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ENVIRONMENTAL PROTECTION SERVICE, ENVIRONMENT CANADA

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MONITORING, ENGINEERS AND THE ENVIRONMENT

BY

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DELIVERED TO
APEBC WORKSHOP ON ENVIRONMENTAL MONITORING
UNIVERSITY OF BRITISH COLUMBIA
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As a member of the Association of Professional Engineers of British Columbia, I feel very much at home with this group. The fact that this particular gathering of engineers is focussing on environmental matters fortifies that feeling. Engineers in the Environmental Protection Service do it all the time.

I'm sure that we will all find these sessions rewarding - the timing and the subject are right.

I expect that to many of you, handling physical and chemical monitoring data is second nature. However, for the balance of today and throughout tomorrow, there are included a number of speakers who are experienced biologists who will, I'm sure, be introducing to you the realm of biological monitoring and its usefulness in a way which will be an interesting addition to your diverse backgrounds.

We are in a phase when the emphasis in environmental preservation is shifting from cure to prophylaxis. Environmental monitoring, of course, is involved in both of these phases. As you can see by the program, it's a term that covers a wide front. But don't let the terminology throw you - none of it is really alien or even very far removed from engineering. Whatever kind of monitoring we're talking about we are really discussing environmental vigilance, environmental wide-angled vision, environmental foresight. All those aspects of perception which add up to not letting trouble sneak up on you unexpectedly - on getting the data straight. All of which is sound engineering practice.

A DECADE OR SO AGO WHEN THE ENVIRONMENTAL AWAKENING HAD JUST BEGUN, THE WORD ON EVERYONE'S LIPS WAS "AWARENESS". THE WORLD BEHAVED RATHER LIKE A PERSON WHO HAS BEEN ON A LIFETIME BINGE AND WHO SUDDENLY GETS WORD THAT UNLESS HE KICKS THE HABIT, THE HABIT WILL KICK HIM. THERE WERE ELOQUENT RENUNCIATIONS OF PAST BAD PRACTICE - NOTABLY ENVIRONMENTAL SHORT-SIGHTEDNESS AND BLIND FLYING. WHOLE COUNTRIES TOOK THE PLEDGE TO HENCEFORTH STAY ON THE STRAIGHT AND NARROW. STEPS WERE TAKEN TO BACK AWAY FROM THE BRINK AND TO DEAL WITH URGENT PROBLEMS. THAT WAS STAGE ONE AND TO SOME EXTENT WE'RE STILL IN IT.

BUT WE'RE ALSO OVERLAPPING INTO THE SECOND STAGE - THE STAGE WHERE RENUNCIATIONS MUST BE PUT INTO PRACTICE, THE PHASE IN WHICH AWARENESS MEANS NOT SIMPLY KNOWING ABOUT THE DANGER, BUT KEEPING A SYSTEMATIC LOOKOUT - DOING OUR ENVIRONMENTAL HOMEWORK AS A MATTER OF ROUTINE. ENVIRONMENTAL CONCERN IS BEING WRITTEN INTO LAW; ENVIRONMENTAL VALUES INTO THE LEDGER BOOKS. ABOVE ALL, WE ARE TRYING TO CLOSE AN INFORMATION GAP. AND IN THIS PHASE, MONITORING IS OF THE ESSENCE. IN PHASE TWO, WE THINK IN TERMS OF LONGER SCHEDULES. THERE AREN'T AS MANY SHORT CUTS AS THERE WERE IN PHASE ONE. YOU CAN CLEAN UP AN ENDANGERED WATER SYSTEM LIKE THE GREAT LAKES BY WORKING AROUND THE CLOCK AND DEPLOYING RESOURCES ON A MASSIVE SCALE. YOU CAN CUT DOWN ON AUTOMOBILE POLLUTION BY CHANGING EMISSION STANDARDS. BUT ONE OF THE MOST BASIC NEEDS OF PHASE TWO IS ENVIRONMENTAL KNOW-HOW -- KNOWLEDGE ABOUT HOW THE SYSTEM WORKS AND HOW WE AFFECT IT. ALTHOUGH

THERE'S PLENTY TO BE LEARNED IMMEDIATELY, SOME OF THE QUESTIONS WILL BE ANSWERED ONLY BY YEARS OF OBSERVATION. LONG-TERM EFFECTS ARE JUST THAT -- THERE'S NO WAY TO STUDY THEM IN THE SHORT-TERM AND BE COMPLETELY SURE OF YOUR FINDINGS. CLIMATIC CHANGES, FOR INSTANCE, MUST BE MEASURED SOMETIMES OVER DECADES OR EVEN CENTURIES.

STILL THERE IS PLENTY WE NEED TO KNOW NOW AND PLENTY OF INFORMATION THAT WE CAN APPLY IMMEDIATELY.

TAKE FOR INSTANCE THE WHOLE FIELD OF PRE-DEVELOPMENT MONITORING -- WHAT WE COMMONLY CALL IN THE TRADE "BASELINE STUDIES". ONE WAY THAT WE LEARN HOW TO HANDLE THE ENVIRONMENT IS BY TAKING WHAT AMOUNTS TO "BEFORE AND AFTER" DATA PICTURES OF THE ECOSYSTEMS INVOLVED. BASELINE STUDIES PROVIDE THE "BEFORE" PICTURE. THIS ISN'T AS SIMPLE AS A LAY PERSON MIGHT BELIEVE. ONE QUESTION, OF COURSE, IS "BEFORE WHAT"? COMPARISON IS COMPLICATED BY THE DIFFICULTY OF DETERMINING WITH ANY DEGREE OF CERTAINTY WHAT THINGS WERE LIKE BEFORE THE HUMAN IMPACT -- BEFORE MAN CAME ON THE SCENE WITH BULLDOZERS, SUPERSONIC TRANSPORTS, AEROSOL CANS, OR WHATEVER.

AND WHEN YOU DO FIND THAT THE ENVIRONMENT HAS BEEN ALTERED OVER A PERIOD OF TIME, HOW CAN YOU BE SURE OF THE CAUSES? HOW CAN YOU BE SURE THEY AREN'T MAN-MADE BUT NATURAL? THE ANSWER OF COURSE LIES IN THE DILIGENCE AND THE PATIENCE AND THE SKILL OF OUR OBSERVATION. OUR MONITORING ABILITY TO PUT IT ANOTHER WAY.

A REAL LIFE EXAMPLE IS THE WIDESPREAD OBSERVATION OF MERCURY IN OUR ENVIRONMENT. SOME OF IT APPEARS TO BE NATURAL, WHILE OTHER

OBSERVATIONS DECIDEDLY ARE A RESULT OF MAN'S ACTIVITIES. THEN THERE IS THE GREY AREA WHERE WE ARE JUST NOT SURE WHAT THE SOURCE IS. IN TRACKING DOWN THE CAUSE IN THIS CAUSE AND EFFECT SEQUENCE, ONE HAS TO BE HALF SCIENTIST OR ENGINEER, AND HALF SLEUTH. ON THE SLEUTHING SIDE, WE DO KNOW THAT MUSEUM SPECIMENS OFTEN TELL US A LITTLE OF PAST PRACTICES. FISH SPECIMENS TAKEN FROM REGIONS OF NO KNOWN INDUSTRIAL SOURCE OF MERCURY, OVER 100 YEARS AGO, HAVE SHOWN MUCH HIGHER THAN CURRENT BACKGROUND LEVELS OF MERCURY. WE ALSO KNOW THAT COAL WAS THE PRINCIPAL FUEL BURNED IN HOMES THEN, AND SOME COALS HAVE ASSOCIATED WITH THEM TRACE QUANTITIES OF MERCURY. THERE MAY BE A LINK. SUCH SLEUTHING HAS ALSO UNCOVERED INFORMATION ON GOLD MINING PRACTICES OF FIFTY YEARS AGO WHERE MERCURY AMALGAM WAS USED TO RECOVER THE GOLD. DESPITE THE FACT THIS TECHNOLOGY HAS NOT BEEN USED FOR ALMOST THREE GENERATIONS, RESIDUAL MERCURY SEEMS TO BE WHAT WE ARE MEASURING TODAY.

IN SOME RESPECTS, WE IN CANADA ARE THE ENVY OF OTHER NATIONS FACED WITH MAKING THESE JUDGMENTS. SO MUCH OF OUR DEVELOPMENT IS IN THE FUTURE -- THE ENVIRONMENTAL AWAKENING HAS TAKEN PLACE BEFORE TOO MANY MISTAKES HAVE BEEN MADE.

THIS GIVES US A GREAT OPPORTUNITY FOR COMMON SENSE. COMMON SENSE MEANING NOT THAT WE SHOULD, AS SOME ALARMISTS SUGGEST, FREEZE INTO A PARALYSIS OF ALL DEVELOPMENT, APPALLED BY THE POSSIBILITY OF DOING ANY DAMAGE. IT DOES SUGGEST THAT WE CAN MAKE THE DEVELOPMENT OF CANADA'S UNTOUCHED AREAS A CLEANER AND MORE EFFICIENT PROCESS. WE ARE ABLE TO SEND IN AN ENVIRONMENTAL ADVANCE GUARD.

IN THESE BASELINE STUDIES, PROFESSIONAL ENGINEERS, IN AND OUT OF GOVERNMENT CAN FIND GREAT FRONTIERS OF CHALLENGE AND OPPORTUNITY.

NATURALLY, GOVERNMENT WILL BE DEEPLY INVOLVED. THE FEDERAL GOVERNMENT FOR INSTANCE WILL OVERSEE AND PARTICIPATE IN SPECIAL BASELINE STUDIES -- FOR INSTANCE THE ATHABASKA TAR SANDS, OR THE IMPACT OF SST'S ON THE OZONE LAYER. BUT WHEN IT COMES TO PREPARING ASSESSMENTS FOR PARTICULAR PROGRAMS OR DEVELOPMENTS, THE RESPONSIBILITY FOR BASELINE STUDIES -- AND FOR DATA INTERPRETATION AND DESIGN -- WILL BE THE SPONSORS. ENGINEERS IN THE PRIVATE SECTOR WILL BE DIRECTLY INVOLVED.

ENGINEERS WILL FIND THE TERMS OF REFERENCE STRETCHING CONTINUALLY. INCREASINGLY THEY WILL FIND THEMSELVES NOT ONLY DESCRIBING BUT UNDERSTANDING WHAT MAKES THE SETTINGS FOR THEIR PROJECTS TICK ENVIRONMENTALLY -- INCLUDING IN THE EQUATIONS THE INTRICATE INTERACTIONS OF THE PHYSICAL, BIOLOGICAL AND CHEMICAL SEGMENTS OF THE ECOSYSTEMS INVOLVED.

IF, FOR EXAMPLE, YOUR PROJECT IS A SMOKE-MAKER, THEN YOU ARE AUTOMATICALLY IN THE BLUE SKY BUSINESS -- THE PRESERVATION OF THE ATMOSPHERIC ENVIRONMENT. THE EXISTING LEVEL OF AMBIENT AIR QUALITY MUST BE DETERMINED. METEOROLOGICAL MAPPING OF UNIQUE SITUATIONS MAY HAVE TO BE CONSIDERED. YOU MAY HAVE TO ANALYZE ATMOSPHERIC CONTAMINANTS IN LOCAL VEGETATION. GIVEN GOOD DATA ON SUCH MATTERS -- DEEP ENOUGH, WIDE ENOUGH, SOUND ENOUGH -- WE CAN MAKE MORE ACCURATE PREDICTIONS OF IMPACT. WE CAN AVOID COSTLY MID-COURSE OR EVEN ON-COURSE CORRECTIONS.

WE CAN DETERMINE WITH GREATER PRECISION THE AMOUNT OF ENVIRONMENTAL CHANGE. AND KNOWING THIS, WE CAN DO EVEN BETTER NEXT TIME WHICH GIVES ME AN OPPORTUNITY TO TALK A LITTLE ABOUT OUR OWN SHOP. THE ENVIRONMENTAL PROTECTION SERVICE ALONG WITH OTHER SERVICES IN ENVIRONMENT CANADA HERE IN THE PACIFIC REGION ARE HEAVILY ENGAGED IN BASELINE MONITORING AND REVIEW OF IMPACT ASSESSMENTS CONNECTED WITH NEW AND EXPANDING DEVELOPMENTS. THESE STUDIES TAKE US OVER WIDE AREAS -- AND NOT JUST IN GEOGRAPHIC TERMS. FOR INSTANCE OUR PEOPLE HAVE BEEN MAKING STUDIES OF THE PROBABLE IMPACT OF NEW MINING OPERATIONS SCHEDULED TO COME INTO OPERATION IN B.C. IN THE NEXT FEW YEARS. WE HAVE BEEN ASSESSING THE CAPACITY OF WATERSHEDS CLOSE TO THESE DEVELOPMENTS TO NURTURE SALMONID FISH SPECIES, LOOKING PARTICULARLY AT THE PROBABLE EFFECT ON THE ABILITY OF THE FISH TO REPRODUCE. TO DO THIS JOB THOROUGHLY, WE HAD TO DOCUMENT SUCH ASPECTS AS SPAWNING BED POTENTIAL AND NUTRIENT LEVELS, AND THE SIZE OF THE NATURAL FISH FOOD CROP. ALL OF THIS INFORMATION WILL BE USED TO TRY TO IDENTIFY THE WATER MANAGEMENT OPTIONS OPEN TO US, AND TO PREDICT THE POTENTIAL TROUBLE SPOTS. ALL OF WHICH SOUNDS VERY BIOLOGICAL FOR ENGINEERS. IN ENVIRONMENT CANADA, ENGINEERS AND BIOLOGISTS HAVE BEEN WORKING ON THE SAME TEAM FOR QUITE SOME TIME. YOU CAN EXPECT TO DO THE SAME IF YOU AREN'T ALREADY. POLLUTION IS ESSENTIALLY "BIOLOGICAL". IF A CONTAMINANT DOESN'T HAVE SOME ULTIMATE EFFECT ON THE BIOLOGICAL COMPONENT OF THE ENVIRONMENT IN ONE WAY OR ANOTHER, IT WOULDN'T BY DEFINITION, BE A CRUCIAL CAUSE FOR CONCERN.

SO MUCH FOR BASELINE STUDIES. MONITORING, OR TO PUT IT MORE GENERALLY FACT-FINDING, DATA COLLECTION, IS THE FIRST STEP IN ENGINEERING RATIONAL, WORKABLE ENVIRONMENTAL LAW. ENGINEERS ARE

INVOLVED IN THIS PROCESS FROM THE START -- AND SHOULD CERTAINLY TAKE AN INTEREST SINCE THEY WILL HAVE TO WORK WITHIN THESE GROUND RULES THROUGHOUT THEIR PROFESSIONAL LIVES.

THE ESTABLISHMENT OF ACHIEVABLE REGULATIONS AND THE SETTING OF ACCEPTABLE ENVIRONMENTAL STANDARDS HAVE NOT BEEN ARRIVED AT BY INSPIRED GUESSWORK, INTUITION OR EVEN BY PULLING NUMBERS OUT OF A HAT. THEY REFLECT A CONSCIENTIOUS ASSEMBLY OF DATA IN EACH INDUSTRIAL SECTOR. FOR EXAMPLE, BEFORE WE WROTE EFFLUENT REQUIREMENTS FOR THE MINING INDUSTRY, WE BEGAN BY DEFINING IN DETAIL THE INDUSTRY'S WATER POLLUTION PROBLEMS. THIS MEANT MONITORING THE EFFLUENT QUALITY OF MANY OF CANADA'S MINES SO THAT WE COULD DETERMINE, AMONG OTHER THINGS, WHICH PROBLEMS WERE COMMON TO ALL AND WHICH WERE OFFBEAT OR PECULIAR TO A GIVEN OPERATION.

MONITORING, THEREFORE, PLAYS AN IMPORTANT PART IN THE EVOLUTION OF ENVIRONMENTAL REGULATIONS. WE NEEDED INFORMATION NOT ONLY ABOUT THE MINING INDUSTRY BUT OTHER INDUSTRIES WHICH CONTRIBUTE TO POLLUTION -- DATA ABOUT EXISTING POLLUTION ABATEMENT PROCESSES AND HARDWARE. WITH THIS INFORMATION, WE COULD GO ON TO TRANSLATE THAT WELL-KNOWN GENERALITY "STATE OF THE ART", OR "BEST PRACTICABLE TECHNOLOGY" INTO PRECISE TERMS. THE USE OF BEST PRACTICABLE TECHNOLOGY (BOTH ADJECTIVES ARE IMPORTANT IN THIS TERM BY THE WAY) IS THE BASIS OF OUR APPROACH TO SETTING NATIONAL BASELINE STANDARDS IN BOTH AIR AND WATER. THE COLLECTION OF DATA, THE DISCOVERY OF INFORMATION ABOUT THE PROBLEM, GOES ON EVEN AFTER REGULATIONS ARE PUBLISHED. WHAT'S BEST AND MOST PRACTICABLE AMONG THE AVAILABLE OPTIONS CHANGES AS TIME GOES ON AND WE REDEFINE WHERE NECESSARY.

TEAMWORK IN GATHERING THE DATA BASE FOR LEGISLATION HAS GIVEN CANADA AN ENVIABLE RECORD OF SUCCESS IN THIS FIELD. FOR THE MOST PART, WE HAVE MANAGED TO AVOID A WASTEFUL AND DAMAGING ADVERSARY APPROACH. FEDERAL AND PROVINCIAL GOVERNMENTS ARE USING THEIR JURISDICTIONAL DISTRIBUTION OF POWERS NOT TO PLAY ADVERSARY GAMES BUT AS THE BASIS FOR AN INTERMESHING STRATEGY.

BUSINESS HAS BEEN FORTHCOMING AND PROGRESSIVE. FOR INSTANCE, WHEN WE WERE DEVELOPING WATER POLLUTION CONTROL REGULATIONS FOR PETROLEUM REFINERIES, WE RECEIVED CLOSE COOPERATION FROM THE INDUSTRY AND ITS ENVIRONMENTAL ARM: THE PETROLEUM ASSOCIATION FOR THE CONSERVATION OF THE CANADIAN ENVIRONMENT. PACE TOGETHER WITH PROVINCIAL GOVERNMENTS HAD REPRESENTATIVES ON THE TASK FORCE THAT DEVELOPED TOXICITY TESTING METHODS. PACE INVESTIGATED THE EFFECTIVENESS OF MONITORING METHODS -- STATIC AND CONTINUOUS FLOW BIOASSAY TECHNIQUES USING EFFLUENTS FROM SELECTED REFINERIES. TESTS WERE CONDUCTED AT THE LEVELS SUGGESTED AS BPT FOR CHEMICAL CONSTITUENTS SUCH AS PHENOL AMMONIA AND pH UNDER SHORT AND LONG-TERM TESTING CONDITIONS. THE ULTIMATE OBJECTIVE WAS TO OBTAIN A CATCH-ALL TOXICITY TEST WHICH COULD BE EFFECTIVE IN ASSESSING THE ADEQUACY OF BEST PRACTICABLE TECHNOLOGY AT EACH PARTICULAR REFINERY. AS A RESULT OF THIS WORK, THE FISH TOXICITY LIMITS AND TEST PROCEDURES DESCRIBED AS A COMPANION TO THE EFFLUENT REGULATIONS FOR THAT INDUSTRY WERE LARGELY INFLUENCED BY THE DATA PUT FORWARD BY INDUSTRY ITSELF.

MONITORING ALSO MEANS RUNNING CONTINUOUS CHECKS TO SEE HOW WELL WE'RE DOING. OUR REGULATIONS ALL SPECIFY THAT EXISTING POLLUTION ABATEMENT FACILITIES MUST BE MONITORED BY THEIR OWNER. THIS DATA

TOO IS FED INTO THE COMPUTER AND THE RECORD. IT IS SCRUTINIZED REGULARLY SO THAT WHEREVER NECESSARY, CHANGES CAN BE MADE. WE CAN ALSO PICK UP THOSE POLLUTION SOURCES THAT CONTINUE TO FALL SHORT OF THE REQUIREMENTS AND DECIDE WHAT TO DO TO BRING THEM INTO COMPLIANCE.

THIS FIELD WILL DEMAND PEOPLE WHO CAN INTERPRET BIOLOGICAL DATA GENERATED FROM BIOASSAY TECHNIQUES -- A COMMON MONITORING TOOL SPECIFIED IN MANY OF THE REGULATIONS. THESE PEOPLE WILL FIND PLENTY TO DO IN PROCESS ENGINEERING, QUALITY CONTROL AND WASTE TREATMENT. FOR INSTANCE, IN THE PULP AND PAPER INDUSTRY, QUALITY CONTROL ENGINEERS EXAMINING PULP MILL WASTE WATERS REQUIRE AN EXTENSIVE BACKGROUND IN THE MONITORING OF PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS TO FULFILL THE REGULATORY REQUIREMENTS OF THAT INDUSTRY.

MONITORING NOT ONLY ALLOWS US TO CORRECT COURSE. IT CAN BE THE OPENING INTO NEW FRONTIERS OF DISCOVERY. THE ENGINEER WITH A FLAIR FOR INNOVATION CAN FIND PLENTY OF CHALLENGE IN THIS FIELD. CURRENT MONITORING TOOLS ARE CERTAINLY NOT UP TO THE LEVEL OF TECHNOLOGY IN OTHER AREAS. CONSIDERABLE EFFORT MUST BE DEVOTED TO NEW TECHNIQUES FOR CONTINUOUS STACK GAS MONITORING; TO THE DEVELOPMENT OF ION SPECIFIC IN SITU PROBES. WE MAY BE ABLE TO PUT MEN ON THE MOON, BUT IN MANY AREAS, WE ARE STILL COLLECTING SAMPLES WITH A TIN PAIL. IN ADDITION, GUIDED BY DATA TURNED UP IN MONITORING THE ENGINEER CAN START BRAINSTORMING NEW TECHNOLOGY -- NOT ONLY FOR ABATEMENT BUT FOR BETTER, MORE ECONOMICAL, MORE CONSTRUCTIVE USES OF EFFLUENTS AND WASTES -- FOR RECYCLING WASTES. THIS FIELD IS PRACTICALLY UNTAPPED. ALSO THE WHOLE AREA OF IMPROVING THE ECONOMICS OF POLLUTION

CONTROL. FOR INSTANCE, BY TACKLING POLLUTION NOT JUST AT THE END OF THE PIPE BUT INSIDE THE PLANT.

RELATIVELY SPEAKING, WE HAVE ONLY JUST BEGUN TO INNOVATE IN THIS AREA BUT ALREADY THERE HAVE BEEN SOME GIANT STRIDES. ONE IS THE RAPSON-REEVE RECOVERY PROCESS WHICH COULD PRODUCE, EVENTUALLY A VIRTUALLY EFFLUENT-FREE KRAFT MILL INDUSTRY. FIELD TESTING ON A REAL LIFE PULP MILL IS PRESENTLY BEING CARRIED OUT BY A COST-SHARING CONTRACT UNDER THE DEVELOPMENT AND DEMONSTRATION OF POLLUTION ABATEMENT TECHNOLOGY PROGRAM -- WHICH IN THE INTERESTS OF SAVING PAPER WE USUALLY SHORTEN TO DPAT. THIS NEW PROCESS IS BEING INCORPORATED FOR THE FIRST TIME AT A NEW BLEACHED KRAFT MILL AT THUNDER BAY, ONTARIO. UNDER THE DPAT CONTRACT, THE EXPERIENCE, EVALUATION AND DOCUMENTATION OF THIS NEW PROCESS WILL BE MADE AVAILABLE TO OTHER INTERESTED COMPANIES.

IT IS FIRMLY BELIEVED THAT ALL NEW KRAFT MILLS WILL BE OF THE EFFLUENT-FREE TYPE AND THAT PROCESS WATER WILL BE COMPLETELY RECYCLED AT SUBSTANTIAL SAVINGS IN CAPITAL AND OPERATING COSTS COMPARED WITH EXTERNAL EFFLUENT TREATMENT. THE TECHNOLOGY WHICH WILL DERIVE FROM THIS PROJECT WILL ALSO ALLOW MOST EXISTING MILLS TO SIGNIFICANTLY REDUCE THEIR DEMANDS FOR PROCESS WATER.

IN SHORT, MONITORING IS CENTRAL TO BOTH MAIN PHASES OF ENVIRONMENTAL ENGINEERING -- IT HELPS US USE EXISTING METHODS MORE EFFICIENTLY TO SOLVE CURRENT PROBLEMS. IT ALSO KEEPS ADDING TO OUR STOREHOUSE OF INFORMATION -- OUR ENVIRONMENTAL UNDERSTANDING, AND PUTS NEW TOOLS WITHIN REACH.

Let me describe one other feature of environmental monitoring which may have been implied from what I have already said. It is an extension of baseline studies to determine the environmental situation in the future and to determine the trends -- how well we are doing or how badly. In many situations where there are countless points of entry of chemicals into the environment, the only means of control is a restriction on the use of a chemical to prevent its release. Such is the realm of the Environmental Contaminants Act. And, since the entire environment is the receiving zone, general environmental monitoring is required to tell us how we are doing. Furthermore, product control can lead to a delay of the chemical entering the environment from the waste stream. For example, it has been estimated that PCB's will reach a peak in the environment in 1985 eventhough non-electrical uses were largely stopped in 1971.

Which brings me to an acronym with a singularly unattractive sound but an extremely important meaning -- EARP -- the federal government's Environmental Assessment and Review Process.

The Government of Canada has made it a matter of policy that every major development in which it is involved, either directly or in other ways -- through financing for instance, or through the use of crown land, must pass through the EARP screen. The first step in EARP is a screening by the initiator -- i.e. the federal department or agency which is going to undertake the project or sponsor it. The initiator screens the plan for probable environmental effects. Ideally this should happen as early as the intention. (We all know which road good intentions are lined with.)

If the project doesn't seem to pose environmental problems, the light stays green. If there are potential ill-effects, it goes yellow and the initiator completes, or gets completed, an Initial Environmental Evaluation -- using guidelines approved by DOE. In many cases, this evaluation will be done by the company, province or other organization involved in the project. The initiator determines if the environmental effects are likely to be significant. If not, the light stays green -- and the initiator proceeds with project planning, based in part on the initial environmental evaluation. The initiator is encouraged at all stages to touch base with the Chairman of the Environmental Assessment Panel, in DOE -- so that the Chairman can give appropriate advice to the Minister of the Environment.

Where projects look as if they will indeed have a significant environmental effect, their initiators will have to submit the plan to the Chairman. The Chairman sets up a Panel of members whose major task is to issue guidelines to the initiator for the preparation of an Environmental Impact Statement. The Impact Statement is submitted to the Panel which then decides on its completeness and acceptability. The Minister of the Environment reviews the Panel's report on the Impact Statement with whichever of his cabinet colleagues is involved in the project. Out of this process comes eventually a final decision or set of decisions about design construction and operation of projects.

Given the scope of federal involvement in Canadian development, EARP is not simply an extension of the government's commitment to the practice of good environmental housekeeping. It is a system

WHICH WILL INFLUENCE DEVELOPMENT IN EVERY SECTOR. ALTHOUGH THE PROCEDURE SOUNDS BUREAUCRATIC TO THE EXTREME WITH ITS REFERRALS AND COUNTER-REFERRALS, IT IS BASED ON FAIRLY SIMPLE PRINCIPLES. THE BOARD CHAIRMAN POINTED OUT IN A RECENT SPEECH "ENVIRONMENTAL ASSESSMENT" IS MORE THAN A PROCESS. ESSENTIALLY, IT IS A JUDGMENTAL DECISION BASED ON, AND IN SUPPORT OF, A NATIONAL POLICY; AN EXAMINATION OF HOW WELL WE'RE LIVING UP TO THAT POLICY. WHAT POLICY? WELL TO STATE IT IN PLAIN LANGUAGE -- TO MAKE SURE OUR INDUSTRIAL DEVELOPMENT DOESN'T UNDERMINE OUR ENVIRONMENTAL BASE.

THIS IS A GOAL THAT PEOPLE IN ALL PROFESSIONS SHARE -- ONE THAT EVERYONE WITH A SOUND SENSE OF SELF-INTEREST CAN AGREE UPON. ENVIRONMENTAL ASSESSMENT IS AN ASSESSMENT OF HOW THE COMMON HUMAN INTEREST IS BEING PROTECTED. THE QUALITY OF THE ENVIRONMENT WILL DEPEND ON THE QUALITY OF THE ASSESSMENT WHICH IN TURN WILL DEPEND ON THE SKILL, THE DILIGENCE AND THE OBJECTIVITY OF THOSE INVOLVED. TO SAY NOTHING OF THE PERSISTENCE WITH WHICH THAT OBJECTIVITY IS DEFENDED -- THE EXTENT TO WHICH ENGINEERS AMONG OTHER PEOPLE KEEP THEIR EYE ON THE BALL.

AS THE PRINTED PROGRAM FOR THIS EVENT PUTS IT "THE ENGINEER THROUGH HIS (AND I ASSUME HER) ENDEAVOURS TO BUILD FOR MANKIND, HAS THE POTENTIAL FOR CHANGING THE ENVIRONMENT IN WAYS NOT ANTICIPATED". THROUGH CLOSE CONTACT AND GOOD SENSE, I HOPE WE CAN INCREASE THE ANTICIPATION FACTOR.

THANK YOU.

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AND

ENVIRONMENTAL PROTECTION SERVICE-ENVIRONMENT CANADA

TOWARDS A LAND USE MANAGEMENT PHILOSOPHY IN BRITISH COLUMBIA

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TOWARDS A LAND USE MANAGEMENT PHILOSOPHY IN BRITISH COLUMBIA

The common theme of this conference is the monitoring of environmental quality. The word "monitoring" implies a more or less continuous process of observation of the object of concern, be it water quality, air quality or whatever, with a view to quality control and management. Just as the individual elements of the biophysical environment - water, air, soil, flora and fauna - may be monitored, so it is both possible and desirable to monitor the entire biophysical system as a total resource for resource management purposes.

Certainly this theoretical ideal is gaining wider acceptance in principle among those various institutions of the Government of the Province of British Columbia which are involved in land use management. At present, however, the practical reality is far from the ideal because of the problems which must be overcome in order to mesh the numerous institutional jurisdictions into a co-ordinated land use management process.

The purpose of this paper is two-fold. Firstly, it outlines the institutional framework within which the Province implements its environment and land use policies; and secondly, it describes some of the programs and approaches which have recently been adopted so as to provide a more complete land management data framework within which to make land use allocation decisions.

1. DEVELOPMENT OF THE PRESENT INSTITUTIONAL FRAMEWORK

Any attempt to unravel the web of provincial environment and land use policies and practices encounters an extremely complex agglomeration of jurisdictions, policies, motivations and interests. The agencies and groups which are involved include provincial departments, Crown boards, corporations and commissions, municipalities, regional districts, the newly-formed regional resource management committees, and, at the top of the hierarchy, the Environment and Land Use Committee and its Secretariat. It is worthwhile briefly to trace the origins of these various institutions in order to explain their current roles and interrelationships.

1.1. EARLY HISTORY OF RESOURCES DISPOSAL

The British North America Act of 1867 bestowed upon the Provinces a jurisdictional responsibility for resources and land use allocation. Exempted from this provision were sea coast and inland fisheries, and any matters of an inter-provincial or international nature; such matters are federal government responsibilities.

The forerunners of most of today's resource departments and resource statutes came into being during the years which immediately followed the acceptance of British Columbia into Confederation in 1871. There were portfolios for the regulation of disposal and exploitation of timber, water, minerals and land (for agriculture and settlement), and for the provision of transportation facilities and public works.

The objectives of the early resource departments were primarily to administer the conveyance of Crown lands and resource rights to would-be settlers in a simple, orderly fashion. Crown rights to land and resources were purposefully alienated on a permanent basis for very low cost in order to encourage settlement. That resources appeared to be limitless was reflected in the absence of concern for the long-term prospect of diminishing resources. There was no perception of the need for resource management and conservation as they are practiced today since resource conflicts within the vast provincial domain were virtually inconceivable and, from the very beginning, therefore, the resource departments pursued independent policies and programs. In other words, the Province, from the outset, viewed the total environmental resource primarily in terms of its component sectors.

1.2. EARLY LAND USE PROBLEMS IN URBAN AREAS

Land use allocation was first perceived as a process which could benefit from some form of control within built-up areas around the turn of the century, particularly in the Lower Mainland. The Province began to organize such areas into municipalities which were granted some powers to provide local works and services, and somewhat weaker powers to control land uses. As urban growth and townscape evolution proceeded, however, there was a virtually complete absence of planning beyond the initial establishment of a lot survey and grid-iron street layout, so that the pattern of urban land uses tended to be relatively random.

With the passage of the Town Planning Act in 1925, municipalities were empowered for the first time to prepare official town plans and to zone lands. Unfortunately the Act did not promote effective town planning in the broad sense. Town planning became equated with the static process of zoning and has remained so to this day within many municipalities.

Meanwhile, it was to be another 21 years before the Province officially recognized the presence of problems within built-up areas situated beyond municipal boundaries. An amendment to the Town Planning Act in 1946 empowered the Cabinet to regulate the subdivision of lands in unorganized areas through the creation of "regulated areas". This measure was designed to prevent the further development of chaotic land use patterns on the rural-urban fringe.

1.3. THE FIRST REGIONAL PLANNING PROCESS

As a logical next step, amendments to the Town Planning Act in 1948 provided for the designation of regional planning areas for planning purposes. The amendment was a response to public pressure in the Lower Mainland where land use problems were becoming serious. The first regional planning board was established in the Lower Mainland in 1949. By 1965, an estimated 70 per cent of the Province's population dwelt within regional planning areas. The areas were centered upon the larger urban concentrations, but extended into the adjacent unorganized territory. Thus, regional planning boards were able to address themselves to the interactions between urban centers and their rural hinterlands. Regional planning boards, however, exercised only an advisory role, with the result that the planning process was heavily dependent upon the goodwill and co-operation of local government participants and other government agencies.

Statutory provisions which were enacted during the period between 1948 and 1965 did not significantly facilitate the planning process for the most part. The Town Planning Act was repealed in 1957, and its municipal planning provisions were transferred to a newly-streamlined Municipal Act. One important new provision was that planning resolutions of a regional planning board could become binding on all local government authority participants if two-thirds of the board members supported the resolutions. The Local Services Act of the same year replaced the provisions of the Town Planning Act with respect to unincorporated areas. The Minister of Municipal Affairs was thereby empowered to establish regulations for zoning, subdivision and construction standards in addition to organizing local services in unorganized areas.

1.4. THE REGIONAL DISTRICTS

The Minister now became heavily involved in the administration of services and controls in unorganized areas. Furthermore, there was widespread concern for the lack of local input into the Minister's decisions. For these reasons, the Minister's functions were formally decentralized in 1965 when, by amendment to the Municipal Act, an interlocking network of 29 regional districts was created.

Regional district boards include both appointed representatives from municipal councils and directly elected members from unincorporated areas. They administer the Minister's regulatory functions in unincorporated areas (zoning, subdivision and construction regulation), provide services, and are also expected to develop regional plans. Individual municipal councils retain considerable autonomy - just as they had done under the regional planning board system - but regional plans and other types of land use resolution may become land use allocation by-laws which are binding on all parties if board members representing two-thirds of the population of the regional district support them.

While the regional districts have proved to be suitable vehicles for the discharge of many local functions, including health and sanitation, recreation, water supply, sewage disposal, fire prevention and garbage collection, they have encountered very considerable difficulties in their attempts to undertake land use planning.

There are many reasons for these difficulties, including: (i) a lack of clear definition of the regional district planning role; (ii) the considerable autonomy of member municipalities; (iii) the geographically inappropriate nature of some of the areas which have been designated as regional districts; and (iv) a lack of staff and funds for planning. Perhaps the single most important problem, however, is the fact that many government agencies exercise environment and land use jurisdictions which are entirely independent of regional district control. In fact, the only largely uncontested jurisdiction of regional districts is exercised on private lands in unorganized areas, and even here, agricultural land reserve (ALR) zoning may severely restrict land use options. All Crown lands are under some form of more centralized provincial jurisdiction.

Crown lands comprise approximately 93 per cent of the area of the Province. Most of the remainder, the permanently alienated seven per cent, is located within municipalities on Vancouver Island and in the Lower Mainland. Few regional districts, particularly in other parts of the Province, exercise primary jurisdiction over more than three or four per cent of their areas.

1.5. AGENCIES WITH CENTRALIZED RESPONSIBILITIES

The more centralized provincial responsibilities are administered through two types of agency, either a department or some form of Crown agency of special status, for example a board, corporation or commission.

The departments tend to be closer to the government process than the special agencies, particularly the Crown Corporations, and have exhibited a greater ability and inclination to adapt their policies and practices to changing priorities (as transmitted through changes in political direction). Most departments have exhibited an increasing awareness of the need for improved environment and land use decisions and they have been willing to contribute to interdepartmental efforts to this end. Perhaps the most impressive aspect of recent progress has been the much greater willingness of the resource departments to liaise with each other on environment and land use questions of mutual interest. Many programs are now being developed within departments which are designed to include inputs from other resource agencies.

Nonetheless, many of these departments are large bureaucratic structures within which there is an inevitable tendency to resist rapid changes in policies and priorities, preferring small-scale incremental changes. Partly for this reason, the present departmental response to environment and land use matters has lagged behind the recognition of problems, so that, while there has been a recent phase of innovativeness in departmental policy making, areas of inadequacy remain.

In comparison to departments, the special Crown agencies are afforded a relatively high degree of autonomy in the planning and implementation of their programs, and the public is typically less aware of their activities. The Provincial Government employs Crown Corporations for almost all major forms of public development, including hydro-electric power generation, railroads, harbours, forest products, petroleum and other forms of industrial development. In fact, the only major public developers with departmental status at present are the Department of Highways and the Department of Housing.

The Cabinet retains its control over these agencies through its powers to appoint board members and it is quite common for Cabinet Ministers to hold positions as directors. However, the development agencies are characteristically secretive while planning developments, and the public is only rarely provided with an opportunity to participate meaningfully in the planning process. The agencies control the processes which determine whether or not the types of development for which they are responsible are required, and it is only recently that such decisions have been questioned. Hitherto it has been sufficient to argue that an increase in the demand for a particular service has been projected and that action must be taken to satisfy the demand. Historically, little concern has been expressed for such issues as: (i) whether the preferable course of action is to meet the demand or to manage it in a fashion which constrains it below projected levels; and (ii) identification of the full range of impacts which stem from a development, both long-term and short-term, and both beneficial and adverse. The powers of the development agencies are usually enhanced by extensive expropriation rights and, in the cases of projects such as dams, highways, railways or harbours, large quantities of lands and resources may be irretrievably committed.

Not all of the special Crown agencies are development agencies. The Province has also established commissions to perform regulatory functions, as in the case of the B.C. Land Commission (BCLC), B.C. Energy Commission (BCEC) and B.C. Assessment Authority (BCAA).

1.6. RESOURCE DEPARTMENT JURISDICTIONS

The plethora of land use jurisdictions which hinders planning in built-up areas is mirrored by the plethora of resource agency jurisdictions and tenure systems which has been superimposed upon Crown lands in unincorporated areas. As noted elsewhere, individual agencies have pursued historically independent programs. This has been a major contributory factor towards the lack of co-ordination and co-operation which has been evident among the resource agencies since 1950 when, as a result of the now much more widespread nature of development, major resource and land use conflicts have become commonplace.

It is not possible in this paper to describe in detail the various resource agency jurisdictions. It is worthwhile, however, to comment briefly on some aspects of current resource management approaches within each agency.

1.6.1. DEPARTMENT OF AGRICULTURE (BCDA)

The BCDA is an advisory and regulatory agency whose major concerns are the administration and regulation of agricultural practices and the quality and quantity of food production. The department has no executive power to control the use of land directly, although it exercises an indirect influence on land use and resource management through public education programs and through its connection to various ARDA (Agricultural Rehabilitation and Development Act) land management programs.

1.6.2. DEPARTMENT OF ENVIRONMENT (BCDOE)

The following observations are based on the assumption that the individual agencies which have been transferred to this newly-created department will continue to pursue their present functions.

(a) The Lands Service (BCLS)

The BCLS administers the disposition of Crown land for both public and private purposes pursuant to the Land Act. The BCLS jurisdiction is effective over 30 to 40 per cent of provincial Crown lands - those Crown lands which are considered to be "vacant" or which have already been Crown-leased according to the terms of an agreement pursuant to the Land Act. Other agencies such as the Department of Forests and the Provincial Parks Branch also exercise Crown land jurisdiction by statute.

Problems have been associated in the past with the BCLS land disposal process. For example, the process has been associated with poorly-located and poorly-serviced subdivisions, with the alienation of forest land and farm land, with the alienation of provincial waterfront rights, and, in general, with the granting of rights which were not necessarily in the broadest public interest.

The BCLS is now striving to achieve a land disposal mechanism which has more of the features of a comprehensive land management process, taking into consideration natural resources management, environmental and socio-economic concerns, local and regional land use planning objectives, and local community aspirations. The success of this objective is highly dependent upon inter-agency co-operation, and the BCLS is now sponsoring local planning studies and resource data base folios with inter-agency input. It will probably be many years, however, before land use allocation decisions at the local scale will be made within the context of the type of all-embracing framework which is described above.

(b) The Water Resources Service (BCWRS)

All matters pertaining to the water resources of the Province are under the jurisdiction of the BCWRS, pursuant to the Water Act and the Pollution Control Act, 1967.

The BCWRS has encountered difficulties in bringing the Province's water resources under a comprehensive water management program. A major problem has been the piecemeal nature of the present water inventory. Data are scarce or non-existent in many parts of the Province. Furthermore, the legislation does not contain water management provisions. The Water Act regulates the orderly granting of water rights but does not specifically require that decisions should be taken within a broad water management framework.

Similarly, the Pollution Control Act, 1967 regulates the licensing of waste discharges without, however, specifically providing for consideration of the characteristics of individual receiving environments in determining maximum acceptable waste discharge levels. Pollution control standards, once set, tend to be applied broadly. Enforcement of these standards to date has been hampered by the high economic costs which are incurred by both industry and the urban taxable base.

Despite the lack of statutory provisions for broadly-based water management and pollution control management, it is now working policy to promote this aspect of the regulatory functions of the BCWRS. For example, the agency is becoming increasingly involved in floodplain management programs and, in particular, is striving to prevent development prior to the construction of protection works in flood-prone areas. The BCWRS has also undertaken water management studies in local situations and usually stresses public involvement in these studies.

1.6.3. DEPARTMENT OF FORESTS (BCDF)

The following observations are based upon the assumption that the newly-formed BCDF will exercise those functions which have been performed hitherto by the B.C. Forest Service. The BCDF has sole responsibility for the administration of Crown timber resources pursuant to the Forest Act.

Forestry is the single most important primary industrial sector in the provincial economy. Over the years, therefore, the Forest Service has developed into the most powerful provincial resource management agency. Its legislated jurisdiction is effective over more than 50 per cent of the Province's area.

The BCDF regulates the harvesting of Crown timber according to sustained yield principles which are designed to prevent long-term depletion of merchantable stocks. At present, however, there is a fear that a long-term depletion is indeed taking place as a result of over-estimation of annual allowable cuts (AAC's) in the Province's public sustained yield units (PSYU's) and tree farm licenses (TFL's). This fear stems from analysis of the ever-improving forest inventory data base which suggests that early estimates of the AAC's, some of which date from the 1950's, may have been too high. All BCDF forest management programs are based upon a very detailed on-going forest inventory mapping program.

An important feature of the provincial forest tenure system is its extreme complexity. Only in the PSYU's has the Province retained for itself complete control of harvesting. The old temporary tenures and TFL's are under less direct forms of provincial control and, as such, are less amenable to manipulation as part of broader regional and local land use management programs.

Resource conflicts are commonly associated with the practice of forestry, since a wide range of resource activities, including agriculture, fish and wildlife management, and recreational activities, may be suited to forested terrain. A fundamental problem arises from the fact that the BCDF, which has an overt commitment to timber management, has been compelled to move into the arena of multi-resource management, although the agency is not necessarily particularly suited to perform an integrative role.

The BCDF now sponsors resource overlay folios as its primary tool for the resolution of resource conflicts. The folios are employed to determine the location of logging operations in a manner which will hopefully preserve other resource values to the greatest extent possible.

1.6.4. DEPARTMENT OF MINES AND PETROLEUM RESOURCES (BCDMPR)

The primary role of the BCDMPR is to regulate the mineral industry in the best interests of the Province. It also shares responsibilities for the regulation of the petroleum industry with other agencies, including the B.C. Petroleum Corporation (BCPC), the B.C. Energy Commission (BCEC), and the Department of Transport and Communications (BCDTC). Mineral management policies are hindered at present by the absence of a comprehensive mineral inventory although mineral potential maps are now available for most areas of the Province.

Recent amendments to the Mineral Act and other mining legislation require that the granting of all new mining permits be contingent upon the development of a satisfactory plan for reclamation and restoration of the pre-mining environment after an operation closes. It is not yet possible to assess the impact of this relatively new policy step.

The mining industry is particularly susceptible to problems which result from resource conflicts because mineral locations are fixed and the resource is non-renewable.

1.6.5. DEPARTMENT OF RECREATION AND TOURISM (BCDRT)

(a) The Provincial Parks Branch (BCPPB)

The BCPPB (formerly of the Department of Recreation and Conservation) manages all aspects of provincial park development and use pursuant to the Park Act. A major feature of BCPPB management programs is the promotion of diversity in the character and quality of the recreational experiences which are provided. It is only since 1973 that the BCPPB has assumed complete statutory responsibility for resource management in parks, and the Branch still does not possess statutory powers to designate new park areas, even on Crown lands. A recreational land bank exists, but is administered by the BCLS.

An important aspect of provincial recreation management is the fact that no single government agency is charged with responsibility for the co-ordination and management of the several independent outdoor recreational programs which are presently implemented by at least 10 public and private groups. A need exists for greater overall direction of recreational programs in the Province in the interests of good resource management. Perhaps the newly-formed Outdoor Recreation Branch will eventually perform this function.

(b) The Fish and Wildlife Branch (BCFWB)

It is possible that this branch of the former Department of Recreation and Conservation will now become a part of the BCDRT. The BCFWB is responsible for the maintenance, protection and enhancement of fish and wildlife resources pursuant to the Wildlife Act. The Branch's effectiveness in the past has been restricted by relatively weak legislation which has tended to render its resource interests of secondary importance to such activities as forestry, mining and agriculture. Symptomatic of this weakness is the fact that the BCFWB is not empowered to set aside land areas for wildlife management. Thus, while it enforces protective legislation designed to control levels of hunting and fishing, it is generally unable to protect wildlife habitats effectively. The agency provides extensive referral services for developers but, to a large extent, must depend upon the goodwill of the latter to protect habitats from adverse developmental impacts.

(c) The Marine Resources Branch (BCMRB)

The BCMRB is the provincial spokesman for, and custodian of, the Province's marine resources in areas of provincial jurisdiction such as shellfish management and marine flora harvesting. Technically, the BCMRB may regulate river-based developments which impede fish migration through powers pursuant to the Fisheries Act. However, this function has not been effectively exercised in the development of many of the Province's hydro-electric power installations. The federal Fisheries Act regulates developments which affect anadromous fish.

1.7. PROGRAMS OF OTHER DEPARTMENTS

There are several other provincial departments whose programs exert a significant influence on the outcome of provincial environment and land use decisions. These agencies are discussed briefly below:

1.7.1. DEPARTMENT OF ECONOMIC DEVELOPMENT (BCDED)

The programs of the BCDED are designed to assist and influence the location and development of industries and the promotion of internal and external markets for trade purposes. The BCDED also exercises a key role in the collection of statistical and economic information. The department exercises, at present, a relatively passive role in the process of regional economic development within what remains basically a free-market economy. It does not intervene actively in the industrial location and development process except through the programs of the B.C. Development Corporation (BCDC) which are closely linked to those of the BCDED (See 1.8.6.). The BCDED is interested in the development of regional economic policies and, to this end, has sponsored a series of regional economic studies, such as the North East Study, which may influence future industrial development by highlighting the more promising economic opportunities.

1.7.2. DEPARTMENT OF HEALTH (BCDHe)

The BCDHe is of present interest through the activities of its Health Branch in the field of environmental health management. Pursuant to the Health Act, the Health Branch regulates public health hazards which are related to aspects of urban development such as drainage, water supply, waste disposal systems, and heating and ventilation systems. These concerns exert a considerable influence on the density and servicing of urban-style developments. The interests of the Health Branch are very site-specific at present, but there may be a role for the Branch in broader regional land management issues in the future, particularly those which are related to the location of future urban development.

1.7.3. DEPARTMENT OF HIGHWAYS (BCDH)

The BCDH plans, builds and maintains the highway system throughout the Province pursuant to the Department of Highways Act and the Highway Act.

Historically, the BCDH has exercised an important role as a development agency in the processes of local and regional development. Until recently, however, the development of the provincial highway network was, at best, an 'ad hoc' process which was usually based upon restrictive perceptions of short-term local and regional needs. Transportation network planning in the modern sense would have required a framework of regional and local planning objectives which the Province has yet to prepare for most regions of B.C. Furthermore, environmental baseline data were scarce or non-existent. It is not surprising, therefore, that, viewed in terms of today's needs, highway location and construction practices appear to have been insensitive to geotechnical hazards, environmental values, and local and regional community needs in many situations.

Nowadays, the BCDH relies heavily on referrals to resource and planning agencies as a means of identifying critical values and key requirements. It is to be expected, therefore, that current and future BCDH-sponsored development will exhibit a sensitivity to environmental values, land management requirements and community needs which has not been witnessed during the past.

1.7.4. DEPARTMENT OF HOUSING (BCDHg)

The BCDHg was established in 1973 in response to a severe housing shortage in the Province. Its mandate is to supervise, acquire, develop, maintain, improve and dispose of housing. At present, the BCDHg development process involves, at best, a rather limited evaluation of the desirability of its proposed developments from the viewpoint of local environmental values, community planning objectives and land management policies. For these evaluations, it relies upon the provincial or municipal subdivision approval procedures, as would a private housing developer. Unfortunately, these processes, particularly the provincial process in unorganized areas, are swamped with applications, and it is not possible to examine thoroughly the local planning and environmental implications of development proposals in all cases.

1.7.5. DEPARTMENT OF MUNICIPAL AFFAIRS (BCDMA)

The BCDMA is responsible for liaison between provincial and local levels of government, pursuant to the Municipal Act. The land use planning machinery which has been set up under this Act, and which is administered locally by individual municipalities and regional districts, is proving to be somewhat cumbersome and ineffective. Successful planning depends heavily upon the goodwill of many parties because the planning agencies themselves, particularly the regional districts, exercise direct jurisdiction over very little of their nominal areas of administration.

There is now increasing support for the notion that the local government administrative unit is an inappropriate level at which to implement regional planning. There are 139 municipalities organized into 29 regional districts. These units are usually too small to be viable planning units. This has been responsible for the planning vacuum which has been identified at the regional level in B.C.

1.7.6. DEPARTMENT OF THE PROVINCIAL SECRETARY (BCDPS)

The BCDPS is responsible for the preservation of objects and places of archaeological and historical value, a function which is implemented through two advisory boards.

The primary function of the Historic Sites Advisory Board (HSAB) is to restore historic sites of particular significance, and to manage them as visitor attractions. The HSAB has only recently begun to compile an inventory of historic sites within the Province and, for most areas, is not yet able to provide such information to agencies which are concerned with developmental impact assessments and other questions.

The Archaeological Sites Advisory Board (ASAB) is primarily concerned with the identification, protection and management of archaeological sites. The inventory of archaeological sites, although far from complete, is more comprehensive than that for historic sites and the ASAB is able to provide some information in most areas. It is also geared to providing consulting services for other government agencies. It appears that the Archaeological and Historic Sites Protection Act, although couched in powerful language, is actually being enforced with leniency because of the economic hardship to developers which would result from strict enforcement. The success of archaeological preservation objectives, therefore, depends, to a large extent, on the goodwill of public agencies and private parties alike.

1.7.7. DEPARTMENT OF RECREATION AND TOURISM (BCDRT)

In addition to absorbing the BCPPB,the BCFWB and the BCMRB, this newly-formed department also contains the former Department of Travel Industry (BCDTI). The role of the BCDTI has been to facilitate and encourage the development of the tourist industry in the Province. The major criticism of the BCDTI is that it implements its promotional programs without regard for the indirect impacts, both beneficial and adverse, of tourism. It appears that cost-benefit studies are not presently undertaken in order to assist with the identification of those tourist programs which are most advantageous to the Province. Considerable unmanaged and undesirable development may result from unconstrained tourist promotion, such as has already occurred, for example, along the east side of Vancouver Island.

1.8. PROGRAMS OF SPECIAL CROWN DEVELOPMENT AGENCIES

1.8.1. BRITISH COLUMBIA HYDRO AND POWER AUTHORITY (BCHPA)

The BCHPA is a major developer of electrical energy resources. It also distributes natural gas and liquefied petroleum gas and provides bus and freight services.

The BCHPA has been responsible for some of the largest developments in the Province through its hydro-electric dam construction program. As with the BCDH programs, past BCHPA energy developments have characteristically been implemented without what would today be regarded as sufficient concern for adverse environmental and socio-economic impacts.

The BCHPA development planning process now considers such impacts in detail. However, it remains to be seen whether or not the current wave of impact assessments will lead to significantly reduced adverse developmental impacts in view of the problems which are entailed in modifying a development program once detailed planning and design are underway.

The BCHPA is also faced with serious problems with respect to the rapid growth in the demand for electrical energy. Management practices which are designed to curtail peak electrical demand are urgently required. Furthermore, it will not be possible to continue to cater to demand solely by relying on hydro-electric power development beyond the next two decades, and alternative energy sources must be identified and encouraged.

1.8.2. BRITISH COLUMBIA RAILWAY COMPANY (BCR)

The BCR is one of the major public development agencies in the Province. It operates more than 1,800 miles of railway track and manages 70,000 acres of industrial land. The primary function of the BCR is to transport freight from the interior and northern regions of the Province to transshipment points and processing areas. The freight consists primarily of forest, mining and agricultural products. BCR developments in the past have resulted in (i) adverse regional economic impacts because of the selection of less-than-optimal general locations and (ii) adverse site-specific ecological impacts because of inadequate protective measures. The BCR is now beginning to commission impact studies for major new projects. Further expansion of the BCR railway system is now being planned within the framework of overall regional development planning, particularly within the North West, where the railroad is viewed as a fundamental development tool.

1.8.3. BRITISH COLUMBIA CELLULOSE COMPANY (BCCC)

The BCCC is a public agent which has acquired, and now manages and operates, forest products industrial plants in various parts of the Province. The BCCC was originally created in 1973 as a major government planning tool for the revitalization of the forest-based economy of the North West. The philosophy appears to be that an increase in the sawn lumber sector of the industry is required in order to revitalize the pulp and paper sector, and that the Province must bring about this re-orientation since the private sector has been unable to do so. The BCCC has also acquired plants in the Vanderhoof and Kootenay areas.

1.8.4. OCEAN FALLS CORPORATION (OFC)

The OFC owns and operates a pulp and paper mill at Ocean Falls which was acquired in 1973 at a time when the private sector was intending to abandon it. The former Crown Zellerbach plant was acquired in order to maintain the local industrial base. It appears, however, that the plant will encounter considerable difficulties in the near future as the result of a serious shortage of accessible timber to maintain operations.

1.8.5. BRITISH COLUMBIA HARBOURS BOARD (BCHB)

The BCHB was established in 1967 in order to promote and facilitate harbour development in the Province. Its most notable achievement to date has been the development of the Roberts Bank Superport, which is now managed by the federal National Harbours Board. The development of the Superport across the ecologically-sensitive Fraser River delta foreshore has resulted in some adverse environmental impacts which were not, however, fully appreciated until after the project was completed.

The primary role of the BCHB at present is the operation of the railroad which serves the Roberts Bank Superport. The BCHB owns considerable amounts of land in the ALR's adjacent to this railroad and has made a commitment to maintain agricultural land uses on a lease basis.

1.8.6. BRITISH COLUMBIA DEVELOPMENT CORPORATION (BCDC)

The purpose of the BCDC is to create, develop and increase income, employment, tax revenues and other economic benefits to the Province by encouraging and assisting in the establishment, expansion and continued operation of industrial enterprises. This function is performed primarily by providing financial assistance to business enterprises and by assembling and servicing industrial land banks. The BCDC is a government economic planning tool and is linked to the overall objectives of the BCDED. It is able to influence the location and character of industrial development in a small way both through the character and location of the enterprises which it choses to sponsor, and through the locations of its land banks. It is expected that the BCDC will be particularly interested in enterprises in economically-depressed areas, although fears have been expressed that the tendency will be to become involved in high-risk ventures.

The locations of several of the BCDC land banks have proved to be controversial on the grounds of adverse environmental or socio-economic impact. Concern has also been expressed for the relatively secretive manner in which the BCDC has sponsored a major steel mill proposal.

1.8.7. BRITISH COLUMBIA PETROLEUM CORPORATION (BCPC)

The BCPC is an agent of the Crown which is empowered to develop, produce and market petroleum and natural gas and to own and operate oil and natural gas transmission facilities. The BCPC was established in 1973 to be the sole purchaser of B.C.'s natural gas well-head production. It is in this manner that the Province influences both export volumes and domestic and export prices in a traditionally federal area of jurisdiction. The reason for this move is to ensure a competitive price structure, particularly with respect to the costs of exports, and to provide the Province with an opportunity to implement natural gas conservation policies. The BCPC has sponsored a major oil refinery proposal in a manner very similar to that with which the BCDC has sponsored its steel mill proposal, i.e. with very limited public information.

1.9. PROGRAMS OF SPECIAL CROWN REGULATORY AGENCIES

1.9.1. BRITISH COLUMBIA LAND COMMISSION (BCLC)

The primary function of the BCLC is to regulate the use of agricultural lands which have been placed in agricultural land reserves (ALR's). The BCLC is also expected to assemble land for green belt reserves, urban and industrial land bank reserves, and park land reserves, but, in these respects, has no powers to designate reserves other than on lands which are owned by the BCLC. The ALR's were designated by a process which involved inputs from the regional districts and municipalities (initially), the BCLC, the Environment and Land Use Committee Secretariat (ELUCS), and the regional resource management committees (RRMC). It is true that some local authorities have been dissatisfied with the manner in which their initial ALR proposals were altered during subsequent stages of the ALR designation process. These initial proposals presumably reflected local planning objectives, and the subsequent alterations are symptomatic of the limited scope of the local planning process in this Province. Despite some public and internal government concerns and disagreements with the ALR concept during the ALR designation process, the ALR zoning is now widely supported and appreciated as a necessary regulatory device for the protection of agricultural lands. This support is reflected in the local opposition which is now engineered by concerned citizens in cases where applications are received for the release of ALR lands for "non-farm uses". Through the ALR designation process, the BCLC has contributed towards increased inter-departmental communication, particularly within the RRMC forum, and has provided the regional districts with an important, if ultimately preliminary, planning function.

1.9.2. BRITISH COLUMBIA ENERGY COMMISSION (BCEC)

The BCEC regulates the operation of energy and telecommunications utilities, regulates the pricing and production standards of petroleum products, arbitrates in disputes respecting the distribution of energy to consumers, and advises the Cabinet on questions of energy resource management. The BCEC is performing a useful research function in its analysis of energy demand forecasts and alternative sources of energy to meet projected energy demands. A BCEC recommendation was responsible for the establishment of the BCPC to manage natural gas exploitation in a conservation-oriented manner. The BCEC also performs an important function in its regulation of energy utilities and has attempted to ensure that new development is in the public interest and will not lead to unjustifiably adverse developmental impacts. It is very surprising that the regulatory jurisdiction of the BCEC over energy utilities does not apply to the operations of the BCHPA in view of the enormous magnitude of its hydro-electric power projects and their considerable developmental impacts. The BCEC has exhibited an inclination to treat existing energy forecasts circumspectly and is now involved in a serious evaluation of alternative energy sources. The public would be more reassured of the need for BCHPA hydro-electric power proposals if these had been through the independent BCEC energy utility approval process.

1.9.3. BRITISH COLUMBIA ASSESSMENT AUTHORITY (BCAA)

The BCAA was newly established in 1974 to assume control over all provincial land assessment responsibilities. It is hoped that the BCAA will overcome many of the assessment problems which existed prior to its formation by establishing all assessments at 100 per cent of real market values and by enforcing more uniform and rigorous assessment standards. When the new system is operational, valid land value data will be available in all areas for land use planning purposes for the first time.

1.10. LAND USE AND RESOURCE JURISDICTIONS - A CHECKLIST

In any given area of the Province, the following land and resource jurisdictions may be encountered:

(a) Federal Jurisdictions

These are exclusively exercised over Indian Reserves, military areas, federal harbours, and federal transportation lands and corridors. The regulatory management of anadromous fish is also a federal responsibility.

(b) Municipal Jurisdictions

Municipal authorities control the allocation of private lands for specific purposes within their boundaries through their powers to zone and to regulate subdivision and building standards pursuant to the Municipal Act. These powers are restricted in ALR's to allocation of land for compatible uses only.

(c) Regional District Jurisdictions

Regional district boards exercise direct control over private lands in unorganized areas pursuant to the Municipal Act. Again, these powers are restricted in ALR's. The boards may also exercise indirect controls on private lands within municipalities where by-laws to that effect have been approved, as in the case of the applicability of the Lower Mainland Regional Plan to the various municipalities within the Greater Vancouver Regional District.

(d) Resource Department Jurisdictions

The resource departments exercise direct land use jurisdictions over most of the Province's Crown lands and resources, including the following:

- Forest tenures pursuant to the Forest Act and administered by the BCDF:
    - Timber Sale Licenses;
    - Tree Farm Licenses;
    - Pulpwood Harvesting Agreements;
    - Old Temporary Tenures.
- Water tenures pursuant to the Water Act and administered by the BCWRS:
    - Water Licenses;
    - Water Improvement Districts;
    - Water-Users' Communities.
- Grazing permits pursuant to the Grazing Act and administered by the BCLS, BCDF or BCPPB.
- Ecological reserves pursuant to the Ecological Reserves Act and administered by the BCLS.
- Provincial parks pursuant to the Park Act and administered by the BCPPB, and regional parks pursuant to the Regional Parks Act and administered jointly by the BCPPB and local authorities.

- Mineral tenures pursuant to a variety of mining legislation, including the Mineral Act, the Placer Mining Act and the Coal Act, and administered by the BCDMPR:
  - Free Miner's Certificates;
  - Mineral Claims;
  - Mineral Leases.
- Petroleum and natural gas tenures pursuant to the Petroleum and Natural Gas Act, 1965, and administered by the BCDMPR:
  - Permits;
  - Licenses;
  - Leases;
  - Reservations.
- Special-purpose leasing arrangements pursuant to the Land Act and administered by the BCLS:
  - Licenses of Occupation;
  - Residential Leases;
  - Recreational Cottage-Site Leases;
  - Agricultural Leases;
  - Foreshore Leases;
  - Subdivision Approvals.
- Vacant Crown lands, administered by the BCLS pursuant to the Land Act.

(e) Regulatory Departmental Jurisdictions

In addition to the many direct forms of land use and resource controls which are exercised by provincial departments, the latter also perform numerous regulatory functions which influence the evolution of land use patterns and resource development. Regulation may be of the following types:

- Subdivision approval procedures in unorganized areas pursuant to the Land Registry Act and administered by the BCDH.
- Regulation of all municipal and regional district functions by the BCDMA pursuant to the Municipal Act.
- Regulation of public health aspects of the servicing of subdivisions and other urban developments by the BCDHe pursuant to the Health Act.
- Regulation of activities along provincial highways, and particularly in the vicinity of controlled access highways by the BCDH pursuant to the Department of Highways Act, the Highway Act, and the Controlled Access Highways Act.
- Regulation of the construction and operation of railways, pipe-lines and industrial access roads by the BCDTC pursuant to the Railway Act, the Pipe-lines Act, the Mines Right-of-Way Act, and the Industrial Transportation Act.
- Regulation of mining operations by the BCDMPR pursuant to the Mines Regulation Act and the Coal Mines Regulation Act.
- Regulation of municipal and industrial waste discharges by the BCWRS pursuant to the Pollution Control Act, 1967.
- Regulation of all hunting and sport fishing activities by the BCFWB pursuant to the Wildlife Act.

- Regulation of activities on sites of archaeological and historical interest by the ASAB and HSAB pursuant to the Archaeological and Historic Sites Protection Act.

(f) Special Development Agency Jurisdictions

The Crown corporations, etc., which are responsible for public developments are generally granted powers to control activities on, and immediately adjacent to, their properties. The BCHPA and BCR are also granted extensive expropriation rights. Other development agencies are empowered to acquire land through normal purchase procedures.

(g) Special Regulatory Agency Jurisdictions

- The BCLC administers all lands in ALR's pursuant to the Land Commission Act.
- The BCEC regulates the construction and operation of energy and telecommunications utilities pursuant to the Energy Act.
- The BCAA influences land uses through the impacts of its property taxation assessments pursuant to the Assessment Act.

1.11. RESOURCE AND LAND USE PROBLEMS

The above discussion has served to demonstrate that while the resource agencies are now taking significant steps towards an improved land use management philosophy in B.C., considerable effort is required in order to combine the numerous individual provincial jurisdictions into a coherent overall decision-making process. Inevitably, these jurisdictions and interests come into conflict from time to time. Conflicts may be of several types, including:

(a) Disagreements between local and provincial levels of government concerning objectives and priorities;

(b) Conflicts between urban, industrial, transportation and energy developments on the one hand, and natural resources management programs on the other; and

(c) Conflicts between the more active and exploitive forms of resource management, such as forestry, mining and agriculture on the one hand, and the more conservation-oriented resource management programs such as wildlife habitat protection and recreation on the other.

The second part of this paper is concerned with some of the initiatives which are presently being undertaken by the Province in order to resolve these problems and to create a more orderly and complete framework for land use and resource management and decision making.

2. TOWARDS A MORE INTEGRATED APPROACH

Several approaches have been adopted by the Province in recent years in order to promote the general objective of improved resource and land use decision making. These approaches have emphasized: (i) the fostering of greater co-operation and more efficient relationships among agencies, and (ii) the generation of more extensive and comprehensive data relating to specific resource and land use problems.
The initiatives which have been selected for mention in this paper are treated under the following headings:

- Institutional
- Inventory
- Regional Resource Planning
- Development Assessment Procedures

2.1. INSTITUTIONAL APPROACHES

2.1.1. THE ENVIRONMENT AND LAND USE COMMITTEE (ELUC)

The decade of the 1960's was characterized by a growing conflict among resource agencies with respect to overlapping jurisdictions and vested interests. It was becoming increasingly difficult, therefore, to resolve resource conflicts at the working level, and progressively more problems were being referred to the Deputy Ministerial and Ministerial level. Even at this level, solutions were difficult to achieve in the absence of good information and without a recognized problem-solving forum.

In 1969, therefore, an informal committee of five Cabinet Ministers was established to consider resource conflicts. The group was known as the Land Use

Committee and included the Ministers of the BCDA, BCDLFWR, BCDMPR, BCDMA and BCDIDTC. There were two major resource conflicts in that year which prompted this development: (i) the conflict for forage between ungulates and domestic cattle around the margins of the newly-formed Libby Reservoir; and (ii) the alienation of forest lands to urban uses in the Vanderhoof area where the objective had been to clear the lands for agriculture.

The duties of the Committee became an important part of resource conflict resolution during the next two years. In 1971, the process was formalized with the passage of the Environment and Land Use Act and the establishment of ELUC as a formal Cabinet group. Today the Committee includes Ministers from nine departments - BCDA, BCDED, BCDOE, BCDF, BCDHe, BCDH, BCDMA, BCDMPR and BCDRT.

The Environment and Land Use Act provides potentially very broad powers for ELUC which, according to Sections 3(a) and 3(b) of the Act, is empowered to:

(a) Establish and recommend programmes designed to foster increased public concern and awareness of the environment;

(b) Ensure that all aspects of preservation and maintenance of the natural environment are fully considered in the administration of land use and resource development commensurate with a maximum beneficial land use, and minimize and prevent waste of resources, and despoliation of the environment occasioned thereby.

Section 6 further states that:

> ......notwithstanding any other Act or regulation......no Minister, department of Government, or agent of the Crown specified in....(an).... order shall exercise any power granted under any other Act or regulation except in accordance with the order.

Armed with these powers, ELUC is now making resource and land use decisions which are of broad significance and which include, for example, the decision to establish the ALR's in 1973, and to plan development in the North West of the Province as an integrated exercise.

2.1.2. THE ENVIRONMENT AND LAND USE COMMITTEE SECRETARIAT (ELUCS)

In 1973, ELUC recognized the need for a regularized support staff. Prior to that year, background information on resource conflicts had been collected for the Committee by individual task forces which were established on an 'ad hoc' basis. The work load had grown sufficiently by 1973 that it was considered necessary to appoint a full-time support staff, and ELUCS was created by Order-in-Council pursuant to the Environment and Land Use Act.

Most of the ELUCS staff were transferred directly from the former B.C. Land Inventory (BCDA) to the newly-formed Resource Analysis Unit (RAU). The roles of this Unit are to co-ordinate the collection and analysis of resource data, to provide long-term inventories of base data which are suitable for a broad range of interpretations, to provide short-term resource inventories for specific project requirements, to develop a biophysical land-use planning inventory program, and to provide technical, mapping and drafting services to ELUCS.

A second Unit, the Resource Planning Unit (RPU),was created in order to prepare regional resource and land use allocation plans, to provide ELUC with professional advice on resource developments within regional contexts, and to examine issues involving competing resource users in a particular region.

A third Unit, the Special Projects Unit (SPU),was created and charged with the formulation of guidelines and procedures for preliminary environmental and socio-economic assessments of various types of development projects, and with co-ordination of inter-agency groups for major project planning and resource allocation issues such as energy generation and transmission, utility corridors, ferry services, reservoir use and coastal development.

2.1.3. THE ELUC-ELUCS DECISION-MAKING PROCESS

There appears to be a relatively standardized or formal pattern of steps by which ELUC receives and treats resource and land use problems:

STEP ONE - An inter-agency environment and/or land use problem is perceived at the departmental working level. It may be that several agencies are affected but that no one agency has clear jurisdiction or that such jurisdiction as exists has been questioned. At the perception source, no solution may be available or, if available, may involve possible changes in agency policy which must be approved by more senior officials.

STEP TWO - No equitable agreement is reached between the involved agencies at the Step One level,and the problem is referred upwards through the departmental hierarchy. The problem will reach the Deputy Minister if no solution is found at an intervening level.

STEP THREE - The Deputy Minister reviews the problem. If he decides that the problem cannot be resolved by approaching directly the equivalent senior officials of other involved agencies, he may elect to employ the ELUC machinery. The problem may go first to the Environment and Land Use Technical Committee (ELUTC), a committee of Deputy Ministers.

STEP FOUR - ELUTC deliberates on the problem. One of the primary functions of the Deputy Ministers in committee is to collect and analyze possible agenda items for ELUC. ELUTC provides about half of the agenda items. The rest are provided by the Ministers themselves. If ELUTC cannot recommend solutions, and if it does not refer the problem back to individual agencies for further information or clarification, the problem is referred to ELUC. Deputy Ministers will at the same time presumably brief their respective Ministers on their opinions of the problem.

STEP FIVE - ELUC deliberates on the problem. Often disputes are settled promptly by this forum.

STEP SIX - Where research and analysis may be required which is interdepartmental in scope, ELUC refers the problem to ELUCS. ELUC may wish for ELUCS to research the problem itself or to direct research by other agencies or by consultants. The ELUCS staff deliberates on the organization of a research program.

STEP SEVEN - A task group (inhouse or inter-agency) is formed, consisting of personnel with special expertise in the problem area. Task force membership may be modified as necessary while the study is in progress. An ELUCS representative may not necessarily direct the task force but is expected to judge the various inputs for their holistic, integrative merits. After the task force members have submitted the various reports which are required, an ELUCS staff member will often produce a summary report and recommendations.

STEP EIGHT - These are then submitted to ELUC. It is possible that interim reports may also be received by ELUC which may then choose to issue new directives for the study.

STEP NINE - Based on the task force submissions, ELUC reaches a solution to the planning or resource allocation problem. ELUC review may be assisted by further inputs from the individual departments as necessary. Hopefully the quality of decision making is enhanced by this process.

STEP TEN - The conflict resolution formula is reported to senior agency officials (Deputy Ministers, etc.) who then are responsible for transmitting the decision downwards through the hierarchy to the working level from which the problem came.

2.1.4. IMPACT OF THE ELUC-ELUCS PROCESS

The process provides, for the first time, a formal decision making mechanism for the resolution of resource conflicts which replaces the relatively 'ad hoc' inter-agency liaison of the past.

However, the implementation of the process encountered initial problems. Among the resource and land use agencies, there has been uncertainty and concern over the role, objectives, priorities and jurisdictions of ELUCS in particular. There have been various criticisms of the manner in which ELUCS conducts itself:

- That ELUCS should be less problem-oriented and more policy-oriented;
- That ELUCS activities infringe on the jurisdictions of other agencies;
- That ELUCS appears to be assuming the responsibilities of other agencies;
- That ELUCS should examine urban as well as rural problems.

These and other problems are a natural consequence of attempts to impose radical changes upon institutional decision-making processes.

Nevertheless, the process has been widely accepted, at least in principle. The emphasis of the system is placed upon inter-agency study of resource problems, both at the Ministerial level (ELUC) and at the working level (through ELUCS task forces). Through the task force forum, resource personnel have been able to acquire an appreciation of the priorities and constraints which govern other resource activities. Officials have exhibited an increasing readiness to approach ELUCS or other agencies directly when matters of mutual interest arise, and some resource agencies have now established special research sections which investigate the broader multi-resource implications of their respective activities. These trends are exerting a beneficial influence on the quality of resource decision making in B.C.

2.2. RESOURCE INVENTORY PROGRAMS

2.2.1. THE CANADA LAND INVENTORY (CLI)

The CLI program was established by the Federal Government pursuant to the Agricultural Rehabilitation and Development Act (ARDA) of 1961. The ARDA program is a jointly-funded federal-provincial rural development program. The B.C. program was established by legislative enactment in 1962 and the B.C. Land Inventory became operational in 1964-1965.

The CLI program is a rapid but comprehensive regional-scale survey of present and potential land uses. Its primary purpose is to provide a basis for land use planning and resource management for agriculture, forestry, recreation and wildlife. The CLI area in B.C., which extends northwards from the U.S. border to all but the most northerly areas, has now been almost completely mapped at scales which vary from 1:50,000 to 1:1,000,000.

The mapping consists of present land use maps and land capability sector maps. The latter usually grade, on a scale of one to seven, the suitability of lands to support agricultural, forestry and recreational activities and to provide habitat for ungulates and waterfowl.

Integrated land capability analysis maps have also been produced for five areas of the Province. These maps designate best potential resource uses for individual land units based upon the highest resource capability ratings among the various criteria.

Although the BCLI program is now eleven years old, it is only relatively recently that the mapped information has begun to be employed on a widespread basis for resource and land use planning.

The soil capability for agriculture mapping has been an important criteria in the delimitation of the ALR's. Only soil classes 1 to 4 were considered for inclusion within the ALR's. In marginal areas of the Province, this information was combined with inventory mapping of climatic capability for agriculture to assist with ALR designations.

Mapping of land capability for the other resource sectors is also increasingly being employed in resource planning studies and in evaluations of the impacts of proposed developments on resource management potential.

2.2.2. <u>THE BIOPHYSICAL MAPPING PROGRAM</u>

As the BCLI program has progressed, the scope of the original CLI objectives have been expanded to include a range of additional types of inventory mapping, a trend which has continued since the BCLI was transferred to the RAU of ELUCS.

One inventory program which is now at a preliminary stage of preparation is the biophysical mapping program. When the various resource capability maps were prepared, it was necessary to collect considerable information on the physical environment in order to establish resource capability ratings. Physical characteristics were not mapped in pure form, however, although they may be inferred to some extent from the capability ratings.

Experience with the CLI ratings has revealed the need for a land classification system which describes the biophysical characteristics of particular land units without reference to a specific resource use, since the resource capability ratings are not value-free and are subject to the vagaries of changing social and economic values.

The present biophysical land classification is being designed to differentiate and classify segments of the land surface which possess internal uniformity and which differ from surrounding land segments. Each land unit is classified according to four criteria - landform, topography, soil and vegetation. There may also be scope for the introduction of climatic indices into the classification.

When completed, the mapping will serve as the basis for future management of land for agricultural, forestry, recreational and wildlife resources, and also for evaluations of land suitability for buildings, sewage disposal, water supply, large structures, reservoirs - in fact, for any type of undertaking for which a knowledge of the physical environment is necessary.

Planning is underway for the collection of the necessary data, some of which is now available. For many years, the BCDA has been preparing soil maps in many parts of the Province. Extensive forest inventory information is available from the BCDF and this is being supplemented now by a vegetation cover mapping program within the RAU. The Soils and Surficial Geology Division of the RAU has almost finalized a comprehensive landform mapping classification system. The Climate and Data Services Division is expanding its network of field stations for the purpose of mapping climatic variables at the local scale.

With the above inventory mapping capabilities, the RAU is also able to produce specific maps on request for such varied purposes as surface soil erosion potential, soil susceptibility to ponding and flooding, ground suitability for septic tank absorption fields, air pollution potential, climatic capability for recreation, and surface gradient. A water-fish capability mapping program is now underway, and the Geographic Division of the RAU is interested in developing mapping programs for land ownership and land status.

2.2.3. RESOURCE OVERLAY TECHNIQUES

One important application of resource inventory mapping has been the preparation of resource overlay folios. The objective is to overlay orthopositives of resource maps of various kinds in order to assist with the highlighting of critical areas.

The first provincial application of this resource planning tool is believed to have occurred during the Vanderhoof forest land study for the Land Use Committee in 1969. Vacant Crown lands with significant forest capability had been cleared for agriculture, found to be ill-suited to this purpose, and were then alienated to urban uses. The land use decisions in this case were aided by the preparation of an overlay folio consisting of maps for agriculture, forestry, wildlife, fish, mining, recreation and water resources.

The BCDF now makes considerable use of resource overlay folios as part of its planning process for the location of Timber Sale Licenses in PSYU's. The map data are collected from district forestry officials and include forest inventory mapping, water resources, fish-spawning streams, wildlife ranges, recreational sites and mineral resource locations. Consultation with BCFWB officials is particularly extensive. With these data, BCDF officials determine, within general areas which have been selected by logging companies, the exact shape, size, location and orientation of each stand which is to be logged. Critical areas such as streams, winter ungulate ranges and erosion-susceptible soils are avoided where possible. Some 400 folios are planned throughout the Province and more than half of these have been completed. Other resource agencies have reacted to the folios as an approach to the resolution of resource conflicts with a mixture of concern and guarded optimism.

The Land Management Branch of the BCLS has also adopted the resource overlay folio as a planning tool in local situations. In addition to the maps which are included in the forestry folios, there may also be maps of land status, present land use, topography, drainage, access, legal boundaries, and local authority zoning.

The BCLC has asked ELUCS to prepare resource folios in areas of the Province where the ALR's are under considerable development pressure, particularly in the Lower Mainland. Such information provides a framework within which to evaluate applications for exemption from the ALR zoning.

2.3. REGIONAL RESOURCE PLANNING

2.3.1. THE REGIONAL RESOURCE MANAGEMENT COMMITTEES (RRMC)

The RRMC (or Inter-Sector Groups) are committees of senior regional resource agency officials which have been established in seven locations across the Province in order to tackle questions which involve overlapping resource management jurisdictions and interests.

Before the formation of the RRMC, there was no formal collective interdepartmental effort to overcome resource conflicts. Such communication as did exist between agency staff at the regional level tended to concentrate upon technical matters rather than upon policy issues. Much of the communication occurred "after the fact" and was designed to mitigate the more deleterious effects of unco-ordinated decision making within individual agencies. The failure to co-operate at the planning and policy levels of decision making was both costly and wasteful of resources.

The first Inter-Sector Group was formed in Prince George during the late 1960's, largely at the volition of local senior regional officials themselves. Members included such regional officials as the district forester, regional highway engineer and regional land inspector. Another group was soon formed in Nelson. These two groups were followed at intervals by five others, some of which developed through local regional initiative while others were constituted as a result of encouragement from Victoria.

The Purcell Study was probably the first government project to be assigned to a committee (the East Kootenay group in Nelson). The study was intended to identify resource conflicts in the Purcell Mountains and to recommend future resource management strategies. A great stimulus was provided to the RRMC in all areas when they were assigned the task of commenting on the ALR proposals. This review process represented the first intimate exposure of many regional officials to the policies and priorities of other agencies.

In recognition of the potential role of the RRMC in resource management, the Province has undertaken to standardize the regional boundaries and regional administrative centers of the resource departments. In January, 1975, Order-in-Council 205-75 (pursuant to the Environment and Land Use Act) created seven Resource Management Regions. The new regions were established after an extensive consultation with resource departments and after evaluation of geographical, biophysical, administrative and operational criteria. It is anticipated that internal departmental adjustments will be problematical. Implementation of the new regional structure for resource management is scheduled to occur over several years.

2.3.2. THE NORTH WEST STUDY

At the time that the ELUCS was created, the need for a major economic investigation of the North West of the Province was recognized at the political level. The chief cause of the economic malaise of the North West has been identified by many as the faltering forest industry. The area has always been a high-investment/low-return economically marginal proposition for industry. It is isolated and its infrastructure is relatively underdeveloped. The forest enterprises of the Columbia Cellulose Co. and Eurocan, and the metallurgical operations of Alcan, have provided much of the industrial base. Columbia Cellulose had, by 1973, been seeking to sell its enterprises for some time, and it appeared that some operations would be closed. Especially threatened were those non-integrated pulp mills which rely on waste from other logging mills for pulp and paper production. In some areas, saw mill operations were not adequate to supply the demand as, for example, at Prince Rupert and Kitimat (by contrast, supplies are relatively plentiful for the pulp and paper mills at Prince George). The Government, therefore, established the B.C. Cellulose Company which bought a controlling share in two pulp mills at Prince Rupert, lumber mills at Terrace and Kitwanga, and a pulp and lumber mill at Castlegar (in the Kootenays).

As part of its North West strategy, ELUC delegated to ELUCS the responsibility for preparing regional development guidelines. The Resource Planning Unit has been directing a steering task force which includes staff from the RAU, the BCDF, the BCFWB and the BCPPB. The task force was expected to identify agency objectives and areas of conflict between forest exploitation and recreational and environmental concerns. The work is part of an overall rationalization of the region's forest industry through a program of integrated resource, social, economic, community and transportation developments.

The task force has had to take into account proposals for sawmills at Burns Lake, Houston and Smithers. Also included in the North West strategy has been a tentative federal-provincial agreement to expand the port facilities at Prince Rupert, and to provide a railroad link between the CNR track at Terrace and the BCR track along its Dease Lake extension.

ELUCS has organized several public hearings in the North West to gauge local attitudes towards the various development proposals. Much RAU resource inventory mapping has also been necessary, particularly between Burns Lake and Smithers. This inventory mapping has been presented at public meetings to facilitate discussion. Among the results of the planning process to date have been the development of a sawmill at Burns Lake and a decision to direct timber to existing mills in the Smithers area where there was public opposition to the development of a large new mill in competition with existing operations.

The North West Study has been an undertaking of exceptional scope which has not been emulated elsewhere in the Province. A number of smaller-scale regional resource planning studies have, however, been undertaken, including studies in the Tsitika-Schoen, Cathedral Lakes Park, Mica Dam, Whistler Mountain, Purcell Mountains, Springbrook and Williston Reservoir areas.

2.4. DEVELOPMENT ASSESSMENT PROCEDURES

2.4.1. ELECTRICAL ENERGY DEVELOPMENTS

One of the first undertakings of the Special Projects Unit was to establish a review process for BCHPA projects. The process involves three major stages of review:

(a) The development of acceptable forecasts of future electrical energy requirements, a process which has involved interaction between ELUCS, BCHPA, BCEC and BCDED;

(b) The selection of those energy generation projects which provide sufficient capacity to meet future demands while at the same time resulting in minimal regional disruption and adverse developmental impacts; and

(c) The preparation of environmental and social impact statements for those developments which are selected to proceed.

All three stages of the review process are in operation. The energy demand forecasts of BCHPA were at variance with those of the BCEC and attempts are now being made to resolve these differences and to arrive at a mutually acceptable growth rate for the future planning of BCHPA developments.

Guidelines for broad regional development assessments are in an advanced stage of preparation and will be applied to most BCHPA proposals. There are only three major hydro-electric power projects which are at such an advanced stage of development that drastic modification would be very difficult to implement. These projects are the Pend-d'Oreille, Mica and Site 1 (Peace River) Dams. Detailed impact assessments are now being completed for these projects which are designed to assess their site-specific impacts on natural and social systems and to recommend compensatory or mitigatory measures where necessary.

2.4.2. COAL DEVELOPMENT GUIDELINES

In view of the recent renewed interest in coal development in the Province, coal development guidelines similar to those for electrical energy development have been prepared. Presently, five mining companies in the South East and two in the North East are at various stages of feasibility and planning studies.

ELUCS and the BCDMPR were charged in 1973 with the preparation of guidelines which would ensure that these feasibility and planning studies would be comprehensive and would cover a full range of economic, social/community, and environmental factors. Complete information is required on all aspects of a coal development project including such varied questions as pollution control, community development, and site reclamation plans.

The coal guidelines are designed to take existing provincial legislation and procedures, company requirements and priorities, and local government, industrial, social and environmental interests into account.

The coal development companies are now proceeding according to the guidelines. Initial reaction has been favourable in general. The companies have indicated that, during the past, there has been some doubt concerning the types of information which should be presented by coal developers to the Province.

3. CONCLUDING OBSERVATIONS

In terms of the general theme of this conference, the processes which are described in this paper do not represent a continuous or semi-continuous monitoring of land use. Of the provincial agencies, only the Department of Finance and the B.C. Assessment Authority maintain province-wide records of land use changes and these data are not at present analyzed for the purposes of resource management or land use planning. Some local authorities maintain such records in local situations.

Various land capability and land use indices have been mapped in a static sense and are contributing towards resource management and land use planning objectives. However, the major point of this paper has been to stress that the dynamics of land use changes are governed to a large extent by a very complicated network of interlocking provincial jurisdictions and interests. A primary provincial objective, therefore, is to streamline these individual jurisdictions and interests into a coherent land management process. Section 2 of the paper has discussed some of the approaches which have been initiated for this purpose.

A future objective, however, must be the establishment of a land use and land capability data bank which is amenable to manipulation for planning purposes. In particular, there is a need to relate projected future demands for resources to the present availability of these resources in provincial, regional and local situations. Some progress has been made towards the development of a provincial computerized data bank. Furthermore, in 1976, ELUCS is hoping to carry out a regional-scale overview of available resources and projected future needs in B.C. This information should provide a useful framework for future resource and land use decisions.

APPENDIX 1

LIST OF ABBREVIATIONS

AAC ('s)	- Annual Allowable Timber Cut(s)
ALR ('s)	- Agricultural Land Reserve(s)
ARDA	- *Agricultural Rehabilitation and Development Act* (Canada)
ASAB	- Archaeological Sites Advisory Board (BCDPS)
BCAA	- B.C. Assessment Authority
BCCC	- B.C. Cellulose Company
BCDA	- Department of Agriculture (B.C.)
BCDC	- B.C. Development Corporation
BCDED	- Department of Economic Development (B.C.)
BCDF	- Department of Forests (B.C.) - Formerly the BCFS of the BCDLFWR
BCDHe	- Department of Health (B.C.)
BCDH	- Department of Highways (B.C.)
BCDHg	- Department of Housing (B.C.)
BCDIDTC	- Department of Industrial Development, Trace and Commerce (B.C.) - Now BCDED
BCDLFWR	- Department of Lands, Forests and Water Resources (B.C.) - Functions Transferred to BCDF and BCDOE
BCDMA	- Department of Municipal Affairs (B.C.)
BCDMPR	- Department of Mines and Petroleum Resources (B.C.)
BCDOE	- Department of Environment (B.C.)
BCDPS	- Department of the Provincial Secretary (B.C.)
BCDRC	- Department of Recreation and Conservation (B.C.) - Functions Transferred to BCDRT
BCDRT	- Department of Recreation and Tourism (B.C.)
BCDTC	- Department of Transport and Communications (B.C.)
BCDTI	- Department of Travel Industry (B.C.) - Functions Transferred to BCDRT
BCEC	- B.C. Energy Commission
BCFS	- B.C. Forest Service - Now BCDF
BCFWB	- B.C. Fish and Wildlife Branch - Now Part of BCDRT

BCHB	- B.C. Harbours Board
BCHPA	- B.C. Hydro and Power Authority
BCLC	- B.C. Land Commission
BCLI	- B.C. Land Inventory - Now Part of RAU (ELUCS) and BCDA
BCLS	- B.C. Lands Service - Now Part of BCDOE
BCMRB	- B.C. Marine Resources Branch - Now Part of BCDRT
BCPC	- B.C. Petroleum Corporation
BCPPB	- B.C. Provincial Parks Branch - Now Part of BCDRT
BCR	- B.C. Railway Company
BCWRS	- B.C. Water Resources Service - Now Part of BCDOE
CLI	- Canada Land Inventory
CNR	- Canadian National Railway
ELUC	- Environment and Land Use Committee (B.C.)
ELUCS	- Environment and Land Use Committee Secretariat (B.C.)
ELUTC	- Environment and Land Use Technical Committee (B.C.)
HSAB	- Historic Sites Advisory Board (BCDPS)
OFC	- Ocean Falls Corporation
PSYU ('s)	- Public Sustained Yield Unit(s)
RAU	- Resource Analysis Unit (ELUCS)
RPU	- Resource Planning Unit (ELUCS)
RRMC	- Regional Resource Management Committees
SPU	- Special Projects Unit (ELUCS)
TFL ('s)	- Tree Farm License(s)

VANCOUVER INTERNATIONAL AIRPORT POLLUTION STUDIES

Stephen G. Pond

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I. INTRODUCTION

The Vancouver Airport Study is the popular name of a group of studies, begun in 1973, to study the expansion of the Vancouver International Airport (VIA) proposed by the Ministry of Transport. I directed a set of pollution studies which were part of a large Environment Canada environmental assessment; the environmental studies were, in turn, only a part of the overall study.

Last August when your conference committee asked me to give a paper on the VIA study I had to give it a lot of thought.

There is a good deal of public and professional interest in these studies. It's an important study because those of us who fly would like to keep or improve the convenience and lack of congestion at VIA; most of us who live in Vancouver don't want any more "bigness" than we have to have, and those of us who think about ecology know that the Fraser estuary, and delta, which VIA is part of, is an extremely valuable habitat which has already undergone much man-made change. As environmental studies go, this was a large and complex one for B.C. and also covered areas such as noise which were new and presumably interesting to professional engineers. So there is no question of the audience interest.

On the other hand, the pollution studies which I directed were only a moderate, perhaps even a minor, part of the overall study. More importantly, last August I had anticipated that the overall study would be concluded by this time, and that the results and recommendations would be the background for a paper of narrow scope. The report of the overall study is not yet complete, and it would be misleading to you, and wrong of me, to get into specific results and recommendations of the pollution studies if you don't have the opportunity of assessing their importance to the overall report.

We decided, however, that it would still be worthwhile for this audience of professional engineers to learn how we went about making the study; what techniques we used, etc. The problem with that, I learned to my chagrin when I set out to do it, is that it takes a much longer time than is allotted.

To end this lengthy apology, I concluded I would try to cover, in a brief and simplified fashion, three topics:

1. The organization brought together to study the proposal.
2. The proposal for expanding the airport.
3. The pollution studies which were carried out.

II. STUDY ORGANIZATION

For Environment Canada, the study dates from January, 1973, when the Minister of Environment, then Jack Davis, directed that an environmental assessment be made of the Ministry of Transport's (MOT) proposed expansion of Vancouver International Airport. The issue had arisen in late 1972, when MOT had announced their proposal and had begun expropriation of properties on Sea Island, previously they had been purchasing properties when they became available.

Although Environment Canada was, at that time, designing "EARP", the Environmental Assessment Review Process, which specified that the project proponent should be responsible for its own environmental assessment, we organized to do this study ourselves. In March, 1973, a Department of Environment Steering Committee (Figure 1) including myself as a representative of the Environmental Protection Service (EPS) was brought together to carry out the study. The study duration was understood to be one year. We used the task force approach, drawing specialists from Environment Canada as required.

The Minister of Environment also created an Advisory Panel to provide independent advice on the airport issue.

The proposed airport expansion eventually aroused sufficient public concern that the issue was taken up at the first meeting of the Greater Vancouver Tri-Level Committee in late March, 1973. This cabinet level political group with Federal, Provincial and GVRD representation agreed to take provincial and regional, as well as public, concerns into account in the planning of the airport expansion. At a later staff meeting, it was agreed to form an Airport Planning Committee (APC). By September, 1973, APC representation was established (Figure 2).

By January, 1974 a study design was accepted. To carry out the study design, sub-committees were formed, as shown in Figure 3.

I can only briefly describe the functions of the sub-committees which will be described in detail in the report of the Airport Planning Committee now in preparation.

The Airports System Sub-Committee

to examine alternative means of accommodating forecast air traffic in the Vancouver region;

The Forecasting and Economic Sub-Committee

to agree upon a range of air traffic forecasts for the Vancouver area and to assess the economic impact of airports on the region;

The Noise Sub-Committee

to assess the effects of aircraft noise on the human environment, (ie. livability);

The Provincial, Regional and Municipal Plans and Social Impact Sub-Committee

to take inventory of existing regional plans and programs and to determine the impact of airports on these; to determine the impact of the airport on regional ground transportation, and to carry out a social impact study;

The Airport Facilities Sub-Committee

to take inventory of present airport facilities in the Vancouver region and to carry out demand-capacity studies for these airport facilities;

The Ecological Sub-Committee

to assess the impact of airport developments on the natural environment.

Environment Canada played major roles in two sub-committees, the Noise Sub-Committee and the Ecological Sub-Committee. The DOE Steering Committee, which had been operating since March, 1973, changed into the Ecological Sub-Committee (Figure 4). This was quite a change for DOE, since for the first time that I'm aware of, it involved members of the general public directly in planning staff DOE studies. The Noise Sub-Committee operated similarly (Figure 5), with representation from members of the APC mixed with other members of the various organizations who were technical specialists.

III. AIRPORT EXPANSION CONCEPTS

As I mentioned previously, our Environment Canada assessment began before the Airport Planning Committee had agreed on the path of studies to be pursued. Our studies, therefore, concentrated on proposed alternative runway locations at Sea Island, rather than the alternative airport sites identified by another Airport Planning Sub-Committee.

The Ministry of Transport outlined five different concepts involving land reclamation for the proposed airport expansion (Figures 6, 7 and 8). These concepts are discussed in more detail in the Environment Canada Summary Report (Environment Canada, 1975). Briefly, Concept One (Figure 6) involves a parallel runway configuration as initially considered by the Ministry of Transport, and involves the reclamation of about 68 acres. Concept Two (Figure 7) entails an alternative development plan requiring the reclamation of 234 acres. Concept Three (Figure 7) represents a longer term and larger development, and requires the reclamation of 508 acres, while incorporating Concept Two as an initial stage. Concept Four (Figure 8) is an extended version of Concept Two, involving the reclamation of 627 acres of land. Concept Five (Figure 8) is also a longer term development incorporating Concept Four as an initial stage and involves, in total, about 1,494 acres.

For all of these concepts, the runway length was to be approximately 11,000 feet. You will note that these plans have no detail in them; they are bare concepts.

You may recall that last fall there was some discussion in the newspapers about a runway completely within the Sea Island dyke, which would be about 9,200 feet long. This concept was not studied by any of the sub-committees.

IV. POLLUTION STUDIES

A. STUDY OBJECTIVES:

The aim of the pollution studies was to determine, for the several alternative runway layouts, the changes in various aspects of pollution that would be produced. Sufficient detail was sought so that:

1. The amount of pollution generated could be compared to relevant standards.

2. Other Environment Canada services could determine the magnitude of the effects of pollution on the resources they managed, and

3. Problems requiring additional investigation, but capable of resolution in a subsequent "Environmental Design" phase were highlighted.

Since an environmental assessment should begin very early in the history of a project, there will be many elements of the proposal (certain details of construction techniques, design of certain facilities) which, following standard engineering practice, will not be determined in detail until completion of the assessment and receipt of approval to proceed. Yet, knowledge of many of these details are essential to predicting the environmental effects. Although in many cases, it will be necessary to obtain detailed information on these elements during the assessment phase, it is possible to stipulate approval of a project for implementation subject to environmental design requiring minor environmental appraisal. If this type of approval is given, criteria must be established for the environmental design phase.

B. WATER POLLUTION:

Individual studies were made in three areas, in varying levels of detail.

1. Dredging and Water Quality

The Department of Public Works identified several borrow sites which were physically capable of supplying material (Figure 9). After a literature survey of possible effects, we concluded we would have to examine the chemistry of these sediments. Although I had assumed the chemistry of Fraser River sediments was reasonably well documented, I was wrong, and we conducted a sampling program of our own. These studies were carried out by our own staff as well as by Pollutech Pollution Advisory Services Limited.

Samples were taken in 1974 and 1975 by a variety of sampling methods at proposed borrow sites (Figure 10 and 11). Two types of analyses were conducted; the first an analysis of chemical content for several possible pollutants; the second on Elutriate test (Kelley & Engler [1974])* which consisted of measuring the change in water quality when potential fill material was experimentally added to a sample of receiving water. In the 1975 sampling we also conducted bioasseys on these elutriates.

To indicate the types of analyses performed, representative results are reproduced in Tables 1 and 2.

We found that neither test was an entirely satisfactory criterion for acceptability. Metals found in apparently unacceptable concentrations in the sediment were shown not to present water quality problems by the elutraite test, which is the more logically satisfying test.

2. <u>Airport Operations</u>

A second area of study was in an assessment of the increase in water pollution that may arise from the operation of an expanded airport. Because of lack of detail in MOT's proposal, we requested our Federal Activities Pollution Abatement Branch (FAPAB) to examine and identify existing operations at VIA and other Canadian airports which do, or could, affect water quality.

* Keeley, J.W. and Engler, R.M. (1974); MP D-74-14, NTIS #AD775826

We took this approach in order to identify problem areas for:

(a) future design work, and

(b) because the FAPAB is interested in identifying existing pollution problems at federal installations and in applying funds from the Federal Clean-Up Fund to correct them.

In addition, we tried to determine whether present airport operations, in aggregate, were causing significant water pollution. We were limited by funding to testing composite water samples from the stormwater discharge gates; these were analyzed chemically and also biologically by bioassay with young rainbow trout. These tests were carried out on one wet day, one dry day, and on the first day of rainfall after an extended summer drought. If we had to do this again, I would carry out caged-fish tests at the same time. This was an area we felt required much further design appraisal.

3. Sewage and Iona Island

Sewage from the airport is sent to the GVRD's Iona Island Sewage Treatment Plant (in fact the last connections were made during the study period, financed by the Federal Clean-Up fund administered by DOE). It makes up a small portion (1-2%) of the flow and the expansion was not considered to affect the plant. However, extending a runway onto Sturgeon Banks would restrict circulation and flushing of the outfall. Any construction such as proposed by the MOT would exaggerate what we felt was already and undesirable situation. We suggested and discussed several possible measures that could be taken if the extension were to be built. In view of the complexity of such a study and the responsibility of other agencies, we did not feel that, at this stage, we could do more than recommend joint studies by those responsible, that is the Minister of Transport, the Greater Vancouver Sewage and Drainage District, the Department of the Environment, and the Pollution Control Board.

4. Solid Waste and Toxic Waste

We were fortunate that the Federal Activities Abatement Group (FAAG) was already carrying out a study of solid and toxic waste and provided the results to us as our impact assessment. This study was overseen by a special Steering Committee established for that purpose, made up of representatives from MOT, EPS, National Health and Welfare and the Health of Animals Branch of Agriculture Canada. The lead role on the committee was assumed by the FAAG of EPS, as it was under the auspices of the Federal Activities Clean-Up Program that the study contract was let.

The study employed interviews and field surveys, determining patterns, sources, weights and composition, and problems with the existing system.

At present, the airport generates about 150 cu. yd./day (15 tons) of solid waste. By 1980 this rate is expected to double, ie. grow in proportion to traffic increase. The proposal adopted by the Sub-Committee was for incineration with heat recovery, with the waste disposal management becoming centralized to MOT.

C. AIR POLLUTION:

Emissions of air pollutants from an airport are generally a small proportion of the total emissions in a metropolitan area. Nevertheless, concern was expressed that an increase in air traffic relative to the reduction of emissions from industrial sources as a result of implementation of abatement programs, will make aircraft-generated pollutants a more significant factor in the over-all air pollution burden of a metropolitan area and, more importantly, in the degradation of air quality in the proximity of an airport.

The present study regarding the Vancouver International Airport set out to determine the magnitude of the emissions, by type of pollutant, from the various airport-related activities within the boundary of Sea Island, as well as the disposition and the influence of the emissions on the ambient air quality within urban areas in close proximity to (ie. most directly exposed to) the airport operations on Sea Island.

The study was carried out by B.C. Research, Vancouver, on a consultant contract basis; the work was co-ordinated and directed by a task force team having representation from the Greater Vancouver Regional District, the Pollution Control Branch of the Province of British Columbia, the Ministry of Transport (Canada) and the Environmental Protection Service and Atmospheric Environment Service of Environment Canada.

This study used as its baseline the programmed air traffic expansion forecast previously developed by the Ministry of Transport. MOT provided air traffic and vehicle traffic projections, based on these passenger traffic forecasts, which were used in conjunction with emission factors obtained from Canadian and American literature to determine total emissions.

We examined emissions from aircraft, ground service vehicles, engine tests, stationary sources, and vehicular access traffic for five classes of emissions: Carbon Monoxide, Hydrocarbons, Nitrogen Oxides, Sulphur Oxides, and Particulates. On Figure 12 we have graphed the average total emissions by source. It was interesting to note that vehicle traffic during the base year 1973 was estimated to account for 44% of the total emission, as compared to 47% by aircraft. This study, of course, only considered aircraft emissions while they were in the immediate vicinity of VIA.

We also predicted theoretical ambient pollutant concentrations, using a relatively standard dispersion modelling approach. Four urban areas contiguous to Sea Island, located southeast, northeast, north and south of the airport.

D. NOISE STUDIES:

Noise Studies were carried out as a joint effort of MOT, DOE and the GVRD, under direction of a sub-committee of the Airport Planning Committee; with representatives from MOT, DOE, GVRD, Richmond, Vancouver, the industry, and the Community Forum.

The committee was chaired by a succession of three DOE people including the author; in the last stages it was chaired by the representative from the Municipality of Richmond. Studies were carried on throughout the life of the committee and the organization of the study went through a process of evolution, finally arriving at a Noise Study Team reporting to the Sub-Committee, through a Co-ordinator, who was a consultant, and finally through a Moderator, who was a Sub-Committee member, with some expertise in the noise field, from GVRD.

The form the study took is best explained in flow chart fashion (Figure 13).

There are many critical steps in the pathway. One that we did spend a great deal of time and effort on was in establishing the units of measurement for noise.

When the study began, the unit used by MOT for measurement and prediction of aircraft noise in Canada was the Noise Exposure Forecast, or NEF. Without going into a great deal of explanation, this unit was not acceptable to several of the Noise Sub-Committee. On reflection, I think there was confusion on both sides with respect to what the NEF did in relation to what it was expected to do. We desired a unit that could be measured physically, ie. a numerical measure, and that could be related fairly well to effects on humans.

We finally concluded that we needed several criteria. These are shown on Figure 14. Having determined the criteria, the various noise contours were calculated. The flow diagram is shown on Figure 15.

The results were noise contour maps, such as shown in Figure 16. From this, the number of people affected and the degrees of effect were calculated.

Within the concerns addressed by the Ecological Sub-Committee; it is my opinion that the loss of fish and wildlife habitat is the most serious concern directly resulting from the proposed runway construction. Pollution will be increased, but can be kept at a minimum. This, however, does not imply that we think the pollution added is of no concern. There is a problem.

The problem is well brought out in the case of air pollution.

The air quality study conducted was a theoretical one utilizing relatively standard techniques for predicting air quality, but having an advantage over similar studies in that long-term meteorological data was available in the immediate locality. The results are intended to determine air pollution from airport activity alone. Although confirmation of this by actual sampling is important, this should be done by extension of the existing National Air Pollution Surveillance system in the area.

Airport activity up to the year 2000 in itself will result in ambient pollutant levels well within the most stringent levels set forth under federal and provincial air quality objectives, on an annual average and a 24-hour average basis.

On a short term basis, it is estimated that of all the pollutants, only nitrogen dioxide may exceed the one-hour concentration limit of the maximum acceptable level of the National Air Quality Objectives. This condition is expected to occur very infrequently and only during the joint occurence of peak airport activity and most adverse climatological conditions. By the year 2000 the local air quality degradation due solely to airport activity will be similar to that presently occurring in central Vancouver due to urban activity, however, this is based on activity projections to the year 2000, which are highly uncertain.

While even the short term maximum pollutant concentrations from airport activity will not be serious from an ecological point of view, they may contribute to an overall pollution prblem connected with our local topograhy. This problem arises when a persistent, elevated inversion lid forms over the Lower Mainland, and air within the basin is not replenished, but is carried backward and forward by land/sea breezes. The airport activity contribution to this is not know, although airport-related emissions are a very small fraction of the total emissions in the Lower Mainland.

It should be evident that the solution to this larger problem is control of individual sources, combined with air resource management planning on a larger scale, and that more research into a realistic air quality model for the Lower Mainland is required. We are fortunate that the control of air pollution problems is on a regional basis, and control of airport generated air pollution (for example by decreasing automobile activity) should be undertaken with recognition of this fact.

The situation with respect to water pollution is somewhat analogous. The study of dredging has concluded that, to the best of our knowledge, limited dredging could take place with proper controls which would not result in a serious pollution problem. A survey of airport generated water pollution discharged through the storm drainage system has identified several intermittent problem areas, which will be further studied and corrected as part of the Federal Government's Clean-Up program described earlier; expansion of facilities without correction would increase pollution, and correction is a pre-requisite to expansion. Limited sampling of outfalls during wet and dry periods, and testing by chemical analysis and laboratory bioassay did not indicate any acute toxicity problem for fish, although the intermittent sources mentioned above could have this effect. The increased amount of sanitary waste from an expanded airport will not have any appreciable effect, by itself, on the effluent discharged from the Iona Island Sewage Treatment Plant (although the Solid and Toxic Waste Study identified a source of heavy metal contamination which will be corrected). However, the proposed embayment of the discharge area is of concern because of its effect on dilution.

The total water pollution loading from the existing airport, or the proposed airport expansion, cannot be accurately determined from our data. We have good reason to believe it is small compared with other sources to the Fraser River; if the recommended corrective action is carried out it could be improved further. Yet, even had this desired data been obtained, we would be little further ahead in our assessment of the impact of water pollution, in view of the lack of data on existing water pollution effects on the aquatic environment of the Lower Fraser.

Knowing that ecological information is lacking, and also knowing that inevitably some pollution will be discharged, EPS attempts to minimize water pollution by devising regulations which demand the application of best practicable technology to pollution sources. Our immediate aims are to minimize discharges of substances which can become harmful by accumulation in aquatic organisms, and to ensure that the effluent is "non-toxic" to fish (this based on well-founded assumption that dilution by good quality receiving water will minimize sub-lethal effects); both of which aims safeguard human use of the water or the aquatic organisms. At the same time, we recognize that even though individual sources are controlled, the overall problem will increase as population and resource utilization increase. A recent study (Hall et al, 1974), on the Lower Fraser, indicates potential problems with heavy metals and by pathogenic organisms in particular.

Although the loss of habitat for fish and birds may be the more serious problem at present, the necessity for the remaining habitat to be of high quality makes the potential pollution problems even more significant, and increases the need for caution in decision-making.

TABLE 1 ELUTRIATE TEST RESULTS (1975)

		ELUTRIATES							RECEIVING WATER
BORROW	1	2	3	5	6	6	7	8	
SAMPLE STATIONS	3	2	4	7	8	5	6	1	
COD mg/l	68.6	51.0	40.8	46.10	51.5	56.4	52.9	41.9	41.2
NITRATE - NITRITE mg/l	0.035	0.060	0.078	0.021	0.018	0.047	0.028	0.045	<0.002
AMMONIA	0.030	0.114	0.286	0.246	1.06	0.455	0.423	0.083	0.045
TOTAL ORGANIC NITROGEN mg/l	0.165	0.680	0.413	< 0.025	0.050	3.19	2.55	0.795	0.206
TOTAL KJELDAHL NITROGEN mg/l	0.195	0.794	0.691	0.245	1.110	3.64	2.973	0.878	0.251
LEAD mg/l	0.001	0.006	0.003	0.002	0.002	0.002	0.003	0.002	<0.001
ZINC mg/l	0.020	0.085	0.026	0.003	0.004	0.046	0.046	0.024	0.003
COPPER mg/l	<0.001	0.003	0.002	< 0.001	0.003	<0.001	0.001	0.001	<0.001
CHROMIUM mg/l	0.0012	0.0004	0.0003	0.0024	0.0016	0.0022	0.0011	0.0018	0.0005
MERCURY mg/l	<0.005	<0.005	<0.005	< 0.005	< 0.005	<0.005	<0.005	<0.005	<0.005

TABLE 2 SEDIMENT ANALYSIS RESULTS (1975)

BORROW		1	2	3	5	5	6	7	8
SAMPLING STATION		3	2	4	7	8	5	6	1
TOTAL SOLIDS	%	78.8	78.3	80.7	79.3	76.1	59.2	68.9	81.3
VOLATILE SOLIDS	%	0.61	0.67	0.74	1.4	1.8	3.7	2.9	0.70
TOTAL PHOSPHORUS	mg/kg	480	460	410	8	8	870	660	420
KJELDAHL NITROGEN	mg/kg	249	199	188	154	259	896	638	234
SULFIDES	mg/kg	<2.0	<2.0	<2.0	-	-	112	6.4	2.6
COD	mg/kg	510	1560	451	665	715	7530	3330	500
LEAD	ug/g	< 50	<50	<50	<50	<50	< 50	< 50	<50
ZINC	ug/g	40	40	40	40	50	100	70	40
CHROMIUM	ug/g	30	50	50	60	60	100	100	50
MERCURY	ug/g	0.23	0.58	0.17	0.16	0.10	0.63	0.63	0.27
COPPER	ug/g	20	20	20	20	20	45	40	20

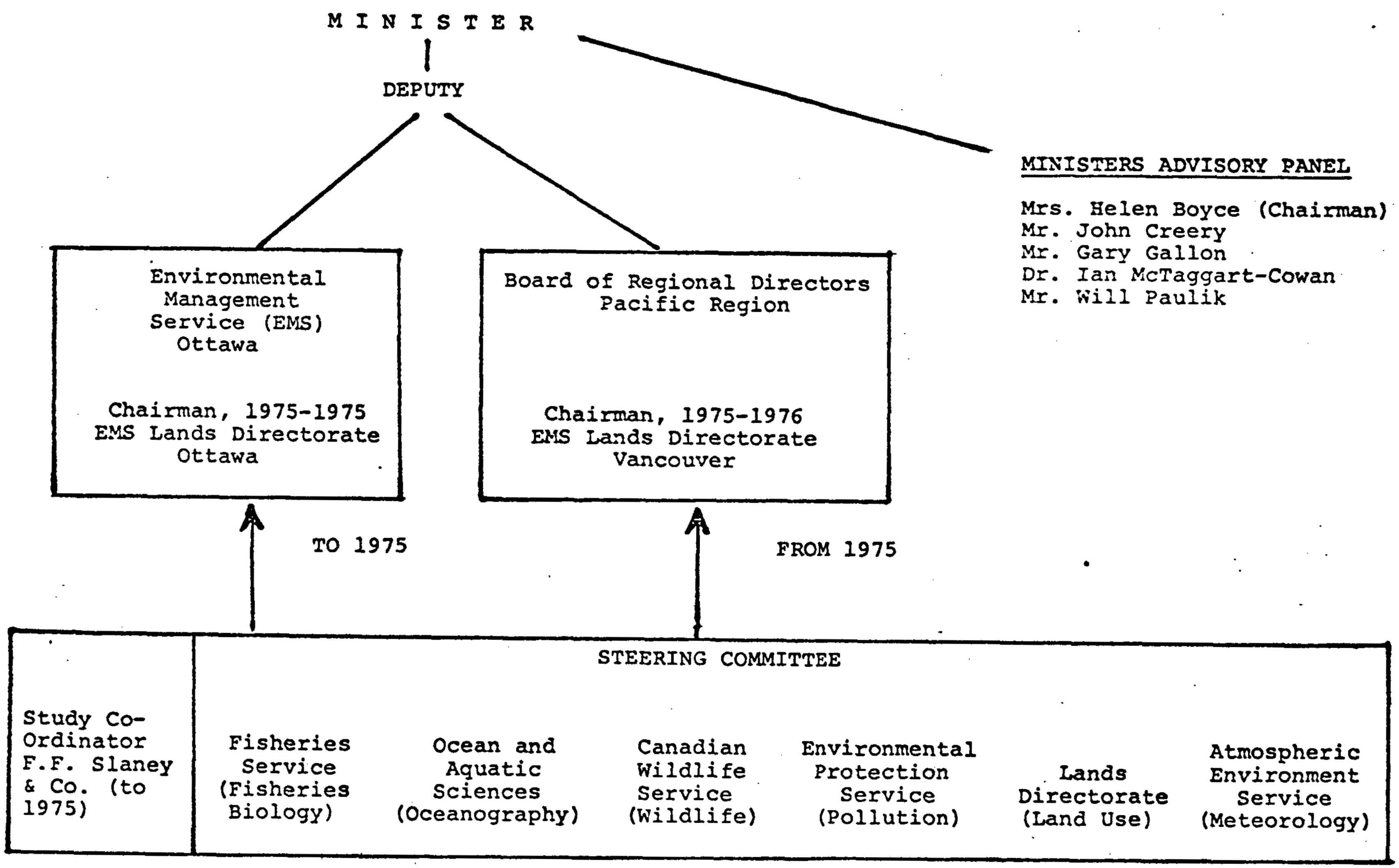


FIGURE 1 - Environment Canada Study organization for Vancouver International Airport Environmental Assessment.

CONSTITUTION OF THE VANCOUVER AIRPORT PLANNING COMMITTEE

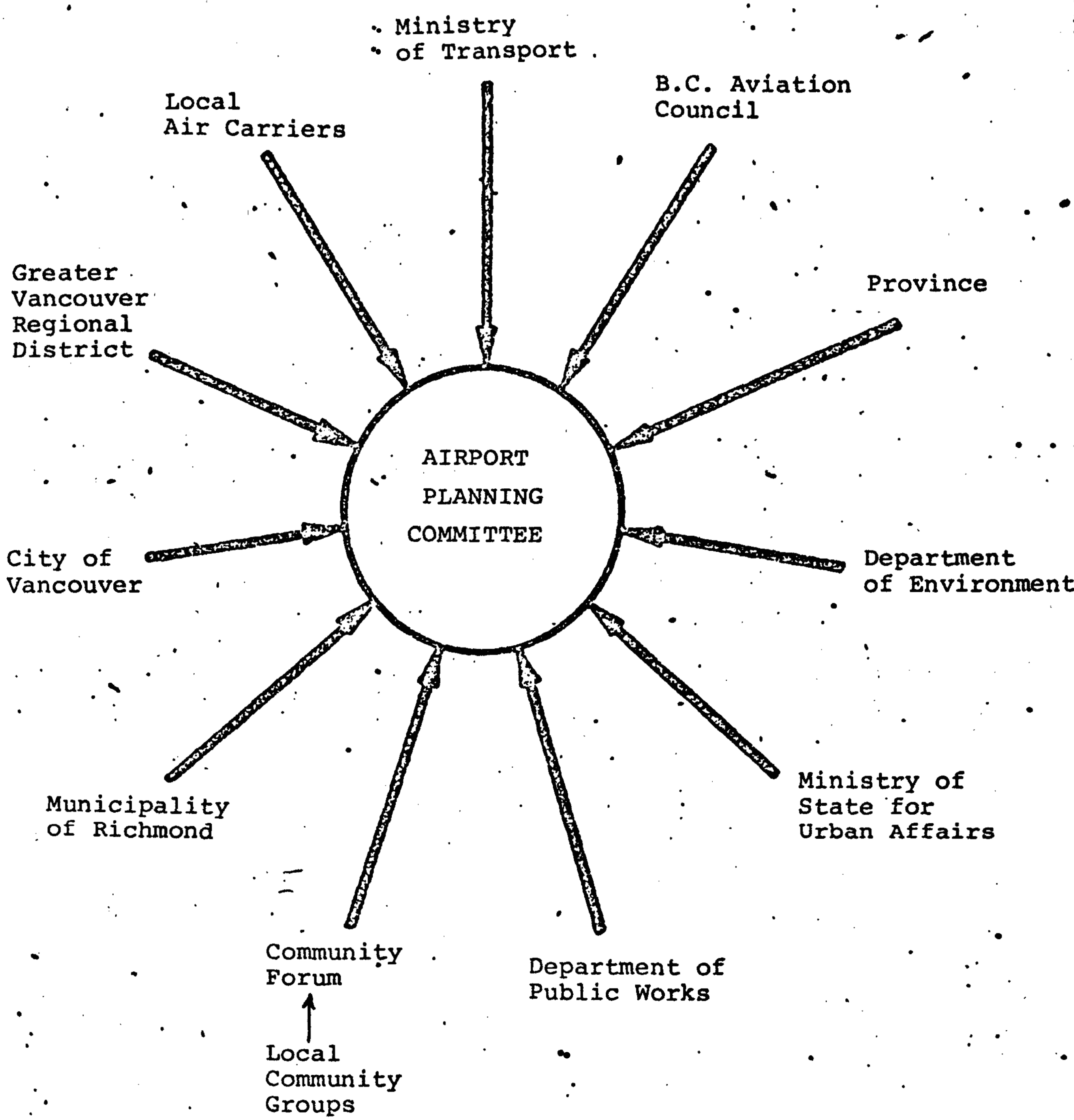


FIGURE 2.

THE VANCOUVER AIRPORT

PLANNING COMMITTEE

and its FUNCTIONAL

SUB-COMMITTEE

STRUCTURE

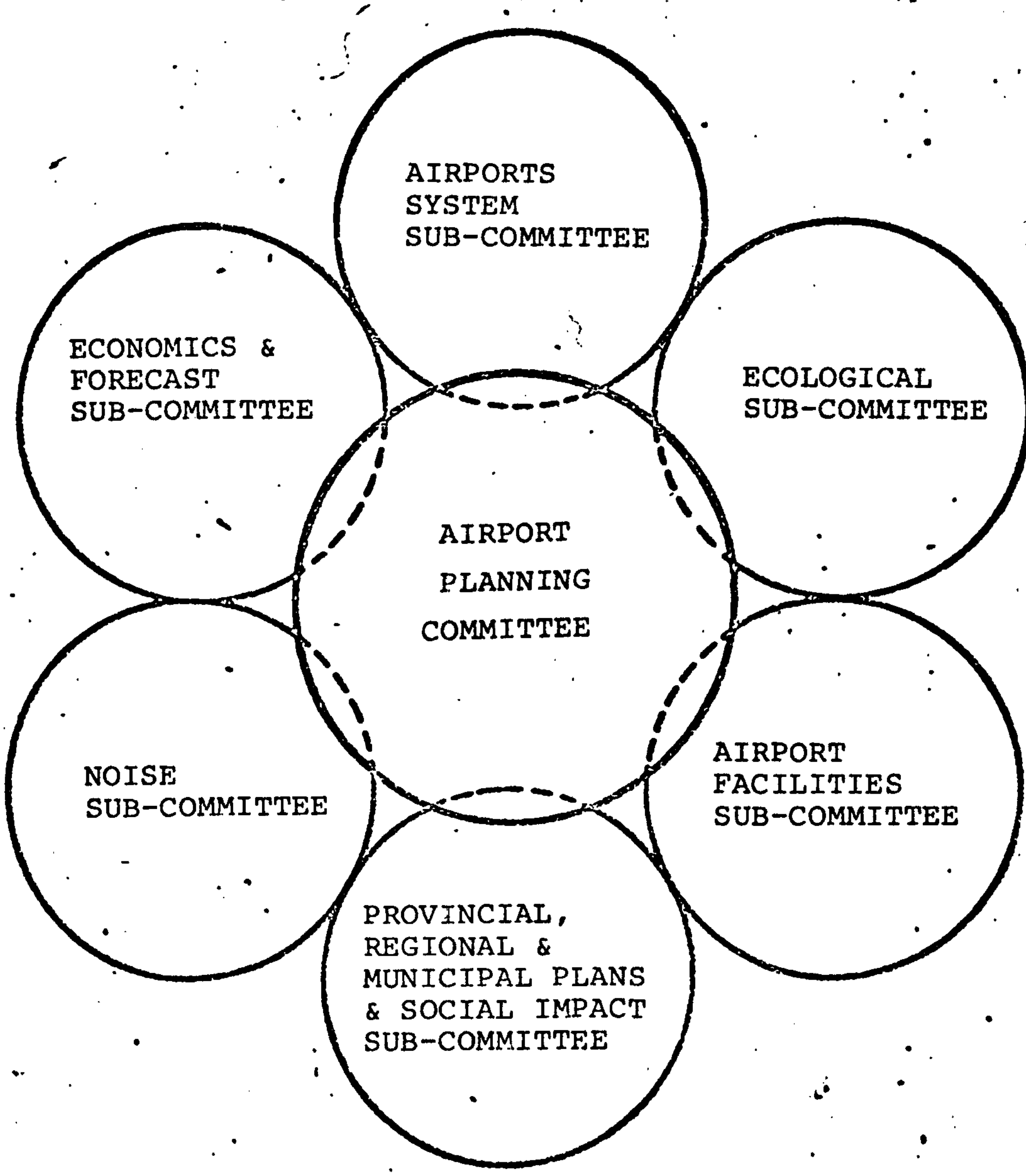


FIGURE 3.

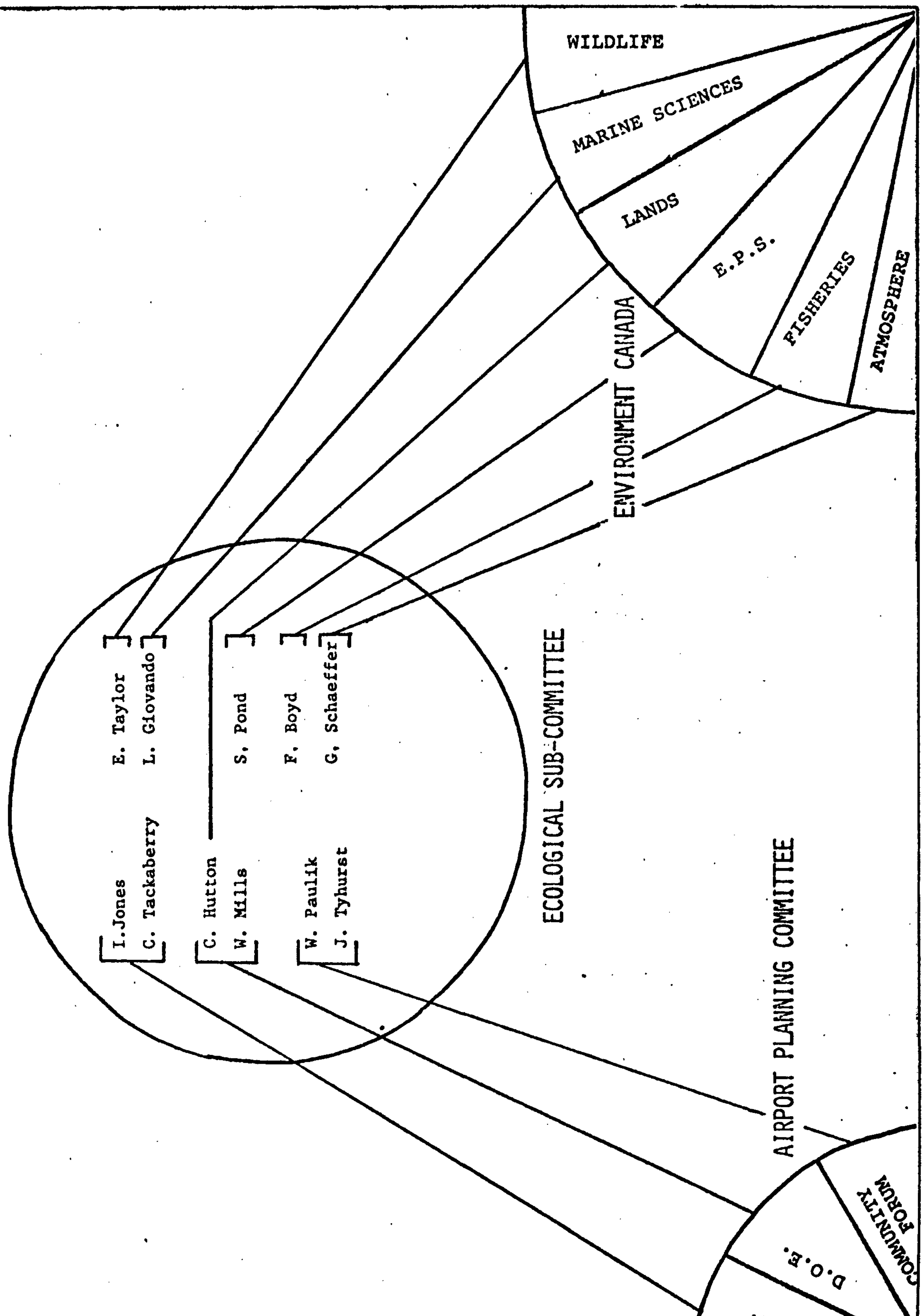

WILDLIFE
MARINE SCIENCES
LANDS
E.P.S.
FISHERIES
ATMOSPHERE
ENVIRONMENT CANADA
E. Taylor
L. Giovando
S. Pond
F. Boyd
G. Schaeffer
I. Jones
C. Tackaberry
C. Hutton
W. Mills
W. Paulik
J. Tyhurst
ECOLOGICAL SUB-COMMITTEE
AIRPORT PLANNING COMMITTEE
COMMUNITY FORUM
D.O.E.
M.O.T.

FIGURE 4.

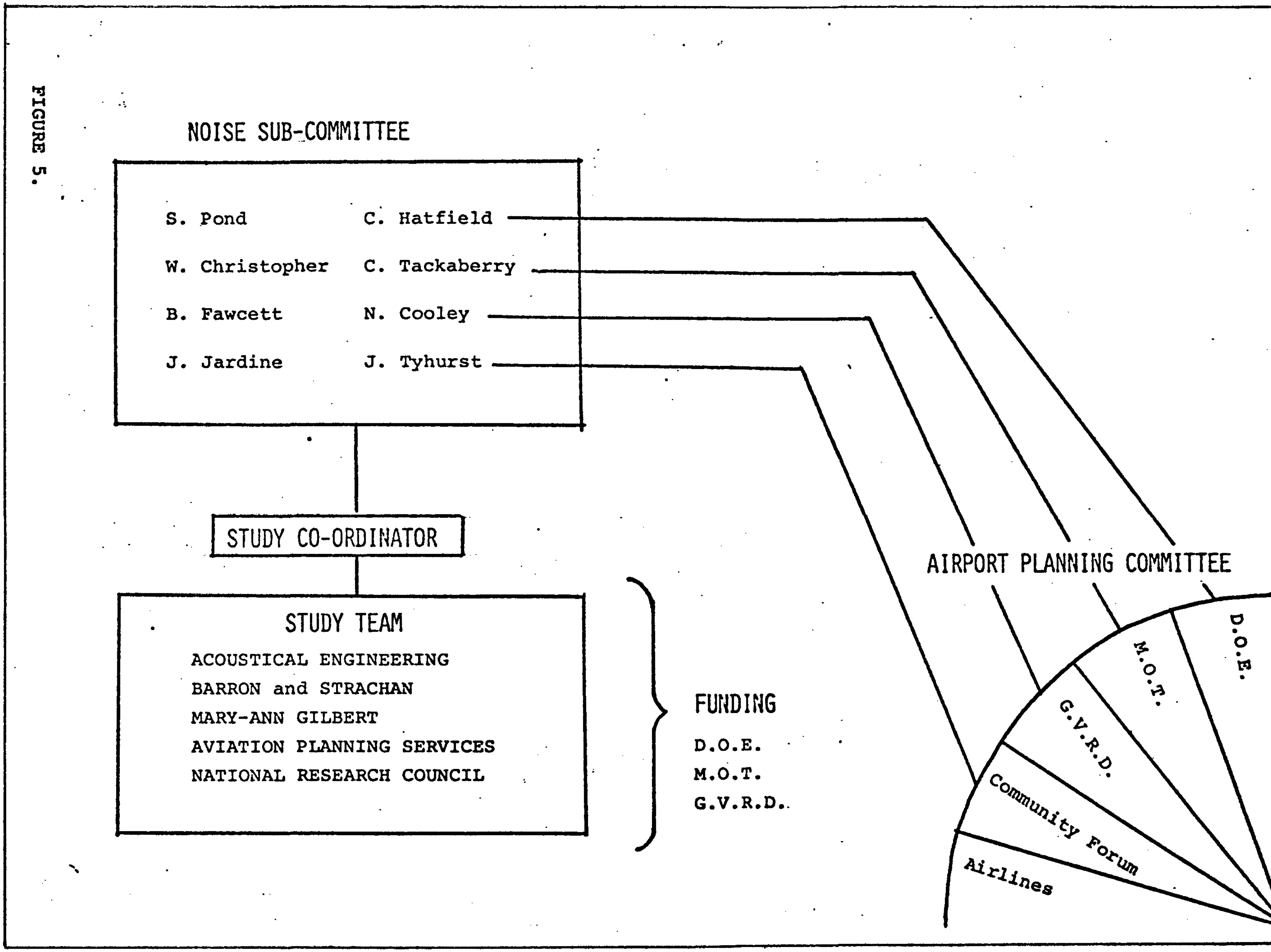

NOISE SUB-COMMITTEE
S. Pond
C. Hatfield
W. Christopher
C. Tackaberry
B. Fawcett
N. Cooley
J. Jardine
J. Tyhurst
STUDY CO-ORDINATOR
STUDY TEAM
ACOUSTICAL ENGINEERING
BARRON and STRACHAN
MARY-ANN GILBERT
AVIATION PLANNING SERVICES
NATIONAL RESEARCH COUNCIL
FUNDING
D.O.E.
M.O.T.
G.V.R.D.
AIRPORT PLANNING COMMITTEE
D.O.E.
M.O.T.
G.V.R.D.
Community Forum
Airlines

FIGURE 5.

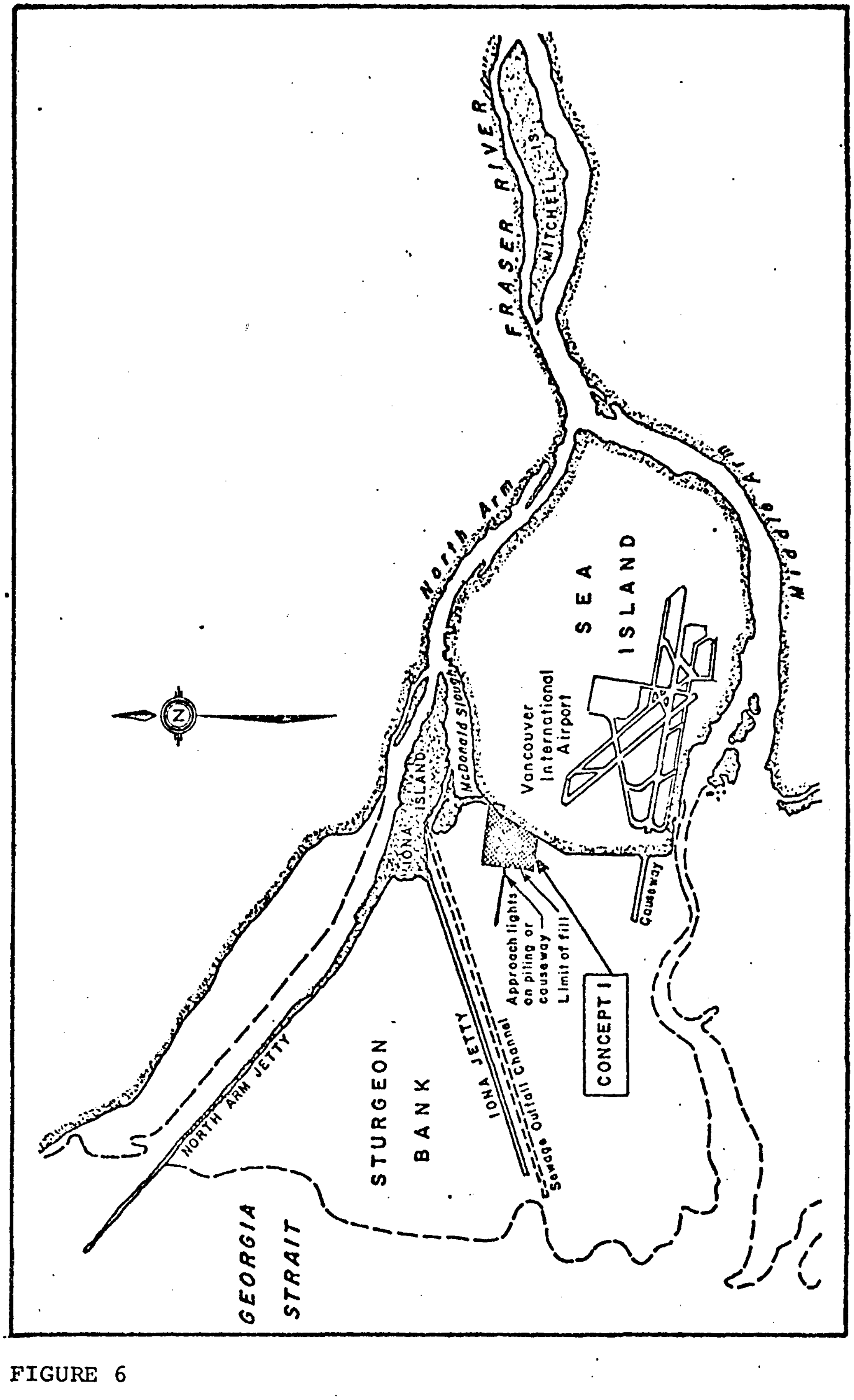


FIGURE 6 VANCOUVER INTERNATIONAL AIRPORT EXPANSION - CONCEPT I

FIGURE 6

FIGURE 7

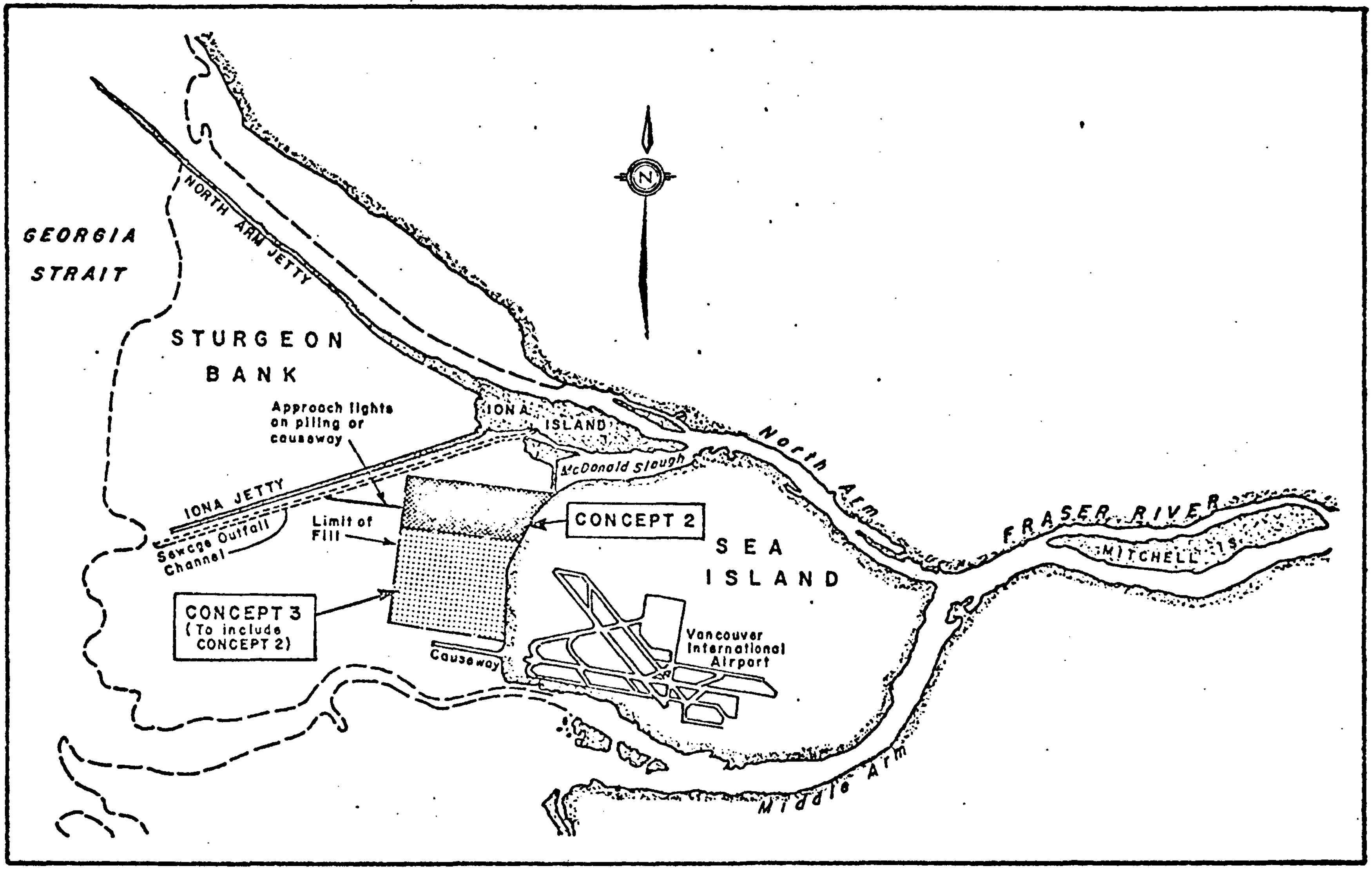


FIGURE 7 VANCOUVER INTERNATIONAL AIRPORT EXPANSION - CONCEPTS 2 & 3

FIGURE 8

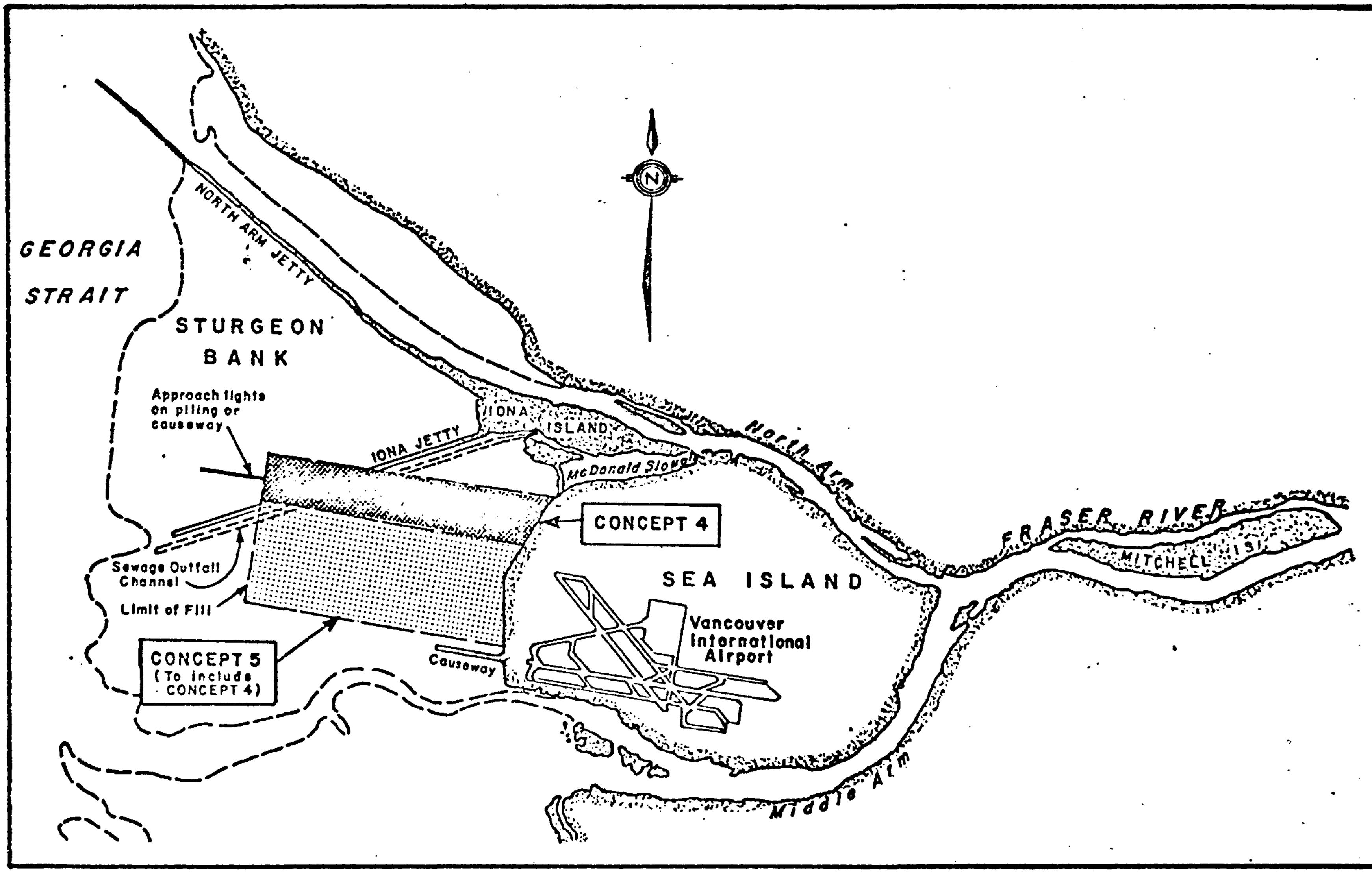
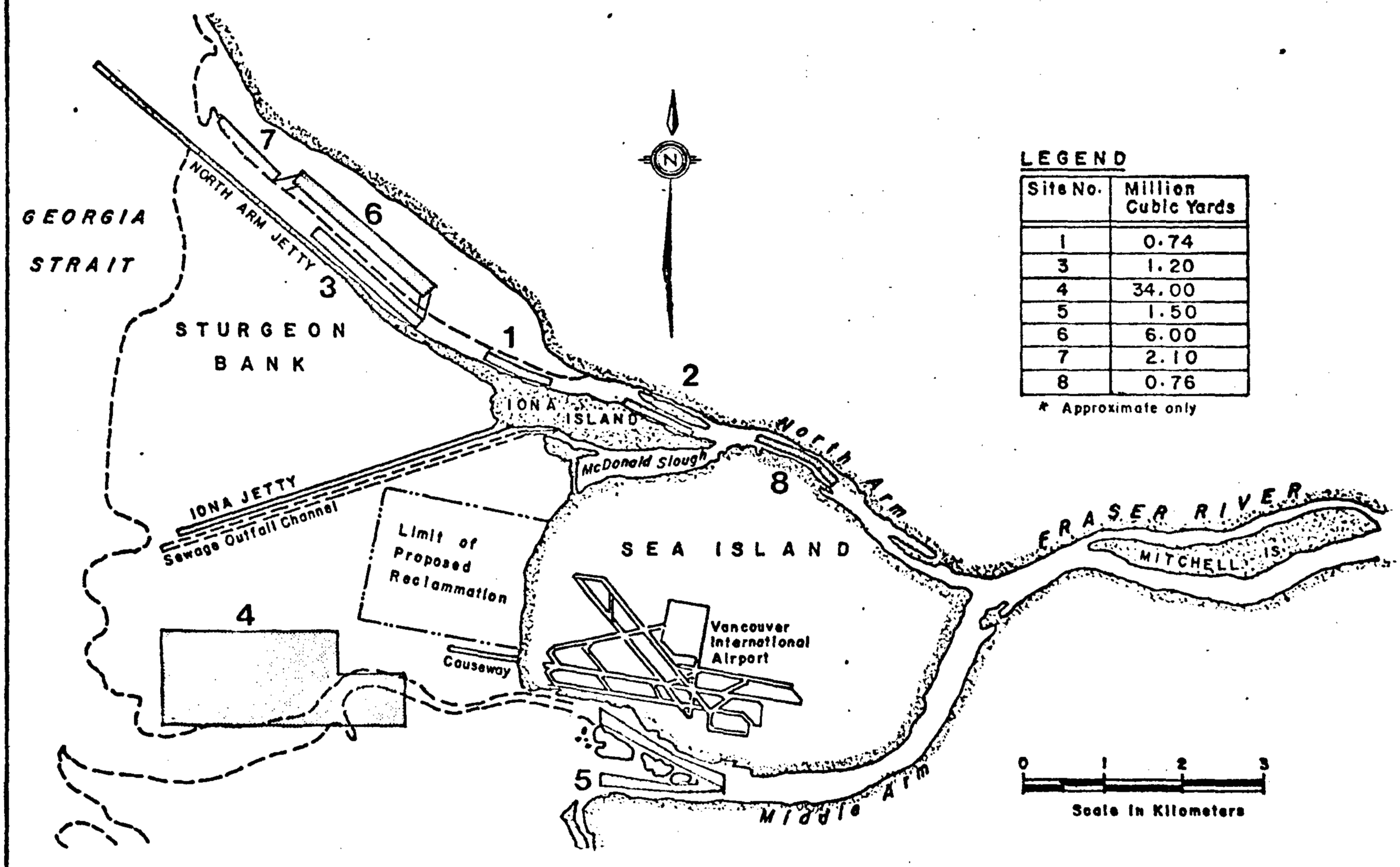


FIGURE 8 VANCOUVER INTERNATIONAL AIRPORT EXPANSION - CONCEPTS 4 & 5



Site No.	Million Cubic Yards
1	0.74
3	1.20
4	34.00
5	1.50
6	6.00
7	2.10
8	0.76

* Approximate only

FIGURE 9 LOCATION OF PROPOSED BORROW SITES.

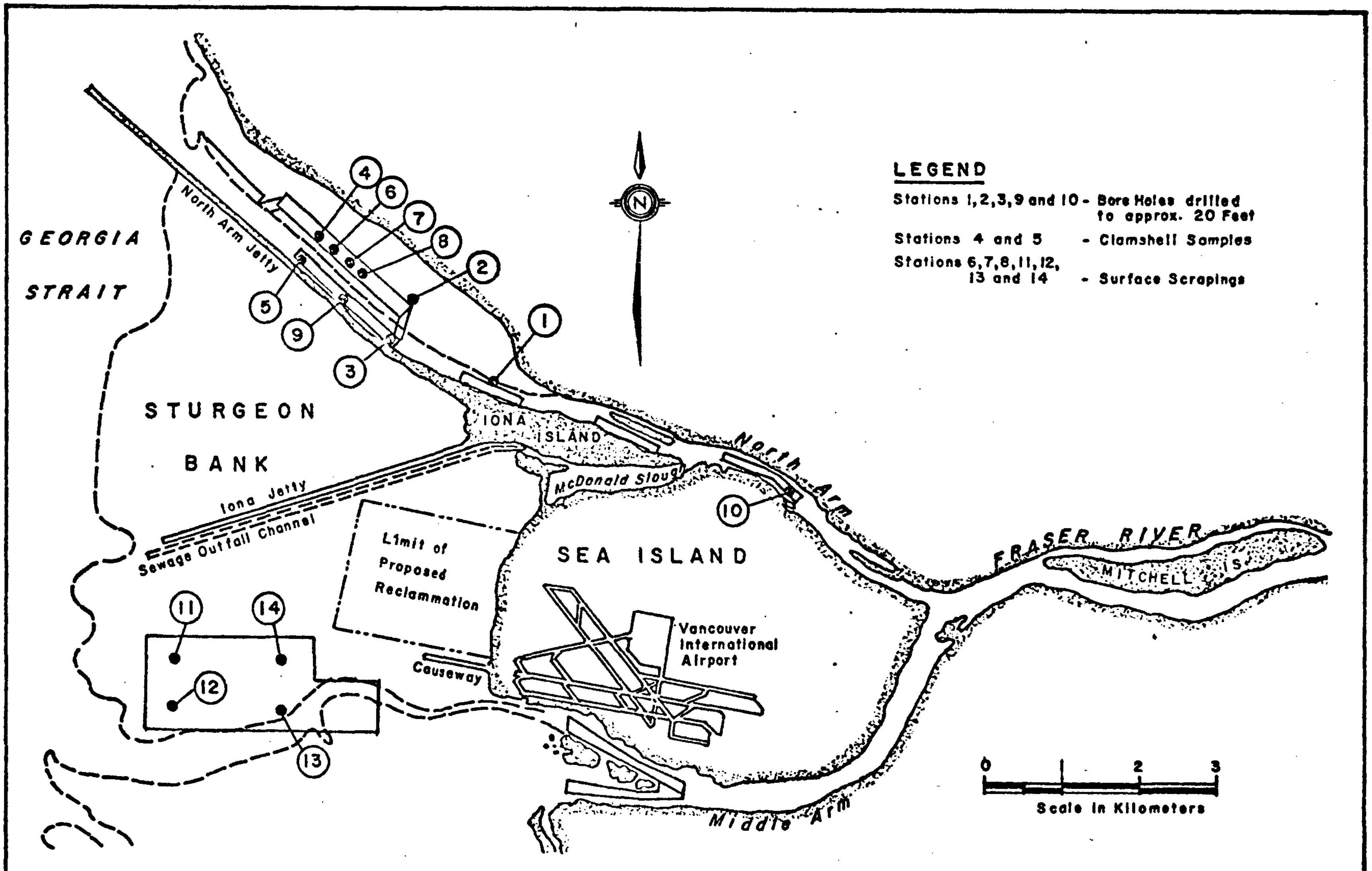


FIGURE 10 LOCATION OF SEDIMENT SAMPLING STATIONS (1974)

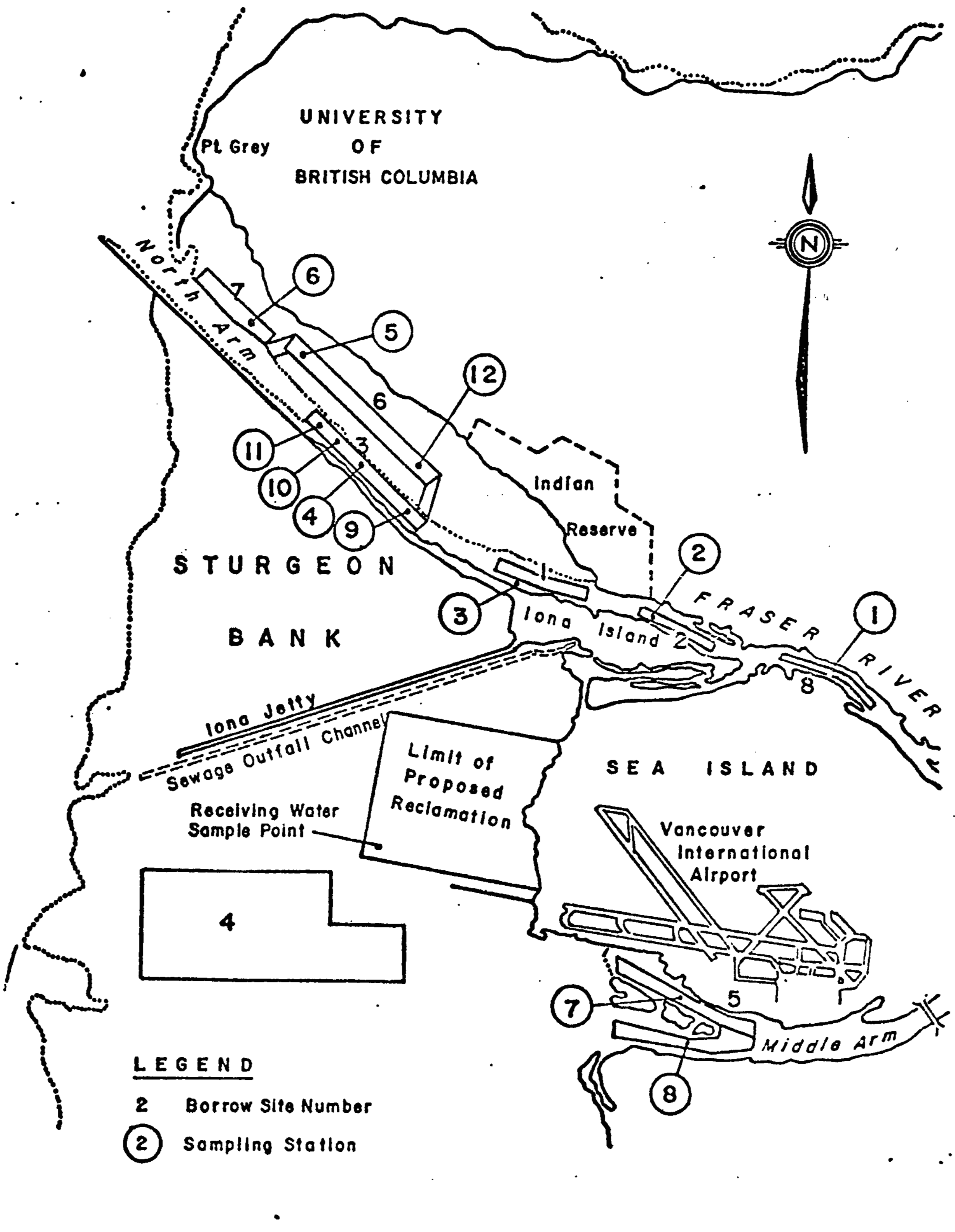


FIGURE 11 LOCATION OF SAMPLING STATIONS 1975

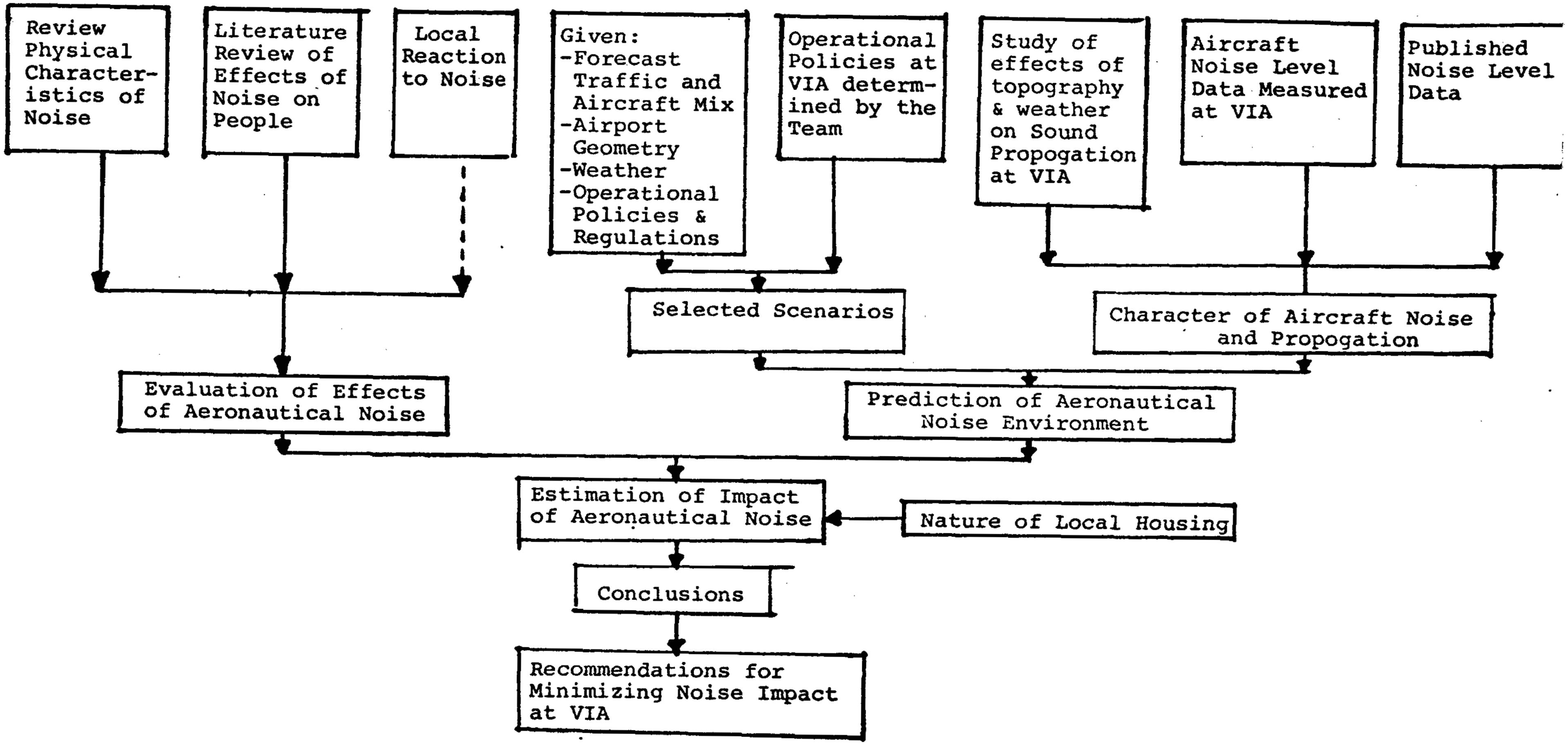


FIGURE 13 : OUTLINE OF AERONAUTICAL NOISE STUDY TOPICS

EFFECT	NOISE DESCRIPTON	EFFECT/LEVEL THRESHOLD
Hearing Damage Dosage	Leq(24)	70 Leg(24)
Indoor		
Concentration Interference	Single Event Peak dBA	80 dBA outdoors
Sleep Disturbance	Single Event Peak dBA	75 dBA outdoors
Expressed Annoyance	Ldn	55 Ldn

dBA - dB is 10 log the sound pressure or amplitude. Sounds can be different pitches, or frequencies; the human ear is more sensitive at 1000 Hz than other frequencies above and below. Therefore, sound meters are built with filters to approximate this sensitivity; we used dBA which in North America is the preferred system for measuring "normal" noise.

Leq(24)-The equivalent 24 hour continuous noise level on an energy basis. Since dBA is logarithmic it is not meaningful to arithmetically average dBA readings. Instead one calculates the amount of sound energy experienced over the period of time desired and averages this.

Ldn - The Leq over a 24 hour day, with 10 dBA added to nighttime readings to compensate for the increased annoyance.

FIGURE 14.

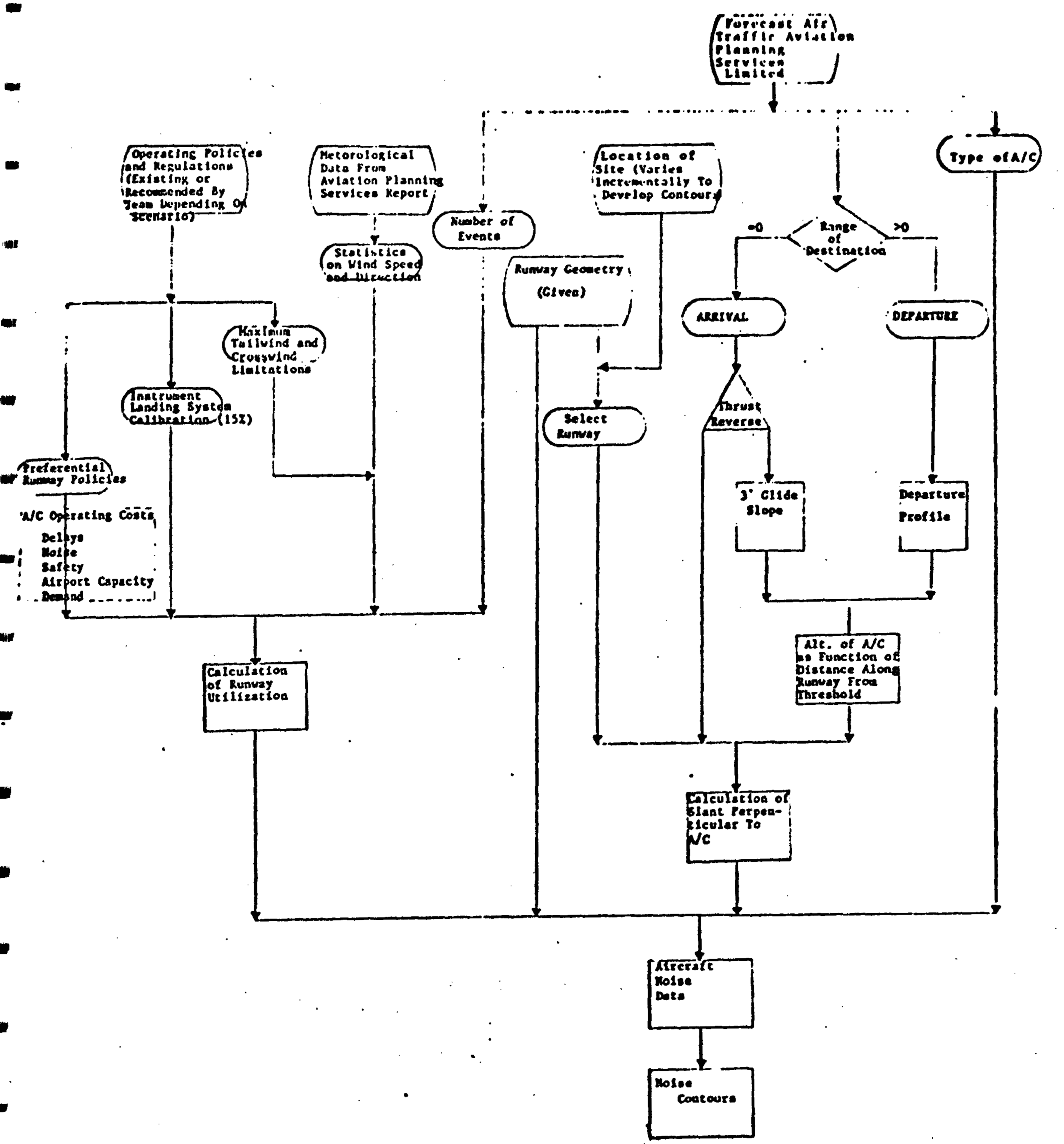
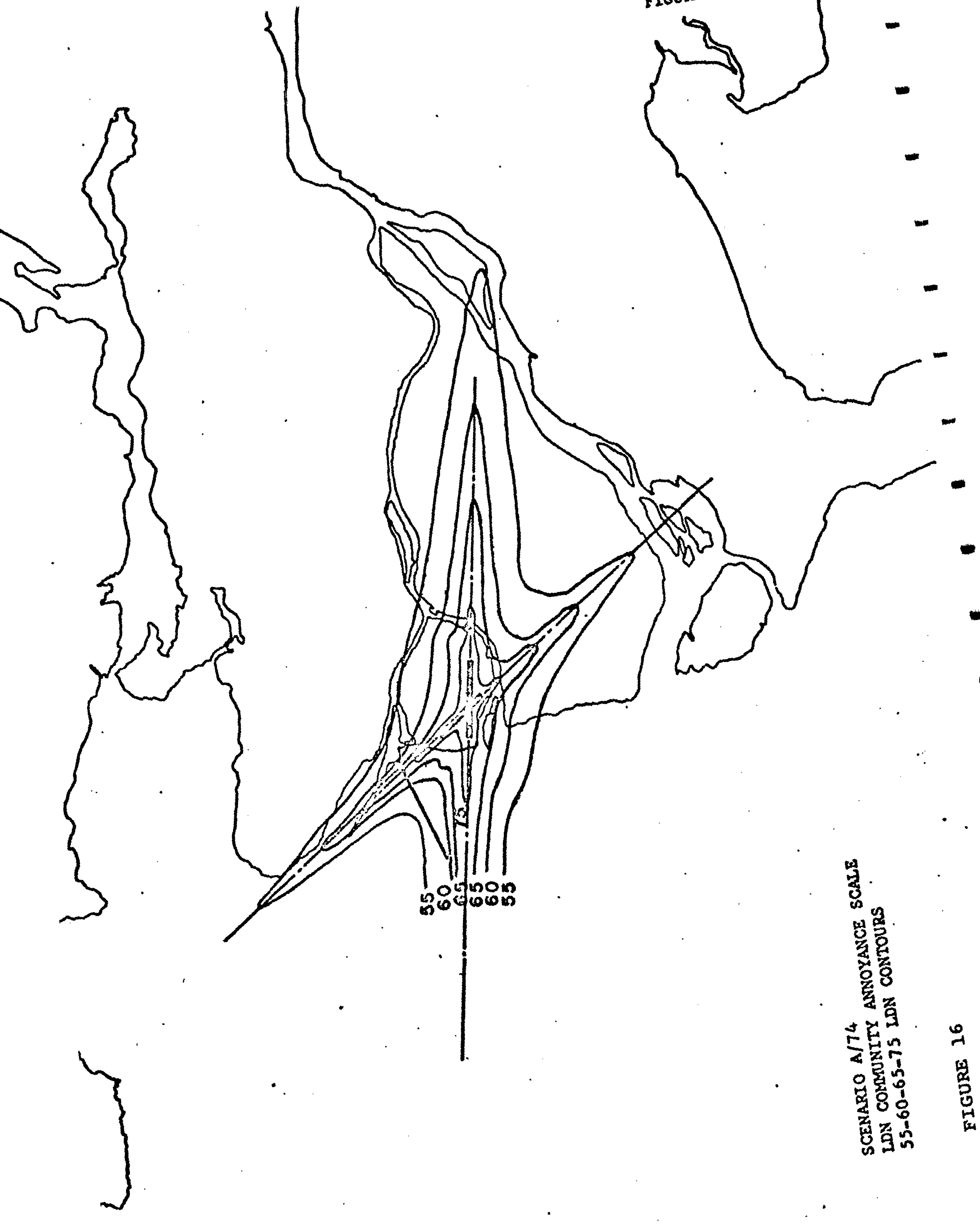


FIGURE 15 : FLOW DIAGRAM OF PREDICTION PROCEDURE



SCENARIO A/74
LDN COMMUNITY ANNOYANCE SCALE
55-60-65-75 LDN CONTOURS

FIGURE 16

"MONITORING BRITISH COLUMBIA'S FORESTS"

I. INTRODUCTION

British Columbia is one of the most important and most significant forest areas in the World. Unfortunately, too often the importance of this Province's forest resource and the magnitude and complexity of the administrative, technical and planning responsibilities involved is not fully appreciated.

For example,

- How may appreciate the fact that British Columbia has the greatest diversity of climatic, topographic and "forestry" conditions in Canada, or,

- How many appreciate the fact that British Columbia has Canada's greatest range of social benefits derived directly or indirectly from the forest resource, including the Nation's most important and diverse fishery resource, or,

- How many appreciate the fact that approximately 40% of the roundwood cut in Canada is harvested in British Columbia, or,

- How many appreciate the fact that British Columbia has a greater acreage of productive forest land and a greater

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Paper presented at seminar re "Monitoring for Environmental Protection", Association of Professional Engineers of British Columbia - February 13, 1976.
By W. Young, Assistant Chief Forester, B.C. Forest Service.

annual harvest from these lands than all the United States National Forests combined, or,

- How many appreciate the fact that the Prince George Forest District (one of six in British Columbia) has a greater annual forest harvest than the combined annual harvests of Alberta, Saskatchewan and Manitoba.

Of course, it follows that with such an important forest resource, British Columbia must have an elaborate method of monitoring the growth and harvest of this resource in order that our forests will continue to provide the wide array of social and economic benefits that we all enjoy. Thus, I have interpreted the theme of this seminar - "Monitoring for Environmental Protection" - as the monitoring of the forest resource itself since it is my opinion that there is nothing that contributes more to the quality of the environment in British Columbia than the Province's forests.

II WHAT IS MONITORED AND HOW

The forests of British Columbia are a renewable resource which involves the harvesting, establishment and tending of the forest until, finally, the sequence begins again.

For the purpose of this paper, I propose to discuss the monitoring aspect by breaking into this renewable circle at the harvesting state and follow it through to the next harvesting phase. I hope that the slides that I will be showing will assist in identifying the various monitoring checks and balances as we follow a forest through its 100 years (more or less) of growth.

A The Harvesting Program

1) Pre-Harvest Timber Cruising

Any business must know the volume and price of its products available for sale at a specific time. So it is for forestry. Thus there is an assessment or monitoring of the standing crop - timber cruising. This program is designed to obtain data on that part of the resource being sold including volume of wood, grade (i.e. quality), species and decay in order to set an equitable price tag on the product.

2) Scaling

Following the actual forest harvest, one of the most important monitoring roles occurs - scaling. Timber is scaled in British Columbia by "stick scale" or "weight scale". The scaling procedure ascertains the actual volume of wood that is cut and removed from any specific tenure. While the timber cruise sets the price, it is on the volume determined by this scaling procedure that the licensees are billed. The scaled volume is compared with the cruised volume for the particular tenure and this provides a basis for assessing waste problems. During the past ten to twelve years, we have seen a major shift from 100% "stick" scaling to a form of sample scaling. This trend has been most evident in the interior of B.C. where approximately 90% of the timber harvested annually is sample scaled through weight scales.

Simply stated, the weight scaling procedure is as follows:

1) Depending on the timber types and its degree of homogeneity, various strata are established for each weight scale station. For example, there could be a Douglas Fir strata, a spruce-balsam

strata and a lodgepole pine strata.

2) Depending on the variable nature of the strata, a sampling schedule is established. This results in a certain percentage of the loads being dumped in a sampling yard where a careful and accurate "stick" scale is made.

3) All trucks are weighed (loaded and empty) and a weight-scale factor developed for each strata.

4) This factor changes continually as new loads are sampled and the weight-scale relationship changes.

2) Residual Assessments

The next monitoring role involves an assessment of residual volumes and potential waste. As mentioned earlier, any major discrepancy between cruised volume and scaled volume may be attributable to an undesirable and unacceptable degree of wood waste left on the ground following logging. In such instances, a field sample measurement of the waste involved is made and the licensee could be subject to waste penalties (financial and timber position). This assessment is done through the establishment of sample plots where a sample of the logged area is measured to determine residual wood comprised of:

a) merchantable felled trees abandoned

b) excessively high stumps

c) merchantable logs and parts of trees.

B. <u>Regeneration</u>

1) Regeneration Surveys

Following a variable period after the forest harvest, a field assessment is made of the logged area to determine if it is satisfactorily stocked with new seedling growth.

This monitoring responsibility involves a major regeneration survey program throughout British Columbia each year. The results of the survey will determine whether Mother Nature plans to restock the area or, conversely, whether the area should be planned for a reforestation planting program. In view of the fact that approximately 400,000 acres are logged annually in British Columbia, the magnitude of this task is self-evident.

2) Planting Check

On all tree planting programs, the quality of the planting is monitored for such deficiencies as loose trees, voids, slit planting and the like. It is on this assessment that projects are approved and tree planting contractors are paid.

3) Survival Plot Surveys

On those areas where tree planting has been completed, a further monitoring survey is conducted following two to three growing seasons. This assessment is designed to determine actual mortality and, where necessary, to prescribe additional "fill-in" planting.

C Other Resource Assessments

Following the forest harvesting operation, other resource managers may, from time to time, assess the effect of the harvesting pattern on their resource. For example, wildlife biologists may monitor the effect on a wildlife species in relation to the size, shape and location of cut blocks; the effect of wildlife corridors and the like.

D Insect and Disease Assessments

Throughout the life of a forest - from regeneration to harvest, it is susceptible to attacks and depletion by a myriad of forest pests and diseases. In British Columbia, and throughout Canada the federal government through the Canadian Forestry Service is responsible for the research into and the monitoring of forest insects and diseases. Each year, the Canadian Forestry Service embarks on a major survey program and through air reconnaissance, plot re-measurements and ground surveys, the state of the provincial situation is updated annually. Following this field assessment, a multi-disciplinary group(government and industry) called the Provincial Forest Pest Review Committee reviews the situation and activates any control programs deemed necessary. Such control programs may involve forest harvesting methodology, curtailment on log movement, spraying and the like.

E Periodic Forest Inventories

The major portion of British Columbia's forest land in under sustained yield management. This land is included in either public sustained yield units (publicly managed) or tree farm licences (privately managed). In both instances, periodic forest inventories are essential to monitor the changing forest scene in order to ensure that the sustained yield objectives are reached.

These periodic re-inventories are carried out at a minimum of ten year intervals with the aid of updated aerial photography and are designed to record and assess such matters as:

1) acreage logged in past period;
2) acreage burned in past period;
3) acreage denuded by forest insect, disease, windfall and the like;
4) success of regeneration on these denuded areas. Of course, if these areas are not restocked in a satisfactory manner, the sustained yield capacity of the area is depreciated and the allowable annual harvest must be reduced;
5) the growth of forest types by site classes. This is normally done through periodic re-measurement of permanent sample plots in order to assess growth rates by forest

site and forest site. In this program, permanent sample plots are established in immature forests and each tree is permanently identified and its species, diameter, height and condition is accurately measured. A re-measurement program is conducted at periodic intervals (e.g. every ten years) and the individual trees re-measured. This periodic assessment of increased diameter growth, increased height growth and the mortality of individual trees enables the forester to assess the net annual growth per acre of that forest type. This type of monitoring of the forest resource is essential if the Province's sustained yield policy of balancing forest growth and forest harvest is to be successful;

6) the effect of intensive forest practices such as fertilization thinning programs and the like on growth rates.

In summary, the forests of British Columbia, their growth and harvest, are subject to intensive and complex monitoring. It is only through such continuous monitoring can the Province's forestry programs, including harvesting, be adjusted to ensure that our forest lands remain in full productivity to provide the wide array of benefits that we all enjoy.

MONITORING FOR ENVIRONMENTAL PROTECTION : PESTICIDES

By

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Pesticides and Hazardous Chemicals,
Environmental Protection Service, Environment Canada

Seminar on Monitoring for Environmental
Protection, Centre for Continuing
Education, University of British Columbia

February 12-13, 1976

PART I: PESTICIDE USES, HAZARDS, AND CONTROLS

INTRODUCTION

Pesticides are used for the control of undesirable plants, insects, fungi, rodents, or other organisms designated as pests. Their purposeful introduction into the environment for pest control results in the contamination of air, water, vegetation, and soil. In addition, they can affect non-target organisms as well as the pests for which they were intentionally applied. Pesticides are very much a part of our technological society and their use poignantly demonstrates both the benefits and hazards common to almost all aspects of that technology.

There is little doubt that millions of our fellow human beings are alive today as a result of disease vector control and the productivity of our agriculture is, in part, due to crop protection with pest control chemicals. However, pesticides can also be very hazardous to beneficial organisms including fish, wildlife, or parasites and predators of the pest itself. These hazards appear to arise as a consequence of four major problems:

- i) CONTAMINATION
- ii) DIRECT TOXIC EFFECTS
- iii) INDIRECT TOXIC EFFECTS
- iv) MISAPPLICATION

It should be emphasized at this point that these are general problems that must be considered *potentially* hazardous to the environment. The *real* hazards will depend to a great extent on the chemical and biological behaviour of a pest control chemical in a particular ecosystem and how it is applied to that ecosystem. It is the purpose of monitoring to identify these real problems before they occur on a wide scale therefore becoming environmental hazards, and to regulate how, where, and under what conditions a pesticide can be used.

POTENTIAL HAZARDS FROM PESTICIDE USE

Contamination

Contamination is a general consequence of application. Pesticides are usually applied to either plants or soil and are subject to physical, biological, and chemical processes determining their stability, dispersal, and concentration. Residues may persist unaltered in the target plants or soil but are usually metabolized by soil microbes or plant enzymes, degraded by chemical or photo-chemical processes, and dispersed in their unaltered or altered form by volatilization from plant and soil surfaces, and by leaching or transport on soil particles to surface and ground waters.

From an ecological point of view, the most important characteristic of a pesticide is its stability. Many of the newer pesticides are rather unstable and are rapidly broken down to non-toxic components. However, stable compounds are not only made persistent in the environment, but also are more subject to dispersal and concentration in organisms. Thus stable pesticides such as DDT and its relatives are totally ubiquitous and have been detected in air, fresh, and salt waters, soils, sediments, plants, and many species of invertebrates, fish, birds, and mammals. Moreover, these compounds are concentrated by living organisms, especially in aquatic systems where animals take up pesticides from contaminated water and pass the residues up the food chain. Therefore, persistence, dispersal, and concentration are the most important parameters requiring assessment to determine the significance of residue contamination.

Direct Toxic Effects

Direct toxic effects are usually either acute (fast-acting) or chronic (delayed) in nature. The extent to which a pesticide has a direct effect on a species depends first on the intrinsic reaction of the species to the chemical -- this can be determined by toxicological experiments, the familiar LD_{50} for birds and mammals or LC_{50} for fish; secondly it depends on the extent to which a species comes in contact with a pesticide, and this depends on the amount of pesticide used, its properties and manner of application, and on the behavoural characteristics of the species.

Pesticides of different chemical groups and even those of the same group can vary greatly in their toxicity. For example, for rats there is approximately a 100-fold difference in acute oral toxicity between the two organophosphate insecticides malathion and parathion. Moreover, even in a group of closely related species the pattern of sensitivity can vary from one chemical to another. This variability is evident upon study of the acute toxicity to fish and wildlife of some of the commonly used insecticides (Tables 1 and 2). Compounds of great potential hazard include most of the highly toxic compounds (e.g., DDT, endosulfan, guthion, malathion, pentachlorophenol for fish; carbofuran, diazinon, phosphamidon, and zectran for birds) and many of the serious fish and wildlife kills in this province have been associated with these toxic chemicals (Tables 3 & 4).

Although toxicity, by itself, is an important factor, it should be emphasized that most ecological situations are multifactorial and fish and wildlife mortalities may result from, or be determined by, many interacting factors. Relatively simple cause and effect relationships may be found but we should not expect them in all cases. For example, the 1972 fish kill in the Little Campbell River (Table 3) resulted from direct application of pentachlorophenol into the water. However, recent waterfowl mortalities in the Richmond - Delta area near Vancouver are illustrative of multiple factors acting together. Duck mortalities (Table 4) were a direct result of ingestion of small granules of highly

Table 1: Fish toxicity of some common insecticides

Product	Fish	Exposure time (hrs)	LC_{50} (ppm)
Abate	Brook trout	48	1.5
Altosid	Salmon	96	32.0
Baygon	Salmon	96	2.4
Bidrin	Trout	24	8.0
DDT	Salmon	96	0.004
Diazinon	Salmon	96	3.0
Dimethoate	Trout	96	9.0
Endosulfan (Thiodan)	Trout	48	0.001
Fenitrothion	Trout	96	1.4
Guthion	Trout	96	0.014
Malathion	Salmon	96	0.043
Methyl Trithion	Salmon	96	0.9
Pentachlorophenol	Salmon	96	0.03
Phosphamidon	Salmon	96	3.0
Rotenone	Salmon	24	0.15
Sevin	Salmon	96	0.76

Table 2: Wildlife toxicity of some common insecticides

Product	Animal	Oral LD_{50} (mg/kg)
Abate	Mallard	80-100
	Pheasant	31.5
Carbaryl	Mallard	2,179
	Pheasant	2,000
Carbofuran	Mallard	0.40
	Pheasant	4.2
DDT	Mallard	2,240
	Pheasant	1,296
Diazinon	Mallard	3.5
	Pheasant	4.3
Endrin	Mallard	5.6
	Pheasant	1.8
Parathion	Mallard	1.9-2.1
	Pheasant	12.4
Phosphamidon	Mallard	3.0
Zectran	Mallard	3.0
	Pheasant	4.5

Table 3: Selected pesticide - related fish mortalities

Year	Pesticide	Program	Location	Approx No.	Type
1956-57	DDT	forest spray	Vancouver Island	45,000	salmonids
1960	copper sulphate	swimmer's itch	Cultus Lake	100+	salmonids
1962	sinox PE	-	Matsqui Slough	-	-
1963	DDT	mosquito	Shuswap Lake	3 million	salmonids
1963	pentachlorophenol	lumber treatment	Sooke Basin	1,000	ocean perch
1964	lindane	garbage	Little Campbell River	2,500	salmonids
1971	dinitrophenol	aerial agriculture spray	Marshall Creek	2,000	salmonids
1971	perchloron	-	Alouette River	100	-
1972	pentachlorophenol	pole treatment	Little Campbell River	2,500	salmonids
1972	pentachlorophenol	lumber treatment	Victoria Harbour	tons	anchovy, herring
1973	pentachlorophenol	lumber treatment	Mamquam Channel (Squamish)	500	salmonids
1973	pentachlorophenol	pole treatment	Surrey	-	cutthroat trout
1973	dinitro	agriculture	Atchelitz Creek	100	-
1975	cutrine algacide	lake treatment	Sardis	many	trout, catfish
1975	malathion	aerial mosquito control	Delta Golf Course	100+	stickleback

Table 4: Selected pesticide - related wildlife mortalities

1963	phosphamidon	-	Queen Charlotte Islands	-	small birds
1967	DDT	apple orchard	Okanagan	-	cedar wax wings
1968	methyltrithion	-	Stanley Park	-	ducks
1973	demeton (suspected)	Alberta Wheat Pool docks	Vancouver	-	ducks
1973	carbofuran	agriculture	Richmond	60	ducks
1974-75	carbofuran	agriculture	Ladner	200	ducks
1974	diazinon	agriculture	Okanagan	8	Canada geese
1974	TEPP (suspected	?	Okanagan	33	chucker partridges
1974	diazinon	garbage dump spraying	Victoria	-	Brewer's blackbirds, seagulls

toxic carbofuran insecticide. The agricultural fields where these kills occurred had been treated to control root maggots in cabbages and turnips. The following factors interacted to produce the kills:

i) *Proximity of fields to large numbers of waterfowl:* near important wintering areas in the Fraser delta and on a major migration flyway to points south;

ii) *Flooding of fields in the winter months:* thereby attracting waterfowl;

iii) *Food supply in the field:* in the form of seeds and crops on which the ducks could forage;

iv) *High concentrations of insecticide granules in the soil and on the crops:* a misapplication of the pesticide;

v) *High acute toxicity of carbofuran insecticide to waterfowl*;

vi) *Feeding behaviour of ducks:* death to foraging ducks which ingested the minute insecticide granules along with the desired seeds.

Recently, in a period of a few days, over one thousand green-winged Teal were killed as a result of these interactions. Deterioration of environmental quality as a consequence of pesticide use requires the isolation and identification of *all* relevant factors, a purpose common to all programs monitoring changes in the environment.

Apart from these fast-acting or acute effects, pesticides may be present in treated areas at low concentrations having no immediate detectable effects. However, these small amounts may cause long-term (chronic) damage which can be more insidious and difficult to define than acute toxicity. Chronic exposure may ultimately cause death or may result in the elimination of a species or individuals through loss of appetite, restricted growth, inability to avoid predators, behavioural abnormalities or other changes. These sublethal effects may be very damaging but cannot be readily detected in most field situations. However, chronic toxicity can, to some extent, be equated with persistence of a pesticide. Certainly, the more stable compounds such as the chlorinated hydrocarbon insecticides have been responsible for chronic damage to both fish and wildlife populations. Hence monitoring for the persistence and stability of pesticide residues in the environment, whether this be water, soil, sediment, plant or animal tissues, should also provide some information on potential chronic problems.

Indirect Toxic Effects

Pesticides may indirectly affect non-target populations in a variety of ways: some dramatic, others subtle and difficult to detect. Secondary poisoning can occur whenever one animal dies from eating another animal containing a toxic pesticide residue. Seagulls were poisoned from scavenging duck carcasses after the 1974 carbofuran duck kill in Delta, B.C. In the past, concentration of pesticides in earthworms has also affected many birds feeding upon them.

Chemical pesticides tend to be non-specific in their effects and can reduce community stability by altering competitive and predator/prey relationships. Of particular concern is the removal of predaceous and parasitic species important as biological controls of the pest itself. The literature is replete with evidence from agriculture that non-selective chemical insecticides disrupt community biocontrol mechanisms producing resurgences of the pest caused mainly by a reduction in predators. Also, food species for organisms of economic importance may be severely reduced. For example, fish production in New Brunswick streams has been temporarily reduced following mortality of their insect food from insecticide spraying to control the spruce budworm in balsam fir forests.

Other stresses that may be considered indirect in nature result from alterations of the physical environment. Herbicides can be very powerful biological tools affecting both plant production and succession. Aerial applications of herbicides to forest lands affects natural succession by removal of undesired hardwoods to allow for faster maturation and growth of conifer species. Broadcast sprays of this sort may present a hazard to fish-producing streams and rivers by inadvertent removal of bankside vegetation. Stream-side vegetation not only provides shade, cover, and food, mainly in the form of insects, but also provides bank stability, therefore preventing erosion and silting of spawning beds and finally, ensures more stable water temperatures.

The broadcast application of herbicides can also affect terrestrial ecosystems, especially when herbicides of a very broad spectrum are used that can kill all trees, shrubs, and herbaceous plants in a treated area. Vegetation control on powerline rights-of-way is oriented to remove or suppress forms of vegetation which impair the function of a utility. In some cases, the use of broadcast sprays to kill a small number of offending tree species can result in an overkill of large numbers of desirable shrub and herbaceous species which contribute to the stability of the plant community and provide wildlife cover. Also, drift of aerially applied sprays may contaminate water, land, and kill desirable plants at considerable distances from the point of application.

Misapplication

Pesticides may be distinguished from other potentially hazardous contaminants *primarily by their deliberate application* to a segment of the environment for control of an undesired insect, weed, or other pest. Application is often not considered an important consequence of pesticide use, but, in a very real way, the effect of a chemical on the environment will depend on how and where it is applied. Environmental hazards can arise from pesticide use as a consequence of both their misapplication and misplacement. The difference between these terms is, perhaps, obscure, but the former may be used to describe situations where the *entire* program is wrong in terms of both the kind and amount of pesticide applied, and the method and area of application. Severe fish kills from a DDT forest spray on Vancouver Island and a mosquito spray near Shuswap Lake or bird kills from carbofuran are clearly misapplications (Tables 3 and 4). Misplacement may be considered to occur as a result of human error during an otherwise acceptable operation. Fish mortalities during pole treatment with pentachlorophenol have resulted from careless application and lack of respect for the material being applied (Table 3).

In the past, misapplication or misplacement have usually been either a determining, or a contributing factor to all major environmental impacts from pesticides; a general consequence of not producing an *in toto* evaluation of multiple resources in a treatment area. However, it is not necessary that one resource be adversely affected in order to protect another, provided pest control programs can be developed and evaluated to satisfy the needs of all segments of the environment to be treated. In this sense, monitoring for environmental protection has a rather broad definition and includes legislative authority to pre-screen pest control programs to determine operational conditions as well as chemical and biological surveillance of approved programs.

CONTROLS ON PESTICIDE USE

Pesticide use is presently regulated in the province by the B.C. Interdepartmental Pesticide Committee, a provincially constituted body designed to control and monitor pesticide use on Crown lands and by Crown corporations. Most of the programs to date have dealt with either herbicide use on forest lands and powerline and railway rights-of-way, or major forest pest control programs with insecticides.

Members of the committee, including various departments within the provincial government and Environment Canada (E.P.S.), screen proposed programs through:

i) applications: proponents of pest control programs apply to the Committee on standard forms giving detailed information on the purpose and location of the project, the name of the pesticide and its method and rate of application, the target species, the approximate date(s) of application, and any relevant information on lakes, rivers, and streams in the area.

ii) inspections: members of the Committee conduct on-site inspections of selected programs. E.P.S. and the B.C. Fish and Wildlife Branch have conducted many inspections to determine site specific environmental hazards.

iii) restrictions and approval: based on the inspections, most programs proceed either unaltered or with modifications. Restrictions that have been required include such items as addition of chemical agents to herbicide formulations to reduce hazards from off-target drift, changes in the method or rate of application, or the use of buffer zones along major streams or rivers to protect these resources.

iv) compliance and surveillance: again members of the Committee are usually present during the actual spray application to ensure that all designated conditions of the program are followed and to conduct either biological or chemical sampling. Past experience would indicate that applicators tend to be more careful under such circumstances and spills, over-spray, or other errors are minimized.

In addition to the Interdepartmental Committee, other bodies of expertise have been formed to evaluate large scale pest control programs in the province, noteably the Aquatic Weed Committee for problems in the Okanagan basin and the Forest Pest Review Committee for control of major insect outbreaks. The functioning of the latter committee will be used to illustrate the proper management of pesticides by having an overall assessment of environmental quality and land use followed by clear objectives and operational planning.

At the present time, forest insects have caused severe defoliation of immature Douglas fir and some Pondersoa pine on approximately forty-thousand acres in the Kamloops Forest District. The larval forms of the Douglas fir tussock moth or mixtures of the tussock moth and false hemlock looper feed on conifer needles and have damaged large areas adjacent to the North Thompson river and south of Kamloops lake. Members of the Forest Pest Review Committee have undertaken an overall assessment of the problem including considerations on:

i) the significance and extent of the pest damage;

ii) methods to control the pest and effectiveness of various pest control agents;

iii) the effect of both the pest control agent and the loss of the watershed on the ecology and land use of the area;

iv) the effect of the pest control agent on water quality and human and domestic animal health;

v) the aesthetics, economic importance, and social or human interest and activities associated with the forest; and finally,

vi) the cost to the public of a pest control operation.

An attempt was made during 1975 to control these insects by spraying with a biological agent, a bacterium called Bacillus thuringiensis. This biological insecticide is both non-polluting and highly effective against defoliating insects, but unfortunately afforded no foliage protection because of deficiencies of manufacture in commercially available material. Consequently, the tussock moth and looper defoliated trees in the North Thompson valley to the point that much of the area will not survive a further attack in 1976..

In 1975, an experimental program was initiated to determine the effectiveness of various pest control materials against the pests and document any adverse side effects. One insecticide, an organophosphate called Orthene, proved to be highly effective with little affect either on birds or small mammals or non-target terrestrial insects. However, at this time, other evaluations are being conducted for an overall assessment including possible benefits from tree loss by opening of the canopy to allow for increased deer browse, the impact of tree loss on water quality from erosion problems, the value of the trees for either lumber or pulp wood, the aesthetic value of the forest, restrictions required to prevent spray contamination of human or domestic animal habitations and water courses, and finally the cost to the taxpayer of spraying. If a spray program should be undertaken in 1976, operational planning will include assessment of both effectiveness and impact of the spray on the total resources of the area.

PART II: PESTICIDE RESIDUE MONITORING: TECHNIQUES AND PROBLEMS

In the previous section, pesticide problems were defined and examples given to illustrate significant local problems. Monitoring was seen to include both pre-surveillance regulations, thereby determining how and where a chemical can be applied, and follow-up actions ensuring compliance and identification of hazard. This section will include a general introduction to pesticide residue analyses, identifying some specific techniques and problems peculiar to monitoring for pesticide contamination, and provide some examples of residue monitoring by the B.C. Interdepartmental Pesticide Committee.

MONITORING FOR CONTAMINATION

Contamination is probably the single most important factor identifying real hazards since other problems such as direct or indirect toxicity usually result from pesticide residues in the environment. Residues may be regarded as any chemical contamination present after application of a pesticide and includes not only the parent compound, but also its metabolites and chemical or photo-chemical degradation products. Monitoring of residues involves a number of procedural steps including sampling design and methods, sample handling and storage, extraction of the residue from the sample, clean-up and removal of co-extractives in the extract, and finally analysis to achieve detection, quantification, and confirmation of the residue.

These various steps are interdependent and must be executed with precision in order to achieve meaningful analytical results. There are a great number of variations in carrying out these steps depending on the nature of the pesticide and its substrate. It is beyond the scope of this paper to discuss all of these methods in detail.

However, a general discussion would be useful describing the objectives, requirements, and problems of each step, followed with an example of herbicide use monitoring to illustrate and present a more detailed account of sampling and interpretation of results.

i) Sampling: analytical results can only be as valid as the samples or sampling scheme used. Samples should represent the environmental component being examined (i.e., water, soil, air, plant or animal tissues) and sampling design should reflect the goals of the monitoring program. The location of sampling sites, the sampling technique, the number of samples, and the frequency and duration of sampling should be oriented toward a satisfactory evaluation of the analytical results. If possible, sampling techniques should compliment each other and all important environmental parameters that may affect the results (eg., weather, soil type) should also be determined.

ii) Sample Handling: sample preservation is usually required after collection to prevent chemical or photo-chemical breakdown of the residue. Losses from improper sample handling and storage have been a serious problem and it is important that the analyst consider the chemical characteristics of the pesticide in question when determining the type and length of sample storage. Additions of chemical preservatives or immediate freezing are usually required to prevent residue degradation. Also, sample containers must not contain or be made of plastics which contaminate the sample and interfere with the analytical method.

iii) Extraction of Residues: pesticide residues are extracted from the sample by either "blending" or "exhaustive extraction" in a suitable solvent or combination of solvents. The method of extraction and the type of solvent or solvent combinations will depend to a large extent on the chemical and physical properties of the pesticide to be extracted. Solvents and reagents must be free of substances that can interfere with the analysis or degrade the residue and it is usually necessary to employ specially purified or distilled-in-glass solvents. Also, the extraction efficiency (degree of residue removal) must be determined in order to demonstrate the usefulness of the particular extraction method.

iv) Cleanup: cleanup is a term used in residue methodology for the isolation of a pesticide from interfering co-extractives (eg., fats, waxes, pigments) in a solvent extract. The type and extent of cleanup will depend on the nature of the substrate and the final method of residue analysis. If an extract is to be analyzed by a method where nearly any organic material will interfere, the cleanup procedure must be extensive. As a general rule, it is usually best to cleanup an extract only as much as necessary since even the most satisfactory methods will remove some residue. Numerous cleanup procedures are available; the most common being thin-layer or column chromatography, liquid-partitioning, or sweep co-distillation.

v) Detection, Quantification, and Confirmation of Residues:

Chromatographic techniques are generally the methods of choice by the residue analyst for both the qualitative and quantitative determination of pesticides in the environment. Gas-liquid chromatography (GLC) is a rapid, highly sensitive tool used extensively in residue work and sensitive, in some instances, at the picogram (1×10^{-12} g) level. The elaborate analytical precautions previously mentioned, including solvent purity, removal of interfering co-extractives, and the sampling and extraction techniques themselves are a prerequisite to any meaningful residue determination. Unfortunately, many inexperienced individuals have been short-sighted in adapting gas chromatography to their monitoring programs and have not been fully cognizant of the difficulties involved. Both qualitative and quantitative errors have occurred through misidentification and quantification of artifacts for pesticide residues. For example, when polychlorinated biphenyl's (PCB's) are present in a sample they exhibit a pattern of GLC peaks with retention times very similar to those shown by DDT, DDE, and other chlorinated pesticides. PCB contamination has been found to be quite ubiquitous in certain environmental samples and much of the previous chlorinated pesticide data appear questionable because, in many instances, the identity of the residues was not confirmed by other methods.

The identity of pesticide residues detected by GLC methods must be confirmed by methods other than the initial gas chromatography. For example, other chromatographic techniques may be used including thin-layer and column chromatography, or indeed GLC columns with different liquid phases and differing polarities. The combination of mass spectrometry and gas chromatography has proven to be a powerful tool in the characterization of residues. Simple chemical reactions can also yield valuable information concerning residue identity. Specific identification may be obtained by comparison of chromatographic characteristics (GLC retention times) of the parent compound before and after chemical treatment.

Monitoring for residue contamination requires the use of highly sensitive micro-analytical techniques. The foregoing discussion emphasized some of the problems in residue detection that must be considered during the execution of field monitoring programs. To illustrate these techniques of program design and sampling, some examples of monitoring herbicide use in British Columbia are worth discussion.

PESTICIDE USE MONITORING: HERBICIDES

Aerial applications of herbicides to control hardwood vegetation in either conifer plantations or along powerline rights-of-way have been subjects of much discussion in the recent past. Spraying on rights-of-way has been especially controversial and unfortunately many individuals, both for and against the use of herbicides, have been irresponsible in their communications to the public.

Much has been written in the press regarding herbicide spraying, but in many instances, little of the information was factual in nature. This is not to belittle those who are concerned, for real problems do exist, especially when spraying rights-of-way which can either pass through or are adjacent to private property. Contamination of domestic water supplies or damage to valuable vegetation can be serious problems.

Pending the recommendations and outcome of the recently completed B.C. Royal Commission of Inquiry into the Use of Pesticides and Herbicides, many forest companies and government agencies have restricted the use of these sprays. However, in the past two years, a number of spray programs were completed under scrutiny of the B.C. Interdepartmental Pesticide Committee. These applications were adjudicated according to protocals described earlier (i.e., written application, inspection, restrictions, and surveillance) and programs monitored during 1975 by the Environmental Protection Service included applications of 2,4-D and 2,4,5-T for alder control in Tree Farm Licene No. 10, Toba Inlet, and in a christmas tree plantation on a powerline right-of-way near Sechelt (Figures 1 and 2). A picloram/2,4-D application to the powerline right-of-way adjacent to Highway 99 north of Pemberton was also monitored (Figure 3).

Pre-spray inspections were conducted in all cases and restrictions on these programs included:

i) the use of 150 foot buffer zones along all major streams to prevent water contamination and destruction of stream-side vegetation (brightly coloured marker ribbons were requested to indicate spray shut-off boundaries);

ii) proper weather and atmospheric conditions at the time of spraying;

iii) addition of proper chemicals to the spray mixtures to control off-target drift;

iv) in the case of the powerline rights-of-way, notification and approval

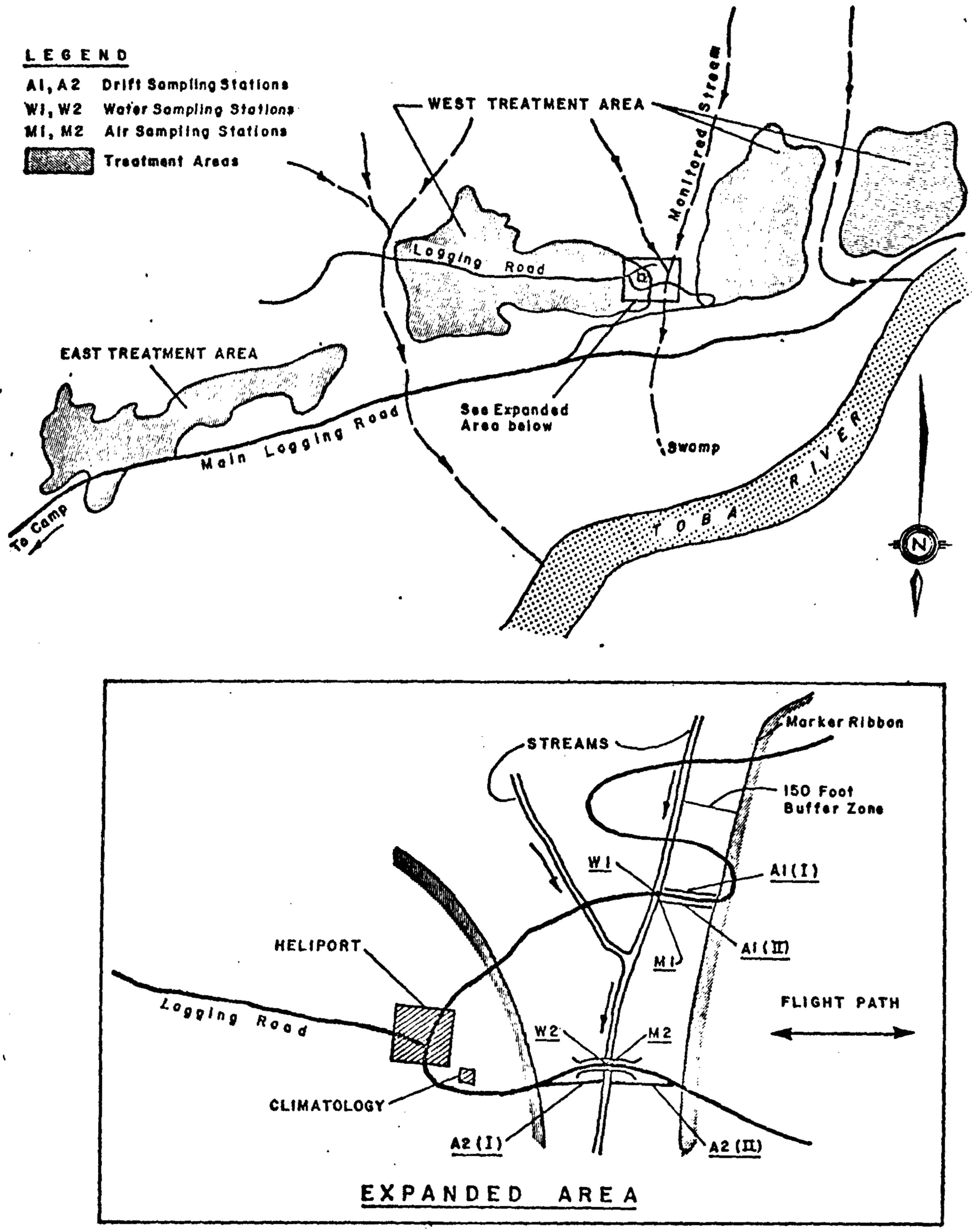

Figure 1: Diagram of spray area and residue monitoring stations - Toba Inlet, B.C.

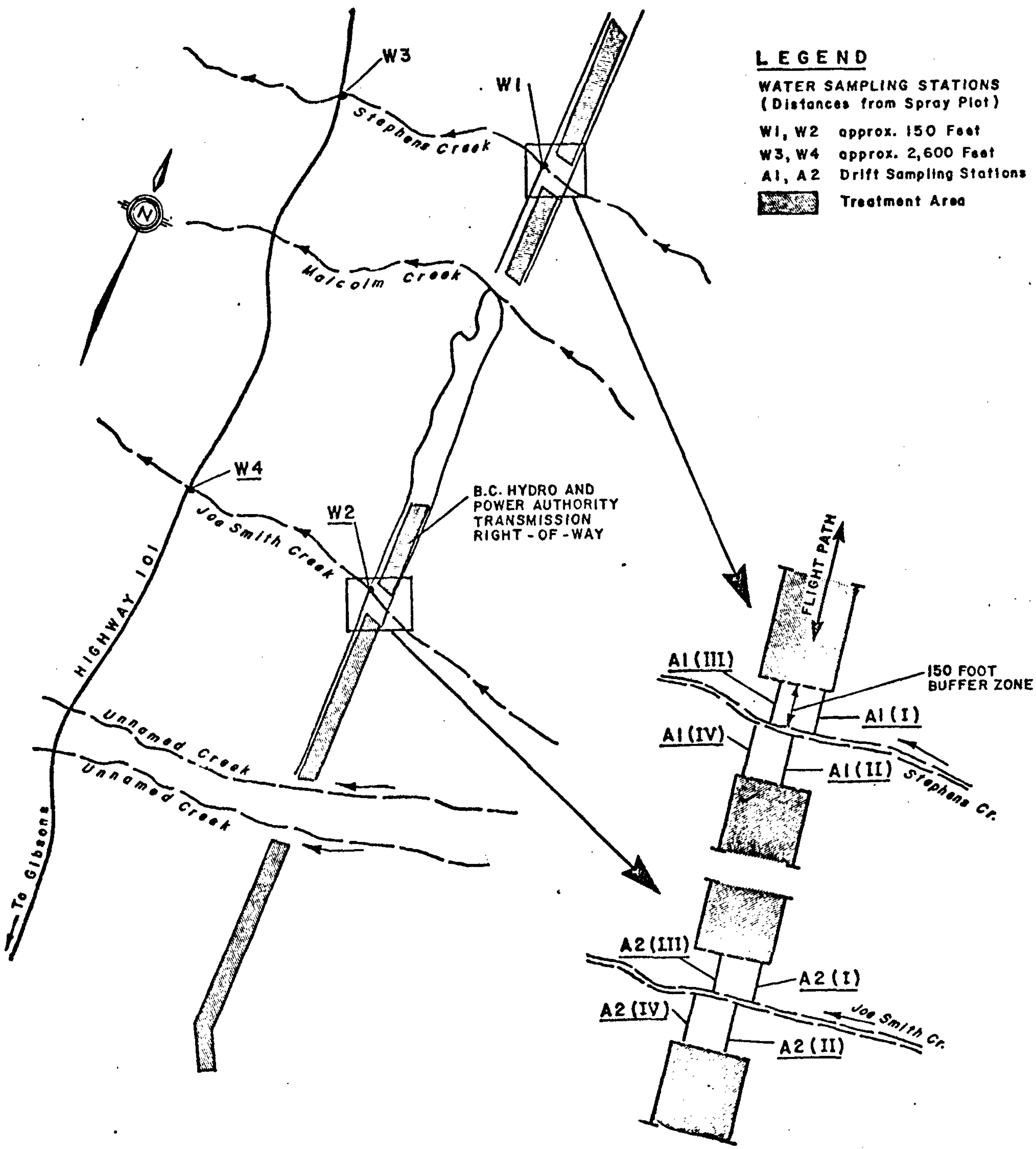

Figure 2: Diagram of spray area and residue monitoring stations - Sechelt, B.C.

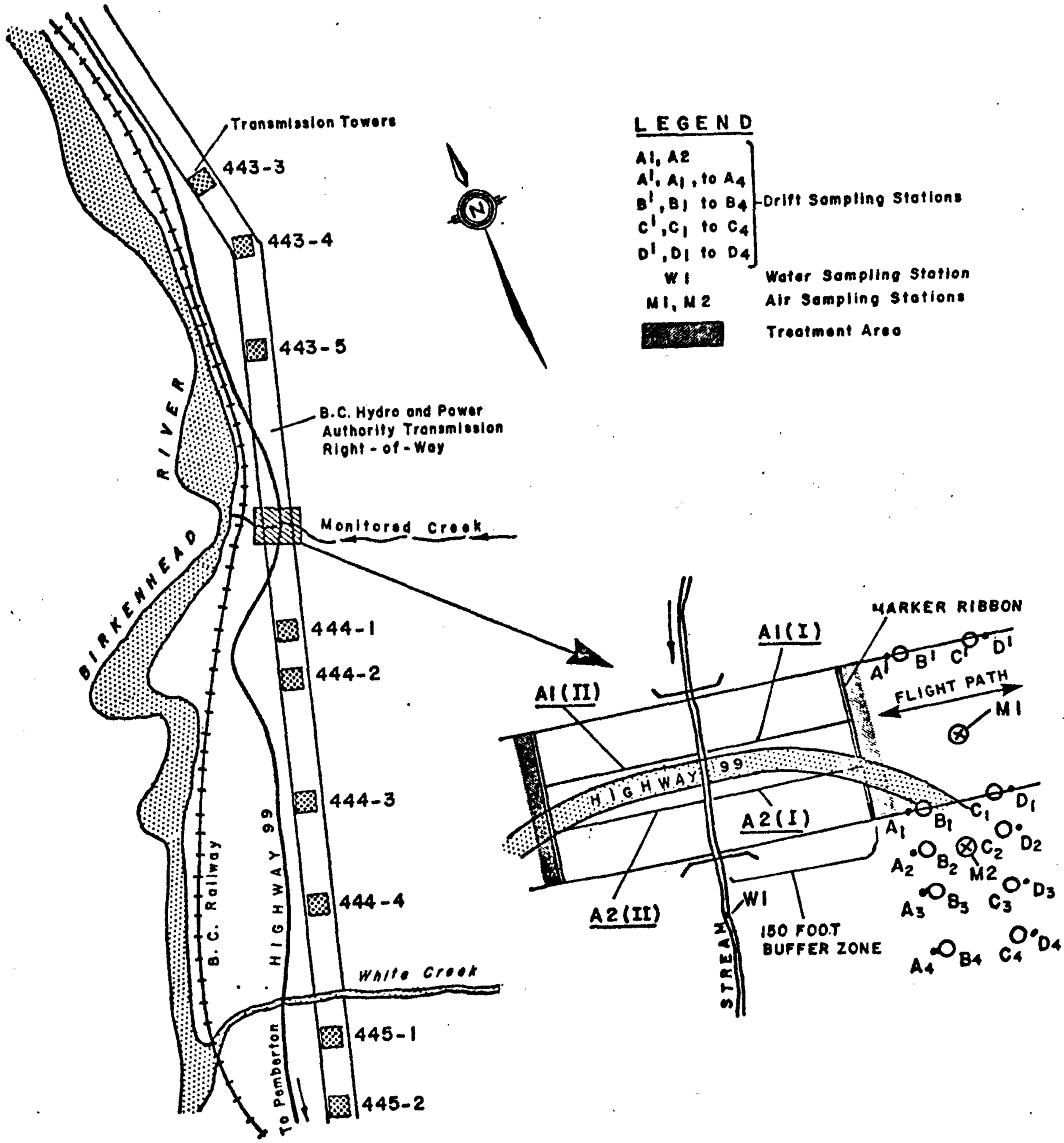

Figure 3: Diagram of spray area and residue monitoring stations - Pemberton, B.C.

of all property owners and other individuals that may be affected by the spray; and finally,

v) precautions required during mixing of chemicals, washing of equipment, and container disposal to prevent unnecessary contamination of the environment.

The objective of the surveillance was to evaluate operating procedures, the effectiveness of the stream buffer zones, and in the case of powerline rights-of-way, problems adjacent to the treated area. Monitoring was, therefore, directed toward measuring direct herbicide drift into the buffer zones, or additionally in the case of powerlines, lateral drift from the right-of-way to non-target areas. Stream water contamination, effects on non-target vegetation, operating parameters of the aircraft (speed, height, spray system), microclimatic conditions, and stream discharge were also determined. In short, all parameters affecting the residue determinations were monitored.

Buffer zone drift was collected on drift plates (150 x 20 mm petri dishes) set on stands about three feet above the ground at 50 foot intervals within the buffer zones (illustrated at A1 and A2 in Figures 1 to 3). Drift off the powerline right-of-way at Pemberton was also measured at 50 foot intervals but 254 mm diameter plates were used in addition to petri dishes (petri dishes illustrated as A and D and plates as B and C in Figure 3).

Drift may occur both as droplets or as fine aerosols and vapours. Plates will only pick up the larger droplets and "fines" or vapours must be sampled from the air directly. Misco air samplers with midget impingers were used to collect the aerosol or vapour component from both direct drift (near the stream at Toba Inlet: M1, M2 in Figure 1) and lateral drift from the powerline at Pemberton (M1 on powerline, M2 fifty feet off powerline in Figure 3). Water samples were also taken downstream from the spray areas at defined intervals up to 24 hours after the spray operations (W1 to W4 in Figures 1 to 3).

All sampling devices including dishes, plates, sampling bottles, and impingers had been rinsed with redistilled acetone and petroleum ether and heated to 200°C for 16 to 20 hours prior to use to remove any entraneous matter that could interfere with the GLC analysis for the herbicides. Also, a 5% KOH solution was added to each sample to prevent hydrolysis of the residues. Extraction, cleanup, and analysis was performed according to prescribed methods for the chlorophenoxy herbicides and picloram.

The greatest particulate drift into the stream buffer zones occurred during the Sechelt 2,4-D/2,4,5-T application (Figure 4) and appeared to result primarily from the use of a fixed-wing aircraft (Cessna Agwagen) travelling at high speed (100 mph) and low flight elevation. Although

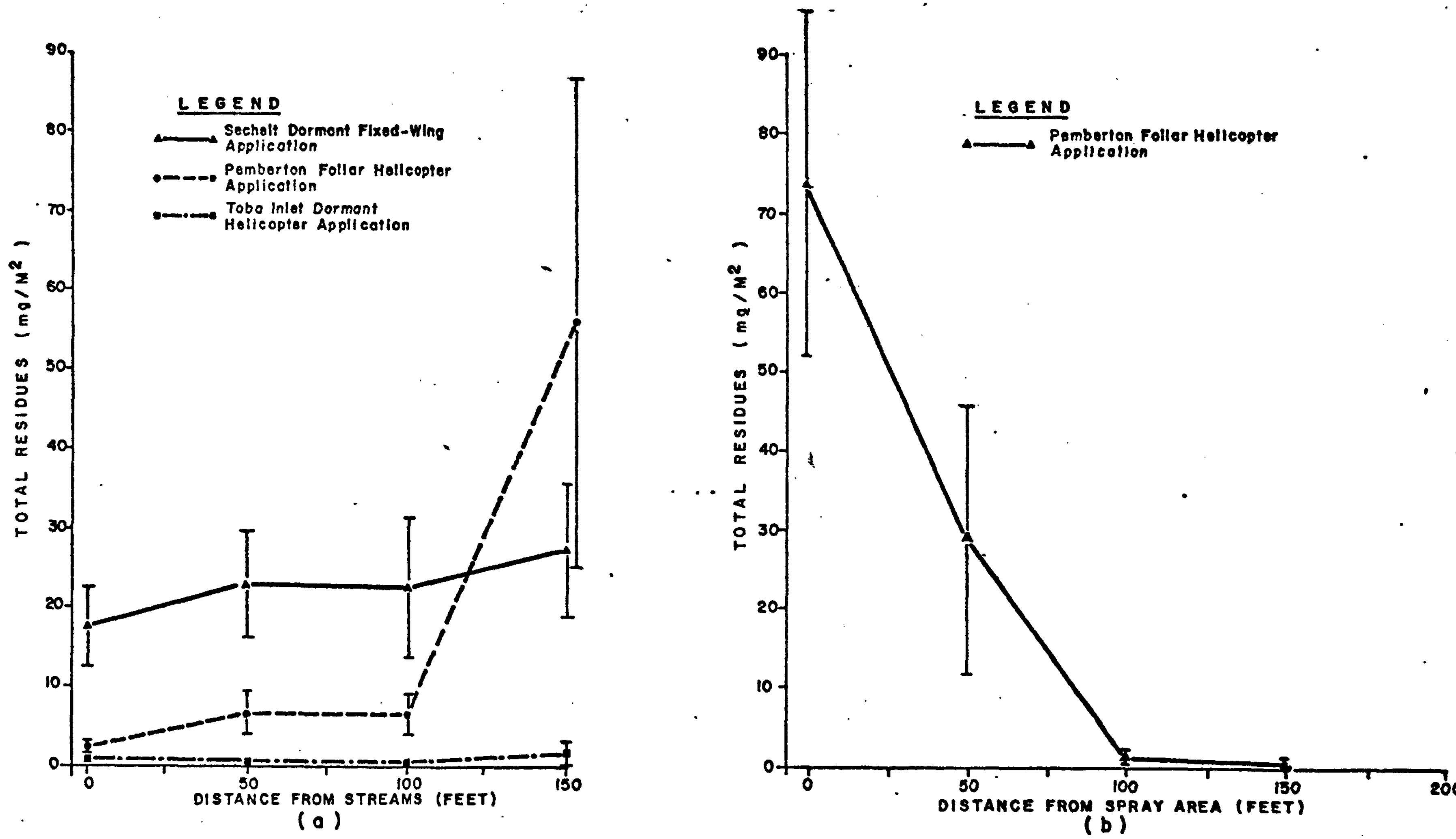

Figure 4: Particulate herbicide drift into stream buffer zones (a) and from the spray plot border (b) (mean and standard error)

the spray was effectively shut off at the 150 foot mark, considerable turbulence was evident and resulted in substantial drift. The other sprays, both helicopter applications, did not contaminate the buffer zones to the same extent. Helicopter drift patterns are usually considerably better than patterns from fixed-wing aircraft because the high speed and disrupting propellor wake are not present.

Drift into the buffer zones was also reflected in the degree of water contamination. At Pemberton, only a small quantity of 2,4-D (0.004 ppm) was detected immediately following the spray application. No residues were detected in water at Toba Inlet. However, high levels of 2,4-D and 2,4,5-T were found in the monitored streams at Sechelt. Residues peaked at 1.74 ppm in Stephens and 3.65 ppm in Joe Smith Creeks forty minutes after the beginning of the spray. However after two hours, levels declined to 0.007 ppm and 0.560 ppm respectively. Nevertheless, these water residues may have contaminated and tainted domestic water supplies. Many of the creeks in the area, including those monitored, serve as water supplies for residents adjacent to the right-of-way. The odour threshold for 2,4-D tainted water has been reported to be in the order of 3 ppm. However, chemical hydrolysis and/or biological degradation of 2,4-D in water to 2,4-dichlorophenol can result in odour and taste problems at concentrations of 2 and 8 *ppb*, respectively.

No aerosol or vapour forms of herbicide drift were detected in the buffer zones at Toba Inlet, reflecting the very low residues detected on the drift plates. However, aerosol picloram/2,4-D was detected at Pemberton in addition to the particulate lateral drift collected on the plates (Figure 4). The residue component in the air was similar both on and off the powerline (2.2 $\mu g/m^3$ at Station M1 vs. 2.0 $\mu g/m^3$ at Station M2) for up to two hours after the beginning of the spray, but declined greatly after four hours. These results may be some cause for concern since a particulating agent had been added to the spray mixture to control drift. The aerosols detected may represent only a fraction of the total since the air samplers were located near the ground and could not detect residues at higher altitudes.

Drift reduction and control in general requires application under atmospheric conditions of low wind speed (0-5 mph), air temperature below 75°F (24°C), and relative humidity above 50 percent. Evaporation and drift of volatile herbicides, especially esters of 2,4-D or 2,4,5-T, is reduced at low air temperatures and high relative humidities. However, these optimum atmospheric conditions occurred during all of the programs (Table 5).

The objective of these monitoring programs was to identify real from potential hazards as well as the usefulness and limitations of restrictions. It is clear that fixed-wing applications can cause problems that may or may not be alleviated by further restrictions (e.g., large buffer zones) and lateral drift off powerline rights-of-way may be potentially harmful.

Table 5: General weather and microclimate conditions during the spray applications

	Toba Inlet	Sechelt	Pemberton
Time of Spray	0630-1045 hrs	0700-0830 hrs	0625-0730 hrs
Weather	Foggy then clear and sunny	Overcast, some sunny periods	Sunny, some clouds
Humidity	56% - 68%	56% - 95%	68% - 81%
Rainfall (inches)	Nil	Some drizzle	Nil
Temperature (°F)			
8 feet	41-47	35-43	51-61
32 feet	41-44		
Wind Speed (mph)	0-1	0-3	0-3
Stream Discharge (cfs)	7.7	1.7 (Joe Smith) 5.1 (Stephens)	~10.0

However, it is also clear that helicopter sprays in combination with effective buffer zones can have negligible impact on the aquatic enviroment.

It is anticipated that results from these studies and similar studies conducted by the British Columbia Fish and Wildlife Branch will provide some information toward the drafting of meaningful guidelines for protection of both the natural and human environment from aerial herbicide sprays.

PART III: BIOLOGICAL ASSESSMENTS OF PESTICIDE IMPACT

In this section, the impact of pesticides on non-target organisms will be discussed in relation to the use of insecticides to control destructive forest insects. As indicated previously, an experimental program was initiated during 1975 to study the effects on pests and non-targets of some pest control chemicals in the Kamloops Forest District. An organophosphate insecticide called Orthene was one material selected for testing in this program because of its low toxicity to birds and fish (oral LD_{50} = 140 ppm for pheasant; 96 hr LC_{50} = 770 ppm for rainbow trout). The impact of this chemical on non-target terrestrial insects will be described to illustrate the principals of biological monitoring. Data from the Environmental Protection Service, Atlantic Region, will also be presented to illustrate monitoring of pesticide effects on aquatic invertebrates from operations to control the spruce budworm in New Brunswick.

A forest may be regarded as a stable ecosystem composed of many biological systems and much faunal, floral, and physical diversity. Insecticides can disturb this stability by diminishing the diversity and productivity of the system or a given community. This situation usually results from the non-specific effects of some pesticides which may affect many different taxonomic groups (e.g., birds, fish, mammals, or invertebrates) or, indeed, many species within the same group (e.g., different arthropods including insects, arachnids, and crustaceans). Impact monitoring must consider both aspects and necessitates the involvement of many areas of expertise.

As in the case of residue sampling, biological sampling must represent the community being examined (e.g., terrestrial arthropods) and sampling design and methods must achieve the goals of the monitoring program. Since the objective of monitoring is to detect abnormal biological changes, the first priority must be to achieve and define the mean and oscillations of the normal. When conducting experiments or monitoring operational spray programs, comparison of sprayed areas with unsprayed controls will provide information towards this end. Also, sampling both before and after the spray application in a given sampling site or sites will provide information peculiar to that area.

Sampling regimes must also reflect the mode-of-action and chemical stability of a pesticide. Thus fast acting compounds, where an immediate effect on both pest and non-target organisms is anticipated, will require rigorous daily or hourly sampling. Moreover, the duration of sampling must be long enough to account for both the normal pertubations in community population dynamics and sustained effects in the sprayed area.

Trapping techniques should be designed to sample those segments of a community most exposed and susceptible to pesticide impact. However, because the toxicological reactions of, for example, different arthropod species to a chemical will be largely unknown, the greater number of different organisms sampled within a community, the greater the likelihood of registering an impact on one or more of these taxa.

Although monitoring impacts of pesticides under field conditions is a necessary requirement to any properly conducted pest control operation, it is salutary to emphasize that sampling of this type can never produce *absolutely* reliable preditions on effects on constituent species. Information on both population ecology and the principal factors controlling the population of a species in a chemically undisturbed environment is usually lacking. Thus, while we can usually accurately describe the pesticide in terms of its chemical, physical, and residue behaviour, we cannot accurately describe the system it affects. The sensitivity of detecting impacts on an ill-defined complex of biological interactions is many orders of magnitude below our ability to detect molecules of the toxicant in the environment.

In June, 1975, Orthene test plots were selected in the Heffley Creek area near the North Thompson River, north of Kamloops, B.C. Since Orthene is a fast acting cholinesterase inhibitor potentially injurious to many arthropod species, the effects of the spray on the non-target terrestrial arthropod community were monitored by the use of:

i) *ultraviolet light traps*: to detect impact on nocturnal aerial fauna (adult insects) in the forest stand;

ii) *pitfall traps*: to detect impact on arthropods of the forest litter community;

iii) *net sweeping*: to detect impact on arthropods inhabiting the short grass undergrowth;

iv) *tree beating*: to detect impact on arboreal arthropod populations in the lower crown of the trees.

Sampling was conducted daily for five days before and ten days after the spray in both treatment and control areas.

Effect of the spray on the population densities of the various arthropod components are illustrated in Figures 5 and 6. Flying insects were characterized by consistently lower numbers caught in treatment plot versus the control and great daily numerical fluctuations. Orthene

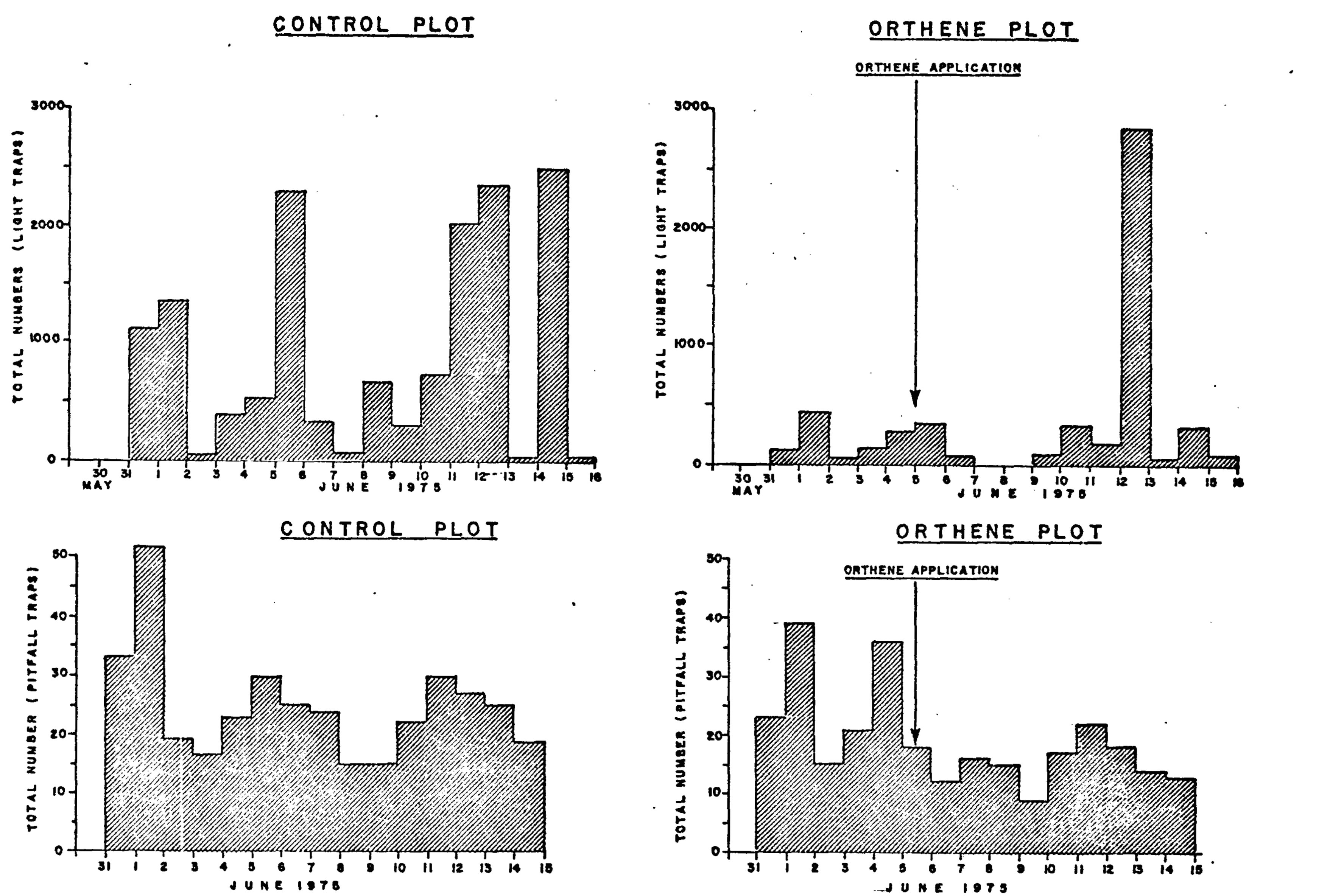

Figure 5: Changes in terrestrial arthropod population densities in Orthene treated and control plots - light and pitfall trapping

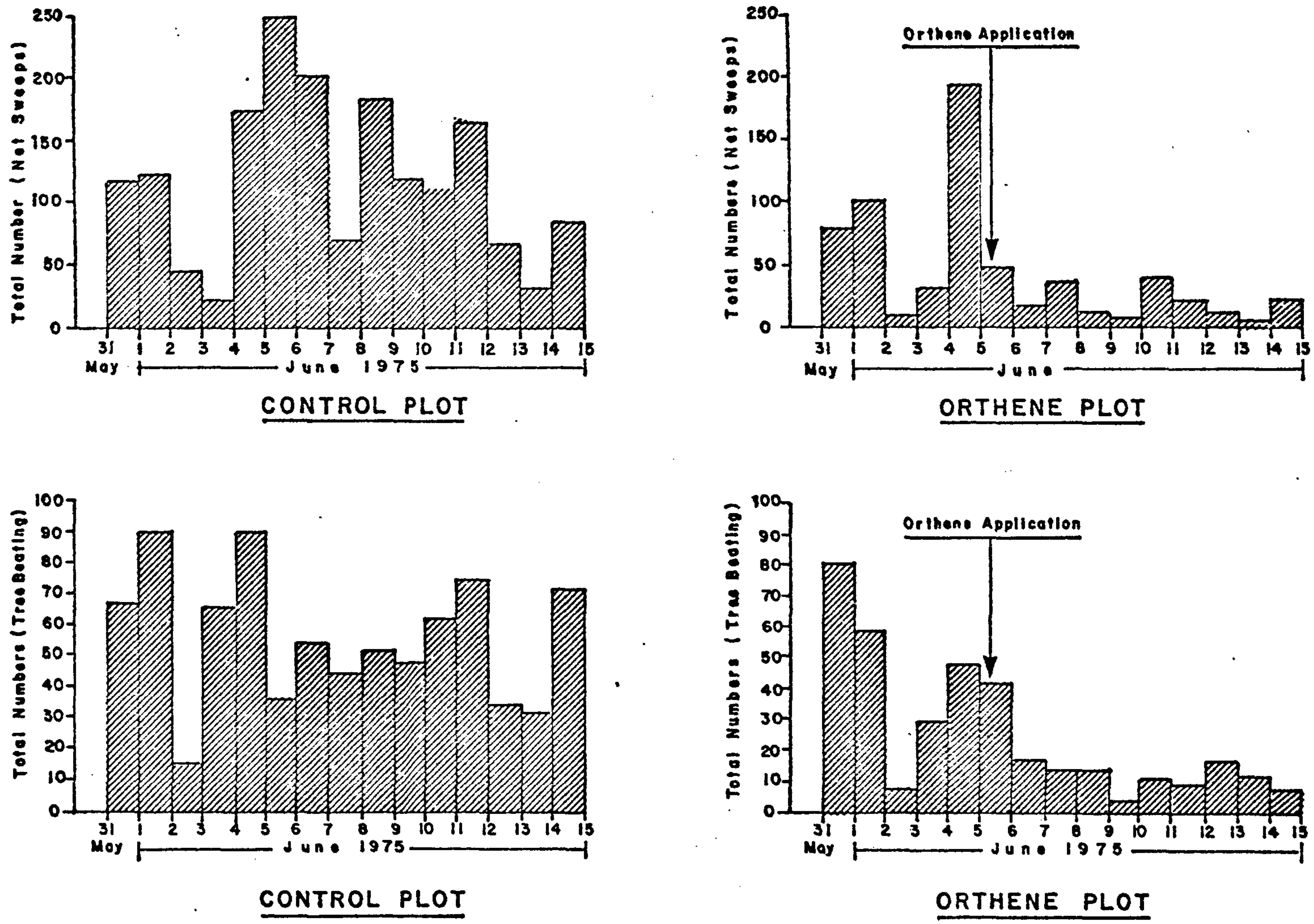

Figure 6: Changes in terrestrial arthropod population densities in Orthene treated and control plots - net sweeping and tree beating.

impact appeared to occur on the 3rd and 4th night following the spray when no flying insects were collected (Figure 5). However, because population densities were generally lower in the sprayed area and the effect was not sustained, other undetermined factors may have accounted for this response. Nevertheless, populations recuperated quickly to pre-spray levels. The reappearance of insects may possibly be attributed to reinvasion from untreated areas, new hatching, or recovery from subacute doses.

Population numbers declined during the post spray period for arboreal, litter, and grass inhabiting arthropods when compared to both pre-spray numbers and populations in the control. Moreover, these effects were sustained over the post-spray sampling period providing additional evidence of an adverse pesticide effect (Figure 5 and 6).

Apart from this apparent pesticide impact, natural biological and physical factors are also regulating population densities. Mortality, natality, or emergence are some biological parameters while relative humidity, temperature, and rainfall are some physical factors that may affect arthropod distributions. The inhibition of arthropod movement and distribution by deteriorating weather conditions (rainfall, increasing relative humidities, decreasing temperatures) is clearly evident from June 1 to 2 in all trapping techniques. The first of June was mainly sunny and warm while the following day was cloudy and much cooler with 0.41 inches of precipitation. Aerial insects were the most affected because aeronautic activity is inhibited during unfavourable weather. A similar adverse weather situation, occurring between the 12th and 13th of June, is also indicated in the light trap data (Figure 5). This illustrates the need for at least some identification of extraneous factors for an adequate interpretation of impact monitoring.

Most ecosystems consist of species which range from very abundant to the very rare. If a pesticide has a broad spectrum of toxicity to species resident in a treated area, it would likely exterminate some of the rarer species and so reduce diversity. Predators are necessarily rarer than their prey and hence are always present in relatively small numbers. Therefore it can be stated as a *general law* that any non-specific pesticide will likely have a severe effect on predators. Table 6 tabulates the mean number of families caught per day during the pre and post spray periods. Fewer litter and grass dwelling, and arboreal families were caught during the period after Orthene treatment. Most of those lost were either predators or parasites with important roles in the forest ecology. Thus, not only was a severe reduction in population density indicated (Figures 5 and 6), but also a reduction in species diversity.

Population reductions or elimination of beneficial parasitic flies (Hymenoptera: Ichneumonidae, Pteromalidae, Platygasteridae) and predaceous spiders (Araneida) and ants (Hymenoptera: Formicidae) occurred in the grass and lower crown of the trees. Spiders and beneficial mites (Acarina) and springtails (Collembola) were also reduced in the litter. Mites and springtails are the main arthropod

Table 6: Mean number of arthropod families caught per day by various trapping methods

Trapping Method		Numbers Caught per Day	
		Pre-Spray (Mean ± SE)	Post-Spray (Mean ± SE)
Light Traps	Control	15.4 ± 3.5	12.8 ± 1.6
	Treated	10.6 ± 2.0	9.5 ± 2.1
Pitfall Traps	Control	9.4 ± 0.8	9.6 ± 0.5
	Treated	9.8 ± 1.2	6.2 ± 0.7
Net Sweeps	Control	18.4 ± 2.2	21.0 ± 1.5
	Treated	15.2 ± 4.8	9.6 ± 1.2
Tree Beats	Control	16.0 ± 2.0	15.0 ± 0.8
	Treated	11.6 ± 1.9	7.1 ± 0.9

agents of litter breakdown. Parasites and predators are a factor in the regulation of pests, pollinators, decomposer, or other organisms in the forest environment and their loss may introduce some instability into the various trophic links.

Although recuperation of these taxa was not indicated ten days after the spray, a hazardous situation would probably not result unless the area was sprayed annually. Data from eastern Canada on the effects of the organophosphate insecticide fenitrothion on non-target terrestrial insects indicates that populations can return to normal within a year. However, it is impossible to know how far such disruptions, if repeated annually, may influence community dynamics and productivity of the food webs in the forest ecosystem. Therefore, forest entomologists must be cognizant of this problem and indicates that Orthene should be tested at a lower rate of application to minimize the impact on desirable arthropod species.

Over the past three years, the Environmental Protection Service, Altantic Region has been studying the effects of fenitrothion insecticide on a small stream in southeastern New Brunswick. This material is sprayed over millions of acres of forest in New Brunswick to control huge outbreaks of the spruce budworm. Since most of the important fisheries streams in the province are exposed every year to this chemical, both long and short term environmental impact assessments were required. The rate of application of fenitrothion is generally far below that required to kill fish. However, of great concern, was its effects on aquatic insect larvae and nymphs of mayflies (Ephemeroptera), caddis flies (Trichoptera), stoneflies (Plecoptera), and some Diptera that are the major food organisms of juvenile Atlantic salmon and brook trout.

Biological sampling designs were similar to that described earlier (i.e., quantitative sampling both before and after the spray application) but, of course, standard aquatic sampling techniques were used. These methods consisted of firstly, Surber sampling to determine the total population of invertebrates occupying one square foot of stream bottom of any given time (usually determined twice weekly). Secondly, twenty-stone counts where the investigator removed twenty stones one at a time from a selected area and counted the insects found on each stone. Finally, insect drift samples were collected to measure the effects on the diurnal downstream movement of aquatic insects.

Results from insect drift sampling during 1972 in Cove brook, the small study stream near Sussex, New Brunswick, are presented in Figure 7. This figure represents the total insect drift based on 15 minute samples collected every third hour for 24 hour periods. Abnormal patterns are clearly evident following the spray applications and the amount of drift occurring immediately post-spray was substantially greater than during pre-spray conditions. The normal perturbations were disturbed by large numbers of dead drifting insects.

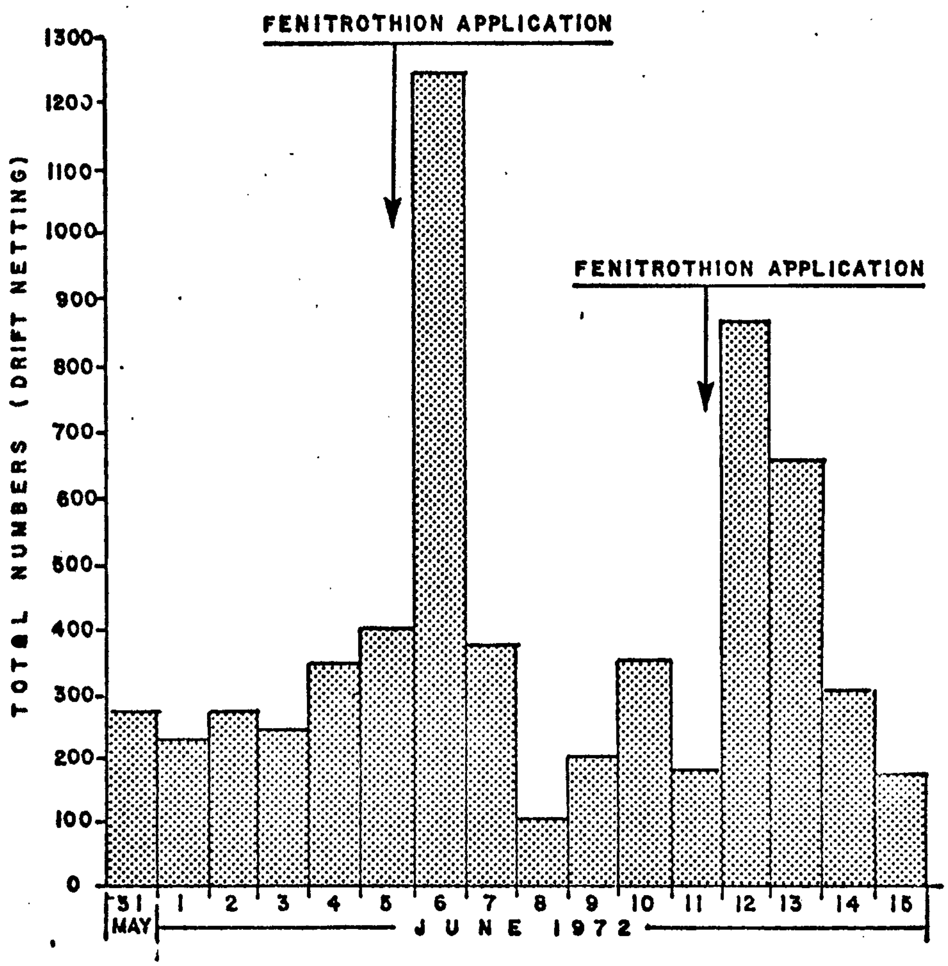

Figure 7: Total insect drift per 24 hour sample periods in Cove brook, New Brunswick*

*From data presented to the Annual Forest Pest Control Forum, Ottawa, Ontario by D.B. Banks and H.A. Hall, Environmental Protection Service, Atlantic Region, December 1972.

The long term effects of fenitrothion are evident upon examination of Table 7 comparing benthic invertebrate populations in Cove brook in 1974 to that present in the stream in previous years. Mean insect numbers per sampling effort were calculated for each year in which Surber samples had been collected. The stream had received doses of fenitrothion in 1971 through 1973 and little recovery was evident after the initial crash in numbers between 1971 and 1972. Studies by the Fisheries Service in New Brunswick have indicated that loss of this insect food can result in short term decreases in fish production.

SUMMARY

Techniques, uses, and limitations of monitoring the impact of pesticides on beneficial terrestrial and aquatic arthropods were described. The major limitations of these techniques result from their inability to provide an adequate assessment of the long term ecological changes because the biological systems themselves are not completely studied or understood. However, the general ecological importance of these organisms and their sensitivity to pesticides (thereby becoming good "indicator" organisms) will ensure a continued place for them in impact assessment.

Table 7: Mean number of insects collected in the benthos per sampling effort*

Year	Ephemeroptera	Trichoptera	Plecoptera	Diptera	Total
1971	92.1	11.2	2.1	83.2	188.6
1972	34.5	5.6	0.4	10.1	50.6
1973	32.2	10.8	0.2	2.0	45.2
1974	35.4	7.5	0.6	11.1	54.6

* From data presented to the Annual Forest Pest Control Forum, Ottawa, Ontario by H.A. Hall and P.B. Eaton, Environmental Protection Service, Atlantic Region, November 1974.

January 1976.

Emission Monitoring for Ambient Control

F. E. Murray

One of the most difficult problems in developing a strategy for air pollution control is the relating of ambient and emission source concentration levels. The choice of control objectives must be based on ambient levels. This is to ensure that people, plants, animals and other things will not be harmed by exposure to the ambient environment.

However, while ambient concentrations are the critical factors in preventing damage from air pollutants, it is not practicable to use ambient standards in an effective control strategy. This results from a number of problems. Ambient concentrations are frequently so low that analytical methods are often stretched to their limit of sensitivity. Gases and particles in the atmosphere originating from a variety of sources may interfere in the analysis to further compound the problem. The prevailing weather conditions and terrain greatly influence the dilution of pollutants as they travel from source to a ground level receptor.

In 1967, Ontario passed an Air Pollution Control Act in which ambient standards for air pollutants became law. Since then, Ontario has had little success in controlling air pollution using ambient standards and monitoring. In one example, the

Ontario Ministry was unable to prove that a plant in Toronto was violating their Act even though health damage was apparent in the surrounding area. The Ontario experience emphasizes that while ambient monitoring is essential, the control of air pollution must depend upon standards and monitoring applied at the source of emission.

The problem then becomes one of relating the desired ambient levels with those required at the emission source or sources. This could be done experimentally by measuring at the stack and at ambient over a wide range of emission levels and weather conditions. Such studies obviously require an existing plant and are very time consuming.

Control agencies seeking to achieve ambient requirements, depend upon atmospheric diffusion calculations to arrive at permissible emission levels. The method employed in using the calculational procedure varies among the control agencies but all have one thing in common. Calculated levels are rough approximations and the existence of hilly terrain or buildings in the plant vicinity make the approximations even more imprecise.

It is of interest to consider how this problem is handled by several Canadian provinces. In British Columbia, diffusion calculations were used to set "safe" stack concentrations based on ambient desires when the Report on the Forest Products Hearings was prepared. This Report, prepared in 1970, set emission source objectives for the B. C. Forest Products Industry. In this work, generalized emission objectives were set based on worst probable sources for a given air pollutant and the calculated ambient levels which would result.

In Alberta, the Division of Environmental Health published ambient air quality standards in 1970. While listing ambient standards, the Alberta agency recognized the need to relate emission and ambient levels. They published "calculated ambient standards" and stated that the "latest Provincial Board of Health approved calculation method" should be used to relate ambient and source concentrations. The calculation is specific for each emission source and hence each source has its specific source standard. This approach complicates the process of air pollution control by introducing a multitude of calculations.

In 1974, Ontario passed amendments to its control legislation which brought in calculated emission source standards based on its ambient standards using equations which are included as part of the Act. However, unlike the Alberta case, where every source requires a calculation, Ontario introduced the concept of a virtual source which included all sources at a plant except those stacks whose plumes are emitted well removed from the surrounding buildings. An equation for ground level concentration for pollutants emitted by the virtual source is included in the Ontario law.

The direct use of diffusion equations to relate source and ambient concentrations as done in Alberta and Ontario is subject to considerable controversy. The criticism centres on the fact that the levels based on calculation are really estimates which may be substantially in error. Under ideal conditions, the calculated value may be inaccurate by a factor of 2 to 5. In hilly country, valleys, and areas subject to localized weather phenomena, errors may be much larger.

It appears questionable that the use of individual calculated source levels is preferable to the generalized approach of setting the same emission standard for an assortment of industrial stacks as has been done in British Columbia. In either case, the value used is a rough estimate with the generalized approach easier to apply and enforce.

Ambient Monitoring of Air Pollutants

A. J. Lynch

I. INTRODUCTION

Ambient air monitoring is used in both atmospheric surveys and air quality studies. An atmospheric survey can be described as a critical examination of a given geographical area for the purpose of determining the nature, sources, extent and effects of air pollution. An air quality study is concerned with determining the concentration of selected pollutants in a given area. It is important that the ambient air monitoring program, supporting either the atmospheric survey or the air quality study, be designed with a clear understanding of the objectives. Some common objectives are:

A. To determine the nature, extent and trend of area wide pollution.

B. To assist in developing air quality standards.

C. To determine the effectiveness of air pollution control programs and plan new abatement procedures.

D. To determine the reduction of contaminants and emissions needed for various classes of sources.

E. To assist in planning future development.

F. To determine the relationship of air contaminant levels to factors influencing concentrations such as population density, source patterns, topography, and meteorological conditions.

G. To determine the relationship of concentrations of air contaminants to their effects on health, plants, animals, vegetation, visability, property and other economic factors.

II. FACTORS IN THE DESIGN OF AN AMBIENT MONITORING PROGRAM

Some of the factors which should be taken into consideration in designing an ambient air monitoring program are discussed below:

A. Background Data

A thorough investigation of existing studies and background data of the area is desirable. Often considerable light can be thrown on the subject and valuable time saved by uncovering existing pertinent data.

B. Sample Site Location

Sample site location is a critical item, reliable data can only be collected if the sampling sites are located in representative areas. The site locations depend upon the type of survey being conducted. Some of the items that must be considered in selecting a site location are:

1. Objective of study
2. Budget
3. Area meteorology
4. Topography of area
5. Personnel available
6. Electricity
7. Protection from children and vandalism
8. Aesthetics
9. Accessibility of site
10. Weight and type of equipment

C. Sample Size

In advance of beginning a sampling program it is necessary to delineate the size of the samples to be taken. Before the size can be stated in terms of air volume, several factors must be examined. If these factors are ignored samples may be taken which contain amounts of contaminants insufficient to permit proper identification and measurement. The following factors should be taken into consideration in determining sample size:

1. Concentration (estimation of minimum concentration needed)
2. Efficiency of the sampling procedure
3. Analytical requirements
4. Sampling time
5. Sampling rate

Sampling time may be calculated as follows:

$$\text{Sample Time} = \frac{\text{Analytical Requirements}}{\text{Concentration} \times \text{Efficiency} \times \text{Sampling Rate}}$$

D. Sampling Frequency

Estimation of sampling frequency is one of the most difficult tasks in the design of a sampling program. Some of the factors that affect the concentration of pollutants over time are:

1. Meteorological factors such as precipation, temperature wind direction and speed, have a direct influence on sampling frequency.
2. Transportation patterns
3. Domestic patterns such as fuel consumption
4. Industrial operations
5. Agricultural operations
6. Reliability of statistical information

E. Selection of Monitoring Methods

There are many methods for the sampling and analysis of air contaminants. A list of the methods in common use is given in Table I. Today because of high labour costs, it is generally more economical to purchase a continuous monitoring instrument rather than collect the samples for subsequent laboratory analysis. For each method the following should be considered:

1. Precision
2. Accuracy
3. Minimum detectable concentration
4. Chemical interferences
5. Reliability of instrumentation
6. Calibration procedure
7. Labour requirements
8. Type of data output

III. OPERATION OF THE MONITORING PROGRAM

The biggest problem with many air quality studies is that investigators will spend considerable time in the design of the study and give adequate consideration to the factors discussed above, but once the ambient air monitoring network is put into operation they then relax and leave the operation in the hands of unqualified personnel. The result of this is either the collection of vast amounts of questionable data or the waste of large sums of money on data that must be eventually be discarded. The same factors used in selecting an instrumental method must be used as in selecting a laboratory method. In the operation of these instruments the same care and attention to detail must be employed in the operation of continuous monitoring instrument as must be employed in an efficiently operated laboratory. All that has happened is the laboratory has been transferred from the bench into an instrument located at the sampling station. It is important that as data is collected it is analyzed to determine if operational adjustments are necessary. It is far better to adjust the program than to trudge on only to find in the end that the data is useless. Some instrument manufacturers make claims that their instruments are capable of long periods of unattended operation. This may be true if the instrument is operated in ideal conditions in mid concentration range, however in most locations in British Columbia contaminants are at the low side of the instrument range. If highly accurate data in low concentrations is required, the following are necessary:

1. Extremely accurate instrument calibration procedures. Some recommended calibration procedures are given in Table I.
2. Frequent instrument checks for drift, electronic calibration. For accurate data in low concentrations, equipment should be visited to check operations once per day.

IV. DATA REPORTING AND EVALUATION

In reporting air monitoring data it is important that:

A. The sampling and analytical methods be reported with the results.

B. The data be presented in a form that aids in interpretation and data evaluation.

In the Environmental Laboratory of the British Columbia Water Resources Service a 7 digit code is used to define the parameter tested, the type of sample and the analytical method used. Every result reported by the Laboratory is accompanied by this 7 digit code. For example, lead in suspended particulate matter collected on a high volume filter and analyzed by atomic absorption spectrophotometry is given the following code:

Parameter: 751 - Lead

Sample Preparation: 52 - Suspended Particulate

Analytical Method: 20 - Hi volume analyses by AA dual operation

The test code would then be 7515220.

Samples of data presentation used in the Lower Mainland Air Quality Study are given in Tables II to V and Figure 1. Some aspects of data presentation as illustrated in the Tables are:

A. 95% Confidence Intervals

95% Confidence intervals for calculated mean concentrations of dustfall and suspended particulate matter are given in Tables I and II. This calculation is useful, when using intermittent sampling in determining if ambient air standards have been met.

B. Number and Percent of Time a Concentration is Exceeded

The number and percent of time a concentration is exceeded is an important calculation in determining if an ambient air standard has been met when a continuous analyzer is used. Table lV shows the comparison of carbon monoxide concentrations in the Lower Mainland within common objectives and criteria.

C. Percent Usable Data

Percent usable data can be used as a measure of the operational efficiency of a monitoring program. If the percent usable data is consistently below 50% it is a sign of serious operational difficulties. If percent usable data is consistently greater than 90% either the data is not being edited, infrequent calibration checks are being made or the cost of operation is excessively high. Table V shows percent usable data for carbon monoxide in the Lower Mainland.

D. Concentration Versus Averaging Time and Frequency

A graph of concentration versus averaging time and frequency is a useful way to present continuous monitoring data, as the data may be easily compared to past, present or future air quality criteria or standards. (Figure 1)

V. SUMMARY

In conclusion an atmospheric survey concerns itself with a planned systematic task of recording, evaluating and relating the various sources and levels of pollutants as well as atmospheric and geographical conditions encountered in a given area. These relationships are in turn used to determine the nature of existing problems, estimate future trends and to develop the understanding necessary to develop reasonable means of control.

A.J. LYNCH
Jan. 15/76

TABLE I

COMMON INSTRUMENTAL METHODS FOR MEASUREMENT AND CALIBRATION OF AIR POLLUTANTS

Parameter	Method	Calibration
Carbon Monoxide	Non-dispersive infrared spectrophotometry	Standard gas in steel or aluminum cylinder audited by a primary standard cylinder from N.B.S. or standard produced from 100% gas using gas dilution sytem
Total Hydrocarbons	Flame ionization	
Specific Hydrocarbons	Gas Chromatography using flame ionization detector	Standard gas in steel or aluminum cylinder audited by a primary standard cylinder from N.B.S.
Sulfur Dioxide	Coulometry or flame photometry with associated scrubbers for removal of other sulfur compounds	SO_2 permeation tube at station. Primary standard: N.B.S. permeation tube or standard from 100% gas using gas dilution system
Specific Sulfur Compounds	Gas chromatography using flame photometric detector	SO_2 permeation tube or standard production from 100% gas using gas dilution system
Ozone	Chemiluminescent reaction of ozone and ethylene	Ozone source (UV lamp) calibrated against UV photometer (5 meter path length)
Nitric Oxide	Chemiluminescent reaction of NO and oxygen	Standard gas in steel or aluminum cylinder calibrated against N.B.S. cylinder or standard produced from 100% gas using gas dilution
Nitrogen Dioxide	Conversion to NO and measured by NO method above	N.B.S. NO_2 permeation tube or gas phase titration using NO or O_3 primary standards

TABLE II

LOWER MAINLAND AIR QUALITY STUDY

SELECTED FIXED STATIONS TOTAL DUSTFALL RESULTS

FROM 1969 to 1970

(TONS/MILE^2/MONTH)

Station	Mean	Max.	Min.	95% CI	Number of Readings
V-4 Vancouver Airport	8.9	15.2	6.4	7.8 - 10.0	20
V-5 Delta High School	6.5	17.3	3.1	2.3 - 10.8	7
V-9 New Westminster Cemetary	10.3	13.7	6.5	9.3 - 11.3	19
V-1 Ambelside Park West Vancouver	7.1	9.8	5.0	6.5 - 7.6	24
V-12 Port Moody Library	14.0	20.9	9.4	12.3 - 15.7	16
V-24 City Analyst Office	20.2	24.4	10.7	18.5 - 21.9	16

TABLE III

LOWER MAINLAND AIR QUALITY STUDY
SELECTED FIXED STATIONS SUSPENDED PARTICULATE DATA
FROM 1969 to 1970
(TONS/MILE^2/MONTH)

Station	Mean	Max.	Min.	95% CI	50th Percentile	84th Percentile	No. of Readings
V-4 Vancouver Airport	54	135	15	48 - 60	20	24	73
V-5 Delta High School	42	116	12	33 - 50	13	17	31
V-9 New Westminster Cemetary	115	520	29	90 - 140	38	41	48
V-1 Ambelside Park	60	202	15	54 - 66	24	29	102
V-12 Port Moody Library	113	315	22	96 - 129	29	45	64

TABLE IV

COMPARISON OF CARBON MONOXIDE CONCENTRATIONS AT VANIER PARK WITH COMMON OBJECTIVES AND CRITERIA FOR THE ENTIRE STUDY PERIOD OF JULY 1969 to DECFMBER 1970

Objective or Criteria	Number of Times Concentration Exceeded	Percent of Time concentration May be Exceeded
Canada, Maximum Acceptable		
- 30 ppm for 1 hr.	Nil	Nil
Canada, Maximum Desirable		
- 13 ppm for 1 hr.	27	0.1% - 1%
USA, EPA Primary & Secondary		
- 35 ppm for 1 hr.	Nil	Nil
Impairment in Time Interval Discrimination		
- 50 ppm for 90 min.	Nil	Nil
- 10 - 15 ppm for 8 hr.	---	0.1% - 1%
Physiological Stress in Patients With Heart Disease		
- 30 ppm for 8 hr.	Nil	Nil

TABLE V

MONTHLY AVERAGES OF CARBON MONOXIDE CONCENTRATION
CONTINUOUS AIR MONITORING STATION - VANIER PARK*
(ppm)

Month	Arithmetic Mean	Standard Deviation	Maximum	% Usable Data
August 69	1.8	1.3	11.4	91
September	1.9	1.4	14.3	75
October	2.6	2.1	18.1	65
November	2.8	2.9	22.5	89
December	2.5	2.0	19.3	82
January 70	2.4	1.9	12.6	88
February	2.8	2.9	19.0	88
March	1.8	1.4	16.0	89
April	1.7	1.0	8.7	85
May	1.9	1.3	7.8	84
June	1.8	1.2	12.6	82
July	1.3	0.9	11.2	90
August	1.3	1.4	13.6	82
September	1.7	1.8	10.0	84
October	2.8	2.8	23.9	74
November	2.7	3.7	28.4	90

*Data from Lynch, A.J., Emslie, J.H., Plummer, J.M., Olson, R.H., Mason, D. "Lower Mainland Air Quality Study - Final Report,(1972)"

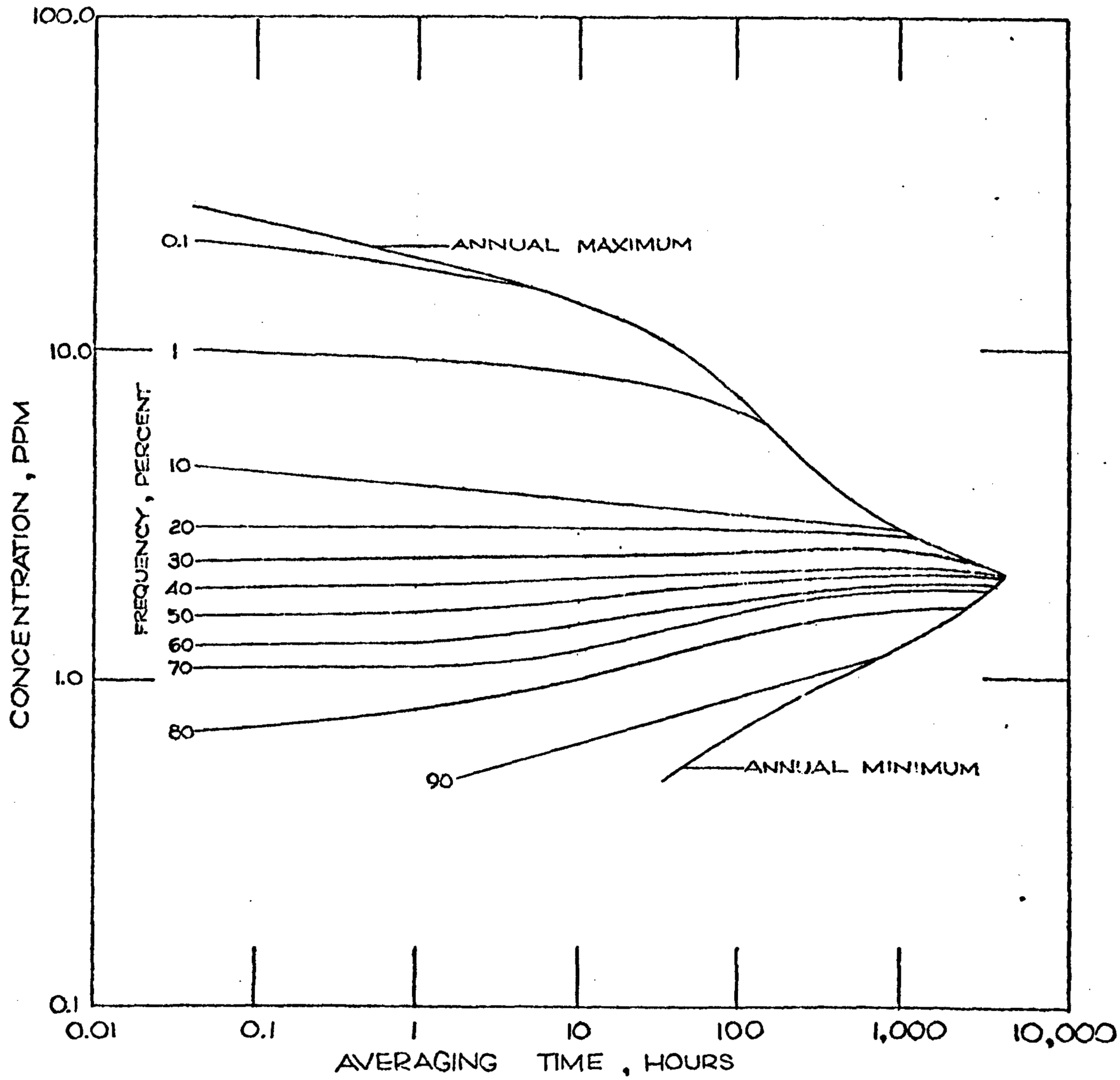

FIGURE I

CONCENTRATION VERSUS AVERAGING TIME AND FREQUENCY FOR CARBON MONOXIDE FROM JULY 1, 1969 TO DEC. 11, 1970.

ESTUARINE MONITORING

FRASER RIVER

by

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ESTUARINE MONITORING

FRASER RIVER

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ABSTRACT

Estuaries are dynamic systems. They undergo large diurnal, seasonal and year-to-year fluctuations. Monitoring for environmental protection must separate effects of man from natural fluctuations. Careful baseline studies are needed first to provide essential background ecological information. Important food chains must be identified. In the Fraser River estuary, the importance of deltaic vegetation (sedge) as a base in the food chain should not be ignored. The production of epifauna is important to fisheries and wildlife. Sediment distribution is vital to the productivity of the system. Contamination by metals, oils and chlorinated hydrocarbons could lead to bioaccumulation and associated problems.

Baseline studies should determine a reasonable monitoring program to provide a maximum of information with a minimum effort on environmental and ecological degradation through man-made changes. Some suggestions are made in this direction for the Fraser River estuary based on existing knowledge.

ESTUARINE MONITORING

FRASER RIVER

INTRODUCTION

The word *monitoring* is used to mean many things to different people. It is sometimes regarded by some as the panacea for any type of pollution problems. Once conditions are monitored, the pollution problems somehow miraculously vanish, because everything is considered to be under control. To a marine researcher,"monitoring" is a bad word. "Baseline studies", "time series" yes; but "monitoring", heavens no! I still have to have someone explain to me simply the difference between baseline studies followed by time series and a good monitoring program.

Somehow the term "monitoring" conjures up for the scientist something closely akin to the salt mines, where it's a daily routine of slogging out to predetermined sampling points, wearily taking the samples, preparing them by a well established recipe for analysis or preserving them, and then taking them back to the laboratory to titrate them, run them on A.A. or spectrophotometer or count the organisms under a microscope and finally produce some numbers. Such drudgery!

I decided in preparing this talk that I would use the Shorter Oxford English Dictionary (unabridged edition) and settle once and for all the meaning of the word, "monitor". After going through some of the more archaic meanings (these are usually followed by "Now somewhat archaic", so you know they are archaic), I came to "A lizard of the family *Monitoridae* or *Varanidae*, inhabiting Africa and Australia, supposed to give warning of the vicinity of crocodiles 1826". It would appear that some of the archaic definitions are better, e.g. "one who admonishes", or "senior pupil in school with duties of keeping order". Actually, to my astonishment, "monitoring" is not defined in the Oxford dictionary according to the usual concept of the meaning of the word as we know it.

My personal definition of the word monitoring is "repeated observations by an established standard technique". The purpose of monitoring in the environmental sense is to enable trends in conditions to be observed if they are present. But in environmental scientific circles you will frequently hear the question asked "Why monitor?" The reason scientists have a general abhorrence of monitoring is that it diverts effort and funds from more creative scientific endeavours. But I maintain that a good monitoring program can contribute useful information for research.

I happen to be involved in a number of international activities concerning marine pollution. In almost all the fora we inevitably bring up the subject of monitoring. We even strike up working groups to develop monitoring programs. Usually a report is prepared and no one pays any attention to it. One of these (FAO, 1971) even provided a definition for monitoring as follows: "'Monitoring' is considered to be the systematic observation of properties related to specific problems concerned with the marine environment, the observations being carried out in such a way as to show how these properties vary with time at a number of fixed locations or geographical areas". On the subject of "why monitor?", it states, "It's purpose is to show (a) physicochemical and biological changes in the ocean both due to natural causes and the activities of man, (b) changes in the marine ecosystems due both to natural causes and the activities of man, (c) the degree of pollution of the ocean."

There is one pilot project on marine pollution monitoring that has been actually underway for over a year, and Canada has been a participant. This is the Pilot Project on Marine Pollution Monitoring under the Framework of IGOSS (Integrated Global Ocean Station System of the Intergovernmental Oceanographic Commission and the World Meteorological Organization[IOC-WMO, 1974]). The project has been carried out largely with the aid of "ships of opportunity" for sampling. Established laboratories do the analyses.

There is another international monitoring program at least on paper. This is the Global Environmental Monitoring System (GEMS) of the United Nations Environment Programme. It has a marine component and is looking to the IGOSS Pilot Project on Marine Pollution Monitoring as a beginning to global monitoring.

The reason that there is a great deal of resistance to monitoring in international circles is that it is a costly business. The United Kingdom, for example, strongly opposes any global monitoring venture because she has limited resources and feels that she is already contributing quite heavily to regional monitoring programs, such as the one in the North Sea under the aegis of the International Council for Exploration of the Sea. Thus any global monitoring program to which the UK is a party will inevitably consist of regional programs coordinated into a global monitoring network, which is the first proposal in the Comprehensive Plan for Global Investigation of Pollution in the Marine Environment, a program being coordinated by the Intergovernmental Oceanographic Commission (IOC, 1975).

But let us come back to B.C., and particularly to the Fraser River estuary. How are we going to monitor it for environmental protection, assuming that monitoring is an acceptable and honourable activity?

What, where and when to monitor

Monitoring can be expensive. It is a relatively simple matter to collect a large number of samples and carry out a series of analyses on them, provided the resources are available. Collecting large volumes of data is one thing, but making the data collection effective is another.

1. What

If it is assumed that the objective is to measure trends from a given baseline, then we should monitor those characteristics that exhibit the earliest changes when the ecosystem is subjected to stress. Ideally, we want an early warning system as a guard against ecological damage, particularly one that is long-term and difficult to reverse. One should avoid relying entirely on those characteristics that exhibit wide natural fluctuations. It would be preferable to monitor those components that exhibit a cumulative effect, rather than those that respond rapidly (short response time) to every environmental fluctuation. It is essential to separate the "signal" from the "noise" in environmental perturbations. We might consider the normal environmental fluctuations as the "noise", and it is often difficult to distinguish the effects of man-made change from this background.

Clearly, one would have to examine closely the kinds of ecological damage that might be anticipated in order that the proper choice is made of properties to be measured. For example, a large input of sewage which threatens the estuarine ecosystem with a voluminous input of nutrients and organic material, along with bacteria and viruses, would demand a scheme of observations in which the concentrations of these substances and their effects are measured. If the problem is heavy metals and bioaccumulation, we would most certainly measure the critical metals in the water, sediments and the biota. If one must be selective, because of limited resources, in choosing the appropriate medium in which to measure the amount of metal one would certainly go to the marine organisms known to concentrate the metals. It was stated by investigators early in the era of concern about chlorinated hydrocarbons in the aquatic environments that there was little point in measuring such lipophylic substances as DDT in water, inasmuch as most of it is quickly taken up by the lipid tissue of organisms. Of course, that was in the days when a fraction of a part per billion of DDT or PCB's in water could not be readily measured.

This is another point that must be noted - the ease with which analyses can be made. Some of the earliest monitoring data acquired on the marine environment concerned radioactivity from nuclear weapons tests in the South Pacific. Many of the critical radionuclides, such as strontium-90 and cesium-137, could be quite precisely measured by established separation methods and available techniques for counting. On the other hand, it is only comparatively recently that mercury could be measured accurately in fish tissues, so that we have become aware of mercury concentrations at the parts per million level in a variety of species, a condition which may have existed in some cases long before man started to introduce large quantities of mercury into the aquatic environment. Unfortunately, by human nature, there is sometimes a tendency to measure those properties which are easiest to measure, whether this has any bearing on the problem or not. Thus, we may end up with a large volume of data which has little relevance to a particular pollution problem.

2. Where

It is particularly important to be selective in developing a network of stations for monitoring. There is hardly any point in collecting data at six stations when one well-chosen station will provide the essential information. What are some of the criteria for site selection? Once again, it is essential to choose a location where the earliest changes due to pollution or environmental restructuring can be identified. It is obvious that in an area where there is regional differential flushing of a body of water, one would choose a location where flushing is slowest and environmental conditions deteriorate most rapidly. In an estuary, for example, one station occupied in the main stem of the river may give the needed data on the well-flushed river channel, but it is the various side channels, sloughs and rivulets in the delta which give some of the vital information on the condition of the estuary. In fact, ecological studies in the Squamish and Fraser River estuaries concentrate on the various sectors of the deltas rather than within the river channels themselves.

The important point to bear in mind in selecting stations for monitoring any coastal area is that locations must be chosen to provide data on the most dynamic processes occurring there, particularly if these processes are affected by pollution or other disturbances by man. For example, if a jetty has been installed to divert fresh water flow from a given coastal area, sampling of water, sediments and biota should be carried out behind the jetty and in front of it, to determine the effect of the diversion of fresh water. This means that one would want to measure the salinity and temperature of the water, the sedimentation rates and characteristics of the sediments, as well as make observations on the flora and fauna. In the case of a dredging and filling operation, there is a need to know the rate of recolonization of dredged bottom and of submerged fill area by benthic organisms. Suitable techniques of measuring populations of both infauna and epifauna must be utilized in order to achieve some measure of quantitative assessment.

3. When

The frequency of sampling for a proper assessment of change in an ecosystem is always a problem. Again, it is a matter of resources and the detail of information that is required. If one is interested primarily in the rather crude year-to-year changes as a result of pollution, one could almost get away with an annual monitoring survey conducted at a time when the effects of pollution might be expected to be at their worst. However, this is seldom sufficient for a detailed monitoring program where natural fluctuations can be adequately separated from those due to man-made effects.

A simple monitoring scheme in coastal waters can be taken at straight monthly or bi-monthly intervals. A more effective distribution of sampling and observation periods, however, if there are sufficient resources to carry out 10 or 12 surveys per year, would be to distribute the observational operations in such a way as to cover more densely the periods of dynamic change in physical, chemical and biological properties, e.g. freshet in river runoff, blooms of phytoplankton, runs of anadromous fishes. Perhaps the first year can establish the frequency of sampling by closely spaced observational periods, and then these can be adjusted according to the need in subsequent years.

One system of observations that has been used for oceanographic data along this coast involved one key station, which would be sampled on a monthly basis, while surveys giving wider coverage would be conducted perhaps on a bi-monthly basis. We have had along the B.C. coast for some 40 years daily seawater observations at lighthouses which provide data on seasonal and year-to-year fluctuations in temperatures and salinity, important properties when considering physical processes in the sea, and these affect movements of salmonids.

How long should a monitoring program be conducted? Scientists are sometimes accused of turning on a certain type of continuing program in year 1 and forget to turn it off. Then it seems to go on forever without anyone carefully analyzing the data. Certainly, any type of monitoring program should be reviewed periodically, perhaps on an annual basis. It should be adjusted as required. But for statistical purposes, a set of continuing data becomes more valuable as more years are covered. A basic program of research in an estuary needs at least a 5-year period to provide the needed information on natural fluctuations for an understanding of the system. One could hardly expect a monitoring program to endure for a shorter period. The research program could define the pattern of stations, the minimum frequency of sampling and the parameters that should be determined. Then the monitoring program could continue as long as there is a need for that type of information.

MONITORING STRATEGY IN ESTUARIES

A good deal has been written on monitoring strategies in the coastal zone, particularly in the U.S.A. (NAS/NAE, 1970; Goldberg, 1972). However, there are few good monitoring programs in the coastal zone anywhere. Perhaps the United Kingdom has done as much as anyone with respect to monitoring in coastal waters, first on radionuclides arising from nuclear reactors, and more recently on heavy metals from industry (Preston *et al*, 1972). The United Kingdom has recently expressed concern about the state of its estuaries and is beginning to examine in detail the conditions of its estuaries in 27 coastal sectors (NERC, 1975). No one has yet developed a universally acceptable monitoring strategy for estuaries. However, it might be worthwhile to examine a few principles involved in an estuarine monitoring strategy.

(1) The estuary has a major influence from the land side through the river runoff. There is a seasonal pattern of runoff which usually repeats itself from year to year. In the Fraser River there is the well-known freshet period of May-June arising from stored runoff in the form of snow melt. Certainly the period of heavy runoff merits considerable attention in the way it affects the estuarine ecosystem, through increased fresh water, silt, stronger river flow, deposition and erosion.

(2) The sea affects the estuary through the diurnal tidal fluctuations, fortnightly changes from neap to spring tides and seasonal changes in tidal range, as well as time of day for exposure of tidal flats. Winds create currents and wave action that affect the estuarine ecosystem. Again wind wave action changes seasonally,affecting intertidal organisms differently in a period of prevailing winds on shore,from one when calm conditions or off-shore winds are more common.

(3) Food chains in the estuary are extremely important from the point of view of preservation of the ecosystem. The significant food chains should be identified. Occasionally, there is a key organism in a food chain leading to commercially-important species, e.g. in the Squamish River estuary a gammarid amphipod (*Anisogammarus confervicolus*) is vital as a food for

juvenile salmonids using the estuary as a nursery ground. It is essential to monitor the population of this species so that the status of this food resource can be established.

(4) The living resources of an estuary are essentially the integral components of the ecosystem, and their state of health reflects the state of health of the ecosystem. Every estuary possesses basically four different types of living resources: (a) vegetation, both aquatic and terrestrial; (b) wildlife, consisting largely of water-fowl; (c) fishes; and (d) invertebrates. An important living component of the ecosystem are the aquatic microorganisms which play a vital role in the decompositon of organic matter and cycling of nutrients.

(5) The estuarine ecosystem is a highly complex system of the plant and animal organisms living in close harmony with the environment. It is a system under natural stress. The organisms are highly specialized to survive under these stressful conditions. The food web is relatively simple with comparatively few species involved in the food chains. For an understanding of how energy flows through the food chains from plant life to the highest predators, basic information on production at each trophic level is required. A monitoring strategy may require continuation of data collecting on organic production, so that any disruption of energy flow through an important food chain can be recognized. Some of the different techniques for biological assessment of pollution effects are given in Table I.

A monitoring program must lend itself to sufficient quantitative analysis so that trends of deterioration can be recognized. A number of studies have been conducted where multivariate analysis has been used to identify and quantify changes. Usually benthic organisms and their communities, which essentially integrate pollution effects over a period of time, can be used for this purpose (Beak, *et al*, 1959). Regier and Cowell (1972) discussed the application of ecosystem theory to conservation problems. Studies in San Francisco Bay (Selleck and Pearson 1974) eventually found that diversity index was the most useful analytical tool for following the effects of pollution, but such an index does not necessarily hold in most estuaries which have a naturally low diversity of species.

FRASER RIVER ESTUARY

The Fraser River estuary is quite unique on the British Columbia coast, indeed in the world (Fig. 1). We chose the Fraser estuary as the first and most important of 18 critical estuaries in British Columbia on which to compile all available information (Hoos and Packman, 1974). There is surprisingly a great deal of information on this estuary, since it has been the focus of investigation for a number of years by federal and provincial agencies, universities and by naturalists. No one has attempted to carry out a comprehensive monitoring program, although certain characteristics are measured regularly.

One should be aware of a number of processes which occur in estuaries in terms of effects of pollution on living resources. These processes often lead to dilution and dispersion of a pollutant, but they may also lead to reconcentration as shown in Figure 2. The Fraser River with its heavy silt load contributes to some of the processes of abstraction of pollutants from the water and deposition in the sediments.

The Fraser River estuary can be well characterized by the following four living resources: (1) vegetation is mainly sedge, a vascular plant generally above high tide. It provides a food resource for aquatic invertebrates in the form of detritus when it dies down and is washed into the water. It also serves as a food for the wildlife. (2) Fish abound in great numbers, especially during certain periods of year when the salmon fingerlings migrate to sea from the many streams and lakes tributary to the Fraser River. (3) Wildlife is extremely plentiful in the Fraser River estuary, being the over-wintering area for many flocks of birds, and the stop-over point for others migrating north in spring and southward in autumn. (4) Aquatic invertebrates serve as food for birds and for fishes. At one time, there was a substantial Dungeness crab fishery on the Fraser delta. To learn something of the impact of development on the Fraser River delta, one would have to look at the effects on each one of these resources.

We have done a considerable amount of work on the Fraser River estuary in connection with the proposed runway extension at the Vancouver

International Airport (Levings, 1975) and the effect of the sewage effluent from the Iona Island Sewage Treatment Plant. The distribution of bottom organisms on Sturgeon Bank is quite revealing (Fig. 3 & 4). The area between the North Arm Jetty and the Iona Outfall dyke is clearly one of the most impoverished on the whole Fraser River delta. No doubt this is related in part to the lack of fresh water in the area, having been diverted by the jetty and dyke. It may also be partly due to the deposition of dredge spoils from the North Arm in the apex between the jetty and dyke. In any case, the bottom organisms have not yet fully adapted to the new environmental conditions, although there is some evidence that the area is being colonized by more marine species.

CONCLUDING REMARKS

The Fraser River estuary is an extremely dynamic system, with enormous seasonal fluctuations in freshwater flow, silt load, and other characteristics associated with runoff. It has considerable daily and seasonal fluctuations also in tidal range, wave action and currents. The delta is growing rapidly with the front extending about 20 ft per year resulting from some 25 million tons of silt deposited annually. The delta is also extremely rich in living resources - vegetation, fisheries, wildlife and benthos. These are closely interrelated with each other and with their environmental surroundings. Any comprehensive study of the Fraser River estuary must be interdisciplinary in nature to examine all the interrelated facets. Only in this way will the processes and the ecosystem trophodynamics be understood. Any monitoring program must take these basic findings into account, if it is to be effective in giving maximum information for protection of the estuary and allowing fullest utilization of its resources.

In the U.S.A., a program known as "Mussel Watch" is being implemented in coastal waters as a means of monitoring bioaccumulation of metals, chlorinated hydrocarbons and petroleum hydrocarbons. The use of filter-feeding invertebrate organisms to monitor conditions in estuaries has a great deal of merit. After all, they are some of nature's best concentrators of everything from viruses in sewage to zinc from electroplating plants and pulp and paper mill effluents.

Finally, any monitoring program must lend itself to some form of quantitative multivariate analysis so that trends can be clearly recognized, if they indeed exist.

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TABLE 1

Rating of Techniques for Biological Assessment of Pollution Effects[*]
(From Waldichuk, 1973)

Test	Marine (M) or fresh (F) water	Duration of test[a]	Practical applicability[b]	Mode of use[c]	References
Fish bioassay					
(short-term, acute)	F	+	L		296
(short-term, acute)	F	+	L		297
(short-term, acute)	F	+	L		298
(short-term, acute)	F	+	L		299
(short-term, acute)	F	+	L		300
(short-term, acute)	M	+	L		192
Bioassay (short-term, acute)	F	+	L		301
Shellfish bioassay	M	+++	LS	BJ	302
Shellfish bioassay	M	+++	LS	BJ	303
Bioassay (use of trophic level)	M	++	S	EQ;BJ	304
Crustacean bioassay, behavior	F	++	L		305
Insect bioassay, behavior	F	++	L		306
Safe dilution level	M	+	L		307
Tolerance levels	F	++	L	BJ	308
Bioassay, AChE	F	++	LS		309
Behavioral, BSC	F	++	L		310
Reproductive behavior	F	+++++	L		311
Feeding behavior	F	++++	L		312
Reproductive behavior	M	+++++	L		313
Feeding behavior	F	++	L		314
Behavior and histology	F	++++	L		315
Saprobien	F	+++++	L	BJ	316
Saprobien (modified)	F	++++	LS	BJ	317, 318
Saprobien (modified)	F	++++	LS	BJ	319, 320
Indicator organisms	M	+++++	L	BJ	321
Indicator organisms	M and F	+++++	L	BJ	322
Indicator organisms	M	+++++	L	BJ	323
Saprobien index	F	++++	L	BJ	324
Biotic index	–	++	LS	EQ	325
Biotic index	F	++	LS	EQ	326
Biotic index	M and F	++	LS	EQ	327
Zonation	S	++++	LS		328, 329
Modes of life	F	+++++	LS		330
Communities	M	+++	LS		331
Communities	M	++++	LS		332
Communities	M and F	+++	LS		333
Communities	M	++	LS		334
Population structure	M	+++++	LS		335, 336, 337
Plant-animal associations	M and F	++++	LS	BJ	362
Reestablishment	M and F	++++	LS	BJ	163
Population structure	F	+++++	LS		338
Species diversity	M	+	LS	BJ;EQ	339
Species diversity	–	+	LS	BJ;EQ	340
Species diversity		+	LS	BJ;EQ	341
Species diversity	–	+	LS	BJ;EQ	342
Species diversity	M	+	LS	BJ;EQ	343
Species diversity	M	+	LS	BJ;EQ	344

TABLE 1 (continued)

Rating of Techniques for Biological Assessment of Pollution Effects*

Test	Marine (M) or fresh (F) water	Duration of test[a]	Practical applicability[b]	Mode of use[c]	References
Species diversity	M	+	LS	BJ;EQ	345
Species diversity	M	++	LS	BJ;EQ	346
Association of species	M	+++	S		347
Dominance	F	++	LS	BJ	348
P/R (photosynthesis/ respiration)	M	+++	S	EQ	345
P/R	M	+++	S		349
Primary productivity	M and F	++	S	BJ	350, 351, 352 353, 354, 355 282
Secondary productivity	M and F	++	LS	BJ	356, 357
Insect/tubificid	F	+	L	BJ	358
Similarity and dissimilarity	M and F	++	S	EQ;BJ	359
MPN (coliforms, most probable number)	M and F	++	LS	EQ	360
MPN	F and F	++	LS	EQ	361

[a] + = Short; ++ = relatively short; +++ = intermediate; ++++ = relatively long; +++++ = long.
[b] L = Limited; LS = low significance; S = significant.
[c] EQ = Biological quantitative data for engineers; BJ = Qualitative and quantitative data for a biologist's judgment.
*Extended and modified from Davies.[144]

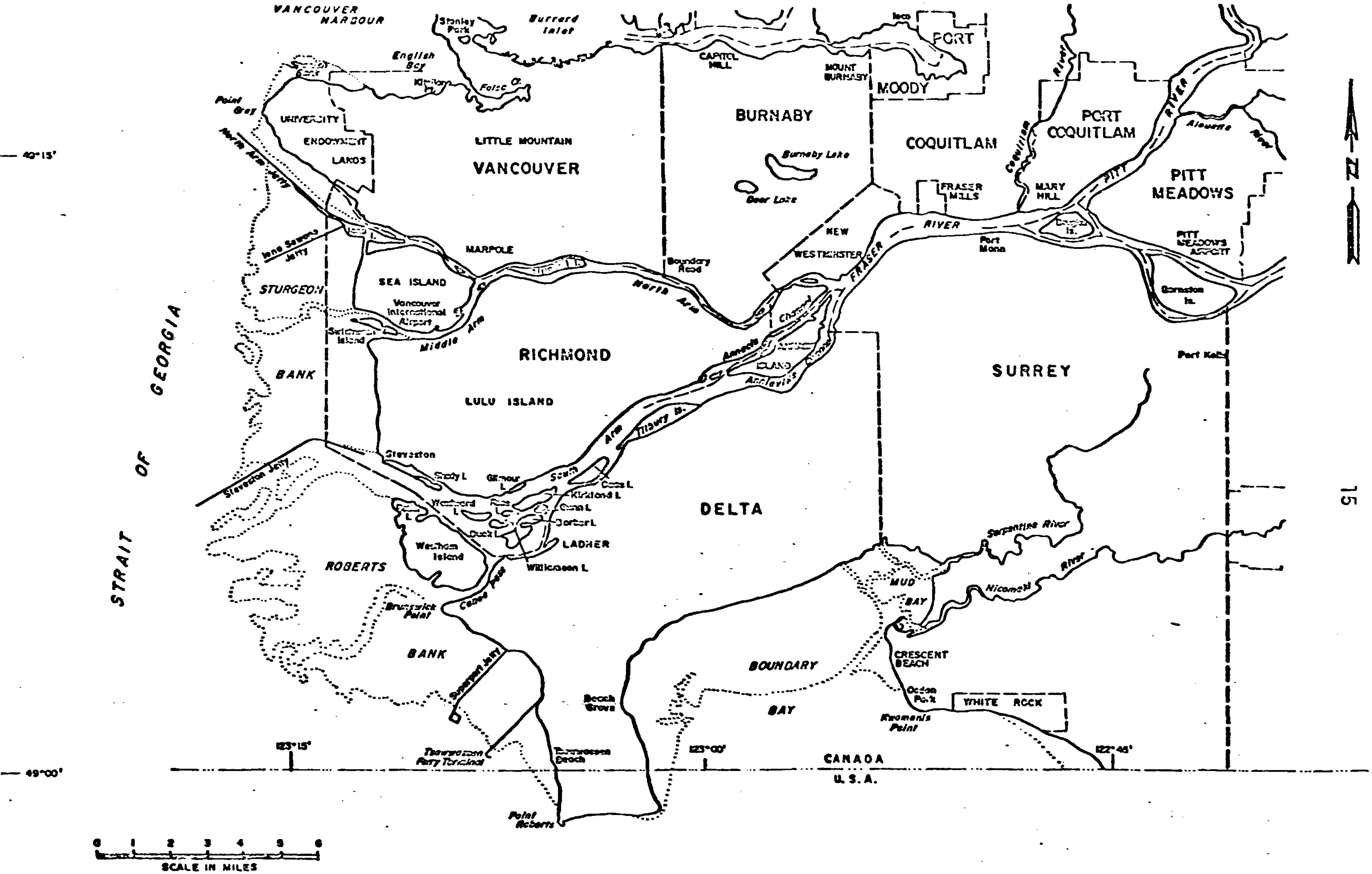


Figure 1

STUDY AREA
(AFTER FORWARD (1968)

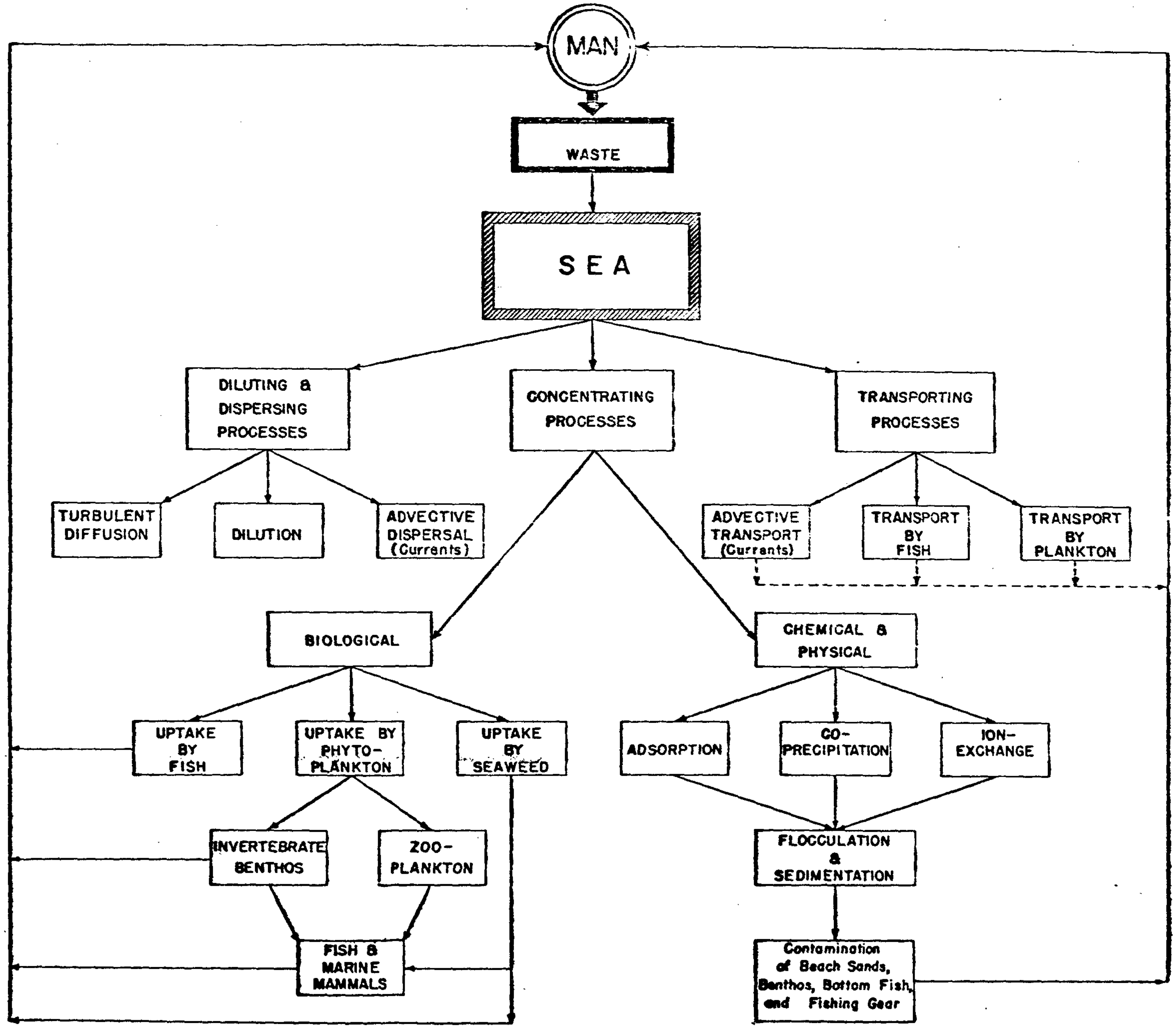


Fig. 2 - Marine processes acting on a pollutant

Fig. 3 - Biomass on Sturgeon Bank
(From Levings, 1975)

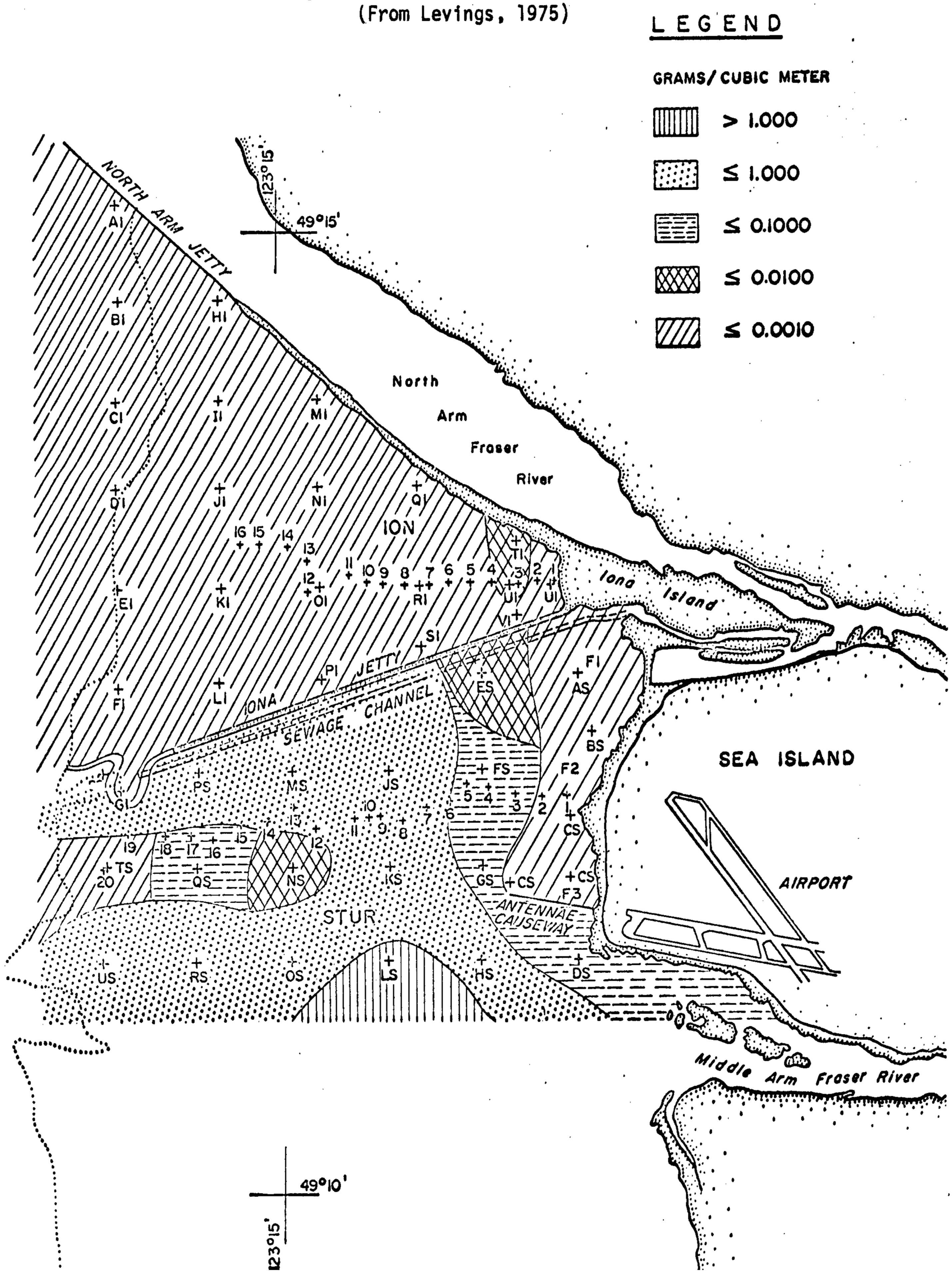
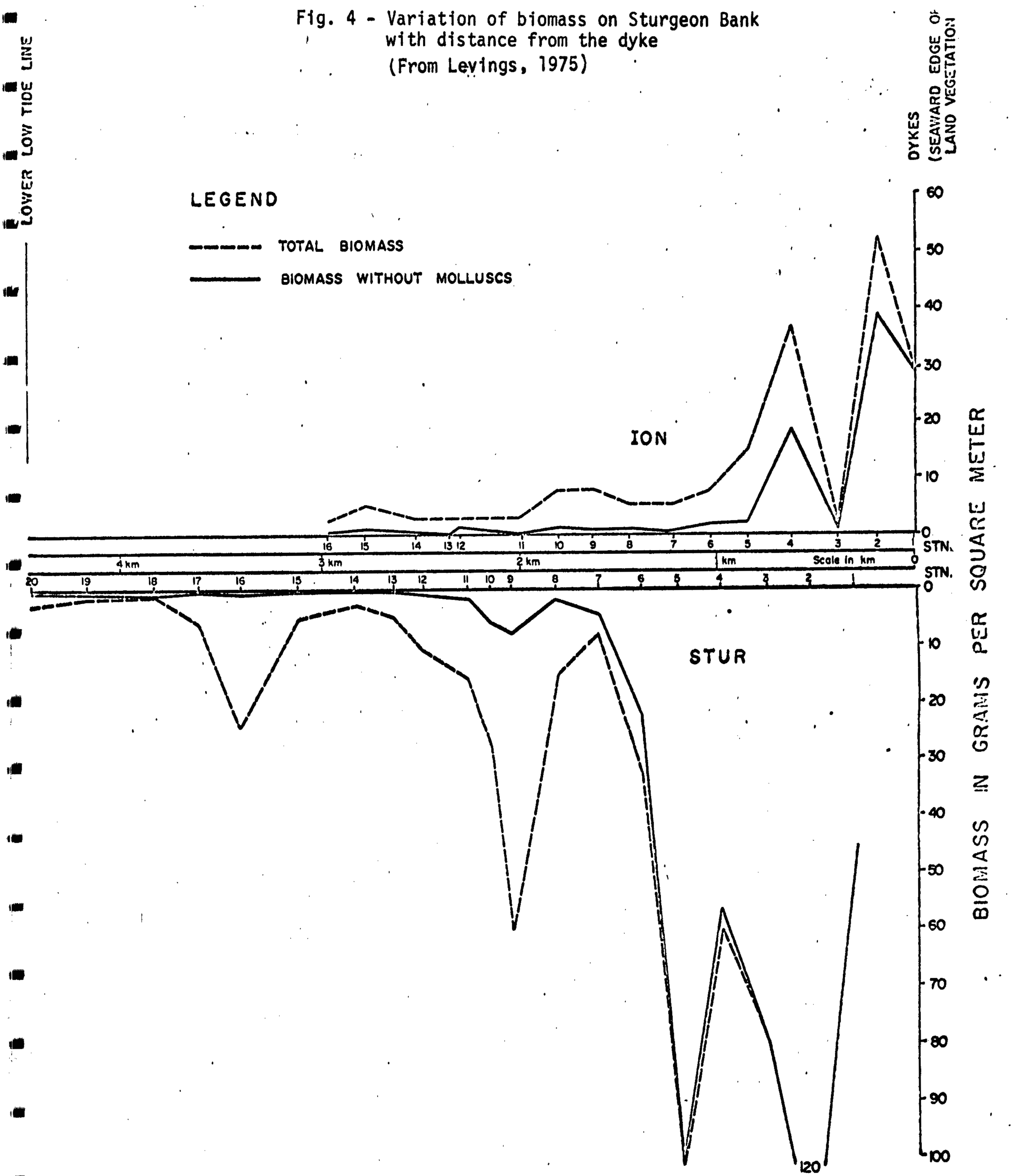


Fig. 4 - Variation of biomass on Sturgeon Bank with distance from the dyke (From Levings, 1975)



ENVIRONMENTAL STUDY OF THE KOOTENAY REGION

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presented at

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INTRODUCTION

The B.C. Water Resources Service has been conducting an environmental study of the Kootenays for over a year. We are now at about the half way mark and the first study reports are being published. I therefore welcome this chance to discuss the origins of the study, its purpose and its planning.

I will be presenting to you our study objectives, how the results will be used and the manner in which we have organized our reports.

The Water Resources Service administers the Water Act and the Pollution Control Act. Consequently the Service has, over the years, collected a large amount of water quality data, some aquatic biology data and, more recently, some air quality data. Other agencies within the Provincial and the Federal Governments have also been collecting similar information. Added to this list of data collectors are consulting firms, Universities and private industry. The data gathered are largely unpublished. They are stored in computer banks or the files of agencies and private companies. Some data have been used in reports and bulletins but these have usually had a limited circulation.

The monitoring programs used to collect this information have generally been conducted independently. Different agencies and industries have collected samples at different times and locations. The sampling of receiving water or ambient air has not always been related to the sampling of the effluent or stack emission. Added to this, the sampling techniques have differed widely as have the methods used to analyze the samples. Consequently this valuable data cannot always be rapidly interpreted to give an accurate picture of the current state of air, land and water.

The Water Resources Service has therefore initiated environmental assessment studies on a regional basis to overcome these difficulties. The Kootenay Region was chosen for our first study since it comprises major discharges to air and water which are causing some concern. There is a wide range of industrial activities, as well as agricultural and municipal type activities. Also further development is planned for the area.

PURPOSE OF THE STUDY AND GENERAL ORGANIZATION

The study objectives can be described as follows:

- To describe the state of air, land and water. This will include an analysis of the sources of contaminants and of their effects on the environment.
- To identify problem areas and to recommend corrective measures or further work required.
- To optimize existing monitoring programs. This will involve establishing the location and minimum number of routine monitoring stations. The monitoring frequency and the type of measurements required at these stations will also be established.

We hope that the study results will have a fairly wide application. One of our aims is to give interested members of the public an understanding of the sources of air and water pollution in the region. We also wish to give people a grasp of the effects of pollution on the environment and of the problems involved in measuring and evaluating these effects. By examining all past data available on the region we expect to provide an up-to-date historical summary of the information and of what it means. This shall eliminate the need for future workers to delve through raw data dispersed at various locations. We believe our analysis will be of use to government and industry in planning waste management programs to control pollution. The results will also help in the design of monitoring programs to assess the effects of specific discharges. Certain agencies will be able to use the results in planning future development. Such planning will also require information on land use, natural resources, wildlife, recreation, etc. which is available from other sources. Since our study deals with air and water quality it will only be a part of the jigsaw of facts needed to plan future developments.

The reports we are preparing are therefore intended to be used by a wide audience, varying from interested laymen to administrators, to specialists in government and industry. To write for such a varied group is a difficult task. One prerequisite for success is to make sure you have a complete understanding of the information available. To achieve this we have called upon various specialists in the Water Resources Service. We are using engineers with experience in chemical, civil, mechanical and agricultural engineering, biologists specializing in fisheries, benthic invertebrates, algae and plant life, and scientists in soils, meteorology and chemistry.

Our study area is the region of the east and west Kootenays as shown in Figure 1. It is a large region made up of three regional districts: Kootenay Boundary, Central Kootenay and East Kootenay. Time and resources are divided about equally between the air and water studies. Both studies are being undertaken in two phases: a Phase I which is an evaluation of all existing information; a Phase II in which data will be collected for approximately one and a half years to fill in the gaps revealed in Phase I.

DESCRIPTION OF WATER STUDY REGIONS

To carry out the water study we divided the Kootenay area into nine hydrographic or watershed areas, as shown in Figure 2. I shall briefly describe the nine regions.

Region 1 is the Flathead River Basin. It is drained by the Flathead River which runs into Montana, U.S.A. The region is relatively undisturbed and unpopulated but a large coal strip mine is under active consideration at Cabin Creek.

Region 2 is the Elk River Basin. The Elk River runs into the Kootenay River. There are three large scale active coal mining operations in the area and at least three more important coal mines are in the preliminary planning stage.

Region 3 is the Upper Kootenay River Basin which contains the upper reaches of the Kootenay River. The area is sparsely populated and contains no industrial centres.

Region 4 is the Lower Kootenay River Basin. The Kootenay River crosses the region, flows through Montana and Idaho and re-enters Canada, in Region 5. There is a pulp mill located on the Kootenay River at Skookumchuck. A large mining and fertilizer complex is located at Kimberley on the St. Mary River, a tributary of the Kootenay River. The Libby Dam is on the Kootenay River in Montana, 50 miles south of the border. The dam has created a reservoir, called Lake Koocanusa, which backs up 40 miles into Canada.

Region 5 is the Kootenay Lake Basin. The Kootenay River enters the lake just north of the International Border. The Duncan Lake feeds into the northern end of Kootenay Lake. The Kootenay River drains the lake via the West Arm and flows into the Columbia River. There are five dams on this section of the Kootenay River. There is a certain amount of agricultural activity in the region. Kootenay Lake can be influenced by discharges in Region 4 to the Kootenay River.

Region 6 is the Slocan River Basin. The Slocan River flows into the Kootenay River and thence into the Columbia River. There is no significant amount of industry in the Region.

Region 7 is the Upper Columbia River Basin which contains the upper reaches of the Columbia River. This river flows north, out of the study area and then south again into the Upper Arrow Lake in Region 8.

There is very little development in the Region. The feasibility of diverting part of the Kootenay River into the Columbia River at Canal Flats is being studied. The purpose of the diversion would be to increase the power output from hydroelectric dams on the Columbia River by raising the water level and increasing the amount of water available.

Region 8 is the Lower Columbia River Basin. The Columbia River flows south into Washington State via the Upper and Lower Arrow Lakes. The flow from the lakes is controlled by the Hugh Keenlyside Dam. There is a pulp mill located below the dam at Castlegar. The capacity of the mill may be doubled in the near future. A large lead-zinc smelter and fertilizer plant are located on the Columbia River at Trail.

Region 9 is the Kettle River Basin. It contains the Kettle River and the Granby River. The region is relatively undeveloped and most of the effluents are municipal type discharges.

DESCRIPTION OF AIR STUDY REGIONS

The air study is being carried out in three separate air regions as shown in Figure 3. We chose these regions because they contain all the major emissions in the Kootenays.

Region A is called the Elkford-Sparwood-Fernie area. The air emissions in this area are mostly from two coal mining operations and associated coal washing plants.

Region B is the Kimberley-Skookumchuck area. The major emissions originate from a pulp mill at Skookumchuck and a mining-fertilizer complex at Kimberley.

Region C is the Trail-Castlegar area. Here the major emissions are from a pulp mill at Castlegar and a smelter and fertilizer plant at Trail.

ORGANIZATION OF PHASE I

As mentioned previously, Phase I for the air and water studies is an evaluation of all existing information, usually up to about 1974. We will publish our findings in reports, one for each of the nine watersheds and one for each of the three air regions. We will attempt to make each Phase I report on each region complete by itself since we do not expect most readers will be interested in all regions. I would now like to describe the organization of the Phase I reports and our treatment of existing data.

There is a general chapter introducing and describing the Region. This chapter provides basic information on climate, geology, hydrology, water uses and land uses. Under land use extra information is presented on agriculture, forestry, mining, recreation and wildlife. Our intention in this chapter is to give a broad overview of the resources of the region and its state of development.

DESCRIPTION OF DISCHARGES

In the next chapter we study the operations which produce effluents and air emissions. Industrial plants are described using simplified process flow sheets whenever possible. Special emphasis is given to the source of effluents and air emissions and to the manner in which they are produced by the process. Treatment or abatement methods, whether in-plant or out-plant, are also described. Municipal type discharges and solid waste disposal sites are dealt with in a similar way. In the water study we also discuss the possible influence on water quality of agriculture, forestry, mining and dams. These influences are usually considered in the category of non point sources of water pollution.

Once we know how the discharges to air, land and water are produced we examine the quality of the discharges. This involves a study of available effluent analyses and stack gas monitoring data. These data are compared to the various guidelines, objectives or standards for the operation in question. Whenever possible we evaluate the efficiency of the treatment or abatement method being used, and, if there is enough information available, we suggest corrective measures as required. Generally the data on effluents and stack gas composition are few and additional monitoring is recommended. In the water study we also evaluate the impact of the effluent in the immediate dilution zone of the river or creek. We have found that monitoring of stack gas is still in the development stage to some extent. There is a lack of correctly located sampling ports in the stacks. Monitoring methods need to be standardized in order to produce reasonably precise data.

DESCRIPTION OF RECEIVING WATER QUALITY

Having analyzed the sources of discharges and the composition of the discharges, our next step is to examine their effect on the environment. In the water study report we devote one chapter to the evaluation of water quality data available for creeks, rivers and lakes. This includes physical data such as temperature, pH, conductivity, turbidity, colour, etc., and chemical data obtained as a result of a large number of tests on each sample. These include parameters such as alkalinity, total and dissolved metals, nutrients, phenols, tannin and lignin type compounds, fluoride, hardness, etc. In several regions these data add up to a large amount of information. For example in Region 2, the Elk River Basin, we have looked at over 10,000 values. Fortunately a large proportion of the data is stored in the Water Resources computer bank. We are thus able to obtain statistical summaries as well as graphical outputs which show the variation of each parameter with time at a particular monitoring site.

I would like to digress slightly here and comment on the presentation of water quality data. When we deal with a large amount of data we use two techniques. The first is to present the maximum, minimum and average values calculated over a period of one or more years. This is done for each parameter at each sample site. The second technique is to list the high and low values which are considered to be most representative by a visual scan of plotted data. These values do not indicate the maximum and minimum levels which were recorded but show the most common range that can be expected at a particular site. One advantage of this technique is that it is easy to obtain a range of values for high water flow and low water flow periods. This is important in some regions where the river flow is high from about May to August and relatively low during the rest of the year. Although visual scanning requires some judgement we feel it is justified in cases where we are interested in the order of magnitude of the result. One other point I would like to mention is that, in our Phase I study, we have not included a statistical analysis of data to demonstrate the accuracy or significance of the results. We don't believe this is a shortcoming at this stage since in our review of past data we are mostly interested in order of magnitude values. For example our concern is not whether the concentration of a parameter is say 1 or 2 mg/l but whether it is approximately 1 or 10 mg/l.

To evaluate water quality data we have often used drinking water standards for comparative purposes. Water at control sampling sites located upstream from all discharges or influences usually meets drinking water standards for most of the year. A comparison of the standards with water characteristics provides a quick check of the degree of water quality impairment, if any. This is especially true for toxic contaminants, although it is not necessarily true for certain heavy metals or for nutrients such as phosphorus. The phosphorus concentration in a lake may meet drinking water standards but could be high enough to cause eutrophication. Similarly, certain heavy metals and toxic elements could be present at a concentration which is safe to drink but which impairs aquatic life. For the latter cases we have developed some criteria for freshwater aquatic organisms. Data from the literature provide concentration ranges and conditions which show lethal toxicity or sublethal toxicity to particular fish and invertebrates. In this way we have another set of guidelines by which to judge possible degradation of water quality.

We also evaluate water quality by calculating loadings of certain contaminants to the receiving water. Loadings are usually expressed in say lb/day of the contaminant. With a knowledge of flow and contaminant concentration for both the effluent and the river, we can calculate loadings and have rough material balances. Since there is a significant degree of uncertainty associated with flow and concentration measurements these calculations are always approximate. Ideally the sum of the loadings in the discharges should equal the loading of material measured to be present in the river. If the difference between the discharge loadings and the river loading does not exceed 25 to 35% we assume all the material in the discharges is present in the water column. In practice the difference can be 50 to 100% or more. In these cases we consider that there has been either a loss or gain of material from the water column, depending upon the direction of the difference. A loss of material from the water column usually indicates precipitation of the material into the sediments. A gain can indicate leaching or re-suspension of existing sediment material back into the water column. In either case a knowledge of sediment composition in the river is needed in order to understand likely exchange mechanisms, or explain material balances which do not balance. Our assessment is usually followed by specific recommendations for monitoring during Phase II to fill gaps in our knowledge or confirm tentative conclusions.

ASSESSMENT OF AQUATIC BIOLOGY

I believe I have now described how, in the water study, we analyze the sources of discharges, the composition of discharges and their effect on water quality. Our final chapter in the report is an assessment of aquatic biology data. In this chapter we are looking directly at the effects of contaminants on organisms living in the rivers or lakes. The biological data include information on benthic invertebrates, which are usually insect larvae, periphyton, which is attached algae, and fish. Benthic invertebrates and, to a lesser extent, periphyton, can be used as indicator organisms. They are relatively sessile, meaning they do not move much, and are sensitive to changes in water and substrate quality. They are also a major part of fish diet. A fine balance exists among the individuals inhabiting a given area. Changes in water quality can result in the predominance of one or two species to the exclusion of others formerly present which creates an unstable situation; migratory fish may be disrupted and prey and predator may be limited to such an extent that all of the individuals may die. Thus a knowledge of indicator organisms is another tool in the detection of subtle changes in water quality and helps us predict future changes in the aquatic community. Invertebrates are collected in special samplers, preserved, identified and counted. Periphyton are collected on artificial substrates submerged in the water and the attached growth is preserved, identified and counted. Identification and counting of organisms requires a considerable degree of skill, and is also time consuming. Thus there are usually far less biological data available than there are water quality data. However, if the right number of measurements are made at the right time and in the right place, the data are invaluable in confirming what one suspects is happening from interpreting large amounts of water quality data and effluent data.

In rivers and creeks biological data are usually evaluated by listing types of species, number of species and biomass, or total weight of organisms present in a sample. The diversity of species decreases under polluting conditions. Certain species, usually known as pollution sensitive, may disappear completely. Others, known as pollution tolerant, may increase in numbers and become predominant. The biomass may increase or decrease as a result of pollution, depending upon the type of species present and the severity of the conditions. There is no commercial fishing in the Kootenay area and fisheries data are rather sparse. Some data are available in the form of creel censuses which give an angler catch effect expressed in fish/hour/angler. Fish tainting experiments have been carried out in which the flavour and odour of fish are tested by a panel. There have also been some *in situ* fish bioassay experiments in which the survival of fish kept in cages in the river is recorded. Such fisheries data are useful in confirming results of invertebrate and periphyton sampling.

DESCRIPTION OF AMBIENT AIR QUALITY

In the air study we describe sources of emissions and the characteristics of the emission, as we have already mentioned. We then examine the effect of the discharges on the environment by evaluating ambient air quality data. In the Kootenays the ambient air quality has been monitored using up to five parameters. These are: dustfall, total suspended particulates, soiling index, sulphation index and continuous sulphur dioxide measurement.

Dustfall consists of those particles in the air that settle out due to gravity. Dustfall usually occurs within 700 to 2000 meters of the emission source and is recorded in g/m^2/month or tons/square mile/month. It is measured by collection in a canister for a period of one month.

Total suspended particulate consists of those particles which do not settle out. It is measured in micrograms per cubic meter. The method used to measure total suspended particulate is the high volume sampler. The sampler draws air through a standard filter at a measured flow rate for twenty-four hours. The filter is replaced every six days. Soiling index is an arbitrary method of measuring suspended particulate. Air is drawn at a known flow rate through a filter tape for two hours. After the sample is taken the tape advances automatically for the next sample. The light transmittance through the tape is measured and the results expressed in terms of a coefficient of haze.

The sulphation index is an indirect method of measuring the sulphur dioxide concentration in the air. It involves the exposure of a petri dish, coated with lead peroxide, for 1 month. Lead sulphate is formed and results are reported in milligrams of sulphur trioxide per hundred square centimeters per day. Multiplication of the sulphation rate by 0.11 gives the approximate sulphur dioxide concentration in parts per million.

The sulphation plate gives only at best a monthly sulphur dioxide concentration. Instantaneous readings of concentration are given by continuous sulphur dioxide analyses which sample and measure the ambient air continuously. These instruments show the peak concentrations which may occur for a few minutes to up to several hours. The continuous graphical output is summarized in the form of hourly average concentrations.

The evaluation of existing air quality data has involved the analysis of large quantities of information. The data are usually plotted to show variation of measurement with time and the results are compared to the available standards. Dustfall standards exist for residential and industrial areas, although dustfall is usually considered to be more of a nuisance than a health hazard. Standards for suspended particulate are expressed as an annual geometric mean concentration or a 24 hour maximum concentration. For sulphur dioxide there are standards for the annual arithmetic mean concentration and the maximum concentration for 24 hours, three hours and one hour periods. Where possible we have used the limited meteorological data available to relate emissions sources with ambient air quality.

PHASE II PROGRAMS

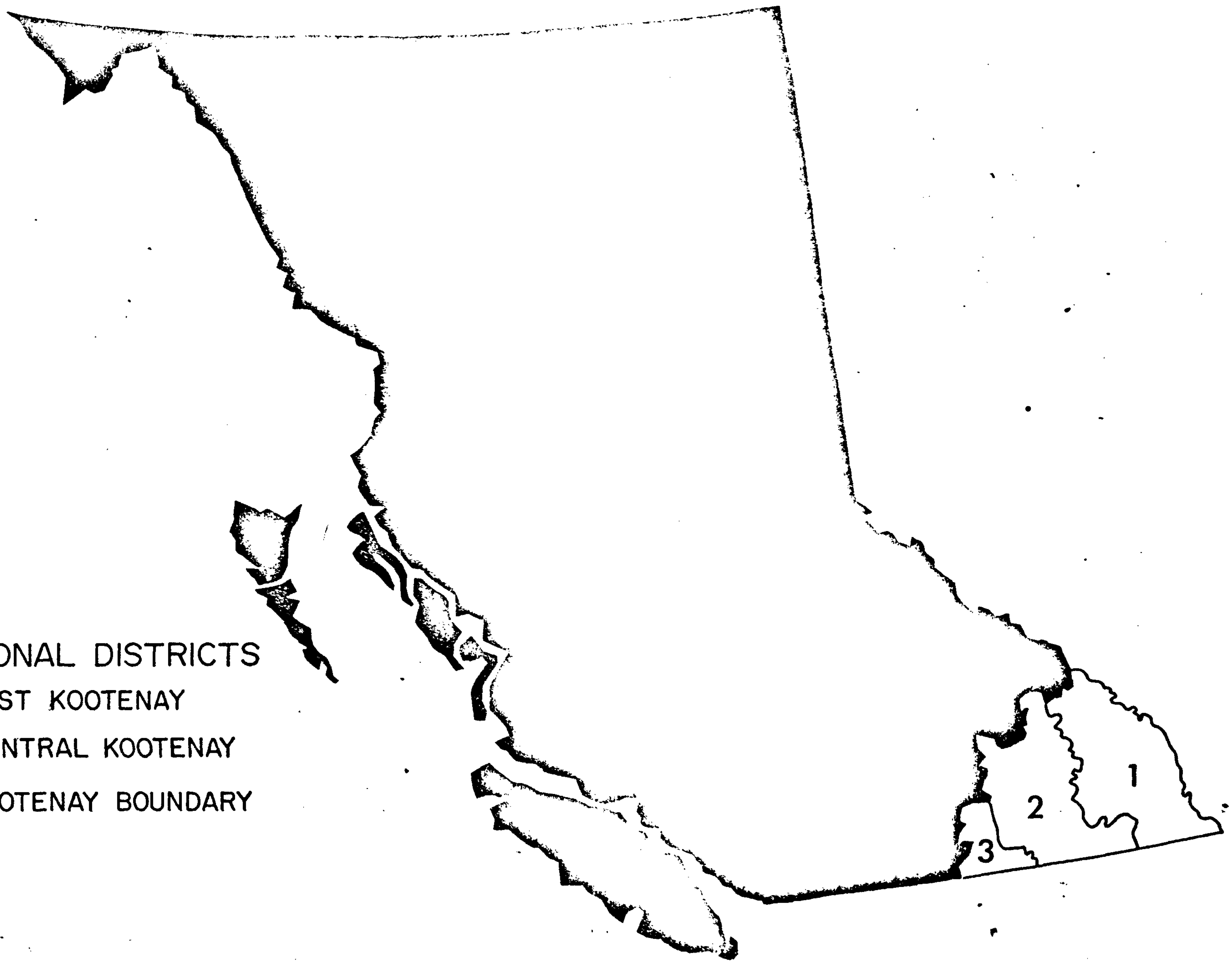
Our Phase I reports describing existing information up to approximately 1974 will be issued shortly. The Phase II sampling programs are now in progress. For the water study we are collecting and analyzing samples of effluent and receiving water at specific locations as well as sampling sediments and aquatic biology. The programs are under continual review and can be altered according to the results obtained, especially with regards to monitoring frequency and parameters measured. For the air study we have set up several air monitoring stations to obtain more complete information. In addition to dustfall cannisters, high volume samplers and sulphation plates we have installed several Philips continuous SO_2 analyzers. We have found that these instruments provide an accurate and reliable record of the SO_2 concentration in ambient air. Several air monitoring stations are equipped with meteorological instruments. These include anemometers which record wind speed and direction, hygrothermographs which record relative humidity and temperature, and rain gauges. We are measuring inversion layers at certain locations with the use of mini sondes. These are balloons containing a temperature measuring device. Their release enables measurement of wind speed and direction in the upper air and establishment of the temperature profile from ground level to up to approximately 2000 ft. Since the Kootenay region has a mountainous and varied topography accurate meteorological data are required to understand plume dispersion and predict ground level conditions.

We expect to begin reporting Phase II programs at the end of 1976. In addition to filling gaps in our knowledge the reports will recommend sites for future routine monitoring. We believe it is important that, in the future, the data collected from routine monitoring be reported and interpreted on a yearly basis. This will ensure that all the information collected is readily available for use by interested parties.

I would like to conclude by showing a few slides of the Phase II activities. The slides show the types of watersheds, creeks, rivers and effluents we have been sampling as well as equipment and installations for the air monitoring stations.

FIGURE [illegible]

KOOTENAY REGION IN RELATION TO BRITISH COLUMBIA



REGIONAL DISTRICTS

1. EAST KOOTENAY
2. CENTRAL KOOTENAY
3. KOOTENAY BOUNDARY

FIGURE 2
KOOTENAY REGION SHOWING WATERSHED AREAS

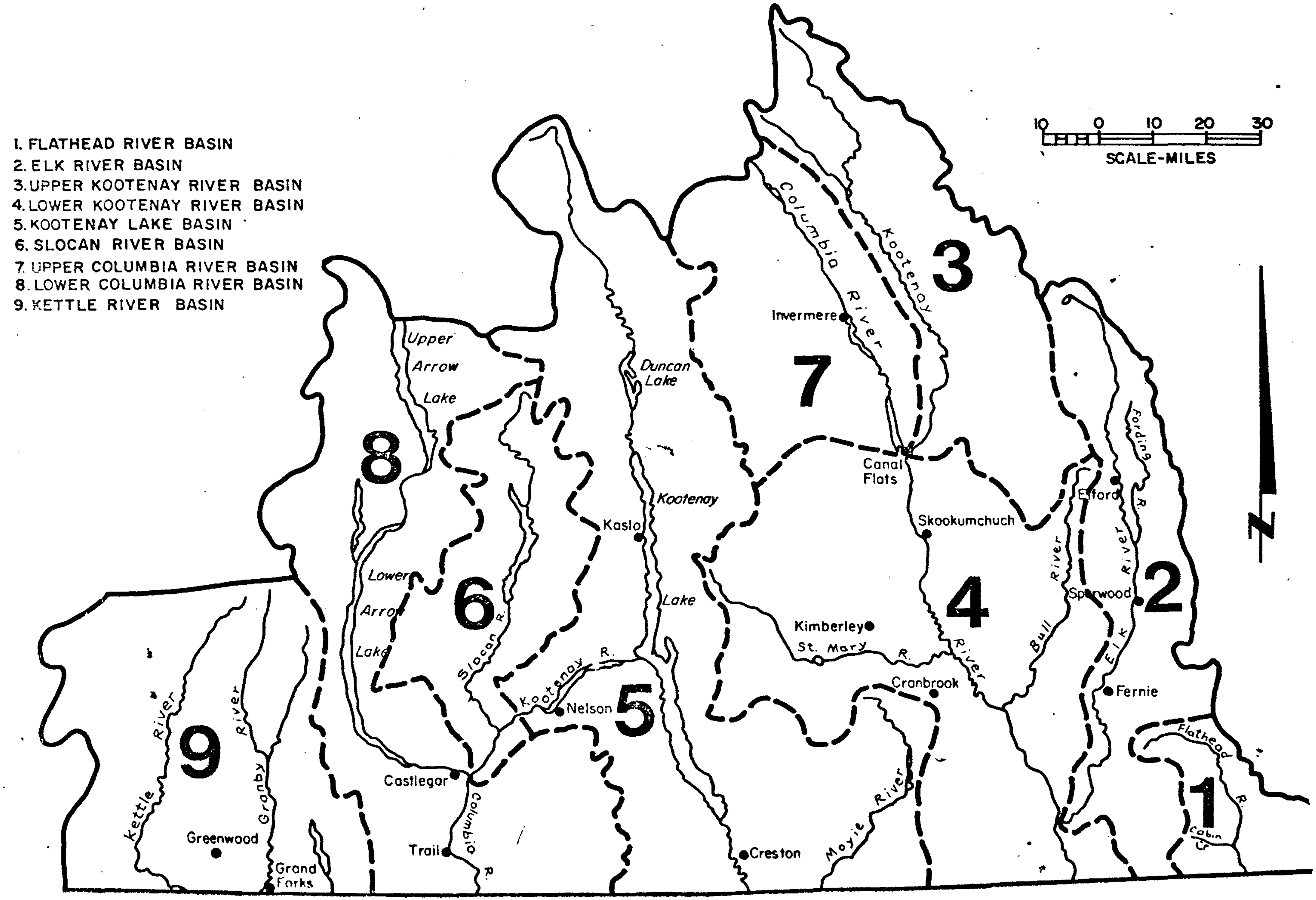
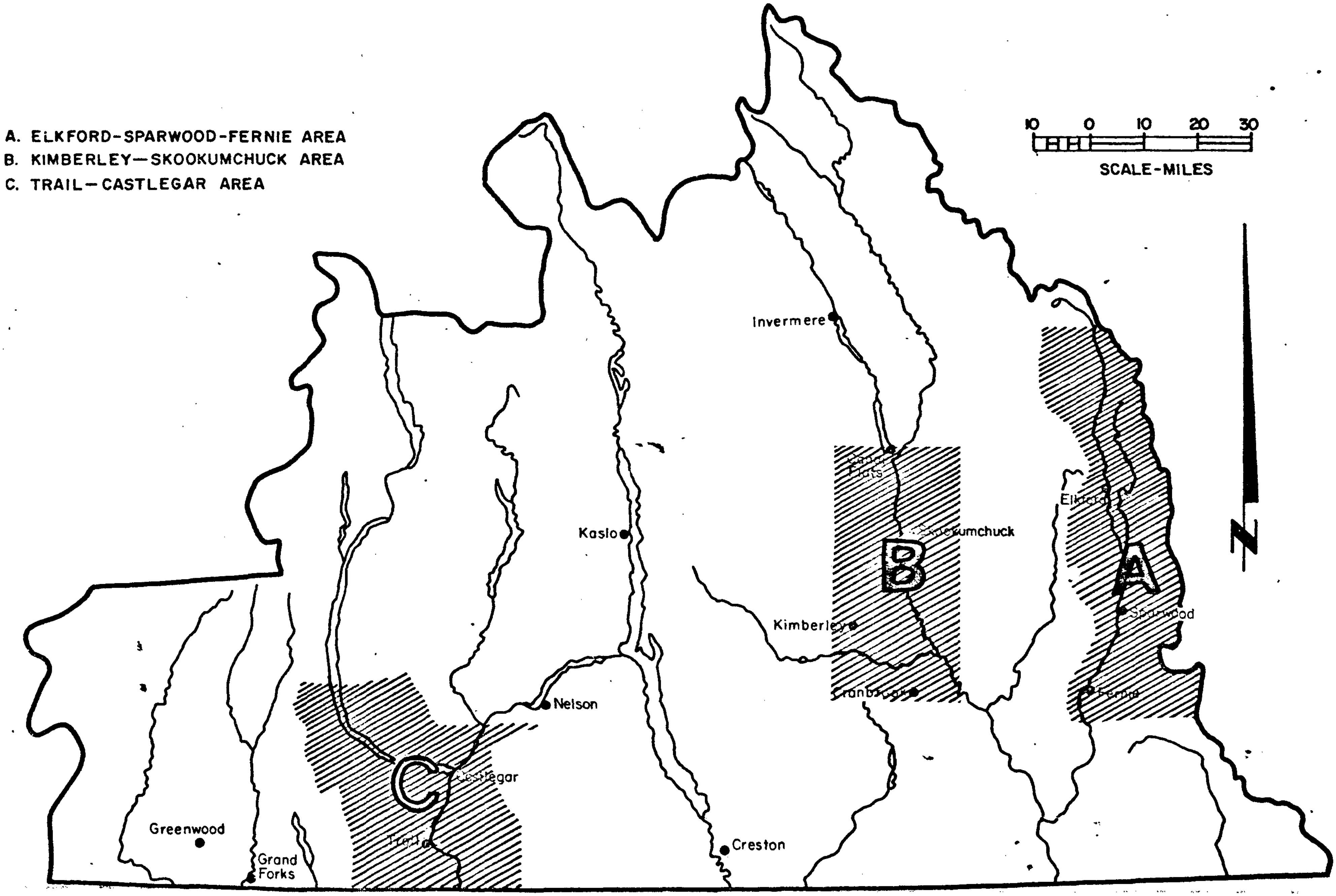


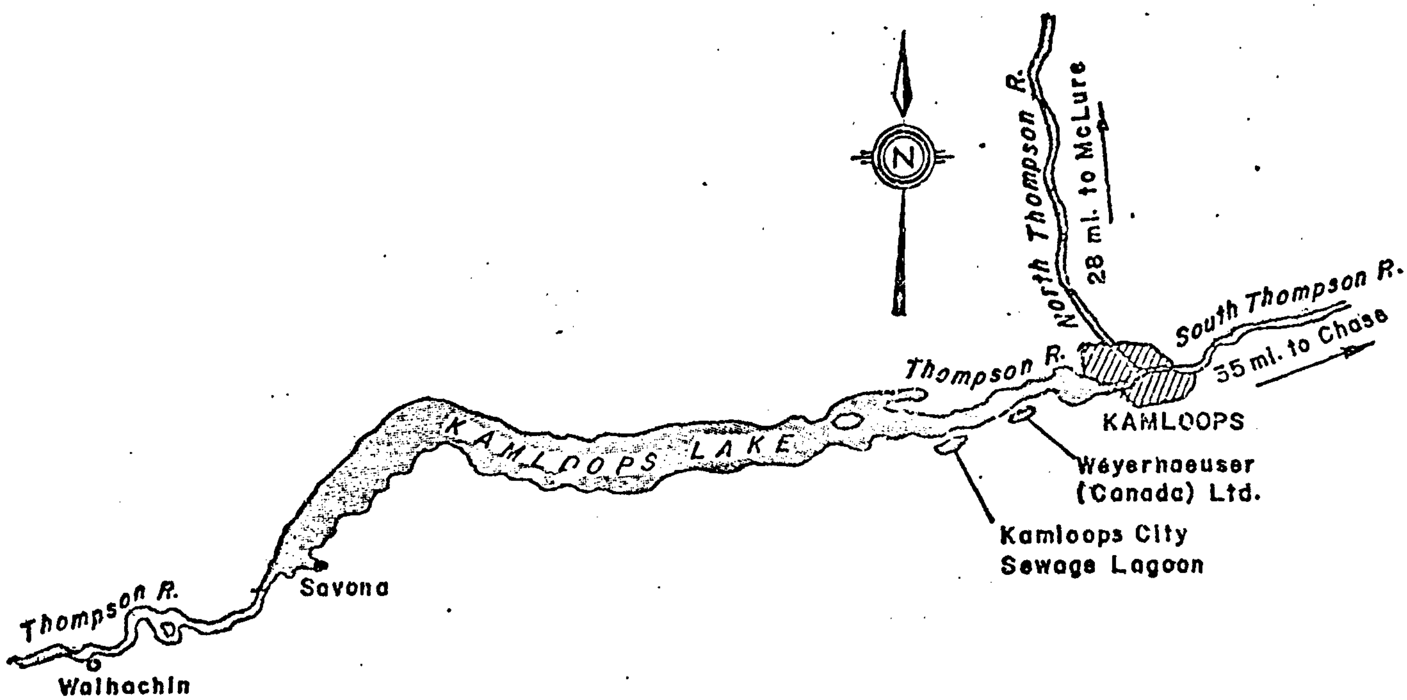
FIGURE 3

KOOTENAY REGION SHOWING AIRSHED AREAS



MONITORING FOR ENVIRONMENTAL PROTECTION

CHEMICAL, PHYSICAL AND BIOLOGICAL MONITORING FOR THE THOMPSON FIVER SYSTEM



Environmental Studies Division
Water Investigations Branch

Dr. J.W. Olan, P.Eng.

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1. INTRODUCTION

This study was initiated because people in the Kamloops area were concerned about their environment. When they noticed changes taking place in the Thompson River they quickly notified their governments of their concerns. They reported that the river water below Kamloops Lake had become dark brown in appearance and that frequent foam patches appeared on Kamloops Lake and in quiet eddies of the Thompson River. Many people also complained about a dark brown growth which covered the river bottom downstream of Kamloops Lake. This algal growth made the river bottom extremely slippery and this made fishing and other recreational activities difficult. There was also concern that this growth could reduce or destroy the fish in the Thompson River through reduction in egg survival and/or destruction of fish food organisms.

A further complaint was that the fish caught downstream of Kamloops Lake had objectionable flavour and odour. Many of the residents of the area were concerned about a decline in the tourist fishery and a resulting decline in revenue brought into the area.

In response to these observations and complaints, an immediate short-term study of the North and South Thompson Rivers, Kamloops Lake and the Thompson River was carried out in the spring of 1973. Data available from previous years and some data collected during the spring of 1973 were used in investigating the source of the increased colour, the foaming agents, the biological growth and the fish-tainting substances. The report, which was completed in May, 1973, presented the following conclusions:

1. The increased colour of the Thompson River was due to the effluent discharged by the Weyerhaeuser Canada Ltd. pulp mill. It was recommended that the Director of the Pollution Control Branch should give consideration to require colour reduction in the pulp mill effluent.

2. Tainted fish were found in the Thompson River, but those substances which caused the off-odour and off-flavour of the fish could not be identified.

3. The source of the foam on the Thompson River could not be identified.

4. The algal growth was tentatively explained by the nutrients in the water but the study could not identify the source of these nutrients.

5. It was recommended that a joint Federal-Provincial Task Force determine the source and effects of nutrients, foaming agents and fish tainting substances on the Thompson River system including Kamloops Lake.

In the fall of 1973, a Federal-Provincial Task Force was formed consisting of the following representatives:

British Columbia	Environment Canada
Dept. of Agriculture	Environmental Management Service
Dept. of Health	Environmental Protection Service
Fish and Wildlife Branch	Fisheries and Marine Service
Forestry Service	International Pacific Salmon Fisheries Commission
Pollution Control Branch	

2. DESCRIPTION OF THE STUDY

A data collection program was initiated in the fall of 1973 and continued until the spring of 1975. This talk describes this study and presents some of the data and conclusions from the various tasks.

The study was divided into two major portions. A major limnological study of Kamloops Lake involving physical, chemical and biological measurements of the lake water and the bottom sediment was carried out by Canada Centre for Inland Waters with some assistance from other agencies within Environment Canada. A technical report outlining their initial findings has been prepared and will be published. I shall not go into any detail on this study, but I shall use some of their findings later in my discussion of the river studies.

The river monitoring study was divided into two sections according to the type of information to be gathered. Chemical and physical monitoring were carried out by the B.C. Pollution Control Branch with some assistance from the Fish and Wildlife Branch, the Federal Fisheries and Marine Service and International Pacific Salmon Fisheries Commission.

Because of the number of agencies involved in the study it was essential that there be maximum co-ordination of effort. Initial meetings of the Task Force were concerned with defining the detailed terms of reference for the study so that there would be a clear understanding of the problems which were being investigated. Once the terms of reference and purpose of the study were clearly identified to all members of the Task Force, it was then necessary to define the exact study area to be investigated. Some initial data, available in a preliminary report, were very useful in restricting our study area somewhat. For the river study we selected sampling locations as far upstream as Albreda (100 miles north of

Kamloops) on the North Thompson River and as far upstream as Chase on the South Thompson River. A total of 12 sites were selected over the Thompson River system with the furthest site downstream just south of Ashcroft.

For every study, especially a complex environmental study, there is a large number of chemical, physical and biological tests that can be carried out. The different kinds of samples that can be obtained at each site are also numerous. Do we want surface water, horizontal composites, composites over a selected time period, sediment samples, filtered samples or what? We also have the problem of how often to take the sample or samples at each site. I shall discuss these problems one step at a time, the first step being to decide what are the important parameters to investigate. After this decision is made, it is usually easier to decide on the frequency of sampling because of the usual limitations of budget and/or manpower.

(a) Parameter selection.

For this study we identified specific problems which suggested some tests that should be carried out. The colour in the river and of various effluents can easily be determined by a colour test, but if we want to know what compounds are causing the colour, we are into a major research study. The problem of the foam is even more difficult since we do not have a foam test available to quantify the amount of foam. In order to investigate the cause of this problem we must look for indicator parameters. For example we can analyze for organic carbon if we suspect that the foaming agent is an organic compound. If we suspect a particular type of organic compound, routine tests are available for some types of compounds such as phenolics or resin acids, but unless we are lucky, we must resort to non-routine, research types of analyses. This type of testing is not usually carried out as part of environmental studies, but is left to those agencies with research capabilities. One example of this type of study is the identification of the compounds which are causing the tainting of fish in the Thompson River.

It has been evident to the residents along the Thompson River that there has been an increase in algal growth over the years. However over the short time period of this study it has been impossible to quantify the increase because of the large natural seasonal variation in the algal levels. It has also been difficult to determine any cause of the increase because of the complex interrelationships which exist in nature.

During the planning phase of this study, the task force members listed all aspects which might affect algal growth in the Lower Thompson River. The list included the major nutrients such as nitrogen, phosphorus, carbon, oxygen and silica and other parameters such as temperature, turbidity and pH. One example of a problem which arose in the study is typified by our phosphorus determinations. Our laboratory lists two routine tests, one is for determination of "total phosphorus" and another determines the concentration of dissolved orthophosphorus (or $(PO_4)^{\equiv}$). The "total phosphorus" test can be run on a filtered or unfiltered sample. Water samples can be filtered either in the field at the time of sample collection or later in the lab.

In order to interpret the results of the phosphorus analyses, we must have some idea what fraction of the total amount of phosphorus present in the water and in the suspended and precipitated sediment is available for biological uptake. We also must have some idea of the rate of uptake and of the possibility of recycling of phosphorus within the biological community. Evaluation of these considerations led us to choose two phosphorus tests for our study. The results of the "filtered total phosphorus" analysis were interpreted as the concentration of biologically available phosphorus present in the water. The "unfiltered total phosphorus" analysis gave us the total amount of dissolved and suspended phosphorus in the water column. The difference between these levels gave an indication of the suspended phosphorus which was not available for immediate biological uptake. (This suspended material was largely phosphate-containing mineral such as apatite).

The same complexities arose in choosing the test for nitrogen. In fact for nitrogen we ran three tests; nitrate-nitrogen, nitrite-nitrogen and kjeldahl-nitrogen.

Within our allotted budget and manpower limitations we then had to decide how often and how many samples to collect at each site. We estimated that analytical costs for each sample were going to be in the order of $100. It would take one man three days to collect a surface sample from the shoreline at each site.

We decided to collect surface grab samples at monthly intervals. The reason we felt justified in taking this approach to sampling is complex. The data we were seeking were order of magnitude approximations. In our judgement the variations in water quality across the river and at different depths were fairly minor because the Thompson River is a large, fairly well mixed river. The concentration differences we were trying to evaluate were those associated with large flow variations or seasonal variations. Single samples were estimated to give a 95% confidence interval of approximately

$\pm$20% for most tests;adequate for this study.

3. DISCUSSION OF THE RESULTS

I shall now discuss some of the data that was collected and the results obtained under the headings as discussed in the introduction, ie.,

(1) Algal growth or Eutrophication of the Thompson River

(2) Fish tainting

(3) Colour of the water in the Thompson River

(4) The fishery of the Thompson River

(5) Foam on the Thompson River

(1) Algal growth or eutrophication of the Thompson River.

Nuisance algal growths in natural waters are almost invariably associated with an excessive supply of the nutrients nitrogen and/or phorphorus. Our analyses of the receiving water at various locations and of the effluents discharged to the Thompson River gave us a good picture of the supply of these nutrients in the Thompson River. It was found that the natural level of biologically available nitrogen and phosphorus in the upper Thompson Rivers remained relatively constant throughout the year. We also discovered that a large nutrient supply to the Thompson River was discharged from two point sources, the City of Kamloops and Weyerhaeuser Canada Ltd. During freshet and during fairly high flows in the Thompson River, these nutrient discharges did not significantly increase the concentrations of nutrients in the Thompson River at the entrance to Kamloops Lake. However during the winter, when the flow of the Thompson River was very low (or less than 5,000 CFS) this influx of biologically available nitrogen and phosphorus caused significant increases in the concentrations of these elements in the Thompson River at this location. We have calculated that the major industrial and municipal discharges upstream of Kamloops Lake add approximately 3300 lbs. of nitrogen and 600 lbs. of phosphorus each day. These additions cause an increase in nitrogen concentration by as much as 100% (from 0.1 mg/1 to 0.2 mg/1) and an increase in dissolved phosphorus concentration by as much as 500% (from 0.003 mg/1 to 0.18 mg/1) at the entrance to Kamloops Lake.

In order to discuss the effect these levels of nutrients might have on Kamloops Lake and the Lower Thompson River, we must digress for a moment and look at the results of one other part of this study, i.e., Environment Canada's study of Kamloops Lake.

KAMLOOPS LAKE STUDY

The data collected on Kamloops Lake included temperature and turbidity profiles of the lake and sediment and water analyses. Preliminary conclusions from the lake study which bear directly on our understanding of the river data are:

(a) Kamloops Lake is characterized by extremely low biological production. This low productivity is not caused by low levels of nutrients but is primarily the result of summer light limitations caused by high natural turbidity.

(b) During the winter the inflow water tends to remain mainly in the surface waters of the lake because of the existing thermal structure. The outflowing water is thus very similar to that which entered the lake within the previous month.

(c) The uptake of nutrate by the phytoplankton in Kamloops Lake during late summer does not reduce the nitrate concentration in the outflowing epilimnion water (warmer upper layer) significantly below that of the inflowing water. Thus the lake is ineffective in immobilizing the nitrate during the summer months. During the low-flow period (January to April) the concentration of nitrate in the outflowing water increases. This increase is caused by internally generated nitrate being mixed throughout the water column at fall overturn. This additional nitrate is produced in the late summer from the sediments and by the conversion of non-nitrate nitrogen form to nitrate. We have calculated that elimination of nitrogen from all effluent sources would cause insignificant reductions in the nitrate concentration in the outflowing water.

(d) The studies revealed that phosphorus released from the city sewage lagoons and the pulp mill is biologically available in soluble or particulate form, however,it is not utilized or sedimented in the lake to any large extent. During the low flow period, the natural level of biologically available phosphorus entering Kamloops Lake is significantly increased by the effluent sources. During the winter low flow period, at least 40 to 90% of the available phosphorus in the outflowing water results from the pollution sources.

THE LOWER THOMPSON RIVER

With the above conclusions in mind, we can now examine the data collected on the nutrient concentrations of the inflow water to Kamloops Lake and make some conclusions on outflow concentrations and the effects of these concentrations on the biota of the river.

The nutrients in the effluent discharges to Thompson River are not seasonally dependent, but are discharged at a constant rate throughout the year. This means that during the low flow period, immediately prior to the spring freshet, Kamloops Lake receives higher concentrations of nutrients than at any other time of the year. At this time of the year this water tends to remain mainly in the surface layers of the lake because of the existing thermal structure and exits the lake in relatively high concentration. Thus an abundant supply of nutrients is present in late winter and early spring when light intensity and water transparency are high and the river level low and constant. In consequence, the annual peak in benthic algal biomass occurs at this time.

The public have reported that the algal biomass in the Lower Thompson River has increased significantly in recent years. There are no quantitative data available on the amount of biomass present in the river prior to 1972. However, we have made enquiries of long time residents of the area, who have fished or worked on the river and who are particularly knowledgeable of its conditions. There seems to be no doubt that the algal biomass has significantly increased since the 1960's, but we do not have any quantitative estimate of the amount of increase.

This study indicates that ample natural nitrate is present in the Thompson River downstream of Kamloops Lake and it is considered highly probable that this has also been the case in the past. An increase in the phosphorus loading to the river is thus the only factor that could have induced the reported recent increases in algal biomass.

(2) Fish tainting.

Starting in the late 1960's fishermen in the Kamloops area began complaining about the taste and smell of fish caught in the Thompson River downstream of Kamloops Lake. In three separate studies we have investigated these complaints using trained taste panels. In 1973, Rocky Mountain whitefish from the Thompson River downstream of Kamloops Lake were found to be significantly poorer in taste and odour than whitefish from the North and South Thompson Rivers.

In further experiments, rainbow trout were exposed to various concentrations (0.5, 2.0 and 5.0%) of pulp mill effluent in the laboratory. Odour and taste were progressively worse on exposure to increasing effluent concentrations and/or with increasing exposure times.

One additional experiment was conducted using rainbow trout placed in cages at various locations in the Thompson River and the North and South Thompson Rivers.

Fish maintained in Sushwap Lake water as control were rated consistently and significantly superior to trout from all experimental sites on both odour and taste. Fish from cages located immediately downstream of the pulp mill diffuser and ajacent to one of the city sewage lagoons were significantly poorer in odour and taste than fish from all other stations.

(3) Colour.

During the study period it was observed that a dark brown stain originated at the diffuser which discharged effluent from Weyerhaeuser Canada Ltd. During most of the year, when the flow of the Thompson River was less than 20,000 CFS, the discharge increased the water colour from background values of less than 6 units to more than 20 units downstream of the diffuser. Colour increases as great as 30 times background were noted at the entrance to Kamloops Lake during extremely low river flows. During the period of low flow in the winter this flow has a large effect on the colour of Kamloops Lake. The effect is accentuated by the fact that much of the highly coloured water tends to remain in the surface layers of the lake. Throughout the winter this coloured water exits the lake into the Lower Thompson River.

The Thompson River, downstream of Kamloops Lake, appears brown to black. This is a result of the discoloured water and also because the river bottom is covered with brown coloured algae. Green coloured algae are predominant in the North and South Thompson Rivers. This change in benthic algal colour accentuates the colour difference of the rivers upstream and downstream of the lake.

There are no accurate historical values for the colour of the water exiting Kamloops Lake. Therefore we cannot quantitatively evaluate any increase in colour over previous years. However, during prolonged pulp mill shut-down from early July to mid-October, 1975, there was a marked change in the appearance of the Lower Thompson River. Data were collected during this period and will be published in a report from the Pollution Control Branch.

(4) Fishery.

A decline of the sport fishery in the Lower Thompson River and of the associated tourist industry has been reported. Our data indicate a decline in angler use and in the total catch of steelhead over a ten year period. Observations by management and enforcement agencies indicate a parallel decline in the resident rainbow trout fishery downstream from Savona over a similar time period.

A reduction in the number of fish present in the river and a deterioration of the associated aesthetics of the river are probably the main reasons for this decline in the fishery. We have no data which indicates which of these factors was most important. However, it is evident from the letters received from the public that for many persons their enjoyment of the recreational aspects of water usage has decreased mainly because of the increase in colour and algae in the Thompson River.

High dissolved oxygen levels were found at all locations in the river system and in Kamloops Lake. An examination of pink salmon egg-to-fry survival in 1973-1974 indicated above average survival when compared to other natural spawning grounds in the Fraser River system. It is improbable that such survival has been reduced from previous years in this river.

(5) Foam.

During freshet in May or June there appears to be a natural high level of foam on the North Thompson River. During the low flow period in the winter of 1973-1973 a large amount of foam appeared on Kamloops Lake and the Lower Thompson River. The cause of this foam or the exact nature of the material producing the foam could not be determined. However, incidents of foam coincided with start-up problems of the expanded Weyerhaeuser pulp mill and foam can be caused by resin and fatty acids which are found in pulp mill effluent.

4. CONCLUSIONS

Based on these data, the Federal Provincial Task Force has reached the following conclusions:

(1) Discharge of phosphorus from Weyerhaeuser Canada Ltd. and the City of Kamloops should be reduced significantly. A treatment system should be adopted which will reduce phosphorus addition to the river as much as is technologically possible during most of the year. Phosphorus releases from settlements, feed-lots, etc., should also be minimized. Maximum allowable phosphorus releases throughout the year are provided in the Canada Centre for Inland Waters Technical Report.

(2) Colour in the Weyerhaeuser Canada Ltd. pulp mill effluent should be reduced to cause publically acceptable aesthetic improvement.

(3) Fish-tainting agents should be identified and removed from the major point source discharges (Weyerhaeuser Canada Ltd. and City of Kamloops) to the Thompson River system.

(4) The Thompson River system should be monitored chemically and biologically on a continuing basis. Monitoring programs should include requirements established by the Task Force in order to detect changes in water quality leading to shifts in species composition and biomass in algal and invertebrate populations. Monitoring results by permittees and regulatory agencies should be evaluated and reported by a federal-provincial committee after a five-year period.

(5) New developments that result in nutrient discharges into the Thompson River basin (e.g., industry, logging, feed-lots, urbanization) should be controlled to ensure that individual and cumulative effects of such discharges does not impair water quality in the system.

(6) A social, economic, and technical study should be initiated to determine the feasibility of elimination of discharges detrimental to the Thompson River system. This could include total recycle, land disposal, joint effluent treatment.

(7) The following research should be encouraged:

(i) A research program should be undertaken on the physiology and nutrient energetics of benthic algal communities typical to British Columbia rivers.
Because of insufficient knowledge in this area, accurate predictions of the changes in algal biomass to be expected in the Lower Thompson River as a result of phosphorus control are not possible. There is no interpretable record of the algal communities that existed prior to recently reported changes. Hence it is impossible to deduce objectively the condition of the Lower Thompson prior to recent reported degradation.

(ii) An investigation of the effluent of the Weyerhaeuser Canada mill should be undertaken to isolate and identify toxic substances which may adversely affect the biota of Kamloops Lake or the Lower Thompson River. Any such substances should subsequtntly be removed from the effluent.

(iii) The effect of altered algal and invertebrate community structures on the feeding ecology of salmonids should be investigated.

ENVIRONMENTAL MONITORING PROGRAM
AT ISLAND COPPER MINE, RUPERT INLET, B.C.

by

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Chief of Environmental Quality

Island Copper Mine

To be presented at the Symposium entitled "Monitoring for Environmental Protection". To be held at the University of British Columbia, Vancouver, B.C. on February 12, 13, 1976.

INTRODUCTION

Island Copper Mine is situated on the north shore of Rupert Inlet on the northern end of Vancouver Island and is the largest open-pit operation located in coastal British Columbia. The mineral reserves indicate approximately 280 million tons of recoverable ore grading 0.52% copper and 0.018% molybdenum. The concentrator has now the capability of processing 38,000 tons of ore per day, while the mine is able to dig and move approximately 160,000 tons of rock per day.

Island Copper Mine is similar in most respects to other new copper prophyry deposits, being a low grade high volume operation. However, one distinct difference exists and that is the method of tailings disposal.

Island Copper employs a submarine tailings disposal system. This system was selected as the most feasible alternative after considering the environmental implications of terrestial disposal versus submarine disposal for this area.

Some of the more important factors that were considered in making the decision concerning the method of tailing disposal were:

(1.) High annual rainfall exceeding 80 inches

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(2.) Precipitation exceeding evaporation, thus an unbalanced water system

(3.) Potential leaching problems

(4.) Earthquake potential

These points were discussed with various provincial and federal agencies and additionally, a public inquiry was called by the provincial government in 1970 at which time various dissenting environmental groups were able to express their views on the proposed submarine tailings system. In view of the magnitude of the development it was obvious some environmental impact would result, namely it would affect deep bottom living organisms.

This impact was acceptable in the eyes of the technical decision makers. The concerns of various environmental groups were in part accommodated by the stringent terms of the pollution control permit which was granted in February 1971.

The permit allowed the discharge of Island Copper tailings into Rupert Inlet at a depth of 150 feet through a submerged outfall system. In order to prevent the possibility of temperature inversion off the discharge point, the slurry was to be pre-mixed with cold dense seawater.

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Stringent controls on the allowable amounts of dissolved constituents both organic and inorganic were stipulated.

The permit, in addition to identifying the physical and chemical limitations of the effluent also directed Island Copper to retain an independent agency to monitor the possible impact of tailings on the receiving environment. The independent agency selected, consisted of an inter-disciplinary group of professors from the University of British Columbia and the University of Victoria representing speciality fields of engineering and marine sciences. The initial objective of this inter-disciplinary group was to assist in the design and implementation of a comprehensive program to establish environmental conditions prior to the discharge of mill tailings into Rupert Inlet.

The second objective of the inter-disciplinary group was to assist in the design of a long term monitoring program to detect and report significant changes to the physical, chemical and biological environment of the receiving system. In order to achieve these objectives the independent group assisted Island Copper in setting up an internal environmental department. This department now consists of eight experienced chemists, biologists and engineers who collect, analyze, compile and report pertinent data under the guidance of the independent agency.

cont'd......

This afternoon I will present the environmental monitoring program implemented by the Island Copper Environmental Department. The sequence of events starts with the tailings discharge system, followed by effluent monitoring and continues through to the receiving environment. In the time allotted I will attempt to cover most programs carried out at Island Copper.

TAILINGS DISPOSAL SYSTEM

The tailings coming from the concentrator are directed to two 375 foot diameter thickeners. At this point the tailings are coagulated with lime and further flocculated with synthetic polyacrylamide flocculent. The thickeners serve two purposes; one as a retention pond to flocculate and thicken the slurry and second, as a water reclamation system. The thickened tailings slurry is gravity fed through a pipeline to the outfall. At the outfall the tailings are diluted with seawater to prevent temperature density inversion at the discharge point. The seawater dilution is a unique, simple hydraulic head differial system. The slurry being denser creates a differial head between the outfall mix tank and the seawater riser pipe outside the tank. The amount of seawater used for dilution is regulated by a one way gate valve.

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The two outfall systems illustrated in the slide have now handled some 42 million tons of tailing.

TAILINGS CHARACTERISTICS

In order to comprehend the possible impact of mill tailings upon the marine environment it is imperative to understand the physical and chemical properties of both the liquid and solid fractions. In this regard, a number of research studies have been completed by the Department of Mineral Engineering at the University of British Columbia. Some of these studies have been reported in a presentation by Evans and Poling (1975).

Let us now look at some of the characteristics of the physical and chemical properties of the solid and liquid portion of the tailings.

cont'd.......

SOLID FRACTION:

Physical characteristics: in order to free the economic mineral 65% - 70% of the ore is ground to -200 mesh (-74 micron).

A typical size distribution of the tailing is shown graphically by Figure 1.

Figure 1

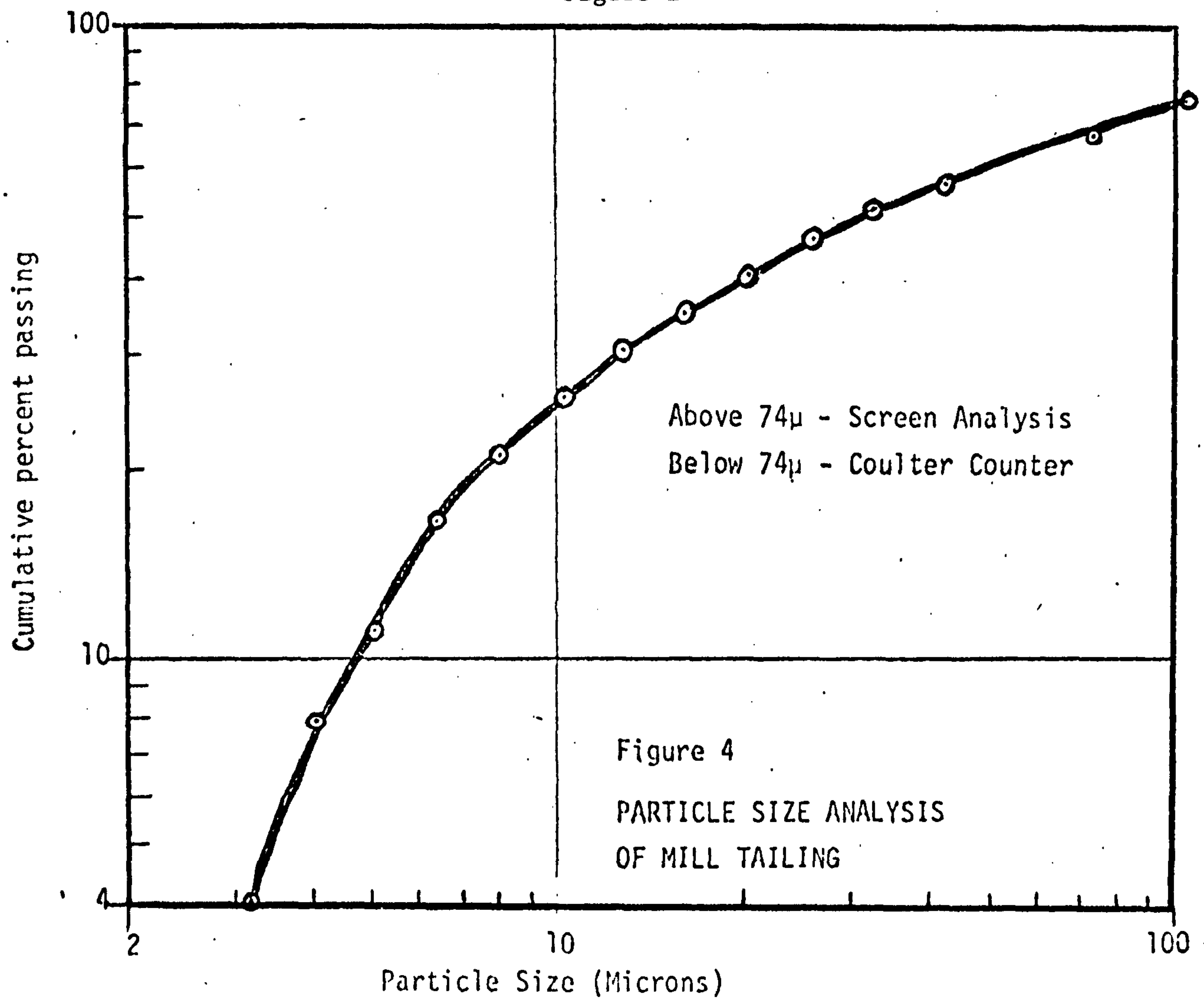

Figure 4

PARTICLE SIZE ANALYSIS OF MILL TAILING

cont'd.......

Chemical characteristics: the solid fraction of the tailings is composed principally of quartz and silicate mineralization - (+90%), with minor amounts of calcite, magnetite and sulphide minerals. Table 1 represents typical chemical and minerological composition of tailings solids.

TABLE I

TYPICAL CHEMICAL AND MINERALOGICAL COMPOSITION OF TAILING SOLIDS IN RUPERT INLET

Element or Oxide	Tailings Solid %	Mineral Species	% Mineral Content in Tailings Solid
SiO_2	62	Quartz	50 - 70
Al_7O_3	14	Feldspars	2 - 20
Ca, K, Na & Mg Oxides	10	Biotite and Chlorite	5 - 10
Fe Oxides	8	Magnetite	2 - 4
Fe Sulfide	2.5	Pyrite	2 - 4
Co_2	2	Calcite	2.5
Total of Above	98.5	-	-
	PPM		
Cu	700	Chalcopyrite	0.2
Mn	650	Mn Oxides	
Cr	140	In Silicates	
Zn	80	Sphalerite	0.02
Mo	40	Molybdenite	0.01
Co	20	In Silicates	
Ni	20	In Silicates	
Pb	20	Galena	0.002
As	5	Arsenopyrite	
Cd	3		
Hg	0.03	Cinnabar	

Liquid fraction of the tailings:

The liquid fraction of the tailings is that portion of the slurry which is less than 0.45 micron and is referred to as dissolved. Physically the liquid has a specific conductance of approximately 400 microhms/cm^2 which is indicative of a relatively low ionic solution. In terms of specific chemical parameters, the liquid is composed of dissolved inorganics and minimal amounts of residual organic chemicals used in the mineral process. For example, the dissolved copper has averaged approximately 0.010 mg/l (ppm) in the last four years of operation. Residual organic levels have been below the limit of detection. There is no significant biological oxygen demand (BOD) in the slurry.

EFFLUENT MONITORING

In order to comply with the Pollution Control Board permit the effluent volume, pH and per cent solids are monitored continuously. In addition, the effluent is sampled three times a day to produce a daily composite sample which in turn produces a weekly composite which is analyzed for the following parameters; dissolved copper, molybdenum, cadmium, chromium, cobalt, iron, lead, manganese, nickel, arsenic, mercury and cyanide.

cont'd.......

The following table II shows the comparison of mill effluent data for a typical month; September 1975 with Pollution Control Board A level objectives.

TABLE II

DISSOLVED HEAVY METAL CONCENTRATIONS

Unit ug/l (p.p.b.)

Element	Mill Effluent (before sea water mix) September, 1975	PCB "A" Level Objectives
As	29	50
Cd	<0.5	5
Co	<0.5	100
Cr	1.0	50
Cu	8.9	50
Fe	29	300
Mn	1.2	50
Mo	190	500
Ni	4.4	300
Pb	3.1	50
Zn	4.0	500
Solid Hg	30.0	1
Dissolved Hg	0.06	
CN	25	100
pH	10.2	6.5 - 8.5

It can be noted that all A level objectives are met except for mercury and pH. In regards to the total acid extractable mercury, the A level objectives for the industry are extremely low when compared to the background levels of mercury occurring in the host rock and natural seafloor sediments of Rupert Inlet.

Jonasson and Boyle (1971) report on the mercury content of igneous rock in parts per billion. They show that intermediate type and acid igneous rock have a mean mercury content of 38-66 parts per billion. This illustrates that a one part per billion objective is unrealistic for analysis of the combined solids and liquid fractions of the tailings. The total extractable mercury of the liquid fraction of the tailings meets A level objectives (averaged to date 0.10 parts per billion).

In regards to pH, the final discharge meets the A level objectives.

The potential biological toxicity of the tailing is a matter of serious environmental concern. Thus, samples of the effluent are collected bi-weekly and submitted to B. C. Research for the 96 hour (T.L.M.) bio-assay test. This test consists of introducing seawater acclimatized coho fry into a 1:1 seawater-tailings mixture.

cont'd.......

The tests to date indicate 100% survival of the fish for 98% of the samples submitted.

The foregoing has been a brief summary of the physical and chemical properties of the tailing to the point of discharge. I will now illustrate the Island Copper marine monitoring program, and present some of results obtained during the past six years.

MARINE MONITORING PROGRAM

Any marine monitoring program must have the scope to encompass natural long term changes in the environment as well as the man induced impacts. Thus, in addition to the effluent program we also have an on-going fresh water program, a meteorological program and of course the primary marine program. The fresh water program and the meteorological program provide data on environmental changes, unrelated to the mining activity.

The extent of the Island Copper environmental monitoring program can be gauged by inspecting table III.

TABLE III

OUTLINE OF ENVIRONMENTAL CONTROL MONITORING PROGRAM

MARINE PROGRAM — 1976

PHYSICAL

Bottom Sediment Distribution	Description	Frequency	Objective
Bottom coring	Cores at 24 stations - log and measure tailings thickness on bottom	Quarterly	Visually determine tailings distribution less than 2 feet in thickness
Bottom Grab Sampling	Sediment sample for heavy-metal analysis	Annually	Chemically delineate the spread of tailings
Seismic Survey	Bottom profile and sediment distribution	Annually	Record Tailings greater than 2 feet in thickness
Suspended Sediment Distribution			
Discrete water Samplings	Water samples collected in profile at 7 stations for turbidity measurements	Monthly	Delineate suspended sediment distribution
Discrete water Samplings	Water samples collected at 7 stations for suspended sediment analysis	Quarterly	Quantify suspended sediment load
Transmissometer Survey	Continuous in situ profiling of water column	Bi-weekly in Rupert Inlet	Delineate turbidity
		Annually throughout system	Clouds in Water Column
Fixed Suspended Sampler Survey	At 4 stations and two depths (30' & 60') sedimentation is monitored	Quarterly	To identify & quantify sedimentation at 30' and 60' (feet).

CHEMICAL			
Chemical Water Analysis	**Description**	**Frequency**	**Objective**
Discrete Water Sample	At 7 stations profile temperature, salinity and turbidity. Color and surface transparency are also measured.	Monthly	Record water-column physical properties.
Discrete Water Sample	At 7 stations profile dissolved oxygen, pH, alkalinity, salinity, spent sulphite, cyanide dissolved and particulate Cu, Mo, Fe, Mn, Ni, Pb, Zn, Cr, Co, Cd and total As, Hg.	Quarterly	Record water-column chemical properties.
BIOLOGICAL (PLANTS)			
Primary Production Study			
Euphotic Depth Survey	Measure amount of light attenuation & scatter at depth	Monthly	Record depth of photozone in the water-column
Discrete Water Sample for Nutrients	Collect water samples at 6 stations for nutrients	Monthly	Record nutrient levels in water-column.
$Carbon^{14}$	At 6 stations monitor the assimilation rate of primary producers	Monthly	Record assimilation rate of primar[y] producers
Chlorophyll "a"	At 7 stations collect sample chlorophyll "a" standing crop	Monthly	Record standing crop of primary producers in water-column
Macrophyte Study	At three sites detailed samples of flora & fauna	Annually	Monitor plant communities at depth
Intertidal Plate Study	At 16 sites artificial samples are set for continuous monitoring	Monthly	Monitor settling organisms and flo[ra] in intertidal zone.

cont'd........

Metal Analysis of Fixed Algae Study	Description	Frequency	Objective
	At 16 sites *Fucus* is collected and retained for metal analysis (Cu, Mo, Cd, Pb, Zn, As, Hg)	Quarterly	Monitor metal concentration in primary producer.
BIOLOGICAL (ANIMALS)			
Zooplankton	At 4 sites collect zooplankton for density, diversity and metal analysis	Quarterly	Monitor population changes and metal concentration
Benthic Organisms	Benthic organisms collected at 24 stations - sort to polychaetes, mollusc and other aboard ship for live counts and biomass.	Quarterly	Monitor benthic population and diversity
	At four stations collect benthis samples for species-diversity study.	Quarterly	Monitor benthic population and diversity
	At each of 24 stations collect 3 samples for detailed identification	Annually	Monitor in detail, change in benthic communities.
Crabs	At 6 stations collect crab samples to determine body condition and metal concentration.	Quarterly	Monitor crab population and metal content
Shrimps and Prawns	At 3 locations collect shrimps and prawns for metal concentration	Annually	Monitor metal content
Intertidal-invertebrates			
Clams	Collect clams at 9 sites , Identify, weight, measure and analyze for metals	Quarterly	Monitor body condition and metal content.
Mussels	Collect blue mussels at 3 sites. Measure weight, and analyze for metals	Quarterly	Monitor body condition and metal content.

cont'd.........

FISH

	Description	Frequency	Objective
Intertidal Fish	At 7 intertidal sites sculpins are collected by beach seining. Identify, weight, measure, and analyze for metals	Semi-Annually	Monitor metal content
Bottom Fish	Longlines set at 4 stations to collect bottom fish. Identify, weight, measure, sex, and analyze for metals	Semi-Annually	Estimate population and monitor metal content
	At 6 sites jigging is done to collect reef dwelling and bottom species. Identify, weight, measure, sex and analyze for metals.	Semi-Annually	Monitor metal content
Pelagic Fish	At five sites gill nets are set to collect pelegic species. Identify, weight, measure, sex, and analyze for metals.	Semi-Annually	Monitor metal content

cont'd ....

This essentially summarizes the scope of the program as it stands today.

At this point it would be appropriate to introduce our vessel, the Mac I, a specially designed twenty-six foot environmental sampling craft. It has been outfitted with standard oceanographic equipment, including depth sounder, winches, and conventional fishing gear. The navigation equipment includes sextants, radar and a precision range finder to assure accurate station positioning.

To get into the discussion of the environmental program, I will commence with the methods and procedures utilized to determine the distribution and dispersal of mill tailings in both the seafloor and in the water column.

Bottom Sediments

There are three principal systems employed to determine the distribution of solid tailings;

1. Sediment coring
2. Chemical analysis of surface sediment samples
3. Continuous Seismic Profiling

cont'd ....

A phleger corer equipment with 60 cm x 3 cm clear plastic liner is used on a quarterly basis at 24 stations to delineate the extent of tailings within the monitored area. The tailings can be visually identified from natural sediment on the basis of both texture and color. When the cores are extruded and split, they illustrate both mine tailings and natural sediment.

In the fringe area where visual identification is difficult, the second method (chemical analysis of sediment) is employed. At twenty-four stations, on an annual basis, surfacial sediment samples are obtained with a Ponar sediment sample . In order to obtain a standard sample, the top 1 cm layer of sediment is retreived. These sediments are put through the regular geo-chemical sample preparation and are analyzed for twelve elements by atomic absorption. In addition, spectrographic analyses have been conducted. This method is highly sensitive in detecting trace amounts of tailings not visible to the human eye.

In areas of heavy deposition (greater than 60 cm), the third method and probably the most sophisticated is employed. This method is continuous seismic profiling. This system is capable of distinguishing mill tailings, recent sediments, ice age strata and bedrock.

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As in previous studies, this system was used to investigate the pre-mine history of natural sedimentation in the Rupert-Holberg area. Subsequently the seismic surveys have been conducted throughout the area on an annual basis. The continuous seismic profiling technique is nothing more than precision echo sounding. A relatively long frequency sound source is mechanically or electrically generated in the water. The signal travels through the water and part of it is reflected from the seafloor while the remainder penetrates into the seafloor and is reflected from different velocity interfacing

These reflected signals are picked up by the hydrophones and are recorded aboard ship.

The resulting record shows the sea surface, the depth of water and the configuration of the sediment and bedrock. Notice in the example the small area of mill tailings on the bottom of Rupert Inlet outlined in orange.

I believe it would now be appropriate to examine what Rupert Inlet looked like prior to deposition of mine tailings.

This is the bathymetry of Rupert Inlet prior to mine production. You will note it is a deep trough, sloping southwestward to a depth of 580 feet. In addition, note it is rather asymetric with the deeper portion of the inlet present on the south shore.

cont'd ....

Now look at the distribution of sediment prior to the introduction of mill tailings. The map illustrates the location of three 1971 seismic profiles. This seismic profile is an axial line at the head of Rupert showing the relatively flat bottom prior to the introduction of mill tailings. The next profile extending across Rupert Inlet from Narrow Island to the south shore shows how recent sediments are asymetrically distributed and banked up against the north wall. Clearly then we are dealing with a sedimentation process which is either not in equilibrium or else is reflecting the northerly natural sediment sources in Rupert Inlet.

Further down stream, next to Hankin Point, a continuous seismic profile shows a more typical U shape cross section. Note the presence of stratified sediment at the water-sediment interface which reaches an appreciable thickness. It exists on both the north and south walls.

The next figure is an isopak map showing the thickness of tailings deposited on the seafloor after approximately one year of mill production and the location of two 1972 seismic profiles. We see the development of a bi-convex tailings pile on the north side of the inlet which extends down slope perpendicular to the inlet axis.

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More detail of this particular deposit is illustrated on the next continuous seismic profile which extends from the outfall to the south shore. The tailings, shown in orange, are concentrated on the north side of Rupert Inlet but part of the mass has slid down slope. Note, no tailings are present on the south wall.

The next slide of the 1972 data shows a thin layer of tailings which has moved down inlet. However, at this particular time, the principle influence of dumping resulted in down slope, cross inlet movement of material whith limited down inlet transport taking place.

The next figure is an isopak map showing the thickness of tailings which have been deposited after two years of operation and the location of three seismic profiles. The tailing have now reached a maximum thickness of 44 feet immediately adjacent to the outfall.

Looking at a 1973 axial seismic profile at the head of Rupert Inlet, we see no influence of mill tailing in the vicinity of the estuary.

The next slide illustrates a cross section practically in line with the outfall. Note the tailing have moved across

cont'd ....

the inlet and reached an appreciable thickness on the bottom. Proceeding slightly down stream, the next slide illustrates a thin layer of tailing starting to advance up the south wall of the inlet. More important however, note the development of a small incipient axial valley which has formed on top of tailing . This represents a fundamental change in the sedimentation and hydraulic regime which existed on the floor of Rupert Inlet prior to this time. Subsequently, it will be shown that this new deposition regime is of utmost importance in defining the ultimate resting site for tailing . The last slide of the 1973 data illustrates a seismic cross section in the Hankin area. Identified in orange is a thin layer of tailing, approximately five feet thick in this region.

In summation, by the end of 1973, the tailing which had been moving by cross inlet slumping previously have now started to move down slope by gravity. In addition, an incipient axial valley has formed in the tailing .

The next slide is an isopak map showing the thickness and distribution of tailing in Rupert Inlet after three years of production. In addition it shows the location of two 1974 continuous seismic profiles. The significant factor of the isopak map is the extent of tailing movement down inlet since 1973. Looking at a 1974 continuous seismic profile, we see the incipient axial valley which had developed in 1973 has now

cont'd.......

been established into a pronounced leveed seafloor valley with banks as high as 20 feet. Presumably this leveed valley system is now funnelling most of the tailings flow down inlet towards Quatsino Narrows.

The next slide, also from the 1974 data, shows the extremity of the leveed seafloor system. Looking at this slide, there appears to be the development of a double leveed valley system.

Proceeding to the October 1975 data, the next slide illustrates the thickness and distribution of mill tailing plus the location of two continuous seismic profiles. Note in particular the seafloor valley which commenced in 1973, and continues to advance down inlet in 1974 has now passed the Hankin Point area and is funnelling tailings into the deepest part of the system in Holberg Inlet. This development is of considerable significance for the tailing are now being transported beyond the area of turbulent mixing which coincides with the Rupert - Holberg gap.

The next slide, a 1975 continuous seismic profile, shows the progression of the leveed valley system. Note the two leveed valleys which are now present. The tailing , identified in orange, are in excess of 25 feet thick.

cont'd ....

The next slide also illustrates the two valleys which are present on the seafloor and considerable thickness of tailing which have been deposited.

The next slide, taken in January 1976, depicts an echo sounding trace of the leveed system that presently exists between Hankin Point and Quatsino Narrows. This type of echo sounding profiling has been initiated as an on-going monthly monitoring program.

In summation, I have shown you the year by year growth of a leveed seafloor valley which commences near the outfall in 1973 and continues to advance down slope towards the deepest part of the system in Holberg Inlet. We have observed essentially a system that has developed, first by cross inlet slumping and subsequently by down inlet turbidity current deposition.

The following map summarized the results from the three methods used to delineate tailing distribution throughout the system.

Now that I have described the bottom sedimentation, let us look at suspended sediments in the water column.

cont'd ....

Suspended Sediments

Suspended sediment, as the connotation implies, are solids - organic or inorganic in nature, which are suspended in the water column. These sediments have multiple sources being derived or manufactured in situ in the sea, surface runoff, or man made activities. Specifically, the aim of the suspended sediment program is to determine quantitatively the relative importance of various sources of sediment. It is well realized that the mill tailings are the major contributor to the suspended sediment load. Fortunately, the preponderance of the suspended sediment load occurs in a "mist-like" turbidity field below 50 meters (150 feet). Thus, the important surface biologically productive zone remains near background level.

The methods employed regularly to quantify the suspended sediment load include:

1. Discreet water sampling and nephelometric determination.
2. In situ water clarity measurements employing a Hydro-Products transmissometer equipped with a meter and chart read-out. This slide illustrates turbidity field in Rupert Inlet at 70 meters.
3. Gravimetric suspended solids analysis done in profile at the seven stations on a quarterly basis. This gravimetric procedure is capable of differentiating between organic and inorganic sediments.

cont'd ....

As in most procedures employed to determine suspended sediment concentrations, the ones we use are difficult to co-relate with one another. Numerous hours have been spent in co-relating Jackson turbidity units to % transmissability and to suspended solids. A relationship between Jackson turbidity units and % transmissibility has been established, but the gravimetric suspended solids are not co-relative.

Based upon 24 and 48 hour continuous monitoring data, it is obvious that the turbidity situation is very dynamic in the area off Hankin Point. As you move away from the reaches of Quatsino Narrows, the system becomes more static. During the period of an extended mill shut down in the summer of 1974, it was observed that the turbidity field settled to background levels. No single postulation can accommodate all the data. The total turbidity story can only be resolved by a complete understanding of the entire oceanographic and meterologic conditions of the area plus a thorough understanding of hydrodynamic properties of the tailings.

Drinkwater (1973) masters thesis at U.B.C. examined the role of tidal mixing and tidal scour in Rupert Inlet. His thesis provided valuable data whereby it was shown that the density differences between Quatsino Sound water and Rupert-Holberg water could result in turbulent upwelling off Hankin Point during flood tides.

cont'd ....

On occasion, turbid boils occur off Hankin Point. It is not clear, at this time, whether the dense water is scouring previously deposited sediment or if it is inter-acting with a suspended sediment cloud at an intermediate depth. Judging from our recent seismic survey, extensive tailings (>15 ft) are being deposited in the trough opposite Quatsino Narrows as an extension of the leveed seafloor valley.

Johnson (1974) PhD thesis measured current velocities in order of one to two knots on the floor of Rupert Inlet in the vicinity of Quatsino Narrows. The highest current velocities measured were intermittent in nature and usually lasted a few minutes. In order to further understand the dynamics of the turbidity story and re-suspension of mill tailings, Island Copper with U.B.C. assistance conducted a tracer (rhodamine B) study in front of Quatsino Narrows. This study conducted in December 1973, was coincidental with the largest spring tidal exchange of the year. Contrary to predictions based upon academic postulations no vertical component developed. The tracer did spread laterally down into Holberg Inlet.

Further current studies are being conducted by the Ocean and Aquatic Affairs Branch of Environment Canada under the direction of Dr. D. Farmer. During the past year, this group has been

cont'd ....

continuously monitoring current velocities, salinities and temperatures in order to identify denser Quatsino Sound water distributed within the Rupert-Holberg system. The main objective of Dr. Farmer's study is to build a conceptual model of the circulation pattern and water exchanges in the Rupert-Holberg system.

Dr. J. Gower also of Ocean and Aquatic Affairs of Environment Canada, has been experimenting with the use of remote sensing in coastal oceanography. Included in his studies is the site of upwelling off Hankin Point at the Rupert-Holberg gap. The time chosen to conduct this aerial photographic surveillance was predetermined from the predicted maximum turbidity upwelling during the equinox.

It is evident from the sediment program that although there are upwellingsof tailing on occasional high tides when dense seawater comes over the Quatsino Narrows sill, the vast majority of the tailing remains on the floor of the Rupert-Holberg system.

In view of the fact that suspended sediments are reaching the surface at Hankin Point on occasions, an additional suspended sampling program has been initiated. This program consists of the implacement of 8 continuous in situ sediment samplers at four sites - (2 in Rupert, 1 in Holberg and 1 in Quatsino).

cont'd ....

Two samplers were installed by scuba divers at each of these sites at depths of 30 and 60 feet respectively. The actual sampling device is a tripod structure with the sampler secured 10 feet from the bottom. In addition, a bottom sediment plate was installed at each sample site to monitor sedimentation actually occurring on the bottom. The samplers installed in October 1975 were serviced in December 1975 and covered the period of torrential rains which took place in November 1975. Analyses being conducted on the suspended sediment consist of the following:

1. Rate of sedimentation expressed in gms/m^2/day
2. % distribution of organic to inorganic
3. X-ray diffraction
4. Identification of minerals
5. Particle size analysis
6. Scanning electron microscopy to determine particle shape

Preliminary analysis of the samples obtained during the period of October to December 1975 reveal sedimentation rate at 60 feet to be from a low of 3.6 gms/m^2/day in Quatsino Sound to a maximum of 45 gms/m^2/day off Hankin Point. Although the latter number may seem large, it should be examined in light of the work by Stephens, Sheldon and Parsons (1967) in Departure Bay.

cont'd ....

In this setting on the east coast of Vancouver Island they found the rate of suspended sediment varied from a high of 20 gms/m^2/day to a low of 5 gms/m^2/day.

Approximately 10 - 15% of the sediment collected in our study was organic in nature. Preliminary photographs from a scanning electron microscope revealed an abundance of diatom frustules within the suspended sediment. This illustrates that the settled tailing is not sterile and contains appreciable organic matter derived from the phytoplankton.

In summary (of the sedimentation programs) it is understandable that the down inlet movement of tailing toward the area of maximum turbulent mixing which occurred in 1974 and 1975 resulted in increased turbidity off Hankin Point. The fact that the leveed valley has now recently extended beyond this intermittently active region and the tailing are being funnelled into the deepest basin of the Rupert-Holberg system may result in decreased turbidity off Hankin Point.

Next I will illustrate the monitoring program associated with the chemistry of the water column. This will include methods, procedures and analytical facilities.

<u>Chemical</u>

In any environmental program much of the data that is generated tends to be relatively heterogenic.

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The chemical data on water quality, however, in one of the more homogenic types of information generated.

At Island Copper, we have placed considerable emphasis on the water quality program. Parameters measured in the water quality program include the following: alkalinity, dissolved oxygen, pH, temperature, turbidity, color, sulphide, cyanide, spent sulphite liquor, suspended solids, and heavy metal analysis for both dissolved and particulate copper, molybdenum, cobalt, iron, nickel, lead, cadmium, zinc, chromium, manganese and mercury. Total extractable arsenic is also monitored. Some of the parameters are monitored on a monthly basis while others are done quarterly.

Conventional oceanographic equipment such as bathythermograph, water bottles, reversing thermometers, secchi disc, Ule color compartor etc. are employed for sample collection.

In order to conduct reproducible analysis in the parts per billion level, it was necessary for Island Copper to design and develop a sophisticated clean air laboratory. The facility is air conditioned to space laboratory specifications which include a wall filtering system that removes 99.97% of particles greater than 0.3 micron in the fresh air.

cont'd ....

As illustrated, the laboratory is equipped with modern instrumentation including a heated graphite furnace. This instrument is capable of detecting copper in water down to one part per billion without pre-concentration. All this instrumentation is meaningless without well trained chemists. We have been fortunate in retaining the services of some excellent personnel.

Quality control is a fundamental facet of our daily operation. In house quality control includes maintaining Cu-SUM quality control chart while outside referencing is done with the U.S. Environmental Protection Agency, Canadian Environmental Laboratories and the University of British Columbia.

Since we operate a copper-molybdenum mine, the obvious elements of public concern are usually copper and molybdenum levels in the receiving environment. A comparison in table III illustrates the dissolved metal inflow into Rupert Inlet from natural streams and mill effluent.

TABLE III

COMPARISON OF DISSOLVED HEAVY METAL INFLOWS TO RUPERT INLET

Metal	Inflow due to Tailing Discharge	Inflow derived from Fresh-Water Streams
Fe	< 1	180
Cu	< 0.2	11
Mo	< 4	6
Pb	< 0.2	6
Zn	< 0.1	39
Cu	< 0.4	3
Cd	< 0.1	1
Cr	< 0.1	2
Ni	< 0.3	6
Mn	< 0.1	7

* (Units - Tons per year)

cont'd ....

The dissolved copper and molybdenum concentrations in the water columns as illustrated in table IV have not shown any increase since mining started.

The background averages shown were derived from 60 pre-operational samplings over a two year period while the operational figures were derived from 192 samplings over a four year period.

TABLE IV

DISSOLVED COPPER AND MOLYBDENUM

(In p.p.b.)

	Rupert Inlet		Holberg Inlet		Quatsino Sound	
	Cu	Mo	Cu	Mo	Cu	Mo
Pre-operational Average	1.7	9.0	2.0	9.1	1.9	9.9
Operational Average	1.6	8.9	1.7	8.4	1.6	9.4

In following the work of Pravdic (1971), estuarine sediments behave as ion-exchange adsorbents for ionic species in sea-water and hence may be responsible for the semi-static state of dissolved metals in the receiving environment.

Biological

This completes the discussion on the physical and chemical characteristics of the environment, let us now review the biological processes operating within the system. The entire inter-acting system of organisms, together with environmental factors are termed an ecosystem.

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Within this system, there are three fundamental categories of organisms, producers, consumers and reducers. For our purpose today, I will discuss methods, procedures and programs related to the producers and consumers.

First, consider the marine plants which can be both microscopic and macroscopic. These are the producers which synthesize new organic matter from inorganic constituents such as carbon dioxide, water and soluble salts. These are the photosynthetic forms. All other living things depend directly or indirectly on these plants for their food and oxygen.

Phytoplankton

The phytoplankton are those unicellular or multicellular microscopic plants that are the very basis of the food chain. These marine plants, like terestial plants, photosynthesize during the day and respire during the night. Of fundamental importance to their photosynthetic process is the availability of light through the water column. The surface layer of water into which sufficient light penetrates for active photosynthesis is referred to as the euphotic zone. In coastal inlets this depth is usually 10 - 20 meters.

At Island Copper the phytoplankton monitoring programs consist of routinely determining the depth of the euphotic zone, available nutrients, the standing crop and the rate of assimilation.

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The standing crop is determined by assessing the quantity of chlorophyll pigment per unit volume. Whereas in the assimilation tests the uptake of a radio-active isotope, carbon^{14} is used in simulated conditions to measure the amount of phytosynthetic activity per unit time. Simply, the first method determines the amount of phytoplankton present at one specific time, where as the assimilation study determines the potential rate of phytoplankton production.During periods of high phytoplankton productivity samples are collected for identification and potential toxicity tests.

Mr. D. Goyette, of the Environmental Protection Services has also been conducting phytoplankton studies in the area. According to Mr. D. Goyette (personal comment), preliminary assessment of the data shows that primary production is higher in Rupert Inlet than Holberg Inlet, but lower than the oceanic waters at the mouth of Quatsino Sound.

Another phytoplankton study conducted during the summer of 1975 in Rupert-Holberg Inlets was that of Dr. John Sibert of the Nanaimo Biological Station. His data is currently being analyzed and we do not have any preliminary indications of the results.

Analyses of Island Copper data over a five year period by Dr.EJR. Taylor, of the University of British Columbia independent agency has revealed that the orders of magnitude for

cont'd ....

the phytoplankton standing crop has remained within those expected for coastal inlets in the region. In fact, Dr. Taylor has stated that there is little doubt that there was a slight increase in chlorophyll values at all stations since the inception of the monitoring program. In addition, he showed that before and after the mine started, stations within Rupert Inlet and Holberg Inlet had higher values than those in Quatsino Sound.

Further in our study of marine plants we have initiated a macrophyte (Fixed Algae) study under the direction of Dr. R. Foremen.

Macrophyte (Fixed Algae)

The original environmental monitoring program did not include a study of the fixed algae in the sublittoral zones of the Rupert Inlet system. However, a program was initiated in the summer of 1974 when 10 sites were qualitatively examined in Rupert Inlet, Holberg Inlet and Quatsino Sound. Three sites were selected for continuous monitoring, two in Rupert Inlet, West Bay and Crab Bay and a control site at Orr Island in Holberg Inlet. Twenty-five quarter meter square quadrants were collected from each site. Each quadrant was sorted by species both for macrophytes and fauna. Dr. Ellis is responsible for sorting the benthic organisms whereas the macrophytes have been identified by the curator of phycology at U.B.C. Some 127 species of macrophytes and 88 species of benthic organisms were collected at the selected stations.

cont'd ....

Considering the macrophytes, Crab Bay contained 103 species (84%), West Bay 87 species (71%) whereas Orr Island (Control) contained 65 species (53%). The greater number of species in the potential impact sites appears to result from the less mature development of the macrophyte communities in these areas. Although the species diversity varies from site to site, the biomass did not vary significantly.

Great difficulty is encountered when attempting to place this data in perspective with other inlets along the coast simply because there is no other data available.

Intertidal Plate Study

Moving up into the shore line, the monitoring program has been examining intertidal growth since 1970, using artificial substrate samplers. These samplers consist of fiberglass plates bolted to concrete blocks and placed upright at the zero tide level. The plates have been placed at 16 stations and are retrieved either at the end of a six-month winter period or at monthly intervals during the summer.

The primary objective is to determine if there are gross reductions in growth in the intertidal zone. This is simply achieved by comparing weights of volatile organic material with time and areas. Five years of data indicates there have been similar quantities of biological growth at all stations. Even at station 10, right beside the mine site, there has been no sign of a decrease in growth.

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The general conclusion from this test is that the mine has not affected the shallow water environment to the extent of reducing the amount of biological growth.

Metal Analysis of Fixed Algae (*Fucus sp.*)

A program has been initiated to determine the potential uptake of metal by the common rock weed (Fucus). The sampling sites correspond to the intertidal plate study. To date, not enough data has been generated to report any trends.

This completes the monitoring being carried out on the microscopic, and macroscopic primary producers.

The following discussion will examine the procedures and methods employed to monitor the animal community in the marine environment.

ANIMALS

In contrast to the plants, these are the consumers which feed on the plants or upon each other.

Zooplankton

The first in the series of programs consist of monitoring the primary consumers the zooplankton. These animals are small, swimming organisms whose movements,apart from vertical migration, are dependent on currents.

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For the past five years, we have been monitoring the density, diversity, and metal concentration of the zooplankton in Rupert Inlet, Holberg Inlet and Quatsino Sound.

The methods employed are both qualitative and quantitative. Clarke-Bumpus samplers are used to quantify zooplankton densities per unit volume. Three of these samplers equipped with flow meter are towed at pre-determined depths. The samples collected are enumerated and identified to species by a biological consulting laboratory. Further sampling consists of collecting large volumes of the organisms for metal analysis.

To date, as illustrated by data accumulated over a five year period, there is no conclusive evidence that the mine is affecting the diversity of species. This is based upon the absence of any obvious change at any one station or between stations.

The density or abundance per unit area in the five years of data accumulation indicates that there has been an overall increase in organisms. This increase has occurred throughout the system with Rupert Inlet showing the most significant increase.

cont'd ....

A further appreciation of the abundance of zooplankton can be achieved from examining scatter layers on echo sounding records. These layers persist in Rupert and Holberg Inlets throughout much of the year. A detail investigation of the phenomenon revealed that the plankton underwent diurinal migration in response to light. Detail horizontal sampling above, in and below the scattering layer show large concentration of plankton at and below the layer. Five meters above the layer was essentially devoid of plankton. This echo sounding technique has been used to locate plankton layers in order to facilitate collection of large quantities of organisms for metal analyses.

Metal analysis to date indicate tremendous variability between sampling dates both from quarter to quarter and from year to year. An investigation into this variability is revealing that various species have varying metal concentrations. For example in September 1973 the animals were predominantly ctenophores (small jelly fish type organisms) while December 1974 the predominant species were euphausids (shrimp-like crustacean).

One notable observation is the similarity of the values from all stations at any one time. In addition the metal values at any one station, when averaged, are not exceptionally different than those at any other station (Lewis 1975).

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Moving into the area of anticipated impact, I will now discuss the methods and procedures of the deep benthos program.

Benthic Organisms

This program was initiated in 1970 when quantitative samples from a grid of stations ranging up to 24 in number scattered throughout Rupert and Holberg Inlets and into Quatsino Sound were obtained.

The main sampling instrument used in this operation is a Ponar grab. This takes the animals and sediments from one-half a square foot of sea-bed and digs to about 3 inches depth. The organisms are separated from sediments by a 30 mesh screen; sorted into groups, counted and weighed. The counts and weights per square foot provide the numerical data for comparisons between stations.

The first data analysis was undertaken by Dr. Ellis of the University of Victoria in 1972; and was to determine the area over which the benthos was obliterated by heavy deposits of tailing. This was shown to be essentially in the trough of Rupert Inlet by the mine-site. Now in 1975 the area extends down the trough to its junction with Holberg Inlet

The extent of the benthic population illustrated in graph #8 shows the average number of organisms per square foot for all stations and the average number of organisms for eight selected stations as determined by live sort and count aboard ship.

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The eight stations consists of # 2, 4, 6, 7, 8, 9, 11 and 22 and were selected in 1974 as areas of possible future obliteration. The graph indicates there was a general reduction in number of benthos within six months of discharge but subsequent higher counts from 1973 onward do not substantiate the mill discharge as the cause of the reduction. There appears to be a gradual return to level of 75 to 100 organisms per square foot. Thus, the 1972 reduction can be taken as within the limits of expected fluctuation.

On an annual basis, the 24 stations grid is sampled for count and detailed identification by an outside laboratory. These laboratory counts usually are four times greater than shipboard counts. This is because mainly macro-organisms are counted in the field and for biomass value this is sufficient.

Jones (1974) in a M. Sc. thesis on Rupert Inlet benthic data demonstrated that polychaete worms were fairly resistent to smothering by light tailings deposits. He also showed that losses started to occur on tailings deposits from 6 to 28 cm thick.

On occasion, heavy metal determination have been conducted on polychaete worms. The problem of acquiring sufficient weight for analysis has made this procedure difficult to conduct routinely.

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In addition, the animals are usually very difficult to clean.

Several relevant points have arisen which lead to the belief that natural recolonization of previously obliterated areas will occur. After a two month operational shut-down, in September 1974, areas previously obliterated showed evidence of colonization. In addition, in areas of light sedimentation, there appears to be sufficient intermixing of natural sediment with tailings to sustain a benthic community. Even with continuous operation, the settling and survival of the benthic larvae has been noted on occasion in areas previously obliterated. These points together provide some reason to believe that underwater recolonization of the tailings deposits may proceed quite quickly once mining has stopped.

Commercial Crabs

Dungeness crabs are monitored quarterly at 6 stations in Rupert, Holberg and Quatsino Sound. The animals are collected utilizing a pair of commercial crab traps set for 18 hours at each station. Upon capture, each crab is sexed, weighed, measured and observed prior to its return to the sea. Carapace widths, measured between the two most posterior notches on the anterolateral border are recorded to the nearest millimeter. Weights are expressed to the nearest gram. The crabs in the burried condition or with empty egg cases attached to their swimmerets (indicating recent hatching) are also noted.

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Male to female size frequency distributions are done comparing individual stations and station to station.

Metal analyses are conducted on 3 representative legal size male specimens. The metal values have not indicated any increasing trend attributable to mining operations. Like other parameters, there appears to be tremendous variation between seasons and not between stations.

To date, there has not been any appreciable decrease in dungeness crabs in the region. However, the past two winters have witnessed large scale commercial crabbing in both Rupert and Holberg Inlets. With modern methods of setting strings of unbuoyed crab traps, extensive harvests are being realized.

Shrimps and Prawns

There has been question of the possibility of heavy metal uptake by deep epibenthos, specifically shrimps and prawns. Consequently, we have initiated a program to monitor possible metal increases. Since this program was initiated after operations commenced, the background heavy metal levels of these crustaceans were established outside the Rupert-Holberg system. The preliminary data collected at 4 stations in Rupert and Holberg Inlet indicates statistically that there is no significant difference by area and by time.

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Intertidal Invertebrates

Following in the line of edible species, we monitor intertidal invertebrates at 9 stations in Rupert Inlet, Holberg Inlet, Quatsino Sound and Queen Charlotte Strait. Six resident species of clam are collected throughout the sampling grid, identified, measured, weighed and retained for heavy metal analysis.

Our results show that over 5 years of testing there have been a few slight elevations of metal near the mine site but these values have not persisted and do not indicate a continuing trend.

All values have been far below level restraints by the food and drug act, and shellfish in the area can be safely eaten.

A special invertebrate testing program has been to monitor the blue mussels which are attached to piling docks. One test station, Rupert shiploading dock and 2 control stations, Coal Harbour dock and Quatsino village dock are the monitoring sites. This is a very rigid test of heavy metal uptake as the test station is part of the copper concentrate ship loading dock. The tests indicated that copper at the test sites were higher than control in September 1973. However, as illustrated, the elevation was not maintained over a period of time indicating that a trend was not in progress. Note the standard deviation for a particular site. This is not analytical deviation but specimen deviation.

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Fishing

Small Intertidal Fishes

In the intertidal zone, small fish are also collected to monitor potential heavy metal uptake. These animals are collected by beach seining at seven sites in Rupert, Holberg and Quatsino Sound. The dominant species are sculpins (both tidepool and staghorn). The small fish are identified, weighed, measured and subsequently analyzed for 7 metals; copper, molybdenum, lead, zinc, cadmium, arsenic and mercury. These fish have not indicated significant changes as compared to background levels.

Another group of edible species are the larger bottom dwelling and pelagic fish.

Bottom dwelling fish are caught principally by two methods - longlining and jigging.

In the longlining procedure, one hundred baited hooks are attached to a longline which is anchored on the bottom for six hours. The dominant species caught on the longline are dogfish sharks, skate, ratfish and on occasion, six-gilled mud sharks. The jigging method is used principally to catch reef-dwelling species. These include sole, halibut, and numerous species of rockfish.
The pelagic fish are caught employing gill nets. The dominant species here include anchovies, herring, salmon, and hake.

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All specimens collected are identified, measured, weighed, and sexed where possible in the field.

In the laboratory, the fish are identified as to species and a sub-sample of the dorsal muscle is blended for wet weight metal analyses. Of the several thousand metal analysis conducted to date, there is no indicative trend that might be attributable to the mining operation.

Data Compilation

With the enormous amount of data generated by this environmental monitoring program, it is obvious that data compilation and reporting is of prime importance. The pressure is continually on the Environmental Department to generate meaningful data. In this respect a Hewlett-Packard Model 9800 programmable calculator is used for individual statistical analysis. The small computer, however, has limited storage and retrieval capacity. Realizing that this system had limitations, preliminary discussions were held with the Pollution Control Branch and with members of the University of British Columbia monitoring group to determine whether to associate with a centralized system or whether to encourage an inhouse, separate system. The latter was chosen and all the data generated to June, 1975 has been transcribed and stored on an IBM disc system.

Computer System

The computer system chosen is known as the RAMIS System. This is basically a data storage and retrieval system.

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A statistical package included with the system is capable of doing most analysis required by our data. The following are some examples of the computer print-out:

1. Tabulation Form
2. Bar Graph Capability
3. Point Graph Capability
4. Statistical Analysis

   (Analysis of Variance of Soft Shell Clam Rupert Inlet #5 and Holberg Inlet #2)

Concluding Remarks

In summary, I hope to have enlightened you concerning the magnitude of the environmental monitoring program at Island Copper. I would like to reiterate some of the highlights of our program as presented to you:

1. A sedimentation system has now developed that funnels the mill tailing down inlet, across the area of maximum turbulent mixing, into the deepest portion of the system in Holberg Inlet.
2. Generally turbidity does not exist at levels that affect primary production.
3. No detectable increases in dissolved metals has occurred in the water column of Rupert Inlet, Holberg Inlet or Quatsino Sound.
4. There is evidence that benthic organisms will re-colonize areas obliterated by tailings upon completion of the mining activity.

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Realizing that the tailing have an impact on the environment, indications are at present that the tailing disposal system can live in harmony with the marine environment.

If significant biological damage was occuring, I believe that a monitoring program, such as the one in use at Island Copper would provide early warning and possibly a mitigatable solution.

Acknowledgement

First, I would like to express my sincere appreciation to the Utah management for their unquestioned support of the Island Copper Environmental Monitoring Programs. Second, I would like to acknowledge my group at Island Copper, because without them particular sections of this paper could not have been presented. Finally, I am indebted to all the individuals from the independent agency,namely: Professor J. B. Evans, Drs. R. L. Chase, D. V. Ellis, W. K. Fletcher, R. E. Foremen, E. V. Grill, J. Leja, A. G. Lewis, J. W. Murray, G. L. Pickard, G. W. Poling, M. J. Quick, F. J. P. Taylor for their guidance and direction.

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Seattle Metro's Marine Water Quality Monitoring Program

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Seattle Metro's Marine Water Quality Monitoring Program

Robert I. Matsuda
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Abstract

Physical, chemical, bacteriological, and biological monitoring of Municipal waste discharges have been carried out in Central Puget Sound to assess and to document water quality conditions. Data collected to date have been valuable in meeting Washington State water quality standards and also identifying potential problem areas. Recently, study emphasis has been directed toward meeting the goals of the Federal Water Pollution Control Act Ammendments of 1972 (PL92-500).

Metro History

Serious water quality problems in Lakes Washington and Sammamish, the Duwamish Estuary, Elliott Bay and Central Puget Sound in the mid-1950's inspired an intense citizen effort to organize a new metropolitan government with the express purpose of solving the area's water quality and sewage treatment and disposal problems. In September 1958, the Municipality of Metropolitan Seattle (Metro) was formed through Washington State legislation and voter approval. The early objective of Metro was clear: Restore, maintain and protect area waters from pollution to the degree suitable for water contact activities, aesthetic consideration and a balanced aquatic ecosystem.

To accomplish this objective, a team of consulting engineers was retained to develop a comprehensive sewerage plan which would solve the Seattle area's water pollution problem. The plan recommended removal of all treatment plant discharges from Lake Washington, and the interception of the direct discharge of millions of gallons per day of raw sewage from the Duwamish Estuary, Elliott Bay, and Central Puget Sound. This was to be accomplished through the construction of more than 100 miles of trunk and interceptor sewers which would transport domestic sewage and industrial wastes to two newly constructed sewage treatment plants. The two major treatment facilities were at Renton (completed in July 1965), and West Point (completed in June 1966). The Renton Plant, designed for activated sludge secondary treatment, has a current treatment capacity of 36 million gallons per day (dry-weather flow). The effluent is initially chlorinated to kill bacteria; it is subsequently dechlorinated with sulfur dioxide before discharge to the Duwamish River, 13 miles above Elliott Bay in Puget Sound.

The West Point Treatment Plant, designed for primary treatment and chlorination, has a current treatment capacity of 125 mgd (dry-weather flow). The effluent is discharged through a three-quarter of a mile long submarine outfall terminating in a 600-foot long diffuser section located in water 240 feet deep.

Metro's three other treatment plants, Richmond Beach, Carkeek Park and Alki Point, serve isolated drainage basins and were designed for daily dry-weather flows of 3, 3, and 10 million gallons per day, respectively.

Water Quality Monitoring

In 1961, Metro initiated a comprehensive quality monitoring program, which at that time was a relatively new responsibility for a sewerage agency in the U. S.. The Water Quality Division was thus formed to carry out water quality monitoring programs to assess the impact of Metro's waste water discharges on various receiving waters.

The monitoring program, developed over a period of some 15 years, now includes more than 600 monitoring stations located in all waters which may be affected by Metro's operation (Figure 1). The cost of Metro's monitoring program, however, is substantial. The annual Water Quality Budget totals $750,000, with a staff of 36 professional and technical personnel. Professional expertise includes such disciplines as chemistry, physics, microbiology, oceanography and various biological sciences. In addition, a full complement of vehicles, field instruments and equipment and a fully equiped laboratory are provided.

Numerous physical, chemical, microbiological, and biological, parameters such as water temperature, transparency, dissolved oxygen, salinity, nutrients, coliform bacteria, algal species composition, chlorophyll a, primary productivity, benthic fauna, demersal fish surveys, and the effects of toxicants to fish have been monitored. Monitoring data have shown that Metro's operations to date have had no observable deleterious effects on the water quality or ecological conditions near Metro's outfalls. Dissolved oxygen levels (percent saturation) in near-surface water (1 meter) over the West Point outfall show little deviation from historical data (1935-42) collected by the University of Washington Department of Oceanography at Point Jefferson (Figure 2). Similarly, comparisons of dissolved oxygen levels at 200 meters from these two locations show minimal differences (Figure 3).

The most dramatic improvement in offshore and near-shore areas was the substantial decline in the level of coliform organisms following the completion of the West Point Plant in 1966. Figure 4 illustrates this change in total coliform levels at several stations along the shoreline of Elliott Bay, an area once receiving millions of gallons per day of raw sewage. With the construction of the Elliott Bay interceptor, diversion of some 20 raw sewage outfalls along the Elliott Bay shoreline was completed in 1970, with the larger outfalls being diverted during the 1969-70 period. As expected, the most significant decrease in coliform counts occurred during this period. A similar decline in total coliform levels is shown directly over the West Point outfall (Figure 5).

Monitoring primary productivity in the Central Puget Sound basin is also of interest to Metro since nutrients (i.e. phosphorus and nitrogen) are contained in wastewater effluents. Primary productivity data, although variable,

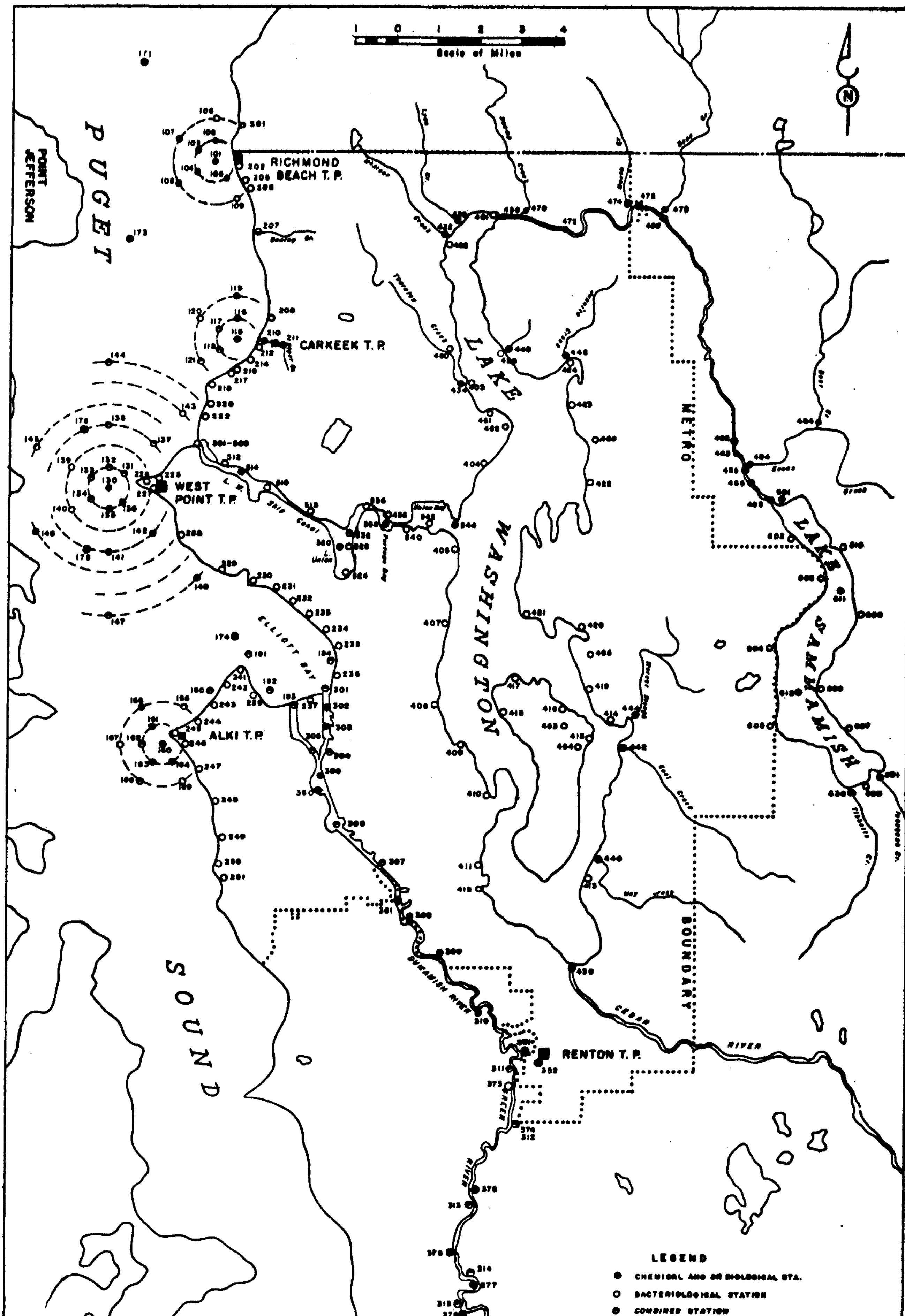

FIGURE I — WATER QUALITY MONITORING STATIONS

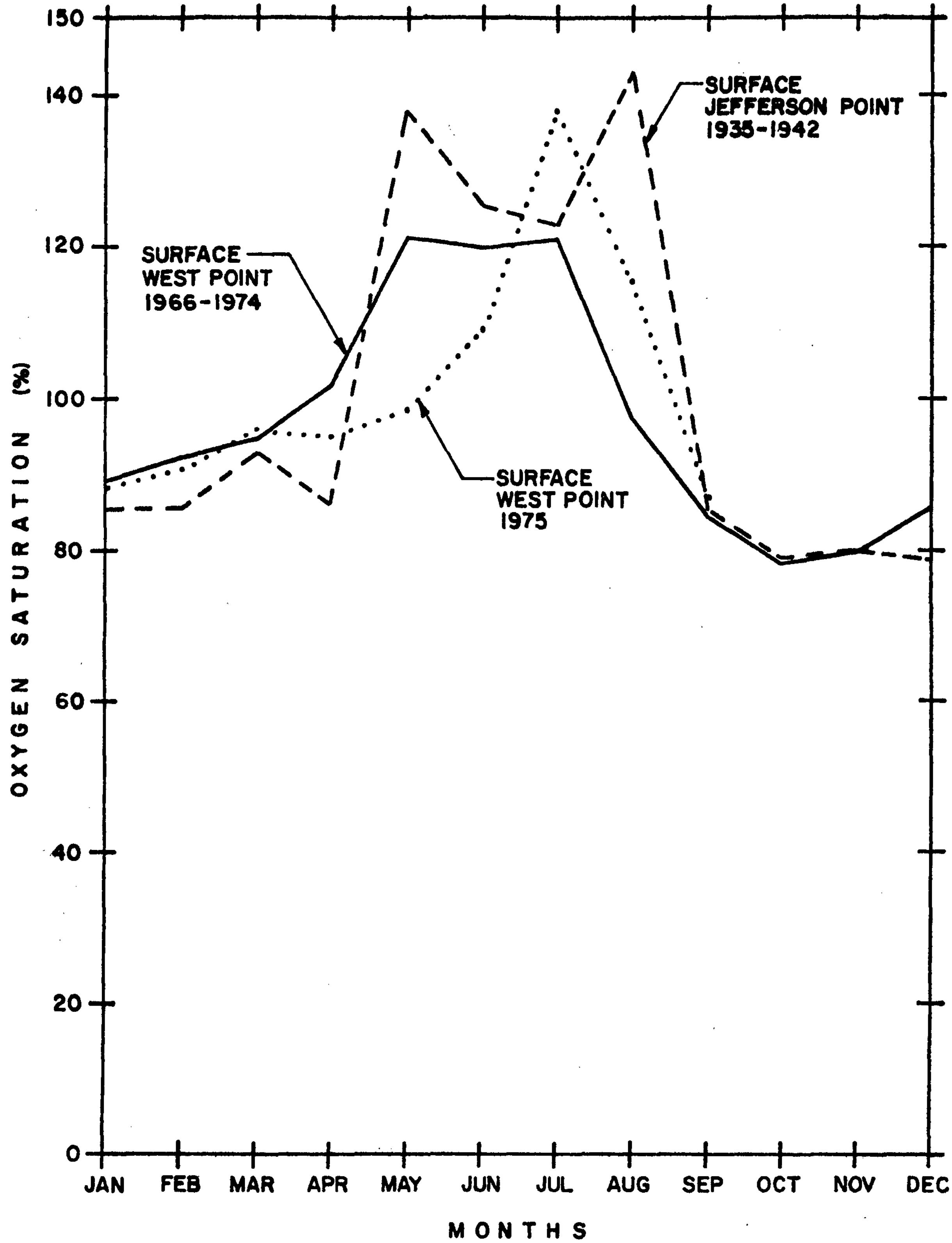

FIGURE 2

DISOLVED OXYGEN
IN SURFACE WATERS OF PUGET SOUND

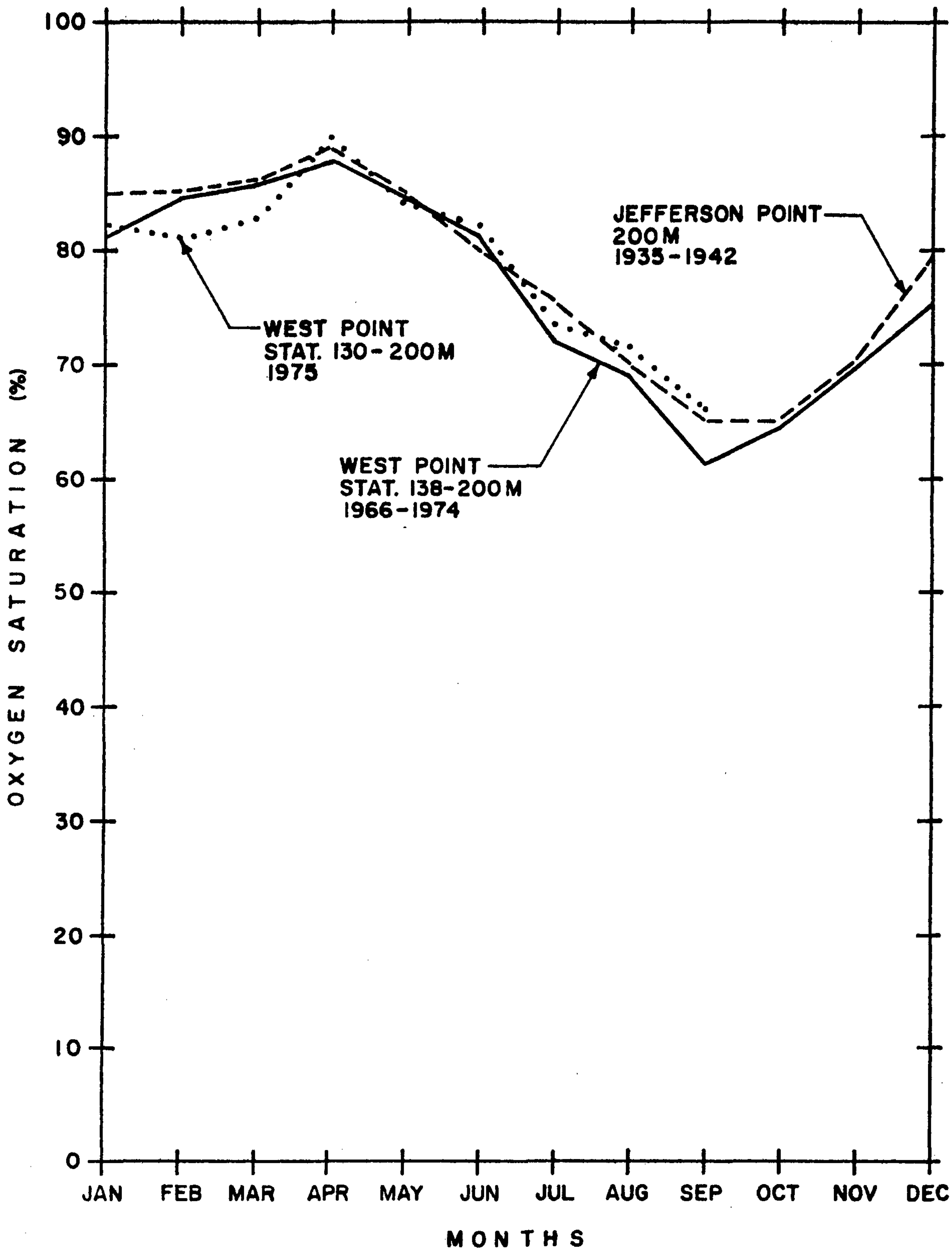

FIGURE 3

DISOLVED OXYGEN

IN DEEP WATERS OF PUGET SOUND

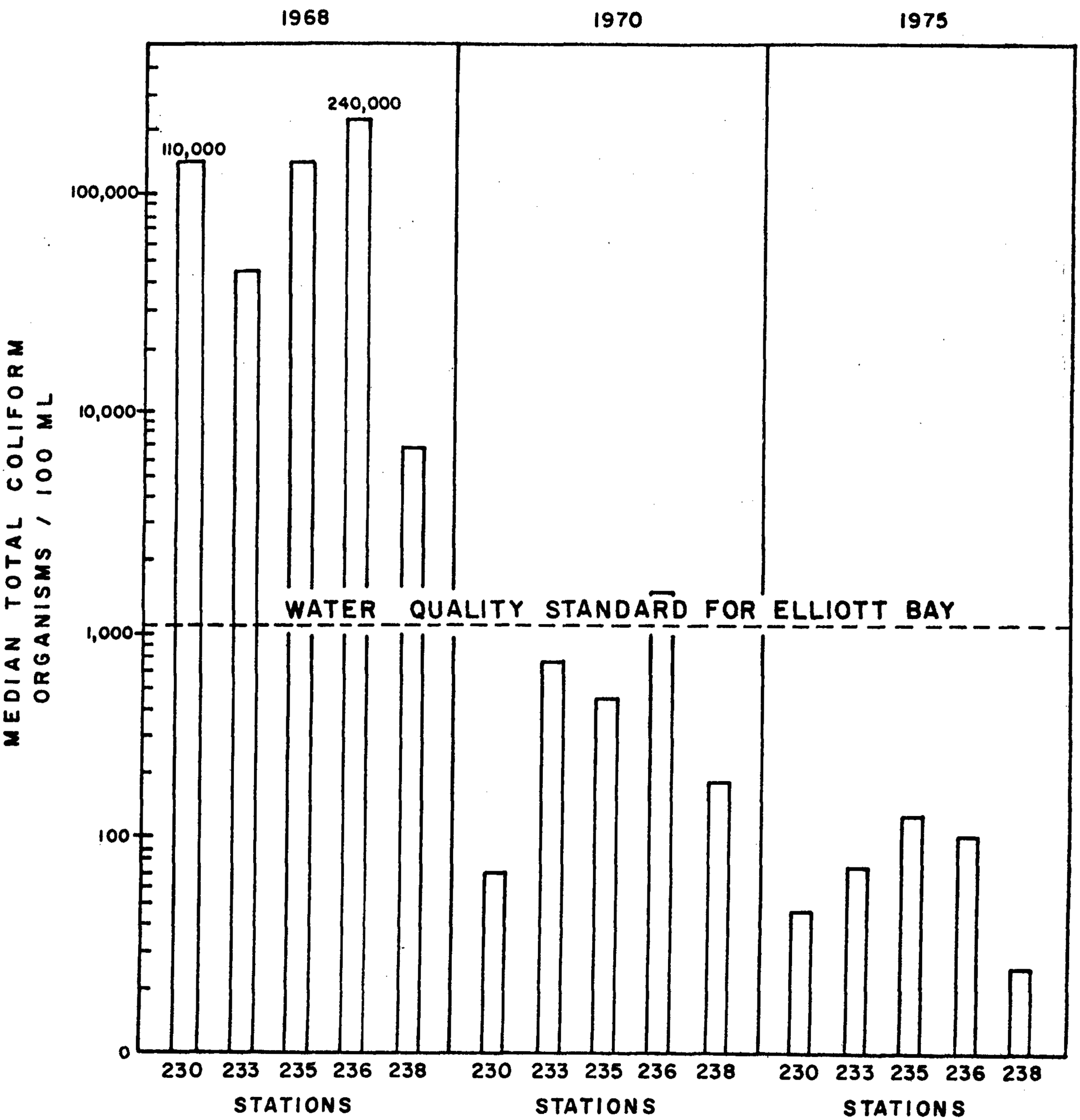

FIGURE 4

ELLIOTT BAY SHORE
COLIFORM CONCENTRATIONS
FOR THE PERIOD JULY – SEPTEMBER

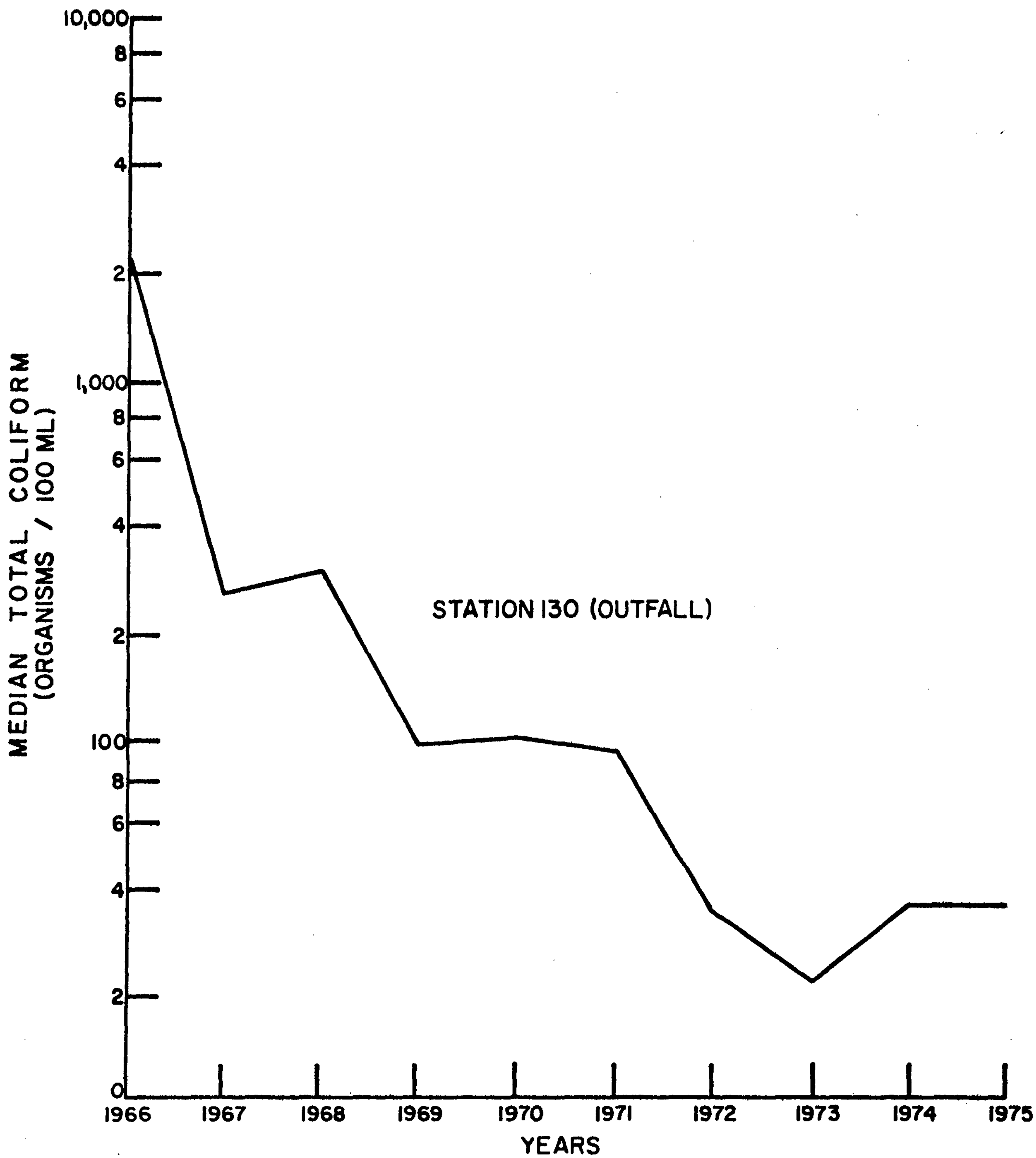

FIGURE 5

PUGET SOUND YEARLY MEDIAN COLIFORM COUNT 1966-1975 shows a slight increase during the study period, 1967 through 1975 (Figure 6). Although nutrient addition to Puget Sound may be contributing to this increase, studies by Anderson (1966) have shown that water column stability and solar energy are probably the most significant factors controlling primary productivity in the Sound. Further, analysis of orthophosphate data collected at Point Jefferson from 1935 through 1971 by Duxbury (1975) showed that the total daily municipal waste discharge of orthophosphate into Puget Sound was about one-twelfth of the phosphate flowing out of the Sound. Professor Duxbury concludes his discussion by stating "Nature, rather than man, apparently still wields the controlling hand in Puget Sound." In contrast, only small amounts of data are available on nitrogen concentration. Studies by Anderson (1966) have shown that inorganic nitrogen occasionally becomes depleted in specific areas and may sometimes be limiting. Nitrogen and its effects on algal productivity is currently under further study.

A study of bottom sediments and associated benthic organisms was also made. The study, covering the period 1966 to 1968, was designed to assess the extent of sludge buildup in the vicinity of the West Point outfall and the effects of the digested sludge on the benthic community (Domenowske and Matsuda 1969). Data from the 1966 survey (prior to the start-up of the West Point Treatment Plant) was used as the base-line condition to which the latter data (1967-68) could be compared. Results of the study showed no definable buildup of organic material in the vicinity of the West Point outfall. The only identifiable material directly attributable to man's activities were vegetable seeds found near the outfall. The localized populations of benthic organisms showed little or no change in either numbers present or response to effluent and sludge discharges. During 1968 and 1971 visual inspections of the outfall structure and the bottom conditions in the immediate vicinity of the West Point outfall were made. Results of the inspection supported data collected during the three year sediment and benthic community study.

Demersal (bottom dwelling) fish surveys were started in January 1973 at the West Point and Alki outfalls to obtain information on the types and numbers of fishes inhabiting these areas and on the general health of these fish populations (Moulton, et al 1973). Studies of tumors ("cancer") and fin erosion ("fin rot") in flatfish were emphasized since these two diseases have been associated by other investigators with discharges from sewage treatment plants (SCCWRP, 1973; Barrada, 1972). Results of the first year study showed that the incidence of tumors were highest in

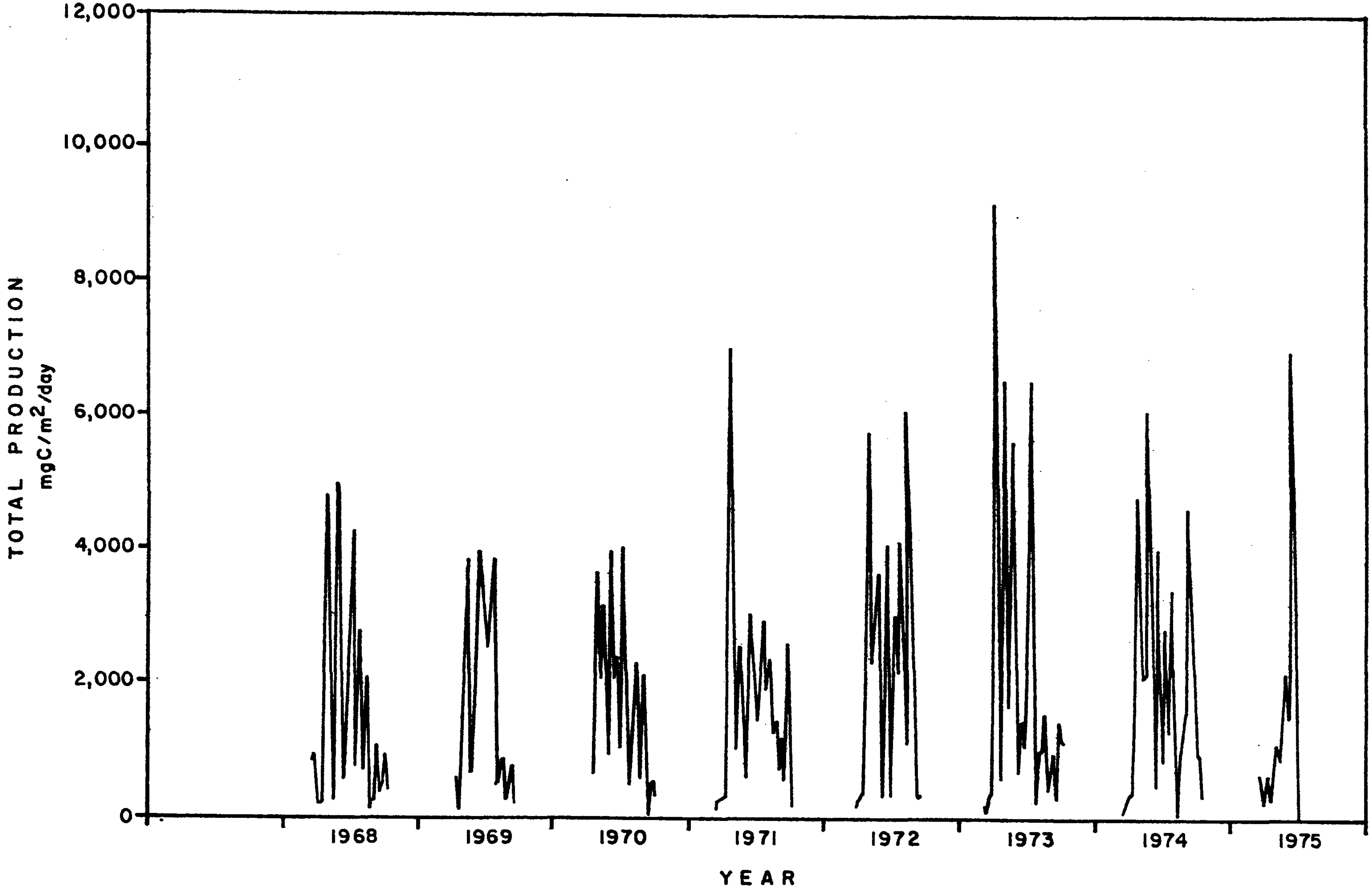

FIGURE 6

PUGET SOUND
PRIMARY PRODUCTIVITY

English sole. Data also suggested that the incidence of tumor-bearing fish at West Point can be considered "high." However, other areas without major sewage influences also showed "high" incidences of tumor-bearing fish. These areas were Puget Sound (Angell 1972; Miller and Wellings 1971), Hecate Strait (Nigerlli, Ketchen, and Ruggieri 1965), and the Bering Sea (Miller, personnal communication). Needless to say, further studies are necessary and are currently being carried out at the West Point, Richmond Beach, Carkeek Park and Alki Point Treatment Plants and a control station to develop a good baseline of information over a span of a few years. Collection of this suite of data is necessary before any attempt at evaluating the significance of the incidence of tumor-bearing English Sole can be made.

All studies mentioned previously, have been designed to assess the effects of waste water discharges on the marine environment by studying the environment itself. However, due to the chemical complexities of municipal sewage, which contains an infinite number of nutritive as well as toxic components, controlled tests are being carried out to ascertain the toxicity of the West Point effluent. In 1972, seven (96-hour) static, acute toxicity bioassays were carried out on chlorinated, primary-treated effluent from the West Point Plant. In such bioassay tests, fish are subjected to various concentrations of effluent/seawater mixtures. At the end of the 96-hour test period the total number of dead fish are recorded and the results expressed as the concentration of effluent/seawater mixture at which 50 percent of the test fish died. This concentration, called the TL50 or tolerance limit at the 50 percent level, is a measure of acute toxicity.

The results of the West Point bioassays indicated that the 96-hour effluent toxicity (TL50) was 7.4 percent effluent, i.e., 7.4 parts effluent in 92.6 parts seawater. Total residual chlorine was determined to be the principal toxicant with an average TL50 concentration of 0.1 mg/l (Buckley and Matsuda, 1972). Further studies using dechlorinated effluent showed that fish will survive for 96 hours in effluent concentrations up to and including 100 percent.

Acute bioassay results provide little information on possible long-term sublethal effects of toxicants in treatment plant effluents to fish. Consequently, long-term sublethal tests were performed at the West Point Plant in 1974 (Buckley, Whitmore and Matsuda, 1976). Yearling coho salmon (*Oncorhynchus kisutch*) were exposed for 12 weeks to chlorinated effluent concentrations of 0.3, 1.1, and 3.6 percent in seawater under continuous flow conditions. Results indicated that the maximum safe concentration of effluent lies between 0.3 and 1.1 percent, with corresponding average total residual chlorine levels of 0.003 and 0.009 mg/1, respectively. No discernable effects were observed on fish exposed to 0.3 percent effluent, however, indications of anemia were apparent in fish exposed to 1.1 and 3.6 percent effluent. The EPA's (1973) proposed maximum standard of 0.01 mg/1 for free residual chlorine in marine waters is supported by the findings of this study. When evaluating the toxicity of the West Point effluent, it is important to consider the effluent dilution in the receiving water. Dilution of the West Point outfall was recently measured at 100:1. This dilution rate applied to an average effluent total residual chlorine level of 0.8 mg/1 results in a final dilution concentration that meets EPA's proposed maximum standard.

Value Of Monitoring

During the course of nearly 15 years of water quality monitoring in the Puget Sound central basin, data collection and analysis provided invaluable information to not only Metro, but also to the governmental agencies, political bodies, special interest groups and the general public. As Metro's Water Quality Monitoring program developed, the value of such a program became increasingly clear. With the passage of the Federal Water Quality Act of 1965, the Washington State Department of Ecology was given the responsibility of establishing water quality standards throughout the state. Metro, in this instance, provided valuable data on existing water quality conditions in the Central Puget Sound basin and adjoining areas.

In 1967, the State Water Quality Standards were adopted. During this period, the ecological movement was at its peak. This movement culminated in the passage of the 1972 amendments to the Water Pollution Control Act (Public Law 92-500). Although there is so much in the law that is good....good in the national commitment to the goal of clean waters, and good in its detailed description for achieving this goal, Metro recognized that major problems in its implementation would arise. One critical area of concern to Metro was the requirement of secondary treatment by the year 1977 and best practicable treatment by 1983.

As I mentioned previously, comparison of historical and recent monitoring data show that Metro's discharge of primary effluent have not affected the dissolved oxygen resources in Puget Sound.

Consequently, Metro disagrees with the PL92-500 secondary treatment requirement. Thus, using the monitoring data base, strategies were approved by the Metro Council (Metro's giverning body) to bypass the secondary treatment standard and move towards developing treatment systems to meet the 1983 goal of best practicable treatment. This strategy would better utilize an estimated $55 million which would have otherwise been spent to meet the secondary treatment requirement.

With the Council's newly adopted strategy, plans were developed to schedule all phases of the construction of facilities to achieve the 1983 goal of best practicable treatment. Plans, relevant to the subject of this paper, called for the development of pilot treatment facilities to test various individual and/or combinations of treatment processes. Coincident with the pilot facilities, additional detailed water quality studies were developed, at a total cost of $1.1 million. These studies were based on data needs identified by the water quality monitoring program and were designed to provide specific information relevant to the development of the pilot treatment facilities. Specific objectives of the studies, now called the Puget Sound Interim Studies, were as follows:

1. Determine effluent direction of travel, dispersion and dilution rates as related to Metro's marine discharges.

2. Determine the effects of nitrogen and other macro nutrients on the biota of the receiving waters.

3. Determine the effects and final disposition of heavy metals on the biota and sediment regimes.

4. Identify other organic toxins and pathogens whose origin might be effluents from Metro facilities.

5. Document various aspects of effluent plume water quality such as dissolved oxygen, temperature, salinity, BOD, chlorine residual, etc..

To accomplish these objectives, teams of scientists from public and private sectors were commissioned to carry out two-year studies, culminating in mid-1976 with a series of project reports to be used as an aid in selecting ultimate treatment systems to meet the 1983 goal.

Ten projects encompassing various physical, chemical and biological investigations are now in progress. These investigations include (1) the measurement of tidal currents near West Point with the aid of drogues, (2) *in situ* measurements and computer analysis of Rhodamine B-dyed effluent to determine direction of travel, dispersion and dilution rates, (3) studies of the interrelationships of hydrographic factors and nutrients on phytoplankton and zooplankton populations in the Central Puget Sound basin, (4) documentation of the baseline biology of planktonic and pelagic organisms using mid-water trawls and acoustic recorders, (5) intertidal studies to document flora and fauna densities on beach areas adjacent to Metro's treatment plants, (6) subtidal studies assessing the micro-and macrofauna populations in relation to sediment composition and effluent discharges, (7) analysis of various heavy metals in the water column, the sediments, and selected benthic organisms, (8) toxicity studies utilizing continuous flow bioassay techniques to assess the toxicity of various trace organics on selected vertebrate and invertebrate species, (9) investigations of the health of various demersal fishes, shrimp and crabs in the vicinity of Metro's sewage outfalls (specific emphysis is being placed on determining the nature and causes of fin rot and skin tumors in flatfishes), and (10) studies using *in situ* instruments to document effluent plume water quality (various physical-chemical parameters are being measured to define the extent of mixing on effluent plume water quality).

The Metro Water Quality Monitoring program also provides a service to various in-house divisions, (i.e. operations, water quality planning and environmental planning), regulatory agencies, the general public, and special interest groups. The Water Quality Monitoring staff, working closely with operating divisions, help increase operator awareness of the impact of effluent discharges on the receiving water environment. This increased awareness oftentimes results in quick reports of unusual wastes entering the plant, and improved in-plant sample collection and analysis. However, it should be recognized that information flow is in both directions. Association with plant personnel helps make Water Quality staff aware of the complexities and problems of operating modern waste treatment facilities.

The same hold true for Water Quality staff associations with the Water Quality Planning and Environmental Planning Division, whose responsibilities lie in the areas of long-range management of our water resources. Reports, special analysis of selected data and in some cases raw data are provided to the Water Quality Planning Division for identification of current water quality problem areas. The information is used to formulate future plans for basin wide water quality management programs.

Support to the Environmental Planning groups is primarily in the area of EIS (Environmental Impact Statement) reviews and both in-house and outside agency EIS reports.

An example of the importance of a systematic monitoring program in meeting regulatory guidelines was mentioned previously in the section on Metro's best practicable treatment strategy. There are other water quality standards set by the State of Washington Department of Ecology which need to be met. One of the most stringent of these standards impacting Metro's operations is the total coliform standard of 70 coliform per 100 mls of water. These standards apply to many areas in Puget Sound including those areas receiving effluent discharges from four of Metro treatment plants. Monitoring has either demonstrated that water quality standards are being met or, if not being met, why substandard conditions exist. For example, during rainy periods, total coliform concentrations may exceed water quality standards in certain locations because of storm water discharges or occasional overflows of combined sewage.

Another regulation affecting Metro is the National Pollutant Discharge Elimination System (NPDES). Established by Public Law 92-500 and administered through the Washington State Department of Ecology, this program requires receiving water monitoring of various parameters (i.e. water temperature, pH, DO, nitrogen, and the heavy metals Cd, Cr, Cu, Pb, Hg, Ni, Zn). These data are systemitically reviewed by the DOE to determine if receiving water quality are being adversely affected by Metro's discharges. In this instance, monitoring has been able to document the effectiveness of our treatment facilities.

Water quality standards, however, were and still are the result of environmental awareness and pressures brought to bear by the general public and special interest groups. Consequently, agencies like Metro continually need to demonstrate that tax dollars are being spent wisely to preserve and enhance water quality. No longer are citizens content to accept the verbal disserations on the how's and wherefores of sewage treatment. They need and demand results. Vivid examples of water quality changes are, often times, a rarity. Consequently, the results of a pollution abatement program are usually in the form of monitoring data showing water quality improvements.

Conclusion

Water quality monitoring has played a very significant role in the success of Metro's Water Pollution Abatement program. Water quality data and associated analyses have been an important part of the decision-making processes required by Metro and by Federal, State, local and private agencies alike. Today, all projects, large or small, require the study and analysis of water quality and other environmental impacts. In Metro's instance, the Water Quality Monitoring program is providing data required to support the argument for wastewater treatment and disposal based on local water quality needs rather than blindly complying with Federal guidelines for the sake of meeting regulations. This type of action has resulted in significant cost savings through changes in regulations or requirements. Conversely, monitoring data has, in some cases, required Metro to implement more costly treatment and disposal programs. However, in the final analysis, protection of the area's water quality is what's important. We at Metro have adhered to the philosophy that the use of public waters for waste disposal carries with it an obligation to protect and enhance the quality of those waters. Water quality monitoring is a key element in meeting this obligation.

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KAISER RESOURCES LTD.

ENVIRONMENTAL MONITORING

G. MICKELSON
JANUARY, 1976

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APPENDICES

ABSTRACT

Kaiser Resources Ltd. operates open pit and underground coal mines in the steep mountainous terrain of southeastern British Columbia. This operation produces six million short tons of metallurgical coking coal annually and operates twenty-four hours a day on a year-round basis.

Kaiser Resources is committed to the operation of its mines and related facilities in an environmentally acceptable manner. In order to meet this committment, KRL maintains an Environmental Services Department which is responsible for all on-site monitoring.

This paper will review the methods, procedures, and equipment utilized in the day-to-day monitoring of air and water quality at Kaiser Resources Ltd. Facilities, along with the parameters for analysis of various constituents relative to the requirements of governmental agencies.

I. INTRODUCTION

In order to meet clean air and water stanadards of government and the corporation, Kaiser Resources Ltd. established an Environmental Control Department in May of 1971 which was then staffed by an engineer and a chemical analyst. In 1972 Environmental Control and Reclamation were combined into the existing Environmental Services Department reporting directly to general management.

Prior to the establishment of the department, the environmental control activities were the responsibility of production departments assisted by consulting firms.

Presently there are nine permanent employees in Environmental Services of which four are directly employed for Environmental Control. Their functions are as follows:

1) To monitor all water, air and solid waste products on or about KRL property.

2) To maintain government-corporation rapport and keep up-to-date on environmental legislation affecting KRL.

3) To make recommendations and to assist in the implementation of remedial action so that ecological standards of both government and the corporation are continually achieved.

II. ENVIRONMENTAL STANDARDS

Governments at all levels have responded, through the creation of environmental departments, to the public concern for environmental management. However it is often confusing as to the overlapping jurisdictions that have occurred between Federal, Provincial and even municipal bodies. It is important to realize that each level of government has proprietory or ownership rights as well as legislative or law making rights. While the division of territorial rights is fairly easy to make, the division of legislative powers is often more difficult. However, regardless of which body establishes standards or objectives, the policing of these standards is generally left to the provincial authorities.

The traditional method of enforcement has been the penalty approach. As such the governments may impose fines, such as provided for in the British Columbia Pollution Control Act, 1967 or they can impose taxes.

In B. C. the most widely used administrative tool is the permit system. These normally take the form of construction and operating permits. These allow the government the opportunity of reviewing construction plans, emission control equipment and environmental impact studies, as well as to institute monitoring programs as the responsibility of the permittee.

Rather than adopt Federal standards, B. C.,following public hearings, established three levels for each general industry. All discharges from existing operations should be meeting level 'C' objectives. It is recommended that existing discharges be upgraded to level 'B' and ultimately to level 'A'. Level 'A' is set as an objective for new or proposed plants.

Standards for the coal industry are listed in the "Pollution Control Objectives for the Mining, Mine-milling, and Smelting Industries of British Columbia. (Appendix I)

III. ACTIVITIES (MONITORING)

1. Air Monitoring

In order to comply with the existing air quality legislation in 1971 (District of Sparwood By-law) an air monitoring program was established in the Sparwood district. At that time four high volume samplers (for suspended particulate) and ten dustfall samplers (established as two networks) were put into operation.

As new legislation came into effect and the need for more information grew, the air monitoring program expanded into its existing state as follows:

1. Six suspended particulate stations
2. Three dustfall networks (14 stations)
3. One sulphur dioxide monitor
4. Two metrological stations
5. Five sulphation samplers.

In addition to the ambient air monitoring, the department also monitors stack emissions (source testing) from one to six times a year as required by conditions of permit or operating need.

2. Water Monitoring

A surface water monitoring program was instituted by Kaiser Resources Ltd. in 1971. This program's purpose was twofold:

1. To determine the natural water quality of the Elk River and its affected tributaries
2. To determine the effect of Kaiser's operations on these water courses.

This program was carried out by the Environmental Control Department, samples being collected by the department's analyst and/or engineer. Sampling and analysis was performed, as far as possible, in accordance with the lastest edition of "Standard Methods for the

Examination of Water and Waste Water".

As the water monitoring program grew into its present form, the time involved for sample collection and analysis dictated the need for the program to be split into three parts. As such there are now three separate networks which are:

1. Elkview Network - 11 samples
2. Michel Network - 14 samples
3. Miscellaneous - 8 samples

These samples are analysed for as many as fourteen consituents.

In addition to the internal monitoring the department also maintains a sampling and monitoring program of ground and surface water as a requirement of Elkview refuse permits, and an effluent monitoring program as a requirement of Harmer and Michel sewage permits.

The major equipment used in the day-to-day monitoring is listed on the following page.

TABLE 1

EQUIPMENT

1. Lab

   a) analytical balance (with pollution chamber)
   b) incubator (capable of holding ±1°C)
   c) pH meter
   d) muffle furnace
   e) colorimeter
   f) spectrophotometer
   g) drying oven
   h) gas partitioner
   i) distillation unit
   j) filtration assembly

2. Field

   a) four wheel drive pick-up truck
   b) high volume samplers (6) and calibration kit
   c) EPA stack sampling train
   d) orsat gas sampler
   e) high volume stack sampler
   f) SO_2 monitor
   g) anemometers (2)
   h) water velocity indicator (direct reading)
   i) dustfall stations (14)
   j) barometer

IV. PARTICULATE MONITORING - AMBIENT

1. Suspended Particulate

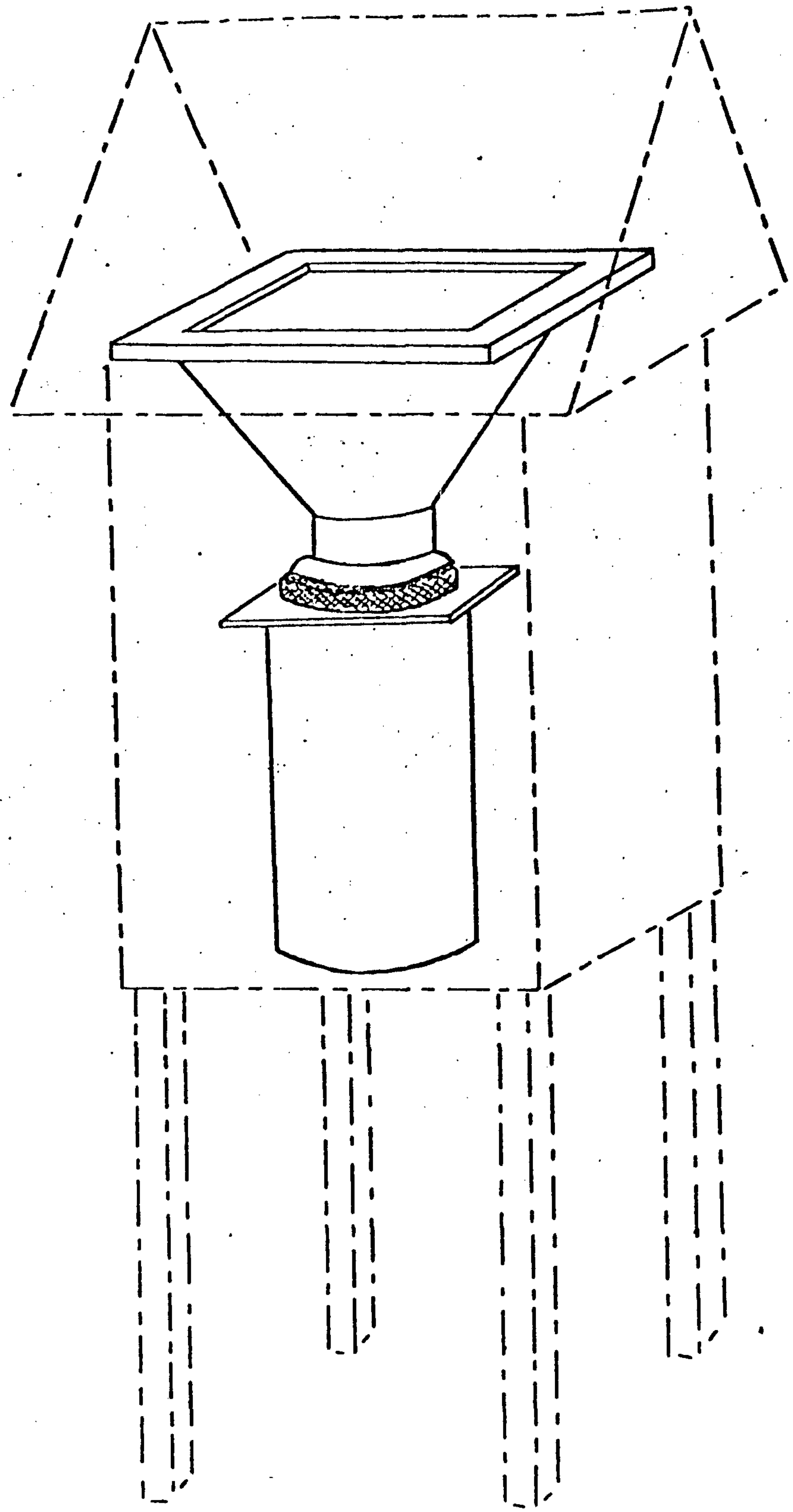
Air-borne dust particles are generally less than 100 microns in diameter. However suspended particulate is considered to be those particles below 10 microns in diameter since they have no significant weight or inertia and tend to remain suspended indefinitely in the atmosphere. Owing to a lower specific gravity, coal dust will become suspended at lower air velocities and tend to remain in suspension longer than road dust. Thus, a given polydispersed distribution of coal particles would result in more suspended particles than a similarly polydispersed distribution of road dust. This point should be kept in perspective when dealing with air quality standards.

Suspended particulate is conventionally sampled with high volume filtration devices. Kaiser Resources operates six standard Hi-volume samplers enclosed in conventional shelters (Figure 1). Two samples are located in residential areas, three in industrial areas and one in a background area (Figure 2).

Glass fibre filters (having a collection efficiency greater than 99 percent - based on particle count) are used to filter particulate matter from the sample air. Ambient air is drawn through the filter at a known rate for a period of twenty-four hours (standards are based on a twenty-four hour sampling period). The weight of the particulate matter is simply divided by the volume of air passed through the filter and the resultant calculation is the average dust concentration (expressed as micrograms per cubic metre) for the sampling period.

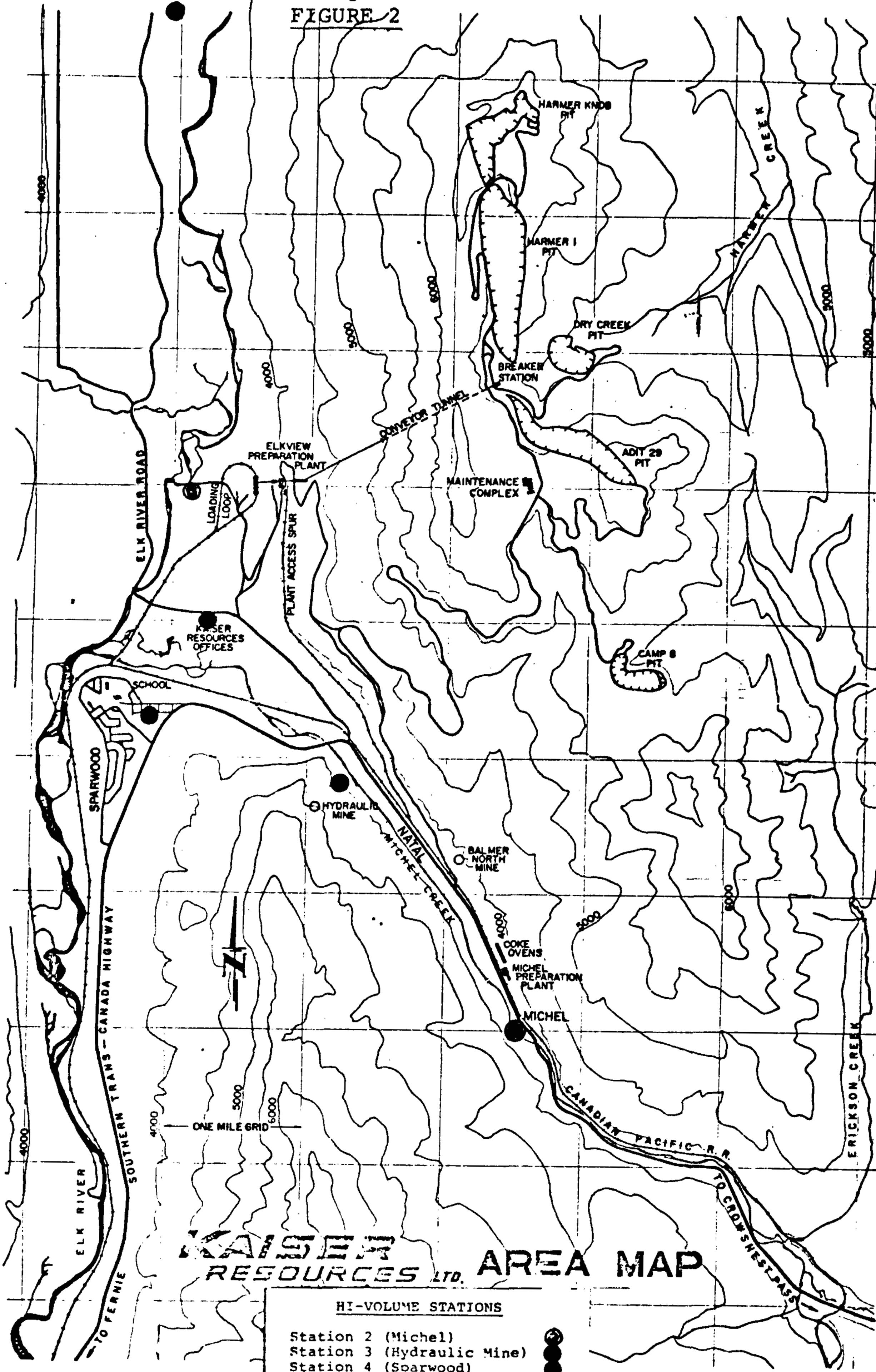
The procedure followed by KRL is presented in Appendix III.

FIG. 1



SAMPLER AND SHELTER

FIGURE 2



HI-VOLUME STATIONS

Station 2 (Michel)
Station 3 (Hydraulic Mine)
Station 4 (Sparwood)
Station 5 (Elkview)
Station 6 (Mian Office)
Station 7 (Elk Valley)

Sparwood By-law #111 (amendment to By-law 57) specifies certain industrial and residential particulate standards (Appendix II). Since most air pollutants are distributed approximately lognormally the Sparwood By-law is set up with limits based on 50% and 84% of the readings being less than given concentrations. In a lognormal distribution, the 50% reading should coincide with the arithemetic mean and the 84% reading represents the concentration which is one standard deviation larger than the mean. The present trend, however, as illustrated in the B. C. Pollution Control Objectives, is toward the use of the geometric means to express criteria and standards for particulate matter. This variance in criteria for setting standards often leads to confusion especially if one desires to determine which standards are the most stringent. Regardless, it is essential that particulate levels comply with all regulations.

The conditions of the KRL permit for air emissions require that suspended particulate be sampled, at all stations, 61 times a year on a random basis. Kaiser operates all high volume sampler four times a week in order that sufficient data can be obtained for correlation with the Sparwood By-law.

The Pollution Control guidelines for coal preparation, coke plants and bulk loading facilities set objective levels for the amount of coal or coke in the suspended matter. Initial attempts were made to determine percent coal by ashing the samples. This procedure was not too successful owing to poor accuracy of results and the need to operate two stations at each location since ashless filter papers cause a rapid reduction of air flow through the sampler. Coal determinations are presently determined by a pyridine coal extraction method.

High volume samplers have been very useful in determining dust levels and effects of control measures. The samplers are very reliable mechanically. Very little maintenance is required beyond periodic brush changes. Calibration of the samplers is recommended every month, however KRL has found that calibration is only required at each change of the brushes. The use of transformers to reduce operating voltage from 110 volts to 80 volts has increased brush life as much as three times. Some samplers operate in excess of four months between brush changes. The use of high volume samplers is limited to areas where electrical power is available. These areas are often near points of high work activity making it difficult to obtain representative samples of more than a very localized area.

2. Dustfall

Dustfall is a measure of particulate matter that settles out of the air. Generally speaking dustfall consists of particles greater than 10 microns in diameter. Particulate matter distribution is usually skewed to the small particle end of a plot percent frequency versus particle size. That is, in a normal particle dispersion, there is a greater percentage of smaller sizes. Thus, the majority of particle sizes is in the form of suspended particulate matter when considering a typical polydispersed distribution. In incidences where a heavy dustfall is found with relatively low suspended particulate matter levels, it can be seen that large particles are being artificially introduced into the atmosphere. These particles usually emanate from mechanical or combustion sources. Most settable matter will only remain airborne for a few days at most.

Dustfall is determined by exposing a cannister containing a collection medium to the air for a one month period. After exposure the cannisters are sealed and taken to the laboratory for gravimetric analysis. Dustfall is expressed in tons per square mile per month or in milligrams per square centimetre per month.

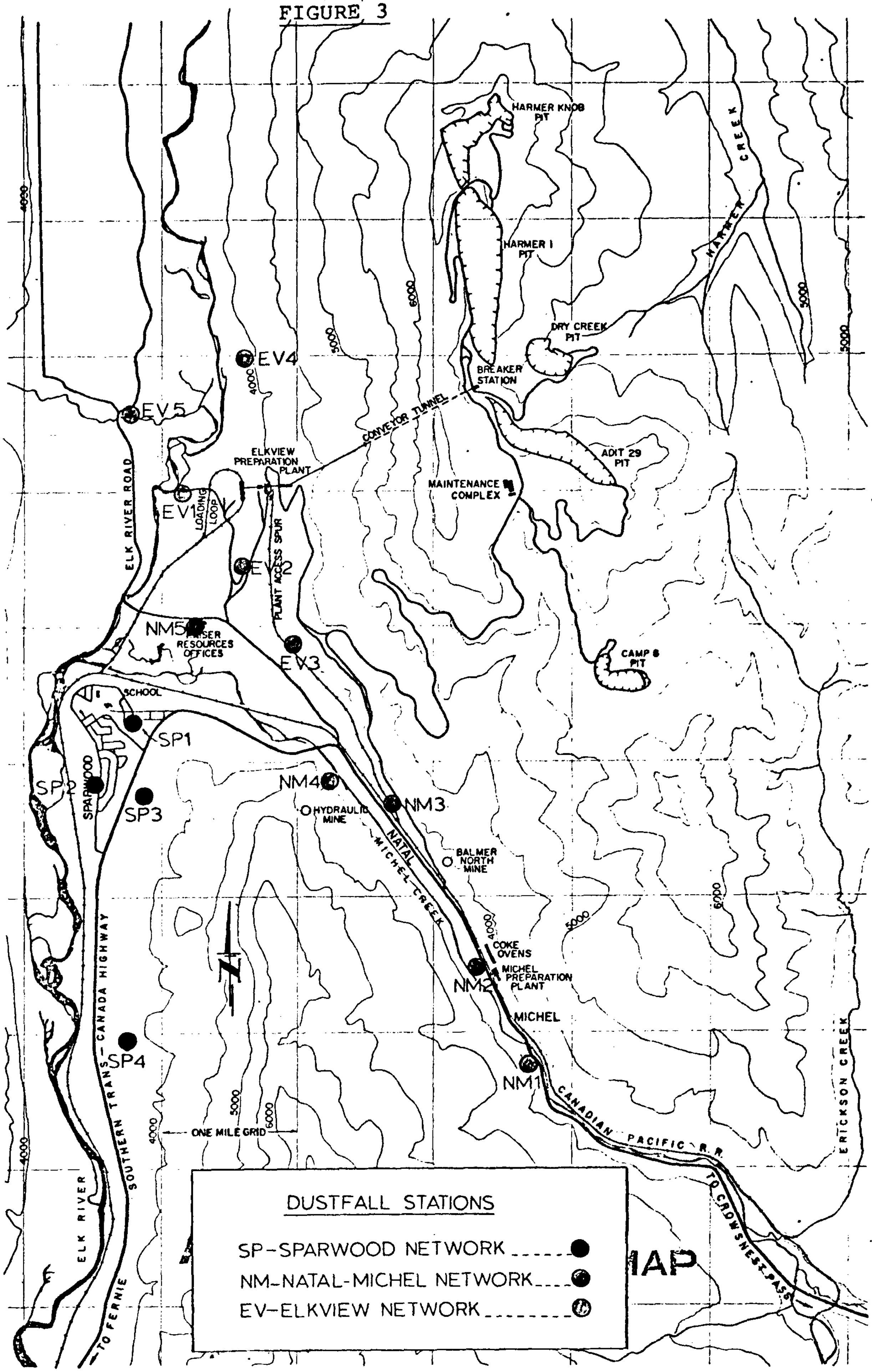
Two dustfall networks, Elkview and Natal-Michel (ten cannisters), were established in December 1971. A third network (four cannisters) were added in the Sparwood area in July 1972. This brought the dustfall monitoring up to its present state (Figure 3). Kaiser uses standard dustfall cannisters which are 8.5 inches high and have a top diameter of 4 inches tapering to 3.5 inches at the bottom. Guidelines as reference to assist in the selection of dustfall sites and the laboratory procedure for the determination of dustfall are presented in Appendix IV.

In the past, dustfall samples, like suspended particulate samples, were ashed in an effort to determine the percent coal. The accuracy of the ash tests is rather poor. Coal determinations are now being made by the quasi-standard pyridine coal extraction method . The success (or failure) of this method has not yet been established by KRL.

Though dustfall measurements are not highly accurate their use by KRL has been very successful. Although stack emissions do contribute to measurable dustfall, large variances in winter and summer dustfall levels indicate that the largest percentage is due to fugitive dust sources such as vehicle travel and stockpiles. Dustfall measurements aid in determining the success or failure of control techniques as well as providing a measurement for the effects in relatively localized dusty areas.

Kaiser's dustfall program was accepted by the PCB as being adequate for dustfall monitoring as a requirement of Elkview's air emission permit.

FIGURE 3


HARMER KNOB PIT
HARMER CREEK
HARMER I PIT
DRY CREEK PIT
BREAKER STATION
CONVEYOR TUNNEL
EV4
EV5
ELKVIEW PREPARATION PLANT
ADIT 29 PIT
MAINTENANCE COMPLEX
EV1
LOADING LOOP
ELK RIVER ROAD
PLANT ACCESS SPUR
EV2
NM5
KAISER RESOURCES OFFICES
EV3
CAMP 6 PIT
SCHOOL
SP1
SPARWOOD
SP2
SP3
NM4
NM3
HYDRAULIC MINE
NATAL
MICHEL CREEK
BALMER NORTH MINE
COKE OVENS
MICHEL PREPARATION PLANT
NM2
MICHEL
NM1
ERICKSON CREEK
SP4
SOUTHERN TRANS-CANADA HIGHWAY
ONE MILE GRID
CANADIAN PACIFIC R.R.
TO CROWSNEST PASS
ELK RIVER
TO FERNIE
DUSTFALL STATIONS
SP-SPARWOOD NETWORK
NM-NATAL-MICHEL NETWORK
EV-ELKVIEW NETWORK

V. SULPHUR DIOXIDE MONITORING - AMBIENT

Sulphation Index is the simplest method for the determination of sulphur dioxide pollution. An inverted plate containing a suspension of lead dioxide is exposed to the atmosphere for one month. Sulphur dioxide reacts with the lead dioxide to form lead sulphate. Sulphation index monitoring has the advantage of being economical, convenient to sample and analyze, and sensitive to low atmospheric concentrations of sulphur dioxide. The resulting lead sulphate is measured turbidimetrically and reported in mg $SO_3/dm^2/day$.

As a requirement of Elkview's air emission permit, five sulphation plates have been located to cover the E - W directions of the Elkview and Michel Plants, measured 12 times per year.

Ambient SO_2 levels have also been monitored using a continuous recording conductivity monitor. This unit is no longer in use owing to extremely high maintenance and difficulties in calibration. A review of SO_2 data indicates that the monitor serves little purpose (ambient levels are always low and the instrument does not indicate plant upsets). Also, since the level of sulphur in the coal is low, it is felt that the operation of this monitor is not required.

VI. METEOROLOGICAL PARAMETERS

Two cup-type anemometers for measuring wind speed and direction have been established in the Sparwood area. One station is located in downtown Sparwood and the other near the Elkview Plant. Also, daily readings of precipitation, barometric pressure, maximum ambient temperature and minimum ambient temperature are recorded.

This data is summarized daily, weekly or monthly as required and reported with ambient monitoring results.

Meteorological data is useful for both data interpretation and site selection for monitoring stations.

VII. SOURCE TESTING

Source testing was first performed for KRL in 1971 by outside consultants in order to obtain necessary data to apply for air emission permits. Since that time, an air emission permit has been received for the Elkview coal prepararion plant and all the necessary equipment is on hand for "in house" monitoring.

In B. C. source testing procedures (stack emissions) for the determination of particulate concentration, SO_2, and the rate of discharge (flow rate) are to be carried out in accordance with the procedures described in the third edition of "Source Testing Manual for the Determination of Discharges to the Atmosphere". Alternative methods must be approved by the Director (of the B. C. Pollution Control Branch).

A summary of stack monitoring as performed by KRL is presented on the following page (Table 2).

To analyse the gaseous constituents of the stack gases, an orsat type analyser is used to monitor high levels (in the percent range) of carbon dioxide, carbon monoxide and oxygen. These data plus percent moisture are used to determine the density of the stack gases.

Stack velocities (and hence rate of discharge) are measured using a pitot tube and inclined manometer. Rate of discharge is reported in standard cubic feet per minute (SCFM) where 1 SCFM is defined as one cubic foot per minute of dry gas at $68^{\circ}F$ and 1 atmosphere pressure.

TABLE 2

STACK MONITORING SUMMARY

Emission source	# of Stacks	Pollution Control Equipment	Monitoring Parameters	Sample Equipment	Emission Type (1)	Annual (4) Monitoring Frequency
Elkview Coal Dryer	2	4 cyclones Impingment Scrubber	Particulates SO_2, flow	EPA (2)	3	4
Raw Coal Silo Dedusting	1	Baghouse	Particulate, flow	Raders (3)	4	1
Elkview Boilers	1	-	Particulate, flow	EPA	4	1
Clean Coal Silo Dedusting	2	Venturi Scrubber	Particulate, flow	Rader	4	1
Met belt Dedusting	1	Venturi Scrubber	Particulate, flow	Rader	4	1
Breaker Station	1	2 cyclones	Particulate, flow	Rader	4	4
Michel Boiler	1	-	Particulate, SO_2, flow	EPA	2	-
Coke Ovens	4	-	Particulate, SO_2, flow	EPA	1	-
Michel Coal Dyer	4	cyclones scrubbers	Particulate, SO_2, flow	EPA	3	-
Michel Breeze Dryer	1	Cyclone	Particulate, SO_2, flow	EPA	4	-

(1) Emission Type:
1. High Temperature, High Moisture
2. High Temperature, Low Moisture
3. Low Temperature, High Moisture
4. Low Temperature, Low Moisture

(2) EPA - Emission Particle Analyser PM 100 sampling train

(3) Rader - High volume stack sampler

(4) Annual monitoring frequency as required by permit

To determine particulate loading, recorded in grains per standard cubic foot, in the various stacks two types of samplers are employed to obtain representative results. One of the two types is specified for the four categories of stack exhausts present.

1. High Temperature, Low Moisture

This type of exhaust is present at the four Michel coke oven stacks. These stacks are sampled with a Lier-Siegler PM-100 EPA sampling train. Moisture is determined by collection in the impingers.

2. High Temperature, Low Moisture

This type of exhaust is present at the Michel Boiler Stack. Sampling is the same as category 1.

3. Low Temperature, High Moisture

This type of exhaust characteristic is commonly found when the flue gases pass through a liquid scrubber system before entering the discharge stack. These exhausts are present at the Elkview and Michel coal dryer stacks. The EPA train is most suitable here owing to its wet impingement collection method.

4. Low Temperature, Low Moisture

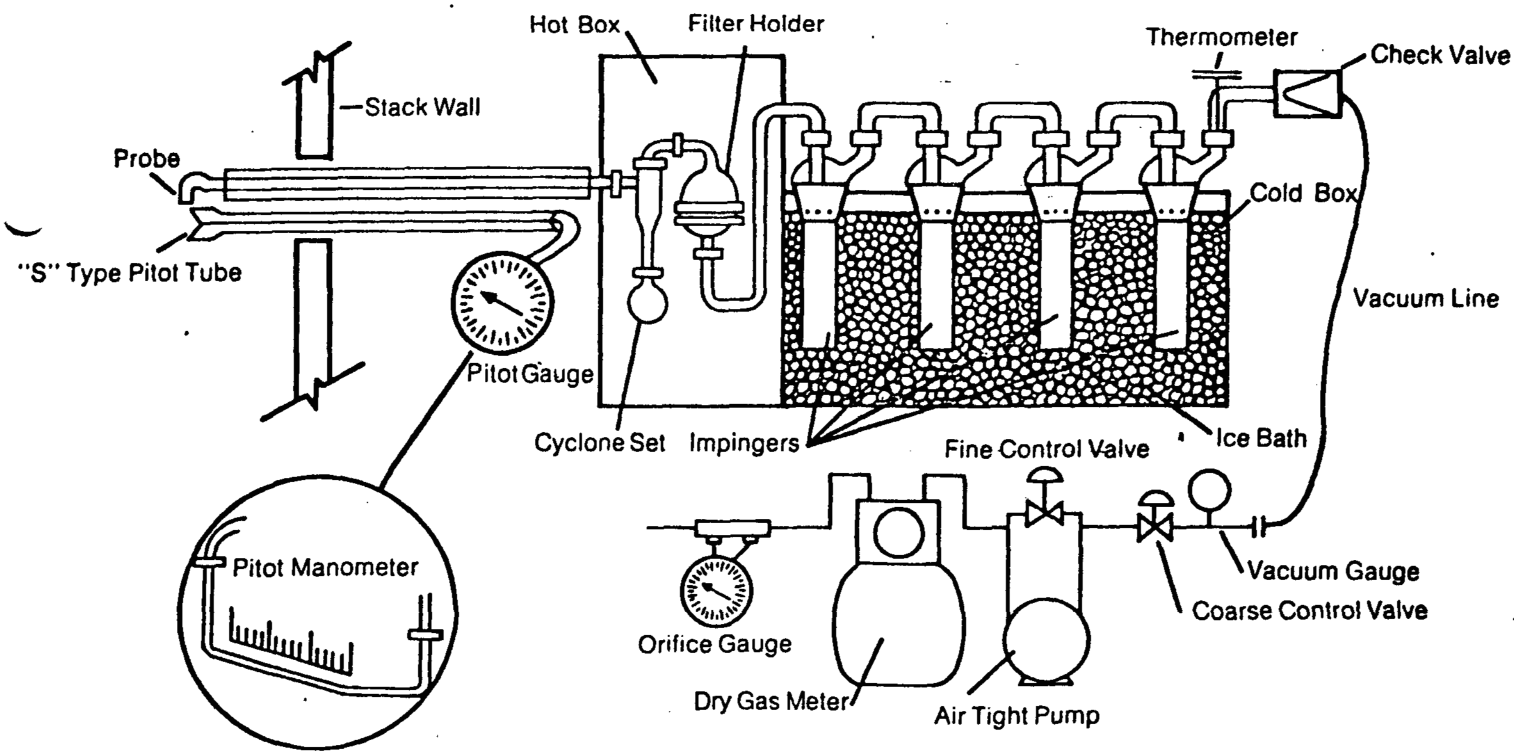
This type of emission is present at the Raw Coal Silos, Clean Coal Silos, Elkview Boilers, Met Coal Belt Deduster, Breaker Station, and Michel Breeze Dryer. For these sources, a high volume stack sampler is often the most appropriate train to use (except for combustion sources).

The emission particle analyser (EPA) sampling train used by Kaiser is a Lear-Siegler PM-100 model. In this sampling train, the gas sample passes through a cyclone, filter, and wet impingers. Sampling rates of 0.5 to 1.0 cfm are used to establish isokenetic sampling conditions. A sketch of the PM-100 sampling train is shown in Figure 4.

The high volume sampler train used by Kaiser Resources is capable of drawing up to 40 cubic feet per minute, thus saving time and labour in collecting samples. Furthermore,

FIGURE 4

PM100 Sampling Train



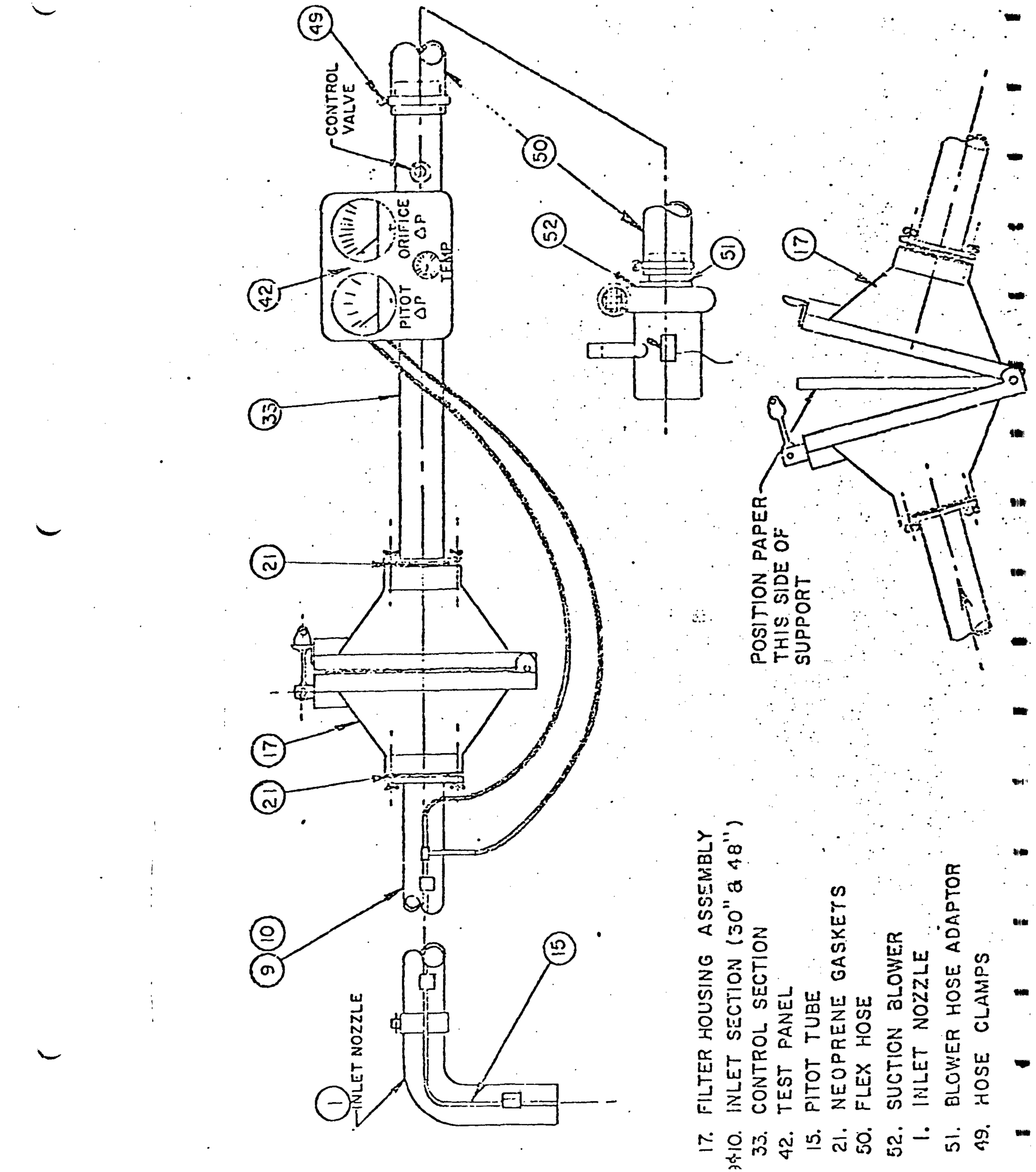
the Rader high volume sampler, as shown in Figure 5, is easy to handle and uses the same type of 8 inch by 10 inch glass filter paper as the ambient high volume samplers. This sampler is widely used in the Pacific Northwest.

The sample is drawn to the collector by a blower located downstream and isokinetic conditions (determined by a pilot near the nozzle entrance)} are maintained by adjusting a vavle located at the inlet to the blower.

The stack sampling data, as well as dustfall and suspeneded particulate data is reported quarterly to the PCB Director as a condition of permit.

FIGURE 5

RADER HIGH VOLUME SAMPLER



VIII. WATER MONITORING

Kaiser Resources maintains an internal water monitoring in addition to the programs required by permit. Unless detailed information is required, such as fluctuations in plant operation, most analyses are performed on grab samples or simple composite samples (over a short time span). Generally, a two litre sample is adequate for most analyses.

Since sample changes may result if long storage periods are required, the internal water monitoring program was split into three networks. This permits collection and analysis of samples to be completed in one day. Comparisions of field analysis and laboratory analysis (except for dissolved oxygen) has shown no sighnificant differences in results if analysed the same day.

1. Internal Water Monitoring

The water samples collected for internal monitoring are listed in Table 3 (parts 1 to 3) and shown in Figure 6. Analysis parameters are listed in Table 4. A typical report sheet is illustrated in Figure 7.

The Michel and Elkview networks are named for the plant operations which may affect part of the samples, and are entirely separate, having no effect on each other. Each group of samples is collected every two weeks. Not all parameters are included in the analyses each time, and some parameters are included as a measurement of background or "unaffected" water quality. There is no set rule for the samples and analyses required. The elimination or continuation of any given sample is based on experience.

All analyses are now performed in accordance with "A Laboratory Manual for the Chemical Analysis of Water, Wastewaters and Biological Tissues", or the 13th edition of "Standard Methods for the Examination of Water and Wastewater".

TABLE 3

WATER SAMPLES

1. Elkview Network

Sample Designation	Description
ER 1	Elk River Upstream to Elkview Plant
EP 2	Elk River Downstream to Elkview Plant
SC 1	Sawmill Creek at confluence with Harmer Creek
HD 1	Influent to Harmer Dam
HD 2	Effluent to Harmer Dam
GC 1	Grave Creek at confluence with Elk River
GC 2	Grave Creek above Harmer Creek
SM 1	Six Mile Creek at confluence with Elk River
OC 1	Otto Creek at confluence with Elk River
WC 1	Whiting Creek at confluence with Elk River
CC 1	Cummings(Wilson) Creek at confluence with Elk River

2. Michel Network

Sample Designation	Description
AC 1	Alexander Creek at confluence with Michel Creek
MC 1	Michel Creek upstream to Michel Plant
MC 4	Michel Creek downstream to Michel Plant and Hydraulic Mine screening plant
MC 2	Michel Creek at confluence with Elk River
MC 3	Michel Creek upstream of Alexander Creek
ED 1	Influent to Erickson Dam
ED 2	Effluent from Erickson Dam
EC 1	Erickson Creek at confluence with Michel Creek
MM 1	Michel Mine water (abondoned Balmer South)
BN 1	Balmer North Mine water upper portal
BN 2	Balmer North Mine water lower portal
MM 8	Coke Oven effluent
MM 9	Michel settling ponds effluents to Michel Creek
BC 1	Baldy Creek at confluence to Michel Creek

TABLE 3 (Cont'd)

3. Miscellaneous Network

Sample Designation	Description
UD 1	Harmer Ridge oxidation ditch influent
UD 2	Harmer Ridge oxidation ditch effluent
UD 3	Harmer Ridge oxidation ditch recycle
LD 2	Michel Oxidation ditch effluent
BC 1	Baldy Creek at confluence to Michel Creek
BC 2	Baldy Creek at head waters below UD 2
BC 3	Baldy Creek upstream to Balmer North Mine
CW 1	Michel Compressor cooling water

4. Elkview Permit Samples

Sample Designation	Description
EP 1	Elk River upstream from Elkview Plant
EP 2	Elk River downstream from Elkview Plant
EP 3	Elkview Plant tailings to lagoons
EP 4	Lagoon supernatant (to recycle)
EP 5	Camp well (destroyed)
EP 6	Well below Lagoon A (destroyed)
EP 7	Well below Lagoon C
EP 8	Well below Lagoon C
EP 9	Well Below Lagoon C
EP 10	Surface water background sample (eliminated from program by PCB)
EP 11	Surface water, Old refuse site (destroyed by expansion of refuse site)
EP 12	Surface water, New refuse site
EP 13	Otto Creek at confluence to Elk River
EP 14	Surface water, swamp below new refuse area
EP 15	Ground water, coarse refuse site
EP 16	Well below Lagoon D
EP 17	Well below Lagoon D
EP 18	Well below Lagoon D

FIGURE 6

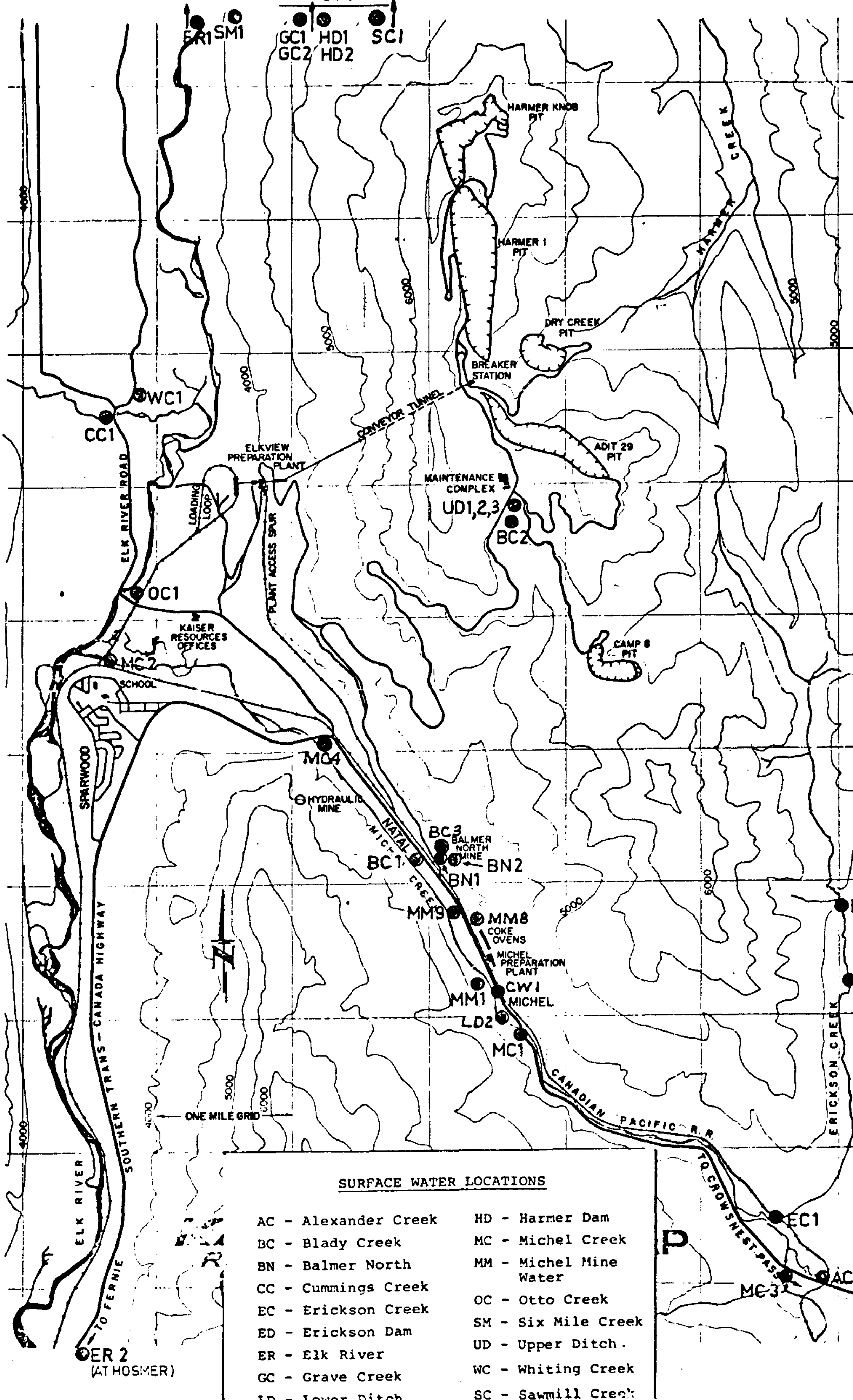

ER1
SM1
GC1 HD1
GC2 HD2
SC1
HARMER KNOB PIT
HARMER 1 PIT
HARMER CREEK
DRY CREEK PIT
BREAKER STATION
CONVEYOR TUNNEL
ADIT 29 PIT
MAINTENANCE COMPLEX
UD1,2,3
BC2
WC1
CC1
ELKVIEW PREPARATION PLANT
LOADING LOOP
ELK RIVER ROAD
PLANT ACCESS SPUR
OC1
KAISER RESOURCES OFFICES
CAMP 8 PIT
MC2
SCHOOL
SPARWOOD
MC4
HYDRAULIC MINE
NATAL
MICHEL CREEK
BC3
BALMER NORTH MINE
BC1
BN2
BN1
MM9
MM8
COKE OVENS
MICHEL PREPARATION PLANT
MM1
CW1
MICHEL
LD2
MC1
ED1
ED2
ERICKSON CREEK
SOUTHERN TRANS-CANADA HIGHWAY
CANADIAN PACIFIC R.R.
TO CROWSNEST PASS
ONE MILE GRID
ELK RIVER
TO FERNIE
ER 2
(AT HOSMER)
EC1
MC3
AC1
4000
5000
6000
SURFACE WATER LOCATIONS
AC - Alexander Creek
BC - Blady Creek
BN - Balmer North
CC - Cummings Creek
EC - Erickson Creek
ED - Erickson Dam
ER - Elk River
GC - Grave Creek
LD - Lower Ditch
HD - Harmer Dam
MC - Michel Creek
MM - Michel Mine Water
OC - Otto Creek
SM - Six Mile Creek
UD - Upper Ditch
WC - Whiting Creek
SC - Sawmill Creek

TABLE 4

ANALYSIS PARAMETERS - WATER

1. Internal
   - Temperature
   - Dissolved Oxygen
   - Biochemical Oxygen Demand (BOD_5)
   - Alkalinity
   - Acidity
   - pH
   - Suspended Solids
   - Dissolved Solids
   - Turbidity
   - Color
   - Iron
   - Phenolics
   - Ammonia
   - Oil and Grease
   - Surfactants
   - Flow Rate
   - Sulphates
2. External
   - Iron
   - Nickel
   - Lead
   - Zinc
   - Chromium
   - Aluminium
   - Copper
   - Mercury
   - Arsenic
   - Filtered Organic Carbon
   - Coliform

FIGURE 7

KAISER RESOURCES LTD.

ENVIRONMENTAL CONTROL

REPORT OF WATER SAMPLES

______ NETWORK

DATE ______

Sample Location													
Sampling Time													
Temperature °C													
Dissolved Oxygen (mg/1)													
BOD (5 Day 20 C)(mg/1)													
Alkalinity (mg/1)	P												
	M												
Acidity (mg/1)													
pH													
Sulphates (mg/1)													
Solids	Susp.(mg/1)												
	Total (mg/1)												
Turbidity (as SiO_2)													
Color													
Iron (mg/1)													
Phenolics (mg/1)													
Ammonia (mg/1)													
Flow rate cfs :													

Sampled By ______

Symbols N.D. = Not Detectable

N.R. = Not Run

Limits of Analysis

I. Iron: 0.01 ppm.

II. Ammonia 0.01 ppm

III. Phenols: 0.10ppm

Analysed By ______

Report Date ______

KRL-REC-2

2. Water Monitoring - Permits

A sampling and monitoring program for surface and ground water was established in conjunction with the granting of refuse permits for the Elkview Preparation Plant. Sample site locations were selected in the field by representatives from the Pollution Control Branch.

Initially, samples were required every six weeks and there were fourteen samples encompassing twenty-two analysis parameters. This program was revised after three years requiring fifteen samples (Figure 8) to be collected every quarter. The number of parameters was reduced to thirteen.

The program in its present form is as follows:

1. Samples are to be collected and reported quarterly

2. Samples consist of seven surface water samples, seven ground water samples and one effluent sample (Preparation Plant fine tailings)

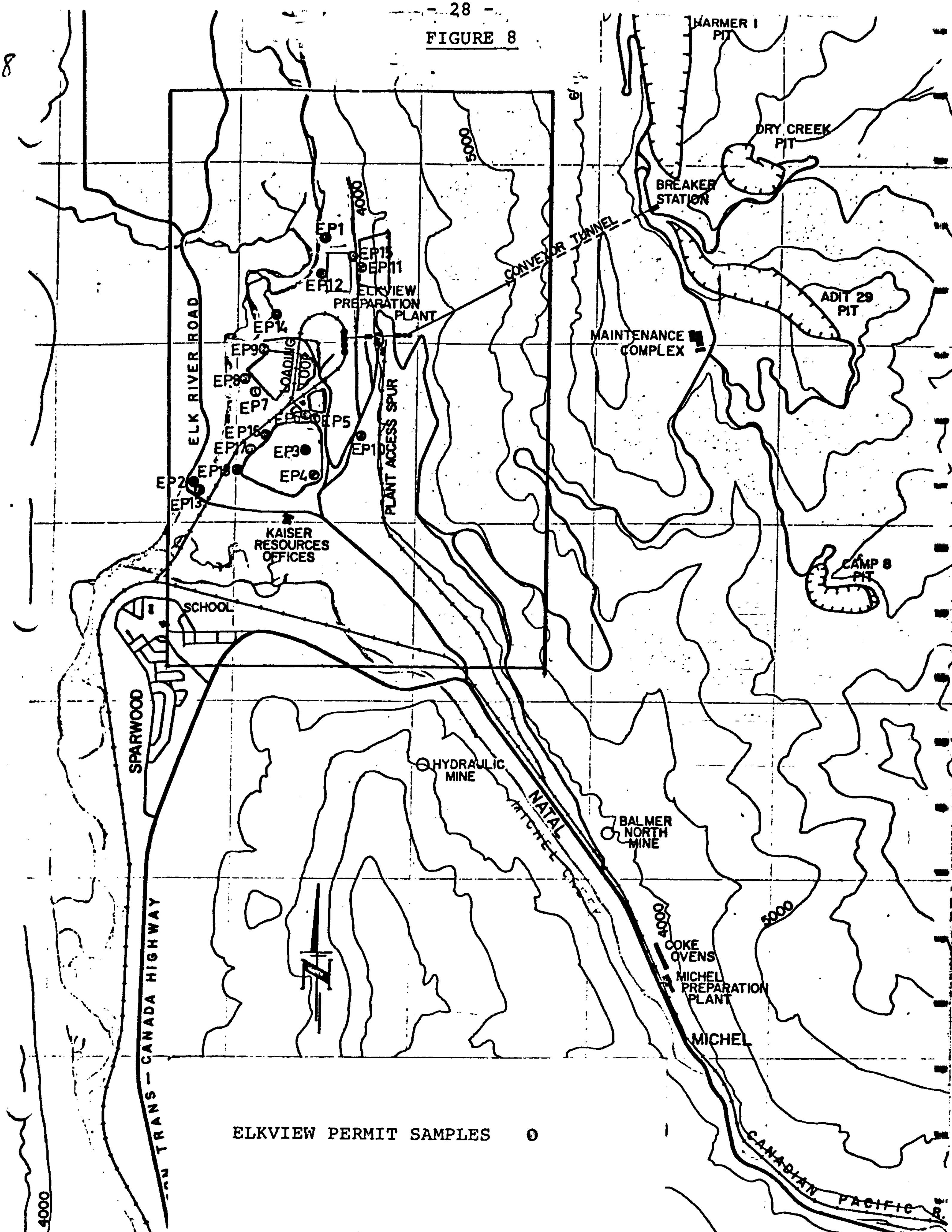
3.Analyses includes the following parameters: total solids, mg/l; turbidity, mg/l as SiO_2; pH; alkalinity, mg/l as $CaCO_3$; acidity, mg/l as $CaCO_3$ to phenolphathalein end point at pH 8.3; total organic carbon filtered, mg/l; dissolved metals, Cu, Pb, Fe, and Cr, mg/l; total Hg, mg/l.

All analysis is performed on site with the exception of total organic carbon filtered, dissolved metals Cu, Pb, Fe, Cr and total Hg.

3. Miscellaneous

Two large dams have been built on Harmer and Erickson Creeks in order to protect down stream values from possible mishaps during surface mining activities. Water licences require that the build up of solids be monitored annually. This is accomplished during the winter by taking depth measurements form the ice surface. During the winter, snowmobiles are required for access to the dams. A set of readings takes three men from two to five days to complete

FIGURE 8



ELKVIEW PERMIT SAMPLES ⊙

depending on ice and weather conditions. Approximately one hundred readings taken at ten to fifty foot spacings are required in order to draw the necessary contour map.

Blowing dust from unit coal trains has long been an aesthetic pollution problem. Control of blowing dust is accomplished by spraying each coal car at the mine site with a chemical binder. At this time the only successful method of monitoring the effectiveness of the binders is to view the individual cars at the unloading port. Effectiveness is based on the amount of binder crust remaining on the coal surface after transport.

Two sewage facilities (oxidation ditches) under permit require composite effluent samples (over four hours) to be collected every three months. Analyses of the samples are made for: a) 5-day Biochemical Oxygen Demand

b) Total Suspended Solids

c) Fecal Coliform Bacteria

Reports of analyses along with the flow rate for a twenty-four hour period each week are submitted to the Pollution Control Branch annually.

IX. DISCUSSION

Kaiser's environmental monitoring has developed steadily over the last five years but still has a long way to go. Reduced or increased water monitoring will take place this year after a detailed review of the data. A suitable procedure for sampling the Elkview dryer stacks has yet to be established owing to the short stacks (eight feet) which are twenty feet in diameter, and have a negative flow in the centre. The optimum use of coal binders both for unit trains and stockpiles has not been determined. The use of continuous monitors, for water and stack emissions needs further investigation and the field of biological analysis has not been entered.

This list is by no means complete. New and improved monitoring devices are coming on the market almost daily and the need for analysis of various parameters is constantly changing.

As a general guide in establishing a monitoring program, the best source of information is the Provincial Pollution Control Branch. The Regional offices of the PCB are generally well staffed with qualified personnel who are very willing to provide information regarding procedures for monitoring and the standards that must be met.

APPENDIX I

POLLUTION CONTROL OBJECTIVES
FOR
THE MINING, MINE-MILLING AND
SMELTING INDUSTRIES
OF
BRITISH COLUMBIA

November 30, 1973
Section 5 Appendices

5. APPENDICES

APPENDIX I

MINING, MINE-MILLING, SMELTING, AND ASSOCIATED INDUSTRIES

Table I—Desirable Levels of Ambient Air Quality

Contaminant	Units	Level A	Level B	Level C	Monitoring
1. Sulphur dioxide					Continuous (supplemented by sulphation plates).
(a) Annual arithmetic mean	μg/m³	53	80	80	
	ppm	0.02	0.03	0.03	
(b) 24-hr. conc. (max.)	μg/m³	266	373	373	
	ppm	0.10	0.14	0.14	
(c) 3-hr. conc. (max.)	μg/m³	—	799	799	
	ppm	—	0.3	0.3	
(d) 1-hr. conc. (max.)	μg/m³	199	—	—	
	ppm	0.3	—	—	
2. Fluoride (gaseous)					Continuous.
(a) Annual arithmetic mean	μg/m³	0.5	0.5	1.0	
(b) 7 days	μg/m³	1.0	1.0	1.7	
3. Suspended particulate matter					24 hours per week.
(a) Total—					
Annual geometric mean	μg/m³	60	70	75	
Max. 24 hrs.	μg/m³	150	200	260	
(b) Lead—					
Annual geometric mean	μg/m³	2	2	3	
Max. 24 hrs.	μg/m³	4	4	6	
(c) Zinc—					
Annual geometric mean	μg/m³	3	3	4	
Max. 24 hrs.	μg/m³	5	5	8	
(d) Cadium—					
Annual geometric mean	μg/m³	0.05	0.05	0.1	
Max. 24 hrs.	μg/m³	0.1	0.1	0.3	
4. Dustfall					Collected over one month period.
(a) Residential	mg/cm²/mo	0.525	0.525	0.700	
	tons/mi²/mo	15	15	20	
(b) Other	mg/cm²/mo	0.875	0.875	1.225	
	tons/mi²/mo	25	25	35	
5. Mercury	μg/m³	1.0	1.0	1.0	Monthly average.
6. Arsenic compounds					24 hours per week.
Annual geometric mean	μg/m³	0.2	0.2	0.5	
Max. 24 hrs.	μg/m³	1.0	1.0	1.0	
7. Asbestos[1]					

[1] To be reviewed.

Table II—Objectives for Gaseous and Particulate Emissions

Contaminant	Objective Levels[1] Unit	A	B	C	Monitoring
Total particulate	mg/m³	229	286	343	Isokinetic sampling on a 0.3-μ glass-fibre filter followed by gravimetric analysis.
	gr/SCF	0.100	0.125	0.150	
Lead as Pb	mg/m³	7	11	23	Isokinetic sampling on a 0.3-μ glass-fibre filter followed by digestion and colorimetric or atomic absorption analysis for lead.
	gr/SCF	0.003	0.005	0.010	
Zinc as Zn	mg/m³	7	11	23	Isokinetic sampling on a 0.3-μ glass-fibre filter followed by digestion and colorimetric or atomic absorption analysis for zinc.
	gr/SCF	0.003	0.005	0.010	
Cadmium as Cd	mg/m³	7	11	23	Isokinetic sampling on a 0.3-μ glass-fibre filter followed by digestion and colorimetric or atomic absorption analysis for cadmium.
	gr/SCF	0.003	0.005	0.010	
Arsenic as As	mg/m³	7	11	23	Isokinetic sampling on a 0.3-μ glass-fibre filter followed by digestion and colorimetric analysis of arsenic.
	gr/SCF	0.003	0.005	0.010	
Mercury as Hg	mg/m³	7	11	23	Isokinetic sampling with absorption in 1 M $KMnO_4$ solution and analyses by flameless atomic absorption.
	gr/SCF	0.003	0.005	0.010	
Sulphur dioxide (excluding power boilers)—					
(*a*) Option I	mg/m³	666	2662	6656	Continuous analysers on discharges greater than 250 ppm.
	ppm	250	1000	2500	
(*b*) Option II	Sulphur dioxide control régime (*See* section 2.2)				

[1] Levels apply to each discharge on an individual basis.

Table III—Control Objectives for Gaseous and Particulate Emissions for Specific Processes

Contaminant	Objective Levels A	B	C	Monitoring
A. *Emission Control Objectives*				
1. Aluminum reduction	—	—	—	Discharge: Isokinetic sampling on a 0.3-μ glass-fibre filter and 0.1 normal sodium hydroxide solution followed by colorimetric or specific ion analysis. Environment: Continuous ambient air analysis and biota-soil survey (*see* section 2.5).
(*a*) Total particulate—lb./ton of Al	10	15[1]	33	
(*b*) Fluoride (gaseous and particulate)—lb./ton of Al	3	5	10	
2. Lead smelting and refining	—	—	—	Isokinetic sampling on a 0.3-μ glass-fibre filter followed by digestion and colorimetric or atomic absorption analysis.
(*a*) Total particulate—lb./ton of Pb	8.5	11.5	13.0	
(*b*) Lead—lb./ton of Pb	0.9	1.5	2.0	
(*c*) Zinc—lb./ton of Pb	0.3	0.5	0.6	
(*d*) Arsenic—lb./ton of Pb	0.3	0.5	0.6	
3. Zinc smelting	—	—	—	Isokinetic sampling on 0.3-μ glass-fibre filter followed by digestion and colorimetric or atomic absorption analysis.
(*a*) Total particulate—lb./ton of Zn	—	5.1	5.8	
(*b*) Zinc—lb./ton of Zn	—	0.7	0.9	
(*c*) Arsenic—lb./ton of Zn	—	0.03	0.2	
4. Nitic acid plants	—	—	—	Daily analyses of oxides of nitrogen either by impinger and colorimetric methods or continuous monitoring.
NOx—lb./ton of acid	5	20	60	
5. Ammonium phosphate plants	—	—	—	Discharges: Isokinetic sampling on 0.3-μ glass-fibre filter and 0.1 normal sodium hydroxide solution followed by colorimetric or specific ion analysis. Environment: Continuous ambient air analysis and biota-soil survey (*see* section 2.5).
Fluoride—lb./ton of P_2O_5	0.2	0.5	1.4	
B. *Ambient Air Control Objectives*				
1. Mining and milling	—	—	—	Collection on a 0.3-μ fibre filter by high-volume sampler operated for one 24-hr. period once per week. Gravimetric analysis.
Total suspended particulate matter—(*a*) (including background)—Annual geometric mean ($\mu g/M^3$)	60	70	75	
Max. 24 hr. ($\mu g/M^3$)	150	200	260	
(*b*) Maximum allowable (above background)—Annual geometric mean ($\mu g/M^3$)	15	20	30	
2. Coal preparation, coke plants, and bulk-loading facilities	—	—	—	Collection on a 0.3-μ glass-fibre filter by a high-volume sampler operated for one 24-hr. period once per week. Analyses—total particulate by gravimetric analysis. Coal by coal-extraction method.
(*a*) Total suspended particulate matter (including background)—Annual geometric mean ($\mu g/M^3$)	60	70	75	
Max. 24 hr. ($\mu g/M^3$)	150	200	260	
(*b*) Coal or coke in suspended particulate matter—Annual geometric mean ($\mu g/M^3$)	5	15	20	

[1] Tentative, subject to review.

Table IV—Objectives for Effluent Discharges

Characteristics	Description	Unit of Measurement	Marine-water Discharge Level A	Marine-water Discharge Level B	Marine-water Discharge Level C	Fresh-water Discharge Level A	Fresh-water Discharge Level B	Fresh-water Discharge Level C
Total suspended solids (non-filterable residue)	That portion of the effluent, as discharged which is retained by an approved filter	mg/l	50[1]	150[1]	([2])	50[1]	150[1]	([2])
Total dissolved solids (filterable residue)	That portion of the effluent as discharged which passes through an approved 0.45-micron pore-sized filter	mg/l	—	—	—	<2,500	<3,500	<5,000
Colour[3]	Colour of the effluent, at the point of discharge	Approved units	—	—	—	—	—	—
pH[2]	The pH of the effluent at the point of discharge	pH units	6.5–8.5[4]	6.5–9.5	6.0–10	6.5–8.5[4]	6.5–9.5	6.0–10
Specific elements and compounds[1]	Material contained in the effluent, at the point of discharge, which passes an approved 0.45-micron pore-sized filter (except where total values are required)	—	—	—	—	—	—	—
Aluminum (Al)	Dissolved in the effluent	mg/l	0.50	1.00	10.00	0.50	1.00	10.00
Ammonia (as N)	Dissolved in the effluent	mg/l	0.50[4]	1.00	10.00	0.50[4]	1.00	10.00
Antimony (Sb)	Dissolved in the effluent	mg/l	0.05	0.25	1.00	0.05	0.25	1.00
Arsenic (As)	Dissolved in the effluent	mg/l	0.05	0.25	1.00	0.05	0.25	1.00
Cadmium (Cd)[5]	Dissolved in the effluent	mg/l	0.005	0.01	0.02	0.005	0.01	0.02
Chromium (Cr)	Dissolved in the effluent	mg/l	0.05	0.30	0.50	0.05	0.30	0.50
Cobalt (Co)	Dissolved in the effluent	mg/l	0.10	0.50	1.00	0.10	0.50	1.00
Copper (Cu)	Dissolved in the effluent	mg/l	0.05	0.30	1.00	0.05	0.30	1.00
Cyanide (CN)	Total cyanide in the effluent	mg/l	0.10	0.50	2.00	0.10	0.50	2.00
Fluoride (F)	Dissolved in the effluent	mg/l	2.50	5.00	15.00	2.50	5.00	15.00
Iron (Fe)	Dissolved in the effluent	mg/l	0.30	1.00	5.00	0.30	1.00	5.00
Lead (Pb)	Dissolved in the effluent	mg/l	0.05	0.10	0.50	0.05	0.10	0.50
Manganese (Mn)	Dissolved in the effluent	mg/l	0.05	0.50	1.50	0.05	0.50	1.50
Magnesium (Mg)	Dissolved in the effluent	mg/l	—	—	—	150	300	500
Mercury (Hg)	Total in the effluent	mg/l	0.0014	0.003	0.01	0.0014	0.003	0.01
Molybdenum (Mo)	Dissolved in the effluent	mg/l	0.50[4]	1.00	10.0	0.50[4]	1.00	10.00
Nickel (Ni)	Dissolved in the effluent	mg/l	0.30	0.50	1.00	0.30	0.50	1.00
Nitrates/Nitrites (as N)	Dissolved in the effluent	mg/l	10.00	25.00	50.00	10.00	25.00	50.00
Phosphate (as P)	Total in the effluent	mg/l	2.00	5.00	10.00	2.00	5.00	10.00
Selenium (Se)	Dissolved in the effluent	mg/l	0.05	0.10	1.00	0.05	0.10	1.00
Silver (Ag)	Dissolved in the effluent	mg/l	0.10	0.50	1.00	0.10	0.50	1.00
Sulphate (SO_4)	Dissolved in the effluent	mg/l	—	—	—	50[4]	250	1,000
Uranyl (UO_2)	Dissolved in the effluent	mg/l	2.00	5.00	10.00	2.00	5.00	10.00
Zinc (Zn)	Dissolved in the effluent	mg/l	0.50	5.00	10.00	0.50	5.00	10.00
Oil and Grease	Total in the effluent	mg/l	15.00	15.00	15.00	15.00	15.00	15.00

NOTE—Acceptable concentrations for characteristics not appearing in this list are to be determined as required. When all liquids are totally recycled, the applicability of the above objectives will be assessed.

[1] Initially, semiquarterly sampling on effluents and at control and test stations in receiving-waters; quarterly sampling on effluent discharged to closed systems.

[2] Daily sampling.

[3] To be reviewed.

[4] Tentative, subject to review.

[5] Subject to review where applied to smelters.

Table V—Objectives for Toxicity for Effluent Concentrations

Characteristic	Marine-water discharge			Fresh-water Discharge			Frequency of Monitoring
	Level A	Level B	Level C	Level A	Level B	Level C	
Limit Toxicity[1]	100%	40%	10%	100%	80%	20%	Quarterly on an initial basis.
Assessing toxicity[2]	—	—	—	—	—	—	As required, prior to start up, and semi-annually after start up.
In situ toxicity[3]	—	—	—	—	—	—	As required in the field, in special cases.

[1] Fifty per cent survival of test fish in designated effluent concentration over a 96-hour exposure time.
[2] Determine effluent concentration at which 50 per cent survival over a 96-hour exposure time.
[3] Undertaken in site-specific situations where an effluent toxicity potential is indicated for down-stream populations of aquatic organisms.

Table VI—Objectives for Receiving-water Quality

Parameter	Marine Water	Fresh Water
Dissolved oxygen — mg/l	90% seasonal natural value.	90% seasonal natural value.[1]
pH[2] — pH units	± 0.2	± 0.2
Turbidity[2] — APHA units	+ 5	+ 5
Colour[3] — APHA units	—	—
Floatable solids — mg/l	None	None
Toxicity	Below detectable limit	Below detectable limit
Æsthetic	No decrease	No decrease
Temperature[2] — °C	+ 3°	+ 3°
Alkalinity[2] — mg/l equiv. $CaCO_3$	—	− 20%
Chloride[2] — mg/l	—	+ 25
Fæcal coliforms[3] — mpn/100 ml	—	—

[1] Excluding lake stations, which should be assessed individually.
[2] Variations in water quality, due to the discharge of waste, should not exceed the numerical increments listed.
[3] To be reviewed.
NOTE—Parameters as determined at the limit of the initial dilution zone (*see* Glossary of Terms, Appendix II).

APPENDIX II

DISTRICT OF SPARWOOD
BY-LAW NO. 111

Being a By-law to amend By-law No. 57 cited as "Air Pollution Control By-law No. 57, 1970"

Section 7 (b) in part

DISTRICT OF SPARWOOD

BY-LAW NO. 111

Ambient Air Quality Limits

Residential, commercial and urban reserve:

Dustfall - Maximum Limits - 15 tons/square mile/month

Suspended Particulate Matter - Maximum Limits up to July 1, 1971
50% of the results to record less than 80 micrograms/cu. metre
84% of the results to record less than 115 micrograms/cu.metre

Maximum Limits after July 1, 1971
50% of the results to record less than 65 micrograms/cu.metre
84% of the results to record less than 100 micrograms/cu.metre

Industrial:

Suspended Particulate Matter - Maximum Limits up July 1, 1971
50% of the results to record less than 180 micrograms/cu.metre
84% of the results to record less than 200 micrograms/cu.metre

Maximum Limits after July 1, 1971
50% of the results to record less than 80 micrograms/cu.metre
84% of the results to record less than 120 micrograms/cu.metre

Sulphur Dioxide - Maximum Limits

Concentration	Average Time	Frequency of Occurrence
1.0 ppm.	5 minutes	once in any 8 hour period
0.5 ppm.	1 hour	once every 4 consecutive days
0.2 ppm.	24 hours	once every 90 consecutive days
0.1 ppm.	48 hours	unlimited

APPENDIX III

STANDARD REFERENCE METHOD FOR THE MEASUREMENT OF SUSPENDED PARTICULATES IN THE ATMOSPHERE

(HIGH VOLUME METHOD)

Air Pollution Control Directorate
Environmental Protection Service

Report EPS 1 - AP - 73 - 2
January 1973

TABLE OF CONTENTS

1. SCOPE

The method is applicable to the measurement of the complete range of concentrations of airborne suspended particulates over designated time intervals. The size of the sample taken allows other analyses to be carried out later.

2. FIELD OF APPLICATION

This method is applicable to the measurement of the mass concentration of suspended particulates in ambient air. When the sampler is operated at an average flow rate of 1.70 cubic metres per minute for 24 hours, an adequate sample will be obtained even in an atmosphere having concentrations of suspended particulates as low as 1 microgram per cubic metre. If particulate levels are unusually high, a satisfactory sample may be obtained in 6 to 8 hours time or even less. For the determination of the mean concentrations of suspended particulates in ambient air, a standard sampling period of 24 hours is recommended.

3. PRINCIPLE

3.1 Air is drawn into a covered housing and through a filter by means of a high flowrate blower at nominal flow rates from 1.13 to 1.70 cubic metres per minute. This allows suspended particulates having diameters of less than 100 μm, Stokes equivalent, to pass to the filter surface. See Figure 1. Particles within the size range of 100 to 0.1 μm are ordinarily collected on glass fibre filters. The mass concentration of suspended particulates in the ambient air, expressed in micrograms per cubic metre, is calculated by measuring the mass of collected particulates and the volume of air sampled.

3.2 The weight is determined to the nearest milligram, the flow rates are measured to the nearest 0.03 cubic metre per minute, the times are determined to the nearest 2 minutes and the mass concentrations are calculated and recorded to the nearest microgram per cubic metre.

4. INTERFERENCES

4.1 Particulate matter that is oily, such as wood smoke or photochemical smog, may block the filter and cause a rapid decrease in airflow at a nonuniform rate. Dense fog or high humidity can cause the filter to become too wet and severely reduce the airflow through the filter.

4.2 Glass fibre filters are comparatively insensitive to changes in relative humidity, but collected particulates can be hygroscopic (12.2).

4.3 Whenever the concentration of particulates is abnormally high, there may be loss of particulates, because of the weak adhesion of the particles to the filter.

5. REAGENTS

Filter media. Glass fibre filters having a collection efficiency of at least 99% for particles of 0.3 μm diameter, as measured by the DOP* test, are suitable for the quantitative measurement of concentrations of suspended particulates, although some other medium, such as paper, may be desirable for certain analyses (12.5). If a more detailed analysis is contemplated, care must be exercised to use filters that contain low background concentrations of the pollutant being measured. Careful quality control is required to determine background levels of these pollutants.

*Based upon the use of monodisperse dioctyl phthalate aerosol as the size calibrating medium.

6. APPARATUS

6.1 Sampling.

6.1.1 Sampler. The sampler is composed of three parts: (i) the face plate, gasket and retaining ring, (ii) the filter adapter assembly, and (iii) the motor-fan unit. The sampler must be capable of drawing ambient air through a portion of a clean glass fibre filter, 406.5 square centimeters in area, at a flow rate between 1.13 and 1.70 cubic metres per minute. The motor must be able to operate continuously per 24 hour periods with input voltages ranging from 110 to 120 volts, 50-60 Hz and must have third wire safety ground. The housing for the motor unit may be of any convenient construction as long as the assembly remains airtight and leak free. The life of the sampler motor can be extended by lowering the voltage by about 10 percent by means of a small "buck or boost" transformer between the sampler and power outlet.

6.1.2 Sampler shelters. It is important that the sampler be properly installed in a suitable shelter. The shelter is subjected to extremes of temperature, humidity and all types of air pollutants. For these reasons, the materials of the shelter must be chosen carefully. Properly painted exterior plywood or heavy gauge aluminum serves well. The shelter must be provided with a roof so that the filter is protected from precipitation and debris. The internal arrangement and configuration of a suitable shelter with a gable roof is shown in Figure 1. The area of clearance between the main housing and the roof at its closest point should be 580.5 ± 195.5 square centimetres. The main housing should be rectangular, with dimensions of about 29 x 36 centimetres.

6.1.3 Rotameter. Marked in arbitrary units, frequently 0 to 70 and capable of being calibrated. Other devices, of at least comparable accuracy, may be used.

6.1.4 Orifice calibration unit. This consists of a metal tube 7.6 cm internal diameter and 15.9 cm in length, provided with a static pressure tap 5.1 cm from one end. See Figure 2. The tube end nearest the pressure tap is flanged to about 10.8 cm in external diameter with a male thread of the same size as the inlet end of the high volume air sampler. A single metal plate, 9.2 cm in diameter and 0.24 cm thick, having a central orifice 2.9 cm in diameter, is held in place at the air inlet end with a female threaded ring. The other end of the tube is flanged to hold a loose female threaded coupling which screws on to the inlet of the sampler. An 18-hole metal plate, an integral part of the unit, is positioned between the orifice and sampler to simulate the resistance of a clean glass fibre filter. An orifice calibration unit is shown in Figure 2.

6.1.5 Differential manometer. Capable of measuring to at least 40 cm of water.

6.1.6 Positive displacement meter. Calibrated in cubic metres or cubic feet, to be used as a primary standard.

6.1.7 Barometer. Capable of measuring atmospheric pressure to the nearest millimetre of mercury.

6.2 Analysis.

6.2.1 Filter conditioning equipment. Balance room or desiccator maintained at 20 to 30°C with less than 50% relative humidity.

6.2.2 Analytical balance. Equipped with a weighing chamber designed to handle unfolded filters, in size 20.3 x 25.4 cm. The balance should have a sensitivity of 0.1 milligram.

6.2.3 Light source. A table of the type used to view X-ray films is convenient.

6.2.4 Numbering device. Capable of printing identification numbers on the edge of the filters.

7. SAMPLING AND SAMPLES

7.1 Filter preparation. Expose each filter to the light source and inspect for pinholes, particles or other imperfections. Filters having visible defects should not be used. A small brush is useful for removing loose particles. Equilibrate the filters in the filter conditioning environment for 24 hours. Weigh the filters to the nearest milligram and record the tare weight and filter identification number. Do not bend or fold the filter before collection of the sample.

7.2 Sample collection. Open the shelter, loosen the wing nuts and remove the retaining ring from the filter holder. Install a weighed and numbered glass fibre filter in position with the rough side up, replace the number, location and any other factors such as meteorological conditions or razing of nearby buildings etc. that might affect the final results. If the sample is defective, discard it at this time. In order to obtain a valid sample, the high volume sampler must be operated with the same rotameter and tubing that were used during its calibration.

7.3 Analysis. Equilibrate the exposed filters for 24 hours in the conditioning environment and then weigh again. After having been weighed the filters can be used later for detailed chemical analyses.

8. PROCEDURE

8.1 Calibration.

8.2 Purpose. Since only a small portion of the total air sampled passes through the rotameter during measurement, the rotameter must be calibrated against actual air flow with the orifice calibration unit. Before the orifice calibration unit can be used to calibrate the rotameter, the orifice calibration unit itself must be calibrated against the positive displacement primary standard.

8.3 Orifice calibration unit. Attach the orifice calibration unit to the intake end of the positive displacement primary standard and attach a high volume blower unit to the exhaust end of the primary standard. Connect one end of a differential manometer to the differential pressure tap of the orifice calibration unit and leave the other end open to the atmosphere. Operate the high volume motor-blower unit so that a series of different, but constant airflows, usually six, are obtained for definite time periods. Record the reading of the differential manometer at each airflow. The different constant airflows are obtained by placing a series of load plates, one at a time, between the calibration unit and the primary standard. Placing the orifice before the inlet reduces the pressure at the inlet of the primary standard below atmosphere. A correction must be made, therefore, for the increase in volume caused by this decreased inlet pressure. Attach one end of a second differential manometer to the inlet pressure tap of the primary standard and leave the other end of the manometer open to the atmosphere. During each of the constant airflow measurements made above, measure the true inlet pressure of the primary standard with this second differential manometer. Measure the atmospheric pressure and temperature. Correct the measured air volume to true air volume as directed in

Section 9.1.2, then obtain the true airflow rate, Q, as directed in Section 9.1.4. Plot the differential manometer readings of the orifice unit versus Q.

8.3.1 High volume sampler. Assemble a high volume sampler with a clean filter in place and run for at least 5 minutes. Attach a rotameter, read the float, adjust so that the float gives a reading of 65 and seal the adjusting mechanism so that it cannot be changed easily. Shut off the motor, remove the filter and attach the orifice calibration unit in its place. Operate the high volume sampler at a series of different but constant airflows, usually six. Take the readings of the differential manometer from the orifice calibration unit and record the readings of the rotameter for each flow rate. Measure the pressure and temperature of the ambient atmosphere. Convert the differential manometer readings to cubic metres per minute, Q, then plot rotameter readings against Q.

9. EXPRESSION OF RESULTS

9.1 Calculations.

9.1.1 Calibration of orifice.

9.1.2 True air volume.

Calculate the air volume measured by the positive displacement primary standard, thus:

$$V_a = \frac{(P_a - P_m)}{P_a} \cdot V_M$$

where V_a = true volume of air at atmosphere temperature, in cubic metres

P_a = barometric pressure, in millimetres of mercury

P_m = drop in pressure at inlet to reference orifice, in millimetres of mercury

V_M = volume measured using the standard orifice, in cubic metres.

9.1.3 Conversion factors.

Inches of mercury x 25.4 = millimetres of mercury

Inches of water x 73.48×10^{-3} = inches of mercury

Cubic feet of air x 0.0284 = cubic metres of air.

9.1.4 True flow rate

$$Q = \frac{V_a}{T}$$

where Q = flow rate of air, in cubic metres per minute

T = duration of sampling, in minutes.

9.2 Sample volume.

9.2.1 Volume conversion. Convert the initial and final rotameter readings to true airflow rate, Q, using the calibration curve established in accordance with Section 8.3.

9.2.2 Calculation of volume of air sampled.

$$V = \frac{Q_1 + Q_2}{2} \cdot T$$

where V = air volume sampled, m^3

Q_1 = initial airflow rate, m^3/min

Q_2 = final airflow rate, m^3/min

T = sampling time, in minutes.

9.2.3 Corrections for pressure or temperature. If the pressure or temperature, during calibration of high volume sampler, is substantially different from the pressure or temperature during orifice calibration, a correction of the flow rate, Q, may be required. If the pressures differ by no more than 15 percent and the temperatures, in °C, differ by no more than 100 percent, the error in the uncorrected flow rate will be no more than 15 percent. If necessary, obtain the corrected flow rate as directed below. This correction applies only to orifice meters having a constant overflow coefficient. The coefficient for the calibrating orifice described in 6.1.4 has been shown experimentally to be constant over the normal operating range of the high volume sampler, of 0.6 to 2.2 cubic metres per minute. Calculate corrected flow rate according to the formula:

$$Q_2 = Q_1 \left[\frac{T_2}{T_1}\frac{P_1}{P_2}\right]^{\frac{1}{2}}$$

where Q_2 = corrected flow rate, m^3/min

Q_1 = flow rate during high volume calibration, m^3/min

T_1 = absolute temperature during orifice unit calibration, °K or °R

P_1 = barometric pressure during orifice unit calibration, in mm Hg

T_2 = absolute temperature during high volume calibration, °K or °R

P_2 = barometric pressure during high volume calibration, in mm Hg.

9.3 <u>Calculation of mass concentration of suspended particulates.</u>

$$S.P. = \frac{(W_2 - W_1) \cdot 10^6}{V}$$

where S.P. = mass concentration of suspended particulates in $\mu g/m^3$

W_1 = initial weight of filter, in grams

W_2 = final weight of filter, in grams

V = air volume sampled, in cubic metres

10^6 = conversion factor from grams to micrograms.

Weights are determined to the nearest 0.1 milligram, airflow rates are determined to the nearest 0.03 cubic metres per minute, times are recorded to the nearest 2 minutes, and mass concentrations are reported to the nearest microgram per cubic metre.

10. PRECISION, ACCURACY AND STABILITY

10.1 Based upon collaborative testing, the relative standard deviation for single analyst variation, or repeatability of the method, is 3.0 percent. The corresponding value for multilaboratory variation, or reproducibility of the method, is 3.7 percent (12.3).

10.2 The accuracy with which the sampler measures the true average concentration depends upon the constancy of the rate of airflow through the sampler. The airflow rate is affected by the concentration and the nature of the dust in the atmosphere. Under these conditions, the error in the measured average concentration may be in excess of ± 50 percent of the true average concentration, depending upon the amount of reduction of airflow rate and on the variation of the mass concentration of dust with time during the 24-hour sampling period (12.4).

11. NOTES ON PROCEDURE

11.1 Maintenance.

11.1.1 Sampler motor. Replace brushes before they are worn to the point where motor damage can occur.

11.1.2 Sealing gasket. Replace when the margins of samples are no longer sharp. The gasket may be sealed to the retaining plate with rubber cement or double-sided adhesive tape.

11.1.3 Rotameter. Clean as required, using alcohol.

11.2 Other equipment. A modification of the high volume sampler incorporating a method for recording the actual airflow over the entire sampling period has been described and is acceptable for measuring the concentration of suspended particulates (12.6). This modification consists of an exhaust orifice meter assembly connected through a transducer to a system for continuously recording airflow on a circular chart. The volume of air sampled is calculated by the following equation:

$$V = Q \cdot T$$

where Q = average sampling rate, m^3/min

T = sampling time, in minutes

The average sampling rate, Q, is determined from the recorder chart by estimation, if the flow rate does not vary more than 0.11 cubic metres per minute during the sampling period. If the flow rate does vary more than 0.11 cubic metres per minute during the sampling period, read the flow rate from the chart at 2 hour intervals and take the average.

12. REFERENCES

12.1 Robson, C.D., and Foster, K.E. "Evaluation of Air Particulate Sampling Equipment." Am. Ind. Hyg. Assoc. J. 24, 404 (1962).

12.2 Tierney, G.P., and Conner, W.D. "Hygroscopic Effects on Weight Determinations of Particulates

Collected on Glass-Fiber Filters." Am. Ind. Hyg. Assoc. J. 28, 363 (1967).

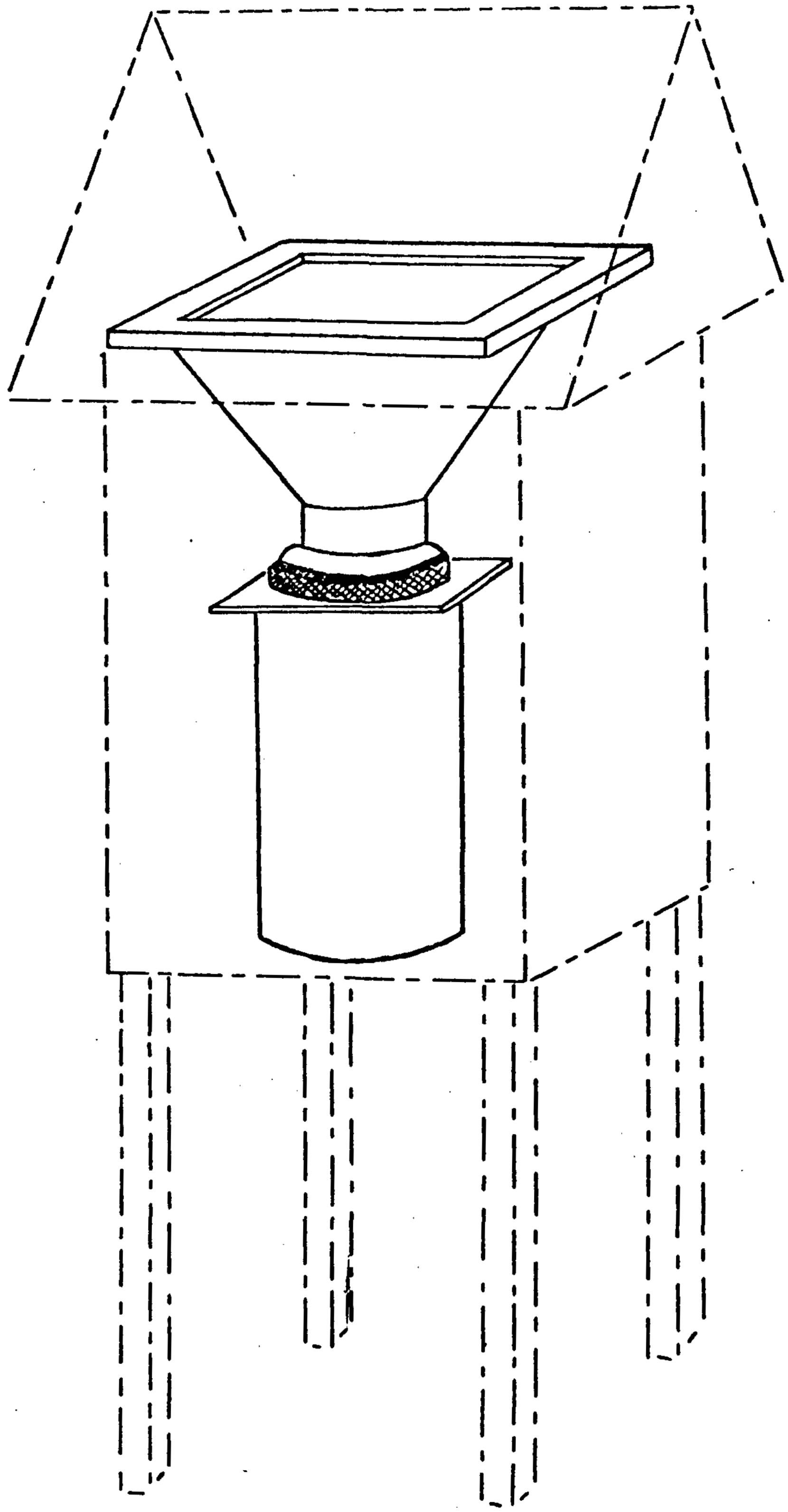
12.3 Unpublished data based on a collaborative test involving 12 participants, conducted under the direction of the Methods Standardization Services Section of the National Air Pollution Control Administration. October (1970).

12.4 Harrison, W.K., Nader, J.S., and Fugman, F.S. "Constant Flow Regulators for High-Volume Air Sampler." Am. Ind. Hyg. Assoc. J. 21, 114-120 (1960).

12.5 Pate, J.B., and Tabor, E.C. "Analytical Aspects of the Use of Glass-Fiber Filters for the Collection and Analysis of Atmospheric Particulate Matter." Am. Ind. Hyg. Assoc. J. 23, 144-150 (1962).

12.6 Henderson, J.S. Eighth Conference on Methods in Air Pollution and Industrial Hygiene Studies. Oakland, California (1967).

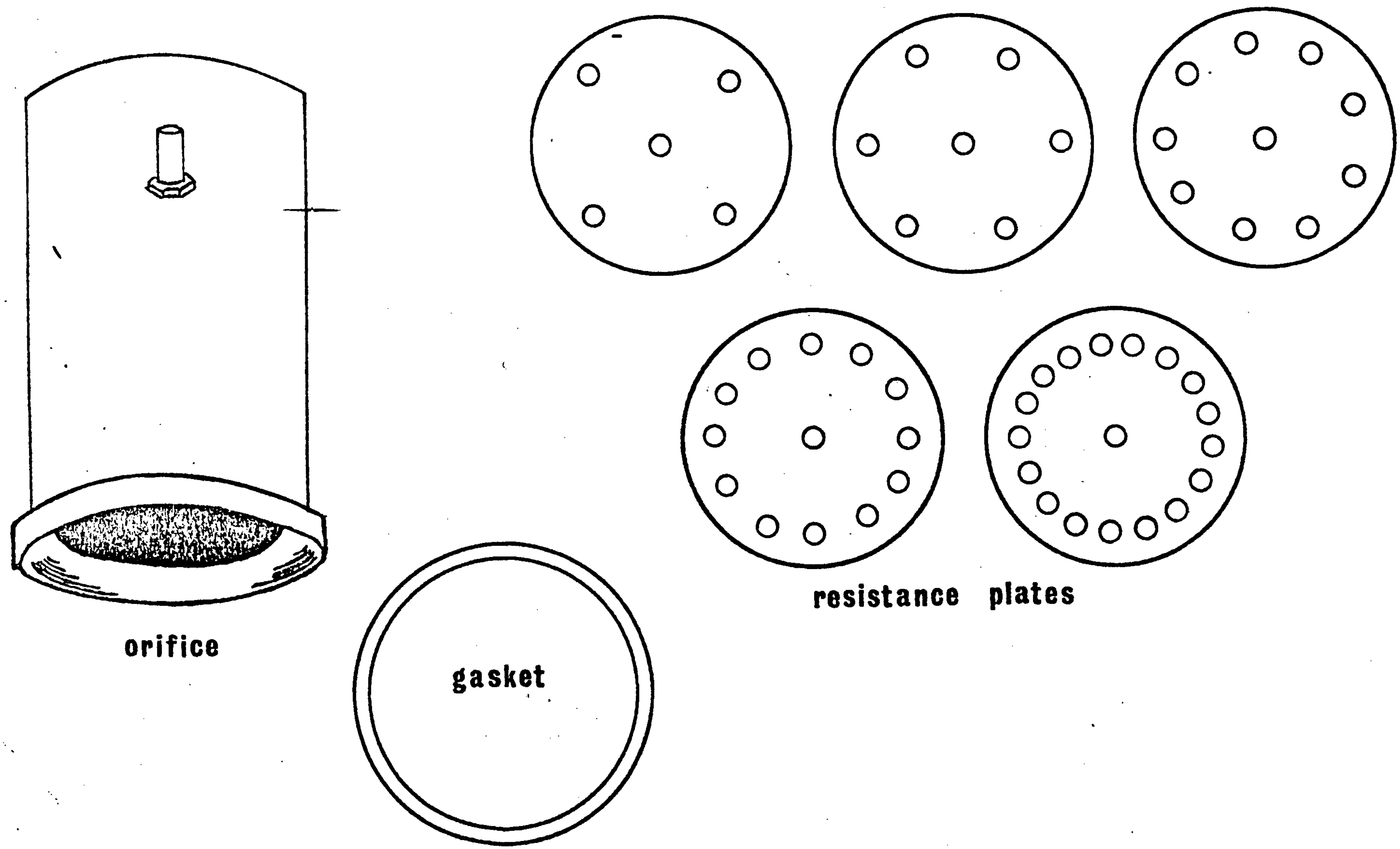
FIG. 1



SAMPLER AND SHELTER

FIG. 2

ORIFICE CALIBRATION UNIT



APPENDIX IV

DUSTFALL GUIDELINES

AND

THE DETERMINATION OF DUSTFALL

Chemistry Laboratory
Water Resources Service
British Columbia
February, 1973

DUSTFALL GUIDELINES

i) The sampling stations have free exposure so that the sample is collected by gravity settling only. They must be free from undue local sources of pollution and free from interference from buildings or other objects or structures. Accessibility and security (freedom from tampering) are major considerations in the selection of a site.

ii) The top of the settleable particulates container be a minimum of 8 feet and a maximum of 50 feet above the ground. It should be 4 feet above any other surface, such as a roof. Higher objects, such as parapets, signs, penthouses, and the like, should not be more than 30 degrees from the hortizontal, as measured in (v).

iii) Telephone poles and fences are suitable provided the holder is attached in such a way that it is free from interference.

iv) Sample stations be set at the plant boundaries, normally ten stack lengths from a major source; upwind for an indication of background data; and downwind at regular intervals.

v) When higher buildings in the immediate vicinity cannot be avoided, the top of any building be not more than 30 degrees above a sampling point. This is, a line drawn from the sampling jar to the nearest edge of the highest point on any building should form not more than a 30 degree angle with the horizontal.

For each area or zone to be tested, a minimum of four sampling stations are necessary. An orderly spacing of the stations should be made so that they are approximately equidistant from each other and form boundaries of the area. If possible, the vertical distance from the collector to ground for each sampling station should be similar. As auxiliary information, weather data, including wind velocity and direction, rainfall, snowfall and barometric readings, plant operations and other information of interest be recorded during each sampling period.

Method: 6505103
6515303
6525403
6535303
6545403
6555101

CHEMISTRY LABORATORY

WATER RESOURCES SERVICE

THE DETERMINATION OF DUSTFALL

Method Codes

6505103	Total Dustfall
6515303	Soluble Dustfall
6525403	Insoluble Dustfall
6535303	Soluble Dustfall Ash
6545403	Insoluble Dustfall Ash
6555101	Combustible Materials

Introduction

Dustfall is a measure of the particulate matter that settles out of the air. It is determined by exposing a canister containing a collection medium to the air for a specified period followed by gravimetric analyses in the laboratory.

Field Preparation

A collection medium is added to a clean canister. In the months May through September this medium is:

1 liter of deionized water

1 ml of ammonium chloride solution (which acts as an algaecide)

Note: if nitrogen determinations are to be done, 1 ml of copper sulphate solution is substituted for the ammonium chloride

In the months of October through April, the one liter of deionized water is replaced by a mixture of isopropyl alcohol and deionized water. The proportion should be such that the freezing point will not be reached. The canister containing the collection medium is sealed and shipped to the field. After exposure for one month the canister is resealed and forwarded to the laboratory. The standard canister is 8.5 inches high and has a top diameter of 4 inches tapering to 3.5 inches at the base.

Storage

Samples should be transported to the laboratory in refrigerated cases and kept at 5°C when possible.

Reagents

1. Ammonium Chloride: Dissolve 0.50 grams ammonium chloride in one liter. Dilute 100 ml of this stock solution to one liter. From the diluted stock solution one ml is used in each canister.

2. Copper Sulphate: Dissolve 0.15 grams copper sulphate in one liter. Dilute 100 ml of this stock solution to one liter. From the diluted stock solution one ml is used in each canister.

Procedure

1. Measure the diameter of the canister in three different places and record the average.

2. Examine and report any evidence of algae growth or tampering.

3. Remove extraneous materials, such as leaves, twigs and bugs from the sample. Pour the sample into a two liter beaker.

4. Wash the canister thoroughly with deionized water using a rubber policeman to free all materials adhering to the bottom and walls.

5. Combine the washings with the sample in the same beaker.

6. Reduce the volume of the sample to approximately 200 ml by evaporating on a hot plate. (Note: Samples which require nitrogen determinations should not be evaporated.)

7. When the volume has been reduced, remove the beaker from the hot plate and allow it to cool.

Insoluble Dustfall

Method Code

6525403

Procedure

1. Ignite an acid washed porcelain crucible in a muffle furnace for one hour.

2. Desiccate and cool the crucible for three hours.

3. Weigh the crucible.

4. Dry a 0.45 u membrane filter, contained in the preweighed porcelain crucible, in an oven at 105°C for three hours.

5. Desiccate and weigh the filter and crucible.

6. Pass the cooled sample (from Step 6 above) through the 0.45 u filter. Use a rubber policeman and deionized water to wash the beaker thoroughly. Filter all washings through the same filtering apparatus as the sample. The filtering apparatus is also washed thoroughly.

7. The residue on the filter represents the insoluble dustfall.

8. The filter and residue are returned to the porcelain crucible, dried in an oven at 105°C for three hours, desiccated and weighed.

Calculations

The increase in weight of the filter, residue and crucible over the initial weight of the filter and crucible is corrected for any insoluble solids found in the blank. This weight, in grams, is equivalent to the insoluble dustfall in the sample.

Insoluble Dustfall Ash

Method Code

6545403

Procedure

1. Transfer the filter and residue in the porcelain crucible from the insoluble dustfall analysis (method 6525403) to a cool muffle furnace.

2. Gradually increase the temperature to 600°C and maintain for one hour.

3. Remove the crucible containing the ash, desiccate for three hours and weigh.

Calculations

The increase in weight of the crucible, filter and residue over the weight of the empty crucible is corrected for any insoluble solids ash found in the blank. This corrected weight in grams, is equivalent to the insoluble dustfall ash in the sample.

Soluble Dustfall

Method Code

6515303

Procedure

1. Adjust the filtrate from the insoluble dustfall analysis (method 6525403) to a convenient volume, generally one liter.

2. Transfer 100 ml of the filtrate to a preweighed platinum crucible and evaporate to dryness on a steam bath.

3. After evaporation, transfer the crucible containing the residue to an oven and dry at 105°C for three hours.

4. Desiccate overnight and weigh.

Calculations

The increase in weight over that of the empty platinum crucible is multiplied by the appropriate factor for the aliquot taken and then corrected for any soluble solids present in the blank. This weight, in grams, is equivalent to the soluble dustfall in the sample.

Soluble Dustfall Ash

Method Code

6535303

Procedure

1. Transfer the platinum crucible containing the residue of the soluble dustfall analysis (method 6515303) to a cool muffle furnace.

2. Gradually increase the temperature to 600°C and maintain for one hour.

3. Desiccate the crucible containing the ash for three hours and weigh.

Calculations

The increase in weight of the crucible and residue over the empty crucible is multiplied by the appropriate factor for the aliquot taken in the soluble dustfall analysis (method 6515303). Then it is corrected for any soluble solids ash in the blank. This weight, in grams, is equivalent to the soluble dustfall ash in the sample.

Total Dustfall

Method Code

6505103

Procedure

1. Complete insoluble dustfall analysis (method 6525403) and soluble dustfall analysis (method 6515303) as outlined.

Calculations

Combine the results of corrected insoluble dustfall and corrected soluble dustfall to give the weight, in grams, of total dustfall in the sample.

Combustible Material

Method Code

6555101

Calculation

Subtract the result of the insoluble solids ash analysis (method 6545403) from the result of the insoluble dustfall determination (method 6525403). Add this figure, which represents the combustible material in the insoluble portion, to the amount of combustible material in the soluble portion. The combustible material in the soluble portion is found by subtracting the result of the soluble dustfall ash analysis (method 6535303) from the result of the soluble dustfall determination (method 6515303).

Calculation

Conversion to standard dustfall units:

1. to Tons/mile^2/month

$$\text{Tons/mile}^2\text{/month} = F \times W$$

where:

W = weight in grams

F = dustfall factor found by $F = \frac{5650}{Di^2} \times \frac{30}{N}$

Di = diameter of canister in inches

N = number of sampling days

2. to mg/cm^2/day

$$\text{mg/cm}^2\text{/day} = \frac{1000\ W}{(Dc)^2 N}$$

where:

W = weight in grams

Dc = diameter of canister in centimeters

N = number of sampling days

Reference

1. American Society for Testing and Materials. Annual Book of ASTM Standards. Part 23, Easton, Md. (1970).