PROCEEDINGS
OF
STRAIT OF GEORGIA WORKSHOP
November 3-4, 1972

Institute of Oceanography
University of British Columbia

Sponsored by Pacific Sub-committee on Oceanography, C.C.O.

Convener; A.E. Gargett, D.O.E.

ENVIRONMENT CANADA
Water Management Service
Marine Sciences Directorate
Pacific Region
1230 Government St.
Victoria, B.C.

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Pacific Sub-Committee on Oceanography

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INTRODUCTION

A workshop on the Strait of Georgia was held on November 3-4, 1972, at the Institute of Oceanography, University of British Columbia. The purpose of the meeting, sponsored by the Pacific Sub-committee on Oceanography of the Canadian Committee on Oceanography through Environment Canada, Victoria, was to review what is known about the Strait and to try to decide what observational and/or research programs will be necessary in order to set and maintain water quality standards for the region. I would like to thank IOUBC for its hospitality and all the participants for donating their time and knowledge, in particular those who introduced and chaired discussions. The following report is based on a tape recording of the proceedings and is more of a summary than an attempt to follow the exact order of the discussions. Any apparent prejudices are the author's.

A.E. Gargett
Convenor.

INTRODUCTION: SESSION I

Dr. R.W. Stewart introduced the first discussion, on means of determining water quality in marine waters. He pointed out that the federal government presently attaches a high priority to work in coastal zones, and that the Strait of Georgia seems particularly suitable for study of human influence on a semi-enclosed marine area which is not as yet grossly polluted. Dr. Stewart suggested that in view of the limited time available, the discussion concentrate on an operational definition of water quality for coastal waters (that is, definition in terms of something(s) which can be measured quantitatively), leaving related questions such as oil spills, biological productivity, aquaculture, etc. to some future meeting.

DISCUSSION:

The following summary presents various ideas which came up during the subsequent discussion of this question of an operational definition of water quality.

1. A present, there are no available water quality standards for marine waters. It appears that even international standards set for fresh water may be of limited use, a fact which emphasizes the extreme difficulty of setting meaningful standards.

2. A question which arose early in the discussion was whether the Strait of Georgia could in fact be considered relatively pure, or whether it has already been seriously affected by human activities. The general opinion was that those areas which have undeniably been affected (e.g. Vancouver

inner harbour, regions of sewage outfalls) are fairly local and relatively easily identifiable. It was pointed out that bottom drifters set near the mouth of the Columbia River have been found within the Strait, raising the possibility that oceanic water entering through Juan de Fuca Strait may already contain contaminants from the Columbia River system. The consensus of opinion was that the Strait of Georgia as a whole is not yet seriously affected by pollution, even though it is certainly affected to some degree in areas near large concentrations of population, particularly Vancouver and Seattle.

3. The question of defining water quality with respect to use was also considered. The Strait of Georgia is a multiple-use region: some of the main activities using its waters are fishing, shipping, recreation and waste disposal. Some of these activities (fisheries) use the entire Strait, others (waste disposal, shipping) are confined to rather local areas, while others (recreation) particularly value certain broad regions. Thus it was suggested that water quality need not be defined uniformly over the Strait, but vary in definition with area, to allow for the fact that different regions are most valued for different purposes. Although this suggestion has a great deal to recommend it in dealing with an area as diverse in natural water qualities as the Strait of Georgia, it is open to one serious objection: because the water in the Strait moves, it will not necessarily remain within its "use" boundaries. Thus, for some properties at least, the most stringent standard must be adopted over-all, in order that it be maintained in just one of the "use" areas.

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4. One suggestion for a baseline description of water quality was to measure the chemical composition of water at various locations in the Strait, compared to a deep ocean standard, monitoring future change in water quality through changes in water chemistry. This relatively straightforward approach has a number of drawbacks, the most serious of which is the limited number of chemical elements or compounds for which reliable analytic techniques in seawater exist at present. The difficulty is the extremely low concentration levels of most substances in seawater: while oceanographic "salinity" is measured in parts per thousand, most trace metals, pesticide residues, etc. are present only to the order of parts per million or less, require extremely sensitive chemical analysis techniques, accomplished technicians, "clean" laboratories, etc. Another problem is the constancy of the deep ocean standard of comparison, in face of the increasingly global character of pollution. If such a deep ocean standard is desirable, perhaps the water should be collected now, in sufficient quantity that large amounts could be stored for further analysis as advanced chemical techniques become available. Another serious difficulty is that very little is known about the noise levels which will be associated with such a measurement. By "noise" we here mean any variations in results which would be introduced by the frequency or methods used to sample a quantity which varies in space and time (noise will also be introduced by analysis techniques, so that a good analytic technique will be one which can produce results with a small scatter from different samples of the same water.) In deciding where and when to collect water samples for measurements of chemical constituents, we must keep in mind the extreme variability of the surface layer of the Strait, forced by the Fraser inflow: it seems obvious that the deep water of the Strait is a more stable region to sample. We

think that spatial variations in the deep water ought to be small, and time variations confined perhaps to a small annual cycle, tied to annual variation of fresh water input. However, in trying to monitor changes in water quality, we will be looking for very small changes in measured quantities: even in the deep water, noise levels may prove sufficient to mask a small trend due to environmental deterioration.

5. A "source-sink" method was suggested as an alternate approach to the problem of determining rates of change of various pollutants within the Strait. Considering a black box model of the system, with respect to some contaminant A, (rate of change of A) = (sources of A) - (sinks of A), so that to obtain the rate at which the quantity A is increasing or decreasing within the total system, it is necessary only to measure the sources and identify and quantify the sinks. Such a model is a necessary beginning for more sophisticated models of contaminant distribution (which would attempt to describe the spatial distribution within the black box) and would be immediately useful, for example, with respect to fish populations which range the Strait, thus integrating contaminant distribution. Having decided to investigate a particular contaminant, say the heavy metal X, it would be necessary to obtain information from pertinent industries and governments located around the entire Strait (including Puget Sound) regarding quantities and composition of materials containing X which enter the water body. It seems likely that such information could be obtained only by legislation, difficult enough if only one country is involved. The question of sinks is perhaps even more difficult than that of sources. Processes to be regarded as sinks will vary with the particular contaminant considered, and depend greatly on the state in which the contaminant enters the water, e.g.

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dissolved or suspended material, pure or compounded, etc. We consider a material to be "removed" from the system when it becomes incorporated into the bottom sediment, either directly by precipitation and/or geochemical processes at the sediment-water interface or indirectly through absorption by biological organisms which subsequently die and sink to the bottom. The multi-disciplinary nature of the problem of identifying sinks is evident.

6. It appears evident in connection with any of the problems of changes in water quality, that the physical oceanography of the Strait requires intensive investigation. The duration and spatial extent (both horizontal and vertical) of flow patterns, the various vertical and/or horizontal mixing processes which occur, will have important, sometimes perhaps crucial effects on contaminant distribution and concentration. Our present knowledge of currents in the Strait is based mostly on a number of sections (each occupied for a period of approximately one month) measured by the Tidal and Current Section of the west coast Hydrographic Service and one section in mid-Strait occupied by the former Pacific Oceanographic Group: the results are sufficient to underline the complexity of currents within the Straits. Deep currents have persistent flows (order of weeks). Unpredictable features which may be associated with events offshore are also present and there appear to be changes in the predominance of tidal motions from west to east across the Strait. Furthermore, changes in currents do not always occur over the entire water column at the same time, so that vertical variations are important. Mixing processes may occur associated with such vertical current shears, with the edges of the Fraser River plume, or with the internal waves which are such an obvious feature of the southern Strait. Mechanisms which promote vertical mixing should be of great interest in

the Strait, where relatively strong vertical stability tends to retain contaminants in the surface layer. Our knowledge of the important physical oceanographic processes in the Strait is certainly insufficient when confronted with problems of pollutants.

7. Instead of trying to measure low concentrations of heavy metals and other contaminants in the water itself, we can perhaps make use of the ability of marine organisms to concentrate substances found in the water in which they live. In analyzing organisms, we reduce the requirements for analytic chemical techniques by using material with much higher concentrations than those typical of seawater. A further advantage of this approach is that organisms integrate effects over time, a type of measure far more useful than a spot measurement of concentration. Examining mobile organisms, such as fish, which spend their entire life cycle within the Strait provides some spatial averaging as well, while sedentary animals like oysters would provide a measure for a more localized region. The main disadvantage of the technique is the introduction of natural variability, the fact that a group of organisms of the same species raised in the same uniform environment do not develop uniformly. The natural variability of organisms substantially raises the noise level of the measurement (noise as discussed in (4) above), making it extremely difficult to detect small trends. Measurements taken by the Fisheries Service of mercury levels in fish and shellfish show ranges, within the same species, which are as large as the mean, indicating the difficult of the sampling problem. However, it seems that in localized regions of known high pollutant concentrations (e.g. Iona Island outfall, parts of Portage Inlet), levels of heavy metals, pesticide residues, etc. in benthic organisms are so much higher than

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"clean" animals of the same species, that such measurements are highly significant, despite seasonal cycles, population variability, etc. A possible observational program could identify certain benthic species which occur throughout the Strait, sample these species and analyze them for chemical concentration to the extent possible with presently available chemical techniques, looking in particular for areas where order of magnitude differences occur, since these are likely to be the regions with which we will first be concerned. If this were conceived as a baseline study, some provision should be made for storing freeze-dried samples for use when techniques for particular metals or other contaminants are either devised or improved.

8. Changes in species diversity was suggested as another tool for monitoring water quality. A group in California has been counting the number of species of diatoms found in unit samples taken with increasing distance seaward from a known source of pollution, and has found a strong correlation between contaminated water and low species diversity. This and related techniques seem to hold promise for estimating the extent of the effect of local sources of pollution. However, on the longer time scales over which the more subtle effects of pollution might be felt by a biological community, the natural exchange of species, about which little is known but much suspected, may be extremely misleading.

9. The technique of "bio-assay" was also discussed briefly. Since water contamination affects the reproduction stage of organisms and/or their ability to pass certain critical stages in their development, determination of some indicator of the species' reproductive success, such as number of

of eggs produced or number of larvae reaching maturity, could perhaps be used as a means of assessing changes in water quality. The chief difficulty here is again that of separating the effect of pollutants from those of other variables, such as food supply, which also change from year to year. A danger in the bio-assay technique has been found by laboratory experiments in which results depend very heavily on pre-treatment of the animals used. Thus, because of the ability of organisms to adapt to long-term changes in their environment, results obtained from field experiments may depend strongly on the life-history of the animals.

10. Another idea was to survey the health of areas of marine plants using infra-red aerial photography, since such growths may be sensitive to changes in water quality. Foresters have found high correlation between the death of certain species of trees and air pollution due to factories, highways, etc., and have found infra-red photography to be a very sensitive tool for surveying stands of timber. Infra-red has also proved useful in surveys of a certain type of marsh grass found along the eastern seaboard of the United States. Aerial survey of seaweeds have apparently been carried out jointly by B.C. Research, Fisheries Operations Branch, and the University of Victoria Biology Department and by the Fisheries Research Board, Nanaimo and the Air Division of the B.C. Department of Lands, Forests and Water Resources; such studies can serve as a start for estimating the usefulness of this approach to water quality.

11. The possibility exists of monitoring certain contaminants by looking at the sediments, where they will presumably be concentrated, if there are regions of the Strait where sediments are not appreciably reworked by

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bottom animals, and where large-scale slumping does not occur. Varved cores (showing distinct layers) have been taken in certain regions of the Fraser Delta, but it is not yet known if the varves are annual, nor if concentrations of such things as heavy metals or pesticides are measurably different over the length of a core. Another possible indicator of gross changes in metallic content of water within the Strait of Georgia may be the managenese nodules which have been found on the sill at the entrance to Jervis Inlet, and may be expected to occur on current-swept areas where sedimentation rate is low. Changes in relative metallic content within the various layers which form a nodule would supply an historical record of changes in dissolved metal content of the seawater.

12. An extremely important question which was raised but never answered is how to decide when a change (as indicated by some monitoring program) has become "critical", in the sense of requiring some hopefully enlightened human intervention.

CONCLUSIONS:

The general conclusion seemed to be that we do not at present know enough about the statistics of any single variable in order to suggest a sensible program for monitoring water quality in the Strait of Georgia. It appears that a number of pilot programs are necessary, to measure certain time series which will clarify the level of "natural" variation through which we hope to perceive some trend. Specific recommendations for such pilot programs are:

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a) Chemical constituents of source waters.

Any of the water within the Strait of Georgia is, to a great extent, some mixture of Fraser River water and oceanic water entering mainly through the Strait of Juan de Fuca. The proposal is to establish one station in each of these source waters and to sample the entire water column monthly over a two year period. Water samples should be uniformly analyzed for chemical components, to the extent of present analytic techniques (and level of support). Such a time series ought to clarify the magnitude of such things as the annual cycle, natural noise, limits of available chemical techniques, and enable us to decide if it would be possible to detect a "significant" trend in the data. The Juan de Fuca station could be established as an extension of the Line P series carried out by the weathership program, handled by DOE, Victoria. The Fraser River station could be handled by the Fisheries Service, Vancouver. Location of this station should be the subject of further discussion; ideally it should be downstream of all major outfalls, which would certainly place it in a brackish rather than fresh water region. In planning such a program, it would probably be instructive to consider results obtained by Dr. E. Grill of IOUBC consisting of chemical analyses of water samples obtained monthly for a year at one depth and one location in the Strait.

b) Chemical concentrations in benthic organisms.

A systematic survey of at least the heavy metal concentrations of species of sedentary animals which are universally distributed within the Strait would serve as a useful indication of regions where at least part of the biological community is already seriously affected by man's activities.

In deciding on metals to be analyzed and sampling statistics, we should profit from the experience of Dr. T.R. Parsons of IOUBC with organisms from two regions within the Fraser Delta. Such a survey would also afford valuable information on the natural variations to be expected in this method of sampling. Again, this is seen as a one- or two-year exploratory program.

c) Distribution changes within the total biological system.

Over the years 1964-68, Dr. Parsons, then of the Fisheries Research Board, Nanaimo, occupied eight stations within the Strait at which he established the most complete statistics of species distribution for the Strait which are available at present. It is suggested that at least one of these stations be re-occupied, hopefully at the same time of year as before, and these population statistics duplicated, in an attempt to see if there has been any significant change.

INTRODUCTION - SESSION II

The second broad area for discussion, introduced by Dr. T.R. Parsons, was that of the estuarine environment of the Strait of Georgia and associated biological problems. Dr. Parsons stressed the practical nature of many of the environmental impact studies which have been or will be required for regions within the Strait and pointed out the interdisciplinary character of these studies: physical properties of flows may affect the observed patchy nature of plankton, while sedimentary geology is crucial to the problems of effect of breakwaters on existing benthic communities. In view of the complexity of biological systems and the physical, chemical and geological factors which influence them, it seems practical to develop mathematical models, in an attempt to discover which factors are mainly responsible for observed variability. An example is the attempt to model the observed zone of high productivity found 5-10 miles off the mouth of the Fraser: it is hoped that such a model will be able to predict changes in productivity due to coal dust or silt suspended in the water through the changes it produces in light levels, or due to the effect of a dam on the Fraser through the associated changes in flow rates.

DISCUSSION:

1. Observations indicate that planktonic plants and animals are not uniformly distributed, but are most often found in patches. The spatial extent of these patches, and the time scales over which they are maintained may be important factors to the survival of larval fish, etc. which feed on plankton.

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The question raised was whether the observed "patchiness" has physical causes in movements of surface water which tend to concentrate plankton. Concentrations of plankton have been found associated with Langmuir vortices in the Sargasso Sea; as well, it seems possible that the "green tubes" seen from the air in the southern Strait may be concentrations of plankton associated with internal wave motion. It seems evident that effects such as tidal mixing in channels will contribute to large local plankton concentrations by mixing upward large quantities of subsurface nutrients. Apart from such well-organized and/or strong circulations, there is some limited evidence for a correlation between biological concentrations and physical parameters such as temperature. However, several people expressed the opinion that the fundamental reasons for patchiness may actually be biological rather than physical. There may be social reasons for planktonic groups; the patches may be feeding aggregates of individuals whose statistical survival is better in a group than as uniformly distributed individuals; since increased prey generally means increased predators, a small initial concentration at some level in the food chain will lead to increased concentrations at higher levels. It appears that both water movements and biological factors probably contribute to plankton patchiness.

2. Some biological models have been developed and used in the Strait of Georgia and should be applied on a routine basis if monitoring programs are established. The Sverdrup model for predicting the initiation and magnitude of spring plankton blooms has been adapted and used in the North Pacific and the Strait of Georgia. Further development of fish predator-prey models is desirable, encompassing the observed patchy nature of plankton rather than assuming that predator and prey are continuously

engaged: we would need to know more about the length and time scales of plankton patches in order to model them realistically. Attempts to model the effects of pulp mill stains on biological productivity may have more widespread application to estuarine areas of the Strait where silt has the same effect of reducing productivity through reduction of light levels.

3. Questions which are most important to fisheries within the Strait concern the mechanisms which are responsible for the large natural fluctuations in fish and shellfish stocks. Factors controlling the survival of larval fish (particularly salmon and herring) in the Strait are unknown, but may be crucial to the size of future adult population. The difficulty of this particular problem is enormous. First, most juvenile fish spend the most sensitive parts of their lives in roughly the upper 5 m of the Strait, the most variable part of the water column. Secondly, it is recognized that large-scale atmospheric or oceanic variations may affect fish populations within the Strait; for example, a quasi-stationary meteorological disturbance may cause increased flow through the Strait of Georgia, carrying immature fish out to sea before the appropriate stage of their development. Shellfish populations also undergo large changes, apparently through natural causes. Correlations have been found between the size of the adult population and water temperatures during critical early stages of their development, but the mechanism for this correlation is not clear. In the field of fisheries stocks, there appears to be a need for simple exploratory models to clarify the interactions between biological and physical parameters.

4. The question of the effect of the present level of pollutants on fisheries in the Strait was raised. The only documented effects are the

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concentration of heavy metals in shellfish and fish and the reduction of resident fish stocks in the Lower Fraser River. Other human influences, such as the destruction of estuaries and spawning grounds by industrial activities, are not direct water pollution effects. Two different opinions were expressed on the effect of sub-lethal amounts of pollutants on fish stocks. One was that, under certain conditions, pollutants may be a critical additional stress to fish stocks which already undergo a wide range of natural stresses. The other was that biological systems have a strong tendency to adapt to changes in environment, so that, provided always that man's activities do not destroy spawning grounds, the fish stocks in the Strait may not be seriously affected by sub-lethal amounts of pollutants. Associated with this last viewpoint, we must realize that the effects of pollution on fish stocks may become harmful to humans long before there is any appreciable harmful effect on the fish themselves (e.g. heavy metal concentrations in fish).

5. Another problem that was mentioned was that of assessing the worth of environmental impact studies. In a number of instances where catastrophic effects on the environment were predicted, the prediction was sufficient to stop the project: in this case there is no possible check on the accuracy of the prediction. One suggestion was that such a study be done of the effect of some project on a small estuary of negligible importance to fisheries, the project then carried through, and the accuracy of the prediction assessed.

INTRODUCTION - SESSION III

Dr. P.B. Crean introduced the final session, concerning numerical modelling of physical systems, with application to the Strait of Georgia. The object of a numerical model of some system is to achieve a quantitative understanding of its dynamics, to be able to respond to various user requirements. A complex and often inter-related set of forcing functions act upon the water within the Strait: the ocean tides (surface and possibly internal tides), fresh water input, mixing over the sills in the vicinity of the San Juan Islands, atmospheric systems, as well as offshore processes such as coastal upwelling. We cannot hope to observe water properties at a sufficient number of locations to describe even the instantaneous state of the Strait of Georgia system, much less how that state changes with time. A rational alternative is to build models which may have limited predictive ability, but serve to greatly reduce the amount of observational data required in order to obtain an overall picture of the Strait. Analytical models are of limited use in the Strait because of complicated topography and the complexity of physical processes involved. At present, there exists a two-dimensional numerical model of the Strait of Georgia - Juan de Fuca Strait-Puget Sound system, which gives tidal currents (assumed to be vertically constant) within the Strait over a 4 km grid. Advantages of proceeding to a three-dimensional model are that estuarine processes and wind stress effects may be included. Various problems arise with such a three-dimensional model: appropriate horizontal and vertical grid sizes, Δx and Δz, and time step, Δt, must be chosen; it is desirable to filter surface waves out of the model to allow longer time steps; short-scale physical processes known to occur in the Strait must be incorporated into the necessarily

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coarser model in a meaningful way; means of looking at selected areas on finer scales should be investigated. Another major problem is that of designing observational programs to provide data for the model, or act as a definitive test of the model.

DISCUSSION:

1. There was a great deal of discussion of the uses which might be made of numerical models of the Strait. In this connection, it should be made clear that the predictive extent of the proposed three-D model will not be great, perhaps 12-24 hours at most, because of the limited predictability of various forcing functions, for example the wind field over the Strait. Such limited predictive ability is clearly all that is necessary for such problems as oil spills within the Strait, where the 12 hours following the spill are most crucial to its containment. Many of the other possible uses of the model have no need of prediction, using instead the ability of the model to interpolate, i.e. produce a distribution for X throughout the Strait for a small number of measurements of X. Such distributions are the ultimate aim of modelling, but at present only a current model is suggested; this is basic to any other, since advective motions within the Straits are so large. An important question which should be answered by a model of the current system is that of the residence time of water in the Strait, that is the time scale over which water is flushed out of the system into the Pacific. This time scale is important to any questions of waste disposal in the Strait. The horizontal transport of water in currents is of interest ot biologists, in determining the movement of planktonic organisms and the larval fish which

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feed on them. Advection of pollutants and Fraser River silt (which affects biological production by changing light penetration) are of interest to biologists, who would also like to obtain distributions of mixed layer depth in connection with onset of plankton blooms and some sort of nutrient budget to aid in estimating the possible total productivity of the Strait. A model of temperature distribution will be much more difficult than the current model, but would be highly valued by biologists because much biological variability appears temperature-correlated: it could also produce estimates of extreme conditions which might be detrimental to possible aquaculture efforts in the Strait.

2. Some of the technical problems of setting up the 3-D current model were discussed. One difficulty is the known occurrence in the Strait of physical processes such as internal waves, mixing at the edge and bottom of the Fraser River plume, etc., which occur over space and time scales which are very short compared to those envisaged for the model, but which may have to be incorporated into the model in some way. Presumably they could enter through vertical and horizontal "eddy diffusivities" placed in the momentum equation, but we must then find reasonable values for these coefficients. One suggestion was for a small scale "box" experiment, measuring distributions within and fluxes into some area of the Strait, where diffusive processes must contribute that change in properties distributions which is not accounted for by convection through the box. However, it appears likely that this technique will give very different results in different parts of the Strait, so that it may be more reasonable to approach the eddy viscosities through the model itself: that is, find out what magnitudes of coefficients are necessary in order to most closely

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reproduce observed distributions. Such a technique is not conclusive, but may be convincing if coupled with physical understanding. Another question is the means of treating the surface boundary condition, so that short period surface waves do not arise in the model but longer period physical processes which produce mean water level changes (e.g. wind set-up, head differences near Fraser) are adequately represented.

3. There was a great deal of discussion of the problems associated with supplying meteorological data for the model. It seemed apparent that the Strait of Georgia model has to be accompanied by an atmospheric model which will produce an estimate of the wind field over the entire Strait (in particular at the grid points required by the Strait model) from a limited amount of information, including standard larger scale synoptic weather maps, and a limited number of stations measuring actual wind around the Strait: such a model is being developed by A.E.S., Vancouver. Location of observing stations should be carefully chosen to be as representative as possible of wind over the body of the Strait. Mud flats on the eastern side of the Strait may be useful locations, accessible at low tides but far enough from land or structures: however a number of buoy-mounted systems may be necessary for an accurate description of the wind over the body of the Strait. The hourly averages presently produced from wind records would be quite sufficient for model input, but in view of the occurrence of low level inversions, it may be advisable to measure the wind at some height which is lower that the 10 m normally used by the Meteorological Service. Oceanographic requirements for model inputs are in the form of boundary conditions across the entrances of the system, Johnstone Strait in the north and the Strait of Juan de Fuca to the south. Johnstone Strait will

be the easiest of the two sections to instrument properly: because it is a relatively narrow and very well mixed tidal channel, a single chain of current meters can be expected to give a good estimate of the total channel flow. The Juan de Fuca section is much wider, allowing for possible horizontal inhomogeneities in flow. If narrow regions of high velocity did exist, measurements of total transport by widely spaced current meter strings would be meaningless. It was suggested that an attempt be made to determine just how representative such section measurements are, by attempting a mass budget for the Strait system, using current meter sections acorss Johnstone and Juan de Fuca Straits and the measured fresh water inflow (metered rivers plus estimate of precipitation). Orders of magnitude difference between input and output would imply serious error, most likely in the Juan de Fuca system: a near balance would provide confidence in present measurement techniques. Since the Hydrographic service is in fact instrumenting a section across Juan de Fuca in 1973, it was suggested that the Johnstone Strait section be added to the program if possible, and such a rough mass budget attempted. Correlations between individual current meters within the same section should provide additional information on horizontal spacing.

4. Design of observational programs for the critical testing of a 3-D model must await model development.

5. The need to fulfill the needs or desires of the public for environmental information was stressed. It is hoped that all observational material obtained by government or university groups in the area will be published in data report form, to allow its use by environmental groups, etc. The existing topographical model of the Strait was mentioned as a nucleus for a

possible display of the various environmental problems, the existing and planned programs within the Strait

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The purpose of this workshop was to exchange information, and to get some sort of idea of the priorities with regard to environmental work in the Strait, that is, what needs to be done first, as fundamental to future programs: in this purpose, I feel that it succeeded. A number of specific recommendations arose from the discussion of water quality. The body of this report is full of problems which invite solution.

STRAIT OF GEORGIA WORKSHOP

PARTICIPANTS

S.O. Wigen	Environment Canada (E.C.) Victoria, Tidal Survey
P.B. Crean	E.C., Vancouver
P.H. LeBlond	Institute of Oceanography, University of British Columbia (I.O.U.B.C.)
H.L. Grant	Defence Research Board Establishment Pacific
R.W. Stewart	E.C., Victoria and I.O.U.B.C.
L.F. Giovando	E.C., West Vancouver
S. Nikleva	E.C., Atmospheric Environment Service, Vancouver
A.E. Gargett	E.C.,Victoria
T.R. Parsons	I.O.U.B.C.
F. Boyd	E.C., Fisheries Service
S. Tabata	E.C., Victoria
G.L. Pickard	I.O.U.B.C.
C. Leving	F.R.B., West Vancouver
G.S. Pond	I.O.U.B.C.
C. McAllister	F.R.B., Nanaimo
M. Miyake	I.O.U.B.C.
J. Luternauer	Department of Geology, U.B.C.
T. Butler	F.R.B., Nanaimo
R. Wright	E.C., Atmospheric Environment Service, Vancouver