwest. This is a very complex area requiring detailed information on both the meteorology and the levels of air pollution.

Air pollution networks have been established in the transboundary area of B.C. These networks primarily monitor the levels of criteria air pollutants such as the oxides of sulphur and nitrogen, ozone, total suspended particulates and others. The chemistry of precipitation is also analyzed for levels of acidity and acid deposition. Fog samples have been taken at high elevation sites near Vancouver B.C. to identify the levels of acidic loading.

These networks indicate that air pollution is exceeding the National Air Quality Objectives for ozone and total suspended particulates in the Greater Vancouver Regional District. Precipitation chemistry analysis of rain and snow samples shows depressed pH values and evidence of anthropogenic pollution. Similar trends toward depressed pHs and pollutant loading are captured in high elevation fog samples as well.

Monitoring programs have started to unravel the many questions about the meteorology and the pollution levels in the transboundary region of British Columbia. However, these networks are primarily for compliance monitoring of criteria pollutants. The data gathered from these networks describes, for the most part, the urban areas and isolated industrial sites. Very little is known about background levels of pollution or the details of air movements in the region. The concentration of various air toxic compounds is known in only a very few locations or not at all. Source/receptor relationships have been established which indicated pollution from the Puget Sound area was impacting areas of the British Columbia in the transboundary region.

The airshed in the transboundary region must be monitored for all pollutants of concern. Sites should be established to gather meteorological data and to quantify and identify pollution levels entering the terrestrial and aquatic environments through the air pathway. These studies must not only be interdisciplinary but also international with agencies on both sides of the transboundary region collecting environmental data using similar methodologies.

The task that must be completed first is "integrated analysis" of the existing environmental data. Environmental scientists from different disciplines must analyze presently available environmental data for the transboundary region. The usefulness of these existing datasets to describe the state of the transboundary region must be ascertained. Only then can a useful "integrated" approach to solving some of the existing data and knowledge gaps be addressed.

TRANSBOUNDARY AIR POLLUTION CONCERNS

Introduction:

The precipitation falling over large portions of southwestern British Columbia is acidic. Southern Vancouver Island, the Strait of Georgia and the Lower Fraser Valley are areas where precipitation chemistry networks have measured rain, snow and fog with pH levels below 5.0. Ozone and total suspended particulates exceed the acceptable level of the National Air Quality Objectives in and around the urban areas of Vancouver and in the Lower Fraser Valley. The geographical location of this area and the regional meteorological conditions would suggest that most of this air pollution is produced locally. It is possible, however, that impacts on the environment have been enhanced by pollution from sources beyond the local area.

In order to identify the presence of transboundary air pollution, the impacts due to air toxics produced within the various sectors of the transboundary region must be quantified and qualified. Concerns over urban air quality and acidic deposition have seen the establishment of monitoring networks throughout the province, particularly in the Lower Mainland and Vancouver Island. These networks primarily fulfil requirements identified under regulatory mandates to assess levels of criteria air pollutants.

It was only after the chemical analysis of precipitation data from these monitoring activities that excess levels of pollutants were identified. Further studies of the chemistry and meteorology of precipitation samples has confirmed the presence of transboundary air pollution. Trajectory analysis of ozone episodes in the Fraser Valley has provided further indications of transboundary air pollution.

The Air Pathway:

The manner in which the air transports pollution from the source to the receptor is controlled by many factors. In the southern portions of British Columbia, the mountains, the proximity to the Pacific Ocean and the Fraser River Valley all play important parts in determining how the different airmasses will move.

The Lower Mainland which includes the Vancouver area and the Lower Fraser Valley is part of an airshed that extends southward into Washington State (see figure 1). This airshed is bounded by mountains to the north and east and by water to the west. The presence of this relatively large body of water and associated sea-breeze effects, further complicates the circulation of polluted air. In the interior of the Province, many of the valleys have orientations that force air to flow north or south. The identification of source/receptor relationships must be carefully considered in this region.

Local topography also controls the precipitation regimes in the area. An airmass laden with moisture from the Pacific Ocean will create heavy rainfalls over coastal areas, light rain inland and perhaps snow over higher elevations. The interpretation of precipitation chemistry analyses must take these effects into account.

Monitoring Networks and Studies:

The two main air quality issues in British Columbia are acidic deposition and photochemical air pollution (ozone). More recently concerns have broadened as the public is becoming more aware of toxic air contaminants. However, most of the monitoring that has been done to date has been for acid rain and common air contaminants.

Air pollution has been underway in the Vancouver area since the late 1940's. In the early 1970's, National Air Pollution Surveillance (NAPS) stations were established in cooperation with the B.C. Ministry of Environment and the Greater Vancouver Regional District (GVRD). The GVRD has established additional stations to monitor air quality in and around the city of Vancouver. Presently there are 42 air quality monitoring stations in the GVRD area of responsibility (see figure 2). The B.C. Ministry of Environment operates three stations to the east of the GVRD in the Lower Fraser Valley. The stations are variously equipped to measure sulphur dioxide, carbon monoxide, carbon dioxide, ozone, nitrogen dioxide, dustfall, coefficient of haze, hydrochloric acid/hydrofluoric acid, total suspended particulate matter and metals in suspended particulates. Temperature, wind speed and wind direction are also monitored at selected stations. Short term field studies have also been conducted in the Lower Mainland area to identify levels of volatile organic compounds (VOC) and polycyclic aromatic hydrocarbons (PAH).

The concentrations of air pollutants in the vicinity of urban centres were measured on a regular basis. Concentrations of these and other pollutants in precipitation had not be measured. To quantify and identify the acidic deposition situation in British Columbia, a wet deposition monitoring network consisting of eight stations was established in 1977. This network now has 10 stations situated close to the border region as shown in figure 3. Weekly samples are collected at these sites and analyzed for SO4, NO3, Na, K, NH4, Mg and Ca plus pH, acidity and alkalinity. Taking composite samples provides useful data on acidic loading and trends. However, identification of source/receptor relationships is lost in the inherent averaging of precipitation events.

In 1982, an event precipitation chemistry network was established with stations situated along the border region with Washington State (see figure 4). As in the weekly analysis, concentrations of the 8 major ions were determined along with selected heavy metals. This network terminated in 1986. Event sampling returned to southwestern B.C. in June 1989 with the establishment of a Canadian Air and Precipitation Monitoring Network station on Saturna Island (see figure 3).

As mentioned earlier, precipitation type is also variable in the area. In addition to rain samples, snow samples were collected at 18 locations (see figure 5) during March 1982. Site elevations varied from 945 to 2069 metres above sea level. Profile samples, one metre core samples and surface samples were taken at each of the sites. The chemical analysis included the 8 major ions, pH and Cu, Fe, Pb, Mn.

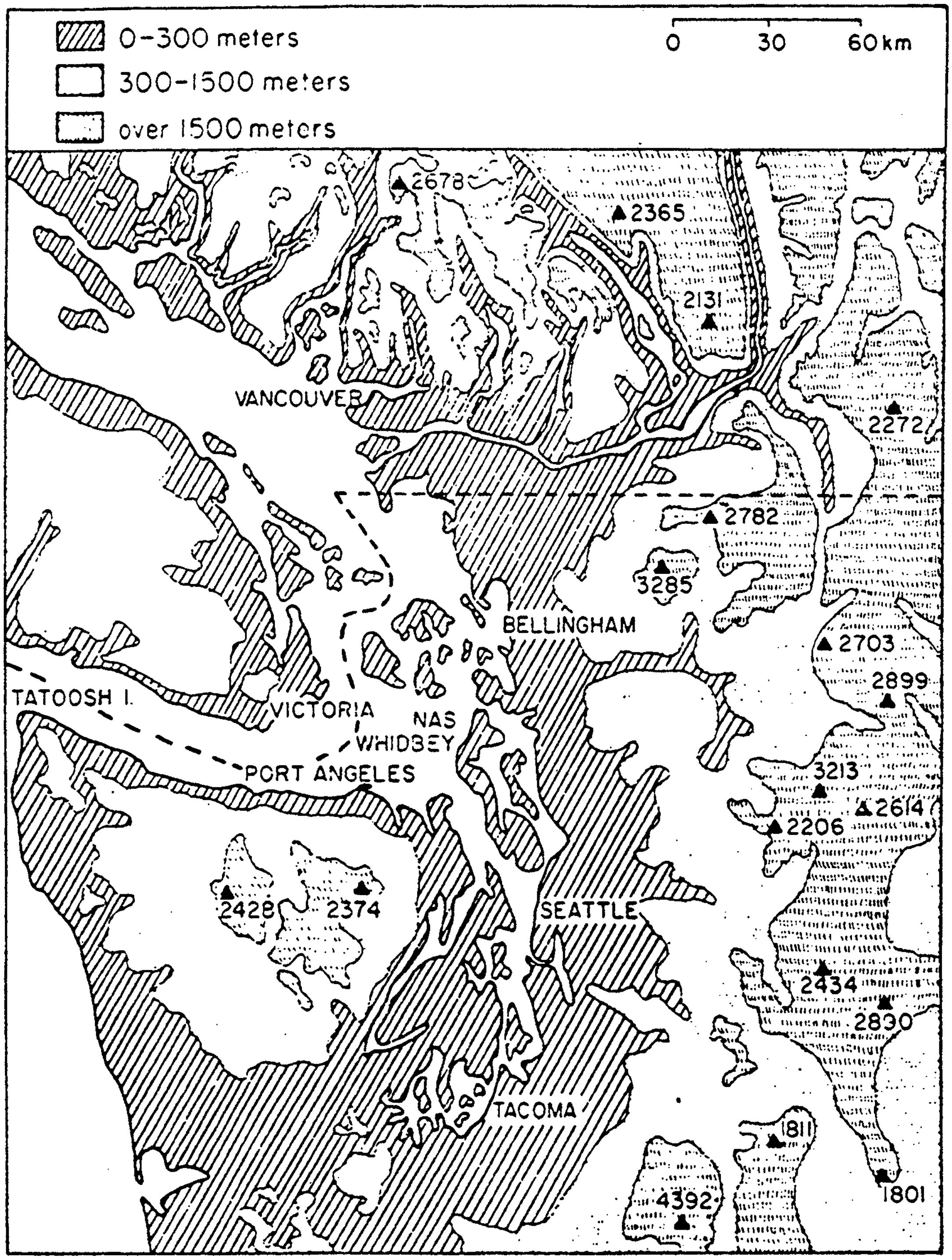


Figure 1. The Airshed of Southwestern B.C. and Northwestern Washington State

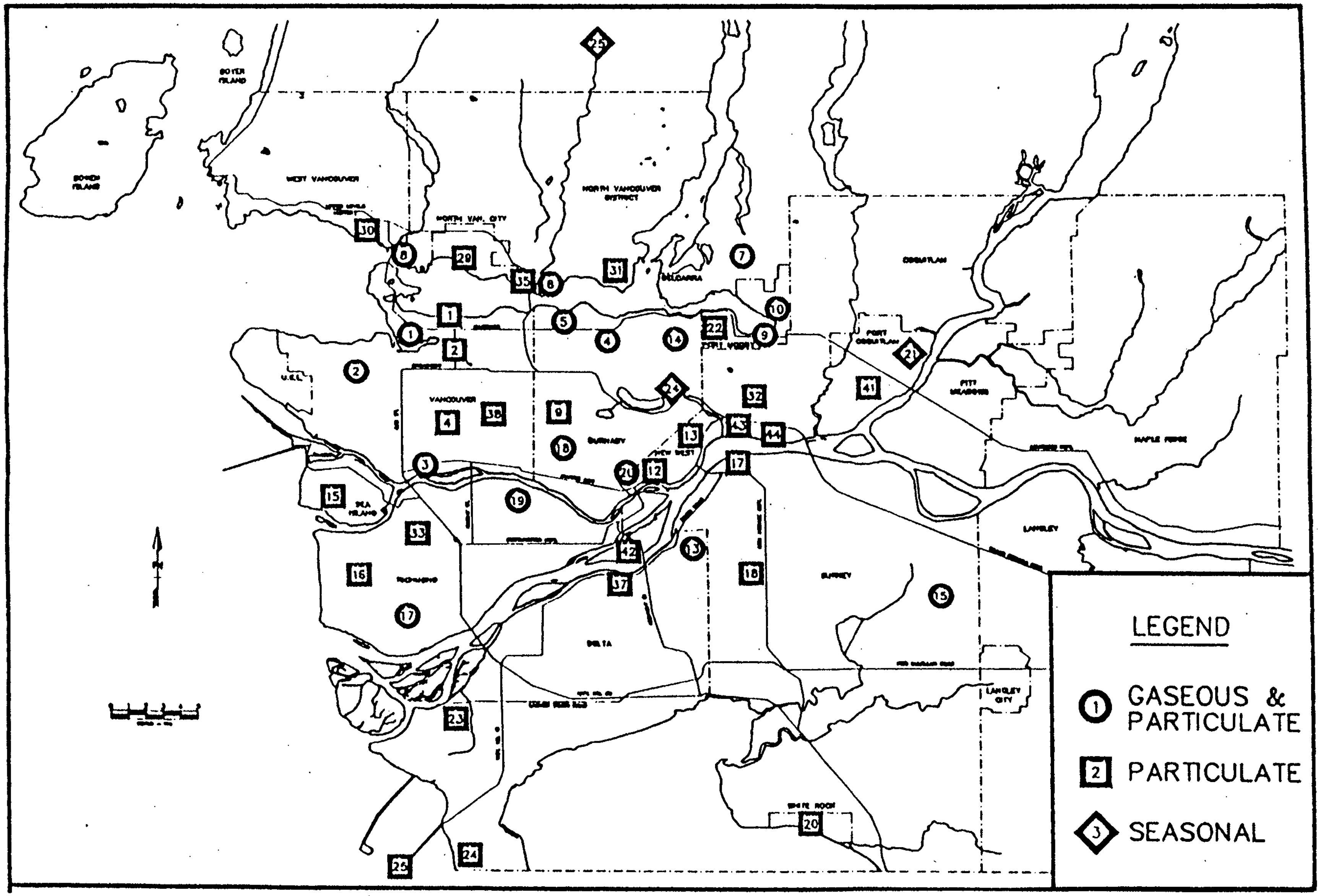


Figure 2. The Greater Vancouver Regional District Ambient Air Monitoring Network - 1988

More recently, samples of fog have been taken at two elevations on Mount Seymour, to the north of Vancouver. Fog is monitored by a passive sampler at the 845 metre level and with active and passive samplers operating at the 970 metre site. This program is now in its second year of operation. Major ions are identified in the chemical analysis of the samples along with acidity.

Organic compounds are monitored by toxic rain samplers at Kanaka Creek, Tofino Airport and Field. Precipitation samples are collected monthly and analyzed for organic herbicide residues and PAH compounds. This network will be expanded to five more sites that will include precipitation analysis for organic herbicides, acid herbicides and pentachlorophenol.

Monitoring Results:

For several decades, the atmospheric pathway over the Lower Fraser Valley and Vancouver Island has been monitored for air pollution. Through these programs information has been gathered to identify and quantify the concentrations and deposition of air pollution in the area.

Air Monitoring:

The concentrations of most of the criteria pollutants in the Lower Fraser Valley are below the National Acceptable Air Quality Objectives. Significant departures from this situation are ozone and total suspended particulates (TSP) (see figure 6). The time series of maximum concentrations for the five criteria pollutants indicates considerable variability. It is interesting to note that both ozone and TSP have increased in 1988 while lead, sulphur dioxide and nitrogen dioxide have decreased. One-hour average ozone concentrations exceeded the 82 ppb level at 13 of 20 stations. The highest one-hour average concentration was 260% of the Maximum Acceptable Level. At five stations, the one-hour average ozone exceeded the Maximum Tolerable Level. Twenty-four hour TSP concentrations exceeded the Maximum Acceptable Level at seven of the 41 stations (GVRD Air Management Plan - Stage 1, 1989).

Special studies have been conducted to quantify volatile organic compounds (VOC) and polycyclic aromatic hydrocarbons (PAH). VOC's were monitored in Vancouver for a one week period in July and in January (W.C. Edwards et al., 1989). Concentrations of VOC's were found to be similar in both January and July (see figure 7). The daily variation was bimodal and concentrations dropped slightly on the weekends. Concentrations for 11 PAH compounds were obtained for February and March of 1985 from an urban and a rural site (D.A. Faulkner, 1985). Levels of PAH were found to be slightly less than those for other cities. Higher concentrations were found at the urban site which was to be expected.

Special field studies have been conducted in the interior of the Province to supplement the monitoring of particulate matter from forestry activities and residential wood smoke that cause deterioration in air quality (P.D. Reid, 1988). Analysis of samples taken in these studies also include PAH compounds.

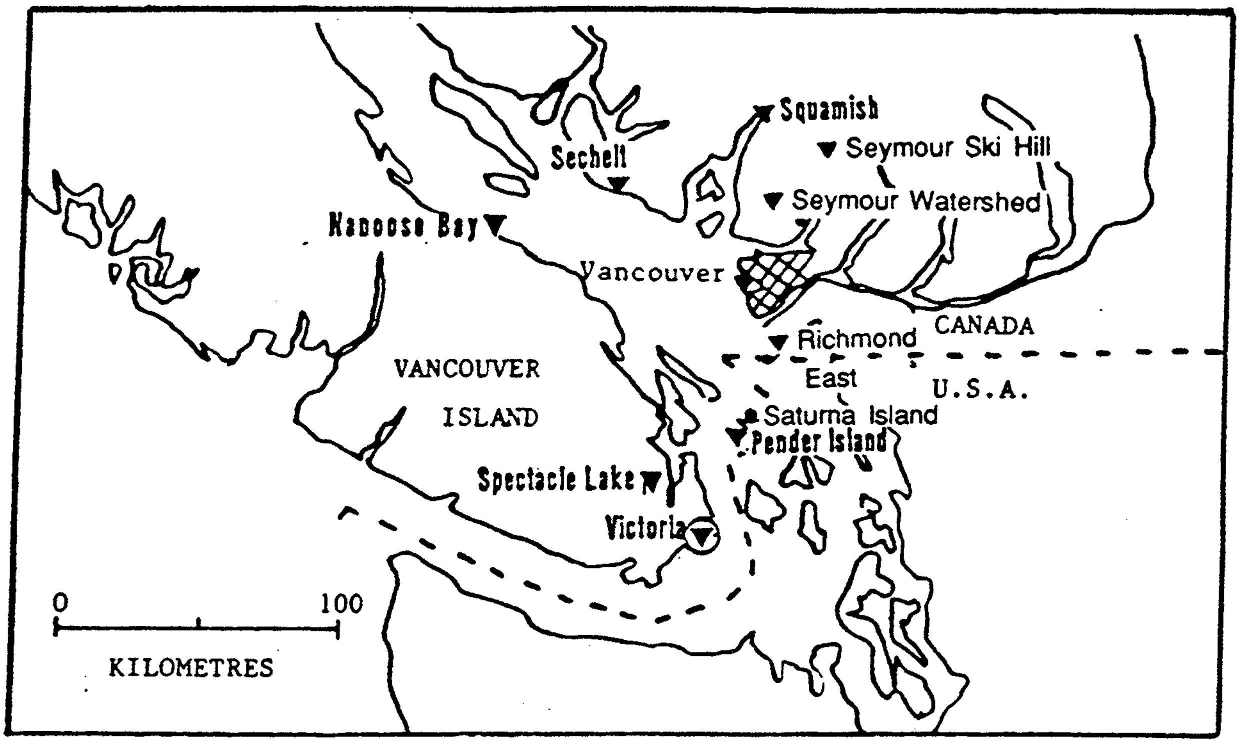


Figure 3. Precipitation Monitoring Stations in the Georgia Strait Area

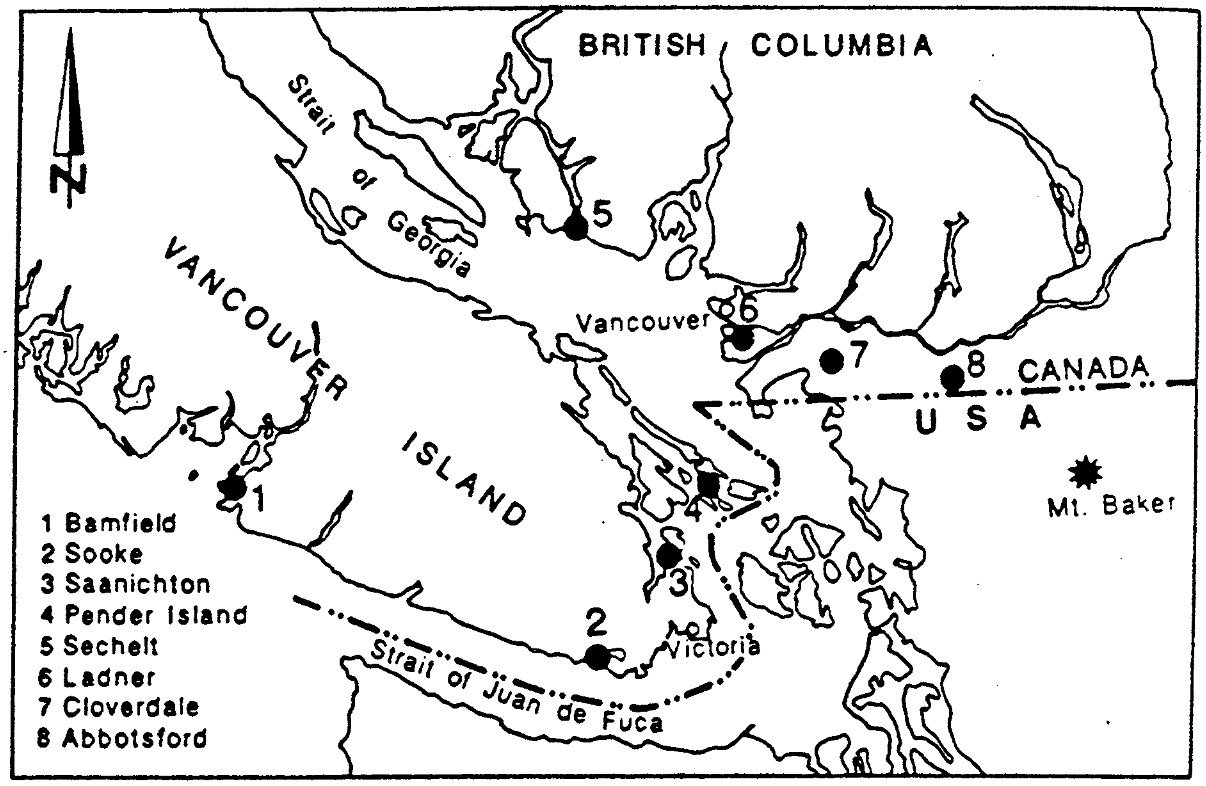
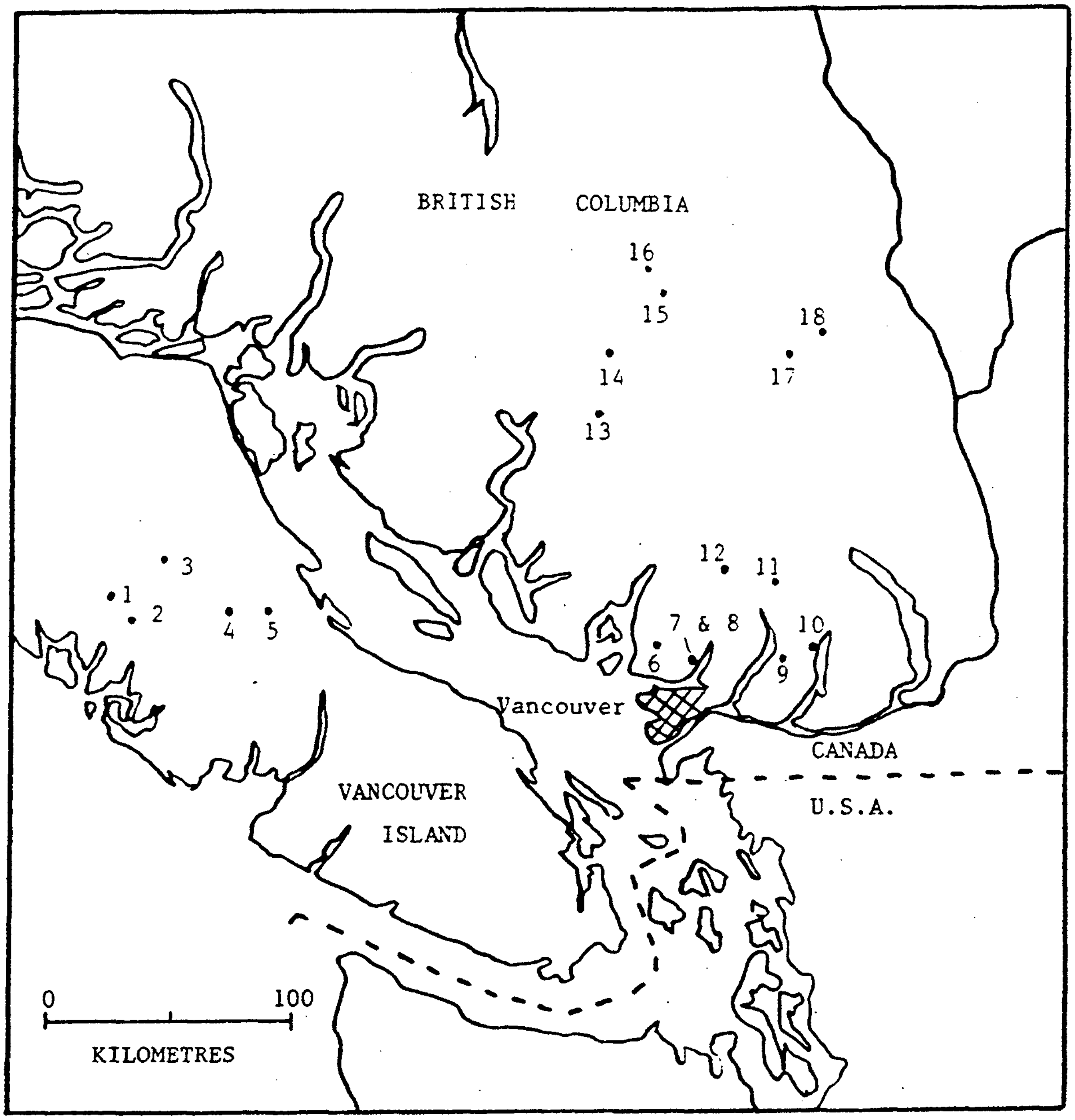


Figure 4. South Coast Event Sampling Network



SNOW SAMPLING LOCATIONS

*01. SPLENDOR MTN LAKE
*02. KOWUS CREEK VALLEY
*03. MT MCBRIDE
*04. COMOX GLACIER
*05. W. OF HAMILTON LAKE
06. THE LIONS
07. MT SEYMOUR (PEAK)
08. MT SEYMOUR (LOGGED AREA)
09. MT BLANSHARD
10. MT ROBIE REID
11. REMOTE PEAK
12. PINECONE LAKE
13. S.W. OF MT CALLAGHAN
14. N.W. OF MT CALLAGHAN
15. NORTH CREEK (1)
16. NORTH CREEK (2)
17. W. OF DUFFEY LAKE
18. CAYOOSH RANGE

Figure 5. Snow Pack Sampling Network

Precipitation Monitoring:

The annual wet deposition of sulphate can be estimated at several locations within the Province. In the Lower Fraser Valley and Vancouver Island area values range from just below 5 kg/ha/yr to more than 25 kg/ha/yr. Levels of pH range from 3.74 to 7.14. Twenty percent of the rain samples from Victoria were strongly acidic (pH < 4.2) with 14 percent being normal (pH > 5.0). In agricultural areas of the Fraser Valley, 92.5 percent of the rain had a pH greater than 5 (M.S. Kotturi, 1988). Isolated industrial areas reported moderate acidity levels (pH $4.3 < 4.5$) in 37 percent of the samples with 12 percent normal and 18 percent strongly acidic. From snow pack analysis, G.A. McBean et al.(1986) determined that in isolated areas the pH was near 5.4 with low ion concentrations and an appreciable sea salt component on the windward mountain slopes. In the Strait of Georgia area and Vancouver region pH values were depressed to near 5.0. Concentrations of sulphate and nitrate analyzed in snow samples were higher than those of remote areas in other parts of the world implying an anthropogenic component. Calculations suggest that sulphate contributes about one-half of the acidity while nitrate and carbonate contribute about one-quarter each. Further away from Vancouver, the concentrations of sulphate and nitrate decrease and the snow becomes less acidic. Interestingly, sulphate levels dropped off much more quickly than nitrate.

Samples of high elevation fog taken from Mount Seymour, north of Vancouver, are acidic having pH values less than 5.0. For the most part, sulphate concentrations are from 2 to 3 mg/l and nitrate 1 to 4 mg/l (personal communication). Sulphate from sea salt was present in several samples but missing completely in others.

Transboundary Air Pollution:

The results of the air and precipitation monitoring programs have identified that the levels of pollution in areas of southern British Columbia are of concern. Is there evidence of transboundary air pollution? Are the levels of these pollutants being elevated by the addition of pollutants from beyond the local area? The answer to both questions is yes!

Regional trajectories derived from the wind regimes of the area provide important insights to the way in which pollution will be transported from a source to a receptor. An analysis of airmass trajectories by D.A. Faulkner (1984) indicated that weather systems from the south to southwest produced precipitation over southwestern British Columbia. This implies that many of the precipitation events will carry pollution from the Puget Sound area.

The first step in dealing with a source/receptor analysis is to sample events. This type of sampling provides an opportunity to trace the airmass trajectory back in time and in so doing identify the source. Fog samples were analyzed in this manner. The preliminary results indicate that an airmass having a trajectory from the south resulted in higher concentrations of sulphate, nitrate and ammonia and lower pH than fog sample that were influenced by cleaner air from the northwest (personal communication).

An analysis of air trajectories associated with ozone episodes in the Lower Fraser Valley (M.C. Coligado, 1988) indicated that there were two source regions. As expected, the Greater Vancouver area was one source with northwestern Washington State being the other.

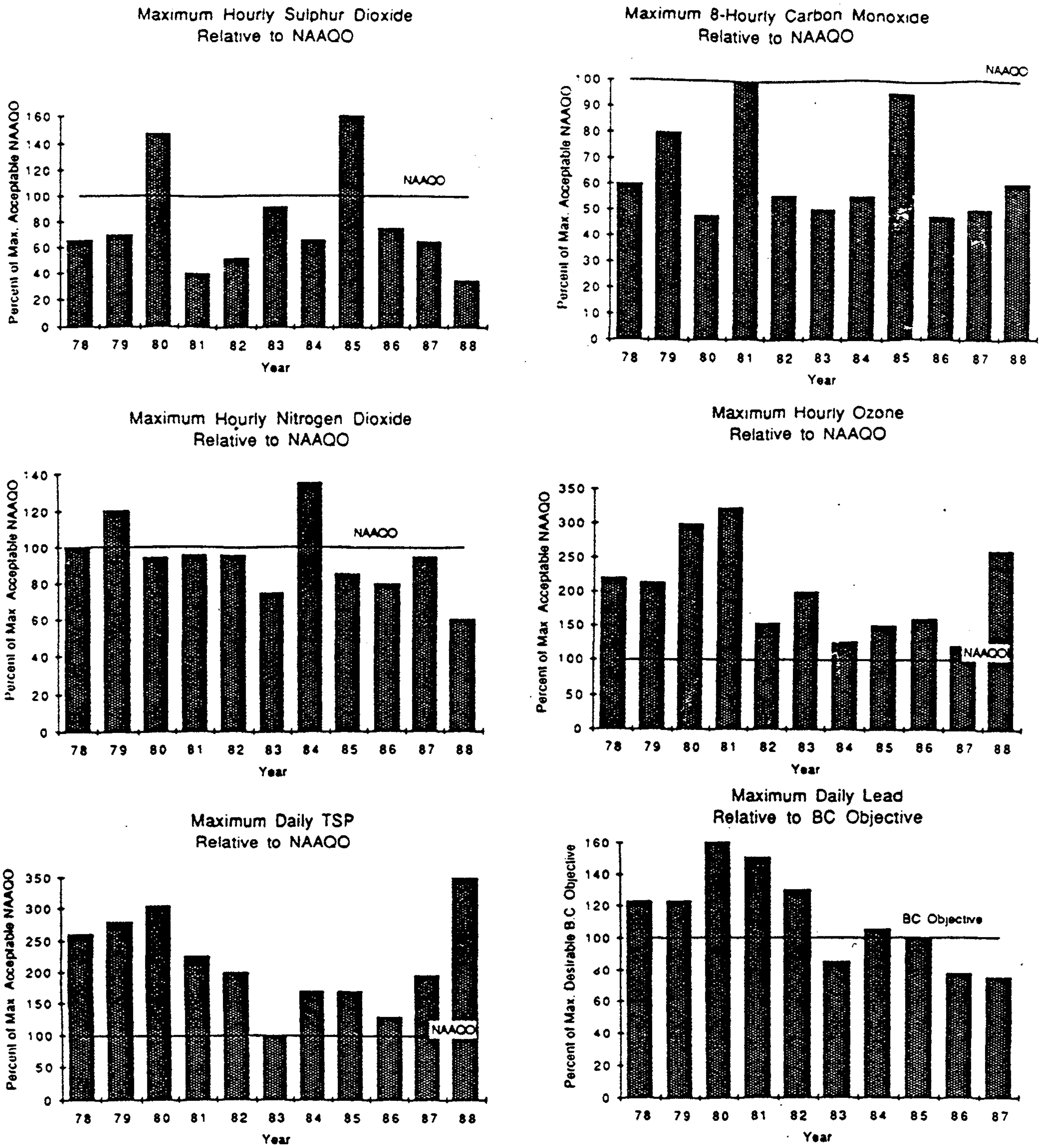


Figure 6. Annual Greater Vancouver Maximum Pollutant Concentrations

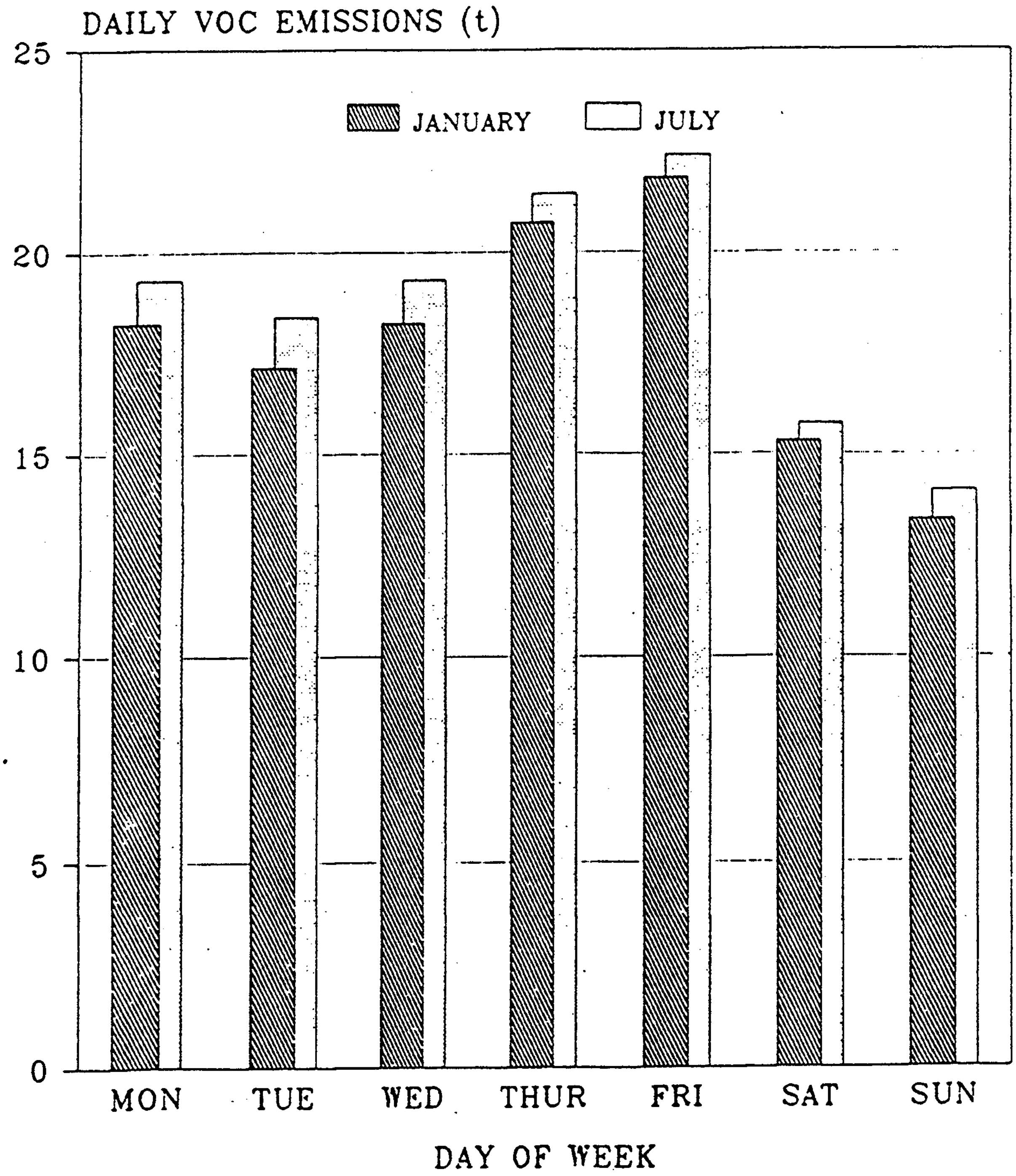


Figure 7. Emissions Volatile Organic Compounds During a Week in January and July 1985 - Vancouver B.C.

Occasionally an opportunity becomes available to identify a source using a chemical as a 'finger print'. Such was the case with the ASARCO smelter near Tacoma in Washington State. The ASARCO smelter was the major source of arsenic in the airshed. D.A. Faulkner (1985) found elevated levels of arsenic in rain samples taken in the Strait of Georgia area. In 1985, the ASARCO smelter closed and arsenic levels decreased dramatically. Once a tracer has been found, correlations with other pollutants can provide further information on sources. The arsenic was correlated with excess sulphate at monitoring sites in the South Coast B.C. network. Sulphate concentrations also decreased after the ASARCO closure.

The establishment of a smelter at Trail in southern B.C. during the 1930's created considerable concern over sulphur dioxide air pollution impacts in the United States. Early International Joint Commission activities partially addressed this issue. In a similar way, the smoke from forestry activities will find its way northward and southward through the steep valleys shared by British Columbia and northern sections of Washington State, Idaho and Montana.

Therefore, it appears that there is a transboundary transport of air pollution. The frequency, concentrations and types of pollutants being transported is still to be ascertained. Trajectories of airmasses must be characterized in an attempt to identify source/receptor relationships.

Needs and Use of Environmental Monitoring Data:

Levels of air pollution in excess of air quality objectives and acidic precipitation have been identified in areas of southern British Columbia. Transboundary air pollution has been documented. There are however several important questions that remain unanswered and further monitoring activities will have to incorporate new design considerations.

In general, environmental monitoring is designed to capture two distinctly different phenomenon; trends and events. Trends can be determined from individual monitoring programs that will maintain a long term data set. This requires a commitment to longevity and maintenance. Source/receptor monitoring necessitates capturing events or episodes and demands spatially and temporally detailed data. This type of monitoring is usually very resource intensive. To adequately understand the processes involved, environmental event monitoring is required. An alternative to event monitoring is to use a chemical mass balance technique to identify source/receptor relationships. This methodology requires detailed speciation of the source pollutants and detailed chemical analysis of the pollution at the receptors. The chemical mass balance technique has been used successfully in apportioning sources contributing to total suspended particulate matter in ambient air samples.

Of prime importance is to identify and quantify pollutants that use the atmosphere as a pathway. Toxic chemicals found in the aquatic and terrestrial systems must be monitored in the atmosphere in conjunction with aquatic and terrestrial studies to ensure episodes can be traced through the entire system. These studies must be combined with meteorological data to provide information on source regions.

Adequacy of Regional Environmental Monitoring:

The concentrations of criteria air pollutants are well documented in the GVRD and surrounding area. The air quality monitoring networks however are deficient with respect to VOCs and PAHs.

Wet deposition trends are becoming established however there are no data on the dry deposition component which is important in areas receiving low amounts of precipitation. Episodic data will be available from the CAPMoN station and will provide information on source/receptor relationships for at least one area in the region.

The meteorological data currently being acquired in the Lower Fraser Valley and southern Vancouver Island are not well suited to describe transboundary airmass trajectories. Existing meteorological data networks are strongly agency specific and do not monitor all of the atmospheric parameters that are important to document environmental issues.

At the present time nearly all of the environmental monitoring is being done in a 'piece-meal' manner with little or no integration. Therefore it is not possible at this time to make statements about holistic environmental impacts. With networks primarily established to address agency mandates, the opportunity to integrate monitoring systems has been limited.

Improvements to Regional Environmental Monitoring:

The meteorological parameters important to the transport and deposition of air pollutants must be measured. Meteorological stations should be upgraded to monitor atmospheric turbulence. Siting of new stations in strategic locations should be addressed to monitor regional and local wind regimes. Existing meteorological networks should be assessed with stations of questionable exposure evaluated. Field studies are required to monitor meteorological parameters during air pollution episodes. Upper air information should be acquired on a regular basis as well as during episode periods to assist in describing vertical temperature and wind profiles.

Precursors of photochemical pollution should be monitored. VOCs in the atmosphere must be speciated. Regular PM10 and acidic aerosol monitoring should be done and total suspended particulate measurements should be phased out. Background wet and dry deposition monitoring should be conducted to determine levels of air pollution and the marine component. More detail is needed on air toxic concentrations in the Lower Fraser Valley and the Strait of Georgia areas.

The monitoring for organic and inorganic compounds in wet and dry deposition should be expanded. A station should also be established in the Lower Fraser Valley to monitor regional background air chemistry, both wet and dry.

In conjunction with monitoring programs, integrated analysis should begin immediately to determine gaps in the existing data. Identified data gaps should then determine the strategy for future monitoring. It is entirely possible that one integrated monitoring site in a region would be sufficient to describe linkages between environmental parameters. These linkages could then be used to integrate the results of existing monitoring networks hence preserving longer term trends.

Summary:

Air pollution networks have been established in the transboundary area of B.C. These networks primarily monitor the levels of criteria air pollutants such as the oxides of sulphur and nitrogen, ozone, total suspended particulates and others. The chemistry of precipitation is also analyzed for levels of acidity and acid deposition. Fog samples have been taken at high elevation sites near Vancouver B.C. to identify the levels of acidic loading.

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