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PROCEEDINGS OF THE
CANADA - BRITISH COLUMBIA WORKSHOP
ON
WATER QUALITY GUIDELINES AND OBJECTIVES:
FOCUS ON THE FRASER

NOVEMBER 16-17, 1988

DONALD D. MACDONALD
RAPPORTEUR

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Inland Waters
Pacific and Yukon Region
Vancouver , B.C.



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Water Quality Branch
Inland Waters, Conservation and Protection
Environment Canada
502-1001 West Pender Street
Vancouver, British Columbia
V6E 2M9

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**PAVILION C
PAN PACIFIC HOTEL
300-999 CANADA PLACE
VANCOUVER, BRITISH COLUMBIA**

**DONALD D. MACDONALD
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Co-hosted by:

**Water Quality Branch
Inland Waters, Conservation and Protection
Environment Canada
502 -1001 West Pender Street
Vancouver, British Columbia
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and

**Water Management Branch
British Columbia Ministry of Environment
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FOREWORD

This workshop was co-hosted by Water Quality Branch, Environment Canada and Water Management Branch, British Columbia Ministry of Environment. Coordination of the meeting was provided by the staff of the Water Quality Branch, Environment Canada, in conjunction with all of the participating agencies. The views, conclusions, and recommendations contained in this document are those of the participants, and do not necessarily reflect the policies or positions of Environment Canada.

ACKNOWLEDGEMENTS

It would be impossible to acknowledge every person who had some degree of input into the organization of this workshop. I would, however, like to take this opportunity to thank, on behalf of the workshop participants, those persons whose assistance was invaluable. The efforts and suggestions of Leslie Churchland, Diana Valiela, John Zeman, Ron Kistriz, and Rolly Rocchini during the organizational phases ensured, to a large degree, the success of the meeting. Peter Toft and Diane Kirkpatrick graciously supported the participation of delegates from Health and Welfare Canada, Ottawa. Thanks are also extended to Bev Huston and Betty Meek for making excellent contributions to the workshop on very short notice. The Session chairs and all of the speakers also deserve a note of thanks for a job well done. Gail Moyle, Chris Baldazzi, Mark Sekala, and Louisa Ng handled the most difficult and unrewarding tasks associated with the meeting: registration and security. Their efforts are hugely appreciated. Lastly, Trudy Anaka deserves thanks for providing word processing support.

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**Canada - British Columbia Workshop on Water Quality
Guidelines and Objectives: Focus on the Fraser - Preamble**

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INTRODUCTION

Water quality criteria, guidelines, and most recently objectives have been used by researchers and aquatic resource managers to enhance their understanding of interactions between water quality and water uses. However, since the release of the Canadian Water Quality Guidelines [Canadian Council of Resource and Environment Ministers (CCREM) 1987] interest in these management tools has increased dramatically, not only among water quality specialists but also among representatives of industry, user groups, and the general public.

In November, 1987, Federal - Provincial and Federal - Territorial information sessions on the Canadian Water Quality Guidelines were held in Vancouver and Whitehorse, respectively. A range of topics were covered at these sessions, including development and use of the guidelines, research needs associated with guidelines development, and the need for guidelines for additional variables (e.g., chlorophenols and barium), conditions (e.g., marine and estuarine guidelines) and media (e.g., guidelines for contaminants in sediment and biota). The meeting resulted in the generation of a specific set of recommendations to the CCREM regarding future work on the Canadian Water Quality Guidelines. More importantly, dialogue amongst and between various Federal, Provincial, and Territorial agencies on the development, implementation, and use of water quality guidelines and objectives was initiated.

The Canadian Council of Resource and Environment Ministers has responded to these recommendations by starting work on a number of the items identified during the information sessions. Perhaps the most significant of these initiatives is the work directed at the formulation of guidelines for estuarine and marine conditions. Other important initiatives include commitments to develop guidelines for those chemicals identified in the Priority Substances List under the Canadian Environmental Protection Act (CEPA), for levels of environmental contaminants in sediments, and for nutrients in running waters. In addition to the work specifically undertaken by the CCREM, a significant amount of effort has been expended by other agencies to satisfy some of the information and research requirements listed at those meetings.

WORKSHOP GOALS AND FORMAT

The present workshop was organized to provide a forum for the presentation of new information and research applicable to the development and assessment of water quality guidelines and objectives. Specifically, the meeting was designed to highlight aquatic resource management issues unique to the Fraser River Estuary, a water body which is, by formal agreement, co-managed by the Federal and Provincial governments. In so doing, it was thought that further communication between and among those agencies concerned with water management in British Columbia would be facilitated.

The workshop was comprised of four functional units. The introductory session contained two general papers on approaches to the development and the role of water quality objectives. Session A consisted of nine papers that focused on guidelines and objectives for toxic organic substances. Guidelines and objectives for inorganic substances were addressed by five papers in Session B. Specific topics on the development and use of water quality objectives were covered by four papers in Session C. Each of the three technical sessions was followed by a one hour discussion session. An open forum format was adopted for the discussion sessions to encourage the free exchange of ideas and insights on any of the topics covered in the session.

Speakers were instructed to submit a brief, camera-ready summary (5 pages or less of text, plus tables and figures) of their presentations for inclusion in these proceedings of the workshop. The summaries were not reviewed or edited by the workshop rapporteur prior to publication of these proceedings.

INTRODUCTORY SESSION

WATER QUALITY GUIDELINES AND OBJECTIVES

Approaches to the Development of
Water Quality Guidelines and Objectives
in Environment Canada

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INTRODUCTION

The development of water quality guidelines and objectives requires intensive use of a variety of types of information. Variables of concern are identified and recommendations are made for each variable. The recommendations may take the form of general guidelines, site-adapted guidelines, or site-specific guidelines. These guidelines can be designated as water quality objectives. This paper identifies major information needs involved in development of guidelines and objectives.

IDENTIFICATION OF VARIABLES

Variables requiring guideline development can be identified by examining water uses, existing water quality, and pollution factors. Specific water uses are known to be impaired by certain variables (e.g. fecal coliform bacteria are indicators of pathogens that impair drinking and recreational uses of water, metals are highly toxic to freshwater aquatic life, dissolved salts are a particular problem for irrigation use, etc.). Study of "background" water quality may reveal variables that are already out of normal ranges or indicate conditions that will create additional or interactive stresses with pollutants. Pollution factors themselves indicate the choice of variables for defining objectives in a water body.

Often, neither "background" water quality nor pollution factors are well characterized in a water body. Thus there is a requirement for special studies and monitoring programs to identify the variables of concern for development of guidelines.

GENERAL GUIDELINES

General guidelines for the identified variables may be used as a starting point for water quality objectives. Commonly used existing guidelines are CCREM 1987, EPA 1986, Butcher 1988, and others. However, guideline documents are highly abstracted and often somewhat out of date relative to the open scientific literature. Thus the original detailed toxicology literature is often consulted to supplement guideline documents. Toxicology bibliographic data bases, such as the EPA funded "Acquire," are useful in this regard.

On a more local level, guideline documents such as the B.C. M.O.E. Criteria Documents (e.g. Butcher 1988), the EP Chemicals in the Environment reports (e.g. Garrett and Shrimpton 1988) and the criteria work done by Fisheries and Oceans (e.g. Rogers et al. in press) are very useful.

Information contained in guideline documents and the toxicology literature may not be sufficient to specify guidelines or objectives, so that new toxicology information must be developed. Often, additional information is required on sublethal chronic effects, on how toxicity of a material varies over ranges of environmental variables, and on joint toxicity of pollutants. When there is no opportunity to obtain this information, guidelines are obtained by using available LC50 information and application factors.

SITE-ADAPTED GUIDELINES

Because conditions in specific aquatic environments can differ substantially from those of laboratory bioassays, general guidelines are often modified for development of water quality objectives. Modifications are only possible for a few variables with known dependencies on other ambient conditions (e.g. ammonia with pH and temperature, metals with hardness). Little is known about how the toxicity of organic pollutants varies with other environmental variables. For cases where modifications of general guidelines can be made, it is important to have good information on existing water quality at the site, again from monitoring and special studies.

Site-adapted guidelines are also determined by what is known or can be learned about the different species present, most susceptible life stages present, and timing of presence. An example of a detailed analysis of this kind is MacDonald et al.'s (1987) site-specific water quality criteria for nitrate, nitrite, and ammonia for aquatic life in the Canadian Flathead River. Knowledge of species present and distribution and timing of life stages allows very detailed definitions of water quality requirements and monitoring strategies for these nitrogen compounds for specific sites and times of years.

SITE-SPECIFIC GUIDELINES

The distinction between site-adapted and site-specific guidelines is a difficult one to define, since the degree of site specificity incorporated in a water quality guideline increases gradually as more local considerations are taken into account. However, site-specific guidelines are usually understood to incorporate some in situ cause-effect work. New bioassays may be conducted to test toxicity under a site-specific set of conditions. Bioassays may be performed on the species of fish or other organisms found in the site. Site water may be used in bioassay work (see Willingham 1988).

It should be noted that guidelines may also be based on in situ bioassay responses (e.g. no Daphnid reproductive effects) rather than only on concentrations of chemicals in various media. In addition, in situ cause-effect experimental work may also be used to determine deleterious levels of exposure to suspended sediments (concentration/duration

combinations) or nutrient regimes causing undesirable primary production conditions. Such studies may involve the use of mesocosm experimental facilities, such as those employed by H. Mundie at Carnation Creek (Mundie, pers. comm.).

MONITORING FOR COMPLIANCE WITH OBJECTIVES

Another area requiring further development is compliance monitoring. At present, it is common practice to use whatever monitoring data exist to compare with guideline or objective levels as a means of determining compliance. However, most or all monitoring programs were not designed for exceedance detection and are therefore ill-suited for this purpose.

Designing monitoring for compliance with objectives is an integral part of the objective formulation process, since the monitoring must reflect the variables, distribution, and timing of the objectives themselves. New approaches are suggested (Whitfield 1988, Valiela and Whitfield in press a. and in press b.) but much work remains to be done in this field.

CONCLUSIONS

Development of general water quality guidelines, site-adapted guidelines, and site-specific guidelines requires intensive use of many types of information. General water quality guideline documents, bibliographic toxicology data bases and the original scientific literature all provide a good starting point for this work. Special studies of water quality and monitoring activity are usually required to understand existing water quality and the qualitative and quantitative nature of point and diffuse source pollution.

There is an urgent need to develop more toxicological information, especially on sublethal effects of environmental pollutants. Other important areas requiring development include dependencies of toxicity of pollutants on other environmental variables and joint toxicity of different pollutants. Information is also required on other aquatic ecosystem responses to environmental perturbations. For example, the relationship between nutrients and stream eutrophication is currently poorly understood. Also, the relevance of research in quantitative structure/activity relationships (QSAR) to water quality objectives development is currently unknown, but may prove useful for management purposes. This possibility ought to be explored.

Field toxicology is of great importance for water quality objectives. A few research initiatives in this area should be supported, augmented and applied to water management. As well, new approaches are required for monitoring for compliance with objectives.

Thus it is apparent that development of water quality guidelines and objectives requires expanded efforts in research and applied science. In spite of the magnitude of these information requirements, progress can be made through cooperation and communication. Resources would be most efficiently and effectively utilized in joint and complementary work among federal, provincial, and municipal governments, the private sector, universities, and other non-governmental organizations.

REFERENCES CITED

- *Butcher, G.A. 1988. Water Quality Criteria for Aluminum. B.C. Ministry of Environment, Victoria. Also Technical Appendix.
- *Canadian Council of Resource and Environment Ministers (CCREM), 1987. Canadian Water Quality Guidelines. Ottawa, Ontario.
- *Garrett, C.L., and Shrimpton, J.A. 1988. Chemicals in the Environment. Pacific and Yukon Region. V. Chlorophenols. Environmental Protection, Vancouver, 48 pp.
- MacDonald, D.D., Fidler, L.E., and Valiela, D. 1987. Site-specific Water Quality Criteria for Fish and Aquatic Life in the Canadian Portion of the Flathead River Basin: Nitrate, Nitrite, and Ammonia. Inland Waters Report, Environment Canada, Vancouver 127 pp.
- Mundie, H. 1988. pers. comm. Biological Services Branch, Fisheries and Oceans Canada. Nanaimo, British Columbia.
- Rogers, I.H., Servizi, J.A., and Levings, C.D. in press. Bioconcentration of Chlorophenols by Juvenile Chinook Salmon (Oncorhynchus tshawytscha). Overwintering in the Upper Fraser River: Field and Laboratory Tests. Water Pollution Research Journal of Canada.
- *U.S. Environmental Protection Agency (EPA). 1986. Bacteriological Ambient Water Quality Criteria for Marine and Fresh Recreational Waters. Office of Regulations and Standards, U.S.E.P.A., Washington, D.C., E.P.A. 440/5-84-002.
- Valiela, D., and Whitfield, P.H. in press a. Monitoring Strategies to Determine Compliance with Water Quality Objectives. Water Resources Bulletin.
- Valiela, D., and Whitfield, P.H. in press b. Designing Site-Specific Water Quality Objectives and Monitoring. Water Pollution Research Journal of Canada.
- Whitfield, P.H. 1988. Strategies for Monitoring to Assess Compliance with Water Quality Objectives. Proceedings Can-B.C. Workshop on Water Quality Guidelines and Objectives: Focus on the Fraser.
- Willingham, T. 1988. Using in situ Bioassays as a Basis for the Development of Site-Specific Water Quality Objectives. Proceedings Can-B.C. Workshop on Water Quality Guidelines and Objectives: Focus on the Fraser.

*These references have series of volumes for different pollutants.

THE ROLE OF WATER QUALITY OBJECTIVES
IN
WATER QUALITY MANAGEMENT
IN
BRITISH COLUMBIA

by

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1.0 THE ROLE OF THE MINISTRY OF ENVIRONMENT

The overall responsibility for water quality management in the Province of British Columbia is assigned to the Ministry of Environment. Two agencies are given leading roles in the management functions; the Waste Management Branch, which regulates the handling and ultimate disposal of wastes, and the Water Management Branch, which regulates the use of water and leads the program of objective-setting for water quality. A third agency of the Ministry, the Pesticide Control Branch, plays an important incidental role in water quality management, through the regulation of the sale, transport, storage and use of pesticides within the province. Other agencies of the Ministry, such as the Recreational Fisheries Branch and the Wildlife Branch, provide advice to the principal regulatory Branches during the adjudication processes for water, wastes and pesticides, in the interests of the living natural resources they manage.

Public health aspects of water, such as the quality of drinking water supplied by purveyors, the quality of water at bathing beaches, and the regulation of septic tanks discharging up to 5 000 gallons/day to ground are in the jurisdiction of the Ministry of Health.

The Ministry of Environment represents the Province of British Columbia in numerous joint initiatives related to water quality management undertaken with other provinces, the federal government and state and federal agencies in the United States. A recent example is the joint development of the "Canadian Water Quality Guidelines" by a Task Force of the Canadian Council of Resource and Environment Ministers (CCREM), an organization with representation from all provinces and territories and the federal government.

1.1 THE ROLE OF WASTE MANAGEMENT BRANCH

The Waste Management Branch is the lead agency in the regulation of waste discharges in British Columbia, under the authority of the Waste Management Act and the Litter Act. Waste dischargers are required to have a Waste Management Permit which specifies the location, time, quantity, type, and characteristics of wastes permitted to be discharged to air, water or land, and may include conditions that must be maintained in the receiving environment. Certain types of dischargers or industries may be conditionally or unconditionally exempted from requiring a Permit, and certain minor discharges or temporary storage of wastes may be approved by means of an Approval from Waste Management Branch.

The Waste Management Branch is guided in part by Pollution Control Objectives established for five broad classes of waste dischargers:

- Food-processing, Agriculturally Oriented, and Other Miscellaneous Industries
- The Forest Products Industry
- The Mining, Smelting and Related Industries
- The Chemical and Petroleum Industries
- Municipal Type Waste Discharges

These Pollution Control Objectives contain policy guidelines for in-plant controls, waste treatment, waste disposal, quality of gaseous, liquid and solid discharges to air, water and land, monitoring of waste streams and the receiving environment, and some receiving-water quality objectives. The Pollution Control Objectives are subject to intermittent review and revision to take account of improved knowledge and technology. They have historically formed the principal policy basis for the provisions specified in Waste Management Permits issued to dischargers of waste into the environment. However, the individual permits specify the requirements to be met and they are established on a site specific basis.

To deal with the special considerations that apply to wastes which are potentially hazardous to human health and/or the environment, and which require special treatment before release into the environment, a Special Waste Program has been initiated. This program will include regulations to define special wastes, register special waste generators, licence special waste transporters and to establish environmental, emission, discharge, siting and operational requirements for their storage, transport and management. Waste included may be ignitable, corrosive, reactive, toxic, infectious, bioaccumulative, mutagenic, carcinogenic or teratogenic. One objective is to maintain control over special wastes from their generation to their destruction and disposal.

Water Quality Objectives prescribed for any particular body of water are a recent (starting 1985) enhancement to the Ministry's more generalized policy as laid down in the Pollution Control Objectives, and provide more site-specific direction to Waste Management Branch in its permitting process. The Branch is guided by them in any decisions made concerning water quality in the water body to which they apply.

1.2 THE ROLE OF WATER MANAGEMENT BRANCH

The Water Management Branch is the lead agency in the development of Water Quality Objectives for British Columbia. The process draws upon expertise of other Branches as may be appropriate, during the information-assembly, the drafting and the review phases. Some steps also draw upon expertise in other Ministries, local governments, federal agencies, academic institutions and state and federal agencies in the United States and other countries. Further details about the process will be elaborated below.

As is the case for Waste Management Branch, when Water Quality Objectives are adopted as policy of the Ministry, Water Management Branch is guided by them in any decisions made concerning water use that have potential for affecting water quality in the water body to which they apply.

2.0 DEVELOPMENT OF WATER QUALITY OBJECTIVES

The Ministry decided in 1981 to develop site-specific Water Quality Objectives. Following several months of planning and procedure development, work began in 1982 on the development of both Water Quality Objectives and Water Quality Criteria. As of October, 1988, nine Criteria documents and 21 Objectives documents have been signed into policy effect. Nine Criteria documents and 15 Objectives documents are in preparation.

Water Quality Objectives are Ministry policy guidelines for decision-makers who issue Water Licences (or Approvals) for water use or works in or about a water course, and Waste Management Permits (or Approvals) for waste disposal. They are also useful to fisheries and wildlife resource managers and regulators of pesticide use, and for assessing the effectiveness of the Ministry in protecting the environment. They are the culmination of a multi-stage process consisting of:

1. Identification of problems in water bodies,
2. Delineation and ranking of water bodies with respect to the urgency of the problems,
3. Ranking of the water quality variables that require policy development,
4. Development of Water Quality Criteria (discussed below) for the quality variables in order of priority,
5. Water Quality Assessment for the specified water bodies in order of priority, itself a multi-phased process:
 - a) Catalog and map all present and anticipated point and non-point waste discharges in the subject area,
 - b) Catalog and map all present and anticipated water uses in the subject area,
 - c) Assemble all available data on waste discharges in the subject area, including the nature, treatment and Permit limits,
 - d) Determine the present waste loads and estimate future waste loads,

- e) Assemble relevant hydrologic, limnologic and oceanographic data and predict the effects of present and predicted waste loads on the receiving waters,
- f) Assemble and map all available aquatic environmental quality data for the subject area, including those for the water, the biota and the sediment,
- g) Analyse key water quality data with respect to the effects of wastes and the suitability of the receiving water for current or proposed uses, taking into account the Water Quality Criteria (discussed below) for the uses,
- h) Designate the water uses to be protected in the water body(s),
- i) Design Water Quality Objectives to protect the designated uses, taking into account the applicable Water Quality Criteria,
- j) Recommend water use designations, Water Quality Objectives, water and/or waste management options, studies, and monitoring to check attainment or suitability of the Objectives,
- k) Review by provincial and federal agencies and affected parties, and finalize the Water Quality Assessment, the use designations and the Water Quality Objectives to be adopted as policy.

6. Adoption of the use designations and Objectives.

In summary, Water Quality Objectives are environmental quality conditions set as targets for specific bodies of water or portions thereof, based on three main factors: (a) the designated use(s) for the water, (b) the Water Quality Criteria that have been adopted for the most sensitive designated use, and (c) the local conditions, including natural circumstances, ongoing and foreseen economic activity in the area, ongoing and foreseen waste loadings, and the actual measured water quality in the area. Objectives are subject to review and revision as circumstances change or knowledge improves.

Either of two approaches may be taken in British Columbia when Objectives are being set. For water bodies with exceptionally valuable resources and good existing quality, the Objectives are set to avoid degradation. For all other bodies, the Objectives are set to protect the most sensitive designated uses, which may allow some degradation (use of the assimilative capacity) or may entail some enhancement where the existing water quality is poorer than desired for the designated uses.

The Objectives do not apply within the initial dilution zone, which is the initial portion of the larger effluent mixing zone. The areal extent of the initial dilution zone is defined on a site-specific basis, and is normally relatively small (e.g., up to 100 m from the point of discharge, but not exceeding 25 to 50% of the width of the water body). The water quality in the initial dilution zone may be outside the Objectives for various uses, and sub-lethal effects may occur, but the condition should not be acutely toxic or conducive to other objectionable effects.

Water Quality Objectives are not themselves legally enforceable. The instrument for enforcement is the Permit, Licence or Order issued by the regulatory authority and which is guided in part by the policy direction implied in the Objectives.

3.0 DEVELOPMENT OF WATER QUALITY CRITERIA

Water Quality Criteria are policy guidelines concerning the acceptable range of conditions for particular water use classes. They apply province-wide, and are taken into account when site-specific Water Quality Objectives are being developed. Pending preparation and adoption of officially sanctioned Criteria for British Columbia, work on Objectives proceeds on the basis of Working Criteria drawn mainly from the "Canadian Water Quality Guidelines" mentioned in Section 1.0 above, but also from the scientific literature and from other jurisdictions.

Water Quality Criteria are developed for five use classes for surface fresh, estuarine and coastal marine waters. The use classes are:

- Drinking, public water supply and food processing (for raw sources prior to treatment),
- Aquatic life and wildlife,
- Agriculture (livestock watering and irrigation),
- Recreation and aesthetics, and
- Industrial uses.

The development of Water Quality Criteria, and the method of application to produce site-specific Objectives, is a multi-phased process:

- a) Identify and rank the water quality variables for which Criteria are needed for Water Quality Assessments and for which Water Quality Objectives are required,
- b) Select the variables for consideration in order of priority,
- c) Assemble scientific data from all sources concerning the effects of various concentrations of the chemical substance, or other physical or biological variable under consideration, on each water use,
- d) Develop Water Quality Criteria for the variable of concern, for each water use, and application methods so the Criteria can be adapted to the specific sites as Objectives,
- e) Recommend the Criteria and the application method(s),
- f) Review by provincial and federal environmental agencies and finalize,
- g) Adopt the Criteria and application method as policy.

As with Objectives, Criteria are subject to review and revision as the knowledge base improves.

4.0 ENFORCEMENT

The principal provincial agency involved in enforcement activities related to water quality is the Waste Management Branch. This activity centres around the Waste Management Permits, and the conditions therein. Most Permits for discharge of significant quantities of wastes prescribe a monitoring program to be performed and reported by the permittee to the Branch. This may be supplemented by independent monitoring by the Branch. The works are also inspected by Branch staff to assure compliance with the Permit. The schedule of reporting for monitoring programs is recorded in a computer system, and the compliance of the permittee is tracked.

To make optimal use of the enforcement resources available, a formal Compliance Strategy was developed for evaluation and enforcement. Each Permit is classified into one of four compliance/impact groups. A series of rating factors and criteria are used to assess the degree of compliance of the permittee, and assign "total compliance or minor non-compliance" or "significant non-compliance", and to assess the degree of impact and assign "low environmental impact" or "high environmental impact". The Branch follows the prescribed enforcement protocol, which includes a range of options, for each Permit according to its class. The actions taken by the Branch range from commending the permittee at one extreme, through warning letters or meetings with senior officials, to prosecution or cancellation of permits at the other, depending on the classification of the case and the circumstances.

The Water Licences, Approvals and Orders issued by the Water Management Branch may contain environmental conditions which affect water quality. The conditions specified are legally enforceable and take account of the Water Quality Objectives for the water body affected. As with the Waste Management Branch decisions, Water Management Branch decisions are appealable to the Comptroller of Water Rights (Branch Director), or to the Environmental Appeal Board, depending on who made the decision being appealed.

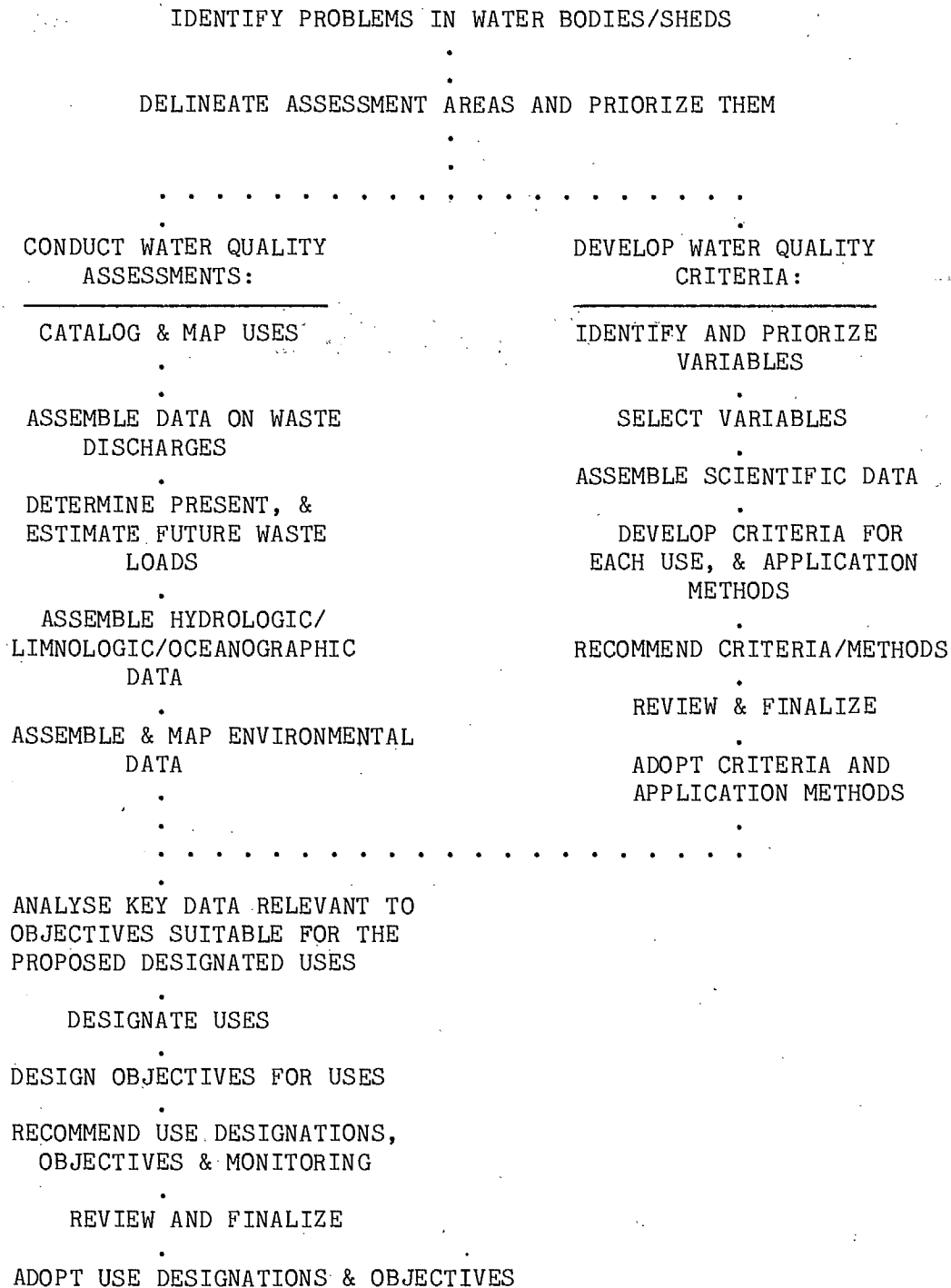
5.0 AMBIENT MONITORING

Apart from the zone-of-influence and control station monitoring prescribed in Waste Management Permits for the permittee to perform, and that performed by the Waste Management Branch to check permittee monitoring, the Waste Management Branch and Water Management Branch collaborate in two major ambient monitoring programs. The first is a program undertaken jointly by Environment Canada and the B.C. Ministry of Environment, and the second is a provincial program aimed at checking the degree of attainment of Water Quality Objectives set throughout the province.

Under the federal/provincial program, there are 24 federal/provincial sites, 40 provincial sites and 26 federal sites monitored. The frequency of sampling ranges from 4 to 52 times per year, most being in the 12 to 26 range. Samples are analysed for from 8 to 65 variables, usually between 20 and 30. All federal/provincial stations are for trend assessment; most provincial stations are for trend assessment and others are for investigation of the effects of wastes, nutrient loading or for surveillance; federal stations are for trend assessment and general surveillance.

The Objectives-related provincial ambient monitoring program provides for sampling and analyses as prescribed in the Water Quality Assessment and Objectives report to determine the degree of attainment of Objectives for each water body. In many cases, this requires five samples at weekly intervals in a 30-day period at a specific time of year. Some monitoring under this program is to secure information needed to develop Objectives, and to assess the appropriateness of provisional Objectives. It is intended to produce annual reports on the attainment of Objectives, starting with monitoring data for 1986. The resulting information will have application in the enforcement program outlined in Section 4.0 above.

PROCESS FLOW DIAGRAM
FOR SETTING WATER QUALITY OBJECTIVES IN BRITISH COLUMBIA
(SIMPLIFIED)



SESSION A

GUIDELINES AND OBJECTIVES FOR
TOXIC ORGANIC SUBSTANCES

Procedural Arrangements For The Development
Of Water Quality Objectives For The Fraser River Estuary^a

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V7T 1A2

INTRODUCTION

The Fraser River Estuary Management Program (FREMP) was established in 1985 with a major goal being to maintain ambient water quality levels in the lower Fraser, outer estuary and Boundary and Semiahmoo Bays that will ensure preservation of fisheries and wildlife and where suitable, provide for water contact recreation. The intent of the program was to improve management decisions regarding water quality by having them made within an estuary wide context and by providing all agencies involved in the estuary with an opportunity to participate. To facilitate this decision making/interactive process, a Management Committee and Executive was set-up with a number of reporting Committees and Activity Work Groups addressing various management issues (Figure 1).

The Standing Committee on the Fraser River Estuary Water Quality Plan was given the responsibility, by the Management Committee Executive, of developing a plan to ensure long-term protection for the estuarine environment. This plan, when completed, will include a coordinated comprehensive environmental monitoring program and federally/provincially agreed to Ambient Water Quality Objectives.

At present, Provincial Water Quality Objectives exist for the study area. These were reviewed by federal agencies during their development but have not been formally endorsed. However, as a starting point for the development of the agreed-upon objectives, the Management Committee Executive have accepted the provisional Objectives entitled, Fraser Delta Area, Fraser River Sub-basin from Kanaka Creek to the Mouth, Water Quality Assessment and Objectives (1985) and Fraser-Delta Area, Boundary Bay and its Tributaries, Water Quality Assessment and Objectives (1988).

The Standing Committee has proposed a mechanism whereby existing or new Water Quality Objectives can be reviewed and agreed upon by relevant federal and provincial agencies and implemented for the FREMP study area.

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- a. Modified from Draft Report - "Fraser River Estuary Management Program, Water Quality Plan - 1989".
- b. Chairman - FREMP Standing Committee on the Fraser River Estuary Water Quality Plan (1988-1989).

MANAGEMENT COMMITTEE

MANAGEMENT COMMITTEE EXECUTIVE

STANDING COMMITTEES

ENVIRONMENTAL REVIEW COMMITTEE

STANDING COMMITTEE ON THE FRASER
RIVER ESTUARY WATER QUALITY PLAN



- 3 - MINISTRY OF ENVIRONMENT
- 2 - DEPARTMENT OF ENVIRONMENT
- 1 - DEPARTMENT OF FISHERIES AND OCEANS
- 1 - GREATER VANCOUVER REGIONAL DISTRICT

ACTIVITY PROGRAM WORK GROUPS

LOG MANAGEMENT

WASTE MANAGEMENT

EMERGENCY MANAGEMENT

HABITAT MANAGEMENT

RECREATION MANAGEMENT

PORT AND INDUSTRIAL-
DEVELOPMENT

NAVIGATION AND DREDGING

DYKING AND DRAINAGE

FIGURE 1: REPORTING STRUCTURE AND RELATIONSHIP OF FREMP COMMITTEES

PROPOSED MECHANISM FOR OBJECTIVE DEVELOPMENT

A draft proposed mechanism to develop agreed-upon federal/provincial Objectives is shown in Figure 2. Any agency or member of the public can propose new or revised Water Quality Objectives using this approach. Initially, the documentation for a Water Quality Objective is forwarded to the FREMP Standing Committee. This Committee may form a technical adhoc subcommittee to review major issues and proposed Objectives. The members of the subgroup would vary, according to the type and complexity of objective(s) being reviewed, and may be drawn from outside the Standing Committee.

If a majority of the Standing Committee agree with the report documentation as submitted or the evaluation and recommendations of the subcommittee, the documentation and recommendation for a new or revised Water Quality Objective is forwarded to the Management Committee Executive for consideration. The Standing Committee will attempt to reach a consensus on all such proposal; however minority reports will be considered by the FREMP Management Committee Executive. The FREMP Management Committee Executive is composed of senior officials of federal and provincial agencies and the Harbour Commissions and agreement with any proposal by these senior managers would give the proposal federal-provincial endorsement. Only proposals receiving approval of the Management Committee Executive would be forwarded to the Ministry of Environment (MOE), since the mechanism is to be used only to issue agreed-upon Water Quality Objectives.

The FREMP Management Committee Executive will forward agreed-upon proposals for new or revised Water Quality Objectives to MOE for consideration. They will review the documentation, obtain input from other parties as required, and then issue the Objective if in agreement, or return it to the FREMP Management Committee Executive with rationale for reconsideration.

DOCUMENTATION FOR DEVELOPMENT OF OBJECTIVES

The documentation for a new or revised Water Quality Objective through FREMP is identical to that now required to prepare provincial Objectives. Much of what follows has been extracted directly from the publication Principles For Preparing Water Quality Objectives in British Columbia (Ministry of Environment and Parks 1986).

Information on some or all of the following will be required, depending on the specific Objective being developed. Where information already exists, reference may be made to the relevant documents.

Water Quality Criteria. These values provide, insofar as possible, information on short-term (acute) and long-term (chronic) effects, persistence, accumulation in biota or sediment, antagonism or synergism with other substances, and environmental fate of substances. Such

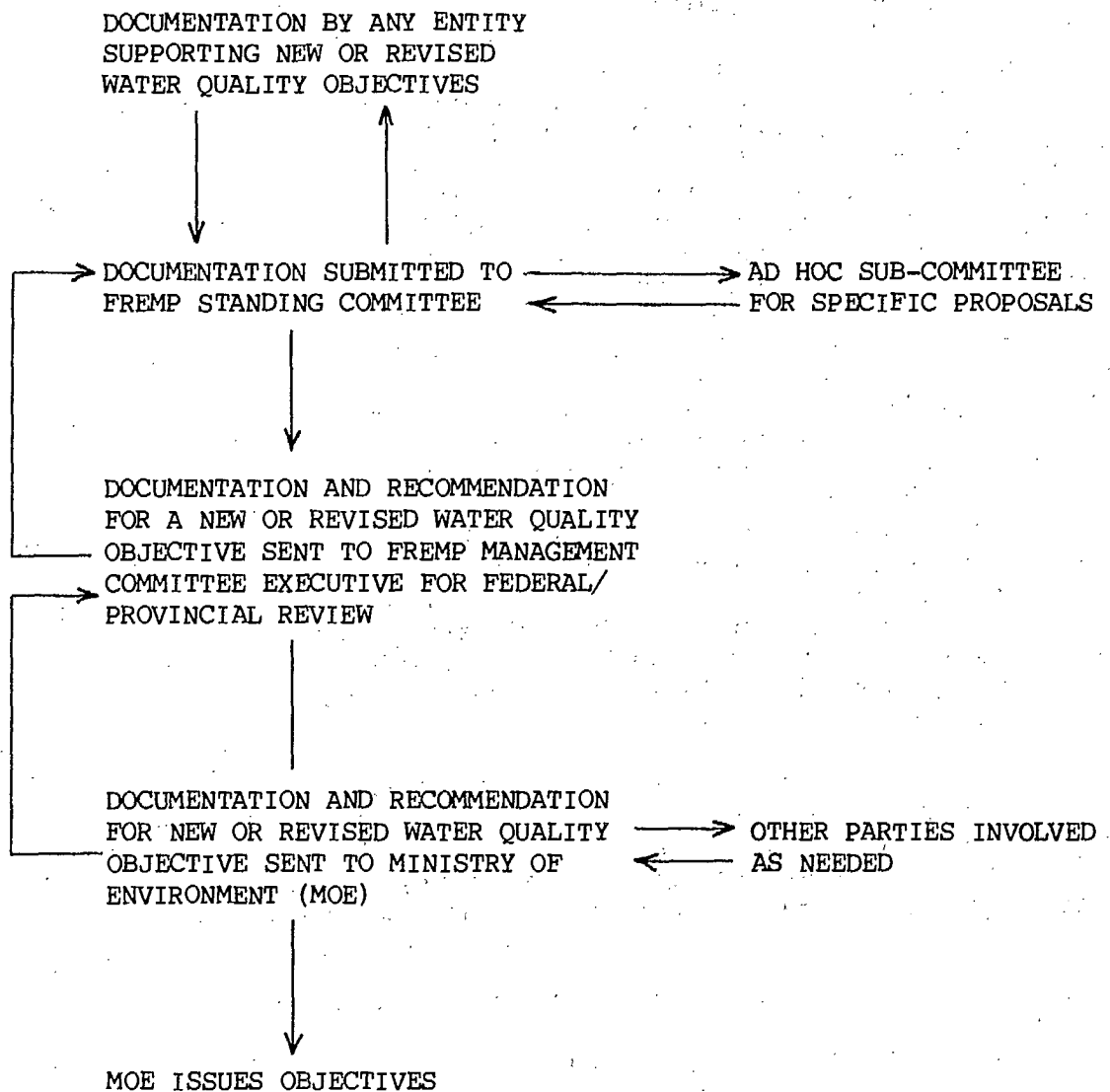


FIGURE 2: FREMP MECHANISM TO DEVELOP AGREED UPON WATER QUALITY OBJECTIVES FOR THE FRASER RIVER ESTUARY

Criteria are available in the Canadian Council of Resource and Environment Ministers (CCREM) 1987 publication, and in Criteria documents prepared by MOE and the U.S. EPA. Some Criteria may be new information developed specifically for the Fraser River estuary or specific sites within the estuary.

The existing environmental quality of the waterbody. This information for the characteristic of concern is described by the physical, chemical, and biological characteristics of the water, biota, and sediment.

The temporal and spatial variability of the characteristic in water, biota, and sediment.

The existing aquatic life in the waterbody and the potential for change as a result of the characteristic. This information includes species, geographic distribution of species, abundance, life history and commercial/social importance of the resource.

The flow or circulation pattern of the waterbody. This would attempt to be related to water flow and water quality.

The existing and potential impacts of the contaminant discharges. This information would attempt to relate the quality of water and sediments to the apparent health of aquatic life.

The potential and existing uses of the water. These can include timing of use and treatment of drinking water, and timing and types of the following uses: recreation, irrigation, livestock and industry.

In developing the assessment for the characteristic of concern, the following should be considered in presenting the information.

Stream flows (e.g., range of maximum and minimum 7-day average low flows, with 2 and 10-year return periods) should be summarized. In estuaries and marine environments, key oceanographic data, such as flushing rate, circulation patterns, and inflow/outflow data should be provided to indicate residence time, the potential for effluent, multiple dosing, or salt wedge influence.

Relevant water uses, waste discharges and ambient water quality monitoring sites should be plotted on maps (scale 1:100 000 to 1:250 000) to suggest any relationships. The nature and volume of the discharges should be described. Waste Management Permit conditions such as effluent volumes, concentrations or loadings, treatment, and monitoring required should be listed and effluent monitoring data should be summarized, wherever it is available.

Non-point sources of pollutants of concern should be shown on maps and their flows estimated. These discharges may include agriculture, sawmilling runoff, mining, septic tank drainage, landfills, urban runoff, atmospheric deposition,

boating, (i.e., any air, land, or water use activity that affects the aquatic environment). Any relevant surface water, groundwater, or precipitation quality data should be summarized.

Dispersion of effluent containing the characteristic of concern should be described in terms of initial dilution, dilution after complete mixing, time and distance to achieve complete mixing, and effluent plume behaviour based on present and projected future conditions and tidal influence.

Monitoring data where available relating to the characteristic of concern, including water, biota and sediment, should be summarized. Data should be arranged by site and other spatial or seasonal characteristics, giving number of values, measure of variability, maximum, minimum, and average, median, or geometric mean values. Water quality should be related to information on point and non-point sources of contaminants of concern where possible. Effects of the contaminant on water, sediments, and aquatic life should be part of such an analysis. The predicted effects should be compared with the effects shown by water quality measurements, and any significant discrepancies should be discussed.

The suitability of water quality for present and future water uses should be assessed by comparing it to Water Quality Criteria for water uses. Water uses that can be supported by existing or improved water quality should be identified, and designated water uses that should be protected should be recommended.

A monitoring program should be recommended to collect the information required to determine whether proposed Objectives are being exceeded or if improvements are needed.

A Summary Report based on the foregoing water quality assessment, including key findings, conclusions, maps of the area, and tables showing designated water uses, Water Quality Objective(s), and monitoring programs should be prepared. The report should be supported by documentation in a Technical Appendix in which the assessment, derivation of Water Quality Objectives, and supporting data and references should be presented in detail.

Water Quality Objectives For PCBs and CPs in the Lower Fraser River

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1.0 INTRODUCTION

Water Quality Objectives were approved for the Fraser River downstream from Hope by the B.C. Ministry of Environment in November 1985 (Swain and Holms 1985a,b). These had been prepared in 1983 prior to being reviewed extensively within the Ministry and by outside agencies.

Two of the approved Objectives of particular interest are for polychlorinated biphenyls (PCBs) and chlorinated phenols (CPs) in the reach downstream from Kanaka Creek (Figure 1). PCBs refer to the sum of all formulations while chlorophenols refer to the sum of all isomers of tri-, tetra-, and pentachlorophenol. The approved Objectives are:

Environmental Compartment	Maximum Concentrations	
	PCBs	CPs
Sediments (ug/g dry)	0.03	0.01
Fish (ug/g wet)	0.5	0.1
Water (ug/L)	N/A	0.2

These Objectives will be assessed relative to selected Criteria published since 1983 and as well as to values measured since that time.

2.0 SEDIMENTS

In 1983, there were no Water Quality Criteria for PCBs or CPs in sediments on which to base a Water Quality Objective so these were derived arbitrarily on the basis of levels measured in what were considered to be uncontaminated areas of the Fraser River Estuary. Objectives were deemed to be necessary for that area because PCBs had been measured in grit discharged in stormwater (Swain 1983) and historically from a paper recycling operation (Swain 1980). Objectives were necessary for chlorophenols because of the large numbers of operations in the estuary area using chlorophenates for anti sapstain control (Krahn et al. 1987). Objectives were deemed to be necessary for sediments due to the presence of benthic organisms, their place in the food chain, and the difficulty to measure levels in these organisms. Due to tidal action and the resulting movement of

water within the estuary area, all three major reaches of the estuary potentially could be affected by these compounds.

2.1 APPROPRIATENESS OF OBJECTIVES

Are the levels established for the Objectives for sediments still reasonable approximately five years after they were formulated? Using data from a number of stations in Puget Sound and testing for various levels of toxicity using different organisms, Tetra Tech (1986) developed Apparent Effect Threshold (AET) values (concentrations of contaminants that are associated exclusively with sediments having statistically significant biological effects relative to reference sediments) as follows:

	Amphipod AET	Oyster AET ug/g dry	Benthic AET	Microtox AET
PCBs (uncorrected)	2.5	1.1	1.1	1.3
CPs (uncorrected)	>0.14	>0.14	>0.14	>0.14
PCBs (Org C normal)	130	>46	270	12
CPs (Org C normal)	>11	>11	>11	>11
PCBs (Fine-grain sediment normal)	4.3	1.4	4.8	>0.23
CPs (" ")	>0.25	>0.25	>0.25	>0.25

The approved Objectives of 0.03 ug/g for PCBs and 0.01 ug/g for CPs compared to the lowest AET have application factors of 0.027 and >0.07, respectively. This, and the fact that a level of PCBs in sediments in Ontario of 0.05 ug/g was recommended (Canviro Consultants Ltd 1985), suggest there is not a need for a more restrictive Objective for either compound. However, prior to permanent Objectives for sediments being prepared, the development of AET values for sites in the Fraser River Estuary should be considered.

2.2 RECENT LEVELS

Swain (1986) and Swain and Walton (1988) reported on levels of PCBs and CPs at six stations from surveys conducted in 1985 and 1987, respectively. In the 1985 survey, PCBs could not be detected (<0.02 ug/g wet) in the Main Arm or at one site in the Main Stem, but were found to exceed the Objective at Site MS-1 (0.093, 0.092, and 0.28 ug/g dry), at Site NA-1 (0.14, 0.137, and 0.168 ug/g dry), and at Site NA-2 (0.099 and 0.097 ug/g dry). Chlorophenol concentrations at the same sites also exceeded the Objective, with average values of 0.038, 0.050, and 0.056 ug/g (dry), respectively. In comparison, values from sampling the same six sites in 1987 were not detectable for either PCBs (<0.02 ug/g wet) or CPs (<0.005 ug/g wet).

All PCB and CP values measured during a February 1988 survey at the same six sites were well below the Objectives, as were

values in sediments near the paper recycling operation and near Mitchell Island (Swain unpublished).

Swain and Walton (1988) also provided data for a further five sites in each of the three main river reaches. PCBs were detected at only 1 of 15 sites in 1987 (0.18 ug/g dry) at a site near the eastern end of Mitchell Island towards the Fraser River's south shore. All CP values at the 15 sites were below the Objective.

3.0 FISH

In 1983, two Water Quality Criteria existed for PCBs in fish. These were a maximum of 0.1 ug/g wet in the whole fish to protect birds and mammals (American Fisheries Society 1979) and 0.5 ug/g wet in tissues (EPA 1973). The latter was used as the working Criterion since most data for fish from the river were for muscle.

At that time, no Criteria existed for concentrations of CPs in fish. In fact, none were proposed in the draft distributed to different reviewers. However, personnel from the Department of Fisheries and Oceans suggested that an Objective for CPs in fish might be appropriate, and that 0.1 ug/g (wet) be considered. Values of <0.1 ug/g seem to be appropriate for areas where contamination has not occurred. Inasmuch as the ratio between values being considered for fish and sediment compartments would compare favourably to those for PCBs, the proposed Objective was accepted.

3.1 APPROPRIATENESS OF OBJECTIVES

Are the levels established for Objectives for fish still reasonable approximately five years after they were formulated? New information on which to judge this are only available for PCBs, and from only one source. Canviro Consultants Ltd (1985) have proposed a level of 2.0 ug/g (wet) for edible fish tissue to protect humans. This is four times the Water Quality Objective for fish tissue in the Fraser River. It thus may be too early to know if changes are required for the existing Objectives.

3.2 RECENT LEVELS

Swain (1986) reported that the Objectives for PCBs and CPs were not exceeded for fish collected at six sites in 1985. However, the fish may not have been resident species since they were about to spawn and may have recently returned from the ocean.

An intensive survey was conducted for the Ministry of Environment in August 1988. Fish were collected from three sites as follows:

SPECIES	MAIN STEM	NORTH ARM	MAIN ARM
Largescale suckers	P	P	P
Northern Squawfish	P	P	P
Threespine Stickleback	-	-	P
Peamouth Chub	P	P	P
Staghorn Sculpin	P	P	P
Starry Flounder	-	-	P
Redside Shiner	P	-	-

The data for both muscle and livers are not available at this time. These data should provide a good basis for determining if the Objective is achieved.

4.0 WATER

No Objective applies to PCBs measured in the water column. For CPs, the most restrictive Criterion when the Objective was formulated was a maximum of 0.4 ug/L (IJC 1981) for pentachlorophenol alone. Recognizing that CPs were not desirable at any level, the Criterion for pentachlorophenol was multiplied by 0.5 and was used for the sum of tri-, tetra-, and pentachlorophenol. This was deemed appropriate since the resulting Objective was still twice the analytical detection limit of 0.1 ug/L at the Environmental Laboratory.

4.1 APPROPRIATENESS OF OBJECTIVE

Since the Objective was developed, McKee et al. (1984) prepared a document whose values were adopted by the Canadian Council of Resource and Environment Ministers (1987), as follows:

CP	Consideration	Guideline (ug/L)
Mono	Taste	7
Di	Taste	0.2
Tri	Acute Toxicity	18
Tetra	Acute Toxicity	1
Penta	Acute Toxicity	0.5

The Objective for the Fraser River for the sum of tri-, tetra-, and pentachlorophenol is still well below this most recent Criteria for pentachlorophenol alone.

4.2 RECENT LEVELS

Data collected in the Fraser River at a number of sites in February 1988 (Swain Unpublished Data) at a time when stormwater would not have been entering the river were all less than or equal to 0.1 ug/L. This is similar to what was found in 1987 (Rocchini Draft 1988) and in 1986 (Rocchini 1987), however when stormwater discharges were occurring, CP values in the North Arm

were as high as 1.3 ug/L (Rocchini Draft 1988) .

These data confirm that CP measurements should coincide with precipitation events . As well , in any revision of the Objectives , that consideration be given to developing Objectives for each of tri- , tetra- , and pentachlorophenol , since the term CPs is too broad to accurately reflect the significance of the CP form present .

5.0 CONCLUSIONS

5.1 SEDIMENTS

Prior to permanent Objectives for sediments being prepared , the development of AET values for sites in the Fraser River Estuary should be considered.

5.2 FISH

It may be too early to know if changes are required for the existing Objectives .

5.3 WATER

CP measurements should coincide with precipitation events . In any revision of the Objectives , consideration should be given to developing Objectives for each of tri- , tetra- , and pentachlorophenol , since the term CPs is too broad to accurately reflect the significance of the CP form present .

6.0 REFERENCES

- American Fisheries Society . Review of the EPA Redbook : Quality Criteria For Water . Bethesda , Maryland . April 1979 .
- Canadian Council of Resource and Environment Ministers . Canadian Water Quality Guidelines . Ottawa , Canada . March 1987 .
- Canviro Consultants Ltd. Review of PCB Occurrence , Human Exposure and Health Effects . Kitchener , Ontario . 1985 . (Prepared for the Ontario Ministry of Environment)
- EPA . Water Quality Criteria 1972 . U.S. Government Printing Office . Report EPA-83-73-003 . Washington , D.C. 1973
- International Joint Commission . Report to the Great Lakes Science Advisory Board , Report of the Aquatic Ecosystem Objectives Committee . November 1981 .
- Krahn , P.K. , J.A. Shrimpton , and R.D. Glue . Assessment of Storm Water Related From Wood Protection Facilities in British Columbia . Environmental Protection Regional Report 87-14 . August 1987 .

McKee , P.M. , R.P. Scroggins , and D.M. Casson . Chlorinated Phenols in the Aquatic Environment . Scientific Criteria Document For Standard Development No. 2-84 . Water Resources Branch , Ontario Ministry of the Environment . Toronto , Ontario . 1984 .

Rocchini , R.J. A Check of How Well Water-Quality Objectives Were Achieved in 1986 . Resource Quality Section , Water Management Branch , Ministry of Environment and Parks . December 1987 .

Rocchini , R.J. The Attainment of Water Quality Objectives in 1987 . Resource Quality Section , Water Management Branch , Ministry of Environment . Draft . August 1988 .

Swain , L.G. Fraser River Estuary Study , Water Quality, Industrial Effluents . Victoria , B.C. November 1980 .

Swain , L.G. Stormwater Monitoring of a Residential Catchment Area Vancouver , B.C. Ministry of Environment . Victoria , B.C. March 1983 .

Swain , L.G. and G.B. Holmes . Water Quality Assessment and Objectives . Fraser-Delta Area , Fraser River Sub-basin From Kanaka Creek To The Mouth . Ministry of Environment . Victoria , B.C. November 1985 .

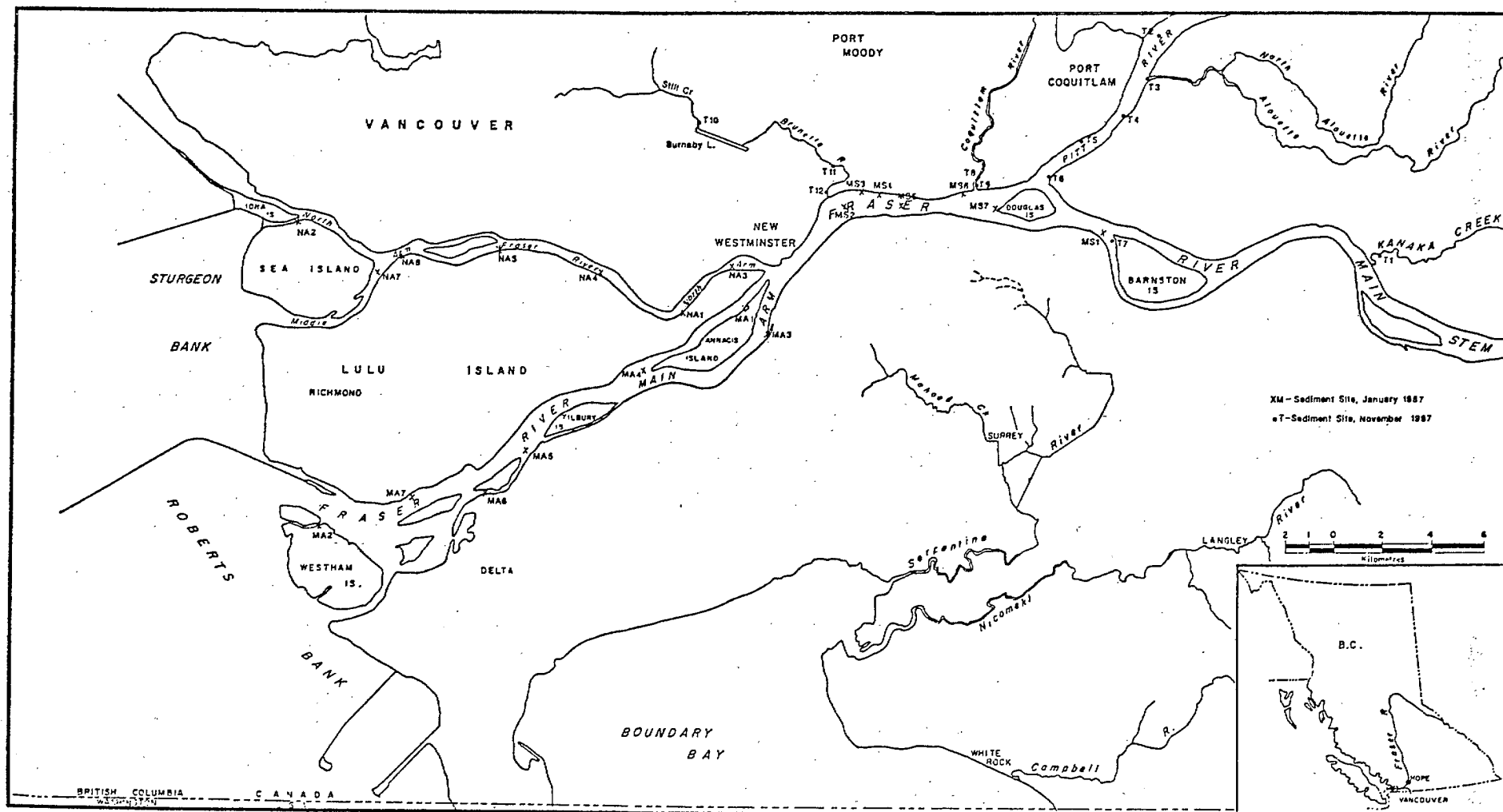
Swain , L.G. and G.B. Holmes . Water Quality Assessment and Objectives . Fraser-Delta Area , Fraser River Sub-basin From Hope To Kanaka Creek . Ministry of Environment . Victoria , B.C. November 1985 .

Swain , L.G. A 1985 Survey of Metals , PCBs , And Chlorophenols in the Sediments , Benthic Organisms And Fish of the Lower Fraser River . Ministry of Environment . Victoria , B.C. June 1986 .

Swain , L.G. and D.G. Walton . Fraser River Estuary Monitoring , Report on the 1987 Benthos and Sediment Monitoring Program . Ministry of Environment and Parks . March 1988 .

Swain , L.G. Unpublished data for sediments and water collected in February 1988 .

Tetra Tech . 1986 . Development of Sediment Quality Values For Puget Sound . Puget Sound Dredged Disposal Analysis Reports . Bellevue , Washington . 1986 .



Pathways of chlorophenols in the Fraser River Estuary, British Columbia.

by

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This presentation summarizes the results of a multi-year study into the sources and distribution of chlorophenolic contaminants in the Fraser River Estuary (Carey et al., 1988; Carey and Hart, 1988; Carey and Lam, 1989). The major chlorophenolics in the estuary were 2,4-dichlorophenol (2,4-DCP), 2,4,6-trichlorophenol (2,4,6-TCP), 2,3,4,6-tetrachlorophenol (2,3,4,6-TeCP), pentachlorophenol (PCP), 3,4,5-trichloroguaiacol (3,4,5-TCG) and tetrachloroguaiacol (TeCG). The sources of all these chlorophenolics were related to the forest industries. Under high flow conditions, concentrations of chlorophenolics were about the same at downstream sites as at an upstream site (Fig. 1). This distribution and the identity of the two most prominent chlorophenolics (3,4,5-TCG and TeCG) indicated that, under these flow and weather conditions, contributions from upstream pulp and paper mills masked inputs of chlorophenols from point sources in the estuary. Under low flow conditions, in addition to the pulp mill related chlorophenolics, significant inputs of 2,3,4,6-TeCP and PCP used in the lumber industry for wood protection, occurred along the North Arm of the estuary (Fig. 1). Studies of the temporal variations indicated that the discharges of wood protection related chlorophenols were episodic, whereas the pulp mill chlorophenolics showed little temporal variations. Maximum concentrations of 2,3,4,6-TeCP and PCP observed at a site on the North Arm well removed from potential point sources were 388 and 175 ng/L respectively. These observations indicate that the provisional objective of 200 ng/L can be exceeded during these episodic inputs and stimulated our interest in identifying the factors controlling the distribution and fate of chlorophenols in the estuary.

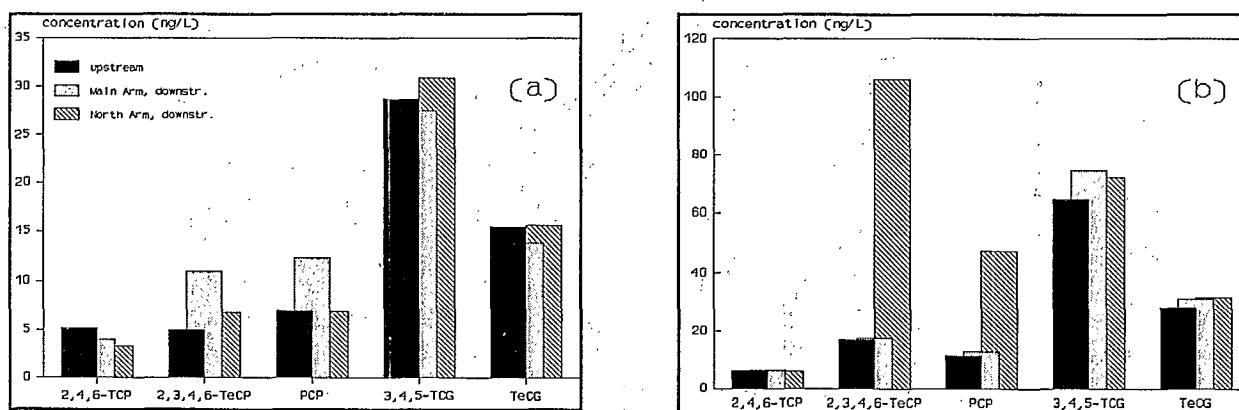
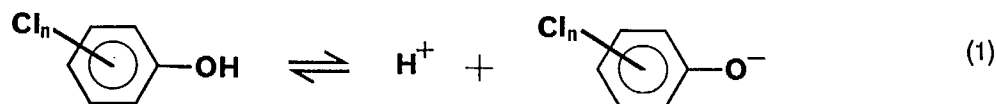


Figure 1. Comparison of average concentrations of five chlorophenolics sampled over four day periods at three sites in the Fraser River estuary under (a) high and (b) low flow conditions (Carey & Hart, 1988).



Chlorophenolics are different from many other organic environmental contaminants because they possess an ionizable proton and much of their environmental behaviour is controlled by the acid-base equilibrium shown in equation (1). The equilibrium constant, K_a , is defined as

$$K_a = \frac{[\text{H}^+][\text{dissoc. PCP}]}{[\text{undissoc. PCP}]} \quad (2)$$

This constant, which is also called the dissociation constant, provides a measure of the strength of the acid. The dissociation constant of acids is usually expressed as a pK_a which by analogy with the definition of pH is defined as $-\log K_a$. The pK_a s of a selection of chlorophenols with a range of chlorine substitution are listed in Table 1. With a pK_a of 4.8-5.0, PCP is the most acidic of the simple chlorinated phenolics. As shown in Table 1, as the degree of chlorine substitution decreases, the pK_a increases (Jones, 1982).

TABLE 1. Ranges of pK_a for selected chlorophenols

Compound	pK_a range
2-CP	8.48-8.65
3-CP	9.08-9.12
4-CP	9.37-9.42
2,4-DCP	7.85
2,6-DCP	6.79-6.91
2,4,5-TCP	7.00-7.07
2,4,6-TCP	6.10-6.62
2,3,5,6-TeCP	5.3
PCP	4.80-5.00

Equation (2) can be modified and rewritten as

$$\log \frac{[\text{dissoc. PCP}]}{[\text{undissoc. PCP}]} = \text{pH} - pK_a \quad (3)$$

In this form, the equation can be used to determine the extent of dissociation at a given pH. The question of speciation is important because the dissociated forms of chlorophenolics are much more water soluble than the undissociated forms. For example, the solubility of PCP increases from 0.05 to 300 g/L upon ionization. Servizi et al. (1988) reported the average pH in thirty-one samples of Fraser River water collected between January 21 and May 20, 1986 to be 7.76 ± 0.88 . Using this value and the pK_a s given in Table 1, the ratio of dissociated to undissociated forms can be calculated from equation (3). The results of this calculation are listed in Table 2.

Table 2. Extent of dissociation of selected chlorophenols at pH 7.76

Compound	[dissoc. CP]/[undissoc. CP]
2-CP	0.16
3-CP	0.05
4-CP	0.02
2,4-DCP	0.81
2,6-DCP	8.2
2,4,5-TCP	5.1
2,4,6-TCP	26
2,3,5,6-TeCP	290
PCP	725

Since the pH of most natural waters is in the 7.0-8.0 range, most of the higher chlorinated phenols exist essentially in the dissociated form while for the lower chlorinated phenols, significant quantities of both forms are present.

For partitioning of a compound between two immiscible phases, most typically an aqueous and a non-aqueous phase, the position of the partitioning equilibrium is proportional to the solubility of the component in the two phases. Since aqueous solubility of the dissociated PCP is so much greater than that of the undissociated form, there is a large decrease on partition coefficient upon dissociation. In this way, acid-base equilibria have a significant effect on bioaccumulation and other pathways involving partitioning into lipophilic phases. For example, Kaiser and Valdamanis (1982) showed that the octanol-water partition coefficient of PCP was highly dependent on pH. Their measured value for the octanol-water log P of the undissociated form was 4.84 whereas that of the dissociated form was around 3. Thus there was a decrease in partition coefficient of two orders of magnitude upon dissociation. Karrickhoff and coworkers (Karrickhoff, 1981; Karrickhoff et al. 1979) have discussed the sorption of pollutants to a wide variety of natural sediments. They observed that sediment-water partition coefficient, K_{sw} , was relatively independent of sediment concentration but was directly related to organic carbon content of the sediment. They determined that sorption of a contaminant onto a particular size class particle could be described by

$$K_{sw} = K_{oc} \times f_{oc} \quad (4)$$

where: K_{sw} is the observed partition coefficient
 K_{oc} is the carbon normalised partition coefficient
and f_{oc} is the fraction of organic carbon in the sediment

and established that the carbon normalised partition coefficient, K_{oc} , was approximately related to the octanol-water partition coefficient according to the equation

$$K_{oc} = K_{ow} \times 0.63 \quad (5)$$

Although the relationships reported by Karrickhoff and coworkers were observed for hydrophobic contaminants only and were not validated for acidic compounds, we attempted to use them to calculate predicted K_{sw} values. According to equation (3) and the K_{ow} values of Kaiser and Valdmanis (1982), the predicted carbon normalised partition coefficients of PCP are 630 and 6.3×10^4 for the dissociated and undissociated forms respectively. In order to predict the extent of sorption, values for the suspended solids concentration and fraction of organic carbon are needed. During a study of chlorophenolics in Fraser River water, we sampled water periodically over four day periods under high and low flow conditions (Carey & Hart, 1988). Suspended solid concentrations at these times averaged 145 mg/L under high flow conditions and 15 mg/L under low flows. The carbon content of the sediment, estimated by calculating 40 % of the loss on ignition, also varied with flow. Under high flow conditions, we estimate the f_{oc} to be 0.016 whereas

under low flow conditions, it was estimated to be 0.06. These estimated values are consistent with inputs of low carbon mineral phases during freshet. Using these values and equation (2), we calculate that the sediment-water partition coefficients for PCP onto Fraser River suspended sediments listed in Table 3.

Table 3. Predicted K_{sw} for PCP on Fraser River sediments.

	dissociated	undissociated
high flow conditions	10	1000
low flow conditions	38	3800

As shown in Table 1, K_{sw} values range from a low of 10 for the dissociated form on the mineral sediment observed under high flow conditions to a high of nearly 4000 for the undissociated form on the low flow suspended sediment. Based on the data presented in Table 2, approximately 99.9 % of the PCP is in the dissociated form in the Fraser River. Thus the higher partition coefficient for the undissociated PCP is offset by its much lower concentration at this pH. If the system can be assumed to be at equilibrium, the contribution of the undissociated form to the sediments should be about 12% of that of the dissociated form. The observed ratio of adsorbed to dissolved concentrations should therefore be in the 10-40 range depending on actual pH and organic carbon content of the sediment. For pH values lower than 7.76 or organic carbon concentrations greater than 6%, the contribution of the undissociated form would be more significant and the observed K_{sw} would be higher. It should be noted that in order for K_{sw} to be dimensionless, identical units must be used to express concentrations in the two phases. To check the accuracy of the K_{sw} predictions, we conducted adsorption experiments using suspended sediments collected with a sediment trap in the North Arm of the estuary under low flow conditions. Average K_{sw} values found were: 341 (+/- 22) for 2,4-DCP; 330 (+/- 5) for 2,4,6-TCP; 912 (+/- 145) for 2,3,4,6-TeCP; and 727 (+/- 116) for PCP. The results indicate that the K_{sw} calculations underestimated actual sediment-water partition coefficients by more than an order of magnitude. There are several possible reasons for this. It is possible that despite the fact that the system was buffered and the measured solution pH was 7.9, the actual pH at the sediment water interface was lower due to surface charge effects. It is also likely that the sorption into hydrophobic phases model used by Karrickhoff to develop his equations is not applicable to ionic compounds. Additional mechanisms of adsorption, eg. ion pairing with surface charges and adsorbed cations, are likely available for charged compounds. This could have the effect of enhancing adsorption. Regardless of the reasons, the results indicate that the chlorophenols partition onto Fraser River sediments to a moderate degree and that for water concentrations in the 10 ng/L range, sediment concentrations in the 1 to 10 ng/g range might be expected. However, when the actual mass of the sediment and water phases is considered, the results indicate that >99% of the PCP remains in dissolved phase under the flow conditions observed to date. Thus the fate of the chlorophenolic contaminants in the Fraser River will be governed by processes involving the water rather than the sediment phase.

The dissociation equilibrium discussed above also effects the extent of bioaccumulation of chlorophenols which has been studied in Fraser River fish by several groups (Carey et al., 1988; Servizi et al., 1988; Rogers et al., 1988). Carey et al. (1988) examined the correlations between the geographical distributions of chlorophenols in fish and water concentrations and concluded that the primary mode of accumulation was directly from the water, not via the food chain. Rogers et al. (1988) arrived at the same conclusion in their study of bioconcentration of chloroguaiacols by juvenile chinook (*Oncorhynchus Tshawytscha*) overwintering in the upper Fraser River. The importance of this direct route of uptake is a consequence of the fact that chlorophenols do not partition strongly into the food and are rapidly cleared by fish. The NRCC (1982) calculated predicted BCFs for PCP based on log P values of 3.8 for the dissociated form and 5.0 for the undissociated form. Using a log P of 5.01, the calculated BCFs for fish ranged from 1120 to 4910, while a log P of 3.8 resulted in predicted BCFs of 220-340. Carey et al. (1988) determined bioconcentration factors for 2,3,4,6-TeCP and PCP in several species of fish from the Fraser River estuary. Bioconcentration factors in starry flounder (*Platichthys stellatus*) were 380 and 100 for PCP and 2,3,4,6-TeCP respectively. In sculpins (*Leptocottus armatus* and *Cottus asper*) the equivalent BCFs

were 1640 and 440. Thus values of the BCFs observed were intermediate between those predicted for either the dissociated or undissociated forms.

An important consideration in evaluating the pathways of contaminants in estuaries is the degree of 'conservativeness' of the compound. This can often be estimated by comparing the half-life for reaction with hydrodynamic residence time. Ages and Woollard (1988) have recently applied a one-dimensional model to simulate the path and residence time of a contaminant in the Fraser River estuary. They estimated that the residence could vary between 6 and 30 hours depending on the time of year. For chlorophenols, chemical hydrolysis and oxidation are not important and since sorption is not important from a total mass viewpoint, the only reactions that need to be considered are biodegradation and photodegradation. Although biodegradation of chlorophenols has been demonstrated in a variety of laboratory and field tests, degradation rates are very site dependent. In some river systems, chlorophenols undergo rapid degradation. In a study of the persistence of dichlorophenols in a small stream in southern Ontario, Carey et al (1984) observed rapid disappearance due to degradation by the periphyton covering the rocks on the streambed. Half-lives were on the order of 4 to 6 hours. However, with higher chlorinated phenols or in systems in which attached microbial communities are insignificant, half-lives can be considerably longer. In their evaluation of chlorophenol pathways in the aquatic environment, the NRCC (1982) concluded that biodegradation was probably not a significant process for removal of PCP from surface waters. In experiments with natural sediments, seawater and freshwater, 30 to 90 day half-lives for biodegradation of PCP have been observed (Trevors, 1982; Baker et al., 1980; Kreuk & Hanstveit, 1981). A number of studies have demonstrated the photodegradation of PCP. Using literature values for photolysis rates, the NRCC (1982) calculated predicted photolysis rates for PCP in the Canadian environment. Predicted half-lives at pH 7 in surface waters ranged from 1 hour in summer to 1.8 days in winter, depending on latitude. Since light is attenuated relatively rapidly in natural water bodies, depth is the controlling factor for photolysis rates in the environment. For a 1m deep system at 45° N in June, the NRCC (1982) estimated a photodegradation half-life of 4 days. In deeper systems, the half-lives are much longer. Data presented by Fox and Joshi (1984) indicate that in the Bay of Quinte on Lake Ontario, the principal route of disappearance is photodegradation which occurs with a half-life in summer on the order of weeks or months. Given the relatively short hydraulic residence times predicted in the Fraser River estuary, it is unlikely that much degradation can occur. In this system, chlorophenols likely are conservative and their main fate is to be transported in dissolved phase into the Strait of Georgia.

REFERENCES

- Ages, A., and A. Woollard. 1988. Tracking a pollutant in the lower Fraser River: A computer simulation. *Water Pollution Research Journal of Canada* **23**: 122-140.
- Baker, M. D., C. I. Mayfield and W. E. Innes. 1980. Degradation of chlorophenols in soil, sediment and water at low temperature. *Water Research* **14**: 1765-1771.
- Carey, J. H., M. E. Fox, B. G. Brownlee, J. L. Metcalfe and R. F. Platford. 1984. Disappearance kinetics of 2,4- and 3,4-dichlorophenol in a fluvial system. *Canadian Journal of Physiology and Pharmacology* **62**: 971-975.
- Carey, J. H., M. E. Fox and J. H. Hart. 1988. Identity and distribution of chlorophenols in the North Arm of the Fraser River Estuary. *Water Pollution Research Journal of Canada* **23**:31-44.
- Carey, J. H., and J. H. Hart. 1988. Sources of chlorophenolic compounds to the Fraser River Estuary. *Water Pollution Research Journal of Canada* **23**: 55-68.
- Carey, J. H., and D. C. L. Lam. 1989. Pathways of chlorophenols in the Fraser River estuary, British Columbia. presented at and submitted for inclusion in the proceedings of the International Symposium on the Fate and Effects of Toxic Chemicals in Large Rivers and their Estuaries, Quebec, Oct 10-14, 1988. Proceedings to be published in *Science of the Total Environment*.

- Fox, M. E., and S. R. Joshi. 1984. The fate of pentachlorophenol in the Bay of Quinte, Lake Ontario. *Journal of Great Lakes Research* 10: 190-196.
- Jones, P. A. 1982. Chlorophenols and their impurities in the Canadian environment. Environment Canada, Environmental Protection Service. Economic and Technical Review Report, EPS 3-EC-81-2.
- Kaiser, K. L. E., and I Valdmanis. 1982. Apparent octanol/water partition coefficients of pentachlorophenol as a function of pH. *Canadian Journal of Chemistry* 60: 2104-2106.
- Karrickhoff, S. W., D. S. Brown and T. A. Scott. 1979. Sorption of hydrophobic pollutants on natural sediments. *Water Research* 13: 241-248.
- Karrickhoff, S. W. 1981. Semi-empirical estimation of sorption of hydrophobic pollutants on natural sediments and soils. *Chemosphere* 10: 833-846.
- Kreuk, J. F. de, and A. O. Hanstveit. 1981. Determination of the biodegradability of the organic fraction of chemical wastes. *Chemosphere* 10: 561-573.
- NRCC. 1982. Chlorinated phenols: criteria for environmental quality. National Research Council of Canada. NRCC #18578. 191 pp.
- Rogers, I. H., J. A. Servizi and C. D. Levings. 1988. Bioconcentration of chlorophenols by juvenile chinook salmon (*Oncorhynchus Tshawytscha*) overwintering in the upper Fraser River: Field and laboratory tests. *Water Pollution Research Journal of Canada* 23: 100-113.
- Servizi, J. A., R. W. Gordon and J. H. Carey. 1988. Bioconcentration of chlorophenols by early life stages on Fraser River Pink and Chinook Salmon (*Oncorhynchus gorbuscha*, *O. tshawytscha*). *Water Pollution Research Journal of Canada* 23: 88-99.
- Trevors, J. T. 1982. The effect of temperature on the biodegradation of pentachlorophenol. *Chemosphere* 11: 471-475.

Organic Contaminant Uptake in Eulachons (Thaleichthys pacificus)
Migrating Through the Fraser River Estuary.

by

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ABSTRACT

Anadromous eulachons (Thaleichthys pacificus) return in the spring to spawn in the coastal rivers of British Columbia. The fish have a high lipid content and the fat was, historically, an important trade item for indigenous coastal communities. We considered that eulachons may accumulate and integrate lipophilic toxic substances (according to the concept of equilibrium partitioning) during their migration through the estuary of the Fraser River. The estuary receives a variety of industrial and municipal wastes. Fish were captured at five sites, from the mouth of the river to a region above the main waste water sources and upstream of salt water penetration. River flow was relatively low, hence waste water dilution would have been less than at freshet conditions which peak approximately six weeks later. Male and female eulachons (whole body (n=80), gonads, livers) and water samples were analysed for chlorophenols, chloroguaiacols, PCB's, p-p' DDT and its metabolites, using electron-capture gas chromatography. Confirmatory identification was by gas chromatography-mass spectrometry.

Water samples contained ng·L⁻¹ levels of 2,4,6-trichloro-, 2,3,4,6-tetrachloro- (TeCP), and pentachloro- (PCP)-phenol. Higher concentrations of the wood preservatives TeCP and PCP occurred in samples from the North Arm of the Fraser River, possibly reflecting the concentration of lumber mills in the area. Chemical byproducts of pulp bleaching (3,4,5-, and 4,5,6-tri (TCG) and tetra- (TeCG)-chloroguaiacol), which are resistant to secondary treatment, were found in low concentrations (ng·L⁻¹) in the river water, despite their origin up to 750 km upstream. The levels of PCB's and DDT's were below our limits of detection (315 and 50 ng·L⁻¹ respectively).

Whole fish of both sexes, taken at the river mouth, contained TeCP and PCP levels to 113 and 44 ng·g⁻¹ wet weight, respectively. They also contained traces of TeCG but no TCG's. Levels of TeCP and PCP were higher in fish captured further upstream after migrating past numerous contaminant sources. Also 3,4,5- and 4,5,6-TCG were detected and measured in fish from sites in the main South Arm of the Fraser River. Traces of DDE were noted in all fish, including those at the river mouth. However, PCB's and DDT were not detected in whole fish extracts (detection limits 15 and 2 ng·g⁻¹, respectively).

Liver samples (n=6, 10 per sample) of male fish, taken at the river mouth, contained 3,4,5-TCG, besides TeCP, PCP and TeCG. The concentrations of these compounds in livers showed an increasing trend with distance from the river mouth. In addition, traces of 4,5,6-TCG were seen in samples from the most upstream site.

Gonads of individual fish (n=60) contained TeCP, PCP and TeCG but 3,4,5- and 4,5,6-TCG were absent. The gonads of some fish of both sexes from the North Arm of the Fraser River and at the site farthest upstream showed distinct PCB patterns. This may relate to historic contamination of the North Arm by PCB emissions from industrial operations.

We conclude that eulachons are suitable indicators of certain lipophilic organic contaminants in the estuary of the Fraser River and this should be more fully explored.

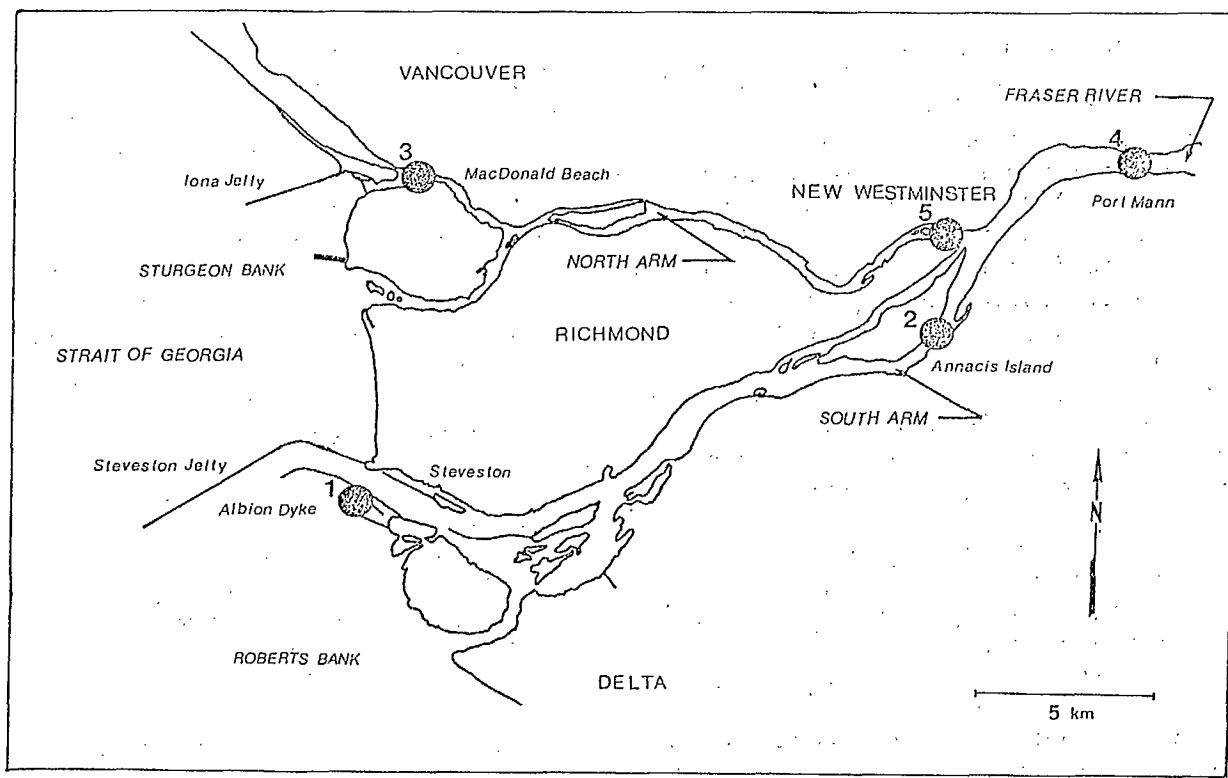


Figure 1. Map of the study area showing location of the fish capture sites in the Fraser River estuary, April 1986 (1 = Steveston, 2 = Annacis Island; 3 = MacDonald Beach; 4 = Port Mann, 5 = New Westminster).

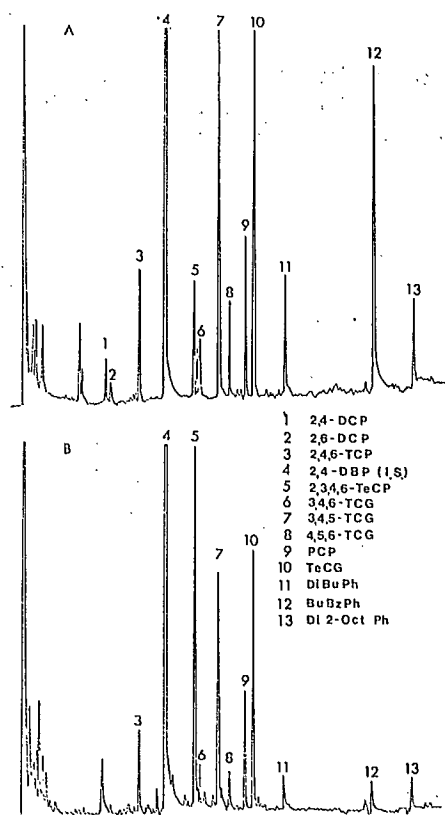
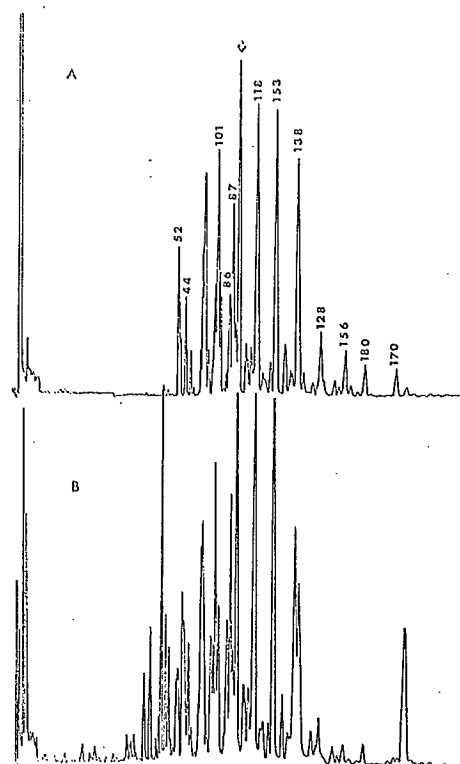


Figure 2. Contaminants in Fraser River water samples in November 1984 from A. Marguerite, B. No. 5 Road, Richmond.

Figure 3. A. Arochlor 1254 standard. B. PCB's from gonad of a male eulachon taken at Port Mann in April 1986.



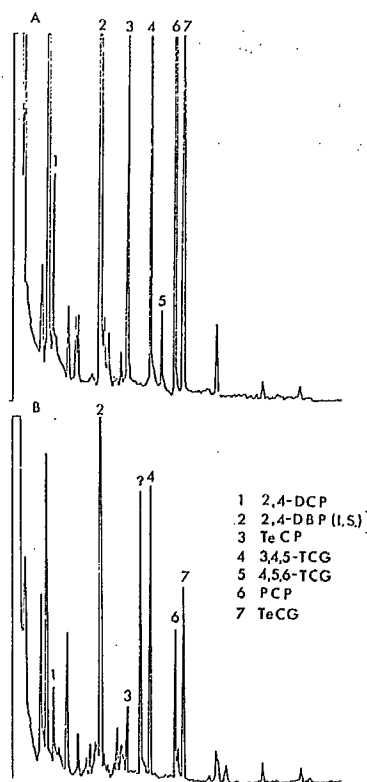


Figure 4. Contaminants in livers of male eulachons, April 1987. A. taken at Port Mann. B. taken at Steveston.

**ASSESSING HUMAN HEALTH RISKS ASSOCIATED WITH EXPOSURE TO ORGANIC
CHEMICALS IN DRINKING WATER - REVISION OF THE GUIDELINES**

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INTRODUCTION

The "Guidelines for Canadian Drinking Water Quality" are developed by a Federal-Provincial Subcommittee composed of representatives from each province, the Yukon and Northwest Territories and the Departments of National Health and Welfare and Environment. In 1987, the first edition of the revision of the "Guidelines for Canadian Drinking Water Quality, 1978" was released (1); the Subcommittee will continue to add to, delete from or revise the guidelines, with updated editions being released more frequently.

A number of additional substances are being considered in the revision of the 1978 Guidelines. Substances for inclusion were chosen on the basis of the following factors: 1. frequent detection in drinking water supplies, sometimes at relatively high concentrations 2. belief on the basis of available data that the substance might cause adverse effects on health at low doses and/or 3. structure of the compound being similar to that of known toxic chemicals. The total number of pesticides and synthetic organic chemicals currently being or already considered has increased since 1978 from 18 to about 60.

DERIVATION OF THE GUIDELINES FOR ORGANIC CONTAMINANTS

The process for revising the Guidelines involves two important but distinct steps. In the first phase (risk assessment), preliminary recommendations are developed on the basis of a consistent approach to the evaluation of risks to health; these recommendations should be considered to be health-based goals. In the second phase (risk management), these preliminary recommendations are considered in terms of their practicability, costs and potential benefits often in relation to other priorities in health protection and on this basis, a maximum acceptable concentration (MAC) in drinking water is derived. These two phases are not unique to the development of drinking water guidelines but are an integral part of most models and approaches to the control of health risks posed by exposure to potentially harmful substances. The second step (risk management), ensures that limited resources are directed to the control of hazards that are priorities in terms of their impact on human health. In most cases, however, the maximum acceptable concentration which is published in the Guidelines is the same as the recommendation developed in Stage 1. The recommendations in Stage 1 are developed principally by the technical Secretariat of the Federal Provincial Subcommittee on Drinking Water, which is provided by the Department of National Health and Welfare. The maximum acceptable concentrations specified in the Guidelines (Stage 2) are then

derived by the Subcommittee, submitted for consideration to their parent committee, the Federal Provincial Advisory Committee on Environmental and Occupational Health and finally, to the Conference of Deputy Ministers of Health for approval.

Data used as a basis for derivation of Stage 1 recommendations for organic contaminants of drinking water are derived principally from toxicological studies in animal species and occasionally from epidemiological investigations of human populations. Epidemiological studies of populations exposed to organic pollutants of drinking water are normally limited to descriptive investigations, also referred to as ecological studies. In such studies, mortality rates for various diseases in populations in different geographical areas are generally examined in relation to available data on concentrations of pollutants in drinking water. Although it is possible to examine large populations in this manner, the lack of data on the exposure of individuals in the population makes it difficult to adjust rigorously for possible confounding factors, which may be as or more important than contaminants of drinking water in the causation of disease. In addition, in such investigations, it is difficult to adequately take into account population mobility. Such studies, are, therefore, not weighted heavily in derivation of the drinking water guidelines. Analytical epidemiological studies (that is, cohort and case control studies), in which exposure and outcome are examined in individuals rather than in populations are more reliable, since it is possible to adjust more rigorously for confounding factors. Still, such studies are relatively insensitive in detecting the likely small risks to health which may be associated with exposure to low levels of organic pollutants in drinking water.

Indeed, for all of the organic chemicals which have been examined to date, the maximum acceptable concentrations have been derived principally on the basis of the results of toxicological studies in animal species. Since concentrations of chemicals found in drinking water are low and because drinking water is consumed daily over a lifetime, it is the chronic or long-term effects (including carcinogenicity) that are generally considered to be most relevant in the derivation of the guidelines. Chronic studies in which the chemical has been administered for a considerable portion of the animal's lifespan, or studies in the most sensitive sub-population (e.g., the embryo or foetus of an exposed mother in teratological studies) are, therefore, preferred. It is also desirable, though not always possible, to use studies in which the chemical has been administered in drinking water since uptake and effects are influenced by the vehicle of administration. Wherever possible, species in which the absorption, distribution, metabolism and elimination of the compound are similar to that of man are used. Several additional features of study protocols are also examined in assessing their adequacy as a basis for derivation of guidelines including the size of the study (i.e., how many exposed and control animals there were), whether the study adhered to the principles of good laboratory practice, the suitability of the administered doses, the adequacy of assessment of biological effects and the statistical analysis of data. The consistency of the results of the principal studies are also taken into account; for example, have similar effects been observed in studies in other species or would such effects have been expected based on the structure of the chemical?

The types of effects observed in such studies fall into several broad categories including organ specific, neurological/behavioural, reproductive, teratological and oncogenic/mutagenic/carcinogenic. For most of these types of effects, it is generally believed that there is a threshold level of exposure below which adverse effects will not occur. For other toxic effects, restricted currently primarily to carcinogenesis, it is commonly assumed that there is some probability of harm at any level of exposure; that is, that there is no threshold. It was necessary, therefore, to adopt two different approaches in the derivation of the drinking water guidelines for organic contaminants, one for compounds with toxic effects other than cancer and one for potential carcinogens. As a result, it was necessary initially to classify compounds with respect to the weight of evidence for carcinogenicity. Compounds were classified into one of 5 main categories, the basis for which ranged from documentation of a causal relationship in well conducted epidemiological studies in human populations in Group I to inadequate or no data on carcinogenicity in Group V.

For chemicals classified as "probably not carcinogenic to man" or for which data on carcinogenicity were "inadequate for evaluation" (Groups IV and V in the classification scheme), the maximum acceptable concentrations were based on acceptable daily intakes. The acceptable daily intake was calculated by dividing the no- or lowest-observed-adverse-effect-level for a biologically significant effect in the critical studies by an uncertainty factor. The uncertainty factor was derived on a case-by-case basis depending on the quantity and quality of data; however in general, a factor of 1 - 10 was used to account for each of the following elements of uncertainty: intraspecies variation, interspecies variation, nature and severity of effect, adequacy of study and whether a no- or lowest-observed-adverse-effect level was used. An additional factor of 1 - 5 times was incorporated where there was information that indicated a potential for interaction with other chemicals and the dietary requirement was taken into consideration if the compound was an essential nutrient at low concentrations. In general, the magnitude of the uncertainty factor ranged from 100 to 5000. To ensure that total exposure from all sources does not exceed the acceptable daily intake, intake from sources other than drinking water was taken into account in derivation of the guideline by apportionment between exposure routes, that is air, food and water. The apportionment was generally based on information on relative exposure by these various routes. For organic chemicals, information on concentrations in food and air in Canada were often not available. Where such data could not be identified, the proportion of total intake ingested in drinking water was arbitrarily considered to be 20 %. In general, derivation of the guideline was also based on average daily intake of 1.5 litres of water by a 70 kg adult.

New organic chemicals which were classified in Groups IV and V ("probably not carcinogenic to man" or for which data on carcinogenicity were "inadequate for evaluation"), and for which maximum acceptable concentrations in the 1987 edition of the Guidelines were derived on the basis of acceptable daily intakes, are presented in Table 1. Aesthetic objectives, which in most cases were much less than the health-based maximum acceptable concentrations, are also presented.

For pesticides, acceptable daily intakes developed by the World Health Organization/Food and Agriculture Organization were used in the derivation

of the guidelines, when they were available and considered to be appropriate. In some cases, where the data were considered insufficient to develop an acceptable daily intake, a "negligible daily intake" established by these organizations was used. Maximum acceptable concentrations (MAC's) were derived from ADI's; interim MAC's (IMAC's) were derived from negligible daily intakes. In Table 2 are presented the MAC's and IMAC's for pesticides considered for the first time in the 1987 revision of the drinking water guidelines. The MAC's for pesticides for which available data were reevaluated in the 1987 Guidelines are also included in Table 2.

For chemicals considered to be carcinogenic, as mentioned previously, it is generally assumed that there is some probability of harm at any level of exposure. Therefore, ideally, carcinogens should be absent from drinking water. However, available treatment technology is inadequate to completely eliminate exposure from this source and analytical methods may be inadequate for reliable determination at extremely low levels. Moreover, the incremental risks associated with exposure to low levels of these chemicals in drinking water (generally estimated by extrapolation of tumour incidence in animals exposed to much higher doses) may be sufficiently small so as to be negligible in comparison with risks commonly encountered in society. Therefore, the maximum acceptable concentrations for chemicals considered to be "carcinogenic to man" or "probably carcinogenic to man" (Groups I and II in the classification scheme), were set as close to zero as possible, taking into consideration the following factors:

- The MAC must be achievable by available water treatment methods at reasonable cost.
- Wherever possible, the lifetime cancer risk (upper 95% confidence limit) associated with the MAC was less than 1 in 100,000 to 1 in a million, a range that is considered to be "essentially negligible".
- The MAC must also be reliably measureable by available analytical methods.

If the estimated lifetime cancer risks associated with the MAC were greater than those considered to be "essentially negligible", an interim maximum acceptable concentration was set with the intention that a more stringent recommendation be made following development of improved analytical methodology or treatment technology.

Thus, for carcinogenic chemicals, the approach is, in essence, a blend of estimation of the magnitude of the health effect, with consideration of the feasibility of reducing the risk to levels which are acceptable from both economic and societal viewpoints.

New organic chemicals in the 1987 Guidelines for which the maximum acceptable concentrations (MAC's) were derived on the basis of carcinogenicity (i.e., those parameters which were classified in Groups I and II), are presented in Table 3; the recommended MAC's and the order of the estimated cancer risks associated with consumption for a lifetime of drinking water containing these compounds at the MAC are also presented.

Owing to limitations of the available data, it is not always possible to clearly designate a substance as "carcinogenic" or "not carcinogenic". For that reason, in the classification scheme presented earlier, there is a group entitled "possibly carcinogenic to man" (Group III). Also included in this group are carcinogens which appear to act by mechanisms for which there may be a threshold. For substances in this category, the MAC's would be

derived in a manner similar to that for chemicals considered to be noncarcinogenic, but with incorporation of a larger uncertainty factor to account for the limited evidence of carcinogenicity.

FUTURE WORK

The Federal-Provincial Subcommittee on Drinking Water will continue to add to, delete from or revise the Guidelines as necessary with updated versions being released more frequently, perhaps as often as every year. In Table 4 are presented those organic parameters which are being reevaluated and those new substances currently being considered for addition to the 1987 Guidelines.

REFERENCES

1. Federal Provincial Subcommittee on Drinking Water. Guidelines for Canadian Drinking Water Quality. Department of National Health and Welfare, Ottawa, 1987.

TABLE 1 - NEW ORGANIC CHEMICALS FOR WHICH GUIDELINES WERE
BASED ON ADI'S - 1987 GUIDELINES

	<u>MAC*</u> (mg/L)	<u>AO*</u>
1,2-Dichlorobenzene	0.2	0.003
2,4-dichlorophenol	0.9	0.0003
Pentachlorophenol	0.06	0.03
2,3,4,6-tetrachlorophenol	0.1	0.001

*MAC = maximum acceptable concentration

AO = aesthetic objective

TABLE 2 - NEW AND REEVALUATED PESTICIDES - 1987 GUIDELINES

	MAC**	IMAC**
	<u>(mg/L)</u>	
<u>NEW</u>		
Aldicarb	0.009	-
Atrazine	-	0.06
Azinphos-methyl	0.02	-
Bendiocarb	0.04	-
Bromoxynil	-	0.005
Carbofuran	0.09	-
Chlorpyrifos	0.09	-
Cyanazine	-	0.01
Dicamba	0.12	-
Diclofop-methyl	0.009	-
Dimethoate	-	0.02
Diquat	0.07	-
Diuron	0.15	-
Glyphosate	-	0.28
Malathion	0.19	-
Metolachlor	-	0.05
Metribuzin	0.08	-
Paraquat	-	0.01
Phorate	-	0.002
Simazine	-	0.01
*2,4,5-T	0.28	-
Temephos	-	0.28
Terbufos	-	0.001
Triallate	0.23	-
<u>REEVALUATED</u>		
Carbaryl	0.09	-
Diazinon	0.02	-
Methoxychlor	0.9	-
Parathion	0.05	-

* Aesthetic objective = < 0.02 mg/L

** MAC = maximum acceptable concentration

IMAC = interim maximum acceptable concentration

TABLE 3 - NEW ORGANIC CHEMICALS FOR WHICH GUIDELINES WERE
BASED ON CARCINOGENICITY - 1987 GUIDELINES

	MAC* (mg/L)	Order of Estimated Lifetime Risk
Benzene	0.005	$\approx 10^{-6}$ to 10^{-5}
Benzo(a)pyrene	0.00001	$< 10^{-6}$
Carbon tetrachloride	0.005	$\approx 10^{-6}$ to 10^{-5}
1,4-dichlorobenzene	0.005	$\approx 10^{-7}$
2,4,6-trichlorophenol	0.005	$\approx 10^{-6}$
Dichloromethane	0.05	$\approx 10^{-8}$

*MAC = maximum acceptable concentration

TABLE 4 - ORGANIC CHEMICALS FOR WHICH GUIDELINES
ARE UNDER DEVELOPMENT OR REVIEW

PESTICIDES

Alachlor	Lindane
Aldrin + Dieldrin	Linuron
2,4-D	MCPA
DDT	Picloram
Dinoseb	TCA
Heptachlor + its Epoxide	Trifluralin

ORGANIC SUBSTANCES

1,2-Dichloroethane	Tetrachloroethylene
1,2-Dichloroethylene	Trichloroethylene
Dioxins and Furans	Trihalomethanes
PCB's	

Health Hazard Assessment
of Chemical Contaminants in Food

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What do we really mean when we use the term "chemical contaminant"? For the purposes of public safety, a food chemical contaminant is defined as any chemical substance present in food which was not intentionally added to the food, and which may pose a potential risk to public health. This definition encompasses substances that are naturally occurring (e.g. mycotoxins) as well as substances which may be inadvertently introduced or increased through human intervention (e.g. PCBs, lead, cadmium). It also includes substances which may be essential components of foods at certain levels but could pose a health hazard at increased levels (e.g. copper, iron, zinc).

Legal Basis for Control of Food Chemical Contaminants

The legal authority for control of chemical contaminants in food is found in the Food and Drugs Act. Section 4(a) of the Act states...."No person shall sell an article of food that has in/or upon it any poisonous or harmful substance", while Section 4(d) states"No person shall sell an article of food that is adulterated". In addition, Section 25 of the Act further states that the "Governor-in-Council may make regulations for carrying the purpose and provisions of this Act into effect and may make regulations declaring that any food or class of food is adulterated if any prescribed substance or class of substance is present therein or has been added thereto".

An important prerequisite, of course, for the control of contaminants in food under the Food and Drugs Act and Regulations is that the food is offered for sale. Since control is applied at the point of sale, the food must be sold or offered for sale before the regulatory provision of the Act can be applied. Thus, strictly speaking, fish caught by a sportsman for his own personal use would not be covered by the provisions under the Food and Drugs Act and Regulations.

Procedures for Evaluating Hazards Posed by Chemical Contaminants in Foods

The assessment of health hazards posed by chemical contaminants in food is a multi-stage process. The first step in this process is a determination of the inherent toxicity of the chemical contaminant with a view to establishing a quantity of the chemical that a human could consume on a daily basis, for a lifetime, with a reasonable degree of assurance that ingestion of this amount of chemical daily would not pose

a health hazard. This quantity is called the "Tolerable Daily Intake" (TDI) and is usually expressed in terms of the quantity of the chemical, let us say, milligrams per kilogram body weight per day.

The TDI is derived from toxicity studies carried out on laboratory animals. Ideally, one likes to have available a full range of toxicity studies including acute, subacute, chronic and special studies such as reproduction, teratology, carcinogenicity, mutagenicity, etc. in several species of laboratory animals. The purpose of such studies is to determine the amount of the chemical that can be given to the animal in the diet without causing any adverse effects. The lowest so-called "No Observed Adverse Effect Level" (NOAEL) is then divided by a number called a "safety factor" to derive the TDI. Generally, if a full toxicity data base is available and depending on the nature of the adverse effects observed, a safety factor of 100 is used. However, in the case of contaminants full toxicity studies are often not available. Under such circumstances, safety factors of several hundred or even several thousand may be used to derive the TDI.

The second step in this process is a determination of the Probable Daily Intake (PDI) for the chemical by humans. Estimation of the PDI is based on data pertaining to the occurrence of the contaminant in food as well as the consumption of food. In the latter regard, both mean as well as upper percentile levels of consumption are taken into consideration so that both average as well as worst case exposure estimates can be determined. In addition, the potential exposure of specific subgroups in the population may be given particular consideration.

In carrying out such exposure estimates there are several considerations relating to the integrity of the data base that must be considered. These include but are not limited to the following:

- 1) The average and range of levels of the contaminant in food;
- 2) Distribution of the chemical among foods, i.e. is it present in only one food or food group or in many foods?
- 3) Background levels of the contaminant naturally-occurring in food;
- 4) Analytical methodology - is the limit of detection low enough to give meaningful results? What is the accuracy and variability of the method? Can the chemical be adequately isolated and recovered from the food matrix?
- 5) What is the chemical nature of the contaminant in food? Is it the same chemical form that the TDI is based on?
- 6) What is the distribution of the chemical in a food i.e. is it present in the edible portion?
- 7) Are there any effects on the level and distribution of the contaminant during processing of the food?

In addition to the potential intake of the contaminant from food, consideration is also given to other routes of exposure such as air and water in order to ascertain a realistic estimate of total exposure. It may be necessary in this regard to consider unique routes of exposure that may contribute significantly to the intake of a contaminant by selective sub-groups of the population. The final step in this process of health hazard assessment is a comparison between the potential total daily intake (PDI) of the contaminant and the TDI. If the PDI exceeds the TDI, some form of risk management action may be warranted. It should be emphasized that although the PDI may exceed the TDI, this does not necessarily suggest that an imminent health hazard exists. But rather it should be used as a yard stick to assess the need for some type of control.

Risk Management Options

Irrespective of the chemical involved, the toxic principles of assessing the health hazards of such substances in food are similar. In essence, a scientific judgement is made on the best data made available. The management of the risk posed by such chemicals may, however, differ.

1. Based on the provisions of the Food and Drugs Act, one option in effecting control of toxic substances in foods is to promulgate specific regulations. In this regard, Section B.01.046 of the Food and Drug Regulations lists a number of toxic substances such as coumarin, saffrole and aflatoxin which, if present in food under the conditions stated, would render the food adulterated and unfit for sale or distribution as human food. In addition, Division 15 of the Regulations contains a table which lists maximum permissible limits or tolerances for heavy metals such as lead and arsenic in certain specified foods.
2. Another mechanism frequently used by the Health Protection Branch to exercise control over chemical contaminants in food, is the development of a guideline. A guideline is a level of a chemical in food below which no health hazard would be presented to consumers. While a guideline does not have the status of a regulation, it does represent the Health Protection Branch's interpretation of Section 4(a) of the Food and Drugs Act, and permits the Branch to take enforcement action as required. Guidelines have been developed for a number of contaminants in specific foods, most notably PCBs in fish, fat of dairy products and meat, and in eggs, as well as for mercury in fish.
3. A contaminant occurring in food as a result of a point source of contamination represents a situation which may be amenable to alternative methods of control. Since the contaminant is likely to be present only in food from the immediate vicinity of the point source, establishment of a regulation or guideline that would be applicable to all food would be inappropriate. Restrictions on the sale or distribution for human consumption of food produced in the

contaminated area while efforts are undertaken to eliminate the source of contaminants could be a preferred approach.

As an illustration of this process the situation concerning dioxins and furans in finfish and shellfish in the vicinity of pulp mills presents an interesting case.

Last spring, the Health Protection Branch was presented with the results of a preliminary survey of dioxins and furans in finfish and shellfish taken from the vicinity of pulp and paper mills and sawmills. Fourteen different sites were sampled: 8 in British Columbia and in total 133 samples were analyzed. The samples were analyzed for 2,3,7,8-TCDD and 2,3,7,8-TCDF, as well as the other tetra, penta, hexa, hepta and octa congeners. Results varied considerably, ranging from non-detectable for any of the congeners to a detectable level of one or more of the congeners or congener groups.

The assessment of the findings from the standpoint of potential significance to human health focused on several factors, the most important of which included:

1. the available data relating to the toxicity of the various congeners of dioxins and furans found; and
2. The potential exposure to the different dioxin/furan congeners resulting from the ingestion of fish/shellfish from the various sites.

Since the concern about dioxins and furans relates mainly to potential adverse effects resulting from long-term exposure to these substances, the exposure focused for the most part on the potential average amount consumed over a lifetime.

The toxicity of 2,3,7,8-TCDD has been studied in considerable detail and has been shown to differ widely depending on the species of animals tested. However, there is general agreement that the lowest no-observed adverse effect level in laboratory animals is 1.0 nanogram per kilogram body weight per day. Applying a safety factor to this level to account for species variation in sensitivity and to ensure that humans will not be exposed to hazardous levels, it is considered that human exposure to 2,3,7,8-TCDD from all sources should not exceed 10 picograms per kilogram body weight per day as a lifetime average is considered appropriate. This then provides a yard stick to assess the residues of 2,3,7,8-TCDD found in these samples. However, as noted above, several other dioxins and furan congeners were found in some of these samples. The toxicity of these congeners has not been as intensively studied. However, based on data that are available they are all considered to be less toxic than 2,3,7,8-TCDD. For example, 2,3,7,8-TCDF ranges from about one tenth to one thirtieth as toxic as 2,3,7,8-TCDD. By applying these comparative toxicity factors for the various congeners, it was possible to "normalize" the findings for each sample in terms of 2,3,7,8-TCDD equivalents. This then allowed us to make estimates of the potential daily intake of 2,3,7,8-TCDD equivalents for each sample. On the basis of this analysis, it was determined that, in general, consumption of the

edible portions of these fish and shellfish would not result in intakes of 2,3,7,8-TCDD equivalents in excess of 10 pg/kg b.w./day. Consequently, it was concluded that consumption of these fish and shellfish would not pose a health hazard to consumers.

INFLUENCE OF BIO-TREATED BLEACHED KRAFT MILL EFFLUENT (BKME)
ON FITNESS OF JUVENILE CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*)

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INTRODUCTION

Biological surveys indicate that juvenile chinook salmon (*Oncorhynchus tshawytscha*) take up residence in the Fraser River. Surveys in August 1984, found juvenile chinook in the Fraser River downstream from Prince George and in the Thompson River (Levings et al 1985). Overwintering populations of juvenile chinook occur in the Thompson River and were found in the Fraser River near the communities of Prince George, Quesnel, Lytton and upstream from Chilliwack (Whelen and Slaney 1986).

Five kraft pulp mills and a chemi-thermomechanical pulp mill discharge biologically treated wastewater to the upper Fraser and Thompson Rivers. In 1985, pulp mills accounted for approximately 79 per cent of the wastewater discharged to the Fraser and Thompson Rivers upstream of Lytton (Servizi 1988). The kraft effluents usually meet detoxification criteria specified by Federal Regulations and Provincial Objectives (Servizi 1988). However, chemical assays reveal residual chloro-organics in the Fraser River which resist biological treatment (Voss and Yunker 1983; Rogers et al 1988). These chloro-organics originate during the chlorine bleaching process where about 5 kg of organochlorine compounds are formed per ton of softwood pulp produced (McKague et al 1988).

Biological surveys and laboratory tests indicate that Fraser River juvenile chinook (*Oncorhynchus tshawytscha*) and pre-emergent pink (*O. gorbuscha*) fry bio-concentrate residual chloro-organics from river water more than 500 km downstream of the discharges (Rogers et al 1988; Servizi et al 1988). The latter authors found a relationship between chlorophenol body burden and chlorophenol content of ambient water. In addition, juvenile chinook collected downstream of Prince George and Quesnel in winter 1988 contained dioxins (TCDD and TCDF) (Rogers, pers. comm.). Surveys also revealed substantial induction of Mixed Function Oxidase (MFO) enzymes in juvenile chinook from these areas, presumably owing to chloro-organic contaminants (L. Lockhart, pers. comm.).

The biological implications for chinook salmon of the above results are undefined. Current effluent and receiving water biomonitoring programs for pulp mill effluents were not designed to detect sublethal effects on salmon populations. McLeay et al (1986, p.xxiii) concluded that sublethal toxic effects or long-term consequences for indigenous aquatic species cannot be derived from the acute lethal bioassays on which pulp mill effluent Objectives and Regulations are based. To better understand possible effects of bio-treated BKME on chinook salmon, a laboratory/field study is scheduled for winter 1988-89. This paper describes the proposed study.

LABORATORY STUDIES

Laboratory studies are composed of acute and chronic exposures to bio-treated BKME using Bowron River (upper Fraser River stock) juvenile chinook reared at Cultus Lake laboratory.

ACUTE TESTS

The object of acute tests is to expose juvenile chinook to high levels of bio-treated BKME to create a measurable impact for reference in the chronic tests. Analyses will include histopathology, biochemical response (Serum Sorbitol Dehydrogenase) and contaminant burden. The latter category includes resin acids, chlorophenols, chloroguaiacols and dioxins.

CHRONIC TESTS

Juvenile chinook will be exposed for 60 days to environmental concentrations of bio-treated BKME at Cultus Lake laboratory. Exposures will be conducted at $<2^{\circ}\text{C}$ to simulate overwintering conditions in the Fraser River. Fish will not be offered food during the exposure. At these temperatures, juvenile chinook are known to reside between or under large cobbles on the river bottom. In a previous experiment at Cultus Lake laboratory, juvenile chinook were torpid at a mean test temperature of 0.7°C and were successfully maintained without food (Rogers et al 1988).

Experimental groups will be exposed to 3 per cent and 1.5 per cent bio-treated BKME. Three control groups will be maintained in Cultus Lake water. The experimental concentrations are based upon calculated dilutions at low average flows in the Fraser River (Derksen 1988). Cultus Lake water will be used for dilution since it is similar to Fraser River water in pH, alkalinity and hardness. Concentrations will be renewed daily, Monday through Friday, using fresh bio-treated BKME. Effluent will be characterized by measuring pH, resin acids, TOC, chlorophenols and chloroguaiacols.

After an initial acclimation period to the test temperature, samples of fish will be analyzed to obtain baseline data (tests I through V, Table 1). A second set of tests will be performed after 60 days exposure to bio-treated BKME (I through V). The fish remaining after 60 days in each of the experimental and two of the control groups will be transferred to four rearing tanks at the Fraser River near Chilliwack. This transfer coincides with migration patterns of some juvenile chinook as they move from the upper to the lower Fraser as spring approaches. The third control group will be maintained at Cultus Lake Laboratory.

Bio-treated BKME will not be added to Fraser River water since the river contains the residual contaminants to which the fish would be exposed if they resided in the river. Fish will be fed and one control group monitored for seawater acceptance. When seawater challenge tests indicate the control group is smolted, all groups will be tested as previously, except that osmoregulatory capacity will also be tested (I through VI, Table 1). The final step is to transfer fish remaining in each group to seawater for a

growth experiment. Dioxin measurements are planned for fish at conclusion of the seawater growth tests.

FIELD STUDIES

Juvenile chinook will be collected from overwintering habitat in the Fraser River in winter 1989. Collections are planned for points upstream and downstream of Quesnel in the Fraser River. Juvenile chinook will also be collected from the Quesnel River to serve as an uncontaminated reference site. The specimens collected will be examined for Mixed Function Oxidase induction and organo-chlorine contaminant burden. Histopathological examination will be made. If sufficient specimens are captured, proximate analyses will be made and somatic indices measured.

EXPECTED OUTPUTS

The biochemical, physiological, pathological and body burden analyses will yield information about sublethal effects. The implications of these effects depend on the duration and intensity of the stressor. A more direct measure of the overall effect of exposure to bio-treated BKME may be seen in osmoregulatory competence and seawater growth since these are fundamental to survival.

PRINCIPAL INVESTIGATORS

The project is a cooperative effort among five principal investigators and their staffs in four laboratories.

Principal Investigators:

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REFERENCES

- Derksen, G. 1988. Report on the status of pulpmill effluent concentrations in the Fraser River drainage. Environ. Protect. 14p. Draft.
- Levings, C.D., J.C. Scrivener, B. Andersen, C. Shirvell and R. Lauzier. 1985. Results of reconnaissance sampling for juvenile salmonids in the upper Fraser River and selected tributaries, August and October 1984. Can. Data Report of Fish. and Aqua. Sci. No. 549. 27p.
- McLeay, D.J., A.B. McKague and C.C. Walden. 1986. Aquatic toxicity of pulp and paper mill effluent: A review prepared for: Env. Canada, Fisheries and Oceans Canada, Can. Pulp and Paper Assoc. and Ontario Min. of Env. 243 p.
- McKague, A.B., M.C. Kolar and K.P. Kringstad. 1988. Nature and properties of some chlorinated lipophilic, organic compounds in spent liquors from pulp bleaching. 1. Liquors from conventional bleaching of softwood kraft pulp. Environ. Sci. Technol. 22(5):523-531.
- Rogers, I.H., J.A. Servizi and C.D. Levings. 1988. Bioconcentration of chlorophenols by juvenile chinook salmon (*Oncorhynchus tshawytscha*) overwintering in the upper Fraser River: Field and laboratory tests. Water Poll. Res. J. Can. In press.
- Servizi, J.A. 1988. Protecting Fraser River salmon (*Oncorhynchus spp.*) from wastewaters: An assessment. Can. J. Fish. & Aqua. Sci. In press.
- Servizi, J.A., R.W. Gordon and J.H. Carey. 1988. Bioconcentration of chlorophenols by Fraser River pink and chinook salmon (*Oncorhynchus gorbuscha*, *O. tshawytscha*). Water Poll. Res. J. Can. In press.
- Voss, R.N. and M.B. Yunker. 1983. A study of chlorinated phenolics discharged into kraft mill receiving waters. Pulp and Paper Res. Inst. of Can., Pointe Claire, Can. 131p.
- Whelen, M.A. and T.J. Slaney. 1986. Late winter sampling of juvenile salmonids in the Fraser River. Report for DFO, West Vancouver Lab. by Aquatic Resources Ltd., Vancouver. 17p & App.

Table 1. Analyses of juvenile chinook from laboratory studies of bio-treated BKME.

Analysis		Laboratory
I.	Proximate analyses Resistance to hypoxia Somatic indexes Hematology	Cultus Lake
II.	Histology	West Vancouver
III.	Mixed function oxidase Serum sorbitol dehydrogenase	Freshwater Institute Winnipeg
IV.	Contaminant burden Extractable organic chlorine	West Vancouver
V.	Dioxin	Canadian Wildlife Service Hull, P.Q.
VI.	Osmoregulatory capacity	Cultus Lake

THE ENVIRONMENTAL IMPACTS AND BEHAVIOUR OF TCMTB

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1.0 INTRODUCTION

Large volumes of chlorophenol compounds are currently used in Canada to preserve and protect wood from attack by various pests. Concerns about acute aquatic toxicity, about occupational impacts, and about hazardous impurities in chlorophenols are among the reasons for rising dissatisfaction with their use. In British Columbia, the formation of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDDs and PCDFs) during the low temperature combustion of chlorophenols and chlorophenol-containing wastes has become a major issue.

The search for alternative chemicals has now intensified. Leading contenders to replace the antistain agent sodium tetrachlorophenate are pesticides which contain the active ingredient 2-(thiocyanomethylthio)benzothiazole (TCMTB).

The purpose of this paper is to review the environmental properties of TCMTB, Busan 1030 and Busan 30WB. TCMTB is the active ingredient in Busan 1030 and Busan 30WB, which are antistain products produced by Buckman Laboratories for the wood protection industry.

Busan 1030 and 30WB appear to be effective antistain agents, and a critical evaluation of their toxicological and environmental impacts has been assisted by Buckman Laboratory's cooperation in providing access to full research reports created for various regulatory agencies. However, there is little information published in the scientific, technical and medical literature on these products, so this paper is based almost solely on information received directly from Buckman Laboratories.

2.0 HISTORICAL BACKGROUND

The commercial use of TCMTB apparently had its origins in with Buckman Laboratories, Inc., of Memphis, Tennessee¹. In the late 1940's this company became involved in the search for solutions to the problem of breaks in paper on high speed paper machines due to the formation of microbiological slime. The company first developed the microbicide BSM-11, a product containing mercuric acetate and trichlorophenol, which seemed to find acceptance in the paper making industry.

However, in view of the potential for adverse health and environmental impacts from the use of mercury compounds, Buckman Laboratories developed a line of organosulphur compounds which also proved to be effective slime control agents. Alone, or in conjunction with other active ingredients, TCMTB is now found in a variety of Buckman products.

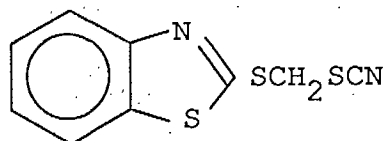
Busan 1030² is a Buckman product, which is organic solvent based, and contains 30% TCMTB as the active ingredient. Under license with Buckman Laboratories, several companies

in B.C. have made 30% TCMTB formulations available for this purpose under the brand names Woodblok 30³, Diachem Woodstat⁴, Mitrol⁵, Woodsheath 11 T-230 Clear⁵, and Concentrate B30 T1090 Liquid Microbiocide⁵. Busan 1030 is recommended for a host of other applications including the control of microorganisms in cooling water systems, wooden cooling towers, water-thinned cutting fluids, crude and refined oils, drilling fluids, and paints^{6,7}. A water-based formulation containing 30% TCMTB, called Busan 30WB has recently been introduced for antisapstain use.

TCMTB was first registered in Canada as a seed treatment in Co-op Co-San Liquid Seed Treatment, which contained 30% active ingredient⁸. The registered uses included control of stinking smut or bunt of wheat, and other seed and soil-borne seed diseases⁹. By 1977 it was also registered as an agent to resist mold and sapstain on freshly cut lumber. Busan 1030 and Busan 30WB are now also registered pesticides with Agriculture Canada^{2,10}.

3.0 PROPERTIES

The structural formula of TCMTB is shown below:



It is a viscous reddish liquid and is insoluble in water, but soluble in organic solvents such as acetone, dimethylformamide, cyclohexanone, benzene and xylene⁸. It has a specific gravity of 1.38⁸, a boiling point greater than 120°C⁸ and a vapour pressure of 3.6×10^{-6} torr¹¹. The supplier normally mixes TCMTB with solvents to form a concentrate. Emulsifiers or surfactants may be added to the concentrate to improve the stability of emulsions formed when the concentrate is diluted with water³.

TCMTB is sold commercially as 80% technical material under the trade name "TCMTB" by Buckman Laboratories, which is the sole manufacturer of the material^{3,12}. The patented preparation involves a reaction of 2-mercaptobenzothiazole and chloromethylthiocyanate³, but confidential data obtained from Buckman Laboratories indicates another preparative method may now be used.

Busan 1030 is a dark brown liquid with a specific gravity of 1.08, a flash point of 50°C and a slight odor¹³. It is miscible with water. Normally diluted to a 0.5 - 1% solution, it may be applied to freshly cut lumber through spray or dipping systems.

Busan 30WB is a milky white liquid containing 30% TCMTB. Like Busan 1030, various surfactants and emulsifiers are used to keep the TCMTB in suspension. It is diluted and used in the same manner as is Busan 1030.

4.0 ENVIRONMENTAL SOURCES, DISTRIBUTION AND BEHAVIOUR

TCMTB is unlikely a naturally occurring material, so its sources are expected all to be man-made. These would include spills and other unintentional discharges, permitted discharges from commercial facilities using the substance, as well as certain materials such as leather, wood, paper, paint and seeds. No reports of measurements of environmental levels of TCMTB were located.

The environmental behaviour of TCMTB has been investigated in a variety of experiments. Recently, a series detailed reports addressing the environmental behaviour of TCMTB was completed in 1987¹⁴⁻²⁰. These studies were designed to meet the requirements of the Pesticide Assessment Guidelines of the United States Environmental Protection Agency, and are summarized below. All studies failed to find significant levels of volatile TCMTB degradation products.

4.1 Aqueous Hydrolysis

The first study¹⁴ considered the hydrolysis of carbon-14 labeled TCMTB in 10 ppm aqueous solutions buffered to pH 5, 7 and 9. The solutions were kept in the dark and analyzed by thin-layer chromatography at specified time intervals ranging from 0-35 days for pH 5 and 7 samples, and from 0-122 hours for pH 9 samples.

At pH 5, TCMTB was stable, but at pH 7, it slowly degraded, with 8% being reported hydrolyzed after 35 days. At pH 9, the hydrolysis was much more rapid, with the half life being calculated at 81 hours. Several hydrolytic products at this pH were observed, representing 43% and 18% of the TCMTB after 122 hours. The hydrolysis products were not conclusively identified, but likely include 2-mercaptobenzothiazole and 2,2'-(dithiobis)benzothiazole.

4.2 Artificial and Natural Sunlight Degradation on Soil

One study by A & L Agricultural Laboratories of Memphis, Tennessee²⁰, indicates sandy loam treated with TCMTB at a ratio of 3.6 g TCMTB/gram of soil had only 1.5% of the TCMTB remaining after two months. On the other hand, Southern Yellow Pine sawdust treated with 18 times its mass of TCMTB left a residue of 81% TCMTB after two months. Neither the conditions for these experiments, nor the characteristics of the degradation products were reported.

The fate of carbon-14 labeled TCMTB on soil was studied by spiking Fox sandy loam soil in petri dishes and following its behaviour in darkness, under continuous artificial sunlight using two Chroma 50 lamps, and natural sunlight¹⁶. The samples were maintained at 25 °C.

Assuming first order kinetics, the half lives were calculated as follows:

	<u>T 1/2 Artificial Sunlight</u>	<u>T 1/2 Natural Sunlight</u>
Experimental	388 hours	23 hours
Control	917 hours	662 hours

From the table above, it is evident that thermal degradation occurred in the control samples, and that this is enhanced by both types of radiation. No degradation products were identified. In the absence of other evidence, the extreme differences in half-lives for the two experimental conditions suggests that the artificial sunlight does not match the natural sunlight very well.

4.3 Artificial Sunlight Degradation in Aqueous Solution

The photodegradation of carbon-14 labeled TCMTB¹⁵ was followed by the irradiation of 10 ppm solutions of TCMTB in sterilized sodium acetate pH 5 buffer at 25 °C. Chroma 50 lamps, which were said to have spectral distributions similar to that of natural sunlight, were used as the radiation source. The degradation appeared to follow first-order kinetics, with a half-life of 3.8 hours. After 8 hours, 28% of the TCMTB remained. No degradation was noted in control samples, which were wrapped in metal foil, but otherwise subjected to the same experimental conditions. The major byproduct was tentatively identified as 2-mercaptobenzothiazole.

4.4 Aerobic Aquatic Metabolism

An experiment using carbon-14 labeled TCMTB studied the aquatic metabolism in lake sediment and water¹⁷. The lake sediment, collected from Lake Mendota in Wisconsin, had 96% sand, 3% silt, 3% clay, and 1% organic matter, with a pH of 7. The lake water had a pH of 8 to 8.5. Spiked samples were incubated at 26 °C, and followed up to 31 days.

The level of TCMTB fell from 88% at day 0 to 1% at day 14, with a calculated half-life of 2.8 days. While six different byproducts were observed, only two were tentatively identified. 2-mercaptobenzothiazole was thought to increase from 1.4% at day 1 to 10% at day 4 and then decreased to 1% by day 31. Another product, tentatively identified as 2,2-dithiobisbenzothiazole increased from 4% at day 1 to a maximum at day 14, and then declined to nondetectable levels at day 31.

It is interesting to compare the half-life of 81 hours determined from the aqueous hydrolysis study above at pH 9, with the half-life in the sediment and water, which is about 67 hours. Since the rate of hydrolysis is less at lower pH values, and since the pH of the sediment and water is slightly less than 9, one might expect a water/sediment half-life above 81 hours to result solely from non-biological degradation mechanisms. Since the experimental result is less than 81 hours, biological degradation mechanisms may be in operation.

4.5 Absorption on Agricultural Soils

In this experiment¹⁸, four agricultural soils, Plainsfield sand, Plano silt loam, Fox sandy loam, and Kewaunee clay loam were each equilibrated with aqueous solutions of carbon-14 labeled TCMTB of 0.5, 1, 5, and 10 ppm at 25 °C for 2 hours. While all the soils adsorbed the TCMTB to some extent, the equilibrium constants varied from 1.9 for the Plainsfield sand, which is low in organic matter, to 38.4 for the Kewaunee clay loam. The potential for leaching seems greatest for the Plainsfield sand.

4.6 Mobility on Soils

The mobility of carbon-14 labeled TCMTB on four soils was studied¹⁹ by coating glass plates with thin layers of soil, spotting the plate with TCMTB, and then allowing water to migrate up the plates. Consideration of the distance the spots moved suggested that TCMTB should be classified, using USEPA mobility classes, as "mobile" in the Plainsfield sand and as having "low mobility" in the Mississippi silt loam, Fox sandy loam, and Hagerstown clay loam.

The mobility of soil-aged TCMTB residues has also been investigated²⁰. In this experiment, Dickenson sandy loam was fortified with carbon-14 labeled TCMTB and incubated at 25°C for 32 days under aerobic conditions. A sample of the aged soil was subjected to thin-

layer chromatography, being eluted by water. The soil-aged TCMTB residues were revealed to be more mobile than nonsoil-aged TCMTB residues. The soil-aged residues were classed as "mobile", while the non-soil aged residues were labeled "low mobility".

5.0 ENVIRONMENTAL TOXICOLOGY

5.1 Aquatic Species Tests on Technical Grade and Pure TCMTB

48 hour LC50: (80% TCMTB)	daphnia -	850 ppm ²¹
96 hour LC50:	rainbow trout -	0.050 ppm ²²
99% TCMTB		0.052 ppm ²²
		0.047 ppm ²²
	Chinook Salmon -	0.026 ppm ²³
		0.025 ppm ²³

5.2 Aquatic Species Tests on Busan 1030 and Busan 30WB

Environment Canada²⁴ has carried out a number of fish bioassays on Busan 1030 and Busan 30WB. The values reported below must be multiplied by 0.3 to obtain the aquatic toxicities based on the concentrations of the active ingredient:

96 hour LC50 (Busan 1030):	rainbow trout	- 0.13 ppm (3 tests).
	chinook salmon	- 0.05 ppm.
		- 0.06 ppm.
96 hour LC50 (Busan 30WB):	rainbow trout:	- 0.15 ppm.
		- 0.18 ppm.

Recently the lowest 96 hour LC50 value from the chinook salmon test, 0.05 ppm was used as the basis for proposing a TCMTB stormwater runoff standard for discharges from wood protection storage areas²⁵.

6.0 FURTHER STUDIES

Further studies on the environmental fate of TCMTB are presently underway, sponsored by Buckman Laboratories and the National Water Research Institute in Burlington, Ontario.

7.0 REFERENCES

1. Buckman Laboratories: Buckman Laboratories (corporate brochure, undated).
2. Buckman Laboratories. Busan 1030, Bulletin No. D37CAN, June 15, 1985.
3. B.C. Research. Division of Environment and Health and Forest Industry Health Research Program. Wood Products Manufacturing Sector Subcommittee. Sapstain Control Chemicals: Copper-8, TCMTB and MBT. A Review of Properties, Uses and Health Hazards, Vancouver, B.C.: B.C. Research, April, 1984.
4. Diachem Industries. Diachem Woodstat, Technical Data. Lumber Anti-stain Biocide (undated).
5. B.C. Research. Industrial Chemistry Division. Occupational Health Group and Forest Industry. Industrial Health Research Program. Anti-sapstain chemicals: Properties, uses, and health hazards of Busan 1030 and Busan 30 WB, Vancouver, B.C.: B.C. Research, July, 1987.
6. Buckman Laboratories. Product Data. Busan 1030, Bulletin C52W, April 10, 1982.
7. Buckman Laboratories. Busan 1030. A New Microbiocide for the Paint Industry (catalogue number and date not provided).
8. Canada Department of Agriculture. Plant Products Division. Production and Marketing Branch. Control Products Section. Memorandum: "Re: Registration of New Pesticide 2-(thiocyanomethylthio)benzothiazole", March 14, 1972.
9. Canada. Agriculture Canada. Compendium of Registered Uses of Pesticides in Canada, December, 1977.
10. Buckman Laboratories of Canada, Ltd. Busan 30WB product label, Canada Pest Control Products Act registration No. 19965, January, 1987.
11. Buckman Laboratories. Personal Communication, June 1, 1988.
12. Buckman Laboratories. TCMTB, Toxicity Profile, TP-TCMTB-W, October 26, 1981.
13. Buckman Laboratories. Material Safety Data Sheet. Busan 1030, April 7, 1986.
14. Hazelton Laboratories America, Inc., Obrist JJ. Hydrolysis of TCMTB in Buffered Aqueous Solutions, Memphis, TN: Buckman Laboratories, Inc., October 9, 1987.
15. Hazelton Laboratories America, Inc., Saxena AM. Artificial sunlight photodegradation of TCMTB in a buffered aqueous solution, Memphis, TN: Buckman Laboratories, October 29, 1987.
16. Hazelton Laboratories America, Inc., Rustum AM. Artificial and natural sunlight photodegradation of TCMTB on soil, Memphis, TN: Buckman Laboratories, October 29, 1987.
17. Hazelton Laboratories America, Inc., Saxena AM. Aerobic aquatic metabolism of TCMTB, Memphis, TN: Buckman Laboratories, October 12, 1987.

18. Hazelton Laboratories America, Inc., Saxena AM. The adsorption and desorption of TCMTB on representative agricultural soils, Memphis, TN: Buckman Laboratories, May 13, 1987.
19. Hazelton Laboratories America, Inc., Lesheski MJ. Determination of the mobility of TCMTB in selected soils by soil thin layer chromatography, Memphis, TN: Buckman Laboratories.
20. Hazelton Laboratories America, Inc., Obrist JJ. Determination of the mobility of soil-aged TCMTB residues by soil thin layer chromatography, Memphis, TN: Buckman Laboratories, April 2, 1987.
21. Buckman Laboratories. Busan 1030, Toxicity Profile, TP-1030W, October 15, 1984.
22. Canada. Environment Canada. Conservation and Protection. Pacific and Yukon Region. Liu S. Personal Communication, February 24, 1988.
23. Canada. Environment Canada. Conservation and Protection. Pacific and Yukon Region. Liu S. Personal Communication, March 3, 1988.
24. Canada. Environment Canada. Liu S. Personal Communication, July, 1987.
25. Canada. Environment Canada and British Columbia. Ministry of Environment and Parks. News Release. Chlorophenate control strategy announced, September 15, 1987.

Update on Current Studies of Dioxin in Great Blue Herons in the Georgia Strait Area

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INTRODUCTION

Since 1977 the Canadian Wildlife Service, Pacific and Yukon Region, has measured organochlorine residues in great blue heron eggs collected from several nesting colonies in the southern Strait of Georgia. The herons are resident in the Strait throughout the year, consequently the nature and level of chemical residues found in their eggs likely reflect the nature and level of organochlorine contamination in areas of the Strait where the herons forage.

The program has three goals: 1) to determine organochlorine levels in a species at the top of the estuarine food chain as an indicator of environmental quality, 2) to track changes in these levels over time and, 3) to determine if the health of the herons is affected by organochlorine residues.

Nest trees are climbed and a single egg per nest is removed from ten or more nests in the colony. The egg contents are then analyzed for a standard package of organochlorine residues (e.g DDE, PCB, HCB, etc.). Changes to the analytical protocol have been introduced throughout the course of the program to either improve accuracy, or to expand the list of substances that are measured.

In 1983 an analytical technique was developed for polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in egg tissue (Norstrom and Simon 1988). As part of a national screening exercise, great blue heron eggs collected in 1982 from a nesting colony on the Endowment Lands of the University of British Columbia (UBC) were analyzed. The levels of PCDDs were unusually high (Norstrom and Simon 1983). Since then dioxins and furans have been measured in several other colonies (Elliott et al. 1988). Table 1 summarizes the data presently available. The most important potential sources of the PCDDs and PCDFs in the Strait of Georgia are chlorophenols used to preserve wood products and protect lumber for export, and chlorine bleaching by pulp and paper mills.

Dioxins are potent avian embryotoxins. As little as 10 ng/kg injected into a chicken egg can cause mortality, teratogenic effects and edema (Verrett 1970). Cheung et al. (1981) reported that 6.4 ng/kg caused a significant increase in the incidence of cardiovascular malformations in chicken embryos. The comparatively high levels of dioxins found in heron colonies at UBC, Crofton and Gabriola Island between 1982 and 1986 (Table 1) did not appear to affect the productivity of the herons. Apparently they are considerably less sensitive than the chicken embryo to the actions of

dioxins and furans. Stalling *et al.* (1986) found that the Herring gull (*Larus argentatus*) in the Great Lakes was also considerably less sensitive than the chicken.

In 1987, the heron colony at Crofton failed to produce any young. While the usual complement of eggs was laid, almost all of them were destroyed before they hatched, and the shells were found lying beneath the nests. At the same time, mean levels of 2378-tetrachlorodibenzo-p-dioxin (2378-TCDD) - the most toxic dioxin congener - increased from 92 ng/kg in 1986 to 252 ng/kg in 1987 (Elliott *et al.* 1988). Whether the sharp increase in 2378-TCDD caused the failure of colony was not certain as natural factors such as disturbance and predation could not be ruled out.

A study was planned for 1988 to address the question of whether or not dioxins were implicated in the failure of the Crofton colony.

METHODS

PRODUCTIVITY

During the winter, mirrors and climbing gear were installed in four heron colonies near pulp mills which are potential sources of some dioxins (Powell River, Crofton, Gabriola Island, and Campbell River), and four distant from known sources (UBC, Nicomekl, Sidney Island, and Parksville). About 160 nests were under direct observation. We planned to monitor on a weekly basis the progress of the nests from egg-laying through incubation, hatching and brooding to fledging, recording the number of eggs laid, eggs hatched, and young fledged from each nest. The herons, however, failed to return to Crofton, Gabriola Island, Parksville and Campbell River. Other heron colonies on the mainland and east coast of Vancouver Island were located (Fig. 1) and were monitored from the ground using binoculars or a spotting scope and the number of young that could be seen was recorded.

IMPACT ON EMBRYOGENESIS

Three colonies, Nicomekl (control), UBC (intermediate level of dioxin contamination) and Crofton (high level of dioxin contamination) were selected for a detailed study of the possible impacts of dioxins on embryo development and the induction of hepatic enzymes.

Embryogenesis

To determine if dioxins were affecting embryogenesis, pairs of eggs were collected from several nests in each colony. One of each pair was analyzed for dioxin content, the other was artificially incubated to hatching.

Fertility and hatching rates, gross morphology (body weight, weight of organs - liver, heart, kidney, small intestine, duodenum, stomach, adrenal glands, spleen, Bursa of Fabricius, and yolk sac - tibia - weight, ash content, length and width - hemactocrit, plasma calcium and phosphorous), and presence of developmental abnormalities (e.g. edema) were reported for each chick.

Hepatic Microsomal Enzymes

The activities of; 1) total hepatic microsomal cytochrome P-450, 2) pentoxyresorufin N-dealkylase (a measure of cytochrome P-450 isozymes b and e), 3) erythromycin N-demethylase (a measure of P-450 p), and 4) ethoxyresorufin N-dealkylase (a measure of P-450's c and d) were determined for each chick.

CLUTCH EXCHANGE

Four complete clutches were removed from the colonies at UBC and Crofton and were transported to the Nicomekl colony. Eight clutches were taken from the Nicomekl colony to provide nests for the UBC and Crofton clutches. The Nicomekl clutches were then transported to UBC and Crofton to replace those removed earlier.

ADULT INCUBATION BEHAVIOUR

The behaviour of adult herons while incubating their eggs, especially their fidelity to the nest, was monitored at both the Sidney Island colony and at Crofton.

RESULTS

When this presentation was prepared most of the data sets generated by the study were either incomplete or only partially analyzed. Only the most general presentation of results, therefore, was possible. Also, dioxin analysis of the eggs collected had not been completed.

PRODUCTIVITY

Information on the productivity of 21 colonies (Fig. 1) representing about 1001 nests is summarized in Table 2. Only 9 of the colonies fledged young. The 9 colonies, however, account for 82% of the nests in the 21 colonies. Of the 12 colonies that failed to fledge young, 8 are within 10 km of a potential source of dioxins. There is also a striking relationship between colony size and productivity. Large colonies (>100 pairs) almost always produce young, small colonies (<15 pairs) almost always fail.

IMPACT ON EMBRYOGENESIS

Embryogenesis

All the eggs incubated whether they came from Nicomekl, UBC or Crofton were fertile, and all but one from both UBC and from Nicomekl hatched. There were no differences among the three colonies in the body weights of the chicks. Of the organs and tissues measured only the kidneys, stomach, and tibia of chicks from the contaminated colonies weighed less or were smaller than the same tissues of chicks from the clean colony. Vitamin D metabolism, as indicated by the % bone ash of tibia and plasma calcium and phosphorous concentrations, was the same for all the colonies. No developmental abnormalities were seen in chicks from the Nicomekl colony. Two chicks (15%) from UBC and four (33%) from Crofton showed subcutaneous edema.

Hepatic Microsomal Enzymes

There were no statistical differences among the colonies in total hepatic microsomal cytochrome P-450, or hepatic microsomal pentoxyresorufin N-dealkylase activity. No erythromycin N-demethylase activity could be measured in any of the liver samples. The Crofton heron colony exhibited induction of hepatic microsomal ethoxyresorufin N-dealkylase activity compared with both the Nicomekl and UBC colonies. The induction was highly significant statistically.

CLUTCH EXCHANGE

The results of the clutch exchange are presented in Table 3. The Crofton colony was abandoned, likely due to the disturbance during egg collection and exchange. Consequently the Nicomekl clutches placed in Crofton nests were lost. The Crofton clutches placed in the Nicomekl nests were retrieved and used to supplement the egg incubation study.

ADULT INCUBATION BEHAVIOUR

The data set concerning the behaviour of adult herons while incubating has not been analyzed.

CONCLUSIONS

1. More data are required to show whether or not the abandonment of some colonies and low productivity of others that was recorded this year is related to dioxin contamination.
2. The present level of dioxin contamination is:
 - 1) not affecting the fertility or hatchability of heron eggs;
 - 2) possibly having a small impact on the growth and development of the embryos in the most contaminated colony;
 - 3) possibly linked to edema found in some embryos;
 - 4) inducing hepatic microsomal cytochrome P-450 c and d isozymes;
3. More information will be needed to clearly demonstrate whether or not the behaviour of adult herons while incubating is impaired by the present levels of dioxin contamination.

BIBLIOGRAPHY

Cheung, M.O.; Gilbert, E.F.; Peterson, R.E. 1981. Cardiovascular teratogenicity of 2378-TCDD in the chick embryo. *Toxicol. Appl. Pharmacol.* 61:197-204.

Elliott, J.E.; Butler, R.W.; Norstrom, R.J.; Whitehead, P.E. 1988. Levels of polychlorinated dibenzodioxins and polychlorinated dibenzofurans in eggs of Great Blue Herons (*Ardea herodias*) in British Columbia, 1983-87: possible impacts on reproductive success.

Norstrom, R.J.; Simon, M. 1983. Preliminary appraisal of tetra- to octachlorodibenzodioxin contamination in eggs of various species of wildlife in Canada. Pages 165-170 in Miyamoto, J. ed. *IUPAC pesticide chemistry: human welfare and the environment*. Pergamon Press, Oxford.

Norstrom, R.J.; Simon, M. 1988. Determination of specific polychlorinated dibenzo-p-dioxins and dibenzofurans in biological matrices by gel-permeation/carbon chromatography and gas chromatography-mass spectrometry. In. *Environmental carcinogens-methods of analysis and exposure measurement*. Vol. 11. Polychlorinated dibenzodioxins, dibenzofurans and biphenyls. World Health Organization, International Association for Research on Cancer, Lyon, France. In Press.

Stalling, D.L.; Peterman, P.H.; Smith, L.M.; Norstrom, R.J.; Simon, M. 1986. Use of pattern recognition in the evaluation of PCDD and PCDF residue data from GC/MS analyses. *Chemosphere* 15:9-12.

Verrett, M.J. 1970. Witness statement. In. *Hearings before the subcommittee on Energy, Natural Resources and the Environment of the Committee on Commerce, US Senate, Serial 91-60*. US Govt. Printing Office, Washington, DC.

Table 1. PCDD and PCDF levels in Great Blue Heron eggs from British Columbia, 1983-87

		Residue level (ng/kg, wet weight), mean \pm SD (range in parentheses)								
Location	Year	N (in pool)	2378- T4CDD	12378- P5CDD	123678- H6CDD	123789- H6CDD	1234678- H7CDD	OCCD	2378- TCDF	23478- P5CDF
Nicomekl	1983	(7)	7	33	70	ND*	6	20	3	15
	1986	5	11	32	60	3	5	2	ND	8
			\pm 2 (7-12)	\pm 12 (14-44)	\pm 35 (21-110)	\pm 2 (ND-5)	\pm 4 (ND-9)	\pm 1 (ND-3)	\pm 4 (2-10)	
Sidney Island	1986	4	11	31	60	5	1	ND	1	3
			\pm 8 (3-18)	\pm 22 (9-59)	\pm 77 (6-174)	\pm 6 (ND-13)	\pm 1 (ND-2.5)	\pm 1 (ND-1)	\pm 3 (ND-6)	
UBC	1983	(10)	15	59	104	ND	6	27	11	48
	1986	7	31	94	136	10	18	11	5	21
			\pm 19 (7-63)	\pm 77 (28-255)	\pm 119 (40-385)	\pm 8 (1-23)	\pm 23 (ND-70)	\pm 16 (2-47)	\pm 4 (ND-10)	\pm 16 (6-51)
	1987	10	71	55	90	6	7	8	22	16
			\pm 54 (9-204)	\pm 28 (23-109)	\pm 36 (39-158)	\pm 4 (2-12)	\pm 4 (2-12)	\pm 7 (2-19)	\pm 16 (5-50)	\pm 5 (9-25)
Crofton	1983	(9)	40	347	911	46	8	25	24	46
	1986	10	92	388	544	35	4	6	5	30
			\pm 68 (8-218)	\pm 315 (11-1018)	\pm 427 (13-1298)	\pm 28 (1-89)	\pm 4 (ND-11)	\pm 6 (ND-21)	\pm 5 (ND-14)	\pm 26 (ND-68)
	1987	10	253	314	505	31	3	4	5	45
			\pm 135 (67-444)	\pm 204 (73-728)	\pm 293 (110-1052)	\pm 16 (9-58)	\pm 1 (ND-4)	\pm 1 (ND-5)	\pm 5 (ND-17)	\pm 26 (10-104)
Gabriola	1983	(8)	22	153	339	23	4	7	11	44

*ND, no peak observed (signal/noise<3).

Table 2. Productivity of Great Blue Heron colonies on the Strait of Georgia: 1988.

Colony	Active Nests	Productivity		
		Eggs/nest	Hatch/nest	Fledged/nest
Powell River*	42	4.0	1.9	0.0
Williamsons Landing*	6			0.0
UBC	150	3.9	2.8	2.1
Point Roberts	330			2.1
Nicomekl	70	3.9	3.0	1.9
Beacon Hill	64			2.3
Sidney Island	99			1.8
Sahtlam A	20			0.0
Quamichan Lake*	15			0.0
Crofton/Arthur St.*	38			0.0
Crofton/Shoal Island*	15			0.0
Saltspring Island A*	19			0.0
Holden Lake*	100			2.4
Hammond Bay	24			1.8
Lantzville	9			0.0
Qualicum	2			0.0
Deep Bay	11			0.0
Fanny Bay	15			0.5
Union Bay	6			1.0
Campbell River B*	3			0.0
Campbell River C*	2			0.0

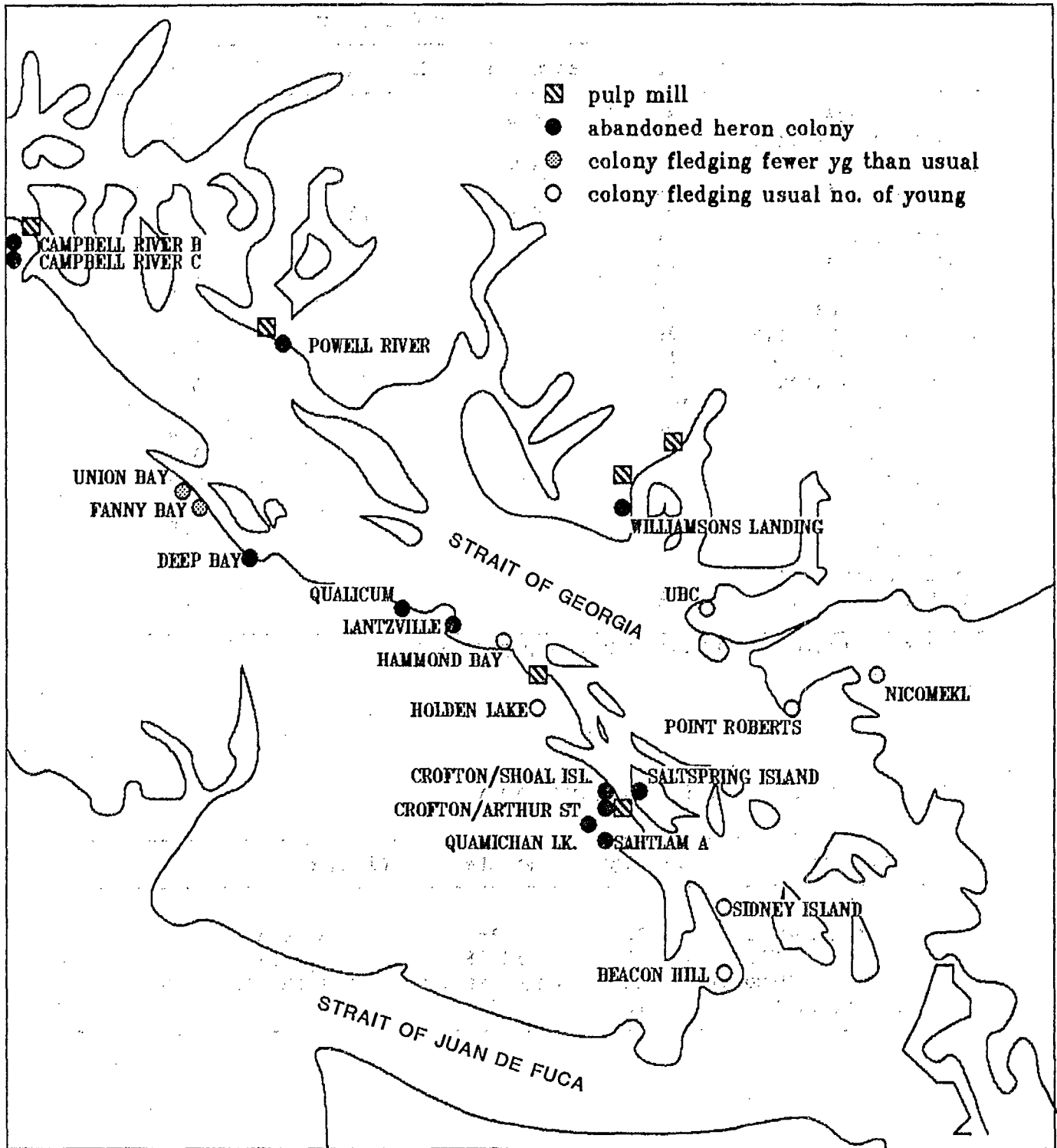
* located within 10 km of a pulp and paper mill

Table 3. Results of the Egg Exchange Study

Exchange	No. Eggs	Hatched	Fledged
UBC to Nicomekl	16	16	13 (81%)
Nicomekl to UBC	16	14-16	8 (50%)
Crofton to Nicomekl	12	eggs retrieved for incubation study	
Nicomekl to Crofton	16	0	0

Figure 1

Map of Great Blue Heron colony sites in the Strait of Georgia, B.C. where productivity was monitored in 1988.



Discussion Session A:
Summary

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1. Impact of Pulp Mill Effluents to Chinook
in the Upper Fraser

- the impacts of chlorinated lignins to reproduction success, immune response, and growth requires investigation.

2. Identification of Deficiencies in the Current Monitoring
Program in the Fraser Estuary

- recommendation that sediment deposits in storm sewers be monitored; US EPA has had good success with this approach.
- recommendation that chloroglycols be added to PCP objectives and monitoring.

3. Concern That Where Water Quality is Well Below Established Water Quality
Objectives, That Government Will Come Under Pressure
From Industry to Allow Increases in Contamination Discharge
to Take the Riverine Water Quality 'Up to the Line'

- the intent is that the Water Quality Objectives should serve as a useful tool or guide to persons responsible for the management of water quality, and the intent is not at all to indicate a pollution limit.
- nonetheless, several persons from various jurisdictions mentioned real examples of industry wishing to use these Objectives to back-calculate so as to be permitted to increase their levels of contaminant discharge.
- from the discussion, this topic clearly is of great concern to environmental scientists present.

- the relationships between effluent quality and environmental impacts, both lethal and (especially) sublethal, are not adequately understood in science to support any type of relationship between effluent quality and Water Quality Objectives.
- strong opinion was expressed that we do not as scientists have an adequate understanding of the environmental impacts of various contaminants, including their interaction with other variables.
- there was some support for industry to use best available technology.

4. Other Concerns Regarding Water Quality Objectives

- concern was expressed that federal and provincial agencies should attempt to come to agreement on what numbers should be set within the water quality objectives. Review arrangements are in place; reportedly, no major disagreements have arisen to date.
- some federal agencies do not agree that the setting of Water Quality Objectives is the best route for protecting the environment. No answer was given to the question as to what would be the alternative to water quality objectives. This seemed definitely to be a minority opinion; there was some opinion that Water Quality Objectives will drive companies towards using better waste treatment technology. (Example given of CINOLA).
- there was concern that Water Quality Objectives will become out-of-date, especially since the list to be done for the first time is so long and presumably takes priority over updating already issued Objectives. All are potentially subject to revision and review, and in fact one (the Similkameen) is already in the process of being revised.
- concern was also expressed that it will be too easy to rely just on Water Quality Objectives alone; it was felt that on-going in situ experiments and studies also are necessary;
- concern was expressed as to whether or not the Water Quality Objectives adequately will protect the environment in situations where the background levels already exceed the guideline levels.

5. Sublethal Biological Monitoring Recommended to Accompany Water Monitoring to Check for Compliance with Water Quality Objectives

- where fish bioassays are performed and show no acute toxicity, it was recommended that the test fish then be used in a challenge bioassay.

SESSION B

GUIDELINES AND OBJECTIVES FOR
INORGANIC SUBSTANCES

Using in situ Bioassays as a Basis for the Development of
Site-Specific Water Quality Criteria

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INTRODUCTION

The United States Environmental Protection Agency (EPA, 1985a) has recommended pH- and temperature-dependent national ammonia criteria for freshwater organisms based on available acute and chronic toxicity data. Modification of the national ammonia criteria for specific aquatic environments is possible using three procedures developed by the EPA (1983). These procedures are intended to account for variations in local water quality and/or differences in sensitivity of resident species and thereby result in more scientifically defensible "site-specific" water quality criteria. The three approaches, (i) the recalculation procedure, (ii) the indicator species procedure, and (iii) the resident species procedure, are described below.

- (i) The recalculation procedure is designed to compensate for any real differences between the sensitivity range of species represented in the national ammonia criteria document and the sensitivity range of those present at the site. This procedure ignores the biological availability of ammonia.
- (ii) The indicator species procedure accounts for differences in the biological availability and/or toxicity of a substance which may be attributable to physical and/or chemical characteristics of the site water. Differences in species sensitivity considered in the recalculation procedure are ignored.
- (iii) The resident species procedure accounts for both major variables, the sensitivity of local species and the affect of site-specific water characteristics on the toxicity of ammonia.

The indicator species procedure was used to develop site-specific water quality criteria for Lake Mead. This study was designed to determine the influence of Lake Mead water on the acute or short-term chronic toxicity of un-ionized ammonia relative to reconstituted laboratory dilution water. If the results of the acute (survival) or short-term chronic (survival, growth, and reproduction) un-ionized ammonia toxicity tests are not significantly different ($p > 0.05$), no adjustment to the national ammonia criteria is

considered necessary. If the results of the tests are different, the national criteria may be adjusted by multiplying them by the calculated water effect ratio (site water LC50 or chronic effect concentration divided by the laboratory water LC50 or chronic effect concentration) (EPA 1983).

The results of the indicator species test procedure ("water effect ratio") were used to propose site-specific un-ionized ammonia criteria for the Las Vegas Bay portion of Lake Mead.

METHODS AND MATERIALS

At the Lake Mead site, in situ bioassays consisted of acute and short-term chronic toxicity tests (EPA 1985b and c). The acute toxicity of un-ionized ammonia to fathead minnows (Pimephales promelas) and Ceriodaphnia dubia was determined in 96 hour and 48 hour tests, respectively. The short-term chronic toxicological assessment consisted of 7 day static renewal tests designed to measure chronic survival, growth, and reproduction of Ceriodaphnia dubia and chronic survival and growth of fathead minnows. In each test, Lake Mead or reconstituted laboratory water was spiked with ammonium chloride (NH_4Cl) and diluted with parent water. Comparison of the results of these short-term tests provides a means of assessing the effects of site water on the responses of the test organisms. In this way, a 'water effect ratio' can be calculated.

RESULTS

Acute Toxicity Tests

The results of the in situ acute toxicity bioassays for un-ionized ammonia are presented in Table 1. These results indicate no significant difference ($p > 0.05$) between the 96 hour LC₅₀ values calculated for fathead minnows in Lake Mead and reconstituted laboratory water. Similar results were obtained in the 48 hour acute toxicity tests run on Ceriodaphnia dubia. This suggests that there is no effect of Lake Mead water (relative to reconstituted laboratory water) on the acute toxicity of un-ionized ammonia to either of the test species.

Short-term Chronic Survival, Reproduction and Growth Tests

Statistical analysis of the results of the short-term chronic survival tests run at the Lake Mead site indicates no difference ($p > 0.05$) between the 168 hour LC₅₀ values for fathead minnows in the two types of water. The results of the Ceriodaphnia dubia short-term chronic toxicity tests were similar (Table 1).

The results of the fathead minnow and Ceriodaphnia dubia short-term growth tests demonstrate that the characteristics of Lake Mead water do not meaningfully modify the effects of un-ionized ammonia (Table 2). This observation is not immediately apparent from a cursory examination of the test results. The no observed (NOEL) and lowest observed (LOEL) effect levels of un-ionized ammonia calculated for fathead minnow growth in Lake Mead and reconstituted water appear quite different. However, when the magnitude of the response of the test organism to the test conditions is also considered, then there is no statistically significant difference between the test

groups ($p > 0.05$). Therefore, the difference between the subsequently calculated maximum acceptable toxicant concentrations (MATC), determined by calculating the geometric mean of the NOEL and LOEL, for the two water types is also not statistically significant. The same is true of the results of the Ceriodaphnia dubia growth and reproduction tests (Figures 1 and 2).

DISCUSSION

The strength of these short-term methods for estimating the acute and chronic toxicities of various pollutants to freshwater fish and aquatic life lies in their relative simplicity, cost effectiveness, and applicability to water quality criteria, standards, or objectives formulation. In the Lake Mead example, there were no statistically significant differences between the results of tests run in Lake Mead or laboratory reconstituted water. The water effect ratio was, therefore, calculated to be unity. That is, the toxicity of un-ionized ammonia in Lake Mead should be no greater or no less than would be expected in standard, reconstituted laboratory water. The United States National Guidelines (EPA 1985a) for ammonia may therefore be used directly to calculate water quality criteria for ammonia specific to the Las Vegas Bay portion of Lake Mead. However, calculation of the final criteria may also account for differences in the sensitivity of local species to un-ionized ammonia.

In situ bioassays are, increasingly, gaining recognition as useful and important tools in water management. In Region 8 (U.S. EPA), bioassays form an integral part of the water quality criteria development process. With the methodology currently available, acute and short-term chronic information can be generated in a reasonable time-frame and on a cost-effective basis. By using standard test species, the results of in situ bioassays can be compared to those obtained at different locations and at different times. These tests, therefore, provide detailed information on the relative toxicity of a contaminant at a specific location.

The applicability of these short-term tests is apparent when the results are compared with those obtained in full life-cycle tests. Thurston et al. (1986) exposed fathead minnows to elevated levels of un-ionized ammonia throughout their life cycle and measured a total of nine different end-points or responses. Comparison of the life cycle test results with the results of the short-term chronic tests run at the Lake Mead site indicates that the in situ methodology is indeed appropriate (Table 3). Specifically, the NOEL and LOEL values obtained for larval growth and survival are very similar for the in situ short-term chronic and laboratory life cycle tests. However, the most interesting aspect of these life cycle tests is that, typically, the most sensitive end-point is not measured in short term tests. In the case of fathead minnows, the most sensitive responses appear to be egg hatchability and the occurrence of brain lesions. The ecological significance of brain lesions is not abundantly clear at the present time. It is possible that viable populations of fish could be maintained even with a high incidence of brain lesions. Work on rainbow trout in the East Galetin River (Montana) suggests that this is indeed the case (Willingham and Thurston, in prep.). However, it is almost certain that introductions of contaminants into aquatic

systems that result in decreased egg hatchability will have negative effects on the populations of those species affected. That the end-point of the bioassay is not necessarily the most sensitive end-point that can be measured must be taken into account when the water quality standards or objectives for the water course are formulated from the site-specific criteria or guidelines.

CONCLUSIONS

The water quality characteristics of Lake Mead, at the time the acute and short-term chronic toxicity tests were conducted, had no affect on the toxicity of un-ionized ammonia to fathead minnows or Ceriodaphnia dubia when compared with the results of tests conducted with reconstituted laboratory water.

The 7-day growth effect levels for fathead minnows in the tests using Lake Mead or reconstituted laboratory water were not significantly different ($p > 0.05$) than those observed for survival. Similarly, levels of ammonia affecting growth and reproductive success of Ceriodaphnia dubia were not significantly different ($p > 0.005$) than those affecting survival. These findings suggest that growth and reproductive success may not be sensitive indicators of short-term chronic ammonia toxicity to fathead minnows or Ceriodaphnia dubia.

Results of the 7-day short-term chronic un-ionized growth and survival tests with fathead minnows are not significantly different ($P > 0.05$) from those reported for full life-cycle chronic ammonia toxicity tests with fathead minnows. These results confirm the utility of short-term tests for predicting the responses of test organisms over longer periods.

REFERENCES

- Environmental Protection Agency. 1983. Guidelines for deriving site-specific water quality criteria. In: Water Quality Standards Handbook. Office of Water Regulations and Standards. Washington, District of Columbia.
- Environmental Protection Agency, 1985a. Ambient water quality criteria for ammonia - 1984. EPA 440/5-85/001. Office of Water Regulations and Standards. Washington, District of Columbia. 217 pp.
- Environmental Protection Agency. 1985b. Methods for measuring the acute toxicity of effluents to freshwater and marine organisms. EPA/600/4-85/013. Environmental Monitoring and Support Laboratory. Office of Research and Development. Cincinnati, Ohio.
- Environmental Protection Agency. 1985c. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms. EPA/600/4-85/014. Environmental Monitoring and Support Laboratory. Office of Research and Development. Cincinnati, Ohio.

Thurston, R.V., R.C. Russo, E.L. Meyn, R.K. Zajdel, and C.E. Smith. 1986.
Chronic toxicity of ammonia to fathead minnows. Transactions of American
Fisheries Society 115: 196 - 207.

Willingham, T. and R.V. Thurston. In preparation. Effects of un-ionized
ammonia on rainbow trout in the East Galatin River, Montana.

Table 1. Acute and short-term chronic toxicity test results for fathead minnows and Ceriodaphnia dubia at Lake Mead.

<u>Species</u>	<u>Water Source</u>	<u>Un-ionized Ammonia (95% C.I.) in mg NH₃-N/L</u>		
		<u>48 hr. LC₅₀</u>	<u>96 hr LC₅₀</u>	<u>168 hr LC₅₀</u>
Fathead Minnow	Lake Mead		1.14(1.03-1.28)	1.13(1.01-1.26)
	Lab Water		1.04(0.91-1.18)	0.90(0.77-1.05)
<u>Ceriodaphnia dubia</u>	Lake Mead	2.63(2.30-3.11)		1.92(1.53-2.50)
	Lab Water	2.88(2.22-3.74)		1.81(1.37-2.52)

Table 2. Reproductive and growth test results for fathead minnow and Ceriodaphnia dubia at Lake Mead

	<u>Fathead Minnow Growth</u>		<u>Ceriodaphnia Growth</u>		<u>Ceriodaphnia Survival</u> ¹	
	<u>Lake Mead</u>	<u>Lab Water</u>	<u>Lake Mead</u>	<u>Lab Water</u>	<u>Lake Mead</u>	<u>Lab Water</u>
NOEL ²	0.26	0.67	1.68	1.06	0.85	1.06
LOEL ²	0.50	1.23	4.22	2.17	1.68	2.17
MATC	0.36	0.90	2.66	1.52	1.20	1.52
Min.Sig.Diff.(μg)	104	180				
Percent Decrease	15	29			34	72

1 3rd brood mean number of neonates

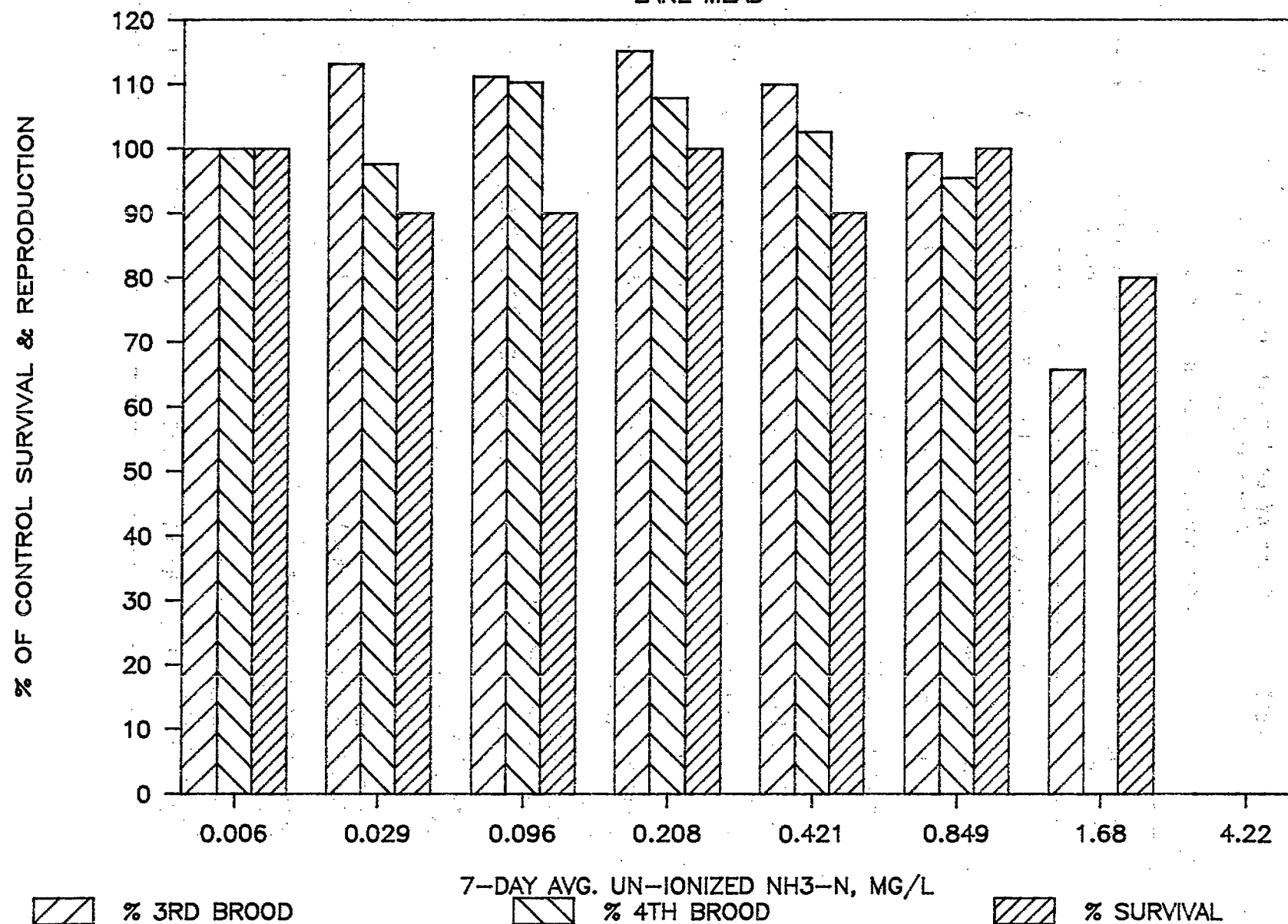
2 mg NH₃-N/L

TABLE 3. Effects of un-ionized ammonia to fathead minnows:
Comparison of full life-cycle
and
7-day short term chronic test results.

Variable Studied	LOEL (P = 0.05) NH ₃ -N	NOEL (P = 0.05) NH ₃ -N	MATC NH ₃ -N
<u>Full Life-Cycle Test Data (Thurston et al., 1986)</u>			
Parental survival	0.75	0.36	0.52
Parental growth	0.75	0.36	0.52
Egg productivity	0.75	0.30	0.48
Egg variability	0.75	0.30	0.48
Egg hatching	0.30	0.16	0.22
F1 larvae survival	-	0.30	>0.30
F1 larvae growth	-	0.30	>0.30
Occurrence of brain lesions	0.17	0.09	0.12
Occurrence of other histological changes	-	0.96	>0.96
<u>7-Day Short-Term Chronic</u>			
Lake Mead Larvae survival	0.99	0.50	0.70
Lake Mead Larvae growth (MSD 104 ug; 15% decrease)	0.50	0.25	0.36
Reconstituted lab water Larvae survival	0.67	0.32	0.47
Reconstituted lab water Larvae growth (MSD 180 ug; 29% decrease)	1.23	0.67	0.90

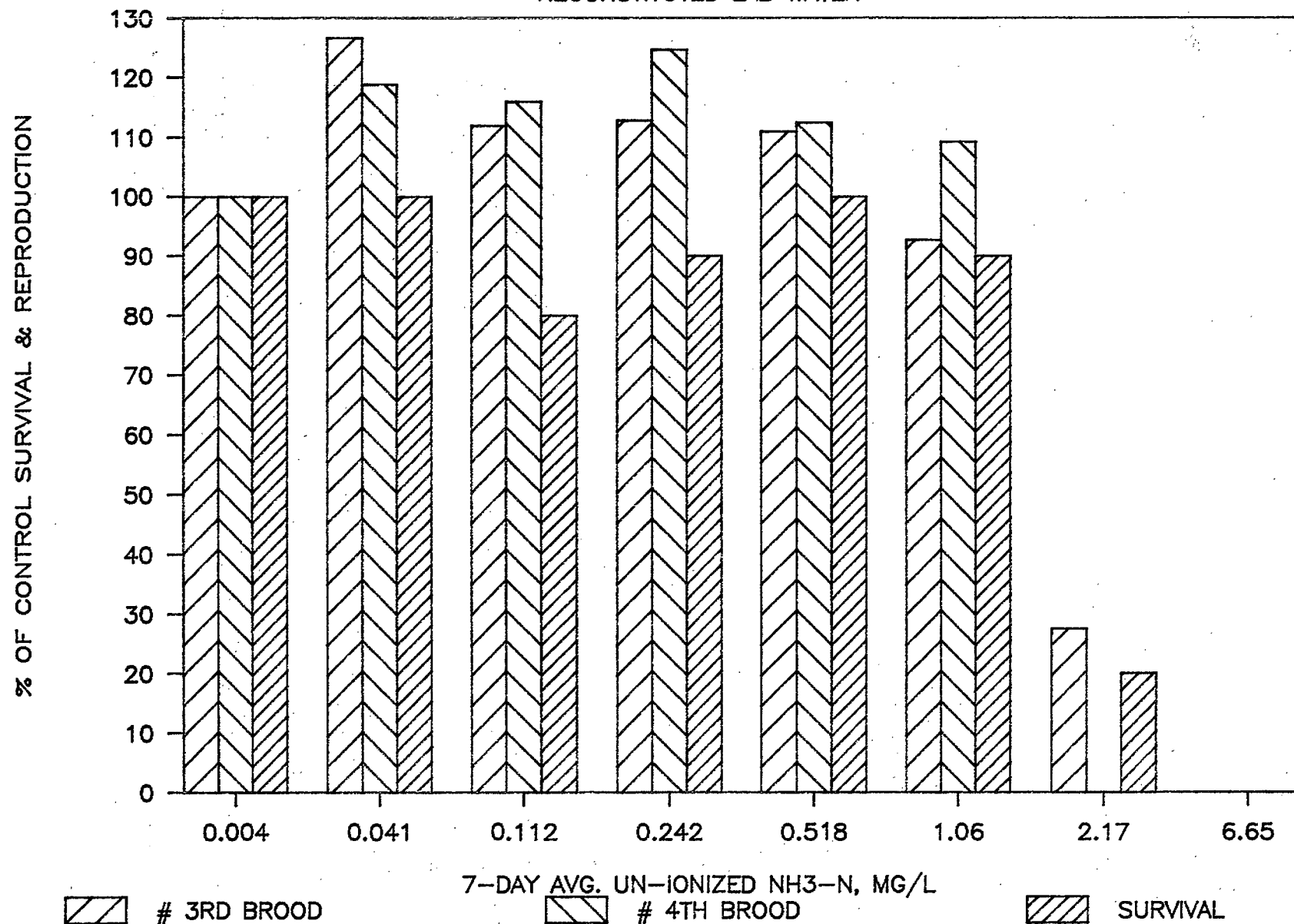
C. DUBIA REPRODUCTION AND SURVIVAL

LAKE MEAD



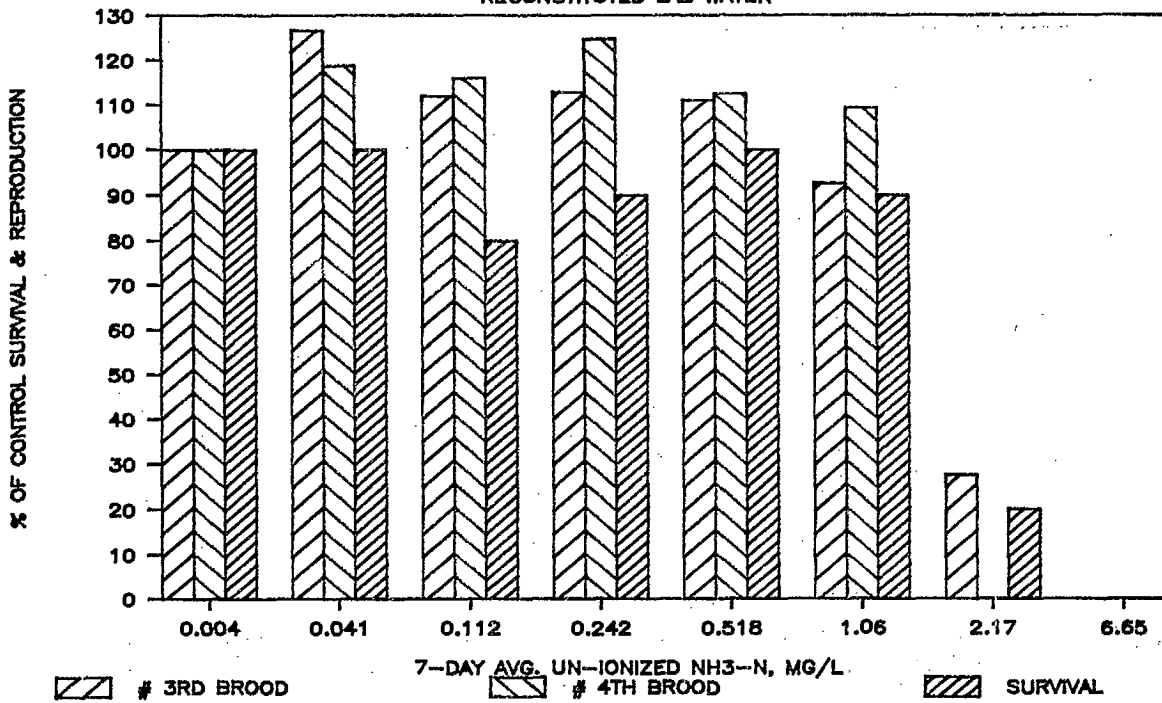
C. DUBIA REPRODUCTION AND SURVIVAL

RECONSTITUTED LAB WATER



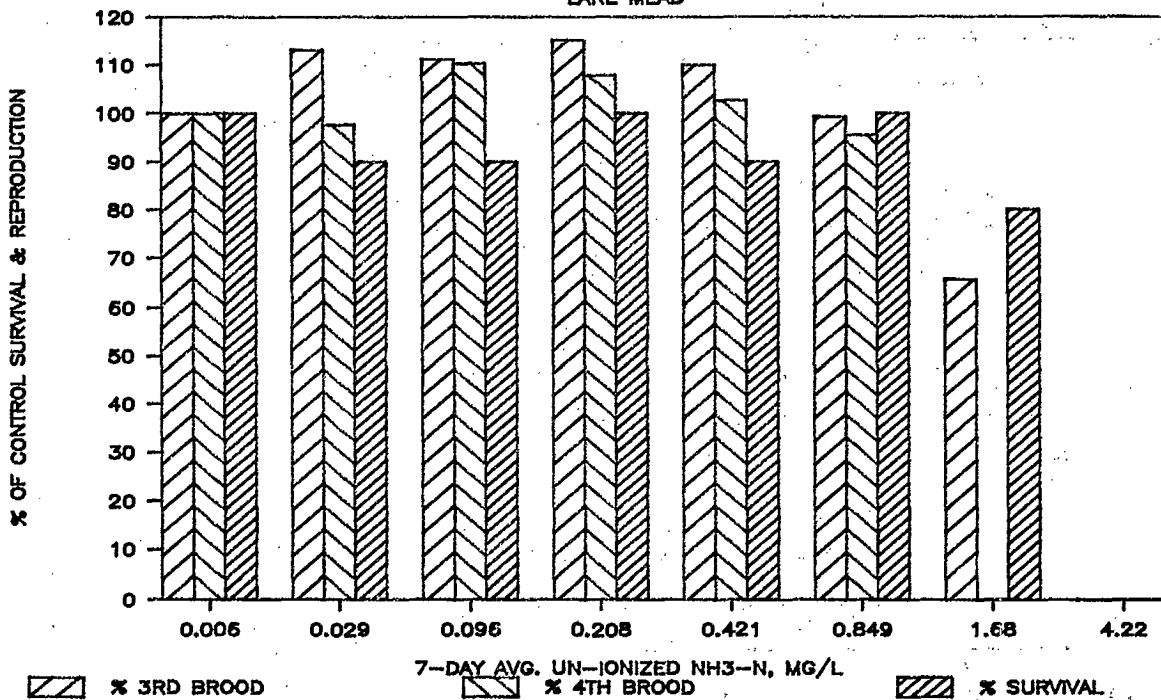
C. DUBIA REPRODUCTION AND SURVIVAL

RECONSTITUTED LAB WATER



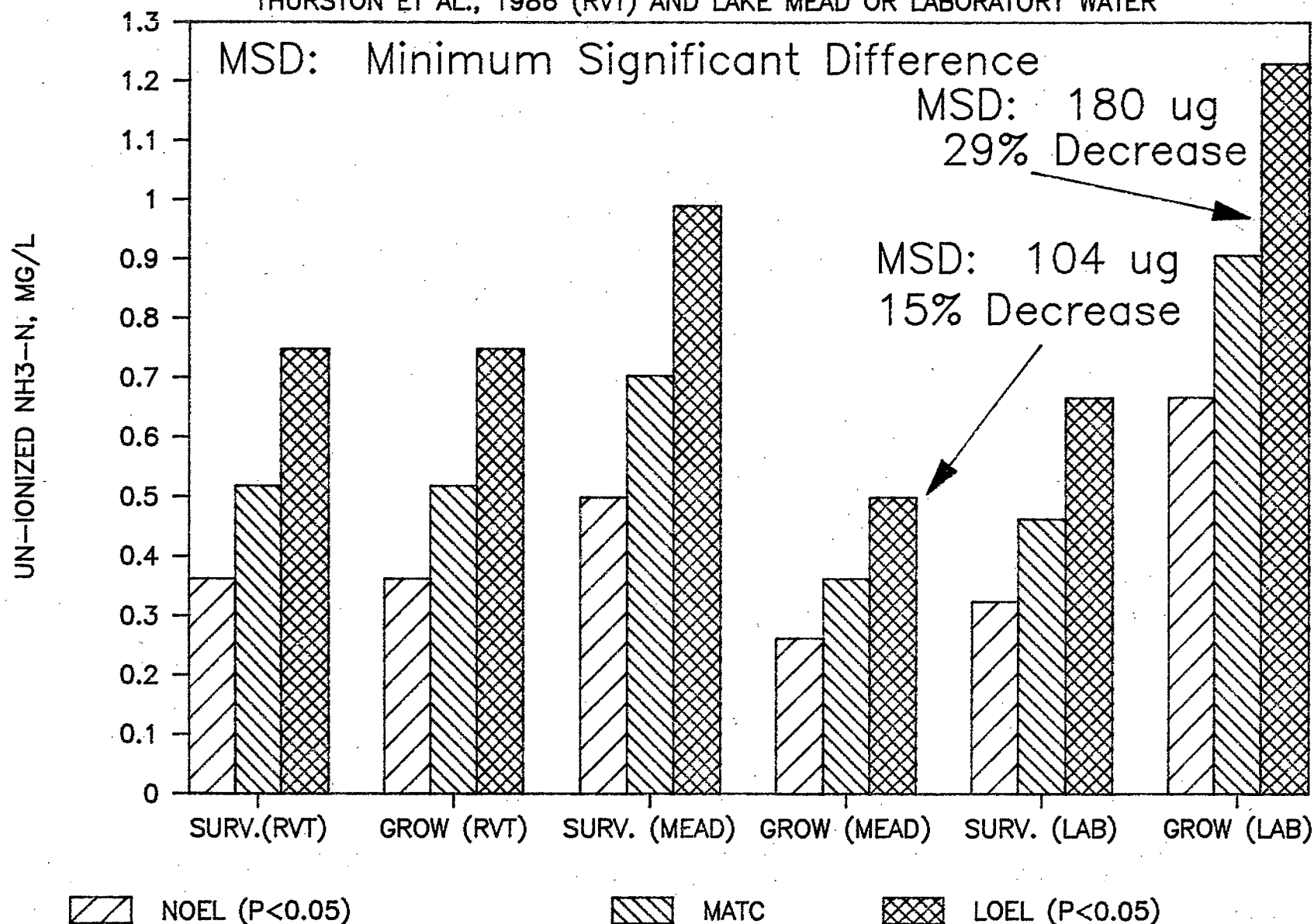
C. DUBIA REPRODUCTION AND SURVIVAL

LAKE MEAD



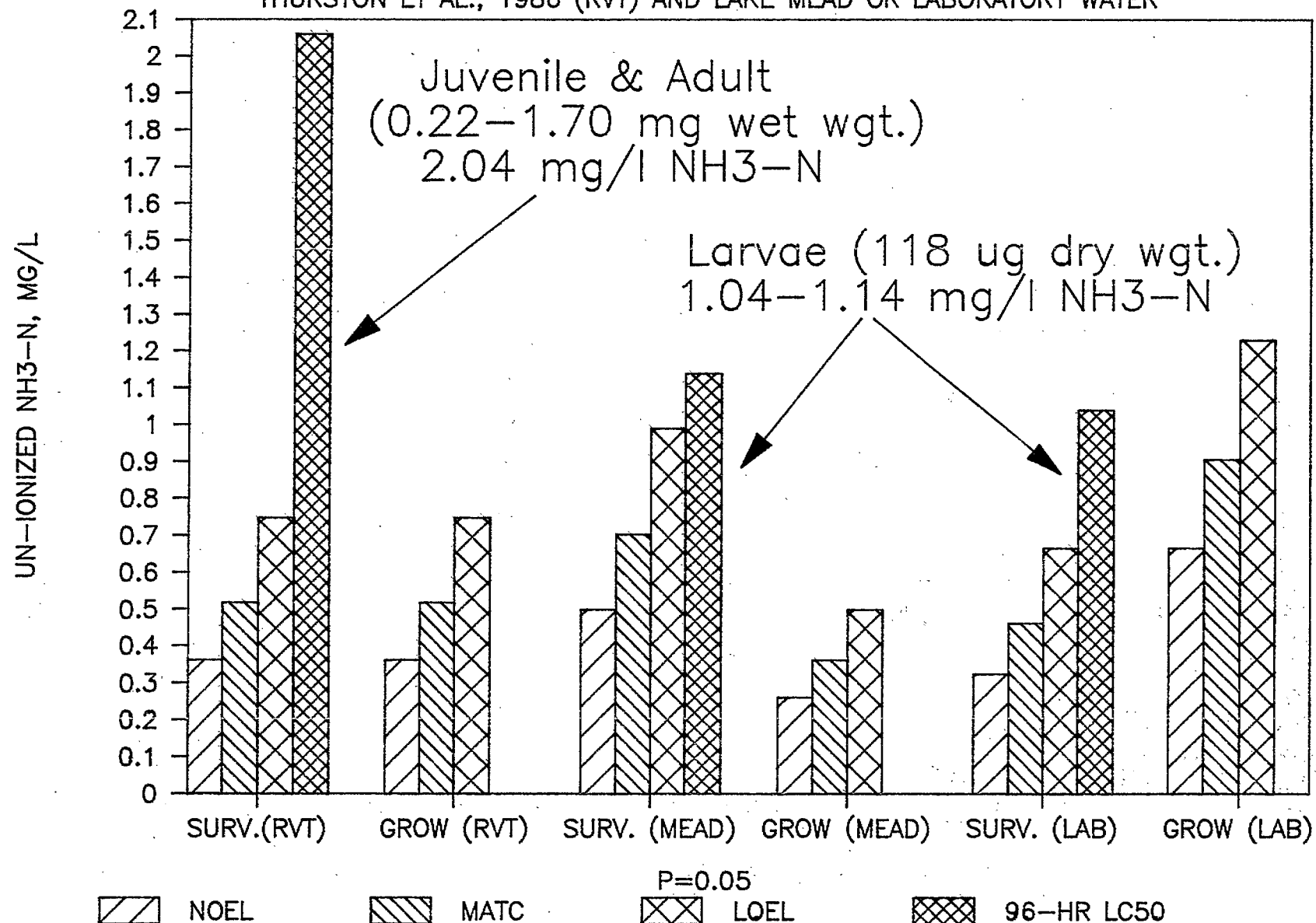
FATHEAD MINNOW 7-D & LIFE-CYCLE NH₃ TOXICITY

THURSTON ET AL., 1986 (RVT) AND LAKE MEAD OR LABORATORY WATER



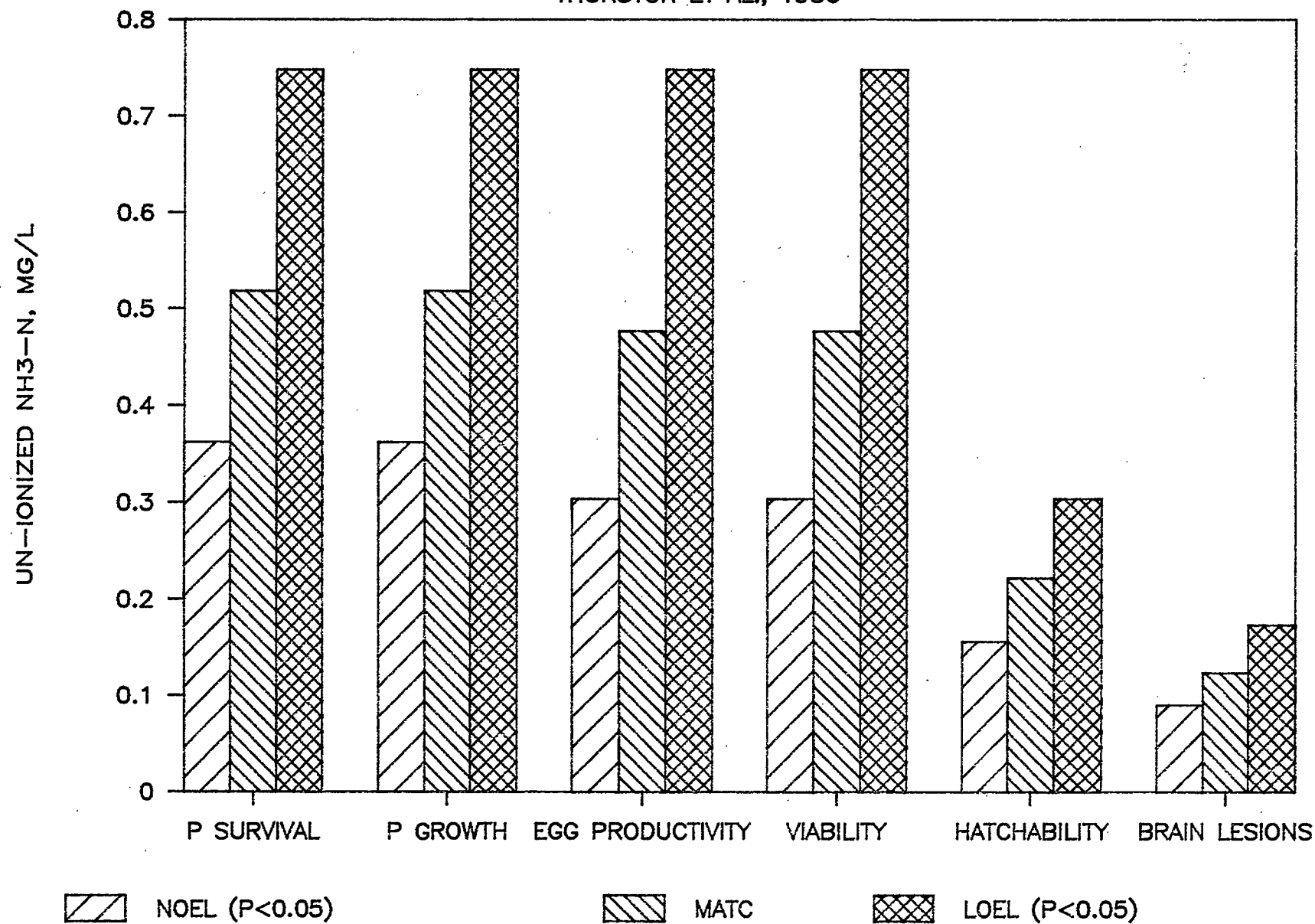
FATHEAD MINNOW 7-D & LIFE-CYCLE NH3 TOXICITY

THURSTON ET AL., 1986 (RVT) AND LAKE MEAD OR LABORATORY WATER



FATHEAD MINNOW LIFE-CYCLE NH3 TOXICITY

THURSTON ET AL., 1986



Factors Influencing the Biological Availability of Metals to Freshwater, Estuarine and Marine Organisms.

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When we look at the biological effect of copper or other metals, we frequently concern ourselves with the total concentration of the metal relative to its effect. We then plot some biological factor such as growth or survival as a function of metal concentration. However, the more that we examine the effects of metals on organisms, the more it appears that the biological effect is a function not only of concentration but also of the chemical state of the metal as well as the physiological state of the organism.

Stated briefly, **the concentration of metal apparent to the organism is not the total concentration of metal in the environment.** This can be demonstrated by any of a number of studies. I will use the results from one of our early 1970's studies (Figure 1; Lewis, Whitfield and Ramnarine, 1973). In this study, the embryonic or "egg" and first two naupliar stages of a copepod were exposed to 5.4 ug/L copper, added as CuCl_2 , to filtered (0.45 μm) seawater from the Strait of Georgia. (Filterable copper in this water was 0.5 and 0.7 ug/L for each of the two months shown.) Survival at this level of copper was 46% and 47% for the two months (standard error <5% of the mean). Survival was increased by adding a synthetic organic that chemically binds copper. Survival was also increased by adding seawater extracts of marine sediments from the Strait of Georgia and Indian Arm. In fact, using the % survival with the sediment extracts allowed an expression of the detoxification ability of the sediment extract in terms of the synthetic metal complexing agent.

These data indicate that there are factors in the natural environment that control the biological impact of the metal. If we consider this in terms of impact assessments, the use of total metal concentration doesn't tell us any more than how much metal is present. It does not, for example, address the impact of a situation such as a spill because the ability of the natural environment to reduce toxicity is not known. Neither does it consider the changes in metal bioavailability that occur as a result of natural events. Seasonal changes in productivity, phytoplankton blooms, anoxic bottom waters and sediments, and lake turnovers are all events that can change the

biological effect of trace metals as well as the total metal concentration.

In the presentation I briefly examine the factors that affect metal bioavailability and present means of measuring what we term the biologically active fraction of metal. I discuss the effect of metal tolerance on metal impact assessment. Finally, I suggest a protocol that could be considered when attempting to assess the effect of metals on the biota.

The terms "biologically available metal" and "biologically effective metal concentration" are used to indicate the fraction of total metal that can be taken up by the organism and which can react with its metabolic machinery. Each metal occurs as an array of chemical species. Using copper as the example, the metal occurs in particulate and "dissolved" states. Within each of these states it occurs in an array of inorganic and organic species. Of all of these species, organisms are able to take up only a few from natural environments. Some of the others are reactive but only at a slow rate and, as such, can be considered as "unavailable".

With most metals it is the chemically labile species that are the most available. By labile, I mean those that readily react with other chemicals. With copper, for example, it is the ionic species that usually is the most labile and, biologically, the most available. Other chemically labile metal species, say for example copper chloride, can serve as a readily available source for ionic copper through equilibrium processes. Chemically refractive chemicals such as copper-carbonates or copper-containing humics are not good sources of ionic metal.

Ideally, what is needed in an assessment is the total concentration of the metal and the concentration of biologically available metal. Estimates of biologically available metal species can be produced with chemical models. It is, for example, possible to estimate from certain chemical models how much metal should be in the ionic species at any one time. This can then be related to metal uptake or toxicity. The drawbacks with model-derived estimates are that they are estimates. They work well in defined media or when there is a great deal of information about the chemical nature of the environment. As a general rule, however, there isn't much information and models do not work well with natural systems. Unfortunately, our knowledge about chemicals and processes in natural waters is very limited. We are also dealing with a variety of metal binding agents in natural environments - ranging from mucopolysaccharides to humic substances in the medium and from amino acids to metallothioneins in the organism. We must also include metal adsorbing agents such as clay

minerals. To place all of these agents into chemical perspective and believe that we can model the availability of metals in natural systems is, at the very least, wishful thinking.

Impact assessments need hard data. I suspect that it would be more difficult to be successful in court with model-based chemical assessments than a fist full of values and observed or bioassay-derived statements about the impact. So what is needed is a technique to measure the concentration of biologically available metal in natural environments.

The measurement of biologically available metal really means the measurement of chemically labile metal species. This can be done either by direct measurement or by removing the biological available fraction and then measuring it. There are several techniques that reportedly allow direct measurement of certain metal ions. Single ion electrodes such as the cupric ion electrode can measure the cupric ion in freshwater. There are certainly problems with the use of these electrodes but at least there is a recognized technique. In estuarine and saltwaters, however, the single ion electrode does not work, at least for copper and several other transition metals. The massive concentrations of major ions causes a competition between the cupric ion and the major ions. This causes the response of the electrode to be nonlinear and irregular, a situation which prevents the use of the single ion electrode.

Techniques to measure labile metal species in marine and estuarine waters are essentially those which allow separation of the metal-containing species from the water. Realize that the technique has to be sensitive enough to separate **only** the labile species and, ideally, only those that are biologically available. Several techniques have been reported to do this:

Anodic-stripping voltammetry, copper amperometry, and various resin techniques.

Each has its own capabilities and problems. ASV, for example, measures more than just the biologically available species and has a major problem with organics in humic-rich waters. Resin techniques are numerous but it is essential to use only a resin that acts like an organism, one with very weak binding capabilities.

The technique discussed in the talk was developed at the University of Alberta, for measuring the cupric ion concentration of milk and sewage (Cantwell et al., 1982). It was then modified for use in seawater, by one of my former graduate students (Zorkin et al., 1986). The resin is a weakly-binding sulfonic-acid cation exchanger that

responds in a manner comparable with bioassay results in a defined medium where metal speciation can be reliably calculated. The original work was with copper. Since that time, the technique has also been found to be suitable for Mn, Pb and Zn. There is also some evidence that it may be suitable for Cd although there are problems with this metal.

There are, of course, limitations. The resin does not work in freshwater. It doesn't work for sediments where a solid medium is involved. It would probably work for sediment porewater although I suspect the high loading of organics and iron colloids would be limiting.

With a technique in hand, the next question is how to use it. From this, a natural question is how much of the total metal consists of the biologically available fraction and what does it mean to the organism? As an example of the former, I will use some of our work in Indian Arm. The concentration of total filterable (0.4 μ m) copper varies but is generally slightly less than 1.0 ppb. In contrast, the concentration of the biologically available fraction amounts to about 1% of that or 0.01 ppb. It is difficult to relate this directly to organism LC₅₀ values because of the complex nature of the chemistry. However, if one uses cupric ion activity and two copepod crustaceans as examples, the 72-h LC₅₀ value for *Acartia tonsa* is between 10^{-10} and 10^{-11} M while the 96-h LC₅₀ value for the adult stage of a west coast harpacticoid copepod, *Tigriopus californicus* is 3.3×10^{-7} M. There is thus a 3 order of magnitude difference between the two. Incidentally, this is a species that has been considered as a bioassay organism!

Tolerance is something that must be considered in estimating impact on a plant or animal community. Since changes in tolerance occur during the life history of an organism it is something that must be considered at different times of the year. Many bioassay organisms are tolerant of elevated levels of biologically available metal. Unfortunately, the reason that they are used as bioassay organisms is far too frequently because they are easy to culture and maintain rather than serve as sensitive monitors of metal bioavailability.

Changes occur in the concentration of both total metal and biologically available metal. In nearsurface waters, phytoplankton productivity during the day can produce a daily increase and decrease of metal complexing agents. Concentrations differ from one body of water to the next, often quite dramatically. Areas where different bodies of water meet are areas where both metal concentration and speciation can change abruptly. Estuaries and tidal fronts are notorious for this.

In estimating impact, it is important to combine estimates of metal concentration, metal bioavailability and metal impact. The total concentration of metal is a requirement to provide an estimate of what is there and, relative to availability, the effect of the natural environment in controlling metal bioavailability. Metal bioavailability will provide an expression of the actual concentration of metal that will affect the organism. In order to determine impact it is advisable to have two types of bioassays. The first uses an organism widely used for bioassay purposes. *Mytilus edulis* or other species of the genus are, for example, assays of this type. Information with these organisms can be compared with information on the same species, or related species, from other areas. But there also has to be a bioassay that will provide specifics about the environment being affected. Here it is possible to use either individual organisms or communities. With the latter, variability in tolerance will affect community structure. This, by itself, can be of diagnostic value.

In summary, total metal concentrations are necessary but do not provide an indication of the biologically available metal. In order to determine impact, the bioavailable metal must be measured by itself. Since organisms have varying degrees of tolerance, they will respond differently to a given excess of biologically available metal. Inasmuch as an impact assessment needs to evaluate the biological effect of excess metal, there is a requirement to relate metal concentrations to bioassay results.

References

- Cantwell, F.F., Nielsen, J.S. and Hrudey, S.E., 1983. Free nickel ion concentration in sewage by an ion exchange column-equilibrium method. *Anal. Chem.*, 54: 1498-1503.
- Lewis, A.G., Whitfield, P. and Ramnarine, A., 1973. The reduction of copper toxicity in a marine copepod by sediment extract. *Limnol. Ocyg.*, 18: 324-326.
- Zorkin, N.G., Grill, E.V. and Lewis, A.G., 1986. An ion-exchange procedure for quantifying biologically active copper in sea water. *Anal. Chim. Acta*, 183: 163-177.

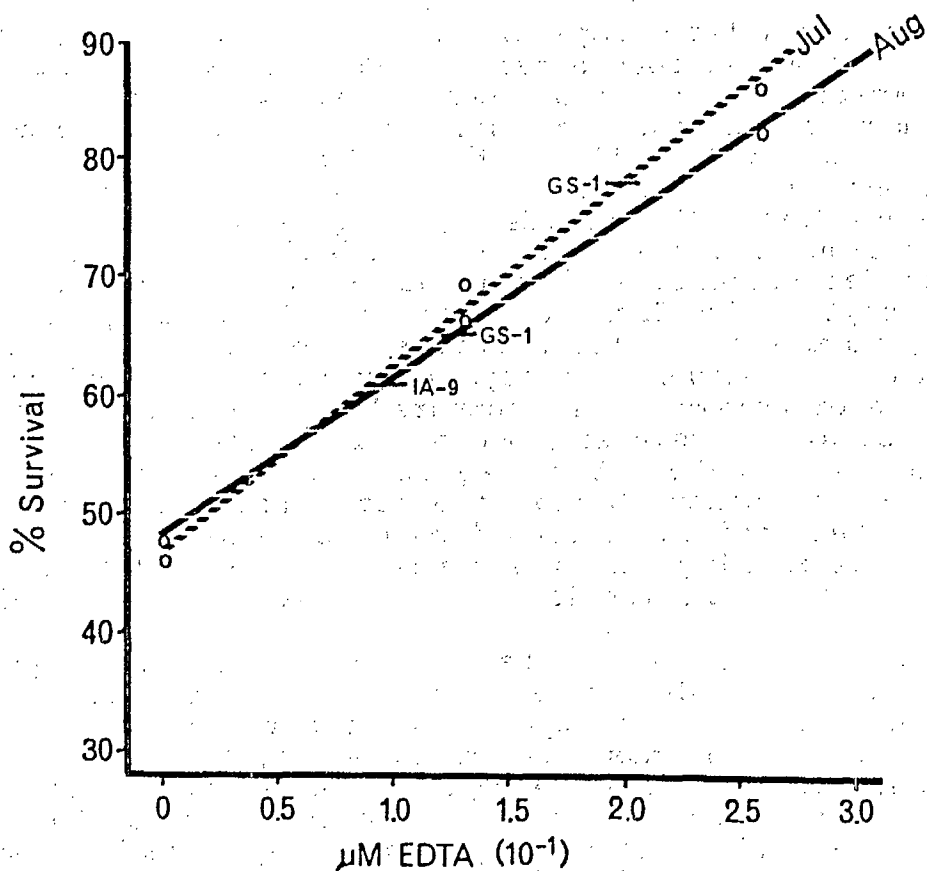


Figure 1. EDTA (ethylenediaminetetraacetic acid) equivalents (uM) of 2% seawater extracts of sediments. Equivalents obtained by plotting survival with sediment extracts on line drawn from survival values obtained for July and August (1972) with EDTA series (open circles). GS-1 = values from sediment samples collected at IOUBC/GS-1 (49 17.0' N, 123 50.5'W). IA-9 = value from sediment sample collected at IOUBC/IA-9 (49 23.5'N, 122 52.,5'W). (Taken from Lewis et al., 1973.)

Criteria for the Aesthetic Characteristics of Water

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INTRODUCTION

There are a number of characteristics of water for which criteria have been, or will be defined, not on consideration of toxicity or health risk, but on human perception of aesthetic acceptability. Because of this basic difference, the normal approach to setting criteria using toxicity data or environmental data does not appear to be directly applicable to cases involving aesthetics.

Examples of aesthetically based criteria, taken only from the Drinking Water Guidelines (1987), include chloride, colour, copper, ethylbenzene, hardness, iron, manganese, pH, sulphide, temperature, toluene, tds, xylenes and zinc. The Recreational Water Quality Guidelines (1983) list turbidity and water clarity as characteristics of concern for aesthetics and give numerical criteria for them. It is interesting that for contaminants such as ethylbenzene, toluene and xylenes, the numerical criteria which are specified are not based on consequences on human health or ecological damage but on evaluation of human acceptance or rejection on aesthetic grounds.

What needs to be examined is the most appropriate process for evaluating and establishing quantitative criteria for aesthetic characteristics. What is discussed here are two example characteristics with two quite different contexts. Periphyton in streams is a concern in many areas and a criterion for British Columbia was established after some consideration of the problems involved and an evaluative process developed (Nordin 1985). Colour is being reviewed at present in consideration of establishing provincial criteria. For colour, criteria have been previously established by a number of agencies.

PERIPHYTON BIOMASS IN STREAMS

In considering stream eutrophication, little information was available on which to base a criterion for British Columbia. No other jurisdictions had developed any criteria and the scientific literature had only a few pieces of information which were relevant to the question which was being

considered. The question was: what level of algal biomass would be acceptable from a strictly aesthetic perspective to persons using the river for recreational pursuits. The consideration of the amount of algae which might cause negative effects on other biota or bring about some undesirable change in stream ecology or water chemistry was a separate evaluation.

The process of aesthetic evaluation which was used in this case was one of a survey of "expert observers". Individuals active and experienced in environmental matters from a variety of agencies were contacted and asked to identify times and locations where quantified data on periphyton biomass existed and where some judgement of presence or absence of an aesthetic problem could be made. From the range of data, coupled with the evaluation of the observers, a continuum of observations could be constructed (Figure 1). There were consistent results that within the lower range no aesthetic problem existed ($<25 \text{ mg/m}^2$) and in the upper range ($>50 \text{ mg/m}^2$) some aesthetic deterioration was consistently seen to be occurring. There was not a good separation in the 25 - 50 mg/m^2 range. It was proposed that 50 be used and this became the provisional criteria.

COLOUR

There have been criteria previously established for two water uses: drinking water and recreation. In contrast to the algal biomass evaluation considered above where no previous criteria existed, for colour we have relatively long established and accepted criteria for drinking water. For drinking water the value for Canada and most other jurisdictions is 15 True Colour Units. There was a criteria for recreational water quality of 100 Pt - Co units proposed by Environment Canada (1972) but this was not adopted in the Recreational Water Quality Guidelines (1983).

In examining the technical basis of these numbers it is very difficult to determine the rationale used in establishing them. For drinking water, the CCREM guidelines (1987), using Health and Welfare Canada (1979) as a reference, indicate that the 15 TCU value is based on "detectable colour in a glass of water". The WHO (1984) guidelines make a similar comment and add that 5 TCU can be detected in larger volumes of water such as a white bathtub. The WHO notes that few people can detect a colour level of 3 TCU. Thus it would appear that one basis of the presently accepted criteria is threshold of perception.

A second line of rationale can be seen in the U.S. criteria. The Blue Book criteria (U.S.E.P.A. 1973) recommended a criteria of 75 platinum-cobalt units for raw water but was accompanied with little explanation. The Red Book (U.S.E.P.A. 1976) reiterated this value but gave some rationale. It noted that raw water of 75 colour units or less could be treated using standard coagulation, sedimentation and filtration to yield a finished water with less than 15 colour units. It would appear that the 15 unit criteria is based on the general availability of technology to produce water of acceptable quality (15 TCU) from most raw water sources i.e. a derived value based on available technology.

The 15 TCU value first proposed in 1962, (U.S. Public Health Service 1962) appears to have been accepted by most jurisdictions without any serious re-evaluation when it is incorporated into updated documents. This is not necessarily a problem with colour or aesthetic characteristics specifically but common to many characteristics of water quality. An attitude of "well the EPA reviewed it and their numbers look okay, so lets adopt it" can be seen in many documents.

DISCUSSION

Although a criterion for drinking water may be ascribed to aesthetics, other factors are also considerations. Practical applied problems associated with excess colour in domestic water supplies include staining of clothes, food or fixtures. Colour has also been used as an indication of contamination by organics or of trihalomethane production. Organically derived colour can also effect chlorine dosage calculations and the persistence of chlorine residual. So although aesthetics evaluation through visual examination may be an important aspect, some evaluation of colour levels associated with staining, organic contamination or effects on disinfection must also be considered.

The primary concern I have with regard to aesthetic criteria (as opposed to criteria concerned with toxic and/or deleterious substances) is the process by which criteria are established and evaluated - particularly how objective and defensible in a scientific sense, some of the existing and proposed criteria are.

Whether or not an aesthetic characteristic has a fundamentally valid basis is not a trivial item. The potential cost to a pulp mill to comply with a criterion for colour or for a sewage treatment plant to remove nutrients to limit periphyton biomass to a limit set by a regulatory agency can involve a substantial economic cost.

What is proposed as a means of evaluating aesthetic criteria is to use a modification of the process described above for periphyton biomass. Evaluation groups, analagous to taste test panels, can be established to evaluate the aesthetic acceptability of, for instance, colour. On the basis of the judgement of a series of review panels, some basis could be generated for threshold concentrations which could be the basis of criteria.

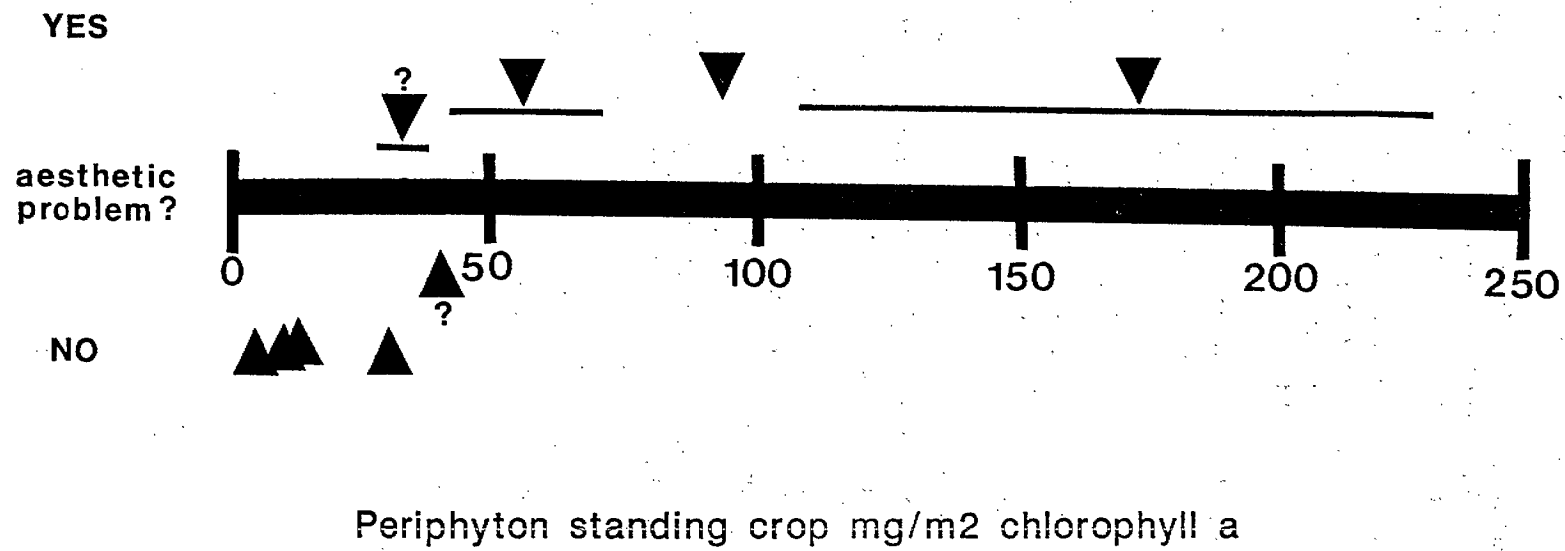
This technique incorporates primarily subjective judgements as opposed to what is generally considered an objective, scientific basis for criteria. It may be difficult for a group such as is present here, who are trained and deal in technical matters to use such an approach; however, the problem of quantifying aesthetic criteria is not one which lends itself to a traditional scientific methodology.

What is the best way of deriving quantitative criteria for aesthetic criteria? I think that work is needed to develop acceptable approaches to deal with this problem. The critical step in evaluation of numerical values is the initial proposed value. Once established, as noted above, there is a tendency for the value to persist. In the evaluation of criteria the

establishment of a quantitative value is a primary step. The proposed criteria then become much easier to re-evaluate in the light of new data and some determination of whether the proposed value should be increased or decreased becomes a much simpler task. However, the primary step of initial establishment of the criteria remains the priority problem and one where some original and innovative ideas are needed.

REFERENCES

1. Canadian Water Quality Guidelines. 1987. Prepared by the Task Force on Water Quality Guidelines of the Canadian Council of Resource and Environment Ministers.
2. Environment Canada. 1972. Guidelines for Water Quality Objectives and Standards. Inland Waters Directorate, Department of the Environment. Technical Bulletin no. 67.
3. Guidelines for Canadian Drinking Water Quality. 1987. Prepared by the Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, Ottawa.
4. Guidelines for Canadian Recreational Water Quality. 1983. Prepared by the Federal-Provincial Subcommittee on Recreational Water Quality of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, Ottawa.
5. Health and Welfare Canada. 1979. Guidelines for Canadian Drinking Water Quality 1978. Minister of Supply and Services Canada, Ottawa.
6. Nordin, R.N. 1985. Water Quality Criteria for Nutrients and Algae. Ministry of Environment, Province of British Columbia, Victoria, B.C.
7. U.S. Environmental Protection Agency. 1973. Water Quality Criteria. 1972. Environmental Studies Board, Committee on Water Quality Criteria, Washington, DC EPA - R - 73 - 033.
8. U.S. Environmental Protection Agency. 1976. Quality Criteria for Water USEPA 440/9 - 76 - 023. Washington, DC.
9. U.S. Public Health Service. 1962. Drinking Water Standards. PHS Publication No. 956. U.S. Government Printing Office, Washington, DC.
10. World Health Organization. 1984. Guidelines for Drinking Water Quality. Volume 1. Geneva.



Impact of Sediment on a Chum Salmon Spawning Channel

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INTRODUCTION

This study deals with the impact of sediment on the Dept. of Fisheries and Oceans' chum salmon spawning channel located on the Little Qualicum (LQ) river. It should be emphasized that this is an artificial stream with controlled surface water flow from the LQ river and a screened gravel streambed. Furthermore the channel has fence structures that allow the density of spawners to be controlled. The conclusions reached in this simplified stream may not be directly applicable to more complex natural streams.

LQ SPAWNING CHANNEL

The general layout of the channel is shown in Fig. 1. Diffuser structures separate the channel into five sections. Channel dimensions are shown below:

Width	25 ft	(7.62 m)
Length	13,683 ft	(4171 m)
Slope	1.5 ft per 1000 ft	
Flow	45 cfs	(1274 L/s)
Gravel depth	22 inches	(55.9 cm)
Settling basin	400 ft by 50 ft	(121.9 m by 15.2 m)
Gravel Size	0.5 inch to 6 inch	(1.27 cm to 15.24 cm)

The channel was designed for 50,000 spawners (1.25 sq meter per female). With an average fecundity of 2800 eggs per female and an egg to fry survival rate of between 60 % and 70 %, the channel should produce between 42 and 49 million fry per year. This fry output would be expected to give a return of between 300,000 and 400,000 adult chum salmon.

BACKGROUND TO STUDY

The LQ study began in 1985 when it became obvious that egg to fry survival rates were declining (Fig. 2). Sediment was suspected of being the problem because the channel had not been cleaned since startup in 1979. Gravel quality testing in July 1985 confirmed this suspicion -- permeabilities and subsurface DO values were low in certain areas of the channel. An attempt was made to clean the gravel in the summer of 1985. However this

effort was unsuccessful and the channel was still loaded with silt at the start of the 1985 spawning cycle. In January of 1986 heavy rainfall caused slides in the upper watershed which increased silt loads in the water supply for several months. In all likelihood the low survival rates for 1985 brood (Fig. 2) were due to a combination of these increased sediment loads and poor initial gravel quality.

The events of 1986 led to a recognition of how sensitive the spawning channel was to siltation. The LQ study was expanded to include the following objectives:

- 1) Develop techniques for monitoring gravel quality in spawning channels.
- 2) Use these techniques to critically monitor the yearly gravel cleaning operation.
- 3) Monitor NFR (Nonfiltrable Residue) of the inflow and outflow water so that removal of sediments by the settling basin and accumulation of sediment in the gravel could be quantified.
- 4) Identify the sources of sediment in the watershed and take corrective action where possible.

RESULTS AND DISCUSSION

Gravel quality techniques were based on work of Wickett (1954), Pollard (1955) and Terhune (1958). Relative permeability (mL/s) and dissolved oxygen concentration (mg/L) 20 to 25 cm (8 to 10 inches) beneath the gravel surface were measured. A non-consumptive oxygen probe (Leeds and Northrup) was used for measuring the subsurface oxygen concentration. Sediment was sampled by pumping subsurface water from the standpipe or by using the freeze probe technique.

These methods have been useful in monitoring the effectiveness of gravel cleaning operations. Figure 3 contrasts the depressed gravel permeabilities of June 1986 with those of September 1988. June/86 values were low due to the cumulative effects of siltation over the first 7 years of operation. Intensive cleaning efforts in 1986, 1987 and 1988 restored the gravel to the near optimum conditions measured in September 1988. Subsurface dissolved oxygen concentrations showed a similar improvement after gravel cleaning (Fig. 4).

The positive correlation between subsurface dissolved oxygen and permeability is shown in Fig. 5. These values represent section averages for both the Big and Little Qualicum channels.

Gravel quality information can also help explain the fluctuations in egg to fry survival rates. This information, along with female density was used to develop a multiple regression model for predicting egg survival rates. Survival to hatch (as measured by hydraulic sampling) has been plotted against gravel permeability and female density in Fig. 6 and Fig. 7. The model accounts for 68 % of the variation in the egg

survival data. This model indicates that at high female densities, high survival rates can be achieved if the gravel permeability is also very high (over 120 mL/s).

Sediment enters the channel via the water supply. The settling basin removes the sand but most of the silt, clay and very fine sand reaches the channel. This fine sediment is filtered by the spawning gravel and accumulates in the channel over the winter and spring. It should be noted that after spawning, the gravel surface is uneven due to redd construction. Since water downwells into the gravel at convex surfaces and upwells in concave areas (Vaux, 1968), the channel is a very effective sediment trap.

Suspended solids (NFR) concentrations down the length of the channel are plotted in Fig. 8. These curves represent typical NFR removals where the inflow concentrations vary between low (4 mg/L) and moderate (17 mg/L) levels. An extreme sediment event (not shown in Fig. 8) occurred on Nov 5, 1988 -- the NFR entering section 1 (after the settling basin) was 94 mg/L while the channel outflow was 5 mg/L. For the cases shown in Fig. 8, the settling basin removed between 30 % and 50 % of the suspended solids while the channel removed between 72 % and 82% of the sediment that escaped the settling basin.

NFR concentration (Fig. 9) and flow data have been used to calculate the weight of solids entering the channel per day between Nov 1, 1986 and April 30, 1987 (Fig. 10). The average inflow of solids over this 182 day period was 595 kg/d (average NFR = 5.2 mg/L) giving a total inflow of 108,000 kg. On this particular year, the sediment was very fine and the settling basin only removed 24 % of the solids while the remainder (82,000 kg) entered the channel. It was estimated that 78 % of these solids (64,000 kg) were removed by the spawning gravel. Most of the sediment was deposited in the first two sections of the channel.

Sediment entered the system at very high rates during periods of high NFR. For example, if the inflow concentration was 25 mg/L and the water flow was 45 cfs, the daily solids load would be 2752 kg/day. With an inflow concentration of 4 mg/L the load would only be 440 kg/day. However, high sediment events are rare and usually of short duration. In 1986/87 suspended solids concentrations over 15 mg/L accounted for only 30 % of the sediment load to the channel. Low concentrations of solids that entered the channel over a long duration contributed the majority of the sediment. It should be emphasized that for the accumulation of solids in a spawning channel, 25 days at 4 mg/L is as detrimental as 1 day at 100 mg/L.

CONCLUSIONS AND RECOMMENDATIONS

- 1) Accumulations of sediment in surface water fed spawning channels lowers both the permeability of the gravel and the dissolved oxygen concentration of the subsurface water.

2) At the high egg densities characteristic of spawning channel operations, reduced gravel quality results in marked reductions in egg to fry survival rates.

3) Suspended solids enter the channel via the water supply. Measures to reduce solids input should be pursued, these include: stabilizing the watershed (bank protection, erosion control etc.); optimizing settling basin performance and reducing channel flows during peak inflows of sediment.

4) Because of the filtering action of spawning gravel, even low concentrations of suspended solids, if chronic, can cause marked reductions in gravel quality. Chronic low concentrations of very fine sediment are common in this watershed. They are difficult to control at their source and are also very difficult to settle. One way to limit their deleterious effects is to prevent their long term accumulation by routinely cleaning the channel once per year.

REFERENCES

- Pollard, R. A. 1955. Measuring seepage through salmon spawning gravel. J. Fish. Res. Bd. Can. 12(5): 706-741.
- Terhune, L. D. B. 1958. The mark VI groundwater standpipe for measuring seepage through salmon spawning gravel. J. Fish. Res. Bd. Can. 15(5): 1027-1063.
- Vaux, W. G. 1968. Intragravel flow and interchange of water in a streambed. Fishery Bulletin: Vol.66 No.3: 479-489.
- Wickett, W. P. 1954. The oxygen supply to salmon eggs in spawning beds. J. Fish. Res. Bd. Can. 11(6): 933-953.

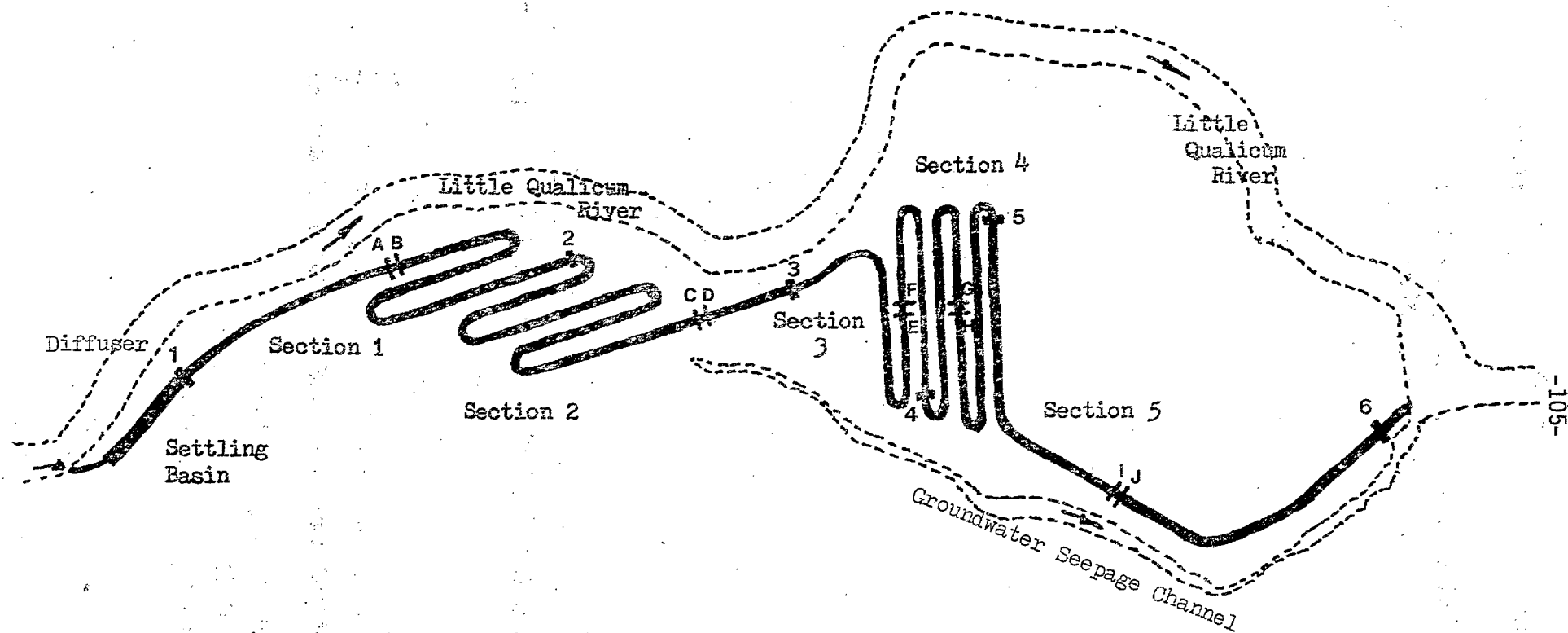


Fig. 1. Little Qualicum Spawning Channel

LQ Chum Spawning Channel Egg survival rates

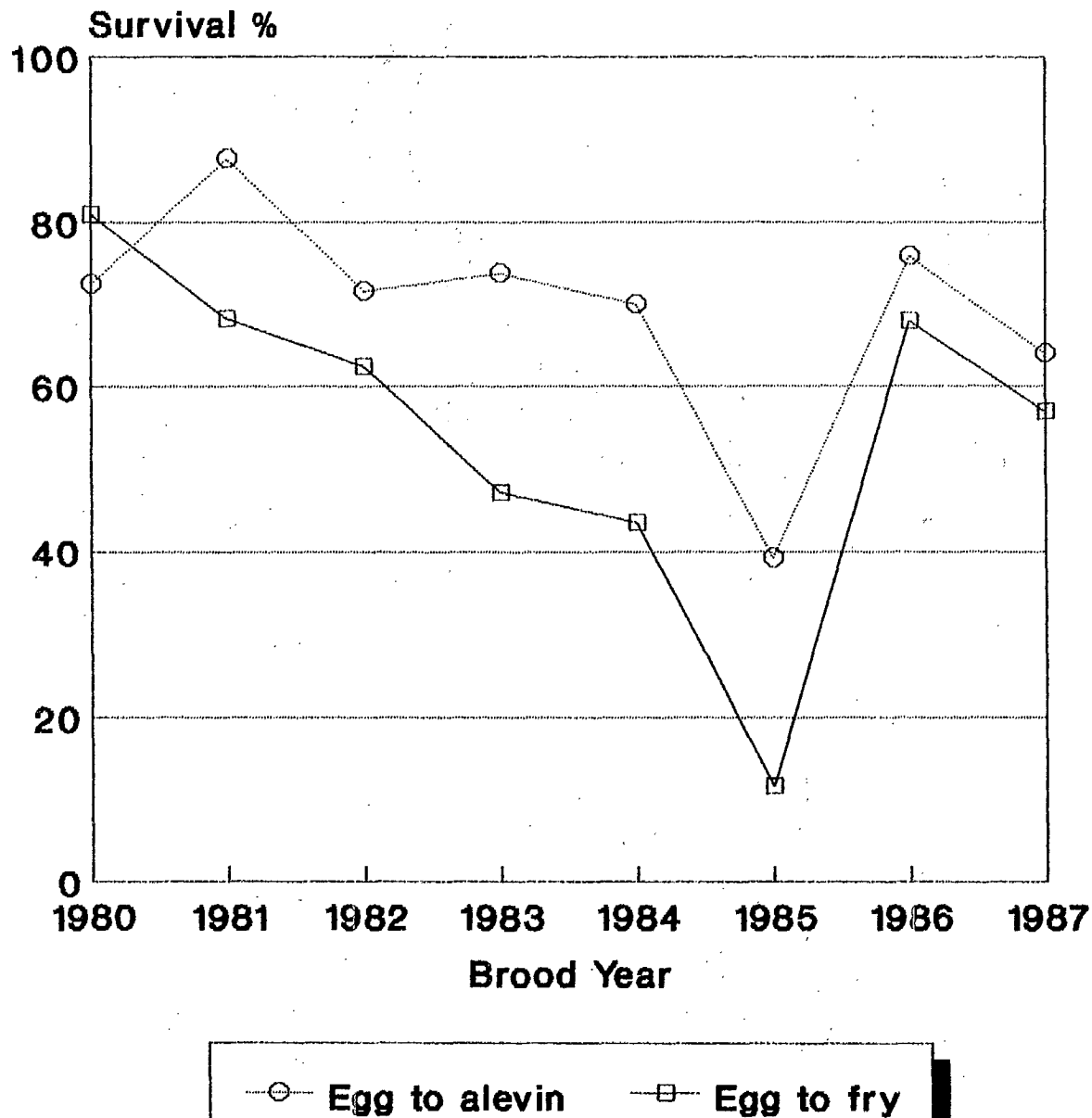


Fig. 2. Egg to alevin (by hydraulic sampling) and egg to fry survival rates (by fry enumeration) vs brood year.

Effects of Cleaning on
LQ Gravel Permeability

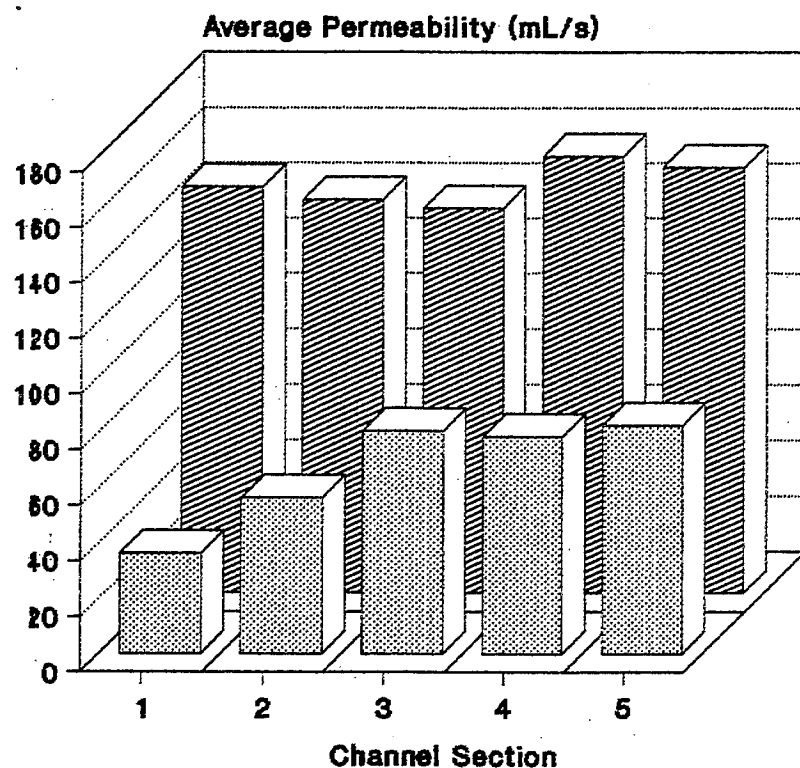


Fig. 3. Permeability of gravel loaded with silt (June 86) vs clean gravel (Sept 88).

Effects of Cleaning on
LQ Dissolved Oxygen (D.O.)

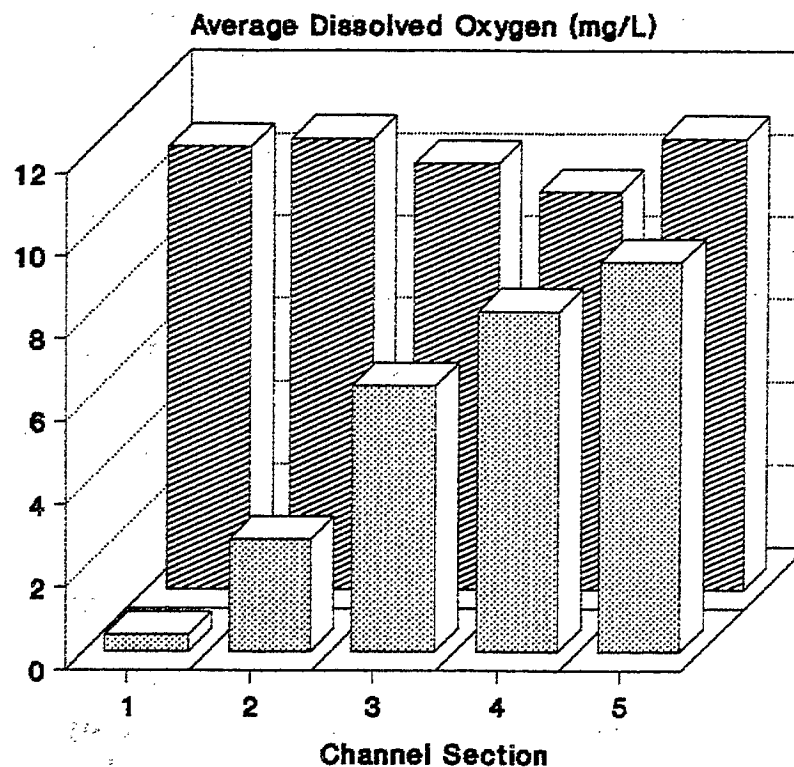
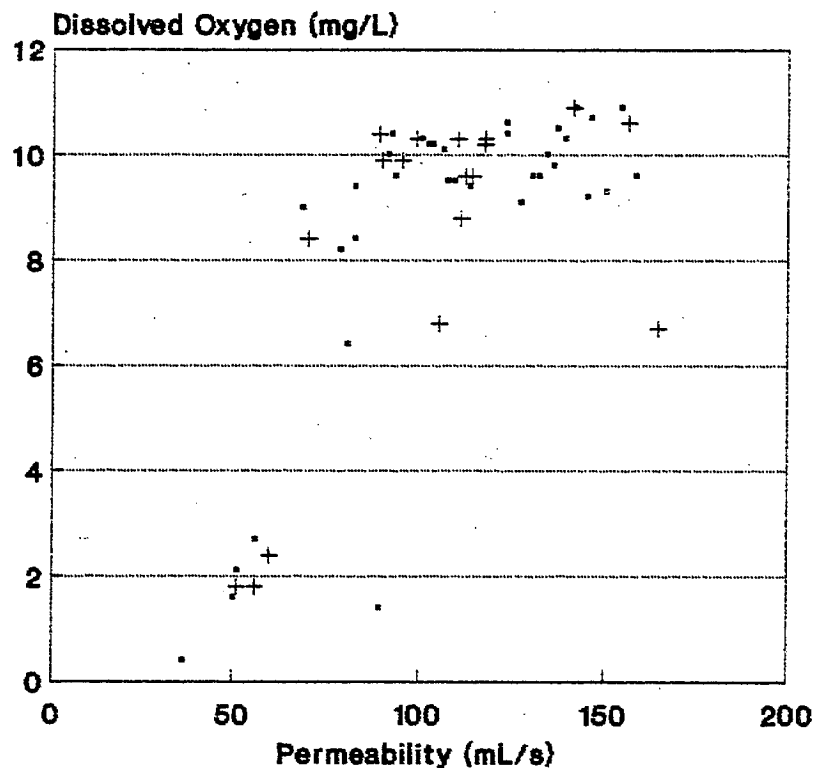


Fig. 4. D.O. of subsurface water when gravel contaminated with silt (June 86) vs clean gravel (Sept 88).

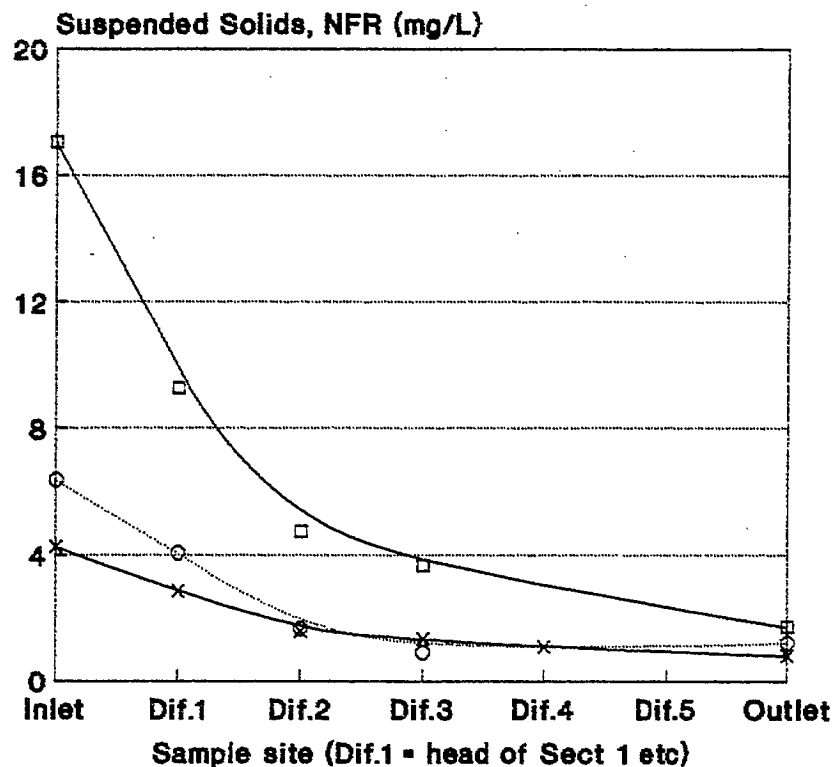
Dissolved Oxygen (D.O.) vs Permeability
Big and Little Qualicum Channels



• LQ D.O. + BQ D.O.

Fig. 5. Subsurface D.O. vs Permeability.
Values are averages for channel
sections.

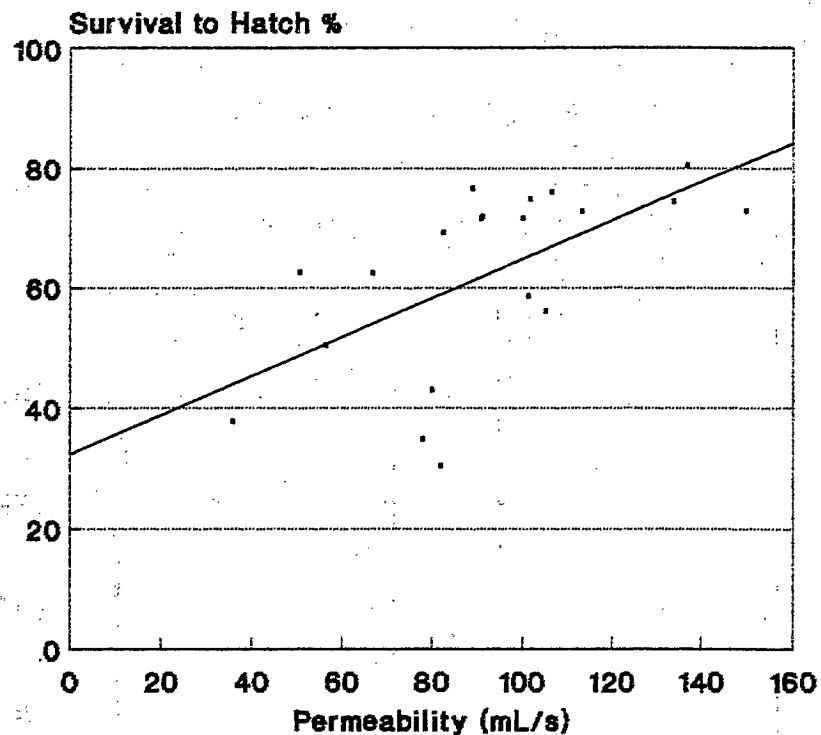
NFR Concentration
LQ Spawning Channel



—x— Feb11/87 —○— Feb3/87 —□— Jan12/87

Fig. 8. NFR concentration down length
of the LQ channel. "Inlet" denotes
inlet to the Settling Basin.

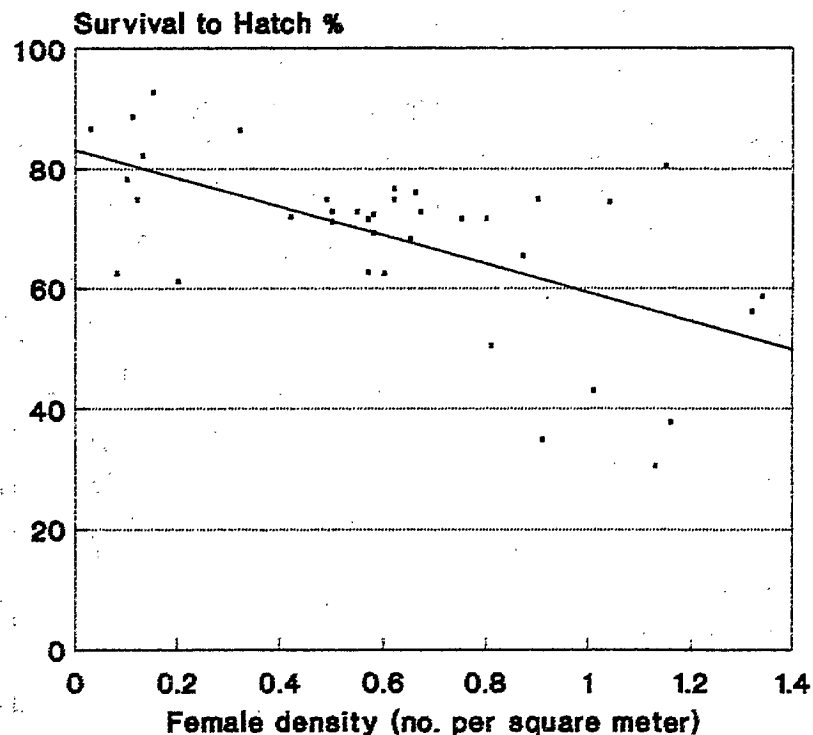
Surv. to Hatch vs Gravel Permeability
LQ Chum Spawning Channel
1984 - 1987 Brood.



— Surv. per Section %

Fig. 6. Survival to hatch (by hydraulic sampling) vs permeability. Values are averages for channel sections.

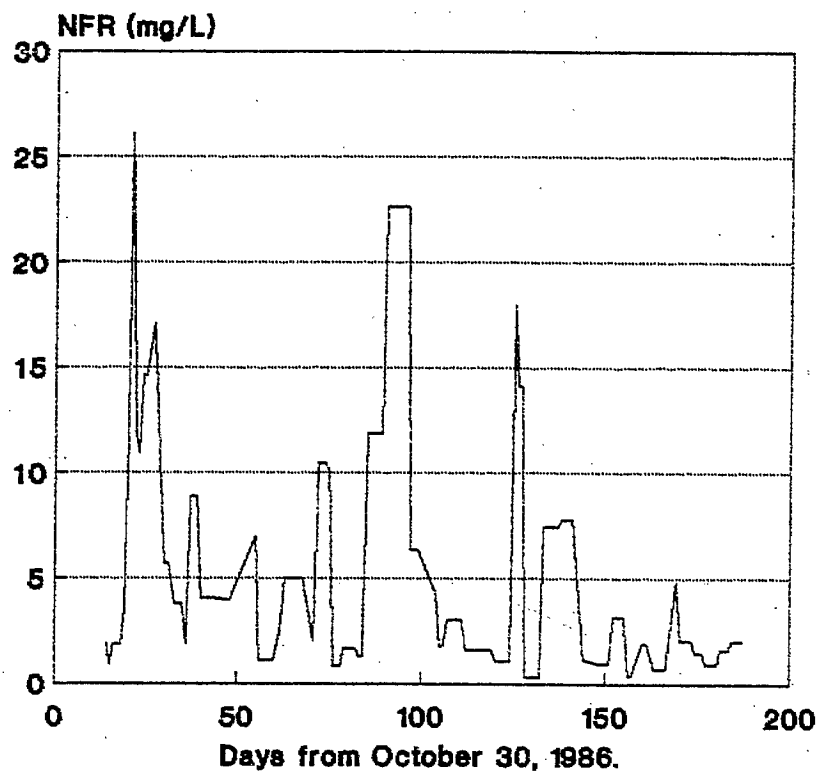
Survival to Hatch vs Female Density
LQ Chum Spawning Channel
1980 - 1987 Brood



— Surv. per section %

Fig. 7. Survival to hatch (by hydraulic sampling) vs female density. Values are averages for channel sections.

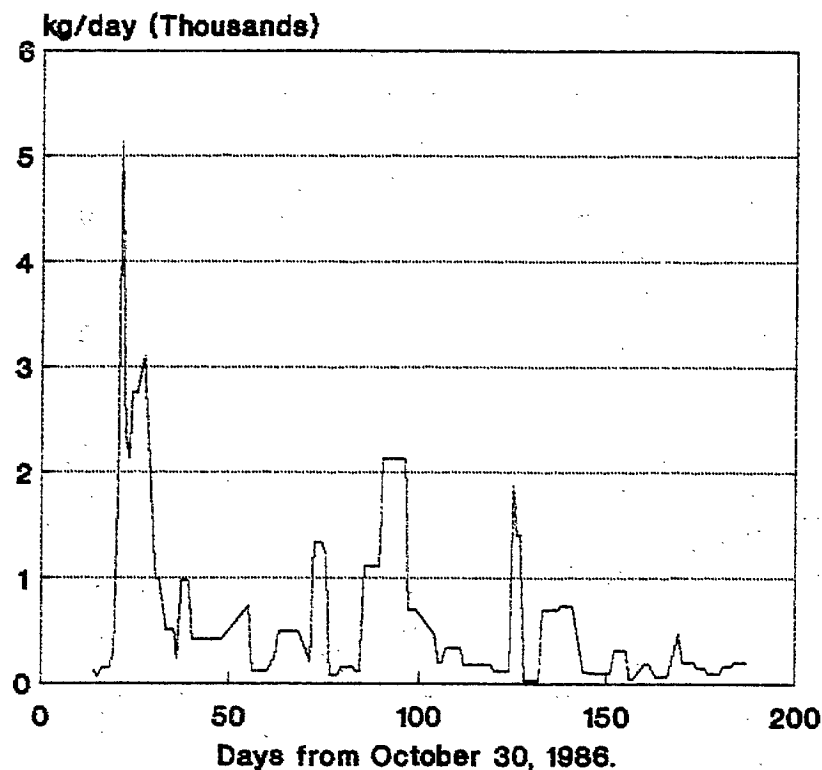
Suspended Solids (NFR) at LQ Channel
Intake, 1986/87



— NFR (mg/L)

Fig. 9. NFR concentration at inflow to
Little Qualicum Settling Basin from
October 30/86 to May 5/87 (day 187).

Suspended Solids in kg/day
Entering LQ Facility 1986/87.



— kg/day

Fig. 10. kg of dry solids per day
at inflow to Settling Basin -
October 30/86 to May 5/87 (day 187).

WATER QUALITY OBJECTIVES FOR WILLIAMS LAKE
AND
THE NONPOINT SOURCES ALONG THE SAN JOSE RIVER

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INTRODUCTION

Water quality objectives for Williams Lake were established late in 1987. Objectives for the San Jose River will be completed in the future. The work on Williams Lake was completed by Norm Zirnhelt of the Waste Management Branch in Williams Lake, B.C., Narendar Nagpal, a soil specialist with the Water Management Branch in Victoria, and myself.

The goals of the study were:

- 1) Set water quality objectives for Williams Lake to protect its most sensitive water uses (domestic water supply, cold water fisheries, and primary water contact recreation),
- 2) Set water quality objectives for the San Jose River (the major inflow to Williams Lake) to reduce the annual phosphorus load to Williams Lake.

The focus of this presentation is on the setting of water quality objectives in Williams Lake for parameters associated with eutrophication (nutrients, algal biomass (chlorophyll-a), water clarity (Secchi disc depth), and hypolimnetic oxygen depletion), and in the San Jose River for the parameters associated with nonpoint source pollution (nutrients, and suspended residues).

STUDY AREA

Williams Lake (Figure 1) is located in the Cariboo area of British Columbia's Fraser Plateau. The winters are cold causing the lake to freeze, while the summers are typically arid causing the soils and water to be very alkaline.

Williams Lake is a relatively large lake (720 ha) with a mean and maximum depth of 12 and 24 metres. The average flushing rate is 0.6 yr^{-1} . The spring overturn phosphorus concentration ranges between 70 to 80 $\mu\text{g/L}$ in a typical hydrologic year.

Williams Lake is used for domestic water supply, primary water contact recreation, industrial uses, and the lake supports a limited cold water fishery. The San Jose River is the only significant inflow to the lake. Nonpoint nutrient loading from ranches adjacent to the San Jose River and its tributaries are the major external source of phosphorus, and suspended inorganic residues to Williams Lake. There are no direct waste discharges into the lake.

WATER QUALITY OBJECTIVES FOR PARAMETERS RELATED TO EUTROPHICATION

In eutrophic, phosphorus limited lakes water quality objectives are required for phosphorus, water clarity, and hypolimnetic dissolved oxygen. Other parameters may require objectives (e.g. microbiological indicators, turbidity (inorganic residues), etc.) but they are not related to the eutrophication process per se.

The interdependence of phosphorus, chlorophyll, and Secchi disc depth in lakes (Dillon and Rigler, 1975; Nordin and McKean, 1984; Figure 2), allows the development of a single objective for the nutrient limiting algal biomass and productivity (usually phosphorus). If phosphorus concentrations in eutrophic lakes can be controlled, then the phytoplanktonic biomass (chlorophyll-a), and limnetic water clarity (Secchi disc depth) will also be controlled.

Two phosphorus criteria were considered for Williams Lake. The first was the criteria developed by Dillon and Rigler (1975; Table 1), which form the basis for the Provincial objectives for Ontario (Ontario, 1979). The second was developed by Nordin (1985; Table 2), which forms the basis for the water quality objectives for the Okanagan Basin, and other lakes with very important recreational, cold water fisheries, and domestic water uses (e.g. Lakelse Lake, McKean 1986).

TABLE 1: CRITERIA DEVELOPED BY DILLON AND RIGLER (1975).

	Chl-a	Phos.	Secchi	Use
Level 1	2 µg/L	9.9 µg/L	> 5m	domestic water supply, cold water fisheries
Level 2	5 µg/L	18.5 µg/L	2 - 5m	preservation of cold water fishery not imperative
Level 3	10 µg/L	29.9 µg/L	1 - 2m	water contact recreation of little importance. Emphasis placed on warm- water fisheries.
Level 4	25 µg/L	56.3 µg/L	< 1.5m	only suitable for warmwater fishery.

TABLE 2: PHOSPHORUS CRITERIA FOR LAKES DEVELOPED BY NORDIN (1985).

Use	Criteria
Drinking water	10 µg/L maximum
Recreation	10 µg/L maximum
Aquatic life	5 - 15 µg/L inclusive

McKean et al., (1987) recommended a combination of aeration and iron addition in Williams Lake to reduce the spring overturn phosphorus concentration from around 80 µg/L to approximately 20 µg/L. Should the restoration techniques be successful in reducing the spring overturn phosphorus concentrations the chlorophyll-a concentrations and limnetic Secchi disc depths will approach the values predicted in Table 1.

A spring overturn phosphorus objective of 20 µg/L was set for Williams Lake. Although an objective of 10 µg/L (as recommended by Nordin (1985)) would be more desirable for the protection of domestic water quality and water contact recreation, however, the lower objective was not considered attainable using present day lake restoration techniques.

A Secchi disc objective of 1.2m was set independent of the phosphorus-Secchi relationship developed by Nordin and McKean (1984), because cyanobacteria can form a surface scum and accumulate on beaches and recreational areas. A water clarity objective is required in eutrophic lakes to allow users to estimate water depth, to see subsurface hazards, and to detect submerged bodies or divers who may be in distress. The objective is based on the guidelines for Canadian recreational water quality (Health and Welfare, 1983), and may require public beaches to be closed to avoid liability in the event of an accident when the Secchi disc depth is less than 1.2m.

The last parameter affected by eutrophication is the hypolimnetic dissolved oxygen concentration. Rather than setting an objective on the hypolimnetic oxygen depletion rate (which requires a detailed sampling regime), a minimum dissolved oxygen concentration for any point in the hypolimnion at a set point above the sediment-water interface was used. The objective of 4 mg/L of dissolved oxygen was based on the work of Davis (1975), and set to minimize the stress on juvenile salmonids present in the lake. The objective was set at 5m above the sediment-water interface to account for the potentially high BOD associated with the sediments.

WATER QUALITY OBJECTIVES FOR NONPOINT SOURCES ALONG THE SAN JOSE RIVER

The San Jose River (Figure 1) is the major external source of phosphorus to Williams Lake. The overwintering of cattle and the production of hay in the summer are the main activities adjacent to the river and its tributaries. Because the overwintering of cattle adjacent to the river is considered a traditional farming practice, the

farmers are exempt from the Waste Management Act. Some clean up of the poor agricultural practices has been achieved through a committee of representatives from the Ministries of Environment and Agriculture, the B.C. Federation of Agriculture, and the local farmers (McKean et al., 1987).

There are two strategies when setting objectives for nonpoint source pollution:

- 1) Absolute Concentrations:
Average or maximum concentrations should be applied for the protection of domestic water quality or aquatic life. Objectives for bacteriological indicators, dissolved oxygen, metals, ammonia etc., would be applied to any point in the river as required.
- 2) Loading rates:
Primarily used for phosphorus and suspended residues, although any parameter can be expressed as a 'loading rate'.

There are two methods of expressing loading rates:
'change in concentration per km of river' or
'change in concentration per km² of watershed'.

The development of objectives for the nonpoint loading of phosphorus or suspended residues are required when excessive loading causes turbidity or eutrophication problems downstream (e.g. Williams Lake).

The major problem with setting objectives using loading rates is 'what is an acceptable loading rate'. There are many studies that relate loading rates of nutrients or suspended inorganic residues to the soil type, slope of land, and the type of crop or farming practice. The setting of objectives based on studies using soils from another water basin (e.g. Fraser Valley, Iowa, etc.,) would not be acceptable to the Ministry of Agriculture or the farmers in the San Jose River watershed.

To set objectives for nonpoint pollution we first conduct a field survey of the mainstem and its tributaries to locate the types of farming, the density of activity, and poor farming practices (if any). Secondly, the areas of high, low, and zero farming density are plotted on a soils map of the area (Figure 3). Water quality sampling upstream and downstream of the soil types with different farming densities will provide an estimate of the phosphorus or suspended residue loading rates from areas with high, low, and no farming density. From these loading rates the objectives for nonpoint pollution can be formulated:

'phosphorus or suspended residue loading rates ($\mu\text{g}/\text{km}$ or $\mu\text{g}/\text{km}^2$) from agricultural areas cannot exceed by more than 25 % (or what percent you feel appropriate) the phosphorus or suspended residue loading rates on similar soil types not influenced by nonpoint pollution'

We will have completed some nonpoint objectives by next meeting, and I can report on the success of the methodology.

- Davis, J.C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian Species: a review. J. Fish. Res. Board of Can. 32:2295-2331.
- Dillon, P.J., and F. H. Rigler. 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. J. Fish. Res. Board Can. 32:1519-1531.
- Health and Welfare. 1983. Guidelines for Canadian Recreation Water Quality. Department of National Health and Welfare, Ottawa, Canada.
- McKean, C.J.P. 1986. Lakelse Lake: Water quality assessment and objectives. Water Management Branch, Ministry of Environment, Province of British Columbia, Victoria, B.C.
- McKean, C.J.P., N.K. Nagpal, N.A. Zirnhelt. 1987. Williams Lake Water Quality Assessment and Objectives. Water Management Branch. Ministry of Environment.
- Nordin, R.N. 1985. Water quality criteria for nutrients and algae. Water Management Branch, Ministry of Environment, Province of British Columbia, Victoria, B.C.
- Nordin, R.N., and C.J.P. McKean. 1984. Shawnigan Lake Water Quality Study. Water Management Branch. Ministry of Environment, Victoria, B.C.

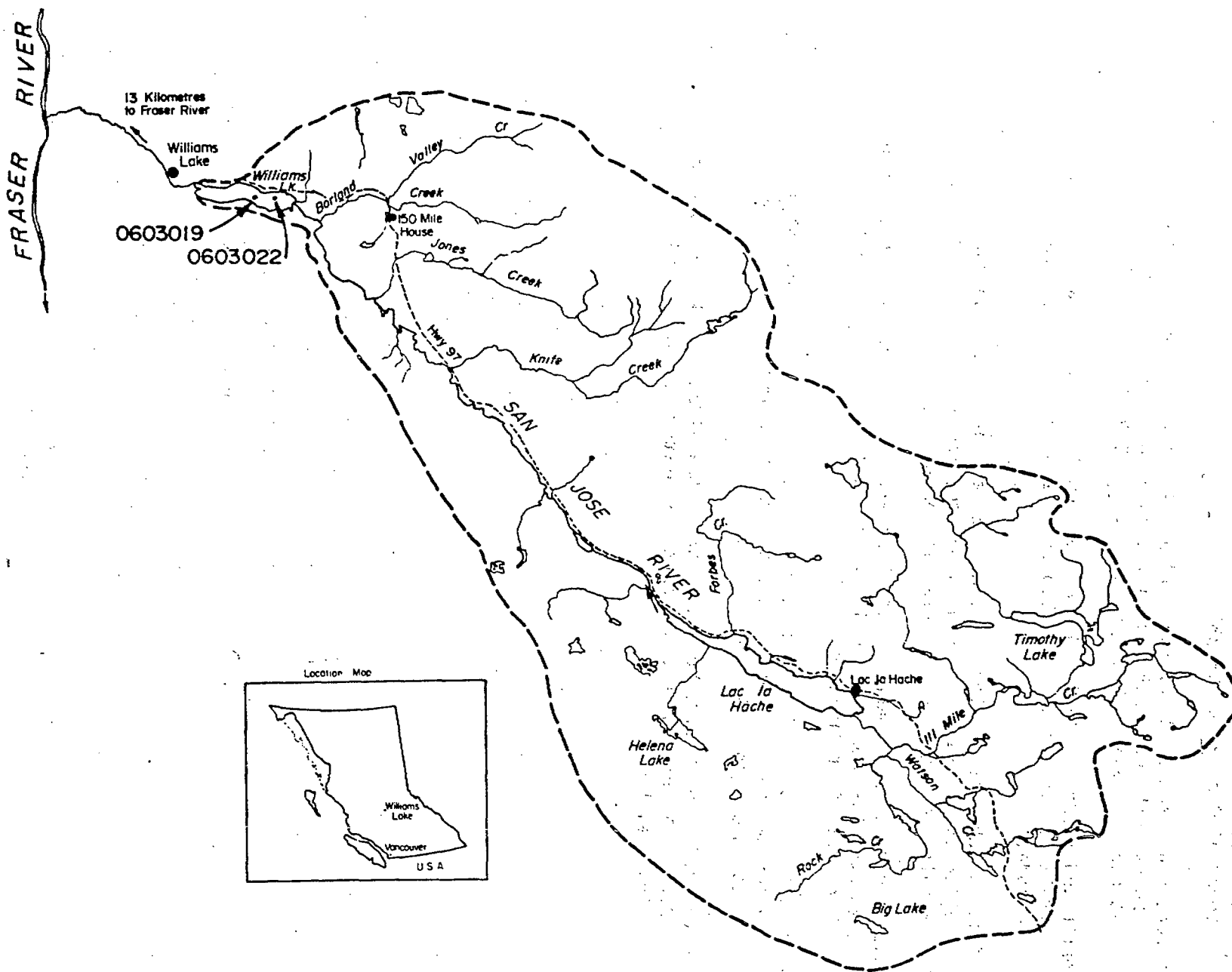


FIGURE 1 - Williams Lake Watershed, scale 1cm = 4 km

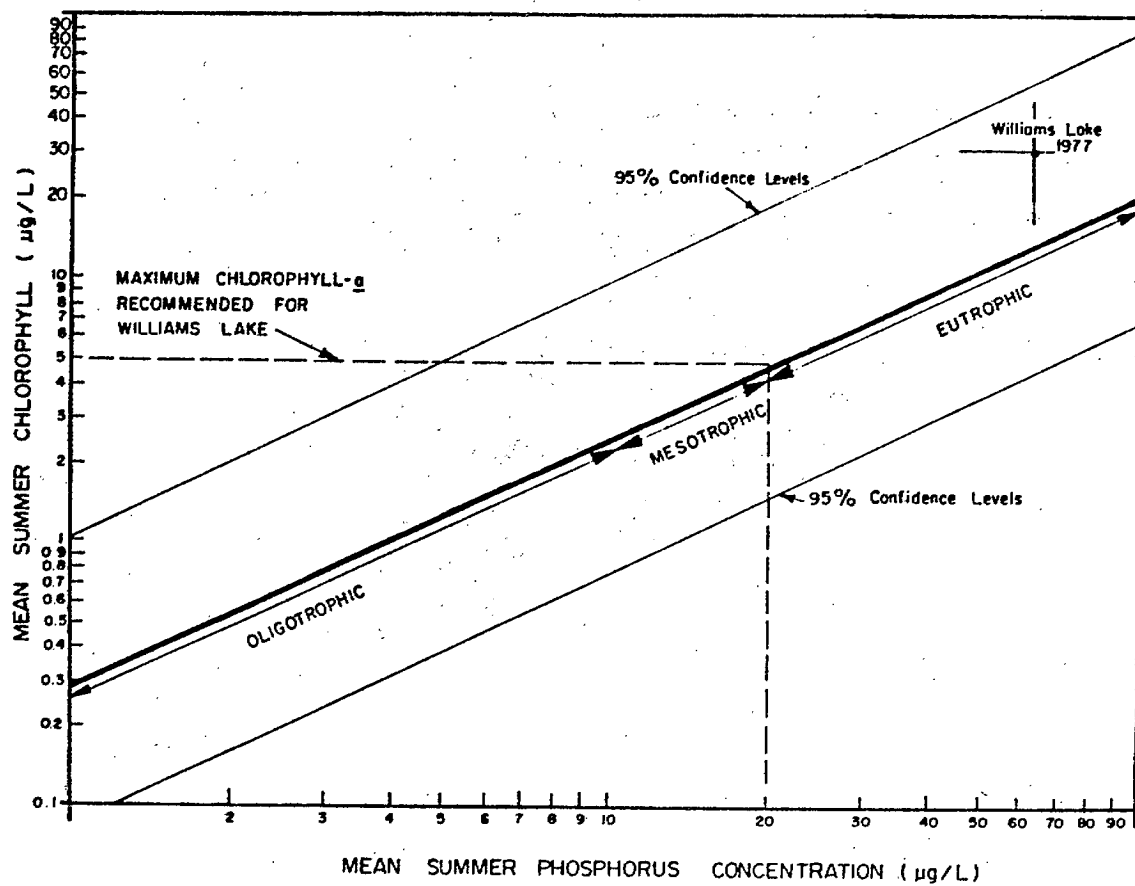


Figure 2. Mean summer chlorophyll-a concentration as a function of mean summer phosphorus concentration.

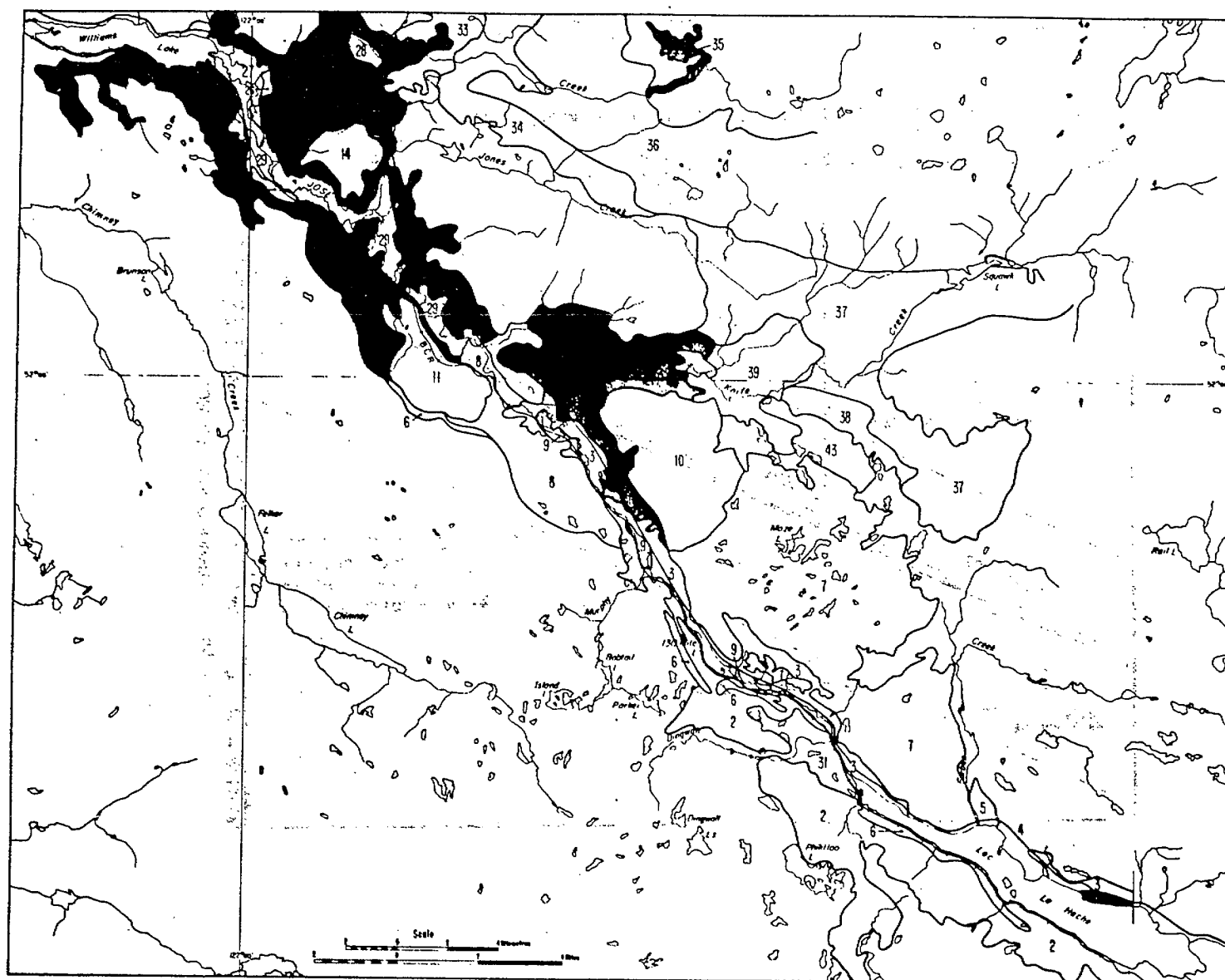


Figure 2. Erosion and runoff potential for the soil and landforms of the San Jose River Watershed. (shaded areas have normal to high runoff or erosion potential, see Table 16).

A Multi-Species Approach to Assessing
the Effects of Environmental Contamination

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Single-species toxicity tests have been used extensively by resource and environmental management agencies to assess the potential impacts of various resource development schemes. While these methods provide abundant information about single-species responses to environmental challenges, they contribute little to our understanding of multi-species or ecosystem responses to these challenges. The following describes a field experiment designed, by H. Mundie (DFO), K. Simpson (DFO), and C. Perrin (Limnotek), to provide information on the responses of algae and aquatic invertebrates to nutrient enrichment.

The purpose of this experiment was to determine the positive response (if any) of invertebrates to additions of nitrogen (N) and phosphorus (P) to nutrient-deficient stream water. Water was passed by gravity feed from a creek to a head tank from which it entered 12 troughs with gravel substrates. The troughs were colonized by invertebrates from the incoming water over a 3 week period. Six of the troughs then received continuous additions of N and P; six acted as controls. Each trough was covered by an insect emergence trap. Samples were taken weekly for water chemistry, settled algae, emergent insects, and exuviae leaving the troughs. After 8 weeks the benthos of each trough was collected. Results analyzed to date show significant positive responses, from an assemblage of 20 species of insects, to enrichment. The method should also be suitable for assessing negative responses of organisms to pollutants. It should be particularly useful for examining the effects of complex mixtures of pollutants of uncertain toxicity. A sufficient amount of the pollutant must, of course, be taken to a clean creek (or to a site located upstream of the effluent outfall) for the test to be carried out.

SESSION C

APPROACHES TO THE DEVELOPMENT OF
WATER QUALITY OBJECTIVES

CEPA and the implementation of Water Quality Objectives

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WATER QUALITY OBJECTIVES AND GUIDELINES

A water quality objective tells us how much or how little of a substance we, as a society will tolerate, in a particular water body with certain uses. Objectives can be set for physical properties (color, odor, turbidity), chemical concentrations (metals, pesticides) and biological properties (amount of bacteria present).

Objectives are used by a number of Provinces in the management of water quality (BC, Alberta, Saskatchewan, Manitoba, Ontario, and Quebec). They have also been negotiated for a number of Canada-US boundary waters and in the case of the Great Lakes are enshrined in a Canada-US agreement. The Prairie Provinces Water Board is in the process of developing interprovincial water quality objectives for eastward flowing streams.

The Canadian Council of Resource and Environment Ministers (CCREM) has published Canadian Water Quality Guidelines. The Guidelines describe the water quality needed for such water uses as; agriculture(livestock watering and irrigation), recreation,aquatic life.. The Guidelines provide some of the basic information needed in the negotiation or establishment of water quality objectives for specific rivers or lakes.. Other information such as water uses, existing water quality, and social and economic factors are also needed.

ENVIRONMENTAL QUALITY GUIDELINES, OBJECTIVES AND CEPA

The Canadian Environmental Protection Act (CEPA), promulgated June 1988, requires the Minister of the Environment to establish and publish environmental quality guidelines and objectives. These are defined in the Act:-

"Environmental quality objectives specifying goals or purposes toward which an environmental control effort is directed, including goals or purposes stated in quantitative or qualitative terms.

Environmental quality guidelines specifying recommendations in quantitative or qualitative terms to support and maintain particular uses of the environment".

Public consultation is required in the development of guidelines and the Minister is also required to publish them in the Canada Gazette. Water quality guidelines and objectives are a subset of environmental quality guidelines and objectives. The definitions in the Act now include all components of the environment, air, soil, wildlife, etc., including water. This paper will deal mainly with the aquatic component of the environment.

TOXIC SUBSTANCE ASSESSMENTS

The Act requires the Minister to compile a list of substances called the "Priority Substance List". The list will be published by the Minister and the substances on it will be assessed for toxicity. In the Act a substance "is toxic if it is entering or may enter the environment in a quantity or concentration or under conditions

- (a) having or that may have an immediate or long term harmful effect on the environment;
- (b) constituting or that may constitute a danger to the environment on which human life depends; or
- (c) constituting or that may constitute a danger in Canada to human life or health."

Substances on the List because of their suspicion for harming the environment, criteria (a), and particularly the aquatic system will need a water quality guideline to assess their toxicity. The DOE, with the CCREM, has already developed water quality guidelines for approximately 40 toxic substances. Based on a cursory review of the Hall panel list of 50 substances, water quality guidelines already exist for 15 of these while another 10 will probably not impact on the aquatic environment. This leaves another 25 substances for which water quality guidelines could be required to carry out an assessment.

ENVIRONMENTAL IMPACT OF CEPA REGULATIONS

After assessing the toxicity of a substance under CEPA the Minister is required to state what regulatory measures are recommended to deal with a toxic substance. These measures could include release guidelines, regulations, or codes of practice and are directed at industrial activities. However, the bottom line of the Act has to be; "has environmental quality improved as a result of the regulatory measures?" Answering this question needs a measurement of the environmental level of the toxic substance and a yardstick to compare the level to. Water quality guidelines are the environmental yardsticks for water.

STATE OF ENVIRONMENT REPORTING

CEPA allows the Minister to periodically report on the state of the Canadian environment and particularly its quality. Environmental quality guidelines define this quality and along with environmental measurements and interpretation allow state of environment reporting.

RECOMMENDATIONS

Water Quality Guidelines

DOE will continue to work with the CCREM on the development, review, and approval of guidelines for toxic substances

DOE will use the Priority Substance List in establishing priorities for

guideline development.

A mechanism will be developed for public consultation in the development of water quality guidelines.

A multi-media approach will be used in developing guidelines for the aquatic environment, which will mean considering components such as water, sediment, biota in both freshwater and the marine component.

Water Quality Objectives

DOE will continue to use existing mechanisms for the development of international and interprovincial water quality objectives.

DOE will ensure that substances on the Priority Substance List are considered in developing water quality objectives for interjurisdictional waters.

DOE will work with other Federal agencies in establishing environmental guidelines for use by departments, boards and agencies of the Government of Canada.

Significance of Initial Dilution Zones in the Development of Water Quality Objectives

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INTRODUCTION

In British Columbia, most water quality objectives apply at the edge of an initial dilution zone, which is a relatively small portion of a waterbody where the initial mixing between a waste discharge and the waterbody occurs. This concept of a zone of mixing where objectives do not apply is used world-wide (Canada, United States, Europe, Australia, etc.), under several different names - initial dilution zone, mixing zone, limited use zone, allocated impact zone, etc. - with various guidelines for location, size, shape, and conditions within the zone. The concept of an initial dilution zone is essential in the management of waste and water quality; if these zones did not exist waste quality would have to meet water quality objectives, which would be very costly and not technically achievable in many cases. A great deal of money would need to be spent for a very small improvement in the environment if these zones were eliminated.

HISTORY OF INITIAL DILUTION ZONES IN BRITISH COLUMBIA

Initial dilution zones (IDZ's) were formally adopted in British Columbia in 1971 as a result of the public inquiry to establish pollution control objectives for the forest products industry¹. An IDZ of 300 feet in all directions from a diffusion system was specified for marine waters and lakes, and 300 feet downstream for streams, but not exceeding one-half the width of the stream. The width requirement was to provide for a zone of safe passage for aquatic life by precluding the extension of a diffuser completely across a stream. Receiving water quality objectives were to be met at any point outside the IDZ, and the more restrictive of effluent and water quality objectives were to be met.

The IDZ concept was refined by subsequent pollution control objectives^{2,3,4,5,6,7} attaining their final form by the 1975 Municipal Objectives⁵. As shown in Figure 1, IDZ's extend:

- up to 300 feet (100 m after metrication) from a discharge, suggesting the possibility of smaller IDZ's
- to not more than 25 to 50% of the width of any waterbody (some of the pollution control objectives specify 25%, others 50%)

- from the bed to the surface.

The IDZ is not to intrude on shellfish beds, restricted routes of migrating salmon and trout, or other significant biological resource or recreational areas.

It should be noted that the IDZ used by the B.C. Ministry of Environment is an arbitrary, administrative zone which does not necessarily bear any resemblance to the actual physical mixing pattern in a waterbody. The initial dilution zone used in hydraulics defines the zone where mixing occurs due to the momentum and buoyancy of the effluent, as opposed to the secondary mixing due to the turbulence of the waterbody. The hydraulic and administrative IDZ's could be similar given a well-designed diffusion system. As illustrated in Figure 2, the administrative IDZ's could be the same in slowly and rapidly mixed situations if it is desired to maintain a zone of safe passage in a stream. A diffusion system is necessary to maximize the dilution and dispersion of effluent within the IDZ, but a diffuser may not be needed to achieve the objectives at the edge of the IDZ. In addition, the objectives may be met much closer to the point of discharge than is allowed by the IDZ.

PRESENT APPLICATION OF INITIAL DILUTION ZONES

The development of water quality objectives in the early 1980's led to some further refinement of IDZ's as outlined in the Principles for Preparing Water Quality Objectives in British Columbia⁸, including:

- provision for site-specific design, considering water uses, aquatic life, and other waste discharges
- absence of acutely toxic conditions, objectionable sludge deposits and floating materials, harmful bioconcentration, and nuisance conditions (e.g. fish tainting, excessive algal growth, etc.)

Absence of acutely toxic conditions in the IDZ does not necessarily mean that the effluent has to be non-acutely toxic. That is certainly one way of achieving no acute toxicity in the IDZ, but this result can also be achieved by having good diffusion so that the volume of water in the IDZ where acutely toxic concentrations of effluent occur is small, and thus the probability is low that the duration of exposure will be long enough to cause acute toxicity to aquatic life. An exception could be where organisms are attracted to an effluent, causing prolonged exposure and thus acute toxicity. The U.S. EPA⁹ reported that only 6 of 53 individual toxicants attracted one or more fish species, but the attraction/avoidance behaviour of mixtures of toxicants, such as occurs in waste discharges, was not studied. In any event, the toxicity of effluents that attract fish should be examined on a site-specific basis.

To avoid harmful bioconcentration, water quality objectives for contaminants in biological tissues are applied everywhere in waterbodies, including IDZ's. This is to avoid the situation of fish bioconcentrating contaminants by preferentially feeding in the IDZ's of waste discharges.

Calculations of the dilution available for waste discharges to determine the effect of a discharge on water quality normally consider the dilution available in the initial dilution zone, as well as the dilution after complete mixing. Thus, for a stream, about 25 to 50% of the minimum streamflow would be used to determine if the objectives can be met at the edge of the IDZ. Dilution is an acceptable way of meeting water quality objectives, provided that the effluent does not contain persistent toxicants that accumulate in sediment and/or biological tissues. For these toxicants, the emphasis should be on minimizing their discharge, considering their loadings and fate in the environment, and establishing and monitoring objectives for sediment and/or biological tissues. The decision on how much of the waterbody width (i.e. 25 or 50%) is in the IDZ is based on such factors as which pollution control objectives are involved (some say 25%, some say 50%), the relative widths of the waterbody and diffuser, the relative flows of the stream and waste discharge, and the size and shape of the initial dilution plume. The 25% width is selected where possible.

IDZ's are relatively small (i.e. ≤ 100 m), and thus for most areas of the province concerns about overlapping or back-to-back IDZ's or the IDZ's occupying a significant fraction of the waterbody are unwarranted. Probably the only area of the province where this may be a concern is in the North Arm of the Fraser River where there are numerous stormwater outfalls. However, even here, the IDZ's do not overlap at 100 m each, the actual zones in which objectives may not be met are much less than the 100 m theoretically allowed, and aquatic toxicity problems are not evident.

The site-specific design of IDZ's has not been a high priority in the development of water quality objectives. Most of the provisional objectives issued arbitrarily grant the 100 m, 25 to 50% of width IDZ. The information requirements to modify existing IDZ's on a site-specific basis are high, e.g. defining the physical mixing zone via modelling and/or monitoring (plume size, shape, variations, concentrations) plus detailed information on the aquatic populations and habitat (species, life stages, timing, exposure) of the site and their significance to the rest of the waterbody. Spending scarce resources to fine-tune the size and shape of the last 100 m is not a priority unless there is evidence of problems. Site-specific design of IDZ's is a higher priority in the case of new waste discharges where we have more information and the opportunity to influence the location, size, and shape of IDZ's during project design. A recent example is the objectives for the Quinsam River system where the IDZ's are being located, sized, and shaped to protect the aquatic populations.

CONCLUSION

In conclusion, we believe that the concept of initial dilution zones is essential and not negotiable. However, we are prepared to discuss the location, size, and shape of IDZ's on a site-specific basis for high priority waterbodies, where it can be shown that problems are occurring or may occur.

References

1. Department of Lands, Forests, and Water Resources. 1971. Pollution Control Objectives for the Forest Products Industry of British Columbia. Water Resources Service, Victoria, B.C.
2. Department of Lands, Forests, and Water Resources. 1973. Pollution Control Objectives for the Mining, Mine-milling, and Smelting Industries of British Columbia. Water Resources Service, Victoria, B.C.
3. Department of Lands, Forests, and Water Resources. 1974. Pollution Control Objectives for the Chemical and Petroleum Industries of British Columbia. Water Resources Service, Victoria, B.C.
4. Department of Lands, Forests, and Water Resources. 1975. Pollution Control Objectives for Food-processing, Agriculturally Orientated, and Other Miscellaneous Industries of British Columbia. Water Resources Service, Victoria, B.C.
5. Department of Lands, Forests, and Water Resources. 1975. Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia. Water Resources Service, Victoria, B.C.
6. Ministry of the Environment. 1977. Pollution Control Objectives for The Forest Products Industry of British Columbia. Pollution Control Board, Victoria, B.C.
7. Ministry of Environment. 1979. Pollution Control Objectives for the Mining, Smelting, and Related Industries of British Columbia. Pollution Control Board, Victoria, B.C.
8. Ministry of Environment and Parks. 1986. Principles For Preparing Water Quality Objectives in British Columbia. Water Management Branch, Resource Quality Section, Victoria, B.C.
9. U.S. Environmental Protection Agency. 1985. Technical Support Document for Water Quality-based Toxics Control. Office of Water, Washington, DC, 20460.

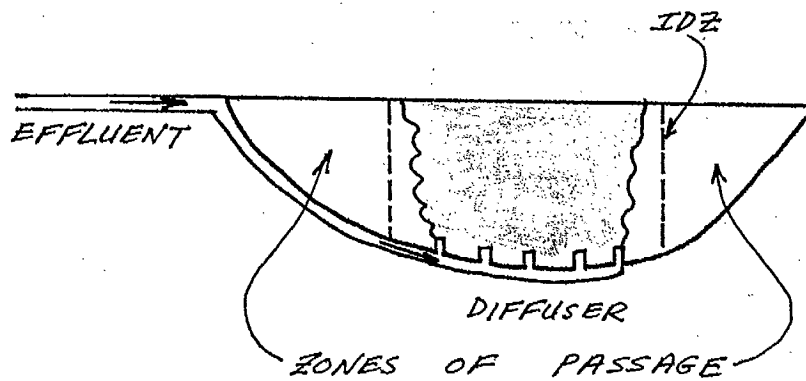
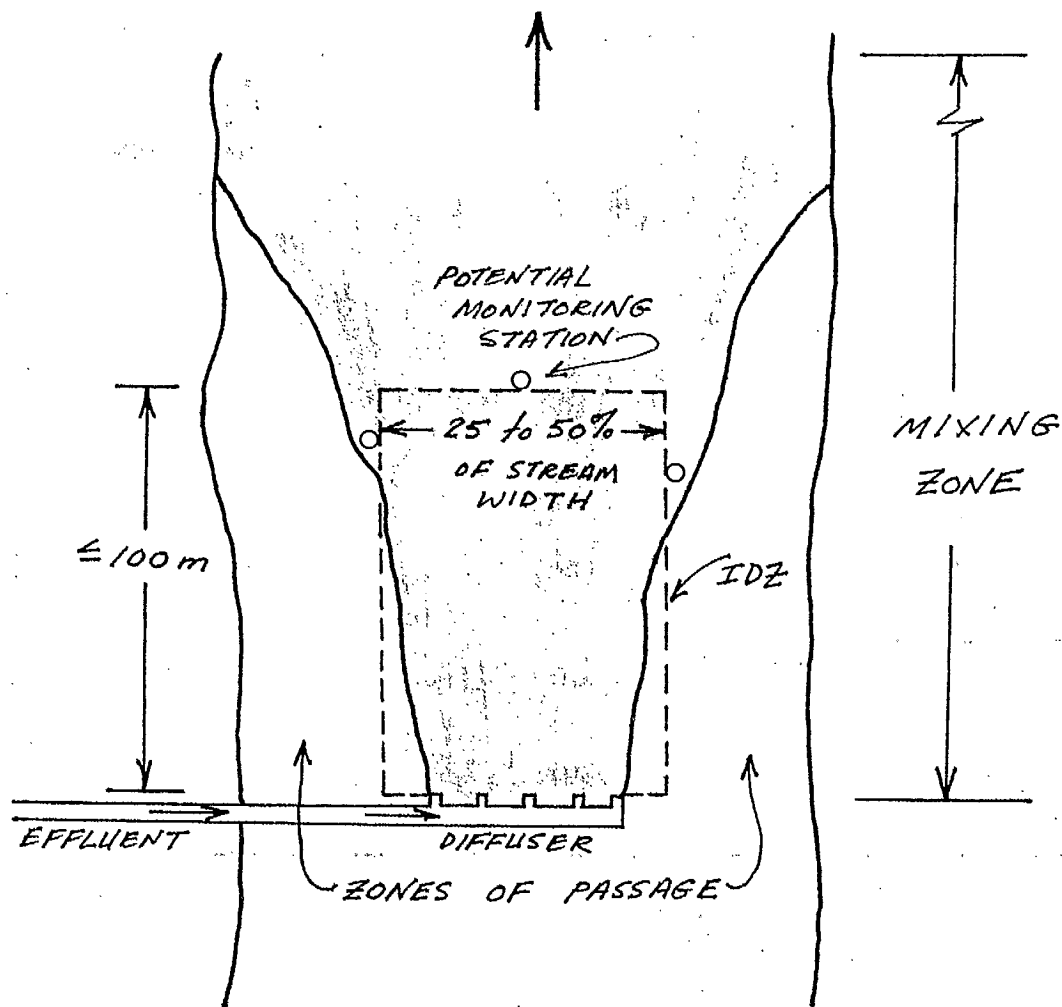


FIGURE 1. EXAMPLE OF AN INITIAL DILUTION ZONE IN A STREAM

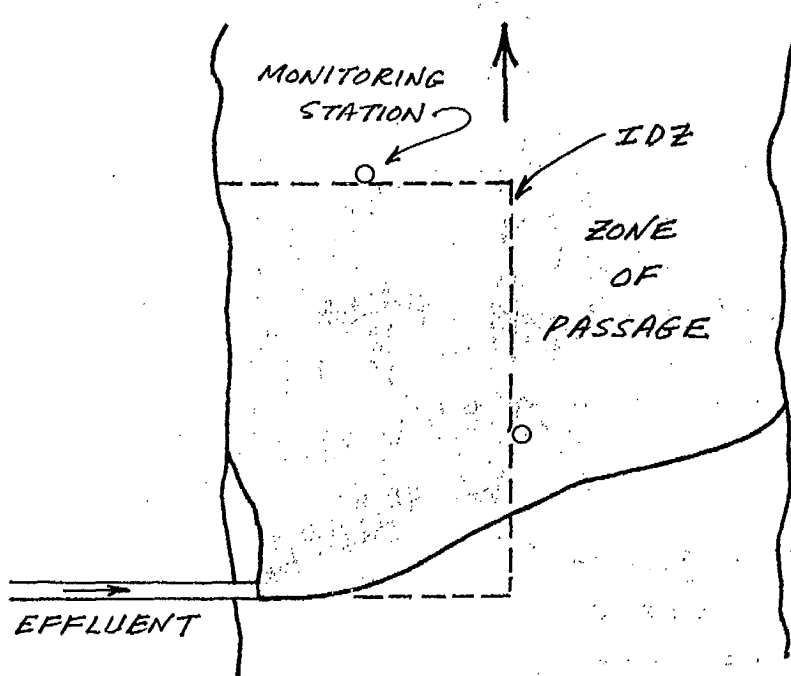
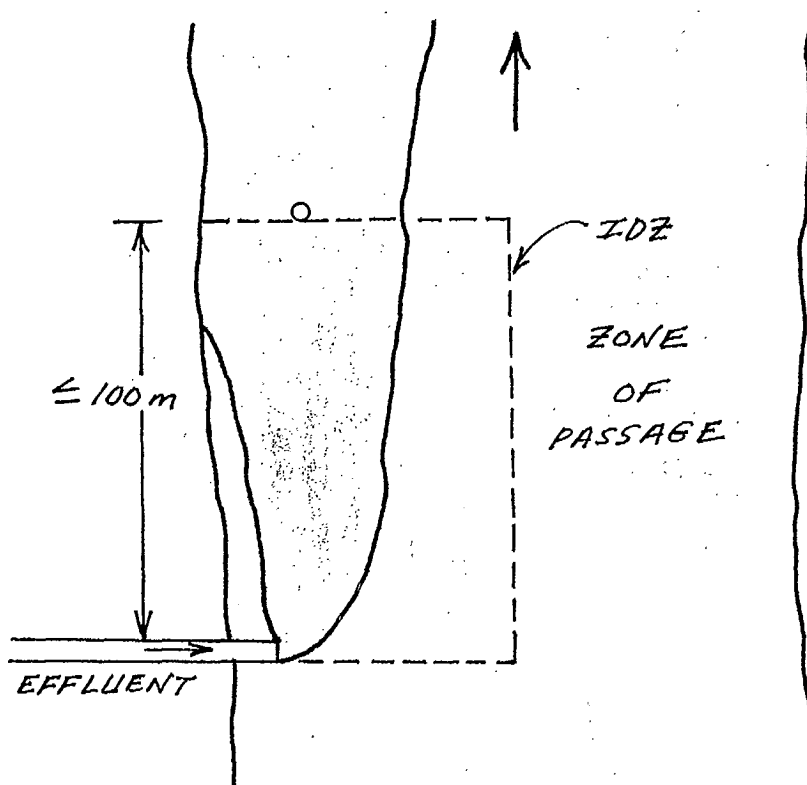


FIGURE 2. INITIAL DILUTION ZONES IN SLOW AND RAPID MIXING SITUATIONS.

Strategies for Monitoring to Assess Compliance with Water Quality Objectives

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INTRODUCTION

The goal of compliance monitoring is to determine whether or not objectives set for water quality are being met. The monitoring of objectives is complicated by two factors, the behaviour of the system for which the objective is set, and, the way in which the objective is written. Different methods of monitoring for compliance may be used. Each method may be effective in certain situations. Schilperoort and Groot (1983) express the effectiveness of such programs as the ratio of the number of detected violations to the number of actual violations. Methods which may be used for effective compliance monitoring include sequential sampling, Markovian sampling, fixed frequency sampling and exceedance driven sampling.

SEQUENTIAL SAMPLING

Sequential sampling is a method of statistical inference. One important feature of sequential sampling is that the number of observations to be made is not determined before the sampling commences. The number of observations is determined by the outcome of the observations as they are made (Wald, 1947). A rule is established for the testing of a hypothesis which has three (rather than 2) outcomes: (1) To accept the hypothesis, (2) to reject the hypothesis, or, (3) to continue the experiment by making an additional observation (Wald, 1945). It is possible to formulate a hypothesis which allows the incorporation of a band of uncertainty (Wald, 1947). To accommodate such a sampling strategy the objective needs to be written appropriately. Sampling of this type can be random or stratified, both of which can greatly reduce sampling cost. Wald (1947) gives a method by which the average number of samples needed can be determined.

In application, this method is similar to laboratory quality control charts. So long as the process being monitored is 'in control' no additional action by the sampler is required. The major short coming of this method is that it is solely directed towards acceptance or rejection of the hypothesis. To be able to

effectively use this approach in the real world a consequence must be applied to the rejection of the hypothesis that the objective is being met. The consequence would provide the mechanics of action following a violation. One example would be to act on the source of the problem, and then to resume sampling. A consequence or other resulting action from detecting a violation is essential for the effective application of this strategy. Sequential sampling is similar to batch testing. Consider all the samples that might be collected during a prescribed period to be a "batch". The goal of the sampling is to determine whether or not the "batch" is good or bad; the more uncertain we are the more samples it takes to make the decision. An example of the application of this method would be to take many sample from the subject area, randomize them, and then start testing. Once either of the two alternate hypothesis are accepted testing stops, otherwise more samples are analyzed.

MARKOVIAN SAMPLING

Another approach to determining compliance with standards or objectives is Markovian sampling. This procedure uses a variable sampling frequency, with infrequent sampling when the process is in compliance and more frequent sampling as the process tends to non-compliance. This procedure can be formulated as a simple Markov process (Arnold, 1970). The water quality at a particular station can be viewed as an ongoing process. This process can, for example, be scaled into two levels of acceptance (the unacceptable-acceptable pair). Arnold (1970) suggests a four level system of 'good', 'moderately good', 'poor', or 'unacceptable'. Depending upon the type of objective which was written, another system might be 'complying', 'marginal', 'warning' and 'alert'. If a process is in compliance, the probabilities for the observation being in any interval are either known or can be estimated. There are two important ways in which these acceptance levels may be implemented: i) the requirement may be for the observed value to be different from a specific level by more than a specified amount, for a specified time (ie. 'too low', 'acceptably low', 'good', 'perfect', 'good', 'acceptably high' and 'too high'), or, ii) the observed value to be not less than a certain level (ie. 'unacceptable', 'poor', 'acceptable but low', 'good') or more than a certain level (ie. 'good', 'acceptable but high', 'poor', 'unacceptable').

The sampling strategy is based on the existence of a specific time delay until the next sampling. The frequency of sampling would thus be less when the process is in compliance and much greater when not in compliance. Based on the probability of each of the levels being observed, and the definition of the time delays for each level, it is possible to estimate the expected sample size prior to the collection of any samples. Arnold (1970) and Smeach and Jernigan (1977) provide equations by which these sample sizes can be estimated.

This strategy has a great advantage in that one is able to determine the optimum number of samples prior to the sampling if a good estimate of the probability of occurrence of each of the levels is available. This is not possible for sequential sampling. One is also able to evaluate the effect of the choice of sampling delay and the width of each interval. In addition this procedure is easily stratified, allowing various critical periods to be individually evaluated and sampled. Either of these strategies provides a ongoing check on the attainment of objectives.

The primary disadvantage to this approach is the inability of laboratory systems to respond to incoming samples so that decisions regarding resampling can be made on an appropriate time scale. This limitation can also affect any sampling strategy that requires a decision to be made regarding when to sample next. Real time or on site analysis is needed to be able to determine compliance while access to the site is still available. An example of the problem would be that a sample is collected in a remote area, it is shipped to a laboratory, it is then analyzed, and the result forwarded to the appropriate authority. Depending upon the variable being considered this could take from one or two days up to several months. Given that the sample is in violation, how rapidly can a resampling of the system take place? For Markovian sampling to be practical, it must be possible to collect and analyze samples within an appropriate time period.

FIXED FREQUENCY SAMPLING

Fixed frequency sampling is a procedure of collecting samples at a predefined constant sampling interval. Such procedures are often implemented as monthly, or weekly sample collections. Valiela and Whitfield (1989) show that fixed frequency sampling is effective and efficient for determining such properties as the mean and variance. Fixed frequency sampling such as that used for trend assessment is shown to be suitable for testing for compliance with "chronic" or long term average objectives. Such sampling is less effective in determining compliance with "acute" objectives, particularly in systems which are autocorrelated or episodic.

EXCEEDANCE DRIVEN SAMPLING

Exceedance driven sampling is a procedure based on a fixed sampling interval with additional sampling taking place when a violation is observed. One example would be a monthly sample interval, with additional more frequent sampling to be started once a violation of the objective is observed. This intensive

sampling continues until violations cease. A stratified sampling method which is exceedance driven is more effective at detecting "acute" violations where the system under study is autocorrelated or highly episodic (Valiela and Whitfield, 1989). Such sampling is highly biased with respect to estimating the mean and variance, limiting the utility of the data for other purposes than compliance with objectives.

SUMMARY

Every strategy has some restrictions to its application. Of particular concern is the need for data collection to be specifically designed for compliance monitoring, with recognition of the limitations of the data for other applications. Compliance monitoring data produces a record which may not provide adequate coverage for other purposes, since some strategies result in tightly clustered blocks of data over time. Given a single water quality objective, strategies such as those described here can be applied quite simply. With multiple objectives, each may have its own sampling strategy. In reality, the implementation of many water quality objectives, each with its own sampling strategy, may not be practical.

The data gathered through these sampling procedures can be used as a basis for revising and refining the water quality objectives. The strategies described each produce unique data sets. The utility of these various types of data should be considered when deciding which strategy to undertake. It may be pragmatic to start with a strategy that provides data which can be used to refine and optimize the sampling design to be used in the future. In other words, forfeit some of the efficiency and effectiveness of a sampling optimized for determining non-compliance to be able to more effectively define probability distribution and other statistical properties.

In addition, it is difficult to be entirely certain of the underlying probability distribution of the variable of concern. Since this is generally estimated from small samples it is often only poorly known. This lack of knowledge seriously affects the estimation of the expected sample size. In most cases the expected sample sizes will be too low because the largest barrier in estimating the probability distribution continues to be estimating the probability of extreme values.

In selecting a strategy to perform compliance monitoring, consider the water quality objective, its purpose, and the nature of the system in which it is to be applied. Each of the strategies presented here is an opportunity to enhance the effectiveness and efficiency of compliance monitoring. However, they each have limitations and advantages which must be considered before selecting a compliance monitoring technique.

LITERATURE CITED

- Arnold, J.C. 1970. A Markovian sampling policy applied to water quality monitoring of streams. *Biometrics* 26:739-747.
- Schilperoort, J. and S. Groot. 1983. Design and optimization of water quality monitoring networks. Presented at International Symposium on Methods and Instrumentation for the Investigation of Ground Water Systems.
- Smeach, S.C. and R.W. Jernigan. 1977. Further aspects of a Markovian Sampling Policy for water quality monitoring. *Biometrics* 33:41-46.
- Valiela, D. and P.H. Whitfield. in press. Monitoring strategies to determine compliance with objectives. *Water Resources Bulletin*.
- Wald, A. 1945. Sequential Tests of Statistical Hypotheses. *Annals of Mathematical Statistics*. 16:117-186.
- Wald, A. 1947. Sequential Analysis. John Wiley. New York. 212 pp.

The Attainment of Water Quality Objectives in B.C. in 1987

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ABSTRACT

This presentation is based on a report, presently being printed, titled: "The Attainment of Water Quality Objectives in 1987". The report summarizes monitoring information collected in 1987 to check water quality objectives which had been set in 20 different water basins throughout the Province. The report was prepared in cooperation with regional and Victoria staff of the Waste Management Branch.

The objectives to protect various water uses were set in the 20 water basins studied to the end of 1987 because of actual or potential water quality problems. The results in this report indicate how well the quality of water in these areas is being safeguarded and thereby, indirectly, how well problems are being dealt with. The report does not describe the state of water quality in the Province as a whole where there are many bodies of water unaffected by man.

The report was written for the use of managers of the water resource and assumes some familiarity with the background information on which the objectives were based. The purpose is to guide managers wishing to take a more detailed look at instances where objectives were not met. This could reveal the need for possible corrective action or for more detailed study. Monitoring in future years will indicate whether the problems are persisting or the situation is improving.

Results of monitoring to check objectives are summarized in tables for each water basin. When considering all 20 water basins, there were about ten times more instances of objectives being met than of objectives being exceeded. Variables for which objectives were exceeded included turbidity, nutrients, chlorophyll-a, fecal coliforms, dissolved oxygen, temperature, cyanide, copper, lead, zinc, and chlorophenols. Objectives for these variables were, of course, not exceeded in all the water basins tested.

The monitoring in 1987, although extensive, was still incomplete. Sampling in future years should be carried out for all variables concerned in areas where objectives apply and at the minimum frequency required to calculate averages and percentiles. Also, laboratory methods for analysis of samples should be chosen so that the minimum detectable limits are less than the objectives levels.

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