Bibliography, including abstracts is part of NRDA docs. (RG-000) - Attached is draft w/out abstracts - needed as part of RPWG admin rec.?

```
 Oil Spill Public Info.        WLN LaserCat V5.04                MARC Display
                                                                      Page 1
       Leader                 REC TYPE=a  BIB LEV=m  ENC LEV=7  RULES=a
     Contrl # 001            |wln94263416
  Cat. source 040     |ac    |Ak|Ak
Local ctrl # 035      |a     |(WaOLN)9330415
  Geog. area 043      |a     |n-us-ak
       Title 245 00   |abc   |Ecological restoration of Prince William Sound
                             and the Gulf of Alaska :|bibliography of relevant
                             literature, including abstracts /|compiled for
                             the Restoration Planning Work Group ; edited by
                             William Warren-Hicks and Lynn E. Noel.
     Imprint 260      |c     |[1990]
Phys descrpt 300      |ac    |i, 217 leaves ;|28 cm.
General note 500      |a     |Exxon Valdez oil spill state/federal natural
                             resource damage assessment document.
General note 500      |a     |Study ID number: Restoration planning work group
                             study number 0.
General note 500      |a     |"December, 1990".
General note 500      |a     |ACE 30001687 - ACE 30001905 (running accession
                             numbers, 1st - last page).

TITLE   KEYWORD "ecological restoration prince william"              More...
F1-Help F2-Return                                 F5-Brief Recs   PgUp PgDn Home
F6-Full F7-Holdings F8-Download                   F10-Print       ESC-New Search
```

RPWG R

```
 Oil Spill Public Info.        WLN LaserCat V5.04                MARC Display
                                                                      Page 2
Subj:topical 650  0 |axzzx|Ecology|Research|Alaska|Prince William Sound|
                             Bibliography.
Subj:topical 650  0 |axzzx|Ecology|Research|Alaska|Alaska, Gulf of|
                             Bibliography.
Subj:topical 650  0 |axzzx|Restoration ecology|Research|Alaska|Prince
                             William Sound|Bibliography.
Subj:topical 650  0 |axzzx|Restoration ecology|Research|Alaska|Alaska, Gulf
                             of|Bibliography.
  Subj:geog. 651  0 |axx   |Prince William Sound (Alaska)|Research|
                             Bibliography.
  Subj:geog. 651  0 |axx   |Alaska, Gulf of (Alaska)|Research|Bibliography.
AE:pers name 700 2  |a     |Warren-Hicks, William.
AE:pers name 700 1  |a     |Noel, Lynn E.
AE:unif titl 730 0  |a     |Exxon Valdez oil spill state/federal natural
                             resource damage assessment.

TITLE   KEYWORD "ecological restoration prince william"              More...
F1-Help F2-Return                                 F5-Brief Recs   PgUp PgDn Home
F6-Full F7-Holdings F8-Download                   F10-Print       ESC-New Search
```

Klinge

ECOLOGICAL RESTORATION OF PRINCE WILLIAM SOUND AND THE GULF OF ALASKA:

Bibliography of Relevant Literature

Compiled for the Restoration Planning Work Group

Edited by

William Warren-Hicks
Kilkelly Environmental Associates
P.O. Box 31265
Raleigh, NC 27622

and

Lynn E. Noel
Western Aquatics, Inc.
P.O. Box 546
Laramie, WY 82070

December, 1990

ACKNOWLEDGEMENTS

The citations and abstracts contained within this literature review were compiled from online database searches, and are copyrighted by the following online databases.

AQUATIC SCIENCES AND FISHERIES ABSTRACTS
POLLUTION ABSTRACTS
Cambridge Scientific Abstracts
7200 Wisconsin Avenue
Bethesda, MD 20814

ENVIROLINE®
R.R. Bowker
245 West Seventeenth Street
New York, NY 10011

New Address Effective January 1991
R.R. Bowker
121 Chanlon Road
New Providence, NJ 07974

BIOSIS PREVIEWS®
Education and Training Group
2100 Arch Street
Philadelphia, PA 19103-1399

NTIS
U.S. Department of Commerce
5258 Port Royal Road
Springfield, VA 22161

ENVIRONMENTAL BIBLIOGRAPHY
Environmental Studies Institute
800 Garden Street, Suite D
Santa Barbara, CA 93101-1552

Addy, J.M.; Levell, D. (1975). *Sand and mud fauna and the effects of oil pollution and cleansing.* Presented at the Institute of Petroleum/Field Studies Council Meeting on Marine Ecology and Oil Pollution, Scotland, April 21-25, 1975, p. 91(100).

Adey, W.H. (1987). *Marine microcosms.* Restoration Ecology: A Synthetic Approach to Ecological Research Jordan, W.R., III; Gilpin, M.E.; Aber, J.D., editors. Pages 133-149. Report Number: ISBN 0-521-33110-2.

Akeda, S.; Uekita, Y. (1987). *Studies on reduction effect of velocity on the shape and arrangement of artificial reef.* Technical Report, Natl. Res. Inst. Fish. Eng., Hasaki, Kashima, Ibaragi 314-04, Japan. Suikoken Giho Suisandoboku, No. 8, pp. 101-109.

Anderson, B.W.; Ohmart, R.D. (1985). *Riparian revegetation as a mitigating process in stream and river restoration.* The Restoration of Rivers and Streams: Theories and Experience. Gore, J.A., editor. pp. 41-80. Butterworth Publishers, Stoneham, MA (USA).

Anderson, D.C. (1987). *Evaluation of habitat restoration on the Naval Petroleum Reserve No. 1, Kern County, California.* Sponsor: Department of Energy, Washington, DC. Report No.: EGG-10282-2179. 107 pp. Contract No.: AC08-83NV10282.

Anderson, E.P. (1985). *Use by juvenile chinook salmon of artificial habitat constructed from dredged material in the Campbell River Estuary.* Ocean Dumping R and D Pacific Region. Department of Fisheries and Oceans, 1983 - 1984 Sidney, B.C. (Canada), 7 Dec 1984. Can. Contract. Rep. Hydrogr. Ocean Sci., No. 20, pp. 4-15.

Anderson, R.C. (1983). *Economic perspectives on oil spill damage assessment.* Oil Petrochem. Pollut. 1(2):79-84.

Anonymous. (1971). *Second annual report of the Advisory Committee on Oil Pollution of the Sea.* Second Annual Report. University of Newcastle upon Tyne, Dept. of Zoology, Research Unit on the Rehabilitation of Oiled Seabirds, Advisory Committee on Oil Pollution of the Sea, England. 38 pages.

Anonymous. (1972). *Recommended treatment of oiled seabirds.* Report. University of Newcastle upon Tyne, Dept. of Zoology, Research Unit on the Rehabilitation of Oiled Seabirds, Advisory Committee on Oil Pollution of the Sea, England. 11 pages.

Anonymous. (1973). *Oil and penguins don't mix.* National Geographic Magazine. Washington, DC, 143(3):384-397, March 1973.

Anonymous. (1974). *Fifth annual report.* University of Newcastle upon Tyne, Department of Zoology, Advisory Committee on Oil Pollution of the Sea. Research Unit on the Rehabilitation of Oiled Seabirds. Annual Report, 28 pp.

Anonymous. (1976). *Draft environmental impact report for proposed gas pipeline from Sacramento Airport to Martinez, California.* Shell Oil Company Environmental Impact Report Aug 15, 1975; Feb 20, 1976, Volume 2, (421).

Anonymous. (1977). *Oil kills North Sea birds.* Mar. Pollut. Bull. 8(8):173.

Anonymous. (1978). *Oiled seabirds get in the swim.* New Scientist 78(1100):213.

Anonymous. (1979). *Alaska pipelines first oil spills.* New Scientist, 84(1176):96.

Anonymous. (1979). *Pollution control plan.* Ship Boat Int., 32(10):59.

Anonymous. (1986). *Artificial reefs.* Technology 8(6):1-16. Publisher(s): PCARRD, Los Banos (Philippines). Report Number: ISSN 0115-7787.

Anonymous. (1986). *Dredged material management: Beneficial use initiative.* Info. Exch. Bull. U.S. Army Corps of Engineers, Waterways Experimental Station, Volume D-86-3, p. 1.

Anonymous. (1986). *Oil recovery specialist battles against the black stuff.* Water Waste Treat. 29(2):36.

Anonymous. (1988). *Basic research for Japanese ocean farming.* World Fish. 37(7):46.

Anonymous. (1989). *Political, economic fallout spreads from Exxon Valdez crude oil spill.* Oil & Gas J, Apr 10, 1989 87(15):13(4).

Ardizzone, G.D.; Bombace, G. (1983). *Artificial reef experiments along a Tyrrhenian sea coast.* Seminar on Scientific Aspects of Artificial Reefs and Floating Mariculture in the Mediterranean, Cannes, December 7, 1982.

Armstrong, D.A.; Incze, L.S.; Armstrong, J.L.; Wencker, D.C.; Dumbauld, B.R. (1981). *Distribution and abundance of decapod crustacean larvae in the S.E. Bering Sea with emphasis on commercial species.* Environmental Assessment of the Alaskan Continental Shelf. Annual Reports of Principal Investigators for the Year Ending March 1981. Volume 2. Receptors - Benthos. Publisher(s): NOAA/OMPA, Boulder, CO (USA), pp. 365-596. Report Number: NOAA-OMPA-AR-81-2.

Armstrong, N.E. (1982). *Spill cleanup. Part 3, biological measures.* In: Hazardous Materials Spills Handbook. McGraw-Hill Book Co., NY.

Armstrong, N.E.; Gloyna, E.F.; Wyss, O. (1984). *Biological countermeasures for the control of hazardous material spills.* NTIS, Springfield, VA (USA). Report Number: NTIS PB84-140276.

Army Engineer District, Mobile, AL (USA). (1984). *Exploration and production of hydrocarbon resources in coastal Alabama and Mississippi.* Final Generic Environmental Impact Statement. 1006 pp. NTIS Number: AD-A154 316/4/GAR. Report Number: COESAM/PD-EE-84-009.

Ash, C.; Garrett, C.; Gray, S. (1989). *Prevention and cleanup of petroleum contamination of ground water Florida's Super Act.* Fla Sci 52(4):225-229.

Aska, D.Y., editor. (1981). *Artificial reefs: Proceedings of a Conference Held September 13-15, 1979, in Daytona Beach, Florida.* Conference on Artificial Reefs Daytona Beach, FL (USA) 13 Sep 1979. Rep. Fla. Sea Grant Program. Publisher(s): FSG, Gainesville, FL (USA), 235 pp. Report Number: FSG-R-41.

Atlas, R.M. (1978). *Potential interaction of microorganisms and pollutants from petroleum development.* In: Marine Biological Effects of OCS Petroleum Development. Wolfe, D.A., editor. Presented at the Formal Scientific Review of Biological Effects Studies, Seattle, WA (USA), Nov 29, 1977. Report Number: NOAA-TM-ERL-OCSEAP-1. pp. 156-166. Publisher(s): NOAA ERL, Boulder, CO (USA).

Atlas, R.M.; Horowitz, A.; Busdosh, M. (1978). *Prudhoe crude oil in arctic marine ice, water, and sediment ecosystems: Degradation and interactions with microbial and benthic communities.* Presented at the Symposium on Recovery Potential of Oiled Marine Norther Environments Halifax (Canada) 10 Oct 1977. J. Fish. Res. Board Can. 35(5):585-590.

Axiak, V.; George, J.J. (1987). *Behavioral responses of a marine bivalve (Venus verrucosa) to pollution by petroleum hydrocarbons.* Water Air Soil Pollut. 35(3-4):395-410.

Backman, T.W.H. (1985). *Selection of Zostera marina L. ecotypes for transplanting.* "Engineering and the Environment" San Diego, CA (USA) 12-14 Nov 1985. Oceans' 85 Proceedings: Ocean Engineering and the Environment 2:1088-1093.

Baden, S.; Hagerman, L. (1981). *Ventilatory responses of the shrimp Palaemon adspersus to sublethal concentrations of crude oil extract.* Mar. Biol. 63(2):129-133.

Baker, J.M. (1975?). *The Field Studies Council Oil Pollution Research Unit.* Presented at Inst of Petroleum/Field Studies Council Meeting on Marine Ecology and Oil Pollution, Scotland, Apr 21-23, 1975, p. 17(3).

Bakke, T. (1986?). *Experimental long term oil pollution in a boreal rocky shore environment.* Env Canada 9th Arctic Marine Oil Spill Technical Seminar, Edmonton, Jun 10-12, 1986, p. 167(12).

Ballou, T.G.; Dodge, R.E.; Hess, S.C.; Knap, A.H.; Sleeter, T.D. (1987). *Effects of a dispersed and undispersed crude oil on mangroves, seagrasses and corals.* Research Planning Institute Inc., Columbia, South Carolina and Bermuda Biological Station for Research, Bermuda. Publisher(s): American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005. Report Number: API 4460.

Banner, A. (1979). *Mitigation under the Corps regulatory program.* Presented at the Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats, Fort Collins, CO (USA), 16 Jul 1979. Gen. Tech. Rep. US Dept. Agriculture Fort Collins, CO (USA). p. 396-399.

Bartha, R.; Atlas, R.M. (1977). *The microbiology of aquatic oil spills.* Adv. Appl. Microbiol., No. 22, 225-266.

Battelle Northwest Laboratories (1967). *Oil spillage study - literature search and critical evaluation for selection of promising techniques to control and prevent damage: BNPG-319.* Sponsor: Coast Guard, Washington, DC. NTIS Report Number: AD-786 403/6.

Beck, R.; Shore, R.; Scriven, T.A.; Lindquist, M. (1981). *Potential environmental problems of enhanced oil and gas recovery techniques.* NTIS, Springfield, VA. Report Number: PB81-240186.

Begley, S.; Drew, L.; Hager, M. (1989). *Smothering the waters.* Newsweek, Apr 10, p. 54(4).

Beillois, P.; Desaunay, Y.; Dorel, D.; Lemoine, M. (1979). *Pollution effects after the Amoco Cadiz grounding: Conditions of fishery resources in the Bays of Morlaix and Lannion.* Report Institut Scientifique et Technique des Peches Maritimes, Nantes, France, January, 1979.

Bell, J.D.; Steffe, A.S.; Westoby, M. (1985). *Artificial seagrass: How useful is it for field experiments on fish and macroinvertebrates?* J. Exp. Mar. Biol. Ecol. 90(2):171-177.

Bell, J.D.; Steffe, A.S.; Westoby, M. (1988). *Location of seagrass beds in estuaries: Effects on associated fish and decapods.* J. Exp. Mar. Biol. Ecol. 122(2):127-146.

Bell, J.D.; Westoby, M. (1986). *Importance of local changes in leaf height and density to fish and decapods associated with seagrasses.* J. Exp. Mar. Biol. Ecol. 104(1-3):249-274.

Bell, J.D.; Westoby, M. (1986). *Variation in seagrass height and density over a wide spatial scale: Effects on common fish and decapods.* J. Exp. Mar. Biol. Ecol. 104(1-3):275-295.

Bell, J.D.; Westoby, M. (1987). *Effects of an epiphytic alga on abundances of fish and decapods associated with the seagrass Zostera capricorni.* Aust. J. Ecol. 12 (4):333-338.

Bell, J.M. (1981?). *Industrial waste.* Purdue Univ. et al. Industrial Waste 36th Conf Proceedings, Lafayette, IN, May 12-14, 1981, (1008).

Bell, P.R.; Greenfield, P.F.; Nicklin, D.J. (1983?). *Chemical and physical characterization of effluent streams from the processing of Australian oil shale.* Colorado School of Mines Oil Shale 16th Sym, Golden, CO, Apr 13-15, 1983, p. 477(10).

Belsky, J. (1982). *Diesel oil spill in a subalpine meadow: 9 years of recovery.* Canadian J Botany, 60(6):906.

Bender, M.E.; Hudgins, J.G.; Jordan, R.A., editors. (1981). *Fate and effects of experimental oil spills in an eastern coastal plain marsh system.* Publisher(s): American Petroleum Institute, 1220 L Street, NW, Washington, DC. Report Number: API 4342.

Bender, M.E.; Shearls, E.A.; Ayres, R.P.; Hershner, C.H.; Huggett, R.J. (1977). *Ecological effects of experimental oil spills on eastern coastal plain estuarine ecosystems.* Presented at the Oil Spill Conference, New Orleans, LA (USA), 8 Mar 1977. Publisher(s): American Petroleum Inst., Washington, DC (USA), p.505-509. Report Number: API 4284.

Bender, M.E.; Shearls, E.A.; Murray, L.; Huggett, R.J. (1980). *Ecological effects of experimental oil spills in eastern coastal plain estuaries.* Environ. Int. 3(2):121-133.

Bendock, T.N. (1979). *Beaufort Sea estuarine fishery study.* In: Environmental assessment of the Alaskan continental shelf. Final reports of principal investigators. Volume 4. Biological studies. Publisher(s): NOAA Environmental Research Laboratories, Boulder, CO (USA), Outer Continental Shelf Environmental Assessment Program. Contract No. 03-5-022-69.

Berge, J.A.; Johannessen, K.I.; Reiersen, L.-O. (1983). *Effects of the water soluble fraction of North Sea crude oil on the swimming activity of the sand goby, Pomatoschistus minutus (Pallas).* J. Exp. Mar. Biol. Ecol. 68(2):159-167.

Bergman, H.L.; DeGraeve, G.M.; Anderson, A.D.; Farrier, D.S. (1980). *Effects of complex effluents from in situ fossil fuel processing on aquatic biota.* First Annl. Oak Ridge Nat. Lab. Life Sci. Symp., Oak Ridge, TN, Sep. 25-28, 1978. In: Synthetic Fossil Fuel Tech. -- Potential Health & Environ. Effects, pp. 204-211. Ann Arbor Sci. Publ., Inc., 230 Collingwood, P.O. Box 1425, Ann Arbor, MI 48106.

Berkner, A.B. (1979). *Wildlife rehabilitation techniques: Past, present, and future.* Presented at the US Fish & Wildlife Service Pollution Response Conf, St. Petersburg, May 8-10, 1979, p. 127(7).

Berkner, A.B.; Smith, D.C.; Williams, A.S. (1977). *Cleaning agents for oiled wildlife.* Presented at the Oil Spill Conference, New Orleans, LA (USA), 8 Mar 1977. Publisher(s): American Petroleum Inst., Washington, DC (USA), p.411-415. Report Number: API 4284.

Berliner, N. (1989). *The year of the spills.* Environ. Action 21(2):12(4).

Beynon, L.R.; Goedjen, H.; Lilie, R.H. (1983). *Field guide to inland oil spill clean-up techniques.* CONCAWE'S Oil Spill Clean-up Technol., Spec. Task Force No. 3. Report Number: 10/83.

Bodennec, G.; Glemarec, G.; Grizel, M.; Kaas, H.; Legrand, R.; Le Moal, V.; Michel, P.; Miossec, P.; et al. (1983). *Oil pollution impact on marine fauna and flora.* Impact des hydrocarbures sur la flore et la faune marines. Rapport collectif. (Oil pollution impact on marine flora and fauna. A collective report.). Michel, P., editor. 1983. pp. 105-182. Contract CEE/ISTPM: BG/82/614 (629).

not found

Bodin, P. (1988). *Results of ecological monitoring of three beaches polluted by the Amoco Cadiz oil spill: Development of meiofauna from 1978 to 1984.* Mar. Ecol. Prog. Ser. 42(2):105-123.

Bodin, P.; Boucher, D. (1982). *Mid-term evolution of meiobenthos and microphytobenthos on beaches touched by the Amoco Cadiz oil spill.* NOAA/CNEXO Joint Scientific Commission Workshops: Physical, Chemical, and Microbiological Studies after the Amoco Cadiz Oil Spill; Biological Studies after the Amoco Cadiz Oil Spill, Charleston, SC (USA), 17 Sep, 1981, and Brest (France), 28 Oct, 1981. Ecological Study of the Amoco Cadiz Oil Spill: Report of the NOAA-CNEXO Joint Scientific Commission. Gundlach, E.R.; Marchand, M., editors. Pages 245-268.

Bodin, P.; Boucher, D. (1983). *Medium-term evolution of meiobenthos and chlorophyll pigments on some beaches polluted by the Amoco Cadiz oil spill.* Oceanol. Acta 6(3):321-332.

Bohme, V.E.; Brushett, E.R. (1977?). *Oil spill control in Alberta.* 1977 Oil Spill Conference, New Orleans, LA, Mar. 8-10, 1977. American Petroleum Institute. Report Number: API 4284, pp. 91-94.

Bokn, T. (1987). *Effects of diesel oil and subsequent recovery of commercial benthic algae.* Hydrobiologia No. 151-152:277(8).

Bombace, G. (1977?) . *Theoretical and experimental aspects relating to artificial reefs.* Atti del 9o Congresso della Societa Italiana di Biologia Marina, Lacco Ameno d'Ischia, 19-22 Maggio 1977. (Proceedings of the 9th Congress of the Italian Society of Marine Biology, Lacco Ameno d'Ischia, Italy, 19-22 May 1977). Cinelli, F.; Fresi, E.; Mazzella, L., editors. Pages 29-41.

Bombace, G. (1979). *Experiments on artificial reefs in the central Adriatic (SE Conero, Ancona).* 1st Convegno Scientifico Nazionale del Progetto Finalizzato "Oceanografia e Fondi Marini" Rome (Italy) March 5, 1979. Atti del Convegno Scientifico Nazionale (Roma 5-6-7 Marzo 1979). [Proceedings of the National Scientific Meeting (Rome 5-6-7 March)], Volume 1, pp. 185-198.

Bombace, G.; Rossi, V. (1986) *Socio-ecological effect following the construction of a marine area protected by artificial reefs in the Porto Recanati zone.* FAO Fish. Rep. No. 357. Report of the Technical Consultation of the General Fisheries Council for the Mediterranean on Open Sea Shellfish Culture in Association with Artificial Reefs, Ancona, Italy, 17-19 March 1986. pp. 157-164. Report Number: ISBN 92-5-0024550-X.

Bondev, I.A.; Simeonov, S.Y. (1979). *Effect of contamination on the dynamics of the higher swamp vegetation in the Poda locality near Bourgas, Bulgaria.* Ekologiya (Sofia) 0(5):3-10.

Bonsdorff, E. (1981). *The Antonio Gramisci oil spill impact on the littoral and benthic ecosystems.* Mar. Pollut. Bull. 12(9):301-305.

Borum, J. (1985). *Development of epiphytic communities on eelgrass (Zostera marina) along a nutrient gradient in a Danish estuary.* Mar. Biol. 87(2):211-218.

Botero, A.J.; Garzon, F.J.; Gutierrez, M.G. (1981). *Establishment and development of a fish community in an artificial reef made from scrap tires.* Bol. Mus. Mar. Bogota, No. 10, pp. 63-81.

Boucher, G.; Cabioch, L.; Chamroux, S.; Dauvin, J.C. (1983). *Ecological survey of the coasts of Britanny: Study of macrobenthos, meiofauna, and bacteria in the Bay of Morlaix.* Publisher(s): Station Biologique, Roscoff, France, 57 pp. Contracts CNEXO 81-6597 and 82-2606.

Boucher, G.; Chamroux, S.; Riaux, C. (1984). *Modifications of physiological and biological characteristics of a sublittoral sand polluted by hydrocarbons.* Mar. Environ. Res. 12(1):1-23.

Brand, D. (1973). *Dry cleaning's helpful if ocean slick leaves oily bird unflappable.* Wall Street Journal 1:25, April 13, 1973. New York, NY.

Brenk, V. (1987). *The concept of research for sea pollution by the transport of hazardous material on sea from the Federal Environmental Agency.* Texte., No. 6, (1987). Meereskundliche Untersuchung von Oelunfaellen. Tagung Der Arbeitsgruppe Zur Meereskundlichen Untersuchung von Oelunfaellen in Loccum, 18-20 September, 1985, pp. 45-57. (Marine Research Investigations of Oil Accidents. Meeting of the Working Group of Marine Research Investigations on Oil Accidents in Loccum, 18-20 Sep., 1985).

Breslin, V.T.; Roethel, F.J.; Schaeperkoetter, V.P. (1988). *Physical and chemical interactions of stabilized incineration with the marine environment.* 81st APCA Annual Meeting & Exhibition Dallas, TX (USA), June 19-24, 1988, p. 22.

Broman, D.; Ganning, B.; Lindblad, C. (1983). *Effects of high pressure, hot water shore cleaning after oil spills on shore ecosystems in the northern Baltic proper.* Mar. Environ. Res. 10(3):173-187.

Bromley, M. (1985). *Wildlife management implications of petroleum exploration and development in wildland environments.* Gen. Tech. Rep., Intermountain Research Station, 48 pp. NTIS Number: PB86-121290/GAR. Report Number: FSGTR/INT-191.

Bronfman, A.M.; Aldakimova, A.Y.; Makarova, G.D.; Tolokonnikova, L.I. (1976). *Distinctive features of self purification of water and sediments of a shallow sea as exemplified by the Sea of Azov Russian-SFSR USSR.* Okeanologiya 16(1):91-97.

Broome, S.W.; Seneca, E.D.; Woodhouse, W.W., Jr. (1988). *Tidal salt marsh restoration.* Aquat Bot 32(1-2):1-22.

Brown, C.H. (1978). *The role of the U.S. Fish and Wildlife Service in responding to oil spills.* Presented at: Energy/Environmnt '78 Los Angeles (USA) 22 Aug 1978. Dep. Interior, US Fish & Wildlife Serv. (ES), National Oil & Hazardous Substances Spill Coordinator, Washington, DC 20240, USA. In: Proceedings: Energy/Environment '78: a symposium on energy development impacts. Lindstedt-Siva, J., editor. Society of Petroleum Industry Biologists Los Angeles (USA). p 321.

Brown, D.J.S.; Baxter, A. (1984). *August 1980 oil spill clean-up project – Bahrain report summary of task force operations.* UNEP Reg. Seas Rep. Stud., No. 44. Combating Oil Pollution in the Kuwait Action Plan Region, pp. 125-146.

Brown, J.; West, G.C. (1970). *Tundra biome research in Alaska - the structure and function of cold-dominated ecosystems.* Tundra Biome Analysis of Ecosystems College Alaska. Sponsor: Cold Regions Research and Engineering Lab., Hanover, N.H. Report No.: 70-1. 157 pp. NTIS Number: PC A08/MF A01.

Brown, R.D. (1981). *Health and environmental effects of synthetic fuel technologies: Research priorities.* NTIS, Springfield, VA. Report Number: PB81-212474.

Brownlee, M.J.; Mattice, E.R.; Levings, C.D. (1984). *The Campbell River Estuary: A report on the design, construction and preliminary follow-up study findings of intertidal marsh islands created for purposes of estuarine rehabilitation.* Can. Manuscr. Rep. Fish. Aquat. Sci., No. 1789, 63 pp. Report Number: ISSN 0706-6473. ✓ found

Bubela, B. (1985). *Effect of biological activity on the movement of fluids through porous rocks and sediments and its application to enhanced oil recovery.* Geomicrobiol J 4(3):313-328.

Buhite, T.R. (1979). *Cleanup of a cold weather terrestrial pipeline spill.* Presented at the 1979 Oil Spill Conference Los Angeles, CA (USA) 19 Mar 1979. Proc. Oil Spill Conf. American Petroleum Institute Washington, DC (USA). pp. 367-369.

Buhrer, H. (1979). *Influence of hydrocarbons on ecology of bacteria in aerobic lake sediment.* Schweiz. Z. Hydrol. Rev. Suisse Hydrol. Swiss J. Hydrol., 41(2):315-355.

Butler, A.C.; Sibbald, R.R. (1986). *Isolation and gas chromatographic determination of saturated and polycyclic aromatic hydrocarbons in mussels.* B Env Contam & Tox 37(4):570(9).

Butler, J.N.; Levy, E.M. Chairmen. (1978). *Summary and overview: Long-term fate of petroleum hydrocarbons after spills - compositional changes and microbial degradation.* Session 1. Symposium on Recovery Potential of Oiled Marine Northern Environments, Halifax (Canada), October 10, 1977. J. Fish. Res. Board Can. 35(5):604-605.

Butler, W.H. (1985). *Multiple land use: An essential part of environmental planning.* Apea J. 25(1):311(5).

Cadena, F.C. (1988). *Treatment of water supplies contaminated with toxic pollutants using tailored soils.* Sponsor: New Mexico State Univ., Las Cruces, NM; Water Resources Div., Geological Survey, Reston, VA. Report No.: WRRI-235. 63 pp. Prepared in cooperation with New Mexico State Univ., Las Cruces, NM. Sponsored by Water Resources Div., Geological Survey, Reston, VA. NTIS Number: PB89-151443/XAB.

Cairns, J., Jr. (1978). *Waterway recovery.* Water Spectrum 3:28-32. not found

Cairns, J., Jr.; Buikema, A.L. (1984). *Restoration of habitats impacted by oil spills: Workshop summary.* Restoration of Habitats Impacted by Oil Spills Symposium Blacksburg, VA (USA) 9-11 Nov 1981. Dept. Biol., Univ. Cent. Environ. Stud., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061, USA. Restoration of habitats impacted by oil spills. Cairns, J., Jr., and Buikema, A.L., editors. Pages 173-180. Report Number: ISBN 0-250-40551-2. not found

Cairns, J., Jr.; Dickson, K.L.; Herricks, E.E. (1977). *Recovery and restoration of damaged ecosystems.* International Symposium on the Recovery of Damaged Ecosystems Blacksburg, VA, March 23-25, 1975, 531 pp. Publisher(s): University Press of Virginia, Charlottesville, VA. not found

Campbell, D.A. (1981). *Enhanced oil recovery and its environmental and economic implications in the United States.* Environ. Conserv. 8(1):5-18.

Canevari, G.P. (1979). *The restoration of oiled shorelines by the proper use of chemical dispersants.* Presented at the 1979 Oil Spill Conference, Los Angeles, CA (USA), 19 Mar 1979. Proc. Oil Spill Conf. American Petroleum Institute Washington, DC (USA). p 443-446.

Capuzzo, J.M. (1981). *Crude oil effects to developmental stages of the American lobster.* Sponsor: Bureau of Land Management.; Washington, DC. Report No.: WHOI-81-75. 108 pp. NTIS Number: PB82-117656. Contract No.: DI-AA551-CT9-5.

Capuzzo, J.M.; Derby, J.G.S. (1982). *Drilling fluid effects to developmental stages of the American lobster.* Woods Hole Oceanogr. Inst., Woods Hole, MA, USA. NTIS, Springfield, VA. Report Number: PB82-220740.

Carlisle, J.G., Jr. (1976). *Artificial modification of the ecosystem.* 1. Artificial reefs. 2. Offshore oil drilling platforms. Joint Oceanographic Assembly, Edinburgh (UK), September 13, 1976.

Carr, R.S.; Linden, O. (1984). *Bioenergetic responses of Gammarus salinus and Mytilus edulis to oil and oil dispersants in a model ecosystem.* Mar. Ecol. (Prog. Ser.) 19(3):285-291.

Carter, J.; Lamarra, V. (1983). *Environmental management — A data based ecosystem approach from the oil shale industry.* J. Environ. Manage. 17(1):17-34.

No Castle, R.W. (1977). *Restoration of oil-contaminated shorelines.* Presented at the Oil Spill Response Workshop, Metairie, LA (USA), February 15, 1977. In: Proceedings of the 1977 Oil Spill Response Workshop. Fore, P.L, editor. p 105-112. Publisher(s): U.S. Fish and Wildlife Service, Biological Services Program NSTL Station, MS. found

CEQ Report (1974). *OCS oil and gas — an environmental assessment.* CEQ Report, Apr 1974, 5:(190).

Chamberlain, G. (1989). *Technology tackles the oil spill.* Design News, Jun 19, 1989, p. 90(6).

Chauvin, D.J. (1980). *Impact of non-toxic mud on Gulf Coast drilling.* Pet. Eng. Int. 52(10):34, 38, 42.

Chemical Week (1980). *Biotechnology: research that could remake industries.* Chemical Week, October 8, 1980, 127(15):23(8).

Choi, D.R. (1984). *Ecological succession of reef cavity-dwellers (coelobites) in coral rubble.* Bull. Mar. Sci. 35(1):72-79.

Church, G.J. (1989). *The Big Spill.* Time, Apr 10, 133(15):38(4).

Clark, J.R. (1976). *Assuring ecological soundness in coastal energy developments.* Trans. North Am. Wildl. Nat. Resour. Conf., 41:356-360.

Clark, R.B. (1978). *Oiled seabird rescue and conservation.* Presented at the Symposium on Recovery Potential of Oiled Marine Northern Environments, Halifax (Canada), October 10, 1977. J. Fish. Res. Board Can. 35(5):675-678.

Clark, R.B. (1982). *Biological effects of oil pollution.* Water Science and Technology 14(9-11):1185. NOTE: Proceedings of the Eleventh Biennial Conference of the International Association on Water Pollution Research and Control, Cape Town 29th March--2nd April 1982.

Clark, R.C., Jr.; Patten, B.G.; DeNike, E.E. (1978). *Observations of a cold-water intertidal community after 5 years of a low-level, persistent oil spill from the General M.C. Meigs.* Presented at the Symposium on Recovery Potential of Oiled Marine Northern Environments, Halifax (Canada), October 10, 1977. J. Fish. Res. Board Can. 35(5):754-765.

Coenen, N.L.; Cortright, B. (1979). *Mitigation in the Oregon Coastal Management Program.* Presented at: The Mitigation Symposium: a National Workshop on Mitigating Losses of Fish and Wildlife Habitats, Fort Collins, CO (USA) 16 Jul 1979. Gen. Tech. Rep. U.S. Dep. Agric., U.S. Dep. Agriculture, Fort Collins, CO (USA). p. 103-107.

Cole, T. (1978). *Preliminary ecological-genetic comparison between unperturbed and oil-impacted Urosalpinx cinerea (Prosobranchia: Gastropoda) populations: Nobska Point (Woods Hole) and Wild Harbor (West Falmouth), Massachusetts.* Presented at the Symposium on Recovery Potential of Oiled Marine Northern Environments, Halifax (Canada), October 10, 1977. J. Fish. Res. Board Can. 35(5):624-629.

Natural recovery info - mussels Cole, J. (1979). *Scientists gauge extent of recovery after an oil spill.* Smithsonian, 10(7):68(7). found

Cook, C.B.; Knap, A.H. (1983). *Effects of crude oil and chemical dispersant on photosynthesis in the brain coral Diploria strigosa.* Mar. Biol. 78(1):21-27.

Cooke, T.S. (1978). *Outer continental shelf oil spill impact on southern California resources.* In: Proceedings Energy/Environment '78: A Symposium on Energy Development Impacts, Los Angeles (USA), August 22, 1978. Lindstedt-Siva, J., editor. Society of Petroleum Industry Biologists Los Angeles (USA). Page 257.

Costa, D.P.; Kooyman, G.L. (1981). *Effects of oil contamination in the sea otter, Enhydra lutris.* Environmental Assessment of the Alaskan Continental Shelf. Final Reports of Principal Investigators. Volume 10: Biological Studies. Publisher(s): NOAA/OMPA, Boulder, CO (USA), pp. 65-107. Report Number: NOAA-OMPA-FR-81-10.

Cox, G.V.; Cowell, E.B. (1979). *Mitigating oil spill damage - ecologically responsible clean-up techniques.* Presented at the Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats, Fort Collins, CO (USA), July 16, 1979. Gen. Tech. Rep. U.S. Dept. Agric. U.S. Dept. Agriculture, Fort Collins, CO (USA). p. 121-128.

Crabtree, A.F. (1979). *Pipelines in streams and wetlands.* Ecolibrium, Winter 1979, 8(1):13(4).

Craig, P.C.; Haldorson, L. (1979). *Beaufort Sea barrier island-lagoon ecological process studies: Ecology of fishes in Simpson Lagoon, Beaufort Sea, Alaska.* Environmental assessment of the Alaskan continental shelf. Annual reports of principal investigators for the year ending March 1979. Volume 6: Effects. p. 363-470. Publisher(s): NOAA Environmental Research Labs, Boulder, CO (USA). Outer Continental Shelf Environmental Assessment Program.

Culley, J.L.B.; Dow, B.K.; Presant, E.W.; MacLean, A.J. (1982). *Recovery of productivity of Ontario soils disturbed by an oil pipeline installation.* Can. J. Soil Sci. 62(2):267-279.

Cundell, A.M.; Mitchell, R. (1977). *Microbial succession on a wooden surface exposed to the sea.* Int. Biodeterior. Bull. 13(3):67-73.

Cushman, R.M.; Goyert, J.C. (1984). *Effects of a synthetic crude oil on pond benthic insects.* Environ. Pollut. (A Ecol. Biol.) 33(2):163-186.

Dauvin, J.-C. (1987). *Long term evolution (1978-1986) of the amphipod populations of the fine sand community of Pierre Noire (Bay of Morlaix, western English Channel) after the Amoco Cadiz disaster.* Mar. Environ. Res. 21(4):247-273.

Davidson, J.W. (1976). *Environmental difficulties encountered in shale oil production.* Alternate Fuels Symposium. Mimeographed Papers.

Davis, R.W.; Williams, T.M.; Thomas, J.A.; Kastelein, R.A.; Cornell, L.H. (1988). *The effects of oil contamination and cleaning on sea otters (Enhydra lutris). 2. Metabolism, thermoregulation, and behavior.* Can. J. Zool. 66(12):2782-2790.

Davis, W.P.; Hoss, D.E.; Scott, G.I.; Sheridan, P.F. (1984). *Fisheries resource impacts from spills of oil or hazardous substances.* Proceedings of the Restoration of Habitats Impacted by Oil Spills Symposium, Blacksburg, VA (USA), November 9-11, 1981. Cairns, J., Jr.; Buikema, A.L., editors. Pages 157-172. Report Number: ISBN 0-250-40551-2. not found

de Jong, E. (1980). *The effect of a crude oil spill on cereals.* Environmental Pollution. Series A: Ecological and Biological 22(3):187-196.

Deis, D.R.; Dial, R.S.; Quammen, M.L. (1987). *The use of mitigation in environmental planning for port development.* Proceedings of the 10th National Conference on Estuarine and Coastal Management: Tools of the Trade, New Orleans, LA (USA), October 12-15, 1986. Volume 2. Lynch, M.P.; McDonald, K.L., editors. Pages 707-718.

Dennison, W.C. (1987). *Effects of light on seagrass photosynthesis growth and depth distribution.* Aquat Bot 27(1):15-26. ✓

Dennison, W.C.; Alberte, R.S. (1986). *Photoadaptation and growth of Zostera marina L. (eelgrass) transplants along a depth gradient.* J. Exp. Mar. Biol. Ecol. 98(3):265-282. ✓

Dewling, R.T.; McCarthy, L.T. (1980). *Chemical treatment of oil spills.* Environ. Int. 3(2):155-162.

Dial, R.S.; Deis, D.R. (1986). *Mitigation options for fish and wildlife resources affected by port and other water-dependent developments in Tampa Bay, Florida.* NTIS Number: PB87-140703/GAR. 171 pp.

Diamant, A.; Tuvia, A.B.; Baranes, A.; Golani, D. (1986). *An analysis of rocky coastal Eastern Mediterranean fish assemblages and a comparison with an adjacent small artificial reef.* J. Exp. Mar. Biol. Ecol. 97(3):269-285.

Diaz, R.J.; Boesch, D.F. (1977). *Habitat development field investigations, Windmill Point Marsh Development Site, James River, Virginia. Appendix C. Environmental impacts of marsh development with dredged material: Acute impacts on the macrobenthic community.* Technical Report, U.S. Army Corps of Engineers, Waterways Experimental Station. 158 p. Publisher(s): U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, VA (USA), November, 1977. Contract No. DACW66-75-C-0053.

Dibble, J.T.; Bartha, R. (1979). *Rehabilitation of oil inundated agricultural land a case history.* Soil Sci 128(1):56-60.

Dicks, B.; Iball, K. (1981?). *Ten years of saltmarsh monitoring — the case history of a Southampton water saltmarsh and a changing refinery effluent discharge.* Presented at EPA/API/USCG 1981 Oil Spill Conf, Atlanta, Mar 2-5, 1981, p. 361(14).

Dillmann, B. (1985). *Mitigation as affected by geographical factors.* 8th Biennial International Estuarine Research Conference, Durham, NH (USA), July 28, 1985. Estuaries 8(2B):110A.

Ditton, R.B. (1981). *Social and economic considerations for artificial reef deployment and management.* Proceedings of a Conference on Artificial Reefs, Daytona Beach, FL (USA), September 13-15, 1979. Aska, D.Y., editor. Pages 23-32. Report for the Florida Sea Grant Program. Report Number: FSG-R-41.

Dolah, R.F. van; Wendt, P.H.; Wenner, C.A.; Martore, R.M.; Sedberry, G.R. (1987). *Environmental impact research program: Ecological effects of rubble weir jetty construction at Murrells Inlet, South Carolina. Volume 3. Community structure and habitat utilization of fishes and decapods associated with the jetties.* Army Corps of Engineers, Waterways Experimental Station, Vicksburg, MS (USA), 163 pp. NTIS Number: AD-A187 676/2/GAR.

Donaldson, E.C. (1979). *Environmental aspects of enhanced oil recovery.* Environmental Control Symposium Washington, DC Nov 1978. Energy Sources 4(3):213-229. ISSN: 0090-8312.

Dorrler, J.S. (1976). *Energy resource extraction; oil and gas production.* Presented at EPA Natl Conf on Health, Env Effects, & Control Technology of Energy Use, Washington, DC, Feb 9-11, 1976, (9).

Eidam, C.L.; Hancock, J.A.; Jones, R.G.; Hanson, J.R.; Smith, D.C.; Hay, K.G.; Mcneil, C.S.L. (1975?). *Oil spill cleanup.* Presented at EPA/API/USCG Conf on Prevention & Control of Oil Pollution, San Francisco, Mar 25-27, 1975, p. 217(52).

Eisenhart, R.W. (1984). *Tracking of hazardous substance spills to inland streams.* The Biosphere: Problems and Solutions. Proceedings of the Miami International Symposium on the Biosphere, Miami Beach, FL (USA), April 23-24, 1984. Veziroglu, T.N., editor. Pages 415-435. Stud. Environ. Sci., No. 25. Report Number: ISBN 0-444-42424-5.

Elouard, B.; Desrosiers, G.; Brethes, J.C.; Vigneault, Y. (1983). *A study of a fish habitat created around islets of dredged material Grande-Entree lagoon, Magdalen Islands.* Rapp. Tech. Can. Sci. Halieut. Aquat., No. 1209F. 77 pp. Report Number: ISSN 0706-6570.

Engelhardt, F.R.; Gilfillan, E.S.; Boehm, P.D.; Mageau, C. (1985). *Metabolic effects and hydrocarbon fate in Arctic bivalves exposed to dispersed petroleum.* Proceedings of the 3rd International Symposium on Responses of Marine Organisms to Pollutants Plymouth (UK) 17 Apr 1985. Moore, M.N., editor. Mar. Environ. Res. 17(2-4):245-249.

Environmental Protection Agency (1980). *Emergency spills research strategy 1980-1984.* EPA Report EPA-600/9-80-063, (20).

Erwin, K.L. (1979). *Restoration and revegetation of exploratory oil well sites in the wetlands of south Florida USA.* Fla. Sci. 42(SUPPL 1):31.

Erwin, K.L.; Best, G.R. (1985). *Marsh community development in a central Florida phosphate surface-mined reclaimed wetland.* 8th Biennial International Estuarine Research Conference, Durham, NH (USA), July 28. 1985. Estuaries 8(2B):111A.

Farrington, J.W. (1985). *Oil pollution: A decade of research and monitoring.* Oceanus, Fall 1985, 28(3):2(11).

Faucher, C. (1983). *Quantitative comparison of benthic populations on St. Efflam beaches.* Etude de la Macrofaune du Microphytobenthos de la Meiofaune des Estrans et Etude des Chenaux des Abers, pp. 1-11. (Ecological Survey of Macrofauna, Microphytobenthos and Meiofauna of the Foreshore, and Survey of the Channels of the Abers Estuaries). Report Number: Contract CNEXO82/2604.

FEA Report (1977). *Strategic petroleum reserve environmental impact statement.* FEA Report, Dec 1976-Jan 1977, (4107).

Federle, T.W.; Vestal, J.R.; Hater, G.R.; et al. (1979). *Effects of Prudhoe Bay crude oil on primary production and zooplankton in arctic tundra thaw ponds.* Marine Environmental Research 2(1):3-18.

Fedkenheuer, A.W.; Heacock, H.M.; Lewis, D.L. (1980). *Early performance of native shrubs and trees planted on amended Athabasca Oil Sand tailings.* Reclamation Review 3(1):47(9).

Flower, R.J. (1983). *Some effects of a small oil spill on the littoral community at Rathlin Island, Co. Antrim.* Ir. Nat. J. 21(3):117-120.

Foley, J.P.; Tresidder, S.J. (1977?). *The St. Lawrence River oil spill of June 23, 1976-are you ever truly ready?.* 1977 Oil Spill Conference, New Orleans, LA, March 8-10, 1977. American Petroleum Institute. Report Number: API 4284, pp. 81-85.

Fonseca, M.S. (1989). *Regional analysis of the creation and restoration of seagrass systems.* In: J.A. Kusler and M.E. Kentula, editors. Wetland Creations and Restoration: The Status of the Science. Volume I: Regional Reviews. EPA/600/3-89/038. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR 97333. pp. 175-198. ✓ not found

cost evaluation for seagrass & intertidal plant communities.

Fonseca, M.S.; Kenworthy, W.; Phillips, R.C. (1982). *A cost-evaluation technique for restoration of seagrass and other plant communities.* Environ. Conserv. 9(3):237-242. ✓ found

Fonseca, M.S.; Thayer, G.W.; Kenworthy, W.J. (1985). *The use of ecological data in the implementation and management of seagrass restorations.* Eighth Biennial International Estuarine Research Conference Durham, NH (USA) 28 Jul 1985. Estuaries 8(2B):125A. ✓ not found

Forget, C.A.; Sartor, J.D. (1971?). *Earthmoving equipment for restoration of oil-contaminated beaches.* API/EPA Conf Jun 15-17, 1971, Washington, DC p. 505.

Franco, P.J.; Giddings, J.M.; Herbes, S.E.; Hook, L.A.; Newbold, J.D.; Roy, W.K.; Southworth, G.R.; Stewart, A.J. (1984). *Effects of chronic exposure to coal-derived oil on freshwater ecosystems: 1. Microcosms.* Environ. Toxicol. Chem. 3(3):447-463.

Frankiewicz, T.C., editor. (1980). *Design and management for resource recovery. Volume 1: Energy from waste.* Ann Arbor Science Publishers, Inc., Ann Arbor, MI, USA. XIV+209 pp. (illus.).

Fricke, A.H.; Hennig, H.F-K.O.; Orren, M.J. (1981). *Relationship between oil pollution and psammolittoral meiofauna density of two South African beaches.* Marine Environ. Res. 5(1):59-77.

Frink, J.; Dein, F.J.; Lauer, D.M. (1982). *Rehabilitation of ruddy ducks contaminated with oil.* J. Amer. Vet. Med. Assoc. 181(11):1398-1399.

Frink, L.S. (1982). *A new approach to oiled bird rehabilitation after oil spills on the East Coast USA.* In: Land and Water Issues Related to Energy Development. Proceedings of the 4th Annual Meeting of the International Society of Petroleum Industry Biologists, Denver, CO, USA, Sept. 22-25, 1981. Rand, P.J., editor. P257-262. Ann Arbor Science Publishers, Woburn, MA, USA; Butterworths, Ltd., Sevenoaks, Kent, England.

Fryberger, J.S. (1975). *Investigation and rehabilitation of a brine-contaminated aquifer.* Ground Water, Mar-Apr 1975, 13(2):155(6).

Fucik, K.W.; Bright, T.J.; Goodman, K.S. (1984). *Measurements of damage, recovery, and rehabilitation of coral reefs exposed to oil.* Restoration of Habitats Impacted by Oil Spills Symposium, Blacksburg, VA (USA), 9-11 Nov 1981. Cairns, J., Jr.; Buikema, A.L., editors. Pages 115-134. Report Number: ISBN 0-250-40551-2.

Fukuda, T. (1987). *Development of the techniques for marine macrophyte (Zostera marina) bed creation. 5. Shoot distribution and surrounding conditions.* Bull. Fish. Exp. Stn., Okayama Prefect, No. 2, pp. 21-26.

Fukuda, T. (1987). *Development of the techniques for marine macrophyte (Zostera marina) bed creation. 7. Depth of seeding.* Bull. Fish. Exp. Stn. Okayama Prefect., No. 2, pp. 32-34.

Fukuda, T.; Sato, J. (1987). *Development of the techniques for marine macrophyte (Zostera marina) bed creation. 6. Differences of germination rate among the density of seeding, and between the seeds obtained from different places.* Bull. Fish. Exp. Stn. Okayama Prefect., No. 2, pp. 27-31.

Galbraith, D.M. (1978). *Reclamation and coal exploration: Peace River coal block, British Columbia, Canada.* Presented at Intl Congress for Energy & Ecosystem (Pergamon) Ecol & Coal Resource Development Conf, Grand Forks, Jun 12-16, 1978, 1:444(3).

Ganning, B.; Reish, D.J.; Strughan, D. (1984). *Recovery and restoration of rocky shores, sandy beaches, tidal flats, and shallow subtidal bottoms impacted by oil spills.* Restoration of Habitats Impacted by Oil Spills Symposium, Blacksburg, VA (USA), 9-11 Nov 1981. Cairns, J., Jr.; Buikema, A.L., editors. Pages 7-36. Report Number: ISBN 0-250-40551-2.

Gannon, J.E.; Danehy, R.J.; Anderson, J.W.; Merritt, G.; Bader, A.P. (1986). *The ecology of natural shoals in Lake Ontario and their importance to artificial reef development.* Artificial Reefs -- Marine and Freshwater Applications. D'Idri, F.M., editor. Pages 113-139. Report Number: ISBN 0-87371-010-X.

Gehu, J.M. (1981). *Phytoecological survey of the Amoco Cadiz oil spill impact in the coastal salt-meadows of northern Brittany.* Publisher(s): Institut Europeen d'Ecologie, Metz (France), 43 pp.

Getter, C.D.; Cintron, G.; Dicks, B.; Lewis, R.R., III; Seneca, E.D. (1984). *The recovery and restoration of salt marshes and mangroves following an oil spill.* Restoration of Habitats Impacted by Oil Spills Symposium, Blacksburg, VA (USA), 9-11 Nov 1981. Cairns, J., Jr.; Buikema, A.L., editors. Pages 65-114. Report Number: ISBN 0-250-40551-2.

Giddings, J.M. (1982). *Effects of the water-soluble fraction of a coal-derived oil on pond microcosms.* Archives Env Contam & Tox, Nov 1982, 11(6):735(13).

Giroux, J.-F. (1981). *Use of artificial islands by nesting waterfowl in southeastern Alberta.* J. Wildl. Manage. 45(3):669-679.

Gladfelter, W.B.; Gladfelter, E.H. (1978). *Fish community structure as a function of habitat structure on West Indian patch reefs.* Presented at the Simposio sobre Ciencias Marinas en las Americas San Jose (Costa Rica) 3 Jul 1977. Rev. Biol. Trop. 26(Suppl.1):65-84.

Glemarec, M.; Husenot, E. (1982). *Response of subtidal populations to perturbations caused by the Amoco Cadiz in the Benoit and Wrac'h estuaries.* NOAA/CNEXO Joint Scientific Commission Workshops: Physical, Chemical, and Microbiological Studies after the Amoco Cadiz Oil Spill; Biological Studies after the Amoco Cadiz Oil Spill. Charleston, SC (USA), October 28, 1981; Brest (France), September 17, 1981. Ecological Study of the Amoco Cadiz Oil Spill: Report of the NOAA-CNEXO Joint Scientific Commission. Gundlach, E.R.; Marchand, M., editors. Pages 191-204.

Glemarec, M.; Hussenot, E.; Moal, Y.Le (1982). *Utilization of biological indications in hypertrophic sedimentary areas to describe dynamic process after the Amoco Cadiz oil spill.* International Symposium on Utilization of Coastal Ecosystems: Planning, Pollution and Productivity, Rio Grande (Brazil), 22 Nov 1982. Fundacao Univ., Rio Grande (Brazil); Duke Univ. Mar. Lab., Beaufort NC (USA). Atlantica 5(2):48. Special issue. Summary only.

Gomoiu, M.T. (1983). *Some ecological aspects of artificial reef construction along the coasts of north-western Black Sea.* Journee d'Etudes sur les Aspects Scientifiques Concernant les Recifs Artificiels et la Mariculture Suspendue, Cannes, France, 7 Decembre 1982. Pages 113-119. (Seminar on Scientific Aspects of Artificial Reefs and Floating Mariculture in the Mediterranean, Cannes, France, December 7, 1982).

Goodman, K.S.; Baker, J., editors. (1982). *A preliminary ecological survey of the coastline of Abu Dhabi, United Arab Emirates.* A report prepared for the Abu Dhabi Marine Operating Company (ADMA-OPCO) by BP International, Ltd., Environmental Control Centre, London. Volume 1. Text, tables and figures. Volume 2. Photographs. Publisher(s): British Petroleum International Ltd., London (UK). 178 pp.

Goodman, K.S.; Nunn, R.M. (1982). *The littoral ecology of the area around Mongstad Refinery, Fensfjorden, Norway, 1981.* An Interim Report to Rafinor A/S and Co. by BP International Limited. Publisher(s): BP International Ltd., Brittanic House, Moor Lane, London EC2Y 9BU, UK, 63 pp.

Gordon, W.G. (1981). *Artificial reefs and the FCMA.* Proceedings of a Conference on Artificial Reefs, Daytona Beach, FL (USA), September 13, 1979. Aska, D.Y., editor. Pages 75-77. Rep. Fla. Sea Grant Program. Report Number: FSG-R-41.

Gordon, W.G. (1986). *NMFS and Army Corps of Engineers restore fisheries habitats: A cooperative venture.* Fisheries, Sep-Oct 1986, 11(5):2(6). found

not relevant coop. Agreement announcement

Gore, J.A., editor. (1985). *The restoration of rivers and streams: Theories and experience.* Butterworth Publishers, Stoneham, MA (USA). not found

Gore, J.A.; Johnson, L.S. (1979). *Biotic recovery of a reclaimed river channel after coal strip mining.* Presented at the Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats, Fort Collins, CO (USA), July 16, 1979. Gen. Tech. Rep. US Dept. Agriculture, Fort Collins, CO (USA). p. 239-244.

Gossen, R.G.; Mann, G.J. (1979). *Environmental Considerations in the Cold Lake Project.* Presented at UN Inst for Training & Research et al. Future of Heavy Crude Oils & Tar Sands 1st Intl Conf, Edmonton, Jun 4-12, 1979, p. 729(5).

Gourbault, N.; Helleouet, M.N.; Naim, O.; Renaud-Mornant, J. (1980). *Amoco Cadiz oil pollution.* Contract COB-MUSEUM 79 5975. Effets de la pollution sur la meiofaune de Roscoff (greve de Roscoff chenal de la riviere de Morlaix). Deuxieme annee. Premiers resultats. [Research contract COB-MUSEUM 79/5975. Pollution effects on the meiofauna in Roscoff (Roscoff beach, Morlaix river channel). Preliminary results after two years study. 6 pp.]. Mus. Natl. Hist. Nat., Prog. Zool.-Vers, Paris, France. (Museum National d'Histoire Naturelle Paris, France).

Greenberg, D.; Hellman, R.A. (1978). *Israel in the Mediterranean ecosystem.* Presented at the Conference of the Coastal States of the Mediterranean Region for the Protection of the Mediterranean Sea, Monaco (Monaco), January 9, 1978. Publisher(s): Environ. Protect. Serv., Jerusalem, Israel. 70 pp.

Griffiths, W.B.; Dillinger, R.E. (1981). *Beaufort Sea Barrier Island-Lagoon ecological process studies: Final report, Simpson Lagoon, Part 5 - Invertebrates.* Environmental Assessment of the Alaskan Continental Shelf. Final Reports of Principal Investigators. Volume 8: Biological Studies. Publisher(s): NOAA/OMPA, Boulder, CO (USA), Volume 8, pp. 1-198. Report Number: NOAA-OMPA-FR-80-8.

Grove, R.S. (1982). *Artificial reefs as a resource management option for siting coastal power stations in southern California.* Mar. Fish. Rev. 44(6-7):24-27.

Grove, R.S.; Yuge, J.E.; Sonu, C. (1983). *Artificial reef technology: A strategy for active impact mitigation.* Proceedings of Oceans '83: Effective Use of the Sea — An Update, San Francisco, CA, August 29 - September 1, 1983. Volume 2: Technical Papers. Mineral Resources and Energy, Non-Mineral Resources, Transportation. Pages 951-956. Report Number: IEEE-83CH1972-9.

Grula, M.M.; Grula, E.A. (1983). *Biodegradation of materials used in enhanced oil recovery.* Final report, July 1, 1978, to November 30, 1981. Oklahoma State Univ., Stillwater, OK 74074, USA. NTIS, Springfield, VA (USA). Number: DE84002019.

Gudin, C.; Syratt, W.J. (1975). *Biological aspects of land rehabilitation following hydrocarbon contamination.* Env. Pollution 8(2):107(6).

Gumtz, G.D. (1972). *Restoration of beaches contaminated by oil.* Report Number: EPA-R2-72-045. 129 pp. NTIS Number: PB-214 419/4 . Contract No.: EPA-14-12-809; EPA-15080-EOT.

Hamburg, S.P.; Homann, P.S. (1986). *Utilization of growth parameters of eelgrass, Zostera marina, for productivity estimation under laboratory and in situ conditions.* Mar. Biol. 93(2):299-303.

Hampson, G.R.; Moul, E.T. (1977). *Salt marsh grasses and N2 fuel oil.* Oceanus 20(4):25-30.

Hampson, G.R.; Moul, E.T. (1978). *No. 2 fuel oil spill in Bourne, Massachusetts: Immediate assessment of the effects on marine invertebrates and a 3-year study of growth and recovery of a salt marsh.* Presented at a Symposium on Recovery Potential of Oiled Marine Northern Environments, Halifax (Canada), October 10, 1977. J. Fish. Res. Board Can. 35(5):731-744.

Hann, R.W., Jr. (1977). *Fate of oil from the supertanker Metula.* Presented at the Oil Spill Conference, New Orleans, LA (USA), March 8, 1977. Publisher(s): American Petroleum Inst., Washington, DC (USA). Pages 465-468. Report Number: API 4284.

Hann, R.W., Jr.; Rice, L.; Trujillo, M-C.; Young, H.N., Jr. (1978). *Oil spill cleanup activities.* In: The Amoco Cadiz oil spill - A preliminary scientific report. Hess, W.N., editor. NOAA/EPA Special report. p 229-275. Publisher(s): NOAA Environmental Research Labs, Boulder, CO (USA); Environmental Protection Agency, Narragansett, RI (USA).

Hannah, R. (1981). *Resource protection measures.* The IXTOC 1 Oil Spill: The Federal Scientific Response. Hooper, C.H., editor. NOAA Spec. Rep. Publisher(s): NOAA/OMPA, Boulder, CO (USA), pp. 105-118. Report Number: NOAA-SR-HMRP-1981.

Hansen, K.; Vestergaard, P. (1986). *Initial establishment of vegetation in a man-made coastal area in Denmark.* Nord. J. Bot. 6(4):479-495.

Harrison, P.G. (1987). *Natural expansion and experimental manipulation of seagrass zostera-spp abundance and the response of infaunal invertebrates.* Estuarine Coastal Shelf Sci 24(6): 799-812.

Hartstein, A.M.; Pawlowski, L.; Alaerts, G.; Lacy, W.J., editors. (1986). *State-of-the-art of the fossil fuel issue in the environment.* Proceedings of the 5th International Conference on Chemistry for Protection of the Environment, Leuven (Belgium), 9-13 Sep 1985, pp. 679-689. Studies in Environmental Science 29. Elsevier Science Publishers, Amsterdam (Netherlands).

Hershner, C.; Moore, K. (1977?). *Effects of the Chesapeake Bay oil spill on salt marshes of the lower bay.* 1977 Oil Spill Conference New Orleans, LA, Mar. 8-10, 1977. American Petroleum Institute Publication 4284, pp. 529-533.

Hersman, L.E.; Klein, D.A. (1979). *Restored oil shale effects on soil microbiological characteristics.* J Env Quality, Oct-Dec 1979, 8(4):520(5).

Heubeck, M. (1979). *A report to SOTEAG on monitoring counts of seabirds and waterfowl in 2 areas of North Shetland, Winter 1978-79.* Shetland Oil Terminal Environmental Advisory Group (UK). 57 p.

Higo, N.; Nagashima, M. (1978). *On the fish gathering effect of the artificial reefs ascertained by the diving observation 2. At the sea of the Satsuma Peninsula in Kagoshima Prefecture.* Mem. Fac. Fish. Kagoshima Univ. 27(1):117-130.

Holmes, W.N.; Cavanaugh, K.P.; Cronshaw, J. (1978). *The effects of ingested petroleum on oviposition and some aspects of reproduction in experimental colonies of mallard ducks (Anas platyrhynchos).* J. Reprod. Fertil. 54(2):335-347. not found

Holmes, W.N.; Cronshaw, J.; Cavanaugh, K.P. (1978). *The effects of ingested petroleum on laying in mallard ducks (Anas platyrhynchos).* In: Proceedings of the Energy/Environment '78: A Symposium on Energy Development Impacts, Los Angeles (USA), 22 Aug 1978. Lindstedt-Siva, J., editor. Society of Petroleum Industry Biologists Los Angeles (USA). Pages 301-309. not found

Horner, R.A. (1978). *Beaufort Sea plankton studies.* Seattle, WA, USA. In: Environmental assessment of the Alaskan continental shelf. Annual reports of principal investigators for the year ending March 1978. Volume 5, receptors--fish, littoral, benthos. p 85-142. Publisher(s): US Environmental Research Laboratories, Boulder, CO. Outer Continental Shelf Environmental Assessment Program.

Howe, J.R. (1989). *Alaska disaster.* Defenders 64(3):20(10).

Hueckel, G.J.; Buckley, R.M. (1986). *The mitigation potential of artificial reefs in Puget Sound, Washington.* Oceans '86 Conference Record: Science-Engineering-Adventure, Volume 2. Data Management, Instrumentation and Economics, Washington, DC (USA), 23-25 Sep 1986, pp. 542-546. Oceans '86. Report Number: IEEE-86CH2363-0.

Hunt, L.J. (1979). *Use of dredged material disposal in mitigation.* Presented at the Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats, Fort Collins, CO (USA), 16 Jul 1979. Gen. Tech. Rep., U.S. Dept. Agriculture, Fort Collins, CO (USA). p. 502-507.

Hutchinson, T.C.; Freedman, W. (1978). *Effects of experimental crude oil spills on subarctic boreal forest vegetation near Norman-Wells Northwest-Territories Canada.* Can J Bot 56 (19):2424-2433.

Hutchinson, T.C.; Hellebust, J.A.; Soto, C. (1981). *Effect of naphthalene and aqueous crude oil extracts on the green flagellate Chlamydomonas angulosa IV. Decreases in cellular manganese and potassium.* Can. J. Bot. 59(5):742-749.

Hyland, J.L.; Hoffman, E.J.; Phelps, D.K. (1985). *Differential responses of two nearshore infaunal assemblages to experimental petroleum additions.* J. Mar. Res. 43(2):365-394.

Ibanez, F.; Dauvin, J.-C. (1988). *Long-term changes (1977 to 1987) in a muddy fine sand Abra alba -- Melinna palmata community from the western English Channel: Multivariate time-series analysis.* Mar. Ecol. (Prog. Ser.) 49(1-2):65-81.

Jacobs, R.P.W.M. (1980). *Effects of the Amoco Cadiz oil spill on the seagrass community at Roscoff with special reference to the benthic infauna.* MarLow chronic additions of no. 2 fuel oil: Chemical behavior, biological impact and recovery in a simulated estuarine environment. Mar. Ecol. (Prog. Ser.). 9(2):121-136.

Jeffries, H.P.; Johnson, W.C. (1976). *Petroleum, temperature, and toxicants: Examples of suspected responses by plankton and benthos on the continental shelf.* NOAA Sea Grant/Univ of Rhode Island Marine Reprint 69, 1976 (15).

Jennings, A.L. (1972). *Spill damage restoration.* Natl Conf Hazardous Material Spill Houston Mar 21-23, 1972, p. 221(3).

Jenssen, B.M.; Ekker, M. (1989). *Rehabilitation of oiled birds a physiological evaluation of four cleaning agents.* Mar Pollut Bull 20(10):509-512.

Jernelov, A. (1976). *The St. Peter oil spill: An ecological and socioeconomic study of effects.* EPA Intl Env Document Report 04209A-Colombia, Oct 1976, 38 p.

Jessee, W.N.; Carter, J.W.; Carpenter, A.L.; DeMartini, E.E. (1986). *Density estimates of five warm-temperate reef fishes associated with an artificial reef, a natural reef, and a kelp forest.* Artificial reefs -- marine and freshwater applications. D'Itri, F.M., editor. Pages 383-400. Report Number: ISBN 0-87371-010-X.

Johansson, S.; Larsson, U.; Boehm, P. (1980). *The Tsesis oil spill: Impact on the pelagic ecosystem.* Mar. Pollut. Bull. 11(10):284-293.

Johnson, B.T.; Romanenko, V.I. (1983). *Fuel oil 2 in a fresh water microcosm impact and recovery.* 83rd Annual Meeting of the American Society for Microbiology, New Orleans, LA, USA, Mar. 6-11, 1983. Abstr Annu Meet Am Soc Microbiol 83(0):Q73.

Johnson, B.T.; Romanenko, V.I. (1989). *A multiple testing approach for hazard evaluation of complex mixtures in the aquatic environment the use of diesel oil as a model.* Environ. Pollut. 58 (2-3):221-236.

Johnson, G.F.; deWit, L.A. (no date). *Ecological effects of an artificial island, Rincon Island, Punta Gorda, California.* Misc. Rep. US Army Coast. Eng. Res. Cent. Contract No. DACW 72-76-C-0011. ✓ not found

Johnson, G.F.; deWit, L.A.; Wales, B.A.; Hurme, A.K. (1978). *Ecological effects of an artificial island.* In: Proceedings of Energy/Environment '78: a symposium on energy development impacts, Los Angeles (USA), 22 Aug 1978. Lindstedt-Siva, J., editor. Society of Petroleum Industry Biologists Los Angeles (USA). p. 145-162.

Johnson, L.A. (1981). *Revegetation and selected terrain disturbances along the Trans-Alaska Pipeline, 1975-1978.* Cold Regions Research and Engineering Lab., Hanover, NH (USA), 122 pp. NTIS Number: AD-A138 426/2.

Johnson, T.L.; Pastorok, R.A. (1985). *Oil spill cleanup: Options for minimizing adverse ecological impacts.* Publisher(s): American Petroleum Institute, Health and Environmental Sciences Department, 1220 L Street, NW, Washington, DC 20005. Report Number: API 4435.

Jones, L.E.; Hunter, R.A. (1981). *Strategies for rehabilitation and enhancement of coastal sites for waterfowl.* 6th Biennial International Estuarine Research Conference, Gleneden Beach, OR (USA), 1-5 Nov 1981. Estuaries 4(3):266. Summary only. found

Jordan, W.R.; Peters, R.L.; Allen, E.B. (1988). *Ecological restoration as a strategy for conserving biological diversity.* Env Management, Jan 1988, 12(1):55(18). not found

Josselyn, M.; Buchholz, J. (1982). *Summary of past wetland restoration projects in California.* Presented at Tiburon Center for Env Studies/et al Wetland Restoration Sym, Hayward, CA, Feb 1982, p. 1(10). not found

Kakimoto, H. (1979). *Artificial fish reefs in Japan Sea coastal regions.* In: Proceedings of the Seventh Japan-Soviet Joint Symposium on Aquaculture, September 1978, Tokyo and Tsuruga, Japan. Yamamoto, G., editor. p 103-109. Publisher(s): Tokai University, Tokyo (Japan); Ministry of Fisheries, Moscow (USSR); Tokai University Press, Tokyo (Japan).

Kaplan, E.; Royce, B.; Garrell, M.H.; Riedel, E.F.; Sathaye, J.; Rotarius, G.J. (1984). *Environmental assessment of enhanced oil recovery.* Miner. Envir. 6(2):54-65.

Kawasaki, Y.; Yamada, S.; Honda, M. (1988). *Development of technique for marine macrophyte bed creation in the coastal zone near Power Plant-10 method for eelgrass Zostera-marina l. bed creation by seedling.* Denryoku Chuo Kenkyusho Hokoku 0(U88030). I-IV, 1-21.

Kelley, K. (1988). *Seagrass replanting efforts may improve fisheries.* Natl. Fisherman 68(11):14-16.

Kentula, M.E. (1986). *Wetland rehabilitation and creation in the Pacific Northwest.* Ecol. Res. Ser., U.S. Environ. Prot. Agency, 29 pp. NTIS Number: PB86-241023/GAR. Report Number: EPA/600/D-86/183.

Kerley, G.I.H.; Crellin, C.G.; Erasmus, T. (1987). *Gravimetric determination of water-repellency in rehabilitated oiled seabirds.* Mar. Pollut. Bull. 18(11):609-611.

Kerley, G.I.H.; Erasmus, T. (1986). *Oil pollution of cape gannets: To clean or not to clean.* Mar. Pollut. Bull. 17(11):498-500.

Kerley, G.I.H.; Erasmus, T. (1987). *Cleaning and rehabilitation of oiled jackass penguins.* S. Afr. J. Wildl. Res. S.-Afr. Tydskr. Natuurnavors. 17(2):64-70.

Kerley, G.I.H.; Erasmus, T.; Mason, R.P. (1985). *Effect of moult on crude oil load in a jackass penguin Spheniscus demersus.* Mar. Pollut. Bull. 16(12):474-476.

Kikuch, K.; Sato, S.; Honda, M. (1987). *Development of the techniques for marine macrophyte bed creation in the coastal zone near a power plant the influence of environmental factors on the flowering shoot formation of Zostera-marina.* Denryoku Chuo Kenkyusho Hokoku 0(U86044):1-10.

Kooyman, G.; Costa, D. (1978). *The effects of oil on temperature regulation in sea otters.* In: Environmental assessment of the Alaskan continental shelf. Quarterly reports of principal investigators for April-June 1978. p 66-69. Publisher(s): U.S. National Oceanic and Atmospheric Administration, Boulder, CO, Environmental Research Laboratories.

Kooyman, G.L.; Costa, D.P. (1978). *Effects of oiling on temperature regulation in sea otters.* In: Environmental assessment of the Alaskan continental shelf. Annual reports of principal investigators for the year ending March 1978. Volume 7, effects. p 1-11. Publisher(s): US Environmental Research Laboratories, Boulder, CO. Outer Continental Shelf Environmental Assessment Program.

Kooyman, G.L.; Costa, D.P. (1979). *Effects of oiling on temperature regulation in sea otters.* In: Environmental assessment of the Alaskan continental shelf. Annual reports of principal investigators for the year ending March 1979, Volume 6, effects. p 1-26. Publisher(s): NOAA Environmental Research Labs, Boulder, CO (USA), Outer Continental Shelf Environmental Assessment Program.

Krebs, C.T.; Tanner C.E. (1981). *Restoration of oiled marshes through sediment stripping and Spartina propagation.* In: Parrotte, R.B., editor. Proceedings of the 1981 Oil Spill Conference, Atlanta, March 2-5, pp.375-385.

support for seagrass plantings.

Not scientific

found

not found

LaRoe, E.T. (1979). *The biological basis for estuarine ecosystem mitigation.* Presented at the Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats, Fort Collins, CO (USA), 16 Jul 1979. Gen. Tech. Rep., U.S. Dept. Agriculture Fort Collins, CO (USA). p. 90-92.

Laubier, L. (1980). *The Amoco Cadiz oil spill: An ecological impact study.* Ambio 9(6):268-276.

Le Moal, Y. (1980). *Ecological effect of the Amoco Cadiz oil pollution on littoral communities living on hard and soft substrata. (2nd year). Part 2: intensive study: Yveline Le Moal.* In: Ecological effect of the Amoco Cadiz oil pollution on littoral communities living on hard and soft substrata. (2nd year). Part 1: extensive study: Claude Chasse. Part 2: intensive study: Yveline Le Moal. Chasse, C.; Le Moal, Y., Universite de Bretagne Occidentale Brest (France)., 1980.

Le Moal, Y. (1983). *Ecological survey of beaches (after the Amoco Cadiz oil spill) on the northern coast of Brittany.* Etude de la Macrofaune du Microphytobenthos de la Meiofaune des Estrans et Etude des Chenaux des Abers. (Ecological Survey of Macrofauna, Microphytobenthos and Meiofauna of the Foreshore, and Survey of the Channels of the Abers Estuaries.), pp. 1-19. Report Number: Contract CNEXO82/2604.

Lee, W.Y.; Macko, S.A.; Nicol, J.A.C. (1981). *Changes in nesting behavior and lipid content of a marine amphipod (Amphithoe valida) to the toxicity of a no. 2 fuel oil.* Water Air Soil Pollut. 15(2):185-196.

Leppaekoski, E.J.; Lindstroem, L.S. (1978). *Recovery of benthic macrofauna from chronic pollution in the sea area off a refinery plant, Southwest Finland.* Recovery potential of oiled marine northern environments: Symposium papers. J.C. Stevenson, editor. Journal of the Fisheries Research Board of Canada 35(5):766-775.

Levasseur, J.; Durand, M.-A.; Jory, M.-L. (1981). *Biomorphologic and floristic aspects of the reconstitution of a phanerogamic vegetal cover, altered by the Amoco Cadiz oil spill and the following clean-up operations: Special study of the Ile-Grande Salt Marshes (Cotes du Nord).* Amoco Cadiz : Fates and Effects of the Oil Spill. Proceedings of the International Symposium. Centre Oceanologique de Bretagne, Brest (France). November 19-22, 1979, pp. 455-473. Report Number: ISBN 2-90272-09-9.

Levasseur, J.E.; Jory, M.L. (1982). *Natural recovery of salt-marsh vegetation destroyed by the Amoco Cadiz oil spill: Circumstances and tendencies.* NOAA/CNEXO Joint Scientific Commission Workshops: Physical, Chemical, and Microbiological Studies after the Amoco Cadiz Oil Spill Biological Studies after the Amoco Cadiz Oil Spill Charleston, SC (USA). Brest (France) 17 Sep 1981. 28 Oct 1981. Ecological Study of the Amoco Cadiz Oil Spill: Report of the NOAA-CNEXO Joint Scientific Commission. Gundlach, E.R.; Marchand, M., editors. Pages 329-362.

Levings, C.D. (compiler). (1980). *An account of a workshop on restoration of estuarine habitats.* Workshop on Restoration of Estuarine Habitats West Vancouver, B.C. and Nanaimo, B.C. (Canada) 19 Oct 1979. Can. Manuscr. Rep. Fish. Aquat. Sci. 36 p. not found

Leymann, G. (1983). *Reflections on the rehabilitation of damages caused by oil pollution in the central Baltic Sea.* Wasser Boden. 35(11):512-514.

Lindall, W.N., Jr.; Mager, A., Jr.; Thayer, G.W.; Ekberg, D.R. (1979). *Estuarine habitat mitigation planning in the southeast.* Presented at the Mitigation Symposium: a National Workshop on Mitigating Losses of Fish and Wildlife Habitats, Fort Collins, CO (USA), 16 Jul 1979. Gen. Tech. Rep. U.S. Dept. Agriculture Fort Collins, CO (USA). p. 129-135.

Linden, O.; Elmgren, R.; Boehm, P. (1979). *The Tsesis oil spill: Its impact on the coastal ecosystem of the Baltic Sea.* Ambio 8(6):244-253.

Linden, O.; Elmgren, R.; Westin, L.; Kineman, J. (1978?). *Scientific summary and general discussion.* In: The Tsesis oil spill. Report of the first year scientific study (October 26, 1977, to December, 1978) - a cooperative international investigation. Kineman, J.J.; Elmgren, R.; Hansson, S., editors. p 43-58. NOAA/Outer Continental Shelf Environmental Assessment Program Boulder, CO (USA). Mar 1980.

Linkins, A.E.; Johnson, L.A.; Everett, K.R.; Atlas, R.M. (1984). *Oil spills: Damage and recovery in tundra and taiga.* Restoration of Habitats Impacted by Oil Spills Symposium, Blacksburg, VA (USA), 9-11 Nov 1981. Cairns, J., Jr.; Buikema, A.L., editors. Pages 135-156. Report Number: ISBN 0-250-40551-2.

Little, A.E. (1983). *A resurvey of rocky shore transects in Milford Haven, January - April 1979: Comparisons with data collected from 1961-1978.* Publisher(s): Oil Pollution Research Unit, Pembroke (UK), 1983. 241 pp., Published in 2 Volumes. Report Number: FSC(OPRU)/6/83.

Lum, A.L. (1978). *Shorebird fauna changes of a small tropical estuary following habitat alteration: Biological and political impacts of environmental restoration.* Environmental Management 2(5):423-430.

Lutz, R.E.; Meck, J.P. (1977). *Recovering for marine life damage: Legal aspects of allocating social costs and protecting public interests.* Presented at the Oil Spill Conference, New Orleans, LA (USA), 8 Mar 1977. Publisher(s): American Petroleum Inst., Washington, DC (USA), pp. 11-14. Report Number: API 4284.

Mackie, P.R.; Hardy, R.; Whittle, K.J. (1978). *Preliminary assessment of the presence of oil in the ecosystem at Ekofisk after the blowout, April 22-30, 1977.* Presented at the Symposium on Recovery Potential of Oiled Marine Northern Environments, Halifax (Canada), 10 Oct 1077. J. Fish. Res. Board Can. 35(5):544-551.

Maiero, D.J.; Castle, R.W.; Crain, O.L. (1978). *Protection, cleanup and restoration of salt marshes endangered by oil spills: A procedural manual.* United Research Services, San Mateo, CA (USA). Contract No. EPA-68-03-2160. found

Mair, J.McD.; Matheson, I.; Appelbee, J.F. (1987). *Offshore macrobenthic recovery in the Murchison Field following the termination of drill-cuttings discharges.* Mar. Pollut. Bull. 18(12):628-634.

Mann, K.H. (1978). *A biologist looks at oil in the sea.* Shore And Beach 46(4):27-29.

Mann, K.H.; Clark, R.B. (1977). *Session 3. Summary and overview: Long-term effects of oil spills on marine intertidal communities.* Presented at the Symposium on Recovery Potential of Oiled Marine Northern Environments, Halifax (Canada), 10 Oct 1977. J. Fish. Res. Board Can. 35(5):791-795.

Marcus, M.D.; Bergman, H.L.; Stoller, D.A.; Brown, S.K.; Molhot, P.A. (1980). *Bibliography of aquatic ecosystem effects: Analytical methods and treatment technologies for organic compounds in advanced fossil-fuel processing effluents.* Ecol. Res. Series. Environmental Protection Agency, Duluth, MN (USA). Office of Research and Development. 362 p.

Maynard, N.G. (1984). *Effects of petroleum residues on intertidal organisms of Bermuda.* Publisher(s): American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005. Report Number: API 4355.

McGill, W.B. (1977). *Soil restoration following oil spills - A review.* J. Can. Pet. Technol. 16(2):60-67.

McIntyre, D. (1983?). *Underground oil spill investigation and cleanup.* API/EPA/USCG Oil Spill 8th Conf, San Antonio, Feb 28-Mar 3, 1983, p. 393(4).

McKell, C.M.; van Epps, G. (1980). *Vegetative rehabilitation of arid land disturbed in the development of oil shale and coal.* NTIS Report Number: PB80-189541, APR 1980. (50).

McVay, M.E.; Heilman, P.E.; Greer, D.M.; Brauen, S.E.; Baker, A.S. (1980). *Tidal freshwater marsh establishment on dredge spoils in the Columbia River Estuary.* J. Environ. Qual. 9(3):488-493.

Meade, N.F. (1981). *The Amoco Cadiz oil spill: An analysis of emergency response clean-up and environmental rehabilitation costs.* Presented at OECD Cost of Oil Spills Conf, France, Jun 16-18, 1981, p. 130(18).

Michaelis, F.B. (1983). *Effect of Turoa oil spill on aquatic insects in the Mangawhero River system.* N.Z. Entomol. 7(4):447-455.

Mickelson, P.G.; Schamel, D.; Tracy, D.; Ionson, A. (1977). *Avian community ecology at two sites on Espenberg Peninsula in Kotzebue Sound, Alaska.* In: Environmental assessment of the Alaskan continental shelf. Volume 5. receptors--birds. U.S. National Oceanic and Atmospheric Administration, Boulder, CO. Environmental Research Laboratories, Mar 1977, p. 1-74. Contract No. 03-5-022-56. Report Number: NOAA/ERL-AR-77-5.

Moldan, A.; Chapman, P.; Fourie, H.O. (1979). *Some ecological effects of the Venpet-Venoil collision.* Marine Pollution B 10(2):60(4).

Moore, S.F. (1976). *Oil spills and the marine environment.* Technology Review, Feb 1976, 78(4):61(8).

Moore, S.F.; Chirlin, G.R.; Puccia, C.J.; Schrader, B.P. (1974). *Potential biological effects of hypothetical oil discharges in the Atlantic Coast and Gulf of Alaska.* NTIS Report COM-74-11089, Apr 1, 1974, 206 p.

Mozley, S.C.; Butler, M.G. (1978). *Arctic effects of crude oil on aquatic insects of tundra ponds.* Presented at the Workshop on Ecological Effects of Hydrocarbon Spills in Alaska, Woods Hole, MA (USA), 8 Apr 1978.

Newell, B.S. (1981). *Restoration of Lake Wellington – a multi-objective experiment.* Aust. Fish. 40(5):19-21.

Nichols, A.B. (1989). *Alaskan oil spill shocks the nation.* WPCF J, Jul 1989, 61(7):1174(12).

Niedzialkowski, D.M.; Kerr, R.L. (1988). *Wetlands mitigation banking: Planning for protection of environmental values.* Proceedings of the Symposium on Coastal Water Resources Wilmington, NC (USA). Lyke, W.L.; Hoban, T.J., editors. Tech. Publ. Ser. Am. Water Resour. Assoc. Pages 789-790. Report Number: TPS-88-1.

Niesen, T.M.; Lyke, E.B. (1981). *Pioneer infaunal communities in the Hayward Salt Marsh restoration (San Francisco Bay).* 6th Biennial International Estuarine Research Conference, Gleneden Beach, OR (USA), 1-5 Nov 1981. Estuaries 4(3):243. Summary only.

Niewolak, S. (1978). *Microbiological aspects of restoration of cultivated soils contaminated with crude oil.* Wiad Ekol 24(2):109-118.

Nulty, P. (1989). *The future of big oil.* Fortune, May 8, 1989, 119(10):46(4).

O'Brien, P.Y.; Dixon, P.S. (1976). *The effects of oils and oil components on algae a review.* Br. Phycol. J. 11(2):115-142.

O'Farrell, T.P.; Mitchell, D.L. (1985). *Habitat restoration plan for Naval Petroleum Reserve No. 1, Kern County, California.* Sponsor: Department of Energy, Washington, DC. Report No.: EGG-10282-2081. 68 pp. NTIS Number: DE86007008/XAB . Contract No.: AC08-83NV10282. ✓ not found

Oviatt, C.; Frithsen, J.; Gearing, J.; Gearing, P. (1982). *Low chronic additions of no. 2 fuel oil: Chemical behavior, biological impact and recovery in a simulated estuarine environment.* Mar. Ecol. (Prog. Ser.). 9(2):121-136.

Owens, E.H.; Rashid, M.A. (1976). *Coastal environments and oil spill residues in Chedabucto Bay Nova Scotia Canada.* Can. J. Earth. Sci. 13(7):908-928.

Owens, E.H.; Robillard, G.A. (1981). *Spill impacts and shoreline cleanup operations on Arctic and sub-Arctic coasts.* Presented at EPA/API/USCG 1981 Oil Spill Conf, Atlanta, Mar 2-5, 1981, p. 305(5).

Pain, S. (1989). *Alaska has its fill of oil.* New Scientist, Aug 12, 1989, 123(1677):34(7).

Palmer, H.V.R., Jr. (1972). *Falmouth's oiled shellfish beds being restored.* National Fisherman 53(4):C10, August 1972. ✓

Pasquet, R. (1981). *Effectiveness and cost of onshore techniques to control the accidental pollution of the sea by oil.* Presented at OECD Cost of Oil Spills Conf, France, Jun 16-18, 1981, p. 112(18).

Perna, A.J.; Wayne, T.J. (1970). *Effects, recovery, reuse of oil from aqueous environments.* Conf at Univ of Rhode Island, Jul 21-23, 1970, p. 232(12).

Perry, M.C.; Ferrigno, F.; Settle, F.H. (1978). *Rehabilitation of birds oiled on two Mid-Atlantic estuaries.* Proceedings of the 32nd Annual Conference Southeastern Association of Fish and Wildlife Agencies, Hot Springs, VA (USA), 5 Nov 1978, 32:318-325.

Petersen, J.A. (1984). *Establishment of mussel beds: Attachment behavior and distribution of recently settled mussels (Mytilus californianus).* Veliger 27(1):7-13. ✓

Phillips, R.C. (1980). *Transplanting methods.* In: Handbook of seagrass biology: An ecosystem perspective. Phillips, R.C.; McRoy, C.P., editors. p 41-56. Publisher(s): Garland STPM New York, NY (USA).

Prince, E.D.; Maughan, O.E. (1978). *Freshwater artificial reefs: biology and economics.* Fisheries, 3(1):5-9.

Prince, E.D.; Maughan, O.E.; Prouha, P. (1977). *How to build a freshwater artificial reef.* Sea Grant Rep. Virginia Polytechnic Inst. Publisher(s): VPI, Blacksburg, VA (USA), 2nd edition. 17p. Report Number: VPI-SG-77-02.

Proskurenko, I.V. (1977). *The planning of technical facilities in mariculture.* In: Proceedings of the Fifth Japan-Soviet Joint Symposium on Aquaculture, September 1976, Tokyo and Sapporo, Japan. Motoda, S., editor. p. 297-304. Presented at the 5th Japan-Soviet Joint Symposium on Aquaculture, Tokyo (Japan), 14 Sep 1976; Sapporo (Japan), 15 Sep 1976. Publisher(s): Tokai University, Tokyo (Japan), Mar 1977.

Putwain, P.D.; Gillham, D.A.; Holliday, R.J. (1982). *Restoration of heather moorland and lowland heathland, with special reference to pipelines.* Env Conservation, Autumn 1982, 9(3):225(11).

Race, M.S. (1985). *Critique of present wetlands mitigation policies in the United States based on an analysis of past restoration projects in San Francisco Bay.* Environ. Manage. 9(1):71-82.

Race, M.S. (1986). *Wetlands restoration and mitigation policies: Reply.* Environ. Manage. 10(5):571-572.

Radecki, E.A.; Matson, C.; Brenoel, M.R. (1987). *Enhanced natural degradation of a shallow hydrocarbon contaminated aquifer.* Haztech Intl (Pudvan) Conf, St. Louis, Aug 26-28, 1987, p. 331(11).

Radvanyi, A. (1980). *Control of small mammal damage in the Alberta Canada oil Sands Reclamation and AF Forestation Program.* For Sci 26 (4):687-702.

Randall, R.M.; Randall, B.M.; Bevan, J. (1980). *Oil pollution and penguins is cleaning justified?.* Mar. Pollut. Bull. 11(8):234-237.

Range, J.D.; Feller, M.A. (1979?). *Congressional perspectives on the need for estimating environmental damage from oil and hazardous waste spills.* Presented at US Fish & Wildlife Service Pollution Response Conf, St. Petersburg, May 8-10, 1979, p. 157(5).

Rauta, C.; Zarioiu, V.; Creanga, I.; Petre, N.; Kaszoni, E.; Carstea, S.; Mihalache, G. (1987). *Preliminary research concerning the technology for bringing under agricultural use some soils polluted with petroleum residues.* An Inst Cercet Pedol Agrochim 47(0):211-220.

Redente, E.F.; Cook, C.W. (1982). *Revegetation studies on oil shale related disturbances in Colorado.* Sponsor: Department of Energy, Washington, DC. Report Number: DOE/EV/04018-6. 90 pp. NTIS Number: DE82020140 . Contract No.: AC02-76EV04018.

Relini, G.; Moretti, S. (1986). *Artificial reef and Posidonia bed protection off Loano (western Ligurian Riviera).* Tech. Consult. of the General Fisheries Council for the Mediterranean on Open Sea Shellfish Culture In Association with Artificial Reefs Ancona (Italy). FAO Fish. Rep. No. 357. Report of the Technical Consultation of the General Fisheries Council for the Mediterranean on Open Sea Shellfish Culture in Association with Artificial Reefs, Ancona, Italy, 17-19 March, 1986, pp. 104-108. Report Number: ISBN 92-5-0024550-X.

Renaud-Mornant, J.; Gourbault, N. (1980). *Survival of meiofauna after the Amoco Cadiz oil spill (Morlaix Channel and Roscoff Beach, Brittany, France).* Bull. Mus. Natl. Hist. Nat. (France) (4E Ser.) (A Zool. Biol. Ecol. Anim.) 2(3):759-772.

Rice, S.D.; Korn, S.; Karinen, J.F. (1979). *Lethal and sublethal effects on selected Alaskan marine species after acute and long-term exposure to oil and oil components.* In: Environmental assessment of the Alaskan continental shelf. Annual reports of principal investigators for the year ending March 1979, Volume 6, effects. p 27-59. Publisher(s): NOAA Environmental Research Labs, Boulder, CO (USA), Outer Continental Shelf Environmental Assessment Program.

Robers, R. (1987). *Beaufort Sea Sale 97, Alaska outer continental shelf, final environmental impact statement. Volume 1.* OCS/EIS/EA/MMS-87-0069-VOL-1. 485 pp. NTIS Number: PB88-118625/GAR. Report Number: MMS/AK/EIS-87/001.

Roland, J.V.; Moore, G.E.; Bellanca, M.A. (1977). *The Chesapeake Bay oil spill - February 2, 1976: A case history.* Presented at the Oil Spill Conference, New Orleans, LA (USA), 8 Mar 1977. Publisher(s): American Petroleum Inst., Washington, DC (USA) . Report Number: API 4284, p. 523-527.

Sabourin, T.D.; Tullis, R.E. (1981). *Effect of three aromatic hydrocarbons on respiration and heart rates of the mussel, Mytilus californianus.* Bull. Environ. Contam. Toxicol. 26(6):729-736.

Samuels, W.B.; Ladino, A. (1984). *Calculations of seabird population recovery from potential oilspills in the Mid-Atlantic Region of the United States.* Ecological Modelling, Jan 1984, 21(1-2):63(22). not found

Samuels, W.B.; Lanfear, K.J. (1982). *Simulations of seabird damage and recovery from oilspills in the northern Gulf of Alaska.* J Env Management, Sep 1982, 15(2):169(14). found

Sanders, H.L. (1977). *The West Falmouth spill Florida 1969.* Oceanus 20(4):15-24.

Schiegg, H-O. (1980). *Field infiltration as a method for the disposal of oil-in-water emulsions from the restoration of oil-polluted aquifers.* Water Research 14(8):1011(6).

Schneider, K. (no date). *Sex and age segregation in Alaskan sea otter populations.* Presented at the 2nd Conf. on the Biology of Marine Mammals, San Diego, CA (USA), 12 Dec 1977.

Scoones, I. (1988). *Ecological impact assessment: The case of onshore oil in Britain.* J Env Management, Jul 1988, 27(1):11(13).

Seaman, W., Jr.; Aska, D.Y. (1986). *The Florida reef network: Strategies to enhance user benefits.* Artificial Reefs -- Marine and Freshwater Applications. D'Itri, F.M., editor. Pages 545-561. Report Number: ISBN 0-87371-010-X.

Segal, W.; Mancinelli, R.L. (1987). *Extent of regeneration of the microbial community in reclaimed spent oil shale land.* J Environ Qual 16(1):44-48.

Seip, K.L. (1984). *The Amoco Cadiz oil spill -- At a glance.* Marine Pollution Bulletin 15(6)(June):218.

Seneca, E.D.; Broome, S.W. (1982). *Restoration of marsh vegetation impacted by the Amoco Cadiz oil spill and subsequent cleanup operations at Ile Grande, France.* NOAA/CNEXO Joint Scientific Commission Workshops: Physical, Chemical, and Microbiological Studies after the Amoco Cadiz Oil Spill Biological Studies after the Amoco Cadiz Oil Spill Charleston, SC (USA). Brest (France) 17 Sep 1981. 28 Oct 1981. Ecological Study of the Amoco Cadiz Oil Spill: Report of the NOAA-CNEXO Joint Scientific Commission. Gundlanch, E.R.; Marchand, M., editors. Pages 363-420.

Senner, S.E. (1989). *The Exxon Valdez oil spill: First impressions and commentary.* Am Birds 43(2):218-220.

Sheehy, D.J. (1979). *Fisheries Development: Japan.* Water Spectrum 12(1):1-9.

Sheehy, D.J. (1986). *New approaches in artificial reef design and applications.* Artificial Reefs -- Marine and Freshwater Applications. D'Itri, F.M., editor. Pages 253-263. Report Number: ISBN 0-87371-010-X.

Sherry, J.P. (1984). *The impact of oil and oil-dispersant mixtures on fungi in freshwater ponds.* Science of the Total Env, Apr 19, 1984, 35(2):149(19).

Shilova, I.I. (1977). *Primary plant successions on technogenic sand outcrops in oil and gas producing regions in the Central Ob' Valley.* Soviet Journal of Ecology 8(6):475-482.

Shin, P.K.S. (1989). *Effects of a spill of Bunker oil on the marine biological communities in Hong Kong.* Environ Int 14(6):545-552.

Shtina, E.A.; Shilova, I.I.; Neganova, L.B.; El'Shina, T.A. (1986). *Effect of methods for the biological recultivation of oil-polluted lands on soil algoflora in taiga.* Ekologiya 0(2):23-30.

Simmons, C.L.; Everett, K.R.; Linkins, A.E.; Webber, P.J.; Walker, D.A. (1983). *Sensitivity of plant communities and soil flora to seawater spills, Prudhoe Bay, Alaska.* NTIS, Springfield, VA (USA) Number: AD-A136 619/4.

Small, J. (1978). *Separating oil from sea birds: Giving witness or saving lives.* Oceans, 11(4):59-61.

Sogard, S.M. (1989). *Colonization of artificial seagrass by fishes and decapod crustaceans importance of proximity to natural eelgrass.* J Exp Mar Biol Ecol 133(1-2):15-38.

Soule, D.F.; Oguri, M.; Dawson, J.K.; Osborn, R.; McGlade, L.R.; Feldmeth, C.R.; Wicksten, M.K.; Soule, J.D.; Smith, R.W.; Dabelstein, D.; Kurtz, S.; Edmands, F. (1978?). *The significance of the Sansinena incident.* Univ. of Southern California, Allan Hancock Foundation 139, Inst. for Marine and Coastal Studies, Harbors Environmental Projects, Los Angeles, CA 90007. Energy/environment '78: A symposium on energy development impacts Los Angeles, CA Aug. 22-24, 1978. In: Energy/environment '78: A symposium on energy development impacts: Proceedings. J. Siva-Lindstedt, editor. p. 295.

Southward, A.J. (1982). *An ecologist's view of the implications of the observed physiological and biochemical effects of petroleum compounds on marine organisms and ecosystems.* The Long-Term Effects of Oil Pollution on Marine Populations, Communities and Ecosystems, London (UK), 28-29 Oct 1981. Philos. Trans. R. Soc. Lond. Ser. B. 297(1087):241-255.

Southward, A.J.; Southward, E.C. (1978). *Recolonization of rocky shores in Cornwall after use of toxic dispersants to clean up the Torrey Canyon spill.* Presented at the Symposium on Recovery Potential of Oiled Marine Northern Environments, Halifax (Canada), 10 Oct 1977. J. Fish. Res. Board Can. 35(5):682-706.

Stevenson, J.C. (1978). *Recovery potential of oiled marine northern environments: Symposium papers.* Journal of the Fisheries Research Board of Canada 35(5):499-795.

Stikney, R.R.; Dodd, J.D. (1979). *Artificial propagation of a salt marsh.* Sea Front. 25(3):173-179.

Straube, M. (1989). *Is full compensation possible for the damages resulting from the Exxon Valdez oil spill?.* Env Law Reporter, Aug 1989, 19(8):10338(13).

Straughan, D. (1978). *Biological studies of the Metula oil spill.* Presented at the Conference on Assessment of Ecological Impacts of Oil Spills, Keystone, CO (USA), 14 Jun 1978. American Institute of Biological Sciences (USA). p. 365-377.

Subrahmanyam, C.B. (1984). *Macroinvertebrate colonization of the intertidal habitat of a dredge spoil island in North Florida.* Northeast Gulf Sci. 7(1):61-76.

Swift, W.H.; Touhill, C.J.; Haney, W.A.; Nakatani, R.E.; Peterson, P.L. (1969). *Review of Santa Barbara Channel oil pollution incident.* (Water pollution control research series). Report No.: USCG-794102/003 or FWPCA-15080-EAG-07/69; W70-06320. 165p. Also available as Water Pollution Control Research Series DAST-20. NTIS Number: AD-726 156 or PB-191 712. Contract No.: FWPCA-14-12-530 or DI-14-12-530.

Swift, W.H.; Touhill, C.J.; Templeton, W.L.; Roseman, D.P. (1969). *Oil spillage prevention control and restoration state of the art and research needs water pollution.* J Water Pollut Contr Fed 41(3-1):392-412.

Sylva, D.P. de (1982). *Potential for increasing artisanal fisheries production from floating artificial habitats in the Caribbean.* Proceedings of the 34th Annual Gulf and Caribbean Fisheries Institute, Mayaguez, PR (USA), Nov 1981, (34):156-167.

Tagatz, M.E.; Tobia, M. (1978). *Effect of barite ($BaSO_4$) on development of estuarine communities.* Estuar. Coast. Mar. Sci. 7(4):401-407.

Taylor, W.E. (1983). *Restoration of oil well drilling sites.* American Soc Agri Engineers Reclamation of Disturbed Lands Conf, Bozeman, MT, Jun 26-29, 83(12).

Thayer, G.W.; Fonseca, M.S.; Kenworthy, W.J. (1982). *Restoration and enhancement of seagrass meadows for maintenance of nearshore productivity.* International Symposium on Utilization of Coastal Ecosystems: Planning, Pollution and Productivity, Rio Grande (Brazil), 22 Nov 1982. Fundacao Univ. Rio Grande (Brazil) Duke Univ. Mar. Lab., Beaufort, NC (USA). Atlantica 5(2):118-119. Special issue. Summary only.

Thomas, M.L.H (1977). *Long-term biological effects of Bunker C oil in the intertidal zone.* In: Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms: Proceedings of a symposium held at the Olympic Hotel, Seattle, WA (USA) on 10-12 Nov 1976. Wolfe D.A., editor. Pergamon New York NY (USA) 1977. p. 238-246. Report Number: ISBN 0-08-021613-7.

Thorhaug, A. (1979). *Mitigation of estuarine fisheries nurseries: seagrass restoration.* Presented at the Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats Fort Collins, CO (USA) 16 Jul 1979. Gen. Tech. Rep. U.S. Dept. Agriculture, Fort Collins, CO (USA). p 667-669.

Thorhaug, A. (1980). *Restoration of seagrass communities: Strategies for lessening man's impact on nearshore marine resources.* Tropical Ecology and Development. Proceedings of the 5th International Symposium of Tropical Ecology, 16-21 April 1979, Kuala Lumpur, Malaysia. Part 2. Furtado, J.I., editor. Pages 1199-1206.

Thorhaug, A. (1983). *Habitat restoration after pipeline construction in a tropical estuary: Seagrasses.* Mar. Pollut. Bull. 14(11):422-425.

Thorhaug, A. (1986). *Review of seagrass restoration efforts.* Ambio 15(2):110-117. ✓ not found

Thorhaug, A.; Miller, B.; Jupp, B.; Bookers, F. (1985). *Effects of a variety of impacts on seagrass restoration in Jamaica.* Mar. Pollut. Bull. 16(9):355-360.

Thorhaug, A.; Miller, B.; Rose, D. (1983). *Restoration of seagrasses in Jamaica: Preliminary summary of Jamaica's management of seagrass restoration.* Seventeenth Meeting of the Association of Island Marine Laboratories of the Caribbean Miami, FL (USA) 16 May 1983. Proc. Assoc. Isl. Mar. Lab. Caribb. 17:10. Summary only.

Thorsteinson, L.K. (1984). *North Aleutian shelf environment and possible consequences of offshore oil and gas development.* Proceedings of a Synthesis Meeting held at Anchorage, Alaska on March 9-11, 1982. North Aleutian Shelf Environment and Possible Consequences of Offshore Oil and Gas Development: Synthesis Meeting Anchorage, AK (USA) 9-11 Mar 1982. National Ocean Serv., Rockville, MD (USA). Off. of Oceanography and Mar. Serv., 178 pp. NTIS Order No.: PB84-209428. Report Number: NOAA-84061404.

Tyler, J. (1981). *Materials placement procedures--surface to bottom transfer.* Artificial Reefs: Proceedings of a Conference held September 13-15, 1979, in Daytona Beach, FL. Aska, D.Y., editor. Rep. Fla. Sea Grant Program. Pages 106-109. Report Number: FSG-R-41.

UK Offshore Operations Association, London, UK; DOE, London, UK; MAFF, London, UK (1983). *Environmental effects of oil based mud cuttings.* Publisher(s): UK Offshore Operators Assoc., London (UK), 124 pp.

URS Research Co., San Mateo, CA (1970). *Evaluation of selected earthmoving equipment for the restoration of oil-contaminated beaches.* Water pollution control research series, 29 Aug 69 - 1 Jul 70. Report No.: W72-04296; EPA-15080-EOS-10/70. 174 p. NTIS Number: PB-206 693. Contract No.: EPA-15080-EOS.

URS Research Co., San Mateo, CA (1970). *Preliminary operations planning manual for the restoration of oil-contaminated beaches.* Water pollution control research series. Report No.: W70-06319; FWPCA-15080-EOS-3/70. 76p. NTIS Number: PB-191 711. Contract No.: DI-14-12-811.

van Gelder-Ottway, S. (1975). *Some physical and biological effects of oil films floating on water.* Presented at Inst of Petroleum/Field Studies Council Meeting on Marine Ecology and Oil Pollution, Scotland, Apr 21-23, 1975, p. 255(32).

Vanderhorst, J.R.; Blaylock, J.W.; Wilkinson, P.; Wilkinson, M.; Fellingham, G. (1980). *Recovery of Strait of Juan de Fuca intertidal habitat following experimental contamination with oil.* NTIS, Springfield, VA Number: PB81-112518.

Vandermeulen, J.H. (1977). *The Chedabucto Bay Spill-Arrow, 1970.* Oceanus 20(4):31-39.

Vandermeulen, J.H. (1978). *Introduction to the Symposium on Recovery Potential of Oiled Marine Northern Environments.* Presented at the Symposium on Recovery Potential of Oiled Marine Northern Environments, Halifax (Canada), 10 Oct 1977. J. Fish. Res. Board Can. 35(5):505-508.

Vandermeulen, J.H.; Buckley, D.E.; Levy, E.M.; Long, B.; McLaren, P.; Wells, P.G. (1978). *Immediate impact of Amoco Cadiz environmental oiling: Oil behavior and burial, and biological aspects.* One day session Amoco Cadiz Brest, France Jun 7, 1978. Centre National pour l'Exploitation des Oceans. Actes de Colloques No. 6, pp. 159-173. ISSN: 0335-8259.

Vanloocke, R.; Berlinde, A-M.; Berstraete, W.; de Borger, R. (1979). *Microbial release of oil from soil columns.* Environ Sci Technol 13(3):346-348.

Vervalin, C.H. (1989). *Bioremediation on the move.* Hydrocarbon Processing-International, Aug 1989, 68(8):50(3).

Wagenet, R.J.; McKell, C.M.; Malek, A.; Fransway, D.F. (1982). *Hydrologic properties of processed oil shale.* Reclamation & Revegetation Research, Jun 1982, 1(1):33(18).

Wallenberg, B. (1977). *The Ekofisk accident: Its environmental and political implications.* OECD Observer 88:9-12.

Walsh, W.J. (1985). *Reef fish community dynamics on small artificial reefs: The influence of isolation, habitat structure, and biogeography.* Bull. Mar. Sci. 36(2):357-376.

Ward, D.M.; Winfrey, M.R.; Beck, E.; Boehm, P. (1982). *Amoco Cadiz pollutants in anaerobic sediments: Fate and effects on anaerobic processes.* NOAA/CNEXO Joint Scientific Commission Workshops: Physical, Chemical, and Microbiological Studies after the Amoco Cadiz Oil Spill Biological Studies after the Amoco Cadiz Oil Spill Charleston, SC (USA). Brest (France) 17 Sep 1981. 28 Oct 1981. Ecological Study of the Amoco Cadiz Oil Spill: Report of the NOAA-CNEXO Joint Scientific Commission. Gundlach, E.R.; Marchand, M., editors. Pages 159-190.

Watanabe, Y.; Terawaki, T. (1986). *Development of techniques for marine macrophyte bed creation in the coastal zone near a power plant. 6. Assessment of a transplanting method to prevent the eelgrass Zostera-marina L. from being washed away.* Denryoku Chuo Kenkyusho Hokoku 0(U86008). I-III, 1-16.

Whitlatch, R.B.; Zajac, R.N. (1985). *Biotic interactions among estuarine infaunal opportunistic species.* Mar. Ecol. (Prog. Ser.) 21(3):299-311.

Whittle, K.J.; Mackie, P.R.; Farmer, J.; Hardy, R. (1978). *The effects of the Ekofisk blowout on hydrocarbon residues in fish and shellfish.* Presented at the Conference on Assessment of Ecological Impacts of Oil Spills, Keystone, CO (USA), 14 Jun 1978. American Institute of Biological Sciences (USA). p 541-559.

Wilcox, C.G. (1986). *Comparison of shorebird and waterfowl densities on restored and natural intertidal mudflats at Upper Newport Bay, California, USA.* Colonial Waterbirds 9(2):218-226.

Wilde, P.A.W.J. de; Kuipers, B.R. (1977). *A large indoor tidal mud-flat ecosystem.* Helgol. Wiss. Meeresunters. 30(1-4):334-342.

Williams, A.S. (1977). *Current methods of oiled bird rehabilitation.* Presented at the Oil Spill Response Workshop, Metairie, LA (USA), 15 Feb 1977. In: Proceedings of the 1977 Oil Spill Response Workshop. Fore, P.L., editor. p 125-134. Publisher(s): U.S. Fish and Wildlife Service, Biological Services Program NSTL Station, MS.

Williams, A.S.; Brundage, S.C.; Anderson, E. (1978). *Saving oiled seabirds: A manual for cleaning and rehabilitating oiled waterfowl.* American Petroleum Institute Washington, DC (USA). 35 p.

Williams, T.D. (1978). *Chemical immobilization, baseline hematological parameters and oil contamination in the sea otter.* Final Report to Marine Mammal Commission, Washington, DC. Report Number: MMC-77/06. 33 p. NTIS Number: PB-283 969/4 . Contract No.: MM7AD094.

Williams, T.M.; Kastelein, R.A.; Davis, R.W.; Thomas, J.A. (1988). *The effects of oil contamination and cleaning on sea otters Enhydra-Lutris l. thermoregulatory implications based on pelt studies.* Can J Zool 66(12):2776-2781.

Williams, U.P.; Kiceniuk, J.W. (1987). *Feeding reduction and recovery in cunner Tautogolabrus adspersus following exposure to crude oil.* Bull. Environ. Contam. Toxicol. 38(6):1044-1048.

Wilson, T.C.; Krenn, S.J. (1986). *Construction and evaluation of an artificial reef designed to enhance nearshore rockfish production.* Oceans '86 Conference Record: Science-Engineering-Adventure, Washington, DC (USA), 23-25 Sep 1986. Volume 2. Data Management, Instrumentation and Economics, pp. 547-551. Report Number: IEEE-86CH2363-0.

Woodward, D.F.; Riley, R.G.; Henry, M.G.; Meyer, J.S.; Garland, T.R. (1985). *Leaching of retorted oil shale: Assessing the toxicity to Colorado squawfish, fathead minnows, and two food-chain organisms.* Trans. Am. Fish. Soc. 114(6):887-894.

Wyers, S.C.; Frith, H.R.; Dodge, R.E.; Smith, S.R.; Knap, A.H.; Sleeter, T.D. (1986). *Behavioral effects of chemically dispersed oil and subsequent recovery in Diploria-strigosa.* Mar Ecol (Publ Stn Zool Napoli I) 7(1):23-42.

Young, C. (1988). *Instant reefs.* Fins. 21(2):12-17.

Zedler, J.B. (1984). *Salt marsh restoration: a guidebook for Southern California.* California Sea Grant Report T-CP-009, 1984, (51).

Zentner, J. (1985). *Wetland restoration in coastal California: A decade of management lessons.* 8th Biennial International Estuarine Research Conference, Durham, NH (USA), 28 Jul 1985. Estuaries 8(2B):30A.

Zieman, J.C.; Orth, R.A.; Phillips, R.C.; Thayer, G.; Thorhaug, A. (1984). *The effects of oil on seagrass ecosystems.* Restoration of Habitats Impacted by Oil Spills Symposium, Blacksburg, VA (USA), 9-11 Nov 1981. Restoration of Habitats Impacted by Oil Spills. Cairns, J., Jr., Buikema, A.L., editors. Pages 37-64. Report Number: ISBN 0-250-40551-2.

Oil Spill Public Info.   WLN LaserCat V5.04   Holdings Display
Page 1

Title: The Campbell River Estuary : a report on the design, construction and preliminary follow-up study findings of intertidal marsh islands created for purposes of estuarine rehabilitation /

Publisher: Fisheries and Oceans, Canada, 1984. [cn 87-070000]

Call #: AkAOS   QH106.2.B8B38

RPWG
R

ALL   BROWSE "campbell river estuary   "   - End -
F1-Help F2-Return   F3-Loan Req   F4-Copy Req   F5-Brief Recs   PgUp PgDn Home
F6-Full   F8-MARC Recs   F9-Lib Name   F10-Print   ESC-New Search

Fisheries and Oceans Pêches et Océans
Michael J. Brownlee
Sr. Program Biologist
Fisheries/Forestry
Habitat Management Division
Fisheries Branch
555 W. Hastings Street
Vancouver, B.C.
V6B 5G3
(604) 666-3541
Facs: (604) 666-3450
Canada

92

The Campbell River Estuary: A Report on the Design, Construction and Preliminary Follow-up Study Findings of Intertidal Marsh Islands Created for Purposes of Estuarine Rehabilitation

Compiled by:
M.J. Brownlee, E.R. Mattice & C.D. Levings

Habitat Management Division
Field Services Branch
Department of Fisheries and Oceans
Vancouver, B.C.
V6E 2P1

August 1984

Canadian Manuscript Report of
Fisheries and Aquatic Sciences
No. 1789

Fisheries and Oceans Pêches et Océans
Canada

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901-1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. Numbers 1426-1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 1789

August 1984

The Campbell River Estuary: A Report on the Design, Construction and Preliminary Follow-up Study Findings of Intertidal Marsh Islands Created for Purposes of Estuarine Rehabilitation

Compiled by:

M.J. Brownlee - Senior Project Manager
Habitat Management Division
Department of Fisheries and Oceans

E.R. Mattice - Assistant Logging Manager,
British Columbia Forest Products, Campbell River

C.D. Levings - Research Scientist,
Fisheries Research Branch
Department of Fisheries and Oceans

Habitat Management Division
Field Services Branch
Department of Fisheries and Oceans
Vancouver, B.C.
V6E 2P1

Cat. No. Fs. 97-4/1789E ISSN 0706-6473

Correct citation for this publication:

Brownlee, M.J., E.R. Mattice and C.D. Levings. 1984. The Campbell River Estuary: a report on the design, construction and preliminary follow-up study findings of intertidal marsh islands created for purposes of estuarine rehabilitation. Can. MS Rep. Fish. Aquat. Sci. 1798 : 54 pp.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont.)

ABSTRACT

Brownlee, M.J., E.R. Mattice and C.D. Levings. 1984. The Campbell River Estuary: a report on the design, construction and preliminary follow-up study findings of intertidal marsh islands created for purposes of estuarine rehabilitation. Can. MS Rep. Fish. Aquat. Sci. 1789: 54pp.

This report focuses on the cooperative efforts of agency staff, members of industry and the public in developing and constructing a new log-handling facility and rehabilitating an industrialized estuarine area of approximately 32 hectares that had been intensively utilized for log handling activities for over 75 years. Reported are the planning and construction of the new dryland log sorting facility and the rehabilitative measures, the design details and preliminary results of the first year's studies of a longer term program being undertaken to assess the stability and biological implications of the rehabilitative measures, and future studies. Preliminary follow-up study results indicate that the intertidal islands are stable, 93% of the 23,302 marsh cores transplanted are growing, invertebrate colonization is still incomplete, juvenile wild chinook and chum salmon utilize the islands and catches are proportional to the abundance of salmon fry in the estuary. Hatchery reared juvenile salmon do not make extensive use of the islands. Migratory bird use of the islands has been recorded. All studies are continuing.

Key words: Campbell River Estuary, estuarine rehabilitation, intertidal islands, marsh core transplants, benthic invertebrate colonization, juvenile salmonid utilization, migratory bird utilization.

RÉSUMÉ

Brownlee, M.J., E.R. Mattice and C.D. Levings. 1984. The Campbell River Estuary: a report on the design, construction and preliminary follow-up study findings of intertidal marsh islands created for purposes of estuarine rehabilitation. Can. MS Rep. Fish. Aquat. Sci. 1789: 54pp.

Le présent rapport traite des efforts coopératifs de personnel d'agences, de membres de l'industrie et du grand public axés sur la conception et la construction d'une installation pour manipuler les billots et sur la remise en état d'une zone estuarienne industrialisée couvrant environ 32 hectares et utilisés intensivement pendant plus de 75 ans pour de telles activités. Il décrit la planification et la construction de la nouvelle installation de triage des billots à terre et les mesures touchant la remise en état, les détails de conception et les resultats préliminaires des études menées au cours de la première année d'un programme à long terme, entrepris en vue d'évaluer la stabilité et l'incidence biologique de la remise en état; on y parle aussi des futures études. Voici les résultats préliminaires du suivi: les îles intertidales sont stables, 93% des 23 302 carottes de végétation marécageuse poussent, la colonisation par les invertébrés n'est pas complétée, des juvéniles de saumons quinnats et kétas sauvages utilisent les eaux insulaires et les prises sont proportionnelles à l'abondance de saumoneaux présents dans l'estuaire. Les saumons juvéniles élevés en piscifacture fréquentent peu les eaux insulaires. On a aussi étudié l'utilisation des îles par les oiseaux migrateurs. Toutes les études se poursuivent.

Mots-clés: estuaire de la rivière Campbell, remise en état d'un estuaire, îles intertidales, transplantation de carottes de végétation marécageuse, colonisation par des invertébrés benthiques, utilisation par des saumons juvéniles, utilisation par des oiseaux migrateurs.

ACKNOWLEDGEMENTS

A project of this magnitude could have been made possible only by the very generous contributions of a great many individuals and organizations. Contributors from the Department of Fisheries and Oceans included: M. Wayne, B. Raymond, A. Von Finster, B. Clark, K. Conlin, J. Morrison, R. Bell-Irving, J. Payne, T. Brown, B. Kask, N. Lemmon, B. Covey, R. Marken, G. Graham, R. Scheck, F. Withler, M. Kotyk; Canadian Wildlife Service: N. Dawe, S. Boyd, D. Tretheway; Ministry of Environment: D. Morrison, K. Bond, L. Erickson, R. Diederich; Ministry of Lands, Parks and Housing: J. Egan; British Columbia Forest Products: W. Burch, S. Techy, K. Gill, B. Iverson, R. Willington, M. Watkins, R. Lloyd, E. Storbach, D. Callas, D. Calder, G. Burton, S. Leigh-Spencer; British Columbia Hydro Authority: I. Pate; Thurber Consultants Ltd.: D. Smith; and Hydraulic Consultant: R. Kellerhals. Other contributors are acknowledged elsewhere in this document. Special thanks to Melanie Sullivan for drafting the figures and assisting with report compilation.

A. INTRODUCTION

The Campbell River has long been associated with the catching of salmon. Headquarters for a commercial fishing fleet; a springboard for fresh and salt water sport fishermen; a major hatchery on the Quinsam River, the Campbell's main tributary; and the home of the late Roderick Haig-Brown: these are some of the major factors which have contributed to Campbell River's reputation. Of particular importance is the substantial contribution of the river to the B.C. salt water sport catch which is valued at approximately $150 million annually.

It is, therefore, incongruous that the Campbell River historically has been and currently still is under heavy industrial alienation and pressure. Hydroelectric development, logging, mining, gravel removal, urban development, wood processing and a myriad of secondary industrial activities have all influenced the watershed in one form or another. These pressures are not diminishing. Current proposals for mine expansion, construction of new mines in the watershed, second growth logging activities and increased urban pressures all serve to make the maintenance or enhancement of salmon resources in the basin a challenge.

This is a report on one such effort that focuses on the cooperative efforts of agency staff, members of industry and the public in developing and constructing a new log-handling facility and rehabilitating an industrialized estuarine area that had been intensively utilized for log handling activities for over 75 years.

This document reports on the factors considered in the planning and construction of the new dryland log sorting facility and the rehabilitative measures, provides the design details and preliminary results of the first year's studies of a longer term program being undertaken to assess the success (stability) and biological implications of the rehabilitative measures, and outlines future studies.

B. STUDY AREA

a) The Watershed

The Campbell River, located on the east coast of Vancouver Island (Fig. A), flows in a northeasterly direction to its confluence with Discovery Passage, just north of the 50th parallel. The river is the third largest with respect to discharge on the east coast of Vancouver Island and drains an area of 1,461 km^2. The river's flow has been regulated since 1949 when the John Hart Power Project was completed. River flow at the estuary is the sum of the Campbell and the Quinsam (the largest tributary, flowing into the Campbell 3 km upstream of the mouth) with an average annual flow of 108 m^3/s (3,816 cfs). Fresh water is also contributed to the estuary by Nunn's Creek.

b) The Estuary (Physical Description)

The estuary has an area of approximately 73 ha (180 acres) at high tide and is confined by Tyee Spit and a shallow gravel bar (Fig. B). Fresh water from the river is quickly dissipated outside these features by the tidal currents of Discovery Passage.

Approximately 60 percent of the estuary (43 ha) has been utilized for log handling activities. The estuary accommodates two marinas and several smaller floats used primarily by seaplanes. (For a detailed description of flora and fauna within the estuary see Raymond et al., July 1981.)

C. FISHERIES RESOURCES (after Raymond et al. 1981)

The Campbell/Quinsam River system supports five species of Pacific salmon, steelhead and cutthroat trout and Dolly Varden char. With a total annual value of at least $3.7 million to the Campbell River area and $9.1 million to the province as a whole. These figures may be compared to estimates for all fishing in the Campbell River area of $21.4 million to the local economy and $34.5 million to the province. Campbell River chinook and coho are harvested by the commercial fishery from the northern end of the Strait of Georgia to southeastern Alaska, and chum and pink are taken almost exclusively in the Johnstone Strait net fishery.

Annual escapements have been recorded since 1929, except for sockeye salmon, which are present in the system in only low numbers. Average annual escapements for a recent 10-year period are presented below (the data include hatchery takes, "surplus" adult and jack coho, and lower Quinsam sport catch of coho):

RIVER	SOCKEYE	CHINOOK*	COHO*	CHUM	PINK*
Campbell (1973-1982)	45	2,707	610	5,120	1,340 (odd) 3,413 (even)
Quinsam (1973-1982)	49	466	27,220	523	13,362 (odd) 15,003 (even)

*includes hatchery returns starting in 1976 for coho, 1977 for chinook, and 1981 for pinks.

A hatchery established on the Quinsam River in 1975 releases approximately one million chinook fry, 1.5 million coho smolts and 20,000 steelhead smolts each spring. In 1980 two million pink fry were released. A colonization program is also being carried out, involving the release of approximately 200,000 coho fry and 17,000 to 35,000 steelhead fry in the upper Quinsam River.

D. DRYLAND LOG SORTING FACILITY AND BOOMING AREA

a) Background

In April 1980, B.C. Forest Products Ltd. (B.C.F.P.) purchased the assets of Elk River Timber Company Limited (E.R.T.), which included approximately 40,500 hectares of privately owned timber lands. In addition, annual cutting rights to 42,500 m^3 on Crown Lands in the Heber River drainage were also reallocated to B.C.F.P.

E.R.T. had operated a booming ground in the Campbell River estuary since 1904, receiving logs originally delivered by rail-road, and more recently by logging trucks. The water flow of the river provided the energy to move logs downstream, through a sorting gap to the booming pockets. Most of the booming was in flat rafts as single logs. Due to the shallow water, the logs often grounded on the gravel bottom at low tides. Bark, limbs and debris, coupled with the chafing on the bottom and shading by the booms, all had an adverse effect on the productivity of the estuary. Dredging, for both deepening the boom pockets and debris removal, originally carried out by bulldozer and later with a clam shell, was a normal winter activity. Due to the booming ground configuration, and the limited work period during low tides, production flow was restricted to about 226,500 m^3 per year.

Projected production from this division is approximately 400,000 m^3 annually, of which approximately 42,500 m^3 will be from second growth lands during winter months, a time of low wood vol-ume flow through the dryland log sorting facility (see below). During the B.C.F.P. peak log flow period of approximately 7 1/2 months annually the remaining 382,500 m^3 must be handled at an average rate of 2,400 m^3 per day (about 40 truck loads). At an average log size of 1.0 m^3, this represents about 2,265 logs per day. These environmental and operational considerations dic-tated that a dryland alternative to the existing facility be sought.

b) Facility Design

i) Planning and Consideration of Alternatives

Planning for the new dryland sort and booming area commenced immediately upon announcement of the purchase of E.R.T. in February of 1980. The first meeting with representatives of Fisheries and Oceans (Habitat Management Division) was held in June 1980, followed soon after by a planning meeting with the Lands Manager, Courtenay, in order to initiate an application under the coastal Log Handling Guidelines.

One of the requirements of the application was the thorough review of alternative sites distant from the estuary, which was undertaken on B.C.F.P.'s behalf by Woodbridge, Reed and Associates Ltd. Six sites were investigated, in addition to the present location in the Campbell River estuary. The sites ranged from Menzies Bay, 12 km north of Campbell River, to Royston, 48 km south of Campbell River and included Middle Point, Duncan Bay and Oyster Bay. Numerous factors such as existing lease holders, strong tides, excessively deep water, proximity to residential and recreational sites or long haul distances over roads owned by others precluded the development or use of any of the alternative sites. (Details of this study are available in either the original report of April 1981 by Woodbridge, Reed and Associates Ltd., or in the Dryland Sort Proposal for the Campbell River Estuary, submitted by B.C.F.P. to the Ministry of Lands, Parks and Housing, July 1981).

ii) The Dryland Log Sort Concept and Operation

B.C.F.P.'s dryland sort design was based on the "flow-through" concept, patterned to facilitate continuous processing from unloading of trucks to log grading, sorting, scaling, bundling and watering (Fig. C). Every effort was made to minimize the storage of wood on land, as double handling causes costly interference with the flow pattern, damages logs and increases greatly the debris accumulation on the sort yard.

The sort was designed to be roughly square in shape, covering an area of between 2.0 and 2.4 hectares. The central operating area of 2.3 hectares (154 m x 146 m) was hard surfaced with asphalt. The base was comprised of compacted dredged materials, analyzed by Thurber Consultants Ltd. as being suitable as a foundation for the support of machines of weight up to 55,000 kg. The surface was carefully graded to ensure surface drainage would flow into settling ponds, before any runoff water was returned to the estuary.

Throughout the summer and fall of 1980, Fisheries and Oceans, Fish & Wildlife and the B.C.F.P. Resource Planning Group continued an intensive inventory of the estuary, supplementing information already available through various studies and reports. DFO provided direction throughout the planning stages of the project, bringing together many agency personnel with varied expertise and background information. Studies were conducted in the estuary, appraising such values as fish, wildlife, waterfowl, esthetics, recreation, pollution (water, air, noise, dust) etc. The impacts on close neighbours such as residents of Indian Reservation (I.R.) #11, floatplane operators, Tyee Spit residents, marina users, other industrial users of the estuary, etc., were all considered and incorporated into the proposal. Specific-use interest groups were involved through informal meetings. These included the Campbell River Estuary and Watershed Society, the Tyee Club, the C.R. Environmental Council, local Fish & Wildlife Groups, Steelhead Society, Save-Our-Salmon, etc. Meetings were also held with Municipal Council, Regional Board, Indian Band, Department of Lands, Parks and Housing, Forest Service, local Fisheries & Oceans officers and others.

Many proposed locations for the dryland sort were investigated, including sites within the existing booming area, i.e. Mud Bay, log storage bay (Fig. B). Field investigation involved water soundings, river flow data, land and water survey boundaries, identification of resource values of bird habitat, marsh sites and onsite evaluations of proposed development plans, construction and operating costs and potential impacts. Consultants appraised materials to be used, while dredging, pile-driving, barging and construction firms offered technical suggestions and cost estimates.

In early March of 1981, agreement was reached with the fisheries agencies on the basic location, chosen from six proposals. The accepted plan incorporated the old storage bay, with an extended side pocket and southern boundary paralleling the I.R. #11 boundary (Fig. D). A key component of the project was the construction of five islands within the old booming ground. Plans were also made for cleanup of the old booming ground and the gradual removal of piles once dryland sort construction was completed.

An application for Crown Land was submitted on April 15, 1981 by W.G. Burch, Vice-President, Timberlands & Forestry, B.C.F.P. Meetings, field trips and consultations continued through the spring and early summer. The prospectus was delivered to the Ministry of Lands, Fisheries & Oceans and Fish & Wildlife offices on July 30, 1981. As these agency personnel had been involved in the development of the project, little time was required for analysis and written approvals were received by September 1, 1981, allowing immediate commencement of construction to meet critical environmental constraints (winter months) for marsh transplanting and site dredging.

c) Facility Construction

Construction for the project was begun on September 2, 1981, with the falling of trees and clearing of brush on site, followed shortly thereafter by backhoe load-out of surface material (overburden) to ensure a stable base for heavy equipment and log movement on the dryland sort. Over 66,000 cubic metres of overburden material was loaded and trucked to the adjacent I.R. #11 for landfill. The removal of 33,000 cubic metres of debris by from the old boom storage pocket clamshell dredge and ocean dumping at an approved dumping site off Cape Mudge on Quadra Island (Fig. A) was completed in October.

In November the marsh donor stock for planting (Appendix II) of the four intertidal islands was excavated and transplanted to a specially constructed overwintering site (Fig. F), with the same tidal elevation and similar brackish conditions as the donor sites.

The diversion pipe to provide fresh water from the river to the booming pocket was installed in December (Fig. C). On January 16, 1982 Sceptre Dredging Ltd. started hydraulic dredging to remove 479,000 cubic metres of material from the booming pocket and deposit it on land as the base for the dry land sort.

On March 12, 1982 the dredging was completed, 3 days ahead of the Fisheries and Oceans' deadline and the rip-rapping of the boundary slope of the booming ground followed closely behind the dredging. In April, the sort surface area was compacted and levelled and steel piles were driven to form the new booming ground. Final grading in preparation for paving was done in May, and the sprinkler system and catch basins installed.

The log sort surface area was paved in June, leaving an adjacent upland log storage area with gravel surface of 3 hectares. The first logs were processed over the new sort on July 6. Cleanup of the old booming ground started July 7th, and proceeded until completed on August 20th.

Equipment combinations at this dry land sort generally consist of an unloading device, 2 or 3 front-end loaders, a sorting shovel and a machine to bore boomsticks on land to eliminate any wood chips in the estuary. Buildings include a scaler's office, crew lunch room and a service shop for the dryland sort equipment and log trucks. Strict pollution control systems to contain fuel, septic effluent and lubricants are employed.

Once logs have been graded, scaled and sorted, they are bundled in either 28 m^3 bundles to be watered immediately via a controlled soft-entry watering ramp, or into smaller 17 m^3 bundles for the minor sorts.

Debris resulting from movement of logs on the sort is "swept" into designated pile areas, loaded into gravel trucks and transported to approved dumping areas on forested lands. The watering ramps are designed so that bark dislodged as bundles move down the ramp to the water can be easily cleaned out.

Once a bundle of logs enters the water it is pushed by a dozer boat into one of 10 booming pockets, or alleyways, approximately 21.5 m wide at entrance, 24.6 m wide at exit and approximately 153.8 m in length. These pockets are lined with boomsticks, which eventually form the outer perimeter of the booms when towed. Booming pockets are controlled by steel pilings. Bundles of 28 m^3 draw approximately 2.46 m of water while 17 m^3 bundles draw approximately 1.84 m. A dredged depth of 3 m below zero tide has been provided.

Upon completion of boom assembly, a tug affixes a tow cable to the exit end of the boom and tows it to a designated storage area. B.C.F.P. presently hold rights to Lot 1440, 6.35 ha and Lot 1588, 1.7 ha, which are used for storage of booms (Fig. E).

Towing of bundle booms within the estuary is limited to times of higher tides (twice during each 24 hour period). Booms are moved to storage areas, upon demand, and then out of the estuary on higher tides across to Gowlland Harbour to log boom storage areas.

E. ESTUARY REHABILITATION

A pre-condition of Fisheries and Oceans' acceptance of the continued log handling operation in the Campbell River estuary was the "active rehabilitation" by B.C.F.P. of those areas historically utilized for log sorting. Rehabilitation for this area included:

1. log storage in lot 1486 (Fig. E) reduced from 32.8 ha. to 6.84 ha.

2) removal of debris and bark accumulations

3) construction of 4 intertidal islands and 1 supratidal island to predetermined elevations and configurations (Fig. G)

4) planting of marsh cores on the intertidal islands (Fig. H)

5) participation in the development and assessment of rehabilitation efforts.

a) Island Design

The islands were designed by biologists from Fisheries and Oceans and the Canadian Wildlife Service assisted by a Consulting Engineer in River Engineering and Hydrology and the B.C.F.P. Resource Planning Group hydrologist. The objective was to create hydraulically stable islands in various configurations while maximizing intertidal area, and providing a suitable substrate for marsh transplanting. The planting layout was designed principally by Fisheries and Oceans and Canadian Wildlife Service biologists (Fig. H).

One of the most important considerations in designing the islands was stability. In this respect, inherent features of the Campbell River such as controlled river flow (John Hart dam), availability of lower velocity areas away from the active river channel, availability of coarse, non-erodible materials for island construction, together with the opportunity for preconstruction studies, appeared to indicate that the project would be successful. Once there was a consensus that intertidal islands in this area were a positive initiative, the preliminary configurations developed by the biologists were finalized by engineering specialists (Fig. G depicts the final island configurations and the results of the physical assessment are contained in Appendix VI). An erodibility assessment was undertaken on July 2, 1981 during a low tide of 0.2 meters. B.C. Hydro released water from the John Hart dam which resulted in a flow of 350 cubic metres/sec at the rehabilitation site. This created a high discharge/velocity condition which permitted a detailed series of velocity/depth measurements (Appendix VII) to provide information on the potential for island erosion. Study results were considered favourable and a decision was made to proceed to the construction phase.

b) Island Construction

While the islands were being designed, it was considered that they could be constructed using material deposited in the river by the suction dredge. Gravel would be pumped to the island locations, spread with bulldozers and then capped with a 30 centimeter layer of silt.

It became apparent in discussions with dredging experts that this method of island construction with the silt capping would be extremely difficult to control and would be unstable, so this procedure was not attempted. Instead, it was decided to excavate by back hoe both the gravel and fine material from the area to be dredged, load it on to dump trucks and build a causeway out to the proposed island locations (Fig. G). The causeway would then be spread by bulldozers during appropriate low tides to form the islands. The silt capping concept was discarded for reasons of instability and the islands were comprised of a coarse and fine mix to allow for planting.

Construction commenced on November 30, 1981 and continued during suitable low tides until February 20, 1982. Approximately 30,000 cubic meters of material were hauled to form the causeway, with the total volume being used to build the islands.

Side slopes of 4:1 were designed for the islands and a slight smooth crown maintained to ensure proper drainage at low tide and to prevent pockets of water being trapped on the island surfaces. Bulldozers established the rough shape of the islands and a back hoe was used for final levelling, swinging a log suspended by chokers from the bucket for the final smoothing of the surfaces. Island construction could only be performed below a 1.7 metre tide. Traction could not be achieved if tides were above this level. This necessitated building the islands at night. The final total area of the islands was 2.4 hectares of flat surface, or 3.2 hectares including the side slopes (Table A). Four of the islands are intertidal, with elevations between 2.5 and 4 metres above zero tide. The elevation of the fifth island, created from excess material, is approximately 6 metres above zero tide.

c) Marsh Establishment

It was deemed desirable to use as donor sites the small remnant marsh areas that would be lost to dredging for the dry land sort construction.

Marsh species were identified by fisheries personnel and a suitable planting design developed (Appendix III). Techniques developed during experimental work on the Fraser River Estuary were used (Pomeroy et al., 1981, see Appendix XI). Those plant communities with the two species *Juncus arcticus* and *Carex lyngbei* dominant, were considered most desirable by fisheries staff and four areas were identified as suitable donor sites (Appendix II).

As the donor sites were to be dredged before the islands were constructed, most of the plants could not be immediately transferred to their final locations. Instead, they were lifted from the donor sites, transported to a holding area and stored over the winter until the islands were completed (Fig. F).

The lifting of the marsh was carried out during the month of November. A large hydraulic excavator (Cat 245) was used to dig up mats that were approximately 1 m x 2 m x 20 cm in size and weighed approximately one tonne each. The excavator then carried each mat to the nearest road and placed it on a large metal pallet on the back of a flat deck truck. In some cases, the excavator carried mats as far as 150 metres to the road. The flat deck trucks then transported the mats to the overwintering area.

At the overwintering storage site, a front-end loader equipped with log handling tynes was used to pick up each pallet, carry it to a specified area within the overwintering area and gently slide the mat into position. The empty pallet was placed back on the flat deck and the process repeated. Three flat decks were used. All work was done at night during low tides. A total of 350 mats were lifted and stored.

At the time of planting, the large mats were removed from the overwintering site using a front-end loader with a one metre flat metal extension welded to its bucket. The mats were carried to a flat area illuminated by flood lights where they were deposited and cut into smaller pieces by hand using a cutting tool. Two sizes were produced. The anticipated size of each sod or plug for planting was a square plug 10 cm x 10 cm x 20 cm deep. This was a difficult size to manufacture because of the nature of the root mass and the variety of the soils encountered. In fact, most plugs produced were 15 cm square by 20 cm deep and were packed into plastic milk carton carriers. Approximately 6 plugs could be fitted into each carrier and care was taken to keep the plugs right side up.

Approximately half of the mats were cut into 30 cm x 30 cm x 20 cm deep sods. These sods were later quartered at the planting site.

Two herring skiffs were used during high tides to transport the milk carton carriers to the islands for planting. The boats were anchored at the prospective planting site and the sods removed during low tides. In addition, two wooden floats were also used to transport the plants, which were subdivided on the floats and packed into milk carton carriers as these became empty during the planting process. Wooden stretchers were used to transport the sods from the skiffs or floats to the actual planting sites.

The planting of the marsh plugs was carried out according to a strict spacing pattern within each of the planting blocks (Fig. H). The corners of the planting blocks were marked with steel stakes. The external boundaries were marked at one meter spacing prior to planting. A nylon surveyor's chain with each metre marked on it with fluorescent tape was strung across the block and provided the planters with spot locations for each row within the block. The chain was moved ahead as each row was completed. Small shovels were used to dig the holes for the sods. All work was carried out at night during the lowest tides. Lighting was considered critical to successful planting and two portable lighting plants were used continuously.

Island #4a, which is above the high tide mark, was planted with Alder and Sitka Spruce.

It became apparent during the planting that the desired number of plugs could not be obtained from the material in the overwintering storage area because of wastage and because plug size was larger than was planned. Accordingly, three nights were spent transferring material from an area that had not yet been dredged (Site 1, Fig. F) where suitable plant species were present. In this case, 30 cm x 30 cm x 20 cm sods were lifted by hand and packed onto the floats using wooden stretchers.

The planting crew consisted of 18 temporarily unemployed loggers and three salaried supervisors. Six men prepared plugs or sods and loaded material onto the skiffs or floats and the remaining 12 men planted or packed plugs on the islands. Weather and tide levels adversely affected planting production as did poor lighting in some areas. Eight mandays were spent going over the area after planting was completed to improve the quality of the planting (i.e., righting upside down plugs, etc.). The details of the planting program are outlined in Tables B and C.

F. EVALUATION OF REHABILITATIVE ACTIVITIES

In view of the substantial rehabilitative activities being undertaken in the estuary, an excellent opportunity was presented for detailed assessments of not only construction and development techniques but also of the biological response to these changes. Detailed studies of water quality and physical conditions, vegetative components (algal and vascular), benthic invertebrate communities, salmonid utilization and waterfowl use were undertaken. In order for these studies to be meaningful, five years was considered by project participants to be required for the program.

For the purpose of project continuity and coordination, each study component became the responsibility of one individual and overall coordination was ensured through a series of meetings, with one individual assuming responsibility for coordinating all the studies.

Component studies included:

Study		Individual Responsible	Affiliation
i.	Vegetation	Neil Dawe	CWS
ii.	Benthos	Bev Raymond	Contract to BCFP
iii.	Fish Utilization	Colin Levings/ Carey McAllister	DFO
iv.	Waterfowl	Don Trethewey	CWS
v.	Physical Studies: (water quality studies, potential erosion problems, topographic monitoring)	Bob Willington	BCFP
vi.	Estuary Cleanup, misc. studies, aerial photos, etc.).	Mike Watkins/Ted Mattice	BCFP

Overall coordination was assumed by Mike Brownlee (DFO) with assistance from Colin Levings (DFO). Bud Iverson, Logging Manager (BCFP), coordinated overall construction and environmental rehabilitation efforts onsite.

The following outlines the experimental design of each of the studies and some preliminary results of the 1982 efforts, and highlights those studies planned for the future. **Concerns regarding the publishing of preliminary results were considered but it was the consensus of the project principals that there was more to be gained by early publication than by waiting for a number of years until more extensive results are available.** Specific reports on component studies will be published as respective authors deem appropriate (Appendix XI lists published reports available at present).

Each study report component has been summarized for purposes of brevity and respective authors may be contacted if more information or details are required. Data and observations are preliminary and subject to change as more information becomes available.

a) Campbell River Estuary - Physical Studies

by R. P. Willington, BCFP
Crofton, B.C.

Work completed to date on the Campbell River Estuary program with regard to the physical characteristics includes the following:

i) Hydrology and Bathymetry

A study (Appendix VII) was conducted in order to provide baseline data for the design of islands in the "old" booming area. Data collection included estuary river flow velocities at various tides (emphasis on low tides) and river discharges at various locations within the areas selected for island creation. Bathymetry data for this same area was collected and mapped at 0.25 m contour intervals.

Post-island installation inspections of the modified estuary environment have been jointly conducted by B.C. Forest Products Limited and the Department of Fisheries and Oceans, to visually assess the stability of the islands and inter-island channels. During the fall and winter of 1982 the estuary was subjected to very high river discharges at low tides, but it appeared that the new islands experienced no damage or destabilization.

Further monitoring of island stability will be required in order to confirm judgements to date.

ii) Mapping

Low level photography taken during the summer of 1982 was used to update the existing 1:1,000 contour map of the Campbell River estuary to include the new islands and the dredged area. Further additions to the map will be the locations of all B.C. Forest Products Limited and Department of Fisheries and Oceans benchmark survey stations considered useful in monitoring long term estuary stability.

iii) Water Quality Monitoring

Water quality (temperature, dissolved oxygen, colour, non-filterable residues, tannins, salinity and benthos) was monitored in the dredged area and a control site near "Tyee Pool" between July and December 1982. This work was performed by B.C. Forest Products Limited and has been summarized in a report to D.F.O. (Appendix X). This water quality monitoring program will continue to collect bench mark data.

b) Vegetation of Man-made Marshes on the Campbell River Estuary 1982: A Preliminary Report

by Neil K. Dawe,
Canadian Wildlife Service,
Qualicum Beach, B.C.

i) Introduction

The Canadian Wildlife Service began monitoring vegetation growth on man-made marshes constructed during the spring of 1982 at the Campbell River estuary to determine the success of the marsh creation project, to provide baseline data from which to note future successional trends, and to determine the timeframe required for a man-made marsh to approach a natural marsh in productivity. The following results are from analysis of one month's data only (July 1982). No attempt has been made to interpret those results. A complete analysis of the 1982 field-work will be provided at a later date.

ii) Methods

Vegetation monitoring began on 12 May 1982 and continued at approximately monthly intervals through August (22 June, 21 July, 18 August).

On each occasion all transplanted plugs were checked for evidence of growth and counted as either successful or unsuccessful. Twenty plugs within each block were then chosen at random and the following data were recorded for each species within the plug: name, length, density, number of flowers, condition, number of new shoots outside plug, other observations.

Permanent transects were laid out through each block and through unplanted control areas. The vegetation falling within a one square meter releve was monitored at five meter intervals along the transect using the Braun-Blanquet cover-abundance scale (Mueller-Dombois and Ellenberg, 1974).

Permanent photo plots were established and colour transparencies were taken over the field season.

Soil samples were taken (three replicates per sample site) from the high, mid, and low elevations of each island. Soil conductivity was subsequently determined using the methods of Yamanaka (1975).

iii) Preliminary Results

From the 15 blocks a total of 23,302 plugs were counted. On 19 May, 18.5% of the plugs observed were considered unsuccessful, however, by 18 August that proportion had dropped to 7.5%. Island 3 had the highest plug mortality (13.4%), particularly at the lower elevations.

As of 21 July, a total of 29 species of vascular plants was recorded from the transplant sites (Table D). Of those, the dominant species in terms of frequency of occurrence were Carex lyngbyei (76%), Eleocharis palustris (55%), Potentilla pacifica (42%), and Juncus balticus (39%).

Table E shows the grand mean length and frequency of occurrence for the top four species from each of the islands. Included for comparison are data for the species growing under natural conditions on Nunn's Island, adjacent to the transplant sites.
While all the species generally showed fair to good growth, by the time of the July fieldwork two in particular appeared to be doing very well. Both Eleocharis and Potentilla were spreading from the plugs to adjacent areas, Eleocharis by its rhizomes and Potentilla by its stolons. Two natural colonizers were also evident by June: Scirpus cernuus and Scirpus sp. Terrestrial colonizers, as well, were observed at the 4m elevation of Island 3, including Plantago major, Rumex sp., Polyeonum sp., Spergularia rubra, Spergula arvensis, and Trifolium sp. Soil conductivity from all islands was less than 2,000 umhos/cm (1067-1850 umhos/cm).

iv) Future Research

Similar studies should be continued for at least the next four years, and preferably until the newly created marshes approach the natural marshes in growth and productivity. Measurements of above ground biomass as an indicator of productivity, measurements of root and rhizome growth and a continuation of the 1982 fieldwork could be undertaken. As Race and Christie (1982) point out, there is insufficient evidence at present to conclude that man-made marshes function like natural marshes. Only by continued monitoring of the Campbell River marshes, both man-made and natural, will we be able to judge the success of the marsh creation project.

Acknowledgements

The following provided input to the initial design of the vegetation research: W. Sean Boyd, Mike J. Brownlee, Don Gordon, Colin D. Levings, and Don E.C. Trethewey.

Able field assistance was carried out by Cathy Cooper, John Davies, Nelly deGeus, Suzanne Hawkes, Heather Jones, Louise Le Brasseur, John McIntosh, Susan McMillan, Mark Palmer, Louise Waterhouse, and Michaela Waterhouse.

Literature Cited

Mueller-Dombois, D. and H. Ellenbers. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York.

Race, M.S. and D.R. Christie. 1982. Coastal zone development: mitigation, marsh creation, and decision making. Environmental Management 6(4): 317-328.

Yamanaka, K. 1975. Primary productivity of the Fraser River delta foreshore: yield estimates of emergent vegetation. M. Sc. thesis, University of British Columbia, Vancouver.

c) Benthic Invertebrates Associated with the Islands in the Campbell River Estuary: A Preliminary Report

by: B. Raymond[2] and C.D. Levings[1]

[1]Fisheries Research Branch, Salmon Habitat Research Section, West Vancouver Lab.

[2]Under contract to B.C. Forest Products Ltd. for majority of this work.

i) Introduction

This study assessed certain factors which might have influenced the development of macrobenthic communities on the new islands. Since benthic animals provide food for fish and birds, results are pertinent to the ultimate success of the island project. Three factors were examined, namely the presence of the islands, presence of vegetation and changes through time (temporal aspects). Since the data are from the first invertebrate collections made subsequent to planting, they also represent an important baseline to measure subsequent changes against.

ii) Sampling Locations

All the new islands were sampled on level parts of the islands at about 3 m in elevation above chart datum. Nunn's Island, a natural marsh island in the eastern part of the estuary, was used as a reference area for comparative purposes. Samples were taken within and outside planted blocks on the new islands. On Nunn's Island samples were also taken within vegetated areas (*Carex lyngbyei*) and outside vegetation where mud covered with the alga *Pelvetiopsis* spp. was the substrate.

iii) Sampling Techniques

On May 26 - 27, June 22, and July 19 - 20, 1982 quadrat samples ($0.06 m^2$) were taken from the new islands and from Nunn's Island. Three replicate samples were obtained inside and outside vegetation as described above. Random sampling sites were selected by laying squared paper over maps of the islands and coordinates were drawn from a random numbers table.

Quadrat samples were obtained by scraping substrates with a trowel to a depth of 2 cm, and material collected was then preserved in isopropanol with rose bengal added as a stain. Mesh size for sieving was 0.5 mm. Core samples ($5 cm^2$) for meiofauna were collected on May 26 and 27 and sweep samples for insects were collected July 21. Sediments from meiofauna cores were sieved through 44 mm sieves.

iv) Results

1. Macrofauna

A total of 40 invertebrate taxa were taken in the samples (Table F). For statistical analyses data were used from 4 crustaceans (*Corophium* spp., *Eogammarus confervicolus*, *Eogammarus o'clairi*, and *Gnorimosphaeroma oregonensis*) and insects (almost exclusively larvae). Two other taxa, not usually food items of juvenile salmonids but useful as indicators of environmental conditions, were also considered. These were polychaetes and oligochaetes. Analyses were also completed for total macrofauna, excluding incidental meiofauna such as harpacticoids and nematodes.

Data were subjected to three-way analyses of variance, after transformation (log 10 X+1), to test for island, vegetation and time effects. The first analysis tested for differences in abundance between islands for each of the categories and showed that differences were statistically significant ($p<0.05$) for all categories except insects. Graphical evidence (Fig. I) suggests this difference is due to large numbers of organisms on Nunn's Island, except for *Corophium* spp., which was most abundant on Island 3. Results for analyses of vegetation effects varied between faunal category. There were no significant differences ($p>0.05$) in abundance of *G. oregonensis*, oligochaetes and total fauna between vegetated and unvegetated sites (Fig. J). Differences were statistically significant ($p<0.05$) for amphipods, insects and polychaetes. Plotting of data from the two habitat types (Fig. J) suggests that the density of all amphipod categories was lower in the marsh but the density of polychaetes and insects was higher in the vegetation. Time effects were not statistically significant ($p>0.05$) for *Corophium* sp., *E. confervicolus*, *G. oregonensis*, oligochaetes and polychaetes. *E. o'clairi*, insects, and total fauna increased with time ($p<0.05$).

A subsequent series of analysis of variance was completed to test for island, vegetation and time effects, excluding data from Nunn's Island (reference location). These analyses showed that there were no significant effects ($p>0.05$) between islands for any of the categories except for *Corophium* spp. and *G. oregonensis*. The former was abundant on Island 3 and the latter most abundant on Island 4 ($p<0.05$) (Fig. K). Vegetation effects were only significant ($p<0.05$) for insects and polychaetes and both taxa were more abundant in planted blocks (Fig. L). Analysis of variance indicated that sampling time had a significant effect on abundance of *Corophium* spp., insects and total fauna ($p<0.05$).

2. Meiofauna

Mean densities (number per 5 cm^2) of major faunal groups occuring in cores are shown in Table G. The most abundant taxa were nematodes, harpacticoids and copepod nauplii. Meiofauna were more abundant in non-vegetated areas than in planted plots on the new islands and more abundant in marsh than under algae on Nunn's Island. Harpacticoids and copepod nauplii were more abundant in non-vegetated areas on new islands and in marsh on Nunn's Island.

3. Adult Insects

Insects were sampled with an entomological sweep net from marsh areas on the new islands and Nunn's Island. Adult insects were by far more abundant and diverse on Nunn's Island than on the recently created islands (Table H).

Acknowledgements

Sample analysis and computing facilities were provided by the Fisheries Research Branch, Pacific Biological Station, Nanaimo.

d) Juvenile Chinook Salmon in Relation to New Island Habitat, Campbell River Estuary, 1982

by C.D. McAllister, C.D. Levings, T. Brown and B.C. Chang
Fisheries Research Branch

i) Introduction

This study compares catches, lengths, weights and condition of juvenile chinook salmon (*Oncorhynchus tshawytscha*) taken in the new islands to averages for the whole estuary during the spring of 1982, immediately following the reclamation. Some catch data from 1983 are also included for reasons which will be evident below.

ii) Study Area and Methods

Fig. M shows the Campbell River study area, indicating the sampling sites, artificial islands, and the new BCFP log sort and booming grounds.

Young salmon were captured using a 1.8 x 15 meter beach seine usually towed off the shore by boat then hauled by hand. The artificial channels on Island 3 were sampled by stretching the net across the mouth of each groove and then hauling it up the channel. Catches of salmonids were identified and counted in the field, and samples retained for length, weight and other laboratory analyses.

The 1982 sampling season in the islands was interrupted by a period in which debris from former log handling was cleaned up, and pilings and dolphins removed. This limited good comparisons to the period March 22 to June 22, 1982. When the islands were again accessible, the summer decline in abundance was well underway. For the spring period, comparisons are based on catches from Islands 1 and 3, as sampling frequency was greatest at these two locations.

After May 15, 1982, the date of first release of unmarked hatchery chinook, the catches per set of wild and hatchery chinook were calculated using total captures of chinook, captures of marked hatchery chinook and a Peterson method (McAllister *et al.*, in preparation). All unmarked chinook taken before May 15 were wild chinook. From May 15 onward, unmarked hatchery chinook were retained in the samples for laboratory analyses not readily done in the field. Hatchery fry and wild fry were easily distinguished by size differences. The data on length, weight and condition in this report represent only wild chinook, as the number of hatchery (large) fish retained in the samples for laboratory analyses was insufficient. The condition factor, K, was estimated as K = 10^5 W/L^3 where W is total weight (g) and L is fork length (mm).

The catch data and the details of methods and sampling locations are given in Brown et al (1983, 1984).

ii) Results and Discussion

1. Catches

In the spring 1982 period for which catch comparison was possible, mean catch per set for the estuary as a whole was about 66 chinook and that for the islands, 33. However, catches in the islands were almost exclusively wild chinook, averaging about 32 per set. The mean catch per set of wild chinook in the estuary for the same period was about 46. The wild chinook began their spring increase in about mid-April in the estuary and about a week later in the islands. The first and second peaks in catch per set in the islands were also delayed by about a week relative to those in the estuary (Fig. N). The maximum average catch per set for all trips was about 160 in the estuary, and 105 in the islands.

Hatchery chinook in the estuary for the period considered here comprised about 30% of the total catch per set, compared to about 1% for the islands. For reference, it may be noted that hatchery chinook at one inner estuary location averaged about 64% of the catch over the entire spring-summer period.

Catches of wild chinook in the islands in 1982 were substantial, even though lower than those in the estuary, on the average. However, mean island catches per set for the islands in 1983, were much lower, for the comparable period, about 3 per set, or 10% of the 1982 value. The reduction in the estuary catches per set was less extreme, to about 14, or about 21% of the 1982 value.

The low use of the islands by wild chinook in 1983 could be a reflection of their generally lower abundance, which might reduce pressures to disperse from main river channel habitats (McAllister et al., in preparation). Local increases in silt and organic matter on the bottom in the artificial grooves on Island 3 and in the terminal bay on Island 1 in 1983 (personal observations) might be speculated to mean lowered water quality, causing avoidance by young salmon. Seki et al. (in preparation) did observe higher bacterial activity than elsewhere in sediments near an artificial groove on Island 3, in 1983, but there was no evidence of water quality lower than in other portions of the estuary. Further, there was no indication that young chinook avoided these particular areas relative to other island locations with less accumulations of new sediment.

The low island catches of hatchery chinook in spring during both years, despite release of similar numbers, are notable. This might result from the larger size of hatchery chinook, relative to wild fry, and a resulting preference for deeper and faster water than encountered in the island beach seining sites (Lister and Genoe, 1970; S. McDonald, pers. comm., 1983). However, the greater relative use of the same island sites by large hatchery smolts during the winter of 1982-83, is not consistently although the latter might be attributed to the preponderence of night sampling during the fall-winter sampling period.

2. Length, Weight, Condition

Length and weight data for individual unmarked chinook are given in Kotyk et al. (1983). Fig. O shows the mean length, weight and condition of unmarked wild chinook at island and non-island locations within the estuary; outside the dates shown, the sample sizes from island sites were too small for meaningful analyses. Analysis of variance showed no significant differences ($p>0.05$) in lengths and weights between islands and the estuary in each trip. Nevertheless, the length-weight relationship did show a significant difference; analysis of covariance showed no significant difference in the slopes of the regression lines between island and estuary ($p=0.26$), but did show a significant difference in the adjusted means ($p<0.01$); the length-weight parameters are shown in Table I. The difference in the adjusted means was reflected in the higher condition seen in the island samples (Fig. N).

The 1982 data thus suggest that the new islands were well used by wild chinook fry having lengths and weights similar to those for the rest of the estuary, and higher condition factors. However, the 1983 decrease in the catch of wild chinook fry was relatively greater in the new islands, and catches of hatchery chinook were low at the sites sampled in both years. Further assessment is required.

Acknowledgements

Thanks are due to Leslie Coultish who performed the majority of the measuring and weighing, and to F.C. Withler for assistance in the sampling.

References

Brown, T.J., McAllister, C.D. Levings, C.D., Kotyk, M., Chang, B.D. and J.S. Macdonald. 1984. Salmonid catch data from Campbell River and Discovery Passage 1983. Can. Data Rep. Fish Aquat. Sci. 444. iii+97 p.

Brown, T.J., C.D. McAllister, C.D. Levings, and M. Kotyk. 1983. Salmonid catch-data from Campbell River and Discovery Passage, 1982. Canadian Data Report of Fisheries and Aquatic Sciences. No. 416.97p.

Kotyk, M., B.D. Chang, T.J. Brown, C.D. Levings and C.D. McAllister. 1983. Length and weight data for unmarked juvenile chinook salmon sampled in the Campbell River estuary and Discovery Passage, 1982. (in preparation).

Lister, D.B., and J.S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon in the Big Qualicum River, British Columbia. J. Fish. Research Board Canada. 27(7):1215-1224.

Seki, H., A. Otsuki, S. Daigobo, C.D. Levings and C.D. McAllister. 1984. Microbial contribution to the mesotrophic ecosystem of the Campbell River estuary during summer. (in press). Archive fur hydrobiol.

e) <u>Campbell River Estuary Habitat Enhancement, Migratory Bird Studies: Progress Report to December 31, 1982</u>

by D.E.C. Trethewey
Canadian Wildlife Service
Delta, B.C.

During October, 1982, the Canadian Wildlife Service (C.W.S.) completed arrangements with the Mittlenatch Field Naturalist Society (M.F.N.S.) of Campbell River to monitor migratory bird use of the Campbell River estuary. The M.F.N.S. provided, on a voluntary basis, personnel to conduct bird counts at the estuary. In return, C.W.S.:

- provided project administration;
- provided data record forms and field maps;
- lent M.F.N.S. a telescope and tripod; and
- reimbursed the M.F.N.S. for out-of-pocket expenses associated with the studies.

The first count was conducted by M.F.N.S. on October 31, 1982 and counts continued approximately weekly to October 31, 1983. Thereafter, counts were conducted every second week to December 31, 1983. Counts will be conducted by M.F.N.S. every second week until March 31, 1984. At that time the project will be reassessed to determine if it will be continued into the 1984-85 fiscal year. Data collected to December 31, 1983 have been entered onto floppy discs, but have not yet been analyzed. As was expected, some bird use of the artificially-created habitat has occurred. However, that use has not been quantified.

The C.W.S. also has had prepared a black-and-white airphoto mosaic of the Campbell River estuary and adjacent foreshore from the ferry slip in the south to just north of Painters Lodge.

I wish to acknowledge the assistance of the following:

- The M.F.N.S. members who volunteered to collect field data, particularly Howard Telosky who organized the field crews and Kay Conway who has agreed to coordinate the data sheets and other paperwork on behalf of the Society.

- Ted Mattice of B.C. Forest Products for arranging permission for the M.F.N.S. field crews to have access to the dry land sort area while conducting bird counts and for lending C.W.S. colour prints and negatives of aerial photography used in the production of a photo mosaic of the estuary.

- Mike Brownlee and Kevin Conlin of D.F.O. for lending C.W.S. colour negatives of aerial photography used in the production of a photo mosaic of the estuary.

- Neil Dawe and Sean Boyd of C.W.S. for their advice and assistance on the project to date.

G. REFERENCES CITED

Pomeroy, W.M., Gordon, D.K. and C.D. Levings. 1981. Experimental transplants of brackish and salt marsh species in the Fraser River estary. Can. Tech. Rep. Fish Aquat. Sci. 1067: 35 p.

Raymond, B.A., Wayne, M.M. and Morrison, J.A. 1981. Vegetation and Invertebrate Distribution and Fish Utilization of the Campbell River Estuary, British Columbia. Can. Man. Rep. Fish. Aquat. Sci. (unpublished; Habitat Management Division, DFO, Vancouver, B.C.).

Read, S.C., and V.A. Poulin. 1982. Economic Evaluation of the Campbell River Fisheries. Prepared for Waste Management Branch, B.C. Ministry of Environment. Environmental and Planning Associates Report. 47 p.

TABLE A

Areas of the Constructed Estuarine Islands

ISLAND #	TOP SURFACE AREA ONLY		TOTAL AREA (including side slope)	
	Hectares	Acres	Hectares	Acres
1	0.92	2.26	1.15	2.84
2	0.34	0.85	0.47	1.17
3	0.56	1.38	0.80	1.98
4	0.55	1.35	0.73	1.81
4a	0.02	0.06	0.07	0.17
Totals:	2.39	5.90	3.22	7.97

TABLE B

Details of the Marsh Plug Planting Program

DATE	PERSON DAYS Lifting	PERSON DAYS Planting	Total	LIFTING Dominant Species	LIFTING Source of Material	PLANTING Location	PLANTING #Planted	Total # Cores Planted
Feb. 01	11		11	Juncus/ Carex	Heel-in*** Slough			
2		21	21			4 A-C-D	2850	2850
3	8	13	21	Juncus/ Carex	Heel-in	4 C	2000	4850
4	6	13	19	Juncus/ Carex	Heel-in	4 C	1950	6800
5	6	15	21	Juncus/ Carex	Heel-in	2 C	1950	8750
6	8	12	20	Carex	Slough	2A 4B-C	2094	10844
7	8	12	20	Juncus/ Carex	Heel-in	3 C 4B	93	10937
								Large float - planted 0.3m sods on 3C *
8	8	12	20	Carex	Slough	2 A-B-C	1327	12264
9	5	13	18	Carex	Heel-in	3 A-D	1512	13776
10	6	11	17	Carex	Heel-in	3 D	645	14421
11		15	15			1 D	2121	16542
16	8		8	Carex	Heel-in			16542
17	6	10	16	Carex	Heel-in	1 D	1701	18243
18	4	12	16	Carex	Heel-in	1 D-C	1161	19404
19		16	16			3B	1700	21104
21		4	4			1C	1040	22144
22		4	4			1A	630	22774
23		4	4			3C	297	23071
24		1/2	1/2					23071
25		4	4			1A	231	23302
	84	191.5 **	275.5					23302

* These 30 cm sods were later cut up into the smaller 15 cm plugs because of a shortage of donor material.

** Approx. 122 plugs planted/personday

*** Heel-in refers to overwintering site

TABLE C

Design of the Marsh Plug Planting Program

ISLAND 1

BLOCK	SIZE (m)	SPACING	ROWS	# PLUGS	DOMINANT SPECIES	LOCATION OF DONOR STOCK
A	20 x 38	1.0	21 x 41	861	Carex	Slough/Overwintering Site
C	35 x 40	1.0	36 x 41	1476	Carex	Overwintering Site
D	10 x 90	0.5	21 x 181	3801	Carex	Overwintering Site
	4 x 40	0.5	9 x 81	729	Carex	Overwintering Site
				6867		

(Note: there is no Block B)

ISLAND 2

BLOCK	SIZE (m)	SPACING	ROWS	# PLUGS	DOMINANT SPECIES	LOCATION OF DONOR STOCK
A	15 x 53	1.0	16 x 51	816	Carex	Overwintering Site
B	10 x 20	1.0	10 x 21	210	Carex	Overwintering Site
C	± 72 x 10*	0.5	134 x 21*	2968	Juncus	Overwintering Site
			(plus 154 plugs)	3994		

* A pie shaped portion could not be laid out by rows so each planting location was marked.

ISLAND 3

BLOCK	SIZE (m)	SPACING	ROWS	# PLUGS	DOMINANT SPECIES	LOCATION OF DONOR STOCK
A	4 x 50	0.5	9 x 83	747	Carex	Overwintering Site
B	4 x 63	0.5	9 x 128	1152	Carex	Slough/Overwintering Site
C	4 x 55	0.5	9 x 111	999	Carex	Slough/Overwintering Site
D	7 x 25	0.5	15 x 51	765	Carex	Overwintering Site
E	7 x 21	0.5	15 x 43	645	Carex	Overwintering Site
				4308		

ISLAND 4

BLOCK	SIZE (m)	SPACING	ROWS	# PLUGS	DOMINANT SPECIES	LOCATION OF DONOR STOCK
A	15 x 30	0.5	31 x 81	2511	Juncus	Overwintering Site
B	15 x 30	0.5	31 x 60	1860	Juncus Mix/Juncus	Overwintering Site
C	25 x 30	0.5	51 x 61	3111	Carex	Slough/Overwintering Site
D	20 x 30	1.0	21 x 31	651	Carex	Slough
				8133		

B - First 30 rows = from Block A juncus/carex mix, next 30 rows - juncus
TOTAL PLUGS: 23302

TABLE D

Plant Species Present on the Campbell River Transplant Sites in 1982

Polygonaceae
- *Polygonum sp.*
- *Rumex* sp.

Caryophyllaceae
- *Spergula arvensis* L.
- *Spergularia rubra* (L.) Presl

Ranunculaceae
- *Ranunculus cymbalaria* Pursh

Rosaceae
- *Potentilla pacifica* Howell

Leguminosae
- *Trifolium wormskjoldii* Lehm.
- *Trifolium* sp.
- *Vicia americana* Muhl.

Malvaceae
- *Sidalcea hendersonii* Wats.

Umbelliferae
- *Lilaeopsis occidentalis* Coult & Rose.
- *Oenanthe sarmentosa* Presl.

Primulaceae
- *Glaux maritima L.*

Scrophulariaceae
- *Castilleja* sp.

Plantaginaceae
- *Plantago lanceolata* L.
- *P. major* L.

Compositae
- *Aster* sp.

Juncaginaceae
- *Triglochin maritimum* L.

Juncaceae
- *Juncus balticus* Willd.

TABLE D (Cont.)

Cyperaceae
- *Carex lyngbyei* Hornem.
- *Eleocharis palustris* (L.) r. & s.
- *Scirpus acutus* Muhl
- *S. americanus* Pers.
- *S. cernuus* Vahl

Gramineae
- *Agrostis* sp.
- *Deschampsia* cespitosa (L.) Beauv.
- *Hordeum* sp.
- *Poa* sp.

Typhaceae
- *Typha latifolia* L.

TABLE E

Vegetation Statistics from Marsh Creation Project, Campbell river Estuary, July 1982. (Figures shown are means from data gathered from the four man-made islands with comparative data from Nunn's Island.)

	Island	Length (cm)	Frequency of Occurrence (%)
	1	38.6	94.3
	2	36.7	70.8
Carex	3	31.3	66.4
lyngbyei	4	35.6	70.8
	Nunn's High	53.4	100.0
	Nunn's Low	101.8	100.0
	1	23.5	48.6
	2	24.0	56.8
Eleocharis	3	20.4	57.8
palustrus	4	22.9	58.4
	Nunn's High	46.4	100.0
	1	12.7	75.0
	2	10.0	22.2
Potentilla	3	13.1	45.4
pacifica	4	14.1	23.6
	Nunn's High	38.9	100.0
	1	46.5	41.1
	2	33.8	22.2
Juncus	3	25.8	38.7
balticus	4	39.6	53.6
	Nunn's High	54.8	100.0
	Nunn's Low	86.4	100.0

TABLE F

Taxonomic Listing of Organisms Recorded during Analysis of Benthic Quadrat Samples

Nematoda		
Mollusca		
Gastropoda		
		Lacuna carinata
		Littorina sitkana
Bivalvia		
		Macoma inconspicua
		Mytilus edulis
Annelida		
Oligochaeta		Enchytraeus (albidus?)
		Lumbricillus sp.
		Nais (communis?)
		Paranis littoralis
		(Tubifex (?) sp. (Immature)
Polychaeta		
	Ampharetidae	
		Ampharete (acutifrons?)
	Capitellidae	
		Capitella capitata
	Cossuridae	
		Cossura longicirrata
	Nereidae	
		Nereis (limnicola?)
		(N. wailsi?)
	Sabellidae	
		Manayunkia aestuarina
	Spionidae	
		Spiophanes
Arthroposa		
Crustacea		
Copepoda		
	Harpacticoida	
		Harpacticus (?) sp.
		Huntmania jadensis
	Ectindsomatidae	
Malacostraca		
	Cumacea	
		Leptocuma sp.

TABLE F (Cont.)

Tanaidacea		
		Anatanais normani
		Pancolus californiensis
Isopoda		
		Gnorimosphaeroma oregonense
		Ianiropsis kincaidi kincaidi
		Idotea ochotensis
Amphipoda		
		Corophium brevis
		C. spinicorne
		Eogammarus confervicolus
Mysidaceae		
Branchiopoda		
Cladocera		
		Podon polyphemoides
Ostracoda		
Cirripeda		
		Balanus cariosus
Chencerata		
Acari		
Insecta		
	Diptera	
		Chironomidae
		Chironomus sp.
		Cricotopus sp.
		Micropsectra sp.
		Polypedilum sp.
		Saunderia clavicornis
		Heleidae
		Palpomyia sp.
		Tabanidae
		Tabanus sp.

TABLE G

Mean Abundance of Meiofauna at Campbell River Estuary
(# of animals per 2.5 cm diameter core)

LOCATION	N	Nematoda		Oligochaeta		Polychaeta		Copepod nauplii		Harpacticoida		Ostracoda		Acari		Insecta		Total Fauna	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1 planted	3	206.3	243.2	6.3	7.8	0.3	0.6	43.3	23.0	66.0	48.1	0.7	1.2	0.3	0.6	0	0	324.7	279.7
1 not planted	3	783.3	442.4	0.7	1.2	0	0	136.7	118.1	114.0	80.1	0.7	0.6	0.7	1.2	0.3	0.6	1036.3	581.6
2 planted	2	44.0	45.3	0.5	0.7	0	0	0.5	0.7	0	0	0	0	1.0	1.4	1.0	1.4	47.0	42.4
2 not planted	2	75.0	59.4	0	0	0	0	14.5	12.0	13.5	3.5	0.5	0.7	0	0	0	0	103.5	75.7
3 planted	3	77.3	6.7	0.7	0.6	0	0	17.0	26.0	19.0	27.9	0	0	1.0	1.0	1.0	1.7	116.0	60.7
3 not planted	3	368.3	360.4	15.3	24.0	0	0	25.7	23.4	30.7	25.9	3.0	3.0	0.3	0.6	0	0	443.3	401.2
4 planted	3	528.7	740.9	4.7	7.2	0	0	14.0	14.0	33.0	26.3	16.3	16.0	0.3	0.6	0.7	1.2	597.7	788.0
4 not planted	2	415.0	76.4	9.0	12.7	0	0	69.0	80.6	101.0	77.8	2.5	0.7	0.5	0.7	0	0	597.5	94.0
Nunn's Marsh	3	108.3	61.2	56.0	39.0	6.0	5.3	13.7	18.5	88.0	82.9	2.3	1.2	0	0	0	0	275.0	63.6
Nunn's Algae	3	113.0	68.0	17.3	7.2	21.3	19.4	3.0	3.6	24.7	40.2	23.0	38.1	10.0	13.9	3.3	4.2	192.7	126.3

TABLE H

Results of Adult Insect Sampling (number of insects per five-sweep sample, July 21, 1982)

Island	1			2			3			4			Nunn's		
Replicate	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
DIPTERA															
Chironomidae	1	1											6	11	11
Dolichopodidae						2						1	1	6	1
Ephyridae													3	2	8
Psychodidae															1
HEMIPTERA															
Nymph (unident)															1
Saldidae											1				1

TABLE I

Length-Weight Parameters for Wild Juvenile Chinook Salmon in Artificial Island and Non-Island Habitats in the Campbell River Estuary, April-June, 1982.

Habitat	n	r^2	a	b
Islands	181	0.93	-13.28	3.51
Non-Island	388	0.89	-12.90	3.39

The length-weight relationship is:

$$\ln(W) = \ln(a) + (b)\ln(L)$$

where W is weight (g), L is fork length (mm), and a and b are constants.

FIG. A Map Showing the Location of the Campbell River Estuary

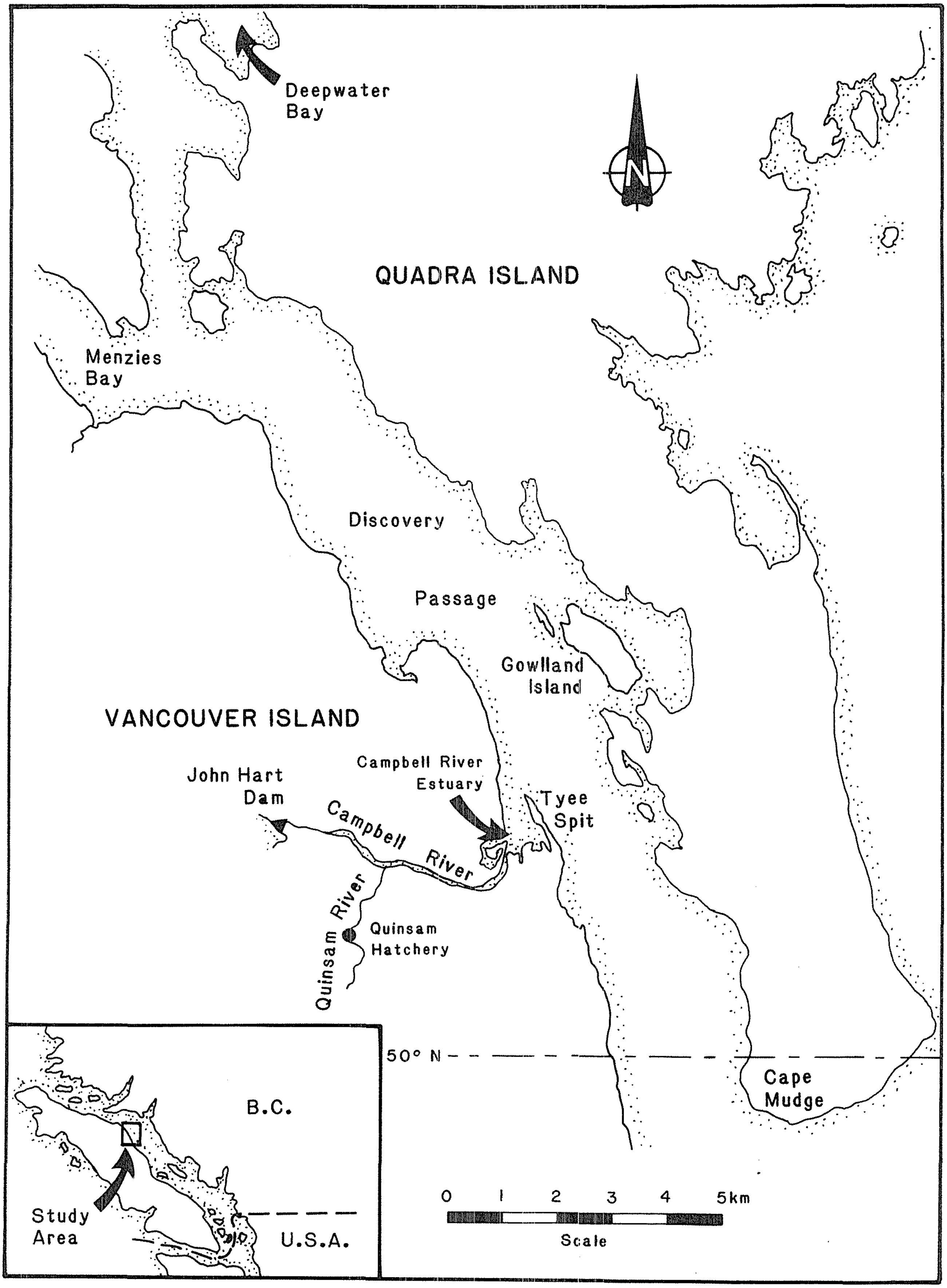


FIG. B The Campbell River Estuary Prior to Construction (Dredging) of the BCFP Log Handling Facility

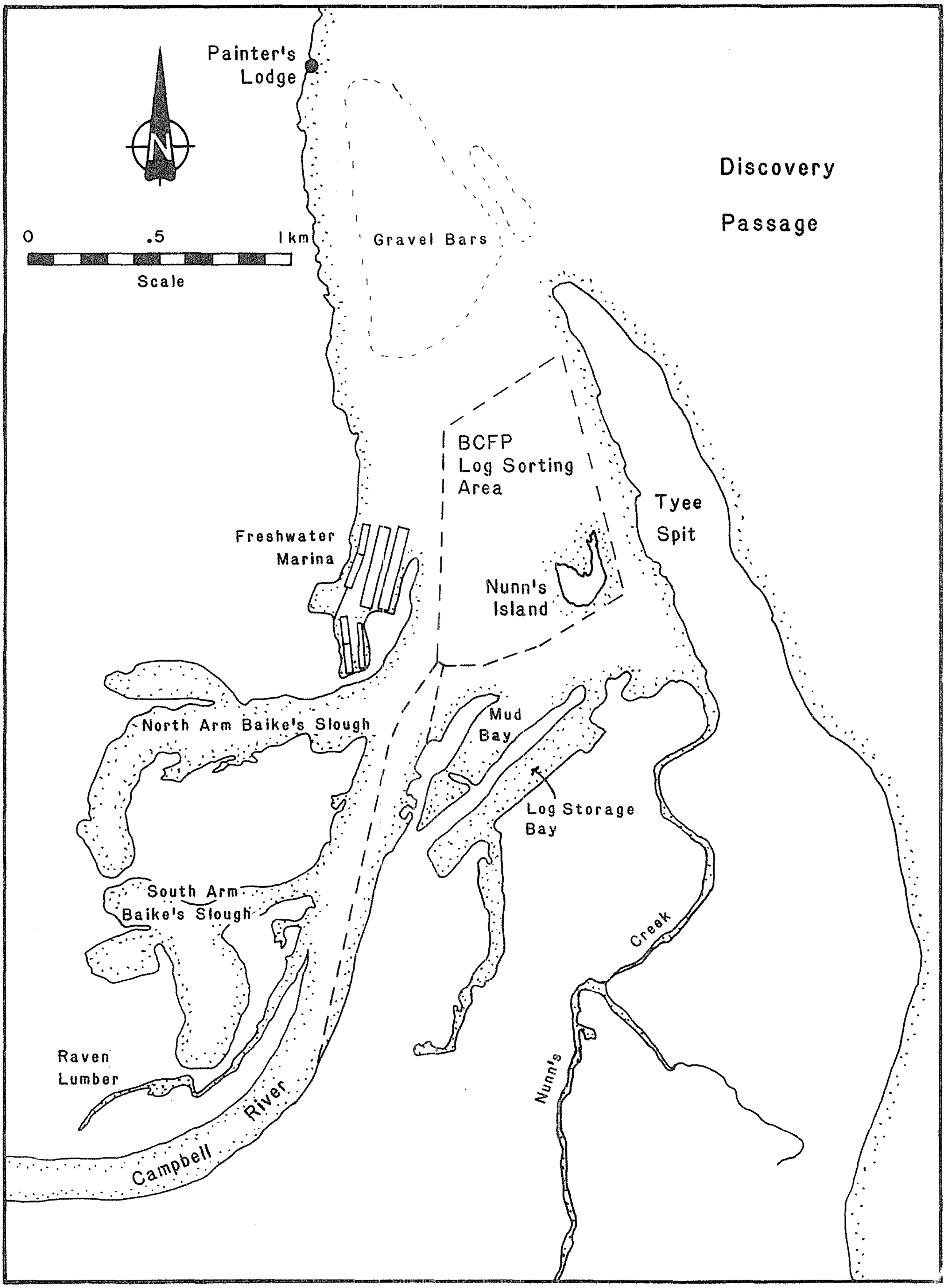


FIG. C BCFP Dryland Log Sorting Operation

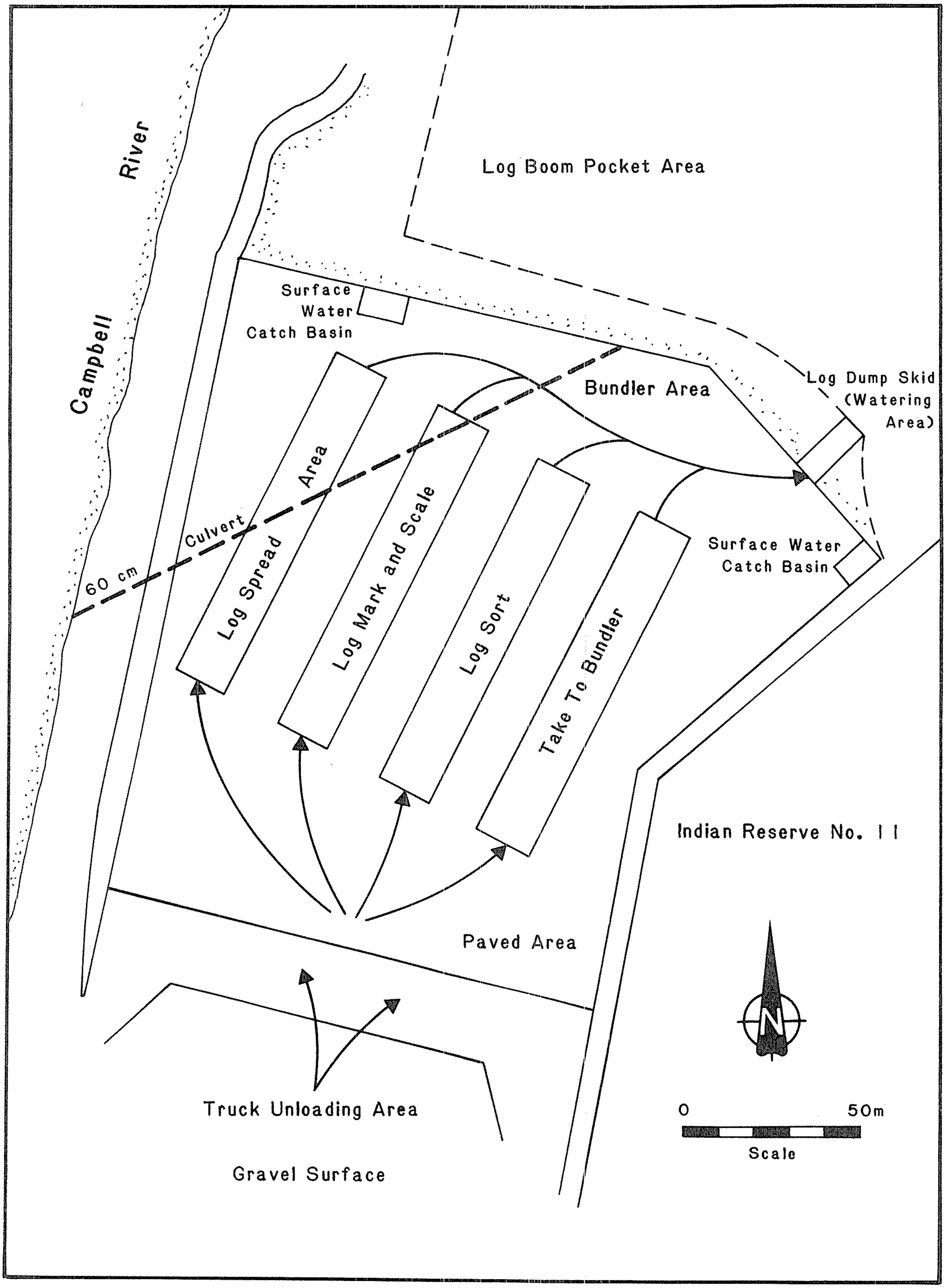


FIG. D Hydraulic Dredging Sequence (1982)

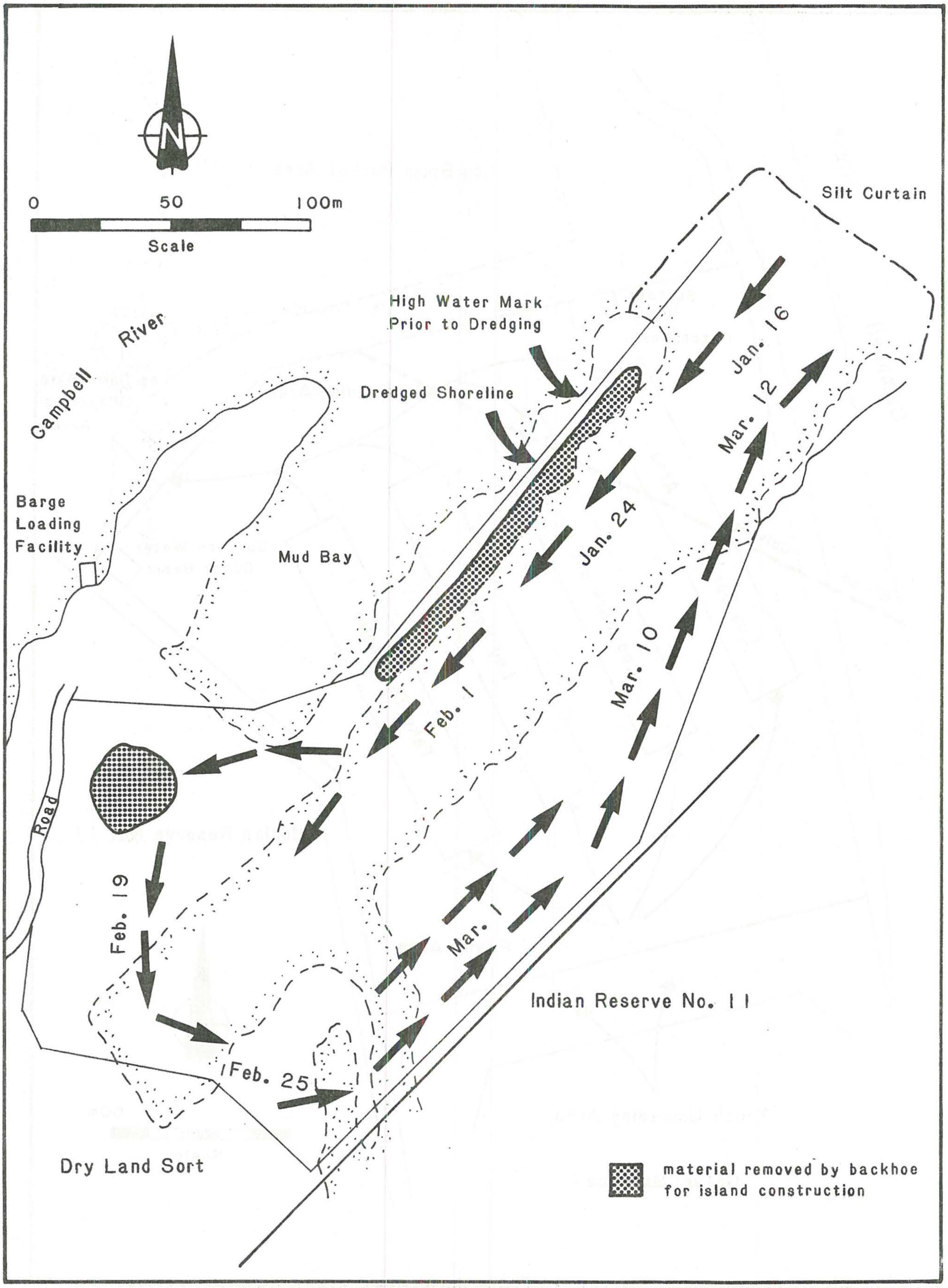


FIG. E Location of the Log Booming Lots within the Estuary

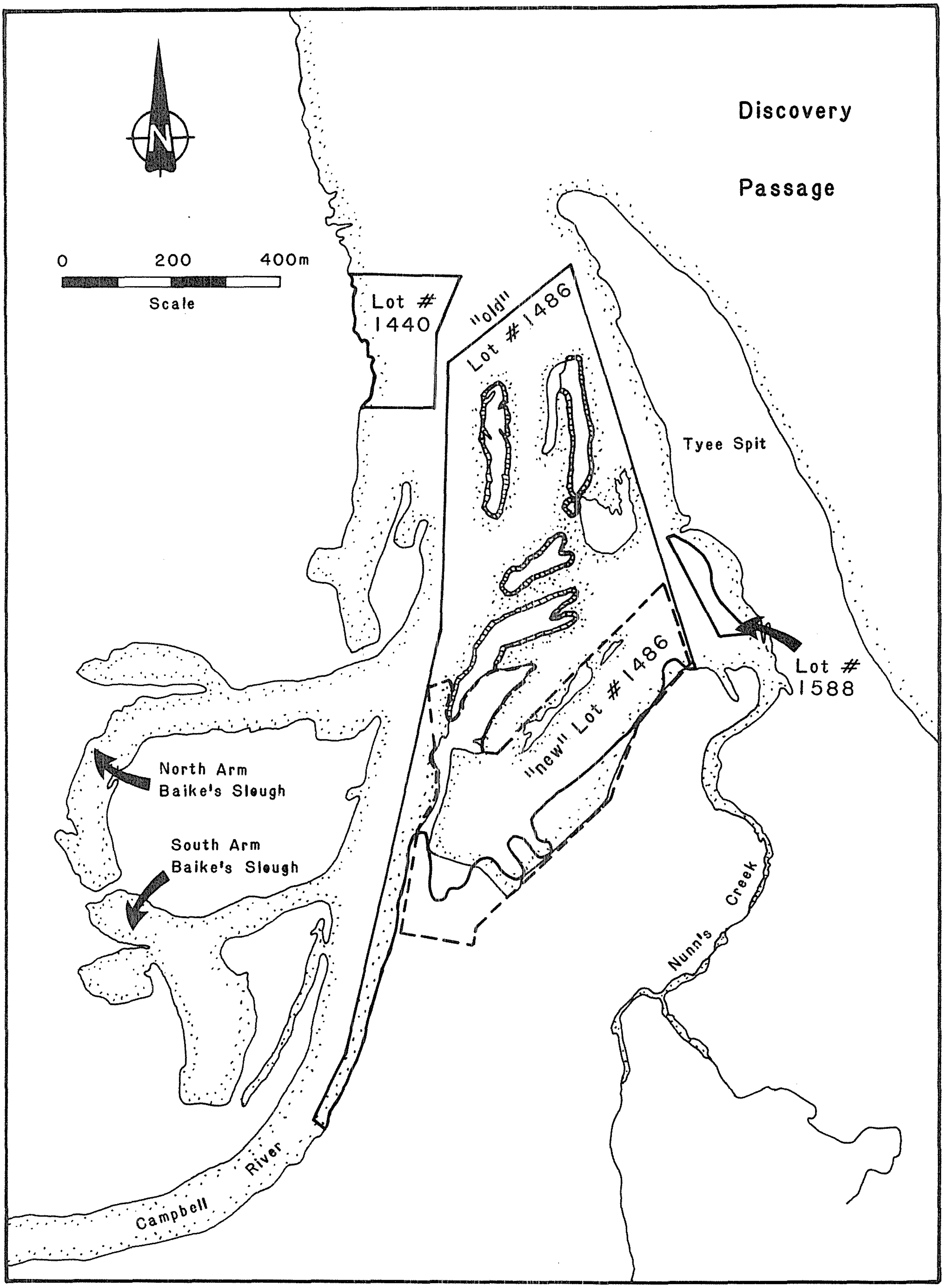


FIG. F Location of the Marsh Core Donor Sites (Predredging) and the Overwintering Area

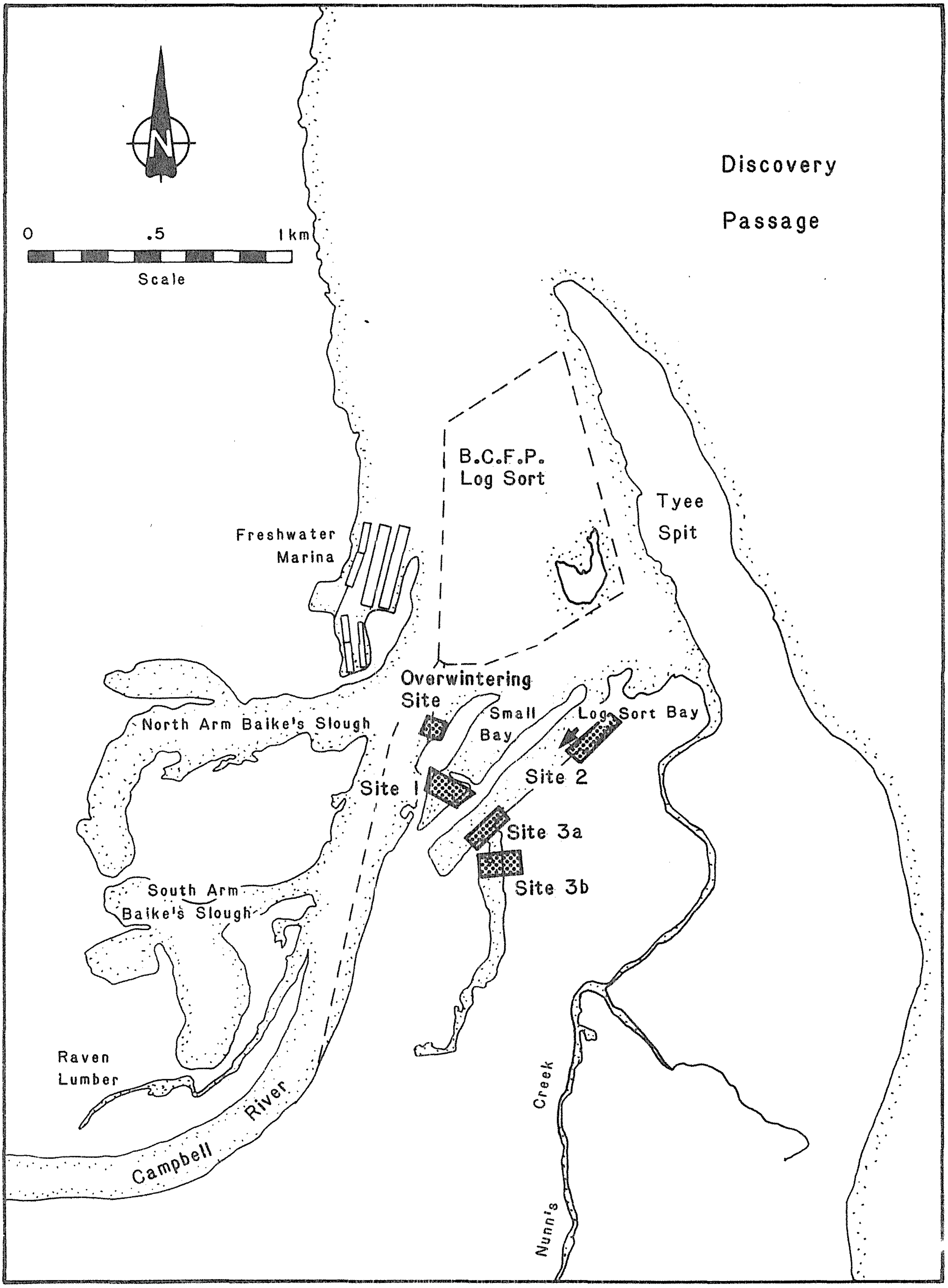


FIG. G Construction of the Causeway Utilized to Form the Estuary Islands

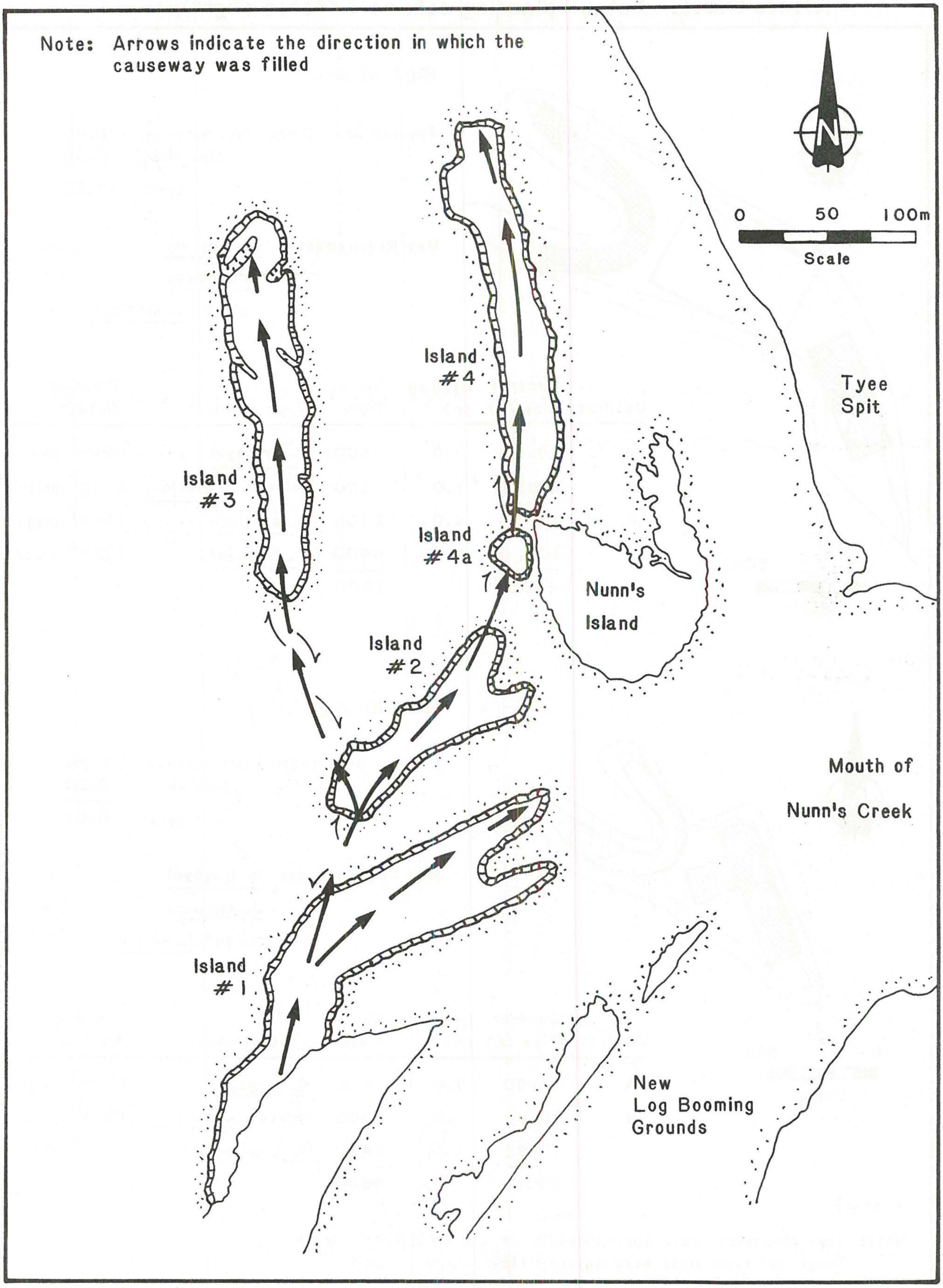
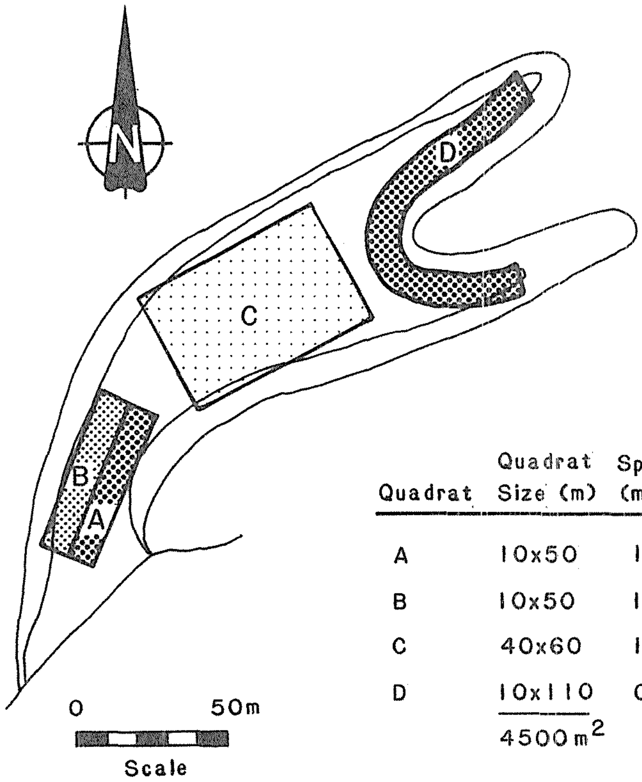


FIG. H Proposed Details of the Marsh Core Planting Scheme for each of the Islands (Note: Actual planting scheme differed slightly)

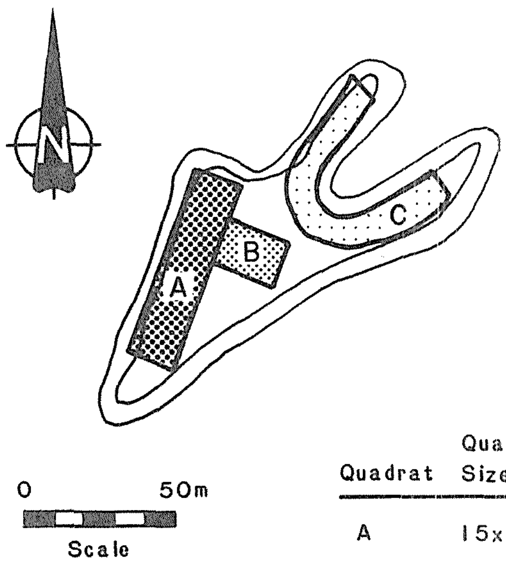


ISLAND #1

Planted Area (ha): flat surface 0.65
side slope 0.38
total 1.03

Mat Requirements: C. lyngbyei 30
J. arcticus 15
"mixed" J. arcticus 4

Quadrat	Quadrat Size (m)	Spacing (m)	No. of Plugs	Type of Plug	Planting Method
A	10x50	1.0	500	C. lyngbyei	10cm^2 plugs
B	10x50	1.0	500	"mixed" J. arcticus	10cm^2 plugs
C	40x60	1.0	2400	J. arcticus	10cm^2 plugs
D	10x110	0.5	4400	C. lyngbyei	10cm^2 plugs
	4500m^2		7800		



ISLAND #2

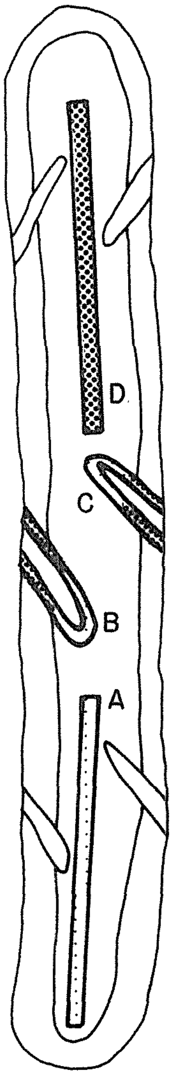
Planted Area (ha): flat surface 0.29
side slope 0.20
total 0.49

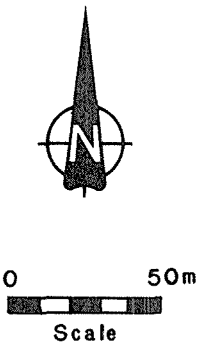
Mat Requirements: C. lyngbyei 8
J. arcticus 24
"mixed" J. arcticus 3

Quadrat	Quadrat Size (m)	Spacing (m)	No. of Plugs	Type of Plug	Planting Method
A	15x60	1.0	900	C. lyngbyei	10cm^2 plugs
B	15x20	1.0	300	"mixed" J. arcticus	10cm^2 plugs
C	10x85	0.5	3400	J. arcticus	10cm^2 plugs
	2050m^2		4600		

Note: Mat dimensions were approximately 1m x 2m x 20cm in depth
Plugs cut from mats were approximately 10cm x 10cm

FIG. H (cont.)





ISLAND #3

Planted Area (ha): flat surface 0.74
side slope 0.57
total 1.31

Mat Requirements: C. lyngbyei 60
J. arcticus 60

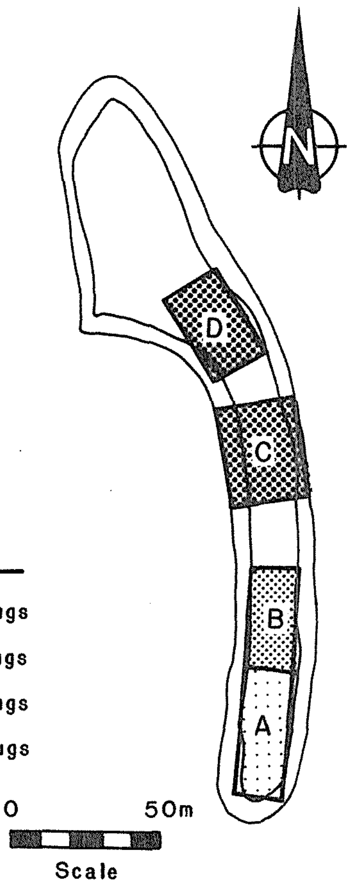
Quadrat	Quadrat Size (m)	Spacing (m)	No. of Plugs	Type of Plug	Planting Method
A	4x100	0.5	1600	J. arcticus	10cm^2 plugs
B	4x100	–	–	Juncus, Carex	mats
C	4x100	–	–	Juncus, Carex	mats
D	5x100	0.5	2000	C. lyngbyei	10cm^2 plugs
	1700m^2		3600		

ISLAND #4

Planted Area (ha): flat surface 0.43
side slope 0.24
total 0.67

Mat Requirements: C.lyngbyei 25
J. arcticus 18
"mixed" J. arcticus 14

Quadrat	Quadrat Size (m)	Spacing (m)	No. of Plugs	Type of Plug	Planting Method
A	40x15	0.5	2400	J. arcticus	10cm^2 plugs
B	30x15	0.5	1800	"mixed" J. arcticus	10cm^2 plugs
C	30x25	0.5	3000	C. lyngbyei	10cm^2 plugs
D	30x20	1.0	600	C. lyngbyei	10cm^2 plugs
	3900m^2		7800		



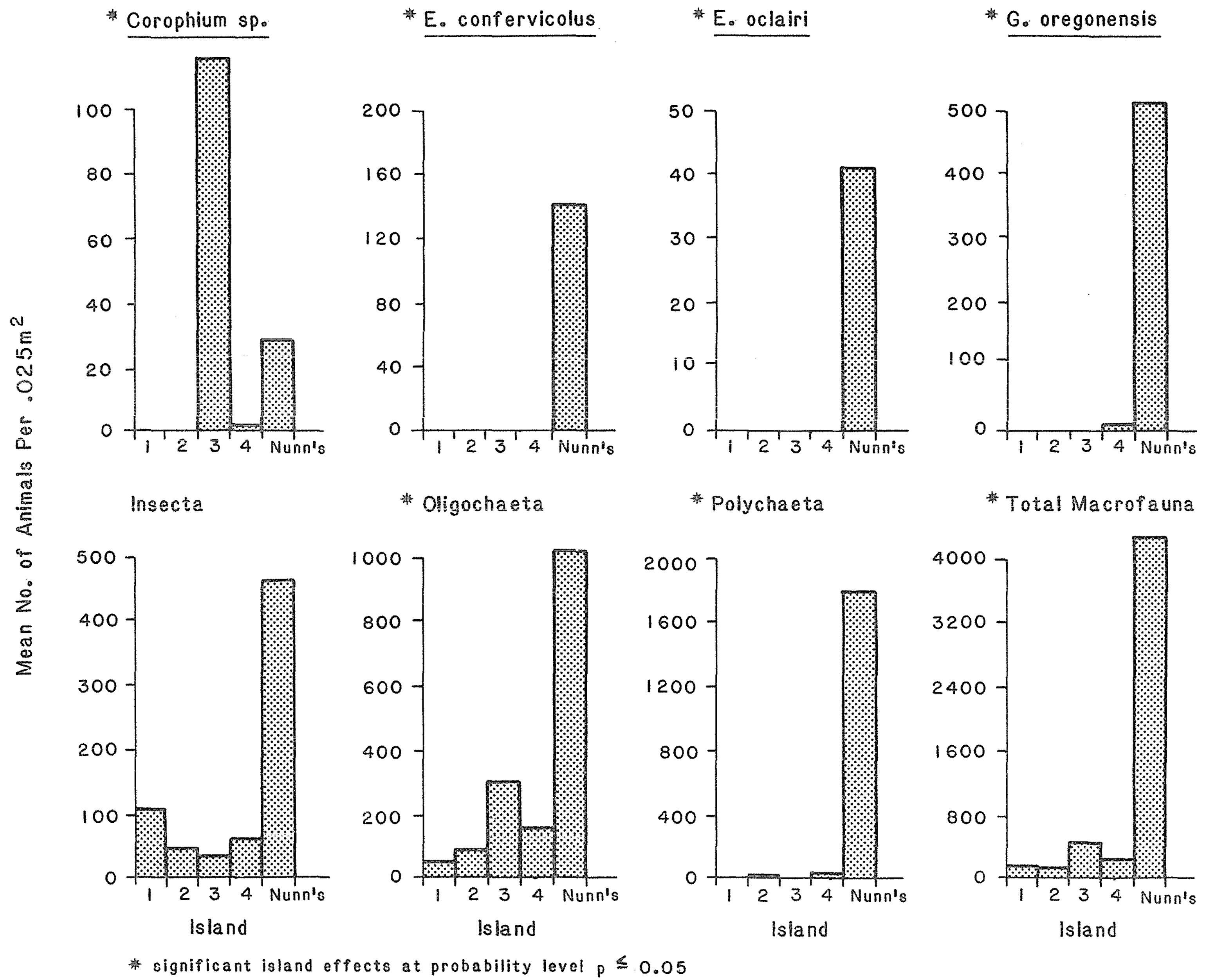


FIG. 1 Differences Between Invertebrate Abundance Among the Newly Formed Estuary Islands (analysis includes Nunn's Island data)

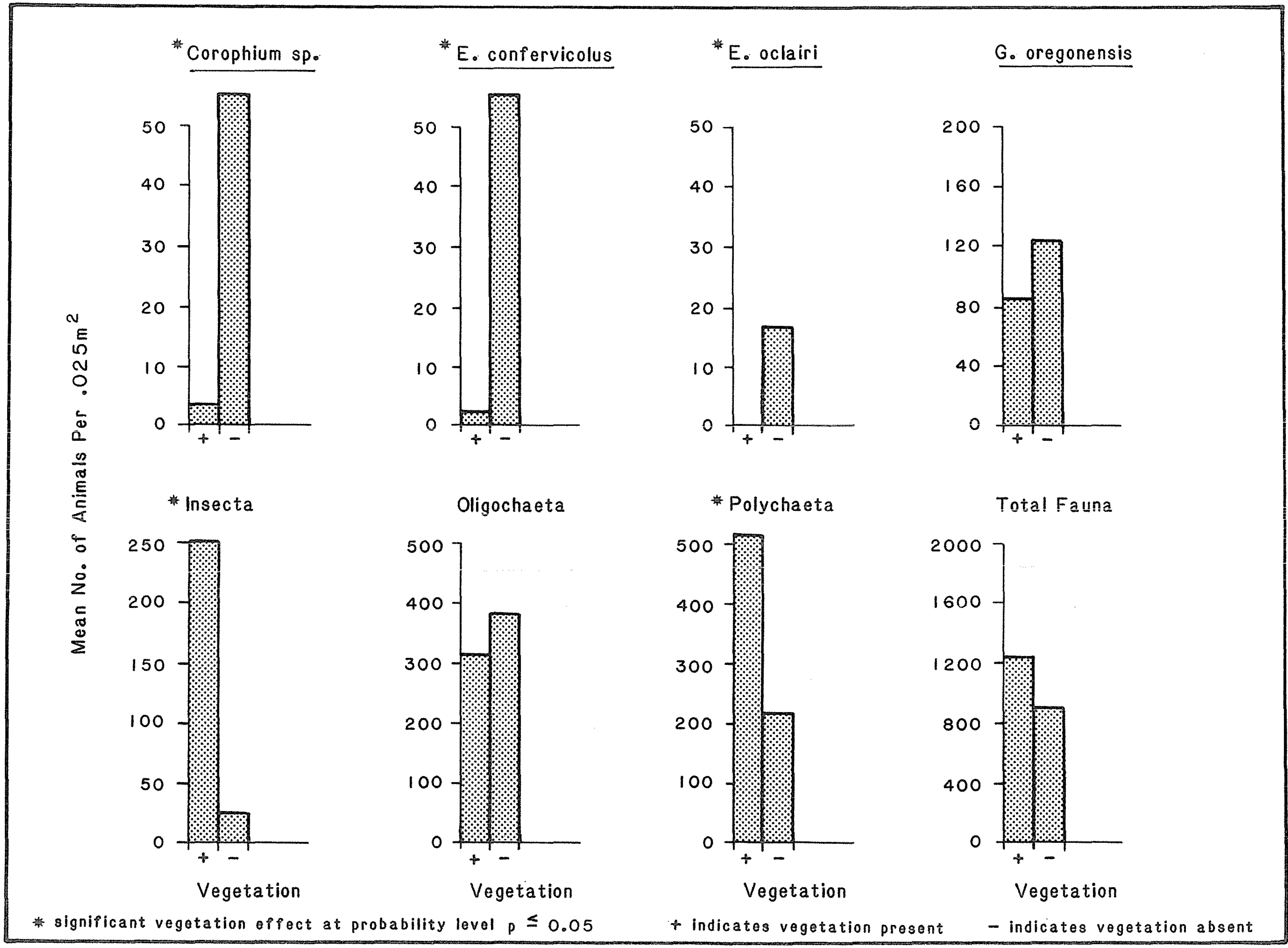
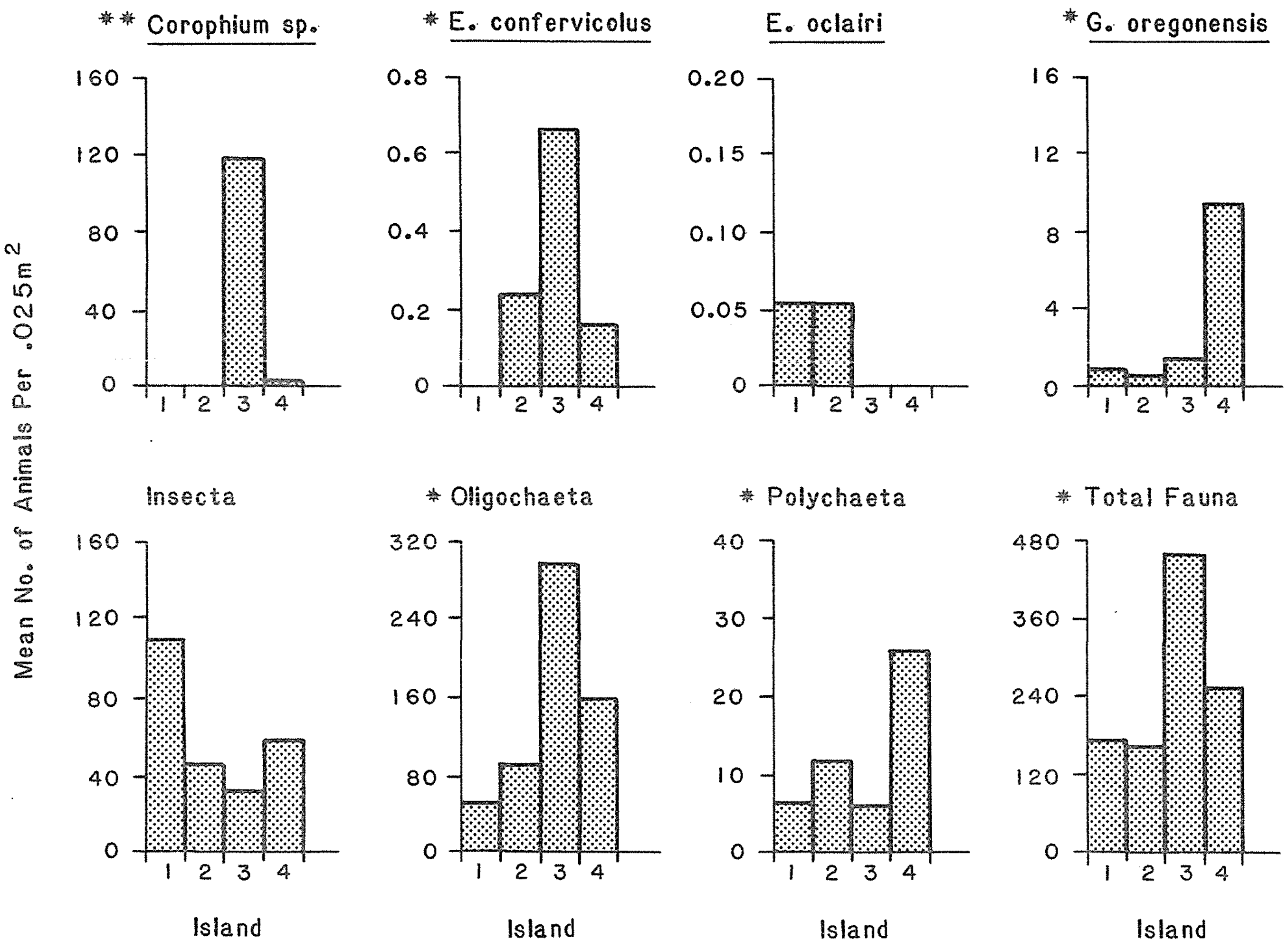


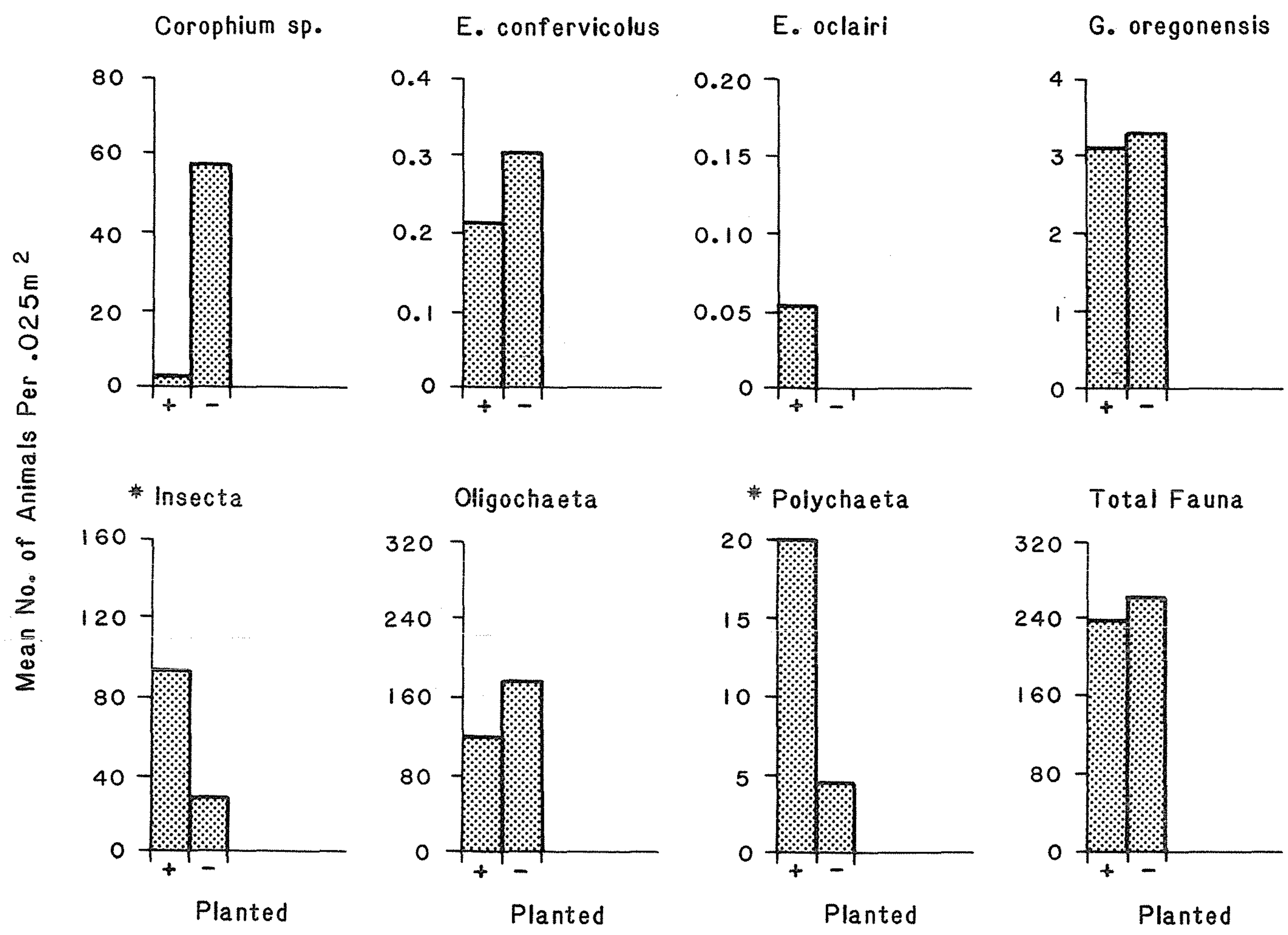
FIG. J Influence of Vegetation on Invertebrate Abundance on the Campbell River Islands (statistical comparison includes Nunn's Island data)



** significant island effect at probability level p ≤ 0.01

* significant island effect at probability level p ≤ 0.05

FIG. K Differences Between Invertebrate Abundance Among the Newly Formed Estuary Islands (analysis excludes Nunn's Island data)



* indicates significant difference in abundance p ≤ 0.05

\+ indicates vegetation present
− indicates vegetation absent

FIG. L Influence of Vegetation on Invertebrate Abundance on the Campbell River Islands (statistical comparison excludes Nunn's Island data)

FIG.M Discovery Passage Beach Seine Stations Sampled in 1982 (Brown et al. 1983)

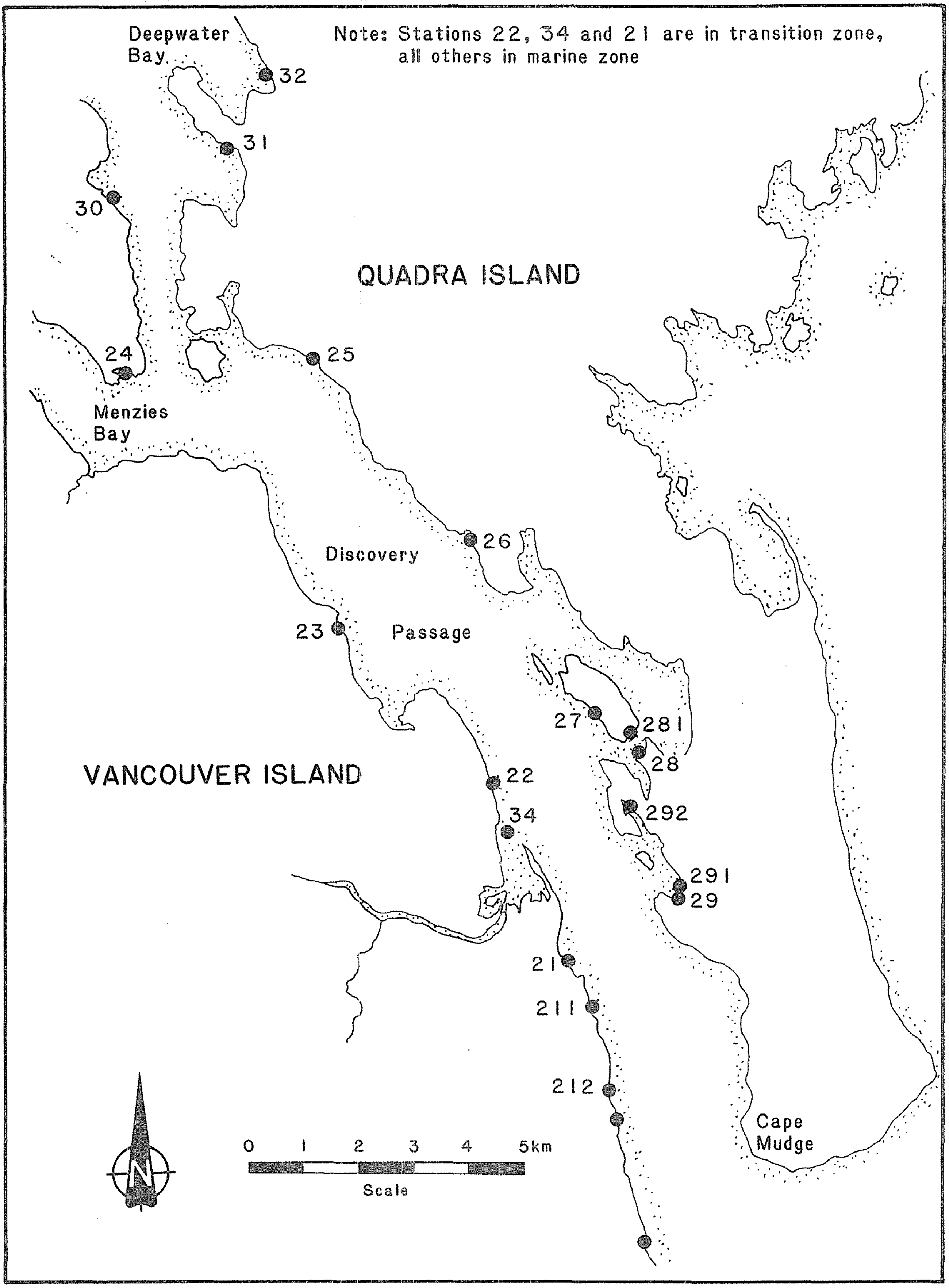
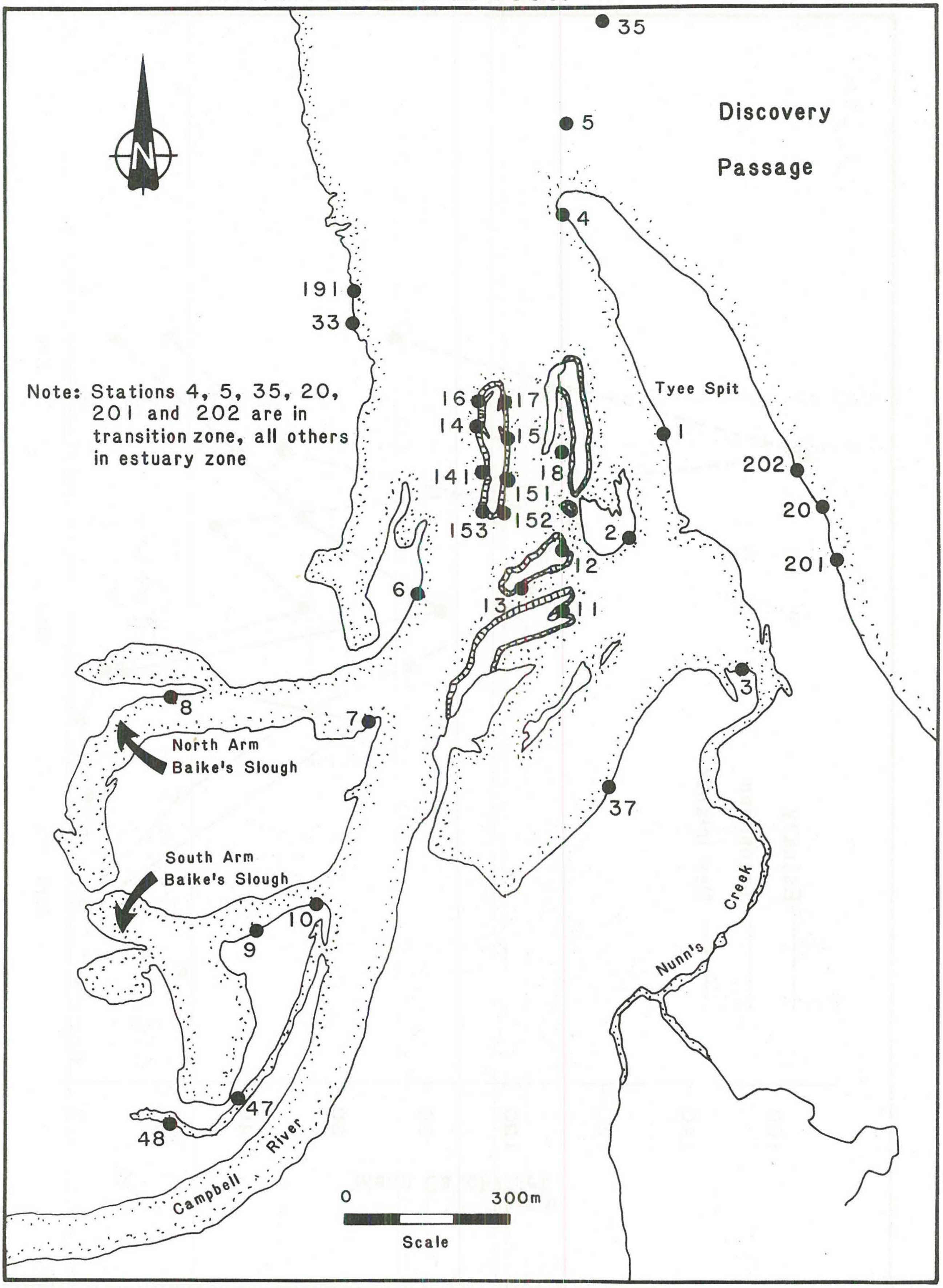


FIG. M (cont.) Estuary and Transition Zone Beach Seine Stations Sampled in 1982 (Brown et al. 1983)



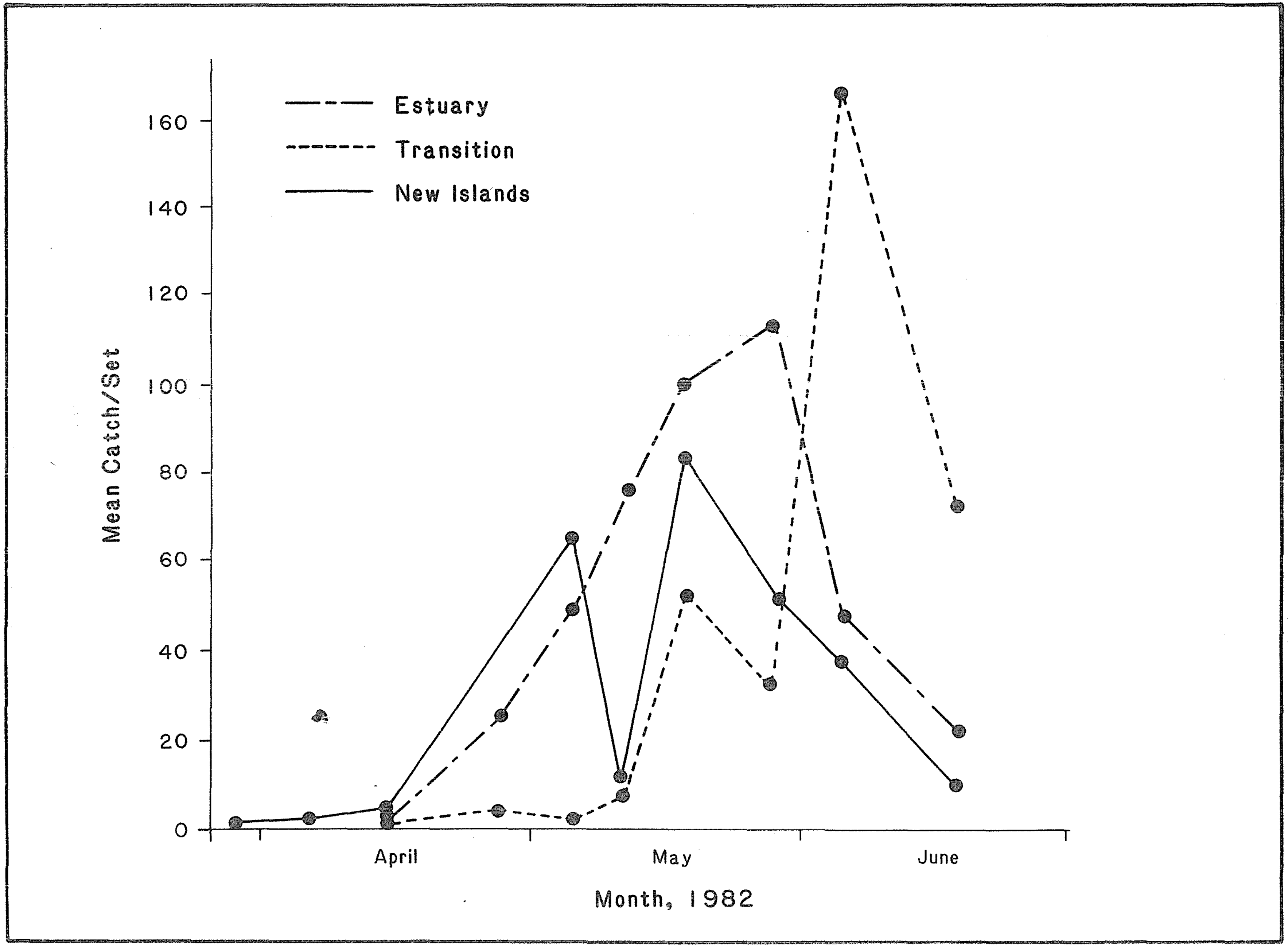
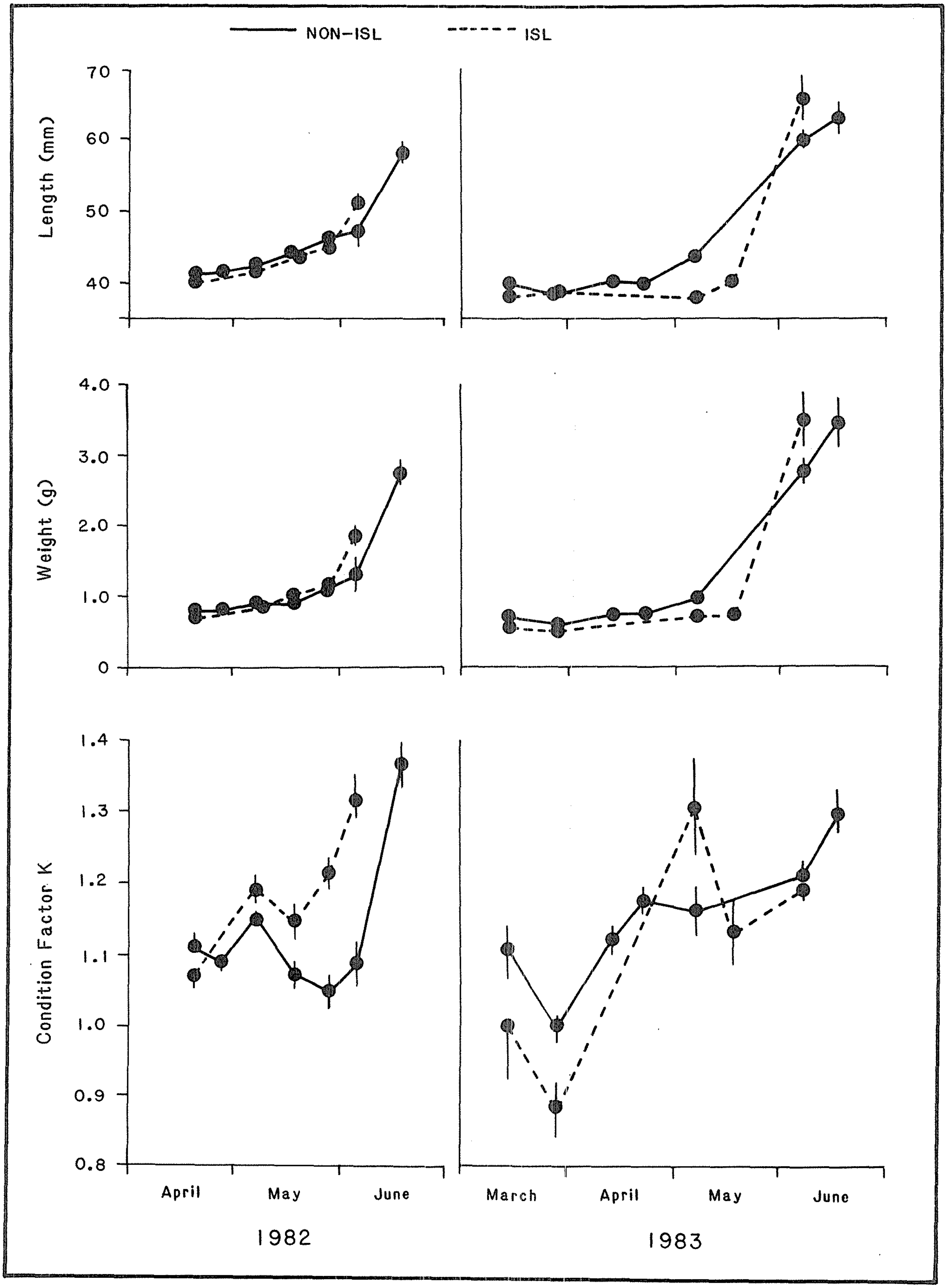


FIG. N Catches of Young Chinook Salmon at Campbell River in 1982

FIG. O Mean Length, Weight, and Condition for Wild Chinook Fry Captured at Island and Non-Island Stations in 1982 and 1983



LIST OF APPENDICES

Appendix I

Significant dates for project planning and construction

APPENDIX I

Significant dates for project planning and construction.

<u>February 15, 1980</u>

- Announcement that BCFP was successful bidder in purchase of Elk River Timber Company Limited assets.

- Planning for new dry land sort and booming area, considered during bidding, commenced.

<u>April 21, 1980</u>

- Elk River Timber officially a part of Campbell River operation, as Elk River Division.

<u>June 2, 1980</u>

- First meeting with representatives of Fisheries & Oceans, Habitat Protection Division, Vancouver Office, followed by later meeting with Lands Manager, Courtenay.

- Requirements for Coastal Log Handling Application were received.

<u>Summer & Fall 1980</u>

- Fisheries & Oceans, Fish & Wildlife, Canadian Wildlife Services and BCFP Resource Planning Group continue intensive inventory of estuary, review of existing data.

- Many "in house" and agency planning meetings to analyze various proposed locations and configurations.

- Recognizing the importance of timing for any construction activity in the estuary being confined to the December - March period, and the length of time required for agency approvals, construction postponed to Winter 81/82.

<u>February 2 - 6, 1981</u>

- Maintenance dredging of sorting gap conducted under close monitoring by BCFP and Fisheries & Oceans.

<u>March 4 - 6, 1981</u>

- Agreement reached with agencies on basic location, and configuration chosen from six proposals. Many specific boundary locations still to be settled.

April 15, 1981

- Application for Crown Land submitted by W.G. Burch, Vice-President Timberlands & Forestry, to be followed by Prospectus when completed.

May - June, 1981

- Several meetings held with B.C. Forest Service, Regional District, Municipal Council, etc., outlining proposal.

- Workshops to develop further biological and engineering details, identify marsh donor sites, etc.

July 30, 1981

- Prospectus hand-delivered to Dept. of Lands, Courtenay; Fisheries & Oceans; Fish & Wildlife.

July 31, 1981

- Written approval received from Dept. of Lands, subject to written approvals from agencies.

September 1, 1981

- Received written approvals from Fisheries & Oceans and Fish & Wildlife.

September 2, 1981

- Falling of site commenced, followed shortly by backhoe load out of surface material.

October 1981

- Clam-shell dredging of old boom storage pocket.

November 1981

- Planting material (marsh) harvested and transplanted to overwintering site.

December 1981

- Island material trucked out to form causeway at 5.0 m elevation. Mixing of materials to provide good stable base and productive growing medium.

- River diversion pipe installed.

January 16, 1982

- Sceptre Dredging Ltd. started hydraulic dredging to remove gravel from booming pocket and deposit as base for dry land sort.

February 1982

- Spreading of causeway material to form islands to precise boundaries and elevations designed by Fisheries & Oceans biologists.

* N.B.: All this work had to be done at night, during low tides, under floodlights.

February 1 - 25, 1982

- Planted 22,850 plugs of Carex and Juncus marsh on the four islands. Project involved 275 man "days" (nights) of labour plus intensive supervision. All work done at night, during low tides.

March 12, 1982

- Dredge portion of project complete, 3 days ahead of deadline.

- Rip-rapping of boundary slope followed closely behind dredging.

April 1982

- Marsh starts to show first signs of growth.

- Preparation of dry land sort surface continues.

- Pile driving the booming grounds (steel piles) underway.

May 1982

- Final grading of sort base and application of crushed gravel.

- Office installed - sprinkling system and catch basin installed.

June 1982

- Paving dry land sort underway.

July 6, 1982

- First logs over dry land sort watered.

July 7, 1982

- Debris clean up program commenced; completed August 23.

DRY LAND SORT/BOOMING GROUND CONSTRUCTION SPECIFICATIONS

LAND AREAS CLEARED

(a) 10.8 acres existing land cleared for new sort and excess gravel stock pile
(b) 8.2 acres existing land cleared prior to dredging.

REMOVAL OF ORGANICS

66,000 cubic yards removed to land fill on adjacent Indian Reserve #11.

DREDGING

(a) Clamshell Dredging
- 33,000 cubic yards clammed onto barges and ocean dumped.

(b) Hydraulic Suction Dredging
- 479,000 cubic yards pumped to sort and storage areas.
N.B.: approx. 150,000 yd^3 remains in stockpile.

(c) Backhoe Dredging
- 40,000 cubic yards removed and utilized in island construction.

DRY LAND SORT SPECIFICATIONS

(a) Depth of gravel fill 10 - 13' (sub-base).
(b) Depth of crushed base 12 inches.
(c) Depth of pavement - 2 x 2" lifts.
(d) Design slops - 1.5%.
(e) Total area paved - 4.6 acres (an additional 1.0 acre will be paved in 1984)
(f) Adjacent gravel surface of about 5 acres will be used for contingency storage.

Appendix II

A survey of potential marsh transplant donor sites in the Campbell River Estuary

APPENDIX II

A Survey of Potential Marsh Transplant Donor Sites in the Campbell River Estuary by Don Gordon

Introduction

Three sites on the Campbell River estuary, which are designated for destruction when development plans by B.C. Forest Products are implemented, were surveyed to determine the feasibility of their being used as donor sites for marsh transplantation. Juncus arcticus and Carex lyngbyei are the two marsh species at these sites for which the most interest in transplanting has been demonstrated. In addition, two existing intertidal island sites within the estuary were briefly surveyed in September 1981.

Material and Methods

Stands of C. lyngbyei and J. arcticus were flagged with wooden stakes to which coloured surveyor's tape was tied. Lime green tape designated J. arcticus, pink for C. lyngbyei and stakes having both lime green and pink designated 'borders' between these two species. The distance between stakes was measured using a metre line. Cores were taken (10 cm in diameter, 16 cm deep), at stations at each of the sites, using a Par A Cup Cutter. Depth of rhizomes and sediment type were determined from these cores. In addition, using the Par A Cup Cutter to obtain cores also allowed one to determine the feasibility of employing this device to obtain transplant plugs. Shoot density and species composition were determined using a 0.03 m^2 quadrat.

Sites 1, 2, 3a and 3b (Fig. 1) were surveyed at low tide whereas the two island sites 4 and 5 (Nunn's Island) were partially covered by the tide by the time we got to them. Thus, flagging was completed at these sites by making observations through the overlying water and pounding stakes into the substrate from a boat.

Results

Juncus arcticus occurs as a dense, almost pure stand that occupies 250 m^2 at Site 1 (Fig. 2, Table 1). A small patch of Carex lyngbyei is located at the southeast corner of the J. arcticus stand. Sidalacea hendersoni is mixed in with the J. arcticus in the northwestern part of the site; however, it is unimportant when compared to the density of J. arcticus. Tall stands of Typha sp. surround the J. arcticus stand. Rhizomes occur at 10 - 12.5 cm depth in the silty-clay sediments.

Fig. 1 Site Location Map

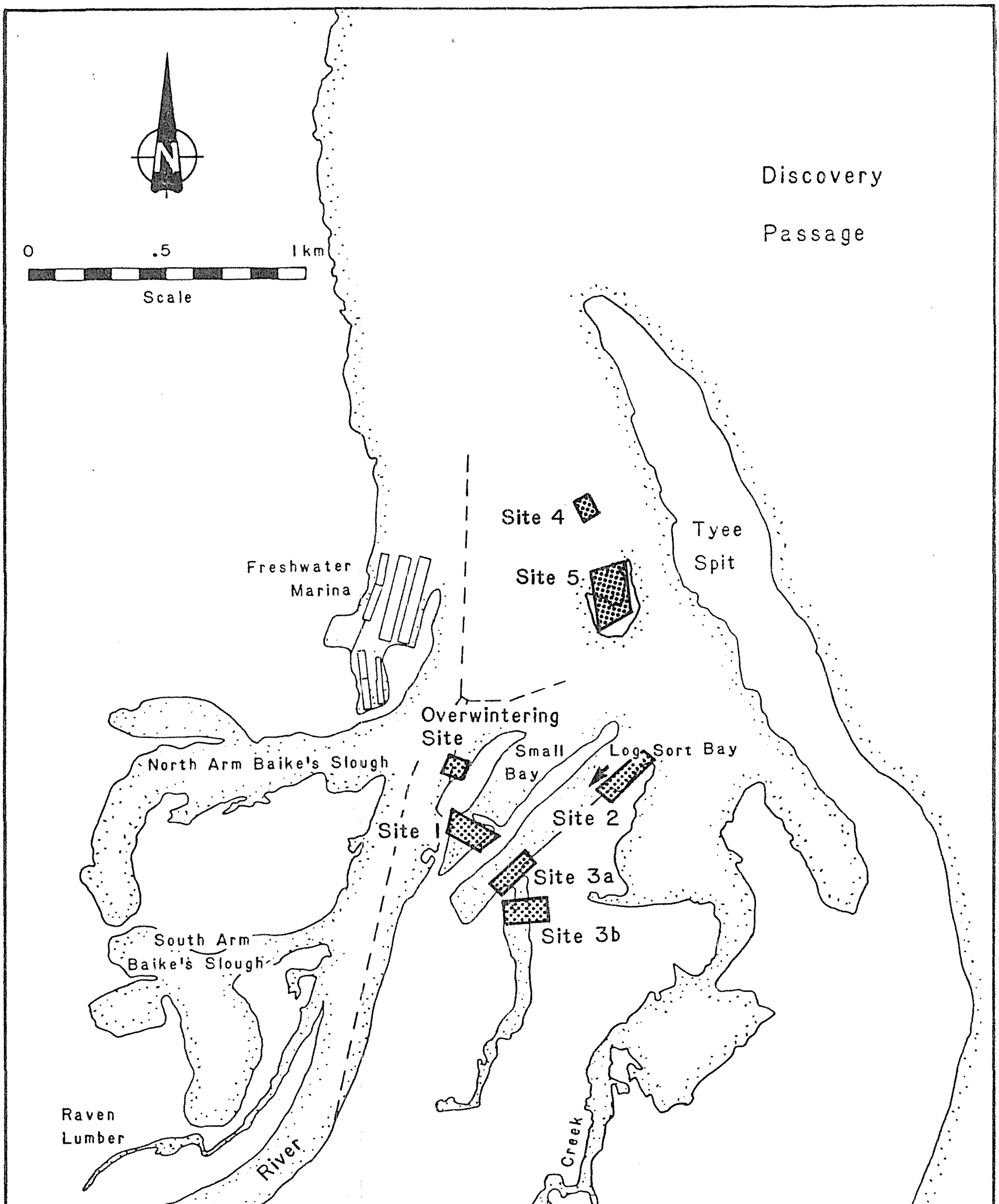


Fig. 2 Survey Map of Site I

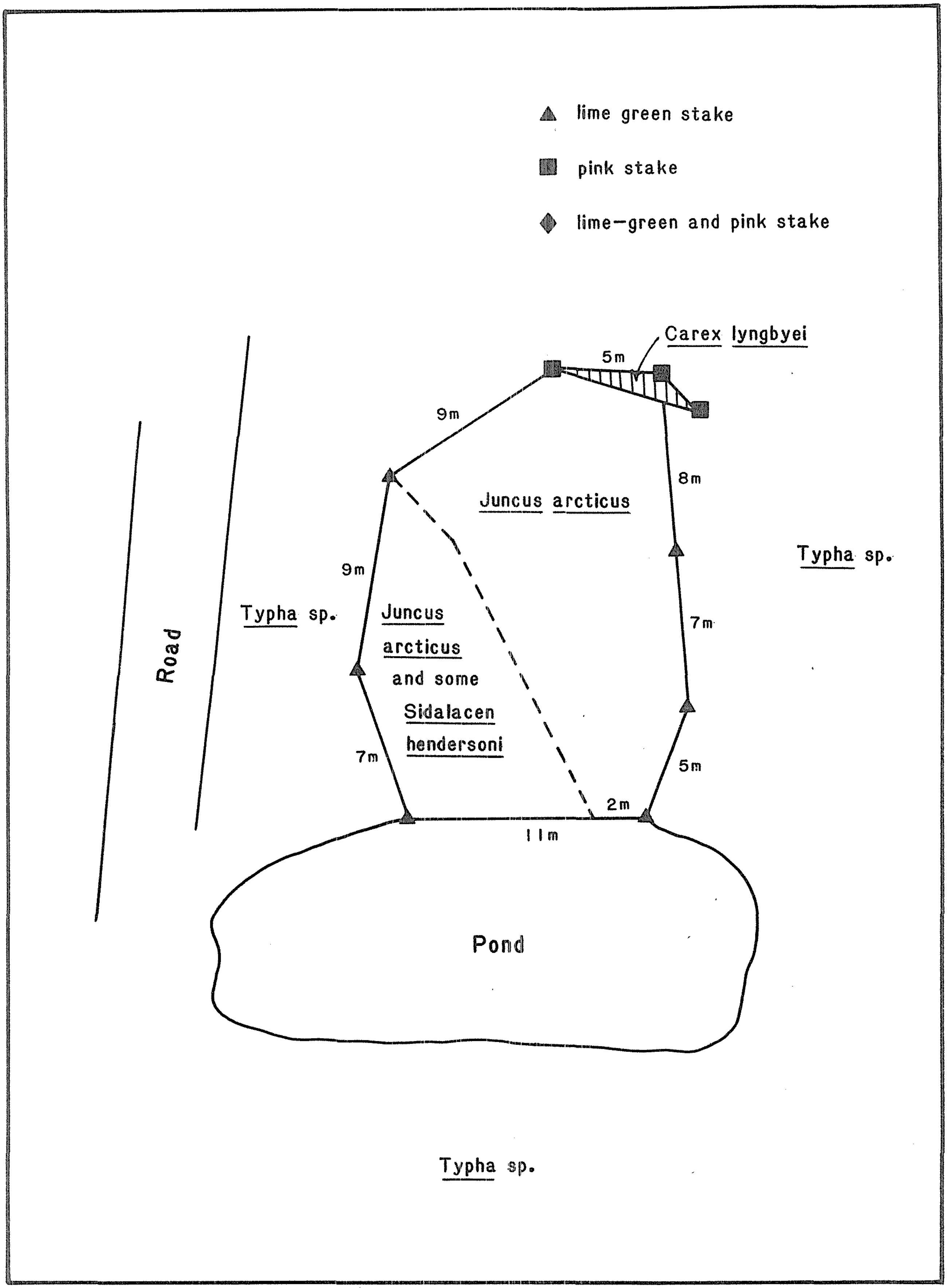


Table 1. Survey results for the three potential donor sites which are designated for destruction.

Site	Stn.	Vegetation[1]	Shoot #/m^2	Rhizome Depth (cm)	Sediment type
1	1	96% Juncus arcticus 4% Carex lyngbyei (t)	2433	10-12.5	silty-clay
2	1	100% C. lyngbyei (t)*	1000	11-16	silty-sand
	2	90% C. lyngbyei (t) 10% J. arcticus	983	10-13	silty-sand
	3	92% C. lyngbyei (t) 8% J. arcticus	1025	6-15	primarily sand, some clay at the surface and gravel at the bottom of the core.
	4	100% C. lyngbyei (t)	850	6-13	silty sand at top, sand with gravel at the bottom of the core.
	5	100% C. lyngbyei (t)	867	6-14	sandy-clay
3a	1	100% C. lyngbyei (t)	533	3-11	sand at surface, sand, gravel at the bottom of the core.
	2	100% C. lyngbyei (t)	433	NS	silt, sand, gravel
3b	1	100% C. lyngbyei (t)	383	4-12	sand, silt, gravel
	2	100% C. lyngbyei (t)+	567	3-12	silt
	3	85% J. arcticus 12% Equisetum sp. 3% C. lyngbyei (s)	1516	2.5-13	silty, but slightly loamy
	4	50% J. arcticus 30% Equisetum sp. 20% C. lyngbyei (s)	1633	2.5-13	silt

1 a t designates the tall C. lyngbyei ecotype and an s the short C. lyngbyei ecotype.

* a small narrow (1.5 m) band of J. arcticus exists just above this.

\+ a narrow band (1.5 m) of J. arcticus, Potentilla pacifica and Eleocharis palustris exists just above this.

The dominant plant species at site 2 (Fig. 3) is C. lyngbyei. Some J. arcticus is found amongst the C. lyngbyei and a narrow (1.5 m) band of J. arcticus exists along the northeast-east corner of the site (Table 1). The C. lyngbyei covers an area of 230 m^2. Sediments are primarily composed of silty-sand but gravel was present in cores from stations 3 and 4. The presence of this gravel sometimes makes it difficult to push the corer in. The upper depth at which rhizomes occur is shallower at stations 3, 4 and 5 than at stations 1 and 2.

Pure stands of C. lyngbyei exist at site 3a (Fig. 4) and cover an area of 60 m^2. Shoot densities (Table 1) are lower than at site 2 and the upper depth at which rhizomes occur is shallower than at site 2. No cores could be obtained from station 2 of this site due to the large amount of gravel in the sediment.

Site 3b (Fig. 4) is comprised of two areas. Station 1 and 2 occur along the banks of the channel and are vegetated by pure stand of C. lyngbyei which cover an area of 120 m^2. Shoot densities (Table 1) are lower than those at sites 2 and 3a, the upper depth of rhizome occurrence is shallow and the sediments are mainly silty. Stations 3 and 4 are found in an embayment behind the channel. Densely mixed stands of J. arcticus, C. lyngbyei and Equistum sp. are found here and occupy an area of 75 m^2. Juncus arcticus is the dominant species (Table 1). Shoot densities are high, being about 2/3 the densities found at site 1. The upper depth at which rhizomes occur is much shallower than at site 1. Sediments tend to be silty in nature.

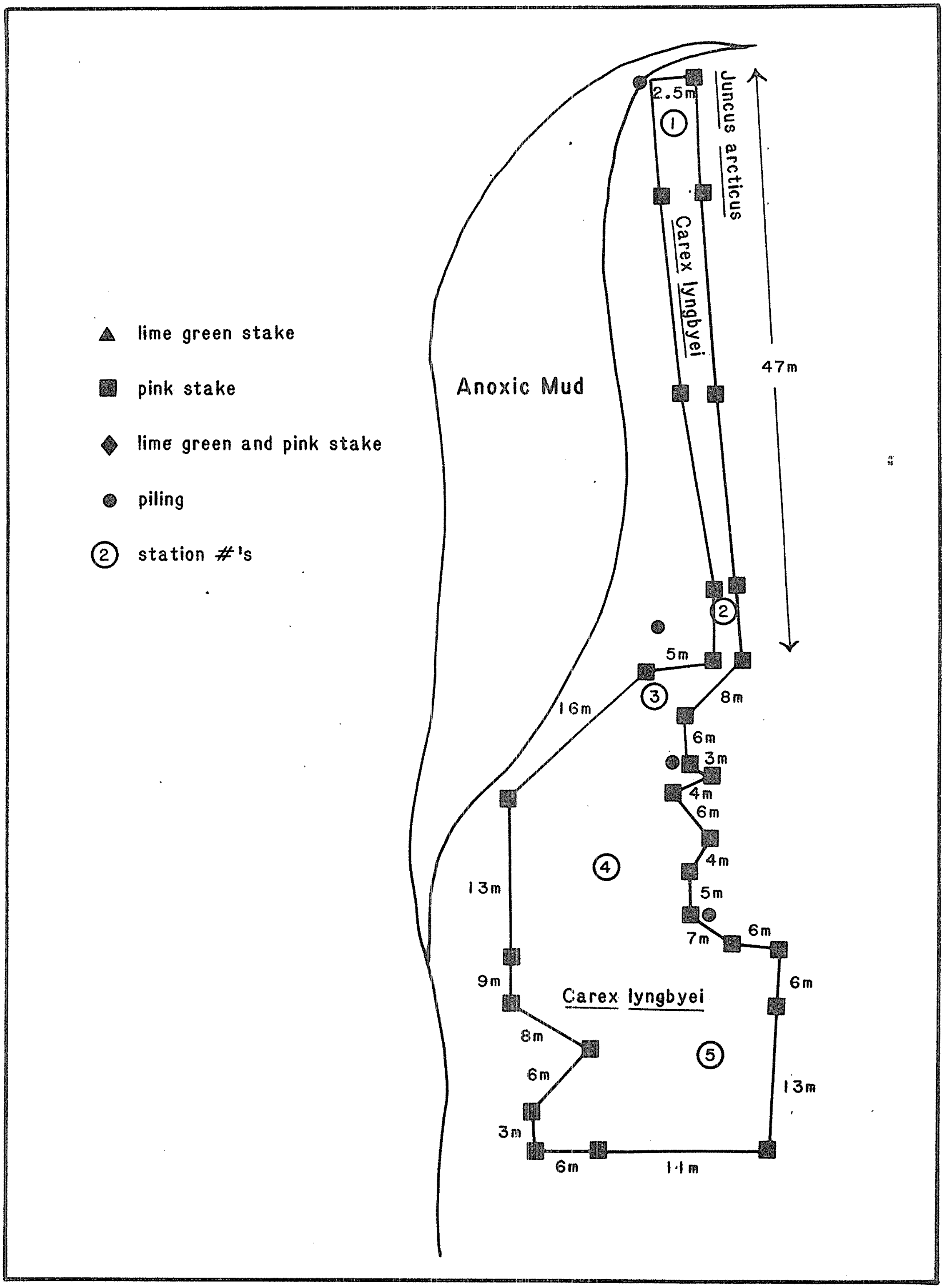
The flagged area at site 4 (Fig. 1) is 44 m^2 in size and encompasses a mixed stand of J. arcticus, Potentilla pacifica and Deschampsia sp.; J. arcticus being the dominant. Some C. lyngbyei is mixed in with this at the lower elevations. Rhizomes occurred at 10 cm depth and the sediment is a silt-sand-gravel mixture. No density measurements could be made.

Site 5 (Fig. 1) also has a mixed stand of J. arcticus, P. pacifica, and Deschampsia sp. and a small amount of Scirpus americanus. Here as at site 4, J. arcticus is the dominant. An area of 250 m^2 was flagged. Carex lyngbyei is found at a lower elevation. An area of 150 m^2 was flagged. The area values given for this site are only approximate figures as the distance between stakes could not be measured but only visually estimated. In addition, no cores could be taken through the overlying water to determine the depth of rhizome occurrence or soil type, nor could shoot density values be determined.

Discussion

The circumstances surrounding the proposed Campbell River development appear to favour the marsh transplant project. Because

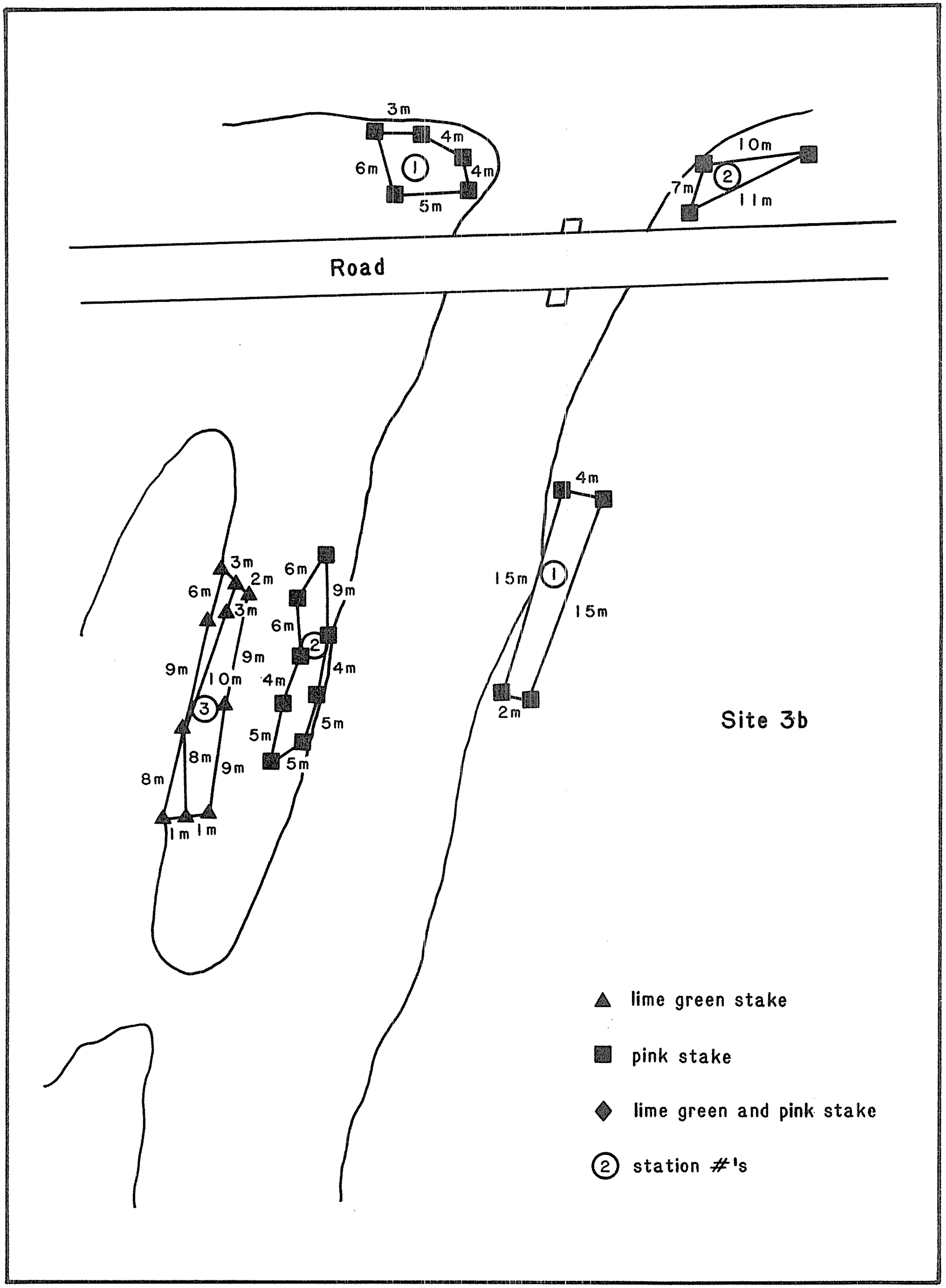
Fig. 3 Survey Map of Site 2



Appendix III

A proposed marsh transplant scheme for the intertidal islands in the Campbell River Estuary

Fig. 4 Survey Map of Sites 3a and 3b



the distance between the donor and transplant sites is relatively small a minimum amount of time and handling will be involved in transport. The salinity regime of the donor and transplant sites is quite similar (unpublished data). Elevations of the transplant sites will be predetermined to suit the requirements of the transplant species. These features should help contribute to the success of the transplant project.

The results of this survey suggest that the core technique, as developed by Pomeroy _et al_. (1981) could be successfully employed at Campbell River. The important aspect of this technique is that a sufficient amount of rhizome and shoot material must appear in each core. Because shoot densities are fairly high at these sites and because the depth of rhizome occurrence is well within the range in which the 'Par A Cup Cutter' works effectively, one can be almost assured of obtaining plant material in each core. In addition, due to the substrate type, cores which were taken maintained their integrity. This adds to the ease of handling and transport.

Sediments at station 2 at site 3a and around station 3 at site 2 contain a sufficiently large amount of gravel to make the 'Par A Cup Cutter' ineffective. To obtain plants from these areas some other technique will have to be employed (i.e., sprigs, large blocks).

In addition to transplanting marsh plants and all the attendant planning that goes along with this, other workers have also had to ensure that they do not damage their donor sites. This is not the case at Campbell River. Since donor sites 1, 2, 3a and 3b are to be devastated anyway one can go in and 'take' everything as transplant material. This means that a large number of transplant cores can be obtained from a relatively small area:

area of cores = 0.008 m^2

# of cores from 1 m^2 = 125 (in theory)

in practice estimate 50 cores/m^2

from donor sites 1, 2, 3a and 3b you would obtain

248 x 50	= 12,400	_J. arcticus_ cores
(230 + 60 + 120) x 50	= 20,500	_C. lyngbyei_ cores
75 x 50	= 3,750	mixed _J. arcticus_ cores
	36,650	

APPENDIX III

Proposed Marsh Transplant Scheme

- original estimates of the proportion of each species in the donor material

Juncus arcticus	250	36%
Juncus arcticus + other species (mixed)	75	11%
Carex lyngbyei	365	53%
	690 m^2	

Planting Scheme #1 (assumes that channels will be made in Island #3)

requires

9800	4" sods of	*J. arcticus*
11400	4" sods of	*C. lyngbyei*
2600	4" sods of	mixed *J. arcticus*
23800		

and

20	mats (1.5' x 3.5') of	*J. arcticus*
60	mats (6.5' x 3.5') of	*C. lyngbyei*
80		

-> the above 'translates' to 210 mats (6.5 x 3.5) worth of donor material.

i.e.: from one 6.5' x 3.5' mat you can obtain (in theory)
190 4" x 4" sods
or
18 12" x 12" sods

Planting scheme #2 (assumes that channels will not be made in Island #3)

requires

11800	4" sods of	*J. arcticus*
17400	4" sods of	*C. lyngbyei*
26	4" sods of	mixed *J. arcticus*
31800		

and

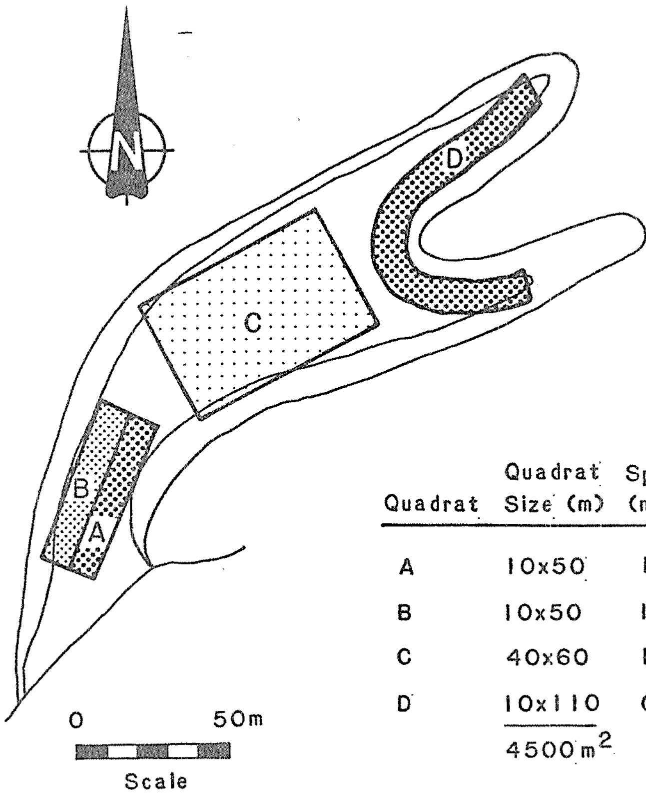
20	12" sods of	*C. lyngbyei*

-> the above 'translates' to 182 mats (6.5' x 3.5') worth of donor material.

Island	Area of top plane	Total Area	Area Planted	% area of top plane planted
1	0.65	1.03	0.45	69%
2	0.29	0.49	0.21	84%
3	0.74	1.31	0.17 (0.37)*	23% (50%)
4	0.43	0.67	0.39	84%
4a	-	0.07	-	-

* bracketed numbers reflect plan 2

Proposed Details of the Marsh Core Planting Scheme for each of the Islets (Note: Actual planting scheme differed slightly)

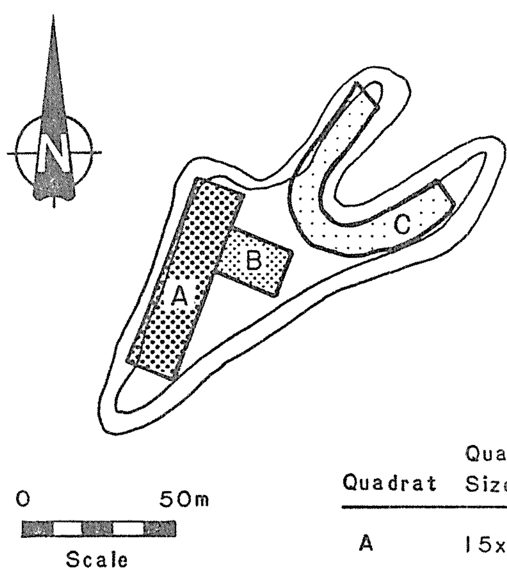


ISLAND #1

Planted Area (ha): flat surface 0.65
side slope 0.38
total 1.03

Mat Requirements: C. lyngbyei 30
J. arcticus 15
"mixed" J. arcticus 4

Quadrat	Quadrat Size (m)	Spacing (m)	No. of Plugs	Type of Plug	Planting Method
A	10x50	1.0	500	C. lyngbyei	10cm^2 plugs
B	10x50	1.0	500	"mixed" J. arcticus	10cm^2 plugs
C	40x60	1.0	2400	J. arcticus	10cm^2 plugs
D	10x110	0.5	4400	C. lyngbyei	10cm^2 plugs
	4500m^2		7800		



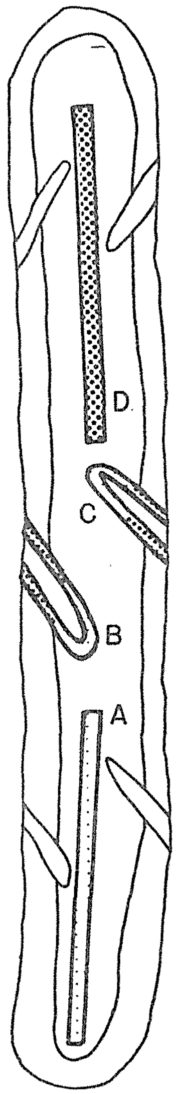
ISLAND #2

Planted Area (ha): flat surface 0.29
side slope 0.20
total 0.49

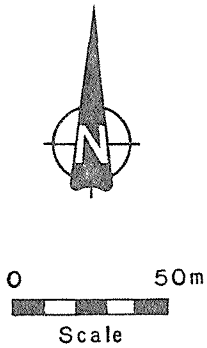
Mat Requirements: C. lyngbyei 8
J. arcticus 24
"mixed" J. arcticus 3

Quadrat	Quadrat Size (m)	Spacing (m)	No. of Plugs	Type of Plug	Planting Method
A	15x60	1.0	900	C. lyngbyei	10cm^2 plugs
B	15x20	1.0	300	"mixed" J. arcticus	10cm^2 plugs
C	10x85	0.5	3400	J. arcticus	10cm^2 plugs
	2050m^2		4600		

Note: Mat dimensions were approximately 1m x 2m x 20cm in depth
Plugs cut from mats were approximately 10cm x 10cm



ISLAND #3



Planted Area (ha): flat surface 0.74
side slope 0.57
total 1.31

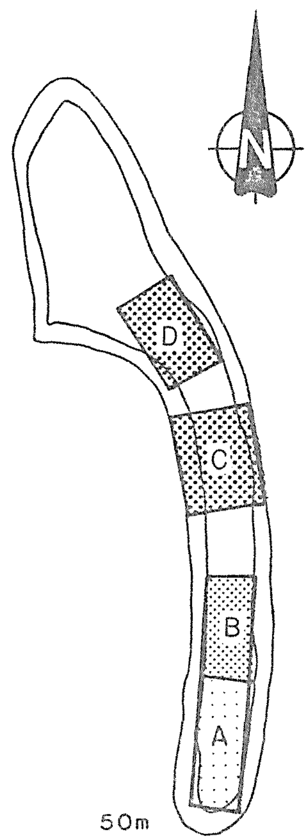
Mat Requirements: C. lyngbyei 60
J. arcticus 60

Quadrat	Quadrat Size (m)	Spacing (m)	No. of Plugs	Type of Plug	Planting Method
A	4x100	0.5	1600	J. arcticus	10cm^2 plugs
B	4x100	–	–	Juncus, Carex	mats
C	4x100	–	–	Juncus, Carex	mats
D	5x100	0.5	2000	C. lyngbyei	10cm^2 plugs
	1700m^2		3600		

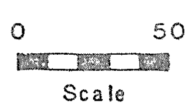
ISLAND #4

Planted Area (ha): flat surface 0.43
side slope 0.24
total 0.67

Mat Requirements: C.lyngbyei 25
J. arcticus 18
"mixed" J. arcticus 14



Quadrat	Quadrat Size (m)	Spacing (m)	No. of Plugs	Type of Plug	Planting Method
A	40x15	0.5	2400	J. arcticus	10cm^2 plugs
B	30x15	0.5	1800	"mixed" J. arcticus	10cm^2 plugs
C	30x25	0.5	3000	C. lyngbyei	10cm^2 plugs
D	30x20	1.0	600	C. lyngbyei	10cm^2 plugs
	3900m^2		7800		



Appendix IV

DFO letter of approval to B.C.F.P. for facility construction and estuarine rehabilitation

Government of Canada / Gouvernement du Canada

Fisheries and Oceans / Pêches et Océans

Fisheries - Pacific Region
1090 West Pender Street
Vancouver, B.C.
V6E 2P1

Pêches - Région du Pacific
1090 rue West Pender
Vancouver (C.-B.)
V6E 2P1

August 31, 1981

Your file Votre référence

Our file Notre référence

5903-85-C26-1

Mr. J.P. Egan,
District Land Manager
Ministry of Lands, Parks & Housing
Room 215, Courthouse
420 Cumberland Road
Courtenay, B.C. V9N 5M6

Dear Sir:

Re: BCFP's Dryland Sort Proposal for the Campbell River Estuary

This letter refers to the prospectus prepared by BCFP and conveyed to the Department of Fisheries and Oceans by copy of your letter dated July 31, 1981.

In response to concerns expressed earlier by DFO, a thorough analysis of alternatives was undertaken by Woodbridge-Reid, but was unsuccessful in identifying an operationally or economically viable alternative location to the Campbell River estuary. We have assumed the Ministry of Lands, Parks and Housing has reviewed the various alternatives and concurs with the report findings with respect to reconciling the socio-economic components with current principles of coastal zone planning for optimum resource use. Recognizing these constraints, considerable effort has been expended by Company and Agency staff in arriving at the present facility design which minimizes the alienation of intertidal estuarine lands. This has been achieved by utilizing to the maximum extent possible adjoining terrestrial areas that, with the exception of the riparian fringe, contribute little or no energy to the estuary. In this respect, we note that riparian tree and brush species will be replaced on completion of the construction phase. In principle then, the Department of Fisheries and Oceans does not object to the proposed facility being constructed at the identified site, as long as the productivity of the estuary under the proposed scheme will be equal to or better than at present.

In this regard, we would like to point out that the compatibility of an operation of this nature with the very high fisheries values of the Campbell River estuary is dependent on the very highest construction and operational standards. A big factor here will be the Company's continuing adherence to their commitment (p5) that they will only move logs out of the estuary at periods of high tide. The Department will not be prepared to approve future requests for dredging or to allow towing at lower water levels which could cause scouring of substrate.

The successful rehabilitation of the area currently being utilized for log sorting and booming will be required as a compensatory measure for the aquatic habitat which will be alienated. It should be pointed out that it is not DFO policy to accept responsibility for the final design of the rehabilitative measures (p39). In all situations of this kind, the onus is upon the proponent to design and construct a stable, productive area of compensatory habitat. While we are participating in the design and the future monitoring program, the overall responsibility must remain with the Company. It is also imperative that once the compensatory habitat is established that it remain in a naturally, undisturbed state in perpetuity. We are looking to the Department of Lands, Parks and Housing for an assurance that some form of tenure or reserve can be established which will prevent the reclaimed land from being used sometime in the future for commercial or industrial purposes. This is a crucial point and should be resolved before final approvals for the scheme are given to BCFP. We should also make clear to you that, as we wish to see a long-term reduction in the level of industrial activity in the estuary, we would not be in favour of the issuance of any future log storage leases in the area.

We understand there is some urgency to the review process as BCFP would like to proceed with clearing the site during the "dry" summer and early fall months. In the context of the aforementioned, the Department of Fisheries and Oceans is prepared to give approval in principle to the proposal, subject to the following conditions being accepted in writing by the Company:

A. Facility Design and Construction

Construction activities may proceed as outlined in the BCFP letter of August 5, 1981 to Mr. M. Brownlee (attached) with the following provisions:

1. All construction activities to be closely supervised at all times by Company staff familiar with the environmental aspects of the project.

2. No activities or materials to be deposited within the intertidal zone without specific approval of DFO staff.

3. A buffer zone of undisturbed vegetation be maintained adjacent to the slough, river and log storage channel until the final stages of site preparation (October).

4. Pilings and stiff legs be extended to the Nunn's Creek point to buffer this sensitive area from potential wave action from log boom towing.

.../3

5. The silt trapped behind the geotextile curtain be removed by the dredge rather than being flushed out into the estuary with the tide.

6. The berm around the oil storage facilities be impervious and of sufficient capacity to contain the maximum volume of oil stored.

7. The debris catch basins be designed such that they may be modified in the event that they are found to be inadequate.

8. Septic facility design be reviewed by regulatory agency staff to ensure there will be no contamination of the river or estuary.

9. The slough which enters the storage bay at the south east corner be bridged to allow an adequate exchange of water on each tidal cycle.

10. The statement on page 9 of the Prospectus "...providing it can be arranged that logs continue to flow through the booming grounds while material is discharged in the islets location" raises the question of what will happen if the desired islet configuration would disrupt log flow? How and when would the compensatory habitat be created? As this is a big factor in DFO approval, it should be resolved immediately.

B. Facility Operation

1. There is to be no maintenance dredging outside of the storage bay to facilitate log transport. Log towing will take place only during high water levels.

2. A monitoring program satisfactory to DFO focussing on water quality, benthic debris accumulations and biological communities be implemented immediately on completion of the construction phase.

3. Operations or facility structures be modified in the event that studies indicate that detrimental effects are occurring.

C. Estuarine Rehabilitation

1. In addition to those commitments identified in the prospectus in terms of being responsible for all costs associated with the site preparation and construction of the islets, further participation by BCFP is anticipated in:

   (a) Annual low level color and infra-red photography for purposes of determining contours and vegetative transplant success.

.../4

(b) Provision of at least one individual full-time for four months each summer and one individual part-time for supervision to participate jointly in the evaluation of the rehabilitative efforts. (a and b to not exceed five years.)

(c) Further modification of islet configurations and/or additional vegetative transplant efforts be undertaken if deemed necessary to ensure the success of the project (likely 2 to 3 years).

(d) Prior to construction of islets accumulations of debris, logs, etc. to be removed as deemed necessary by Agency and Company staff.

While the foregoing may be perceived as being somewhat cautious, you will appreciate that a project of this magnitude in an area of such high fisheries values dictates this level of care. The need for very close supervision during the construction phase and a continuous exchange of information between Company and Agency personnel cannot be over-emphasized. I would suggest that Mr. N. Lemmen, M. Brownlee and myself should be the points of contact for the Department of Fisheries and Oceans through the construction phase.

Yours truly,

Original Signed by
J. PAYNE

J. Payne, P. Eng.
Chief, Land Use Unit
Habitat Management Division

MJB/JP/mmd

cc: D.N. Brock, Area Mgr.
South Coast Div.

N. J. Lemmen, District Supervisor
Campbell River

D. Morrison
Fish & Wildlife Branch, Nanaimo

R. Bell-Irving, Chief
Water Use Unit, HMD

T. Mattice
BCFP, Campbell River

Dr. I.K. Birtwell
West Vancouver Laboratory

attach.

Throughout the hydraulic suction dredging operations the dredgeate is transported by a 26" floating or bottom lying pipe which has minimal, if any, impact on submarine or terrestrial flora & fauna.

The dredge machine advances and withdraws using both "Spuds" (stiffleg projections which act as pivotal advancement points) and anchors.

The remainder of the dredgeate will perform only one function directly relevant to the project construction, that being the base foundation of both the paved area and unpaved area of the 17 acres mentioned in Section A. This 12 acre portion will require ± 210,000 of select gravel with the remainder, ± 215,000 $yd.^3$ to be stockpiled to the south, or directly adjacent to the southerly extremity of the area designated as gravel sort on attached plan.

Dredging will be to lines located in field as being furthest extremity of disturbance, (see Plan) with final trimming (slope grooming) of edges to exacting requirements performed by barge mounted, clamshell equipped crane, the same as mentioned in Section B.

To maintain water quality throughout Section C, the following steps will be taken -

Before any deposition of materials takes place in our land fill and stockpile areas a berm will be created, using native material, around the entire area of deposition. This berm will serve to contain the ± 18,500 gallon per minute of water which is the volume moved by the dredging process. Perimeter ditches will in turn carry the waste water to a central settling pond where fines will be deposited before the water passes through a spill box and returns directly into the area where the dredge is working. Any siltation into the main body of estuary can be contained by the use of a "silt curtain", this being a geotextile fabric suspended vertically in the water, supported on top by floats and held vertical by weights. This acts as a filter, whereby water has a free flow but any suspended sediment is trapped, to be flushed upon opening of the silt curtains at the appropriate outgoing tide.

January 4 - February 8

D. Upon completion of slope grooming by clamshell, which will result in a slope of 1½:1, a protective covering of rock rip-rap must be placed on the gravel slope to maintain as near to a vertical angle as possible due to our overall width restrictions. This rock rip-rap will be of a size class 24" minus which is necessary to counteract bow wave and prop-wash erosion by boomboat activity. Source of material is at this time thought to be the Ideal Cement quarry on Texada Island. Materials will be barge loaded at source, towed to dredge site and placed by the same machinery that performs the final slope trimming. Rip-rap will extend vertically to a height no higher than the natural ground level at top of slope.

The whole slope armouring procedure must follow as closely behind slope grooming as practicably feasible because natural existing gravel slopes in the sort by area tend to lie at 3:1, therefore any time delay will cause natural/unnatural created wave action weathering on our 1.5:1 slope with prohibitively restrictive results.

SEC.2

A summary of progress at this time (around Feb. 8) has dredging complete with slopes stabilized with rip-rap. Major formation of sort complete with sub-grade in place, including a vertical wall-length 100' located in extreme southeast corner of newly formed boom area. This wall, although not previously mentioned, is important in that it allows direct vertical access to small boat tie-up wharf (see Plan). Access is necessary in this fashion so that equipment and booming gear can be lowered either onto boats or work float for dispersement throughout booming ground. Other works which will take place during and after placement of sort fill, prior to paving are:

1. Installation of a ± 48" ashphalt coated steel pipe from the Campbell River to a point of outfall in the area of the dump skids. This pipe will be buried at an appropriate depth below final sort elevation and will serve to provide a fresh-water input to the newly formed sort bay. This input will serve to provide a flushing action and prevent any stagnation within booming ground and will also help relieve the head pressure of water from river acting on remaining river edge at times of lower tides. Input end at river will be equipped with a gate valve to control flow at will, and a debris screen.

2. Formation of subterranian catch-basins at strategic points around sort perimeter which when fed by concrete perimeter ditches, will through their design serve as settling ponds for:

a) any debris from sort surface
b) normal fuel leakage
c) any other dirt, fines etc. which may be created during log handling activities.

After settling process these basins can be cleaned when necessary and will ensure that only sediment free water will return to booming area by way of 18" dia. effluent pipes.

3. Installation of power and water lines will probably also take place before final fill elevation is reached to ensure a proper and adequate depth of coverage. Power installations will serve to light sort area, power offices and buildings. Water installations will be for domestic use in office buildings and also for paved sort irrigation, a dust preventative measure. Sewer lines are also to be installed to the shop complex with septic fields for boom shack, etc.

All above work completed by May 1, 1982

British Columbia
Forest Products Limited
Campbell River Logging Office
830 Thirteenth Avenue
Campbell River, British Columbia, Canada V9W 4H2
Telephone (604) 286-0711

BCFP

August 5, 1981

Environment Canada
Fisheries & Oceans,
1090 West Pender St.,
Vancouver, B. C.
V6E 2P1

Attention: Mr. Mike Brownlee

Dear Mike,

The attached information and map will act as a supplement to the construction schedule included in the Prospectus.

The clearing and grubbing phase scheduled to commence on August 1, has obviously been delayed due to the strike of I.W.A. members. We foresee a new starting date of August 17 providing a solution to labour problems can be reached via special permits etc.

Our intentions are, as listed in text, to start in "background" with no "presence" at least until after Labour Day when Campbell River's compliment of tourists starts to drop.

We feel we must start on or around the mid-August date for ease and efficiency of operations. Equipment mobility is best during dry season, any groundwater flow is best controlled when general water table is at a low, debris burning most efficient in dry weather and removal and separation of organics also best with little or no rainfall.

With a startup date of August 17, we would expect clearing and grubbing to be completed by October 20 with a return to text schedule on November 1 with clamshell dredging.

For your consideration and earliest convenient reply.

Yours truly,

BRITISH COLUMBIA FOREST PRODUCTS LIMITED

p. [signature]

C. H. G. Iverson, P. Eng.
Area Manager

DRYLAND SORT/BOOMING GROUND

SEC. 1

CONSTRUCTION PROCEDURES & SEQUENCE

A. Commencing August 1/81 - Clearing and grubbing of ± 17 acres of ground above H.W.M., utilizing heavy equipment, and burning of all brush, stumps and any other non-merchantable material. Within this 17 acres are 12 acres which must be stripped of 60,000 yards of organic material which if left, would deteriorate and jeopardize the integrity of overlying structures (ie. pavement). This organic material will be removed to a suitable site as a sanitary land fill, recognizing any constraints F & W and Pollution Control would have on this site. Schedule for clearing and grubbing is as follows:

August 1 - September 30, 1981

Area A	August 1 - 7
Area B	August 1 - 14
Area C	August 14 - Sept. 11
D & E	September 11 - 30

B. Upon completion of the sort site preparation, the next step will be raking and clamming at the bottom of the existing sort bay and duck pond, hopefully commencing Nov. 1/81 with a completion date of December 20. The procedure for raking involves the removal of all large sunken debris (logs, wire). This will be accomplished by utilizing a log loader on the N.W. side of the Raven pocket and a mobile tail hold on the S.E. side. A large rake will be dragged across the pocket to accumulate the debris on the existing road. The procedure will be the same to clean out the duck pond area. The debris will then be loaded aboard scows for ocean dumping. All logs dredged will be hauled away via Elk River Division mainline. Because of the consistency of the dredgeate an 85% water/15% organic slurry) and its unmanageability on land, ocean dumping should be the process of disposal for the clammed material. Approximately 45,000 M^3 must be disposed of in this manner. Method of removal would be by barge mounted clamshell equipped crane which would pile dredgeate on belly dumping scows which would then be towed to designated dump site south of Quadra Island. Application for ocean dumping has been made June of 1981.

January 4 - February 8

C. To remove ± 490,000yd^3 of gravel by hydraulic suction dredging which would commence with first material to be removed located directly to the east of Nunn's island where a small projection of ± 5,000 $yd.^3$ remains as a ridge between two previous dredging operations.

This material, being of a known, coarse nature will form the base of one or more of the islets proposed as part of Federal Fisheries & Oceans estuary rehabilitation requirements.

The main body of the dredging centres around the existing "sort bay" or as locally known, the old Raven pocket. Here the hydraulic dredge will advance in two or more passes taking the grade of the bottom down to a point lying 10 feet below zero tide. The first ± 75000 $yd.^3$ will also go to the north to form the main body of the aforementioned islets.

SECTION E

After subgrade formation and installation of ancillary structures, the sort will be left for a settling period of 2 to 3 months, taking us to May 1st at which time sort work will progress. During this 2 to 3 months time frame, the construction of the actual booming ground will take place in the following steps.

Pile driving:- March 15 to April 7/82 - Immediately after slope armouring, Section D, the external pile lines will be driven. To facilitate the driving, a section of rock at the toe of the rip-rapped slope must be removed, pile must be driven, and then the rock must be replaced. Piles will be steel H-piles with a section heavy enough to withstand the high forces necessary to drive through a hard lense of cobbles,plus resist corrosion. The section of rock must be removed to allow proper pile alignment as piles cannot readily be driven through rock and any mis-alignment would not allow proper boom pocket construction.

Driving of the remaining single piles and dolphins will take place in a similar manner, less the removal and replacement of rock. Either a drop or vibratory pile-driving hammer will be used; specific application of either to be determined at the discretion of the contractor.

During pile-driving operation we would also expect the contractor to be fabricating the standing-booms, or boom pocket perimeter bounds, on land. This operation entails predrilling boomsticks on land then placing in water to be fastened to pile lines in a suitable manner. Configuration of standing boom and pile locations can be seen on attached plan. Boomsticks will be pre-floated and marked to ensure they eventually float with holes vertical.

Another portion of pile-driving operation will be support foundations for the bundle skids. This again will require removal of rock from slope, pile driving, and replacement of same.

Remaining work to be done in booming ground area is minor, consisting of small docking facilities, etc. Total expected time span approximately ± 20 working days or April 7th completion.

SECTION F

As mentioned in Section E, the dryland sort subgrade must settle for 2 to 3 months, therefore, let us assume re-commencement of activities May 1st, which are:-

Final elevation and slope grading of paved area of D.L.S. using 1" minus gravel crushed on site by the paving contractor followed by 4" of ashphaltic pavement lying at a slope of 1½% towards perimeter ditches.*

Perimeter ditches (as mentioned in mid-way summary - Section 2) to be formed around perimiter of pavement utilizing place formed gunnite concrete.

Concrete catch basins of 20 & 30,000 gals. to be constructed at appropriate ends of concrete ditches (see plan)

* Also paved, will be in and out roads, plus unloading site (see plan).

SECTION F Cont'd.

Installation of power poles with a dispersement such that the entire area of paved sort can be lighted, with appropriate fixtures, to a luminosity of no less than 2½ foot candles. Lighting power source will include kiosks at points deemed appropriate by ourselves and electrical inspector to service ancillary structures.

Placement of prefabricated skidways and "dumper bunks" which will meet F & O requirement that bundles be "soft-watered" to minimize bark loosening upon entry into water

Complete installation of "weeper" irrigation system for dust control.

Sewer (septic field) hookups to be completed and installation of trailers to act as offices, dryroom/lunchroom.

SECTION G

The creation of islets, although briefly mentioned in Section C, has not been fully covered.

As this rehabilitation project is a relatively new endeavor for Fisheries & Oceans on a scale such as this it is still under a good deal of study. Summary of study progress is as follows:

1) Air photo of estuary flown by B.C.F.P. at a time of extremely low tide from which a detailed (25 cm) contour map of rehab. area was made.
2) Numerous water velocity measurements made (ongoing).
3) Substrate mapping (ongoing).
4) Vegatative map made on 25 cm base.
5) Benthic populations sampled and assessed.
6) Debris mapping.

From the above information and several on-site field trips and study groups involving F & O and B.C.F.P. personnel, a preliminary plan has been formulated. This plan includes the building up of several extensive intertidal zones on which known & experimental transplant methods will utilize rhizomes which are within planned areas of disturbance. These intertidal areas will have extensive channels excavated which will serve as rearing and resting areas for ocean-bound salmonids.

Complete information on methods, timing and potential of rehabilitative aspect of project after a more complete analysis of needs by Fisheries & Oceans staff. Projected deadline July 15, 1982.

SECTION H

Esthetics:-

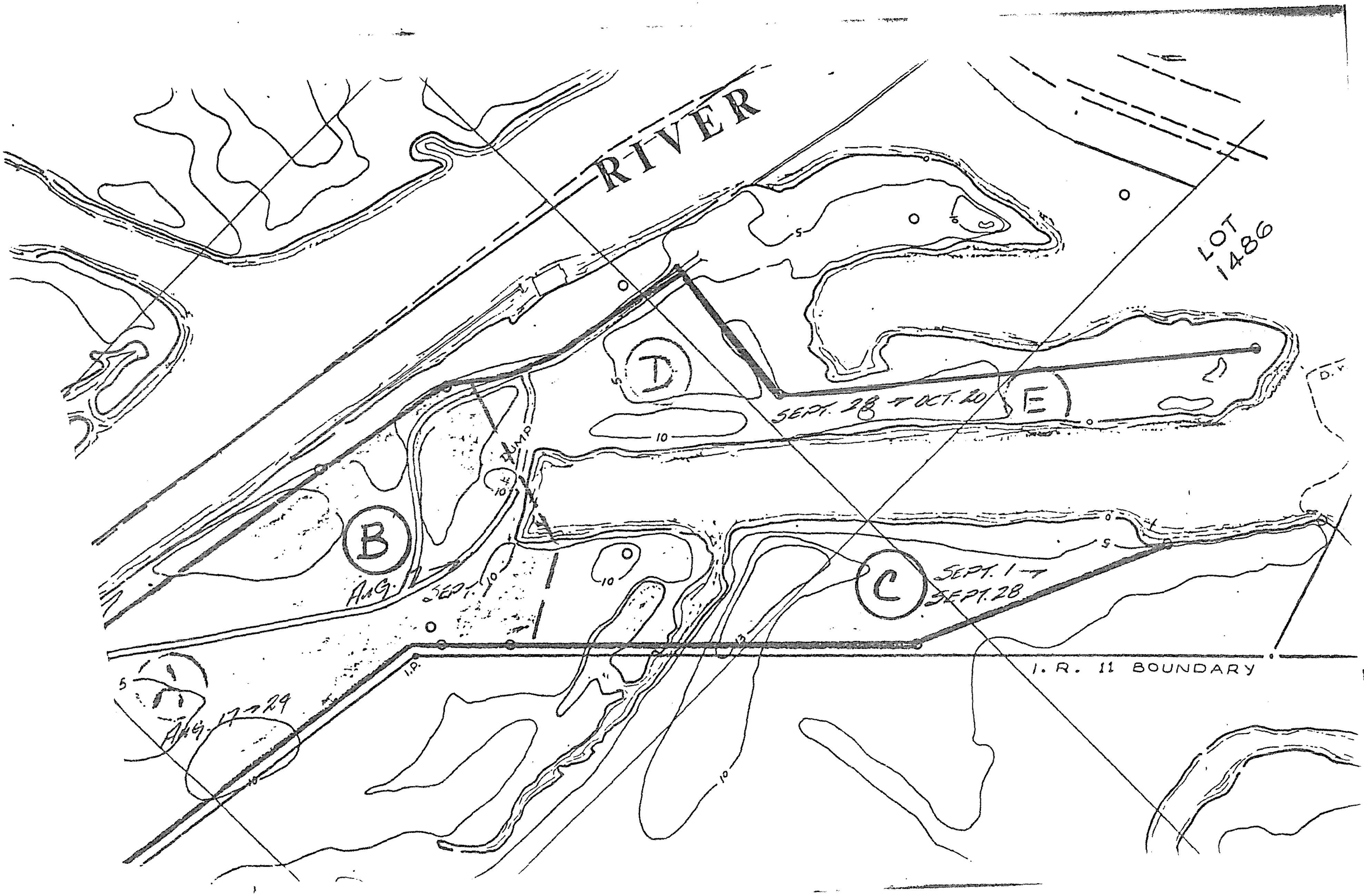
To return the perimeters of the new development area to as near-natural a state as physically possible, and to also make perimeters as productive as possible, F & O and F & W staff are investigating the productive potential of various species of evergreen and deciduous trees, with an understory of brush and grasses also to be included. Streambank flora is the main source of feed for all creeks and rivers and while not directly as important in an estuary for post

Appendix V

Proposed island configurations by the Biologists

SECTION H Cont'd.

emergent salmonid species, these tree "grocery stores" still provide a significant amount of nutrients in the form of insects, insect larvae and small particles of organic matter.


RIVER
LOT 1486
D
E
SEPT. 28 → OCT. 20
B
C
SEPT. 1 → SEPT. 28
AUG.
SEPT.
AUG. 17 → 29
I. R. 11 BOUNDARY
PUMP
10
5

Government of Canada / Gouvernement du Canada

Fisheries and Oceans / Pêches et Océans

Fisheries - Pacific Region
1090 West Pender Street
Vancouver, B.C.
V6E 2P1

Pêches - Région du Pacific
1090 rue West Pender
Vancouver (C.-B.)
V6E 2P1

October 5, 1981

Your file Votre référence

Our file Notre référence
5903-85-C26-1

Mr. R. P. Willington
Forest Hydrologist
Crofton Logging
British Columbia Forest
Products Limited
PO Box 130
Crofton, B.C. VOR 1RO

Dear Bob:

Re: Islet Configuration - Campbell River

Please find attached a copy of the islet configurations drafted by the 'Biological Component' of the Campbell Project.

We have attempted to incorporate the data collected during the July "flood" in designing the islets, although I understand the review by the "physical types" is best undertaken with something to work with so we have drafted what we consider to be desirable.

In view of the limited time remaining, I hope you will be able to get together with the others and Dr. Kellerhalls to comment on the establishment of the islets, etc. as soon as possible.

Yours very truly,

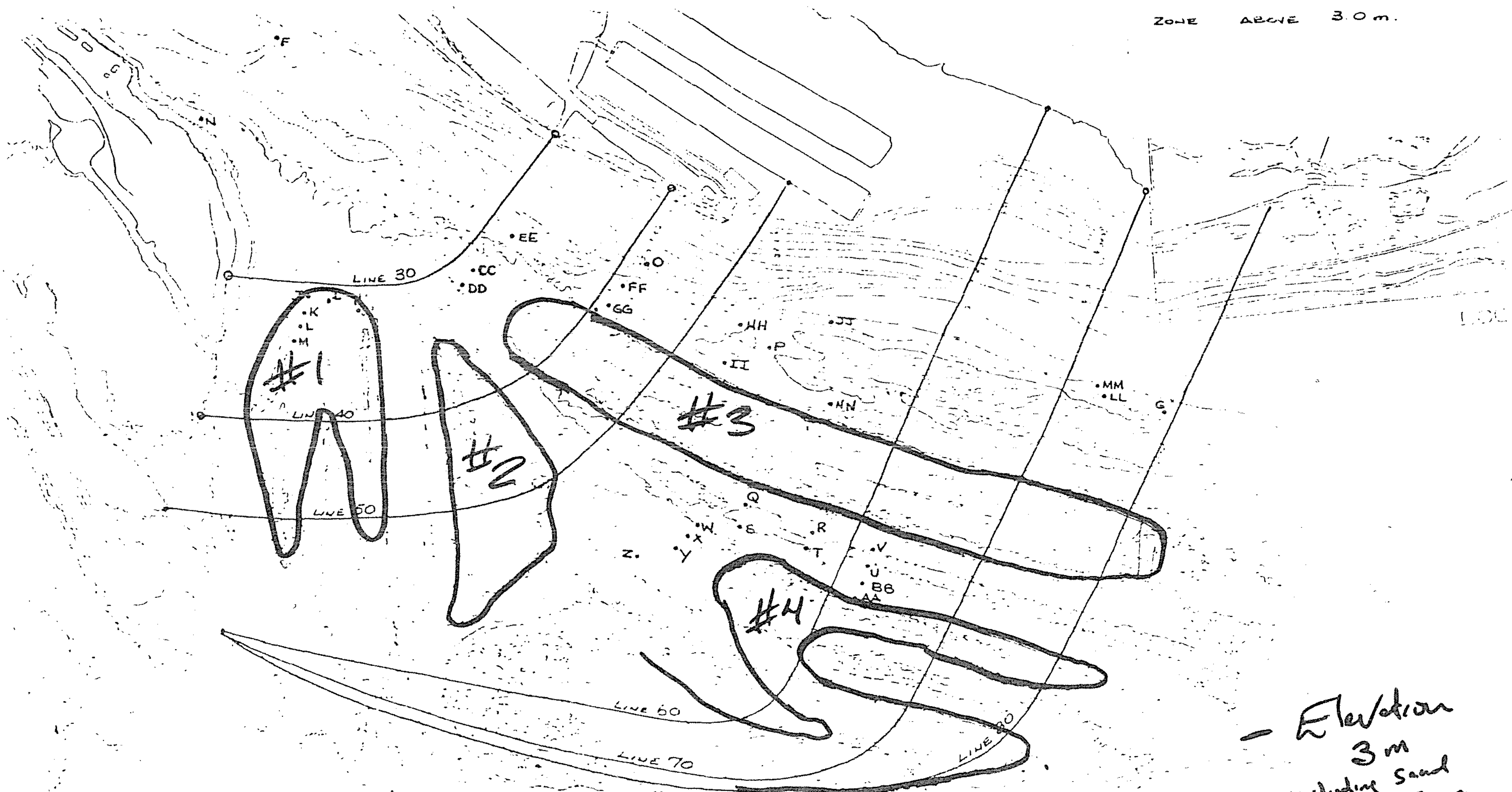
M. J. Brownlee, Sr. Project Manager
Forest Harvesting/Urban Development
Habitat Management Division

MJB/mmd
attach.
cc: J. Payne, P. Eng.
Chief, Land Use Unit, HMD

Dr. L. Giovando
West Vancouver Laboratory

R. Eliasen
Land Use Unit, HMD

T. Mattice
BCFP, Campbell River



Campbell River Islets (proposed).

- Elevation 3 m including sand cap of ~25 cm
- may require armouring on u/s edge

Appendix VI

Engineering review of the potential erodibility of proposed Campbell River Islands

Government of Canada / Gouvernement du Canada
Fisheries and Oceans / Pêches et Océans

Fisheries - Pacific Region
1090 West Pender Street
Vancouver, B.C.
V6E 2P1

Pêches - Région du Pacific
1090 rue West Pender
Vancouver (C.-B.)
V6E 2P1

January 22, 1982

Your file Votre référence

Our file Notre référence

5903-85-C26-1

Mr. Robert P. Willington
Supervisor, Resource Planning Group
British Columbia Forest Products Limited
Crofton Logging Office
PO Box 130
Crofton, B.C. VOR 1RO

Dear Bob:

I have reviewed Rolf Kellerhals' letter and am encouraged with his responses to your questions. It is reassuring to have his considered opinion that the construction of the four islands will not affect flooding in the lower river or BC Hydro's water release regime from the John Hart Dam.

With regard to the scouring of gravel and subsequent downstream aggradation, we should ensure that a regular monitoring program of gravel accumulation is built into the post-development study program. As you are aware, one of our main objectives in approving the overall scheme was to obviate the need for regular dredging in the estuary. However, Kellerhals has stated that occasional minor dredging only should be necessary and I am sure that we will be able to develop mutually satisfactory criteria, which when combined with the monitoring program, will allow the maintenance of the navigation channel with no detrimental influence on the surrounding fish habitat. We can discuss this further the next time we meet.

Yours truly,

Payne

J. Payne, P. Eng.
Chief, Land Use Unit
Habitat Management Division

JP/mmd

cc: N.J. Lemmen, District Supervisor
Campbell River

British Columbia
Forest Products Limited

Crofton Logging Office

P.O. Box 130
Crofton, British Columbia, Canada V0R 1R0
Telephone (604) 246-3264

BCFP

000044

JAN 12 '82

5903-35 C.26-1

January 7, 1982

Mr. John Payne
Habitat Protection Division
Resource Services Branch
1090 West Pender Street
Vancouver, B.C.
V6E 2P1

Dear John,

Herewith enclosed please find Rolf Kellerhals' letter of response to the questions I posed in my letter (also enclosed).

Once you have reviewed Rolf's response, I would very much like to learn of your reaction to the points he has raised.

Yours truly,

BRITISH COLUMBIA FOREST PRODUCTS LIMITED
RESOURCE PLANNING GROUP

Bob Willington

Robert P. Willington
Supervisor

RPW:ao

Encl.

KELLERHALS ENGINEERING SERVICES LTD.
Consulting Engineers in River Engineering and Hydrology

Telephone (604) 285-3570
Box 204
Heriot Bay, B.C.
V0P 1H0

ROLF KELLERHALS, P.ENG.
Dipl. Ing., M.Sc., Ph.D.

December 23, 1981

BC Forest Products Ltd.,
830 13th Ave.,
Campbell River, B.C. V9W 4H2
Attn. Mr. Robert P. Willington

Dear Bob,

Re: Campbell River Estuary
Island Configuration

Thank you for your letter of December 16, 1981. Both of your questions raise rather difficult technical problems that are not easily answered without major study efforts involving both analysis and field data collection. There is also no assurance that detailed studies would in the end provide an accurate prediction of future conditions. However, I am trying to give you a rough idea of what I feel is most likely to happen, assuming that the islands will be built as planned.

Question 1: "Will the construction of the islets require BC Hydro to release water at rates lower than 22 000 cfs and if so by how much?"

Mr. Ian Pate, the manager of BC Hydro's John Hart generating station sent me a graph of their outflow operating criteria. It shows that general channel capacity downstream of the Campbell River Lodge imposes a severe restriction on the amount of water that can be released at John Hart without flooding parts of Campbellton (623 m^3/s, 22000 cfs). Tide levels above 3.6 m add further restrictions, down to practically zero flow at the highest tides of 5.3 m. By removing most of the pilings and all the log booms from the estuary, BCFP will increase channel capacity while the islands will tend to have the opposite effect. The overall effect is unlikely to lead to more severe outflow restrictions for B.C. Hydro. In addition one can expect that the channel capacity of the most critical reach

...2/ (Cont)

immediately above the estuary will increase gradually as the sediment accumulation along your row of pilings in the central part of the river gradually gets removed by floods. This effect could be assured immediately by dredging."

Question 2: "Can we expect inter-islet channel scour and if so, what is the anticipated downstream aggradation zone for the eroded materials?"

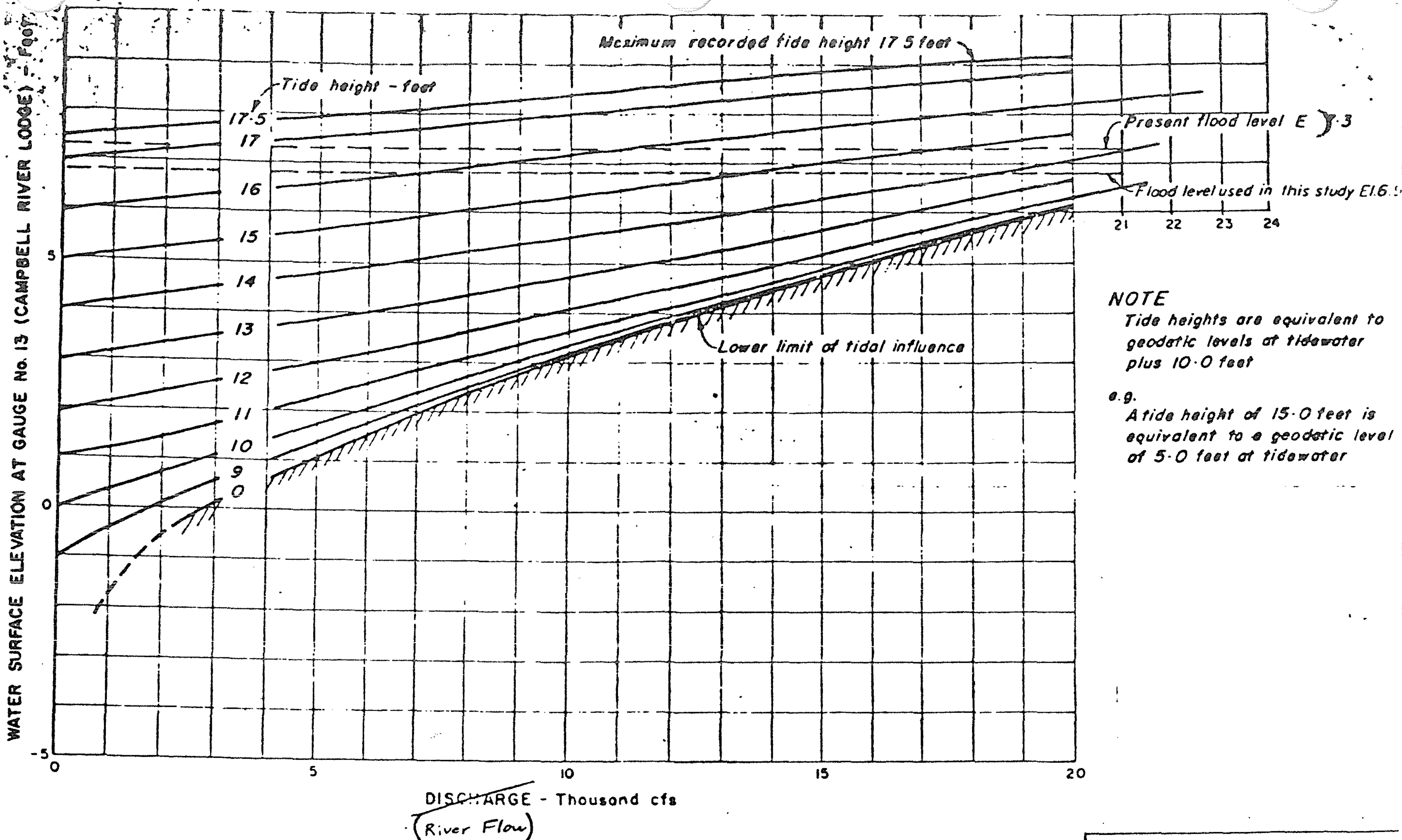
There is considerable evidence of gravel transport in the lower Campbell River. The material probably originates in the Quinsam River and is deposited mainly in the upper parts of the estuary. During occasional large floods that happen to coincide with a very low tide much of the gravel accumulation gets carried out to Discovery Passage, but some may be carried into slack-water areas of the estuary. BC Hydro has noted a significant increase in channel capacity after any prolonged period of high flows. Some slack-water areas are also likely to experience a gradual accumulation of suspended sediments (sand and silt). The deep, dredged channel immediately to the east of the spit is the most obvious slack-water site for potential sediment accumulation.

In general it is reasonable to expect that there will be a slow, continuing tendency for channels, bars and islands in the estuary to shift position. This shifting is particularly slow in the Campbell River due to the reduction of floods and interception of gravel by BC Hydro's dams. With continuing monitoring and occasional minor dredging it should be possible to maintain an essentially stable estuary configuration over prolonged periods.

Although I am unable to answer your questions in a clearcut manner, I hope that this will provide some guidance to BCFP and to others interested in the rehabilitation of the Campbell River estuary. Please let me know if I can be of further help.

Yours truly,

Rolf Kellerhals P.Eng.



NOTE

Tide heights are equivalent to geodetic levels at tidewater plus 10.0 feet

e.g.

A tide height of 15.0 feet is equivalent to a geodetic level of 5.0 feet at tidewater

BRITISH COLUMBIA HYDRO AND POWER AUTHOR	
CAMPBELL RIVER OPERATING GUIDELINES STAGE VERSUS DISCHARGE ON THE CAMPBELL RIVER AT THE CAMPBELL RIVER LODGE	
DATE AUG 1981	FIG. 8
DWN SJF	DWG No. 502A-C14-B5

British Columbia
Forest Products Limited
Campbell River Logging Office
830 Thirteenth Avenue
Campbell River, British Columbia, Canada V9W 4H2
Telephone (604) 287-6269

BCFP

December 16, 1981

Mr. Rolf Kellerhals, P. Eng.
Box 204
Heriot Bay, B.C.
VOP 1HO

Dear Rolf,

Attached is the Campbell River Estuary Islet configuration that has been adopted for construction in January 1982. At a meeting of B.C. Forest Products Ltd. and Federal Department of Fisheries and Oceans personnel on December 16th, 1981 further concerns with respect to the Islet plan were raised. These include the following:

1.) During the winter B.C. Hydro must release stored water to account for storm runoff into the reservoir. The rate at which they can release this water is governed by tides and stage height allowances dictated by shoreline residents. They can currently release 22,000 c.f.s. (not including the Quinsam flow) at low tides, but flows exceeding this inundate the Campbell River Lodge.

Question: Will the construction of the islets require B.C. Hydro to release water at rates lower than 22,000 c.f.s. and if so by how much?

2.) Given that the islets can be constructed so that they will not erode, concern has been expressed over inter- Islet channel scour initiated by the reduction in cross-sectioned area. My calculations suggest this area reduction to be about 35% (below 3m).

Question: Can we expect inter- Islet channel scour and if so what is the anticipated downstream aggradation zone for the eroded materials?

In lieu of our Friday, December 18th, 1981 meeting, we (B.C.F.P. and D.F.O.) would appreciate your analysis of the data supplied to you with respect to the questions posed herein. Your analysis would then be the basis for a meeting with B.C.F.P., D.F.O., B.C. Hydro and yourself on December 22nd, 1981.

Your input in the matter of Campbell River Estuary Islet configurations is required in order to ensure that all parties having a vested interest in the estuary and environs (upstream and downstream) will not incur short and / or long term economic hardships accruing from the construction of the Islets.

I am available for further telephone communications regarding this request at my office (246-3264) or home (748-0194).

Yours truly,

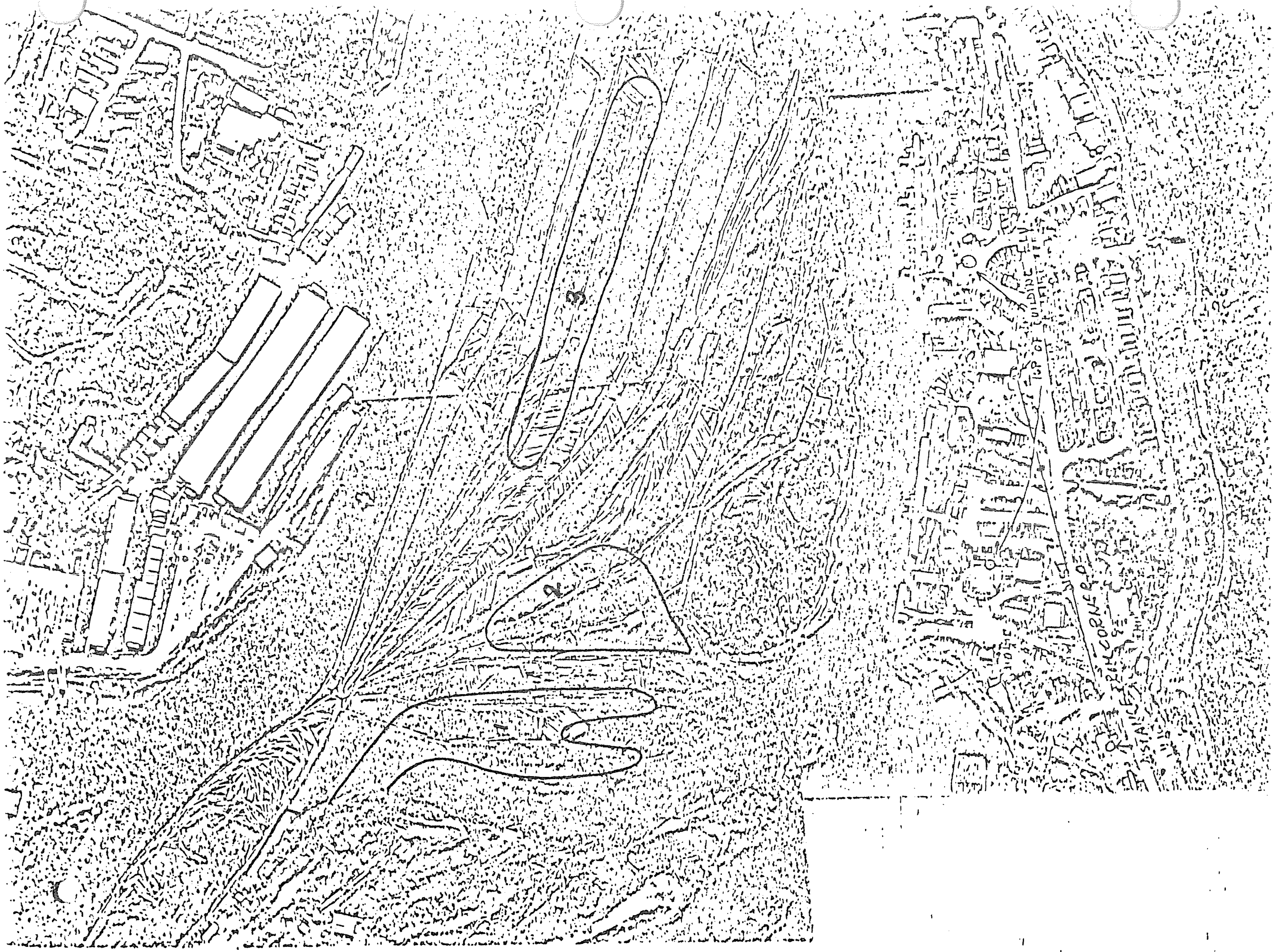
B.C. FOREST PRODUCTS LIMITED

Robert P. Willington

Robert P. Willington

RPW/pw

cc: C.H.G. Iverson



Appendix VII

Campbell River hydrology analysis

CAMPBELL RIVER HYDROLOGY

ANALYSIS

Robert P. Willington

A series of data were collected during June, July, 1981 in order to secure a better understanding of the hydrology of the Campbell River estuary. This report presents these data in a manner intended to facilitate their use by Federal Fisheries and Oceans staff in their interpretative needs for their proposed rehabilitation of this estuary.

Data Collected:

a) Flow Velocities

On several occasions, velocities of the Campbell River were measured at several sites (Appendix I). These velocities were measured to facilitate interpretations for erosion and flow volume and stage height in the Campbell River estuary. Measurements were made by BCFP staff using the following velocity meters:

Set Up A: OTT type 10.002 No. 18548 propeller R-19843
- loaned to project by Dr. D. Golding, Faculty of Forestry, University of B.C.

Set Up B: OTT type 10.002 No. 46086 propeller R-44989
- property of BCFP Resource Planning Group.

Set Up C: OTT type C2 10.150 No. 60670 propellor 60416
- loaned by Dr. D. Golding and Dr. M. Quick, Faculty of Applied Science, University of B.C.

All of the velocity data is presented in Appendix II.

b) Estuary Contours

A contour map of the Campbell River estuary was developed by Mr. Joe Weiss (BCFP) with contours at 0.25m intervals beginning at approximately -0.25m (from Ø tide). In order to complete the contours to depths not interpretable from the air photos, BCFP ran bottom profiles using a Raethon precision depth finder.

Analvtical Procedures:

The objective of the physical-hydrological study of the Campbell River estuary is to evaluate the degree by which the Campbell River estuary is used by the Campbell River to discharge flows. At low tides and high peak flows it was felt that the maximum flow velocities would be experienced. Also, at low tides the computation of estuary cross-sectional area used for river flow alone could be facilitated without the confounding effect of tide level.

Campbell River Flow Regime:

On July 2, 1981, B.C. Hydro opened the flood gates on John Hart Dam by request of Fisheries and Oceans in order to duplicate winter events involving high flows and low tides. The total flow which lasted from 1200 hours to 1400 hours was judged to be about 350 m^3/sec (B.C. Hydro and Power Authority). The tide during this period was about 0.2 meters.

Table I outlines the flow regime for Campbell River and indicates that the flow of 350 m^3/sec. on July 2, 1981, is frequently exceeded annually and is often in excess of 350 m^3/ sec. for a day or more.

The attached map (Appendix I) indicates that tidal damming (effect of standing sea water on inflow from river) of some of the channels through the estuary occurs at tides in excess of 1.0 m and the others at tides in excess of 1.25m. During the winter when peak flows from Campbell River can be expected, tides of a stage less than 1.25 m can occur during mid-November, mid and late December, and at various times in January and February (Table II).

Analysis of July 2, 1981 Flow:

During the two hour period that the 350 m^3/sec. flow was being released in the Campbell River, velocities were measured at four sites in the estuary.

TABLE I. Summary of flows for Campbell River.

CAMPBELL RIVER NEAR CAMPBELL RIVER - STATION NO 08HD001

MONTHLY AND ANNUAL MEAN DISCHARGES IN CUBIC METRES PER SECOND FOR THE PERIOD OF RECORD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	YEAR
1949	---	---	---	---	---	---	---	---	..	---	...	157	...	1949
1950	57.9	74.6	75.5	76.9	102	164	116	38.7	62.0	106	131	151	95.5	1950
1951	115	74.7	34.0	88.1	110	80.5	46.8	30.1	38.7	87.0	84.5	71.4	71.2	1951
1952	32.3	46.3	37.9	90.7	106	141	129	58.1	52.6	61.2	61.2	91.4	75.8	1952
1953	137	108	48.6	56.2	140	125	120	70.9	70.2	88.6	277	144	119	1953
1954	79.8	149	78.2	68.1	101	107	125	81.5	68.3	---	260	445	..	1954
1955	82.2	84.3	---	---	47.7	79.9	99.8	66.1	66.1	57.1	122	65.7	---	1955
1956	73.4	69.1	66.1	62.0	131	133	120	67.8	63.1	56.6	121	124	90.9	1956
1957	65.3	70.5	64.4	56.8	27.3	20.7	23.6	34.0	23.1	51.8	51.6	31.9	43.7	1957
1958	90.6	147	90.9	85.8	174	129	80.5	108	86.3	91.6	100	207	116	1958
1959	117	95.5	88.6	87.4	120	180	85.5	79.6	89.2	78.0	81.5	99.9	99.5	1959
1960	76.3	88.9	75.9	111	130	145	96.1	64.6	72.3	92.0	119	108	98.2	1960
1961	241	183	133	101	120	152	98.9	72.3	71.9	71.2	89.4	66.0	114	1961
1962	146	123	91.0	80.2	72.7	74.3	68.3	71.9	51.6	75.0	207	136	109	1962
1963	116	127	76.7	103	80.6	88.0	96.1	76.6	74.9	139	169	193	111	1963
1964	154	118	93.5	71.7	57.3	120	147	89.4	72.6	99.4	101	109	101	1964
1965	118	111	74.1	59.9	53.5	61.7	67.0	66.8	55.1	72.8	140	172	97.5	1965
1966	138	125	120	114	115	122	82.7	54.5	96.0	100	124	245	120	1966
1967	132	128	121	122	70.3	116	97.6	73.0	60.1	140	141	158	114	1967
1968	279	136	126	124	115	84.2	49.0	44.4	66.0	143	191	144	125	1968
1969	123	79.8	88.0	111	125	188	119	92.9	100	109	118	126	115	1969
1970	117	108	97.5	76.8	54.1	69.1	70.0	60.2	60.6	65.8	52.7	63.4	74.4	1970
MEAN	119	107	83.1	87.3	98.1	112	92.3	67.1	66.9	89.3	111	132	95.9	MEAN

LOCATION - LAT 50 02 17 N DRAINAGE AREA, 1 460 km²
LONG 125 17 41 W REGULATED SINCE 1947

CAMPBELL RIVER NEAR CAMPBELL RIVER - STATION NO 08HD001

ANNUAL EXTREMES OF DISCHARGE AND ANNUAL TOTAL DISCHARGE FOR THE PERIOD OF RECORD

YEAR	MAXIMUM INSTANTANEOUS DISCHARGE (m³/s)	MAXIMUM DAILY DISCHARGE (m³/s)	MINIMUM DAILY DISCHARGE (m³/s)	TOTAL DISCHARGE (dam³)	YEAR
1949	---	507 ON DEC 1	---	---	1949
1950	230 AT 12:15 PST ON JUN 23	221 ON JUN 24	17.3 ON JAN 28	3 040 000	1950
1951	311 AT 05:00 PST ON FEB 15	208 ON OCT 19	21.4 ON DEC 25	2 250 000	1951
1952	292 AT 17:30 PST ON DEC 30	250 ON MAY 22	21.2 ON JAN 1	2 400 000	1952
1953	835 AT 17:00 PST ON NOV 15 *	799 ON NOV 15 *	14.3 ON APR 6	1 640 000	1953
1954	612 AT 14:45 PST ON NOV 20	580 ON NOV 20	10.5 ON APR 19	---	1954
1955	603E AT 14:30 PST ON NOV 4	504 ON NOV 5	---	---	1955
1956	337 AT 14:00 PST ON NOV 16	286 ON MAY 23	23.0 ON SEP 10	2 880 000	1956
1957	---	82.1 ON JAN 14	15.9 ON SEP 4 *	1 380 000	1957
1958	515E AT 17:30 PST ON DEC 3	450 E ON DEC 3	23.5 ON JAN 1	3 550 000	1958
1959	405 AT 17:00 PST ON JUN 13	360 ON JUN 14	31.7 ON MAR 30	3 140 000	1959
1960	504 AT 20:00 PST ON DEC 13	456 ON DEC 13	34.0 ON DEC 25	3 110 000	1960
1961	640 AT 20:00 PST ON JAN 17	575 ON JAN 17	37.4 ON DEC 26	3 570 000	1961
1962	513 AT 07:30 PST ON NOV 20	479 ON NOV 20	34.0 ON JUL 2	3 410 000	1962
1963	467 AT 09:00 PST ON DEC 27	419 ON DEC 25	33.3 ON SEP 2	3 520 000	1963
1964	348 AT 16:00 PST ON JAN 4	309 ON JAN 4	17.7 ON APR 5	3 250 000	1964
1965	425 AT 05:00 PST ON DEC 5	411 ON DEC 5	15.7 ON OCT 17	2 760 000	1965
1966	456 AT 18:45 PST ON DEC 20	422 ON DEC 21	38.2 ON SEP 4	3 780 000	1966
1967	422 AT 03:15 PST ON NOV 1	405 ON NOV 1	38.8 ON SEP 4	3 590 000	1967
1968	617 AT 04:15 PST ON JAN 22	580 ON JAN 22	34.5 ON AUG 29	3 950 000	1968
1969	320 AT 04:11 PST ON JUN 11	314 ON JUN 11	47.0 ON SEP 2	3 630 000	1969
1970	129 AT 21:02 PST ON MAR 16	127 ON JAN 1	17.1 ON MAY 23	2 350 000	1970
MEAN				3 120 000	MEAN

* - EXTREME RECORDED FOR THE PERIOD OF RECORD

E - ESTIMATED

TABLE II. Campbell River Tide Table (PST) (Z+8)

1951

JANUARY-JANVIER

Day	Time	Ht/ft	Ht/m	Jour	Heure	H/pi	H/m
1	0310	11.9	3.6	16	0220	12.7	3.9
	0645	11.1	3.4		0615	11.3	3.4
TH	1245	13.9	4.2	FR	1235	15.0	4.6
JE	2055	5.0	1.5	VE	2105	3.1	.9
2	0350	12.6	3.8	17	0325	13.5	4.1
	0730	11.6	3.5		0845	12.0	3.7
FR	1315	13.6	4.1	SA	1325	14.7	4.5
VE	2140	4.1	1.2	SA	2145	2.4	.7
3	0420	13.2	4.0	18	0420	14.2	4.3
	0940	11.8	3.6		1040	11.9	3.6
SA	1355	13.5	4.1	SU	1420	14.4	4.4
SA	2205	3.4	1.0	D	2230	2.0	.6
4	0455	13.6	4.1	19	0500	14.6	4.5
	1050	11.8	3.6		1135	11.7	3.6
SU	1415	13.5	4.1	MO	1500	14.2	4.3
D.	2245	2.9	.9	LU	2325	2.0	.6
5	0525	13.9	4.2	20	0535	14.8	4.5
	1145	11.7	3.6		1215	11.3	3.4
MO	1505	13.5	4.1	TU	1600	13.8	4.2
LU	2330	2.5	.8	MA	2350	2.3	.7
6	0600	14.2	4.3	21	0620	14.9	4.5
	1220	11.8	3.6		1310	10.8	3.3
TU	1550	13.5	4.1	WE	1655	13.5	4.1
MA	2350	2.3	.7	ME			
7	0630	14.4	4.4	22	0040	2.9	.9
	1300	11.4	3.5		0655	14.9	4.5
WE	1635	13.4	4.1	TH	1350	10.4	3.2
ME				JE	1735	13.0	4.0
8	0020	2.4	.7	23	0115	3.8	1.2
	0710	14.6	4.5		0740	14.8	4.5
TH	1345	11.0	3.4	FR	1445	9.9	3.0
JE	1725	13.2	4.0	VE	1830	12.5	3.8
9	0100	2.9	.9	24	0130	4.8	1.5
	0745	14.8	4.5		0805	14.7	4.5
FR	1450	10.5	3.2	SA	1520	9.4	2.9
VE	1810	12.8	3.9	SA	1920	12.0	3.7
10	0120	3.6	1.1	25	0210	6.0	1.8
	0830	15.0	4.6		0845	14.5	4.4
SA	1555	9.8	3.0	SU	1610	8.8	2.7
SA	1910	12.3	3.7	D.	2035	11.4	3.5
11	0205	4.7	1.4	26	0250	7.3	2.2
	0915	15.1	4.6		0925	14.3	4.4
SU	1650	8.9	2.7	MO	1655	8.2	2.5
DI	2025	11.6	3.5	LU	2145	11.0	3.4
12	0245	6.1	1.9	27	0330	8.6	2.6
	0950	15.3	4.7		1000	14.1	4.3
MO	1730	7.8	2.4	TU	1750	7.4	2.3
LU	2205	11.2	3.4	MA	2315	11.0	3.4
13	0320	7.5	2.3	28	0430	9.8	3.0
	1025	15.3	4.7		1040	13.8	4.2
TU	1830	6.6	2.0	WE	1840	6.6	2.0
MA	2340	11.3	3.4	ME			
14	0415	9.1	2.8	29	0120	11.3	3.4
	1100	15.3	4.7		0530	10.8	3.3
WE	1915	5.3	1.6	TH	1100	13.5	4.1
ME				JE	1925	5.8	1.8
15	0115	11.8	3.6	30	0310	12.1	3.7
	0520	10.4	3.2		0635	11.4	3.5
TH	1145	15.2	4.6	FR	1140	13.4	4.1
JE	2010	4.1	1.2	VE	2010	4.9	1.5
				31	0335	12.7	3.9
					0755	11.8	3.6
				SA	1205	13.2	4.0
				SA	2045	4.1	1.2

FEBRUARY-FEVRIER

Day	Time	Ht/ft	Ht/m	Jour	Heure	H/pi	H/m
1	0410	13.2	4.0	16	0400	14.1	4.3
	0805	11.9	3.6		1045	11.2	3.4
SU	1310	13.2	4.0	MO	1415	13.5	4.1
D	2140	3.5	1.1	LU	2220	3.0	.9
2	0425	13.6	4.1	17	0430	14.3	4.4
	0915	11.8	3.6		1130	10.7	3.3
MO	1405	13.2	4.0	TU	1505	13.3	4.1
LU	2215	2.9	.9	MA	2310	3.1	.9
3	0500	13.9	4.2	18	0510	14.4	4.4
	0920	11.5	3.5		1215	10.2	3.1
TU	1450	13.3	4.1	WE	1605	13.2	4.0
MA	2245	2.5	.8	ME	2350	3.5	1.1
4	0530	14.2	4.3	19	0545	14.4	4.4
	1020	11.1	3.4		1245	9.6	2.9
WE	1545	13.4	4.1	TH	1645	13.1	4.0
ME	2315	2.4	.7	JE			
5	0605	14.4	4.4	20	0015	4.2	1.3
	1250	10.5	3.2		0620	14.4	4.4
TH	1640	13.5	4.1	FR	1330	9.1	2.8
JE	2350	2.8	.9	VE	1740	12.8	3.9
6	0640	14.6	4.5	21	0030	5.1	1.6
	1315	9.9	3.0		0645	14.3	4.4
FR	1730	13.3	4.1	SA	1355	8.6	2.6
VE				SA	1830	12.5	3.8
7	0015	3.4	1.0	22	0050	6.1	1.9
	0700	14.8	4.5		0715	14.1	4.3
SA	1355	9.0	2.7	SU	1440	8.0	2.4
SA	1820	13.0	4.0	D	1915	12.2	3.7
8	0100	4.6	1.4	23	0125	7.1	2.2
	0740	14.9	4.5		0750	13.9	4.2
SU	1455	8.1	2.5	MO	1515	7.6	2.3
D	1930	12.6	3.8	LU	2025	11.9	3.6
9	0125	5.9	1.8	24	0200	8.3	2.5
	0820	15.0	4.6		0815	13.6	4.1
MO	1545	7.2	2.2	TU	1545	7.0	2.1
LU	2040	12.2	3.7	MA	2125	11.6	3.5
10	0215	7.4	2.3	25	0255	9.4	2.9
	0855	14.9	4.5		0845	13.2	4.0
TU	1555	6.3	1.9	WE	1630	6.6	2.0
MA	2210	11.9	3.6	ME	2255	11.7	3.6
11	0300	8.9	2.7	26	0410	10.3	3.1
	0935	14.8	4.5		0905	12.9	3.9
WE	1750	5.5	1.7	TH	1725	6.2	1.9
ME	2330	12.0	3.7	JE			
12	0415	10.2	3.1	27	0010	11.9	3.6
	1020	14.5	4.4		0525	11.0	3.4
TH	1845	4.8	1.5	FR	0940	12.6	3.8
JE				VE	1825	5.8	1.8
13	0100	12.5	3.8	28	0125	12.4	3.8
	0510	11:1	3.4		0630	11.3	3.4
FR	1125	14.2	4.3	SA	1015	12.4	3.8
VE	1945	4.1	1.2	SA	1910	5.2	1.6
14	0215	13.2	4.0				
	0615	11.7	3.6				
SA	1220	13.9	4.2				
SA	2045	3.6	1.1				
15	0320	13.7	4.2				
	0940	11.6	3.5				
SU	1320	13.7	4.2				
DI	2130	3.2	1.0				

MARCH-MARS

Day	Time	Ht/ft	Ht/m	Jour	Heure	H/pi	H/m
1	0220	12.8	3.9	16	0245	13.8	4.2
	0755	11.3	3.4		0925	10.2	3.1
SU	1140	12.2	3.7	MO	1315	12.2	3.7
D.	2010	4.6	1.4	LU	2100	4.3	1.3
2	0300	13.2	4.0	17	0320	14.0	4.3
	0850	11.1	3.4		1020	9.5	2.9
MO	1250	12.3	3.7	TU	1425	12.3	3.7
LU	2050	4.0	1.2	MA	2200	4.5	1.4
3	0335	13.4	4.1	18	0400	14.0	4.3
	1000	10.6	3.2		1100	8.8	2.7
TU	1350	12.6	3.8	WE	1525	12.5	3.8
MA	2140	3.5	1.1	ME	2255	4.7	1.4
4	0410	13.6	4.1	19	0430	13.9	4.2
	1050	10.1	3.1		1145	8.2	2.5
WE	1445	13.0	4.0	TH	1605	12.6	3.8
ME	2230	3.2	1.0	JE	2330	5.2	1.6
5	0445	13.8	4.2	20	0500	13.8	4.2
	1115	9.4	2.9		1205	7.6	2.3
TH	1550	13.3	4.1	FR	1655	12.7	3.9
JE	2325	3.4	1.0	VE			
6	0515	14.0	4.3	21	0000	5.9	1.8
	1200	8.5	2.6		0535	13.6	4.1
FR	1635	13.5	4.1	SA	1250	7.1	2.2
VE	2335	3.9	1.2	SA	1740	12.7	3.9
7	0550	14.3	4.4	22	0040	6.6	2.0
	1255	7.5	2.3		0600	13.4	4.1
SA	1740	13.6	4.1	SU	1315	6.6	2.0
SA				D.	1820	12.6	3.8
8	0020	4.8	1.5	23	0045	7.5	2.3
	0625	14.5	4.4		0625	13.2	4.0
SU	1340	6.6	2.0	MO	1345	6.1	1.9
D.	1830	13.4	4.1	LU	1910	12.5	3.8
9	0045	6.1	1.9	24	0140	8.4	2.6
	0645	14.6	4.5		0655	13.0	4.0
MO	1425	5.7	1.7	TU	1415	5.9	1.8
LU	1935	13.1	4.0	MA	2005	12.4	3.8
10	0125	7.5	2.3	25	0240	9.2	2.8
	0725	14.5	4.4		0705	12.7	3.9
TU	1510	5.0	1.5	WE	1450	5.6	1.7
MA	2045	12.7	3.9	ME	2105	12.3	3.7
11	0225	8.9	2.7	26	0340	10.0	3.0
	0810	14.4	4.4		0730	12.5	3.8
WE	1605	4.6	1.4	TH	1545	5.5	1.7
ME	2205	12.6	3.8	JE	2205	12.2	3.7
12	0335	10.1	3.1	27	0440	10.5	3.2
	0850	13.9	4.2		0800	12.2	3.7
TH	1655	4.4	1.3	FR	1630	5.4	1.6
JE	2325	12.7	3.9	VE	2320	12.4	3.8
13	0520	10.9	3.3	28	0545	10.8	3.3
	0930	13.4	4.1		0835	11.8	3.6
FR	1755	4.3	1.3	SA	1720	5.3	1.6
VE				SA			
14	0100	13.1	4.0	29	0035	12.7	3.9
	0655	11.1	3.4		0655	10.7	3.3
SA	1050	12.8	3.9	SU	0925	11.5	3.5
SA	1905	4.3	1.3	DI	1820	5.1	1.6
15	0200	13.5	4.1	30	0125	13.0	4.0
	0815	10.9	3.3		0745	10.4	3.2
SU	1200	12.3	3.7	MO	1050	11.2	3.4
DI.	2000	4.3	1.3	LU	1910	4.8	1.5
				31	0200	13.3	4.1
					0900	9.8	3.0
				TU	1245	11.3	3.4
				MA	2015	4.6	1.4

TABLE II. Campbell River Tide Table (PST) (Z+8)

1981

APRIL-AVRIL

Day	Time	Ht/ft	Ht/m	Jour	Heure	H/pi	H/m
1	0255	13.6	4.1	16	0310	13.8	4.2
	0955	9.2	2.8		1050	7.0	2.1
WE	1355	11.8	3.6	TH	1520	11.8	3.6
ME	2045	4.5	1.4	JE	2230	6.6	2.1
2	0325	13.6	4.2	17	0345	13.7	4.2
	1025	8.3	2.5		1110	6.3	1.9
TH	1455	12.4	3.8	FR	1610	12.1	3.7
JE	2125	4.7	1.4	VE	2245	7.3	2.2
3	0350	13.9	4.2	18	0410	13.5	4.1
	1055	7.1	2.2		1150	5.6	1.7
FR	1545	13.1	4.0	SA	1700	12.4	3.8
VE	2230	5.2	1.6	SA	2350	8.0	2.4
4	0420	14.0	4.3	19	0435	13.2	4.0
	1140	5.9	1.8		1210	5.0	1.5
SA	1650	13.5	4.1	SU	1740	12.7	3.9
SA	2305	5.9	1.8	DI			
5	0455	14.1	4.3	20	0000	8.6	2.6
	1145	4.8	1.5		0510	12.9	3.9
SU	1735	13.8	4.2	MO	1230	4.6	1.4
DI	2325	6.9	2.1	LU	1820	12.9	3.9
6	0530	14.2	4.3	21	0050	9.2	2.8
	1240	3.9	1.2		0525	12.6	3.8
MO	1830	13.9	4.2	TU	1240	4.3	1.3
LU				MA	1900	13.0	4.0
7	0015	8.0	2.4	22	0145	9.7	3.0
	0610	14.2	4.3		0555	12.4	3.8
TU	1335	3.3	1.0	WE	1325	4.1	1.2
MA	1945	13.7	4.2	ME	1950	13.0	4.0
8	0115	9.1	2.5	23	0245	10.1	3.1
	0645	13.9	4.2		0605	12.1	3.7
WE	1420	3.1	.9	TH	1350	4.2	1.3
ME	2040	13.5	4.1	JE	2055	13.0	4.0
9	0250	10.0	3.0	24	0340	10.4	3.2
	0720	13.5	4.1		0645	11.8	3.6
TH	1515	3.3	1.0	FR	1430	4.4	1.3
JE	2150	13.3	4.1	VE	2150	13.0	4.0
10	0410	10.5	3.2	25	0440	10.5	3.2
	0810	12.8	3.9		0715	11.4	3.5
FR	1615	3.8	1.2	SA	1520	4.6	1.4
VE	2305	13.3	4.1	SA	2255	13.1	4.0
11	0550	10.6	3.2	25	0545	10.4	3.2
	0910	12.1	3.7		0800	11.1	3.4
SA	1705	4.3	1.3	SU	1605	4.8	1.5
SA				DI	2345	13.2	4.0
12	0015	13.5	4.1	27	0650	10.1	3.1
	0715	10.3	3.1		0910	10.7	3.3
SU	1045	11.4	3.5	MO	1710	5.0	1.5
DI	1815	4.9	1.5	LU			
13	0125	13.8	4.2	28	0040	13.4	4.1
	0825	9.6	2.9		0750	9.5	2.9
MO	1210	11.1	3.4	TU	1100	10.4	3.2
LU	1930	5.4	1.6	MA	1805	5.2	1.6
14	0210	13.9	4.2	29	0115	13.6	4.1
	0915	8.7	2.7		0840	8.7	2.7
TU	1325	11.2	3.4	WE	1245	10.7	3.3
MA	2045	5.8	1.8	ME	1900	5.4	1.6
15	0240	13.9	4.2	30	0150	13.8	4.2
	1015	7.9	2.4		0925	7.5	2.3
WE	1435	11.4	3.5	TH	1350	11.4	3.5
ME	2140	6.2	1.9	JE	1950	5.9	1.8

MAY-MAI

Day	Time	Ht/ft	Ht/m	Jour	Heure	H/pi	H/m
1	0225	13.9	4.2	16	0250	13.5	4.1
	0950	6.2	1.9		1030	4.7	1.4
FR	1450	12.1	3.7	SA	1620	12.0	3.7
VE	2035	6.5	2.0	SA	2240	9.2	2.8
2	0300	14.1	4.3	17	0325	13.2	4.0
	1040	4.8	1.5		1105	4.0	1.2
SA	1545	12.8	3.9	SU	1705	12.4	3.8
SA	2130	7.3	2.2	DI	2310	9.7	3.0
3	0335	14.3	4.4	18	0350	13.0	4.0
	1120	3.4	1.0		1140	3.3	1.0
SU	1655	13.4	4.1	MO	1740	12.7	3.9
DI	2215	8.1	2.5	LU	2355	10.1	3.1
4	0415	14.3	4.4	19	0415	12.7	3.9
	1145	2.3	.7		1155	3.0	.9
MO	1740	13.8	4.2	TU	1830	13.0	4.0
LU	2330	9.1	2.8	MA			
5	0445	14.3	4.4	20	0050	10.3	3.1
	1230	1.6	.5		0425	12.5	3.8
TU	1835	14.1	4.3	WE	1230	2.8	.9
MA				ME	1905	13.3	4.1
6	0045	9.8	3.0	21	0150	10.5	3.2
	0525	14.0	4.3		0455	12.3	3.7
WE	1310	1.4	4	TH	1300	2.8	.9
ME	1940	14.2	4.3	JE	1950	13.4	4.1
7	0210	10.3	3.1	22	0240	10.6	3.2
	0605	13.5	4.1		0525	12.0	3.7
TH	1350	1.7	.5	FR	1325	3.0	.9
JE	2040	14.1	4.3	VE	2030	13.6	4.1
8	0315	10.5	3.2	23	0330	10.6	3.2
	0650	12.8	3.9		0610	11.7	3.6
FR	1435	2.4	.7	SA	1350	3.4	1.0
VE	2130	14.0	4.3	SA	2120	13.7	4.2
9	0425	10.3	3.1	24	0420	10.4	3.2
	0740	11.9	3.6		0650	11.3	3.4
SA	1535	3.4	1.0	SU	1440	3.8	1.2
SA	2235	14.0	4.3	DI	2210	13.8	4.2
10	0535	9.9	3.0	25	0525	10.0	3.0
	0845	11.0	3.4		0755	10.7	3.3
SU	1630	4.5	1.4	MO	1515	4.4	1.3
DI	2345	13.9	4.2	LU	2250	13.9	4.2
11	0645	9.3	2.8	26	0615	9.3	2.8
	1045	10.4	3.2		0900	10.2	3.1
MO	1725	5.5	1.7	TU	1610	5.1	1.6
LU				MA	2335	13.9	4.2
12	0025	13.9	4.2	27	0700	8.4	2.6
	0800	8.4	2.6		1100	10.0	3.0
TU	1205	10.3	3.1	WE	1705	5.9	1.8
MA	1830	6.5	2.0	ME			
13	0110	13.9	4.2	28	0025	14.0	4.3
	0845	7.4	2.3		0755	7.2	2.2
WE	1325	10.6	3.2	TH	1235	10.4	3.2
ME	1940	7.3	2.2	JE	1805	6.7	2.0
14	0145	13.8	4.2	29	0055	14.1	4.3
	0930	6.5	2.0		0845	5.8	1.8
TH	1435	11.0	3.4	FR	1345	11.2	3.4
JE	2045	8.0	2.4	VE	1900	7.6	2.3
15	0215	13.7	4.2	30	0140	14.3	4.4
	1005	5.5	1.7		0925	4.3	1.3
FR	1525	11.5	3.5	SA	1450	12.1	3.7
VE	2145	8.6	2.6	SA	2000	8.5	2.6
				31	0200	14.4	4.4
					1000	2.9	.9
				SU	1550	12.9	3.9
				DI	2100	9.3	2.8

JUNE-JUIN

Day	Time	Ht/ft	Ht/m	Jour	Heure	H/pi	H/m
1	0255	14.5	4.4	16	0250	12.8	3.9
	1040	1.8	.5		1055	2.6	.8
MO	1655	13.7	4.2	TU	1735	13.2	4.0
LU	2125	10.0	3.0	MA	2355	11.0	3.4
2	0325	14.4	4.4	17	0325	12.6	3.8
	1130	.9	.3		1125	2.3	.7
TU	1740	14.1	4.3	WE	1810	13.4	4.1
MA	2215	10.6	3.2	ME			
3	0400	14.3	4.4	18	0050	11.0	3.4
	1210	.6	.2		0350	12.5	3.8
WE	1840	14.4	4.4	TH	1200	2.2	.7
ME				JE	1855	13.6	4.1
4	0045	10.8	3.3	19	0130	10.9	3.3
	0450	13.9	4.2		0425	12.3	3.7
TH	1230	.7	.2	FR	1220	2.2	.7
JE	1920	14.4	4.4	VE	1920	13.7	4.2
5	0200	10.9	3.3	20	0210	10.8	3.3
	0535	13.3	4.1		0500	12.1	3.7
FR	1320	1.3	.4	SA	1300	2.5	.8
VE	2020	14.4	4.4	SA	2010	13.9	4.2
6	0300	10.6	3.2	21	0255	10.5	3.2
	0620	12.5	3.8		0555	11.8	3.6
SA	1400	2.3	.7	SU	1320	2.9	.9
SA	2105	14.4	4.4	DI	2050	14.0	4.3
7	0415	10.2	3.1	22	0355	10.2	3.1
	0720	11.5	3.5		0650	11.4	3.5
SU	1440	3.5	1.1	MO	1405	3.5	1.1
DI	2205	14.3	4.4	LU	2130	14.1	4.3
8	0525	9.5	2.9	23	0450	9.6	2.9
	0845	10.6	3.2		0755	10.8	3.3
MO	1525	4.8	1.5	TU	1430	4.4	1.3
LU	2245	14.3	4.4	MA	2200	14.3	4.4
9	0630	8.7	2.7	24	0545	8.7	2.7
	1015	10.0	3.0		0915	10.2	3.1
TU	1615	6.1	1.9	WE	1515	5.5	1.7
MA	2330	14.2	4.3	ME	2255	14.4	4.4
10	0735	7.7	2.3	25	0640	7.5	2.3
	1155	9.9	3.0		1105	10.1	3.1
WE	1710	7.4	2.3	TH	1610	6.7	2.0
ME				JE	2325	14.5	4.4
11	0015	14.1	4.3	26	0735	6.1	1.9
	0820	6.6	2.0		1240	10.5	3.2
TH	1315	10.3	3.1	FR	1700	8.0	2.4
JE	1755	8.6	2.6	VE			
12	0055	13.9	4.2	27	0010	14.6	4.5
	0855	5.6	1.7		0820	4.6	1.4
FR	1440	11.0	3.4	SA	1345	11.3	3.4
VE	1845	9.6	2.9	SA	1800	9.2	2.8
13	0125	13.6	4.1	28	0050	14.6	4.5
	0935	4.6	1.4		0900	3.1	.9
SA	1545	11.7	3.6	SU	1500	12.3	3.7
SA	1925	10.3	3.1	DI	1900	10.2	3.1
14	0200	13.3	4.1	29	0125	14.6	4.5
	1000	3.8	1.2		0945	1.9	.6
SU	1625	12.3	3.7	MO	1600	13.1	4.0
DI	2020	10.8	3.3	LU	2000	10.9	3.3
15	0225	13.0	4.0	30	0205	14.5	4.4
	1035	3.1	.9		1030	1.0	.3
MO	1715	12.8	3.9	TU	1655	13.9	4.2
LU	2300	11.0	3.4	MA	2115	11.3	3.4

V-6

TABLE II. Campbell River Tide Table (PST) (Z+8)

1981

JULY-JUILLET

Day	Time	Ht/ft	Ht/m	Jour	Heure	H/pi	H/m
1	0255	14.3	4.4	16	0245	12.6	3.8
	1110	.5	.2		1100	2.0	.6
WE	1730	14.3	4.4	TH	1745	13.5	4.1
ME	2220	11.4	3.5	JE			
2	0345	13.9	4.2	17	0005	11.0	3.4
	1150	.5	.2		0325	12.5	3.8
TH	1825	14.5	4.4	FR	1135	1.9	.6
JE				VE	1815	13.7	4.2
3	0100	10.9	3.3	18	0100	10.6	3.2
	0435	13.5	4.1		0410	12.5	3.8
FR	1230	1.0	.3	SA	1215	2.1	.6
VE	1910	14.6	4.5	SA	1855	13.9	4.2
4	0155	10.5	3.2	19	0155	10.2	3.1
	0515	12.9	3.9		0505	12.4	3.8
SA	1310	1.6	.5	SU	1230	2.5	.8
SA	1955	14.5	4.4	D	1930	14.0	4.3
5	0245	10.0	3.0	20	0240	9.7	3.0
	0615	12.2	3.7		0550	12.1	3.7
SU	1340	2.9	.9	MO	1310	3.2	1.0
DI	2035	14.4	4.4	LU	2005	14.2	4.3
6	0350	9.5	2.9	21	0315	9.2	2.8
	0720	11.5	3.5		0645	11.8	3.6
MO	1420	4.2	1.3	TU	1345	4.2	1.3
LU	2115	14.3	4.4	MA	2035	14.3	4.4
7	0435	8.9	2.7	22	0410	8.3	2.5
	0835	10.8	3.3		0755	11.2	3.4
TU	1505	5.6	1.7	WE	1415	5.4	1.6
MA	2200	14.1	4.3	ME	2115	14.3	4.4
8	0535	8.1	2.5	23	0455	7.4	2.3
	0955	10.2	3.1		0915	10.6	3.3
WE	1540	7.0	2.1	TH	1500	6.8	2.1
ME	2240	13.9	4.2	JE	2145	14.4	4.4
9	0620	7.3	2.2	24	0545	6.3	1.9
	1120	10.1	3.1		1055	10.7	3.3
TH	1635	8.4	2.6	FR	1550	8.2	2.5
JE	2325	13.7	4.2	VE	2235	14.4	4.4
10	0710	6.4	2.0	25	0650	5.1	1.6
	1315	10.5	3.2		1225	11.1	3.4
FR	1720	9.6	2.9	SA	1650	9.5	2.9
VE	2355	13.5	4.1	SA	2320	14.4	4.4
11	0800	5.4	1.6	26	0740	3.9	1.2
	1455	11.2	3.4		1345	11.8	3.6
SA	1815	10.5	3.2	SU	1755	10.6	3.2
SA				DI			
12	0040	13.2	4.0	27	0005	14.3	4.4
	0840	4.5	1.4		0840	2.7	.8
SU	1550	12.0	3.7	MO	1505	12.7	3.9
DI	1920	11.1	3.4	LU	1905	11.2	3.4
13	0055	13.0	4.0	28	0050	14.2	4.3
	0925	3.6	1.1		0920	1.5	.6
MO	1625	12.6	3.8	TU	1550	13.3	4.1
LU	2140	11.4	3.5	MA	2150	11.4	3.5
14	0130	12.8	3.9	29	0150	14.0	4.3
	0950	2.9	.9		1005	1.3	.4
TU	1705	13.0	4.0	WE	1635	13.9	4.2
MA	2245	11.4	3.5	ME	2255	11.2	3.4
15	0205	12.7	3.9	30	0240	13.7	4.2
	1035	2.3	.7		1050	1.1	.3
WE	1715	13.3	4.1	TH	1720	14.2	4.3
ME	2330	11.3	3.4	JE	2350	10.8	3.3
				31	0340	13.5	4.1
					1130	1.3	.4
				FR	1755	14.3	4.4
				VE			

AUGUST-AOUT

Day	Time	Ht/ft	Ht/m	Jour	Heure	H/pi	H/m
1	0030	10.4	3.2	16	0025	9.8	3.0
	0435	13.2	4.0		0415	12.8	3.9
SA	1215	2.1	.6	SU	1140	2.7	.8
SA	1840	14.4	4.4	DI	1815	13.8	4.2
2	0150	9.9	3.0	17	0100	9.2	2.8
	0520	12.8	3.9		0510	12.6	3.9
SU	1230	2.9	.9	MO	1220	3.3	1.0
DI	1910	14.3	4.4	LU	1850	14.0	4.3
3	0225	9.3	2.8	18	0150	8.4	2.6
	0620	12.3	3.7		0610	12.7	3.9
MO	1310	4.0	1.2	TU	1245	4.2	1.3
LU	1945	14.2	4.3	MA	1920	14.1	4.3
4	0310	8.7	2.7	19	0240	7.6	2.3
	0715	11.7	3.6		0705	12.3	3.7
TU	1330	5.3	1.6	WE	1310	5.4	1.6
MA	2025	14.1	4.3	ME	1955	14.3	4.4
5	0345	8.0	2.4	20	0310	6.8	2.1
	0820	11.2	3.4		0805	11.9	3.6
WE	1410	6.7	2.0	TH	1345	6.8	2.1
ME	2105	13.8	4.2	JE	2020	14.3	4.4
6	0440	7.5	2.3	21	0415	5.9	1.8
	0940	10.8	3.3		0930	11.6	3.5
TH	1455	8.1	2.5	FR	1425	8.3	2.5
JE	2135	13.5	4.1	VE	2105	14.2	4.3
7	0520	6.8	2.1	22	0510	5.0	1.5
	1105	10.8	3.3		1055	11.6	3.5
FR	1545	9.4	2.9	SA	1525	9.7	3.0
VE	2210	13.1	4.0	SA	2145	14.0	4.3
8	0615	6.2	1.9	23	0605	4.3	1.3
	1245	11.1	3.4		1225	12.0	3.7
SA	1650	10.4	3.2	SU	1645	10.8	3.3
SA	2250	12.8	3.9	DI	2240	13.7	4.2
9	0655	5.5	1.7	24	0700	3.7	1.1
	1440	11.8	3.6		1355	12.7	3.9
SU	1800	11.1	3.4	MO	1825	11.3	3.4
DI	2315	12.4	3.8	LU			
10	0745	4.8	1.5	25	0005	13.3	4.1
	1520	12.4	3.8		0805	3.2	1.0
MO	1915	11.4	3.5	TU	1450	13.3	4.1
LU				MA	2100	11.3	3.4
11	0005	12.2	3.7	26	0045	13.0	4.0
	0840	4.1	1.2		0900	2.9	.9
TU	1550	12.8	3.9	WE	1535	13.7	4.2
MA	2120	11.4	3.5	ME	2205	10.8	3.3
12	0050	12.2	3.7	27	0155	12.9	3.9
	0925	3.5	1.1		0950	2.7	.8
WE	1625	13.1	4.0	TH	1610	14.0	4.3
ME	2205	11.1	3.4	JE	2300	10.1	3.1
13	0200	12.2	3.7	28	0245	12.9	3.9
	1000	3.0	.9		1050	2.8	.9
TH	1650	13.3	4.1	FR	1650	14.1	4.3
JE	2245	10.7	3.3	VE	2355	9.4	2.9
14	0245	12.4	3.8	29	0350	12.9	3.9
	1030	2.6	.8		1130	3.2	1.0
FR	1715	13.4	4.1	SA	1725	14.1	4.3
VE	2350	10.3	3.1	SA			
15	0335	12.6	3.8	30	0030	8.9	2.7
	1120	2.5	.8		0430	12.9	3.9
SA	1745	13.6	4.1	SU	1210	3.9	1.2
SA				DI	1750	14.0	4.3
				31	0100	8.3	2.5
					0525	12.7	3.9
				MO	1240	4.7	1.4
				LU	1825	13.8	4.2

SEPTEMBER-SEPTEMBRE

Day	Time	Ht/ft	Ht/m	Jour	Heure	H/pi	H/m
1	0145	7.8	2.4	16	0100	6.1	1.9
	0615	12.5	3.8		0610	13.3	[illegible]
TU	1255	5.8	1.8	WE	1235	6.2	1.9
MA	1900	13.7	4.2	ME	1815	14.1	4.3
2	0215	7.3	2.2	17	0150	5.2	1.6
	0715	12.2	3.7		0705	13.2	4.0
WE	1335	6.9	2.1	TH	1320	7.4	2.3
ME	1935	13.4	4.1	JE	1855	14.1	4.3
3	0255	6.8	2.1	18	0240	4.6	1.4
	0805	11.9	3.6		0810	12.9	3.9
TH	1400	8.1	2.5	FR	1410	8.7	2.7
JE	2000	13.1	4.0	VE	1935	14.0	4.3
4	0330	6.5	2.0	19	0330	4.2	1.3
	0915	11.7	3.6		0925	12.7	3.9
FR	1450	9.2	2.8	SA	1540	9.8	3.0
VE	2020	12.8	3.9	SA	2010	13.7	4.2
5	0415	6.1	1.9	20	0425	4.0	1.2
	1020	11.6	3.5		1045	12.7	3.9
SA	1605	10.1	3.1	SU	1650	10.6	3.2
SA	2045	12.5	3.8	DI	2100	13.3	4.1
6	0505	5.8	1.8	21	0515	3.9	1.2
	1200	11.8	3.6		1215	12.9	3.9
SU	1715	10.8	3.3	MO	1810	11.0	3.4
DI	2105	12.2	3.7	LU	2200	12.7	3.9
7	0545	5.5	1.7	22	0620	4.0	1.2
	1325	12.2	3.7		1320	13.4	4.1
MO	1830	11.1	3.4	TU	1945	10.8	3.3
LU	2150	11.8	3.6	MA	2320	12.2	3.7
8	0650	5.1	1.6	23	0735	4.1	1.2
	1425	12.7	3.9		1420	13.7	4.2
TU	1945	11.0	3.4	WE	2055	10.2	3.1
MA	2300	11.5	3.5	ME			
9	0740	4.7	1.4	24	0045	12.0	3.7
	1510	13.0	4.0		0840	4.2	1.3
WE	2100	10.7	3.3	TH	1500	13.9	4.2
ME				JE	2150	9.4	2.9
10	0030	11.5	3.5	25	0200	12.0	3.7
	0840	4.2	1.3		0935	4.5	1.4
TH	1520	13.2	4.0	FR	1535	14.1	4.3
JE	2200	10.2	3.1	VE	2240	8.6	2.6
11	0150	11.7	3.6	26	0300	12.2	3.7
	0925	3.9	1.2		1015	4.9	1.5
FR	1555	13.4	4.1	SA	1610	14.1	4.3
VE	2240	9.5	2.9	SA	2320	7.8	2.4
12	0240	12.1	3.7	27	0350	12.4	3.8
	1010	3.7	1.1		1105	5.4	1.6
SA	1620	13.5	4.1	SU	1630	14.0	4.3
SA	2300	8.8	2.7	DI	2350	7.0	2.1
13	0340	12.6	3.8	28	0440	12.6	3.8
	1050	3.8	1.2		1150	6.1	1.9
SU	1650	13.6	4.1	MO	1715	13.7	4.2
DI	2355	7.9	2.4	LU			
14	0425	13.0	4.0	29	0030	6.4	2.0
	1130	4.3	1.3		0530	12.7	3.9
MO	1715	13.8	4.2	TU	1220	7.0	2.1
LU				MA	1730	13.5	4.1
15	0020	7.0	2.1	30	0045	5.8	1.8
	0520	13.2	4.0		0615	12.8	3.9
TU	1205	5.1	1.6	WE	1300	7.8	2.4
MA	1745	13.9	4.2	ME	1805	13.2	4.0

V-6

TABLE II. Cambell River Tide Table (PST) (Z+8)

1981

OCTOBER-OCTOBRE

Day	Time	Ht/ft	Ht/m	Jour	Heure	H/pi	H/m
1	0110	5.6	1.7	16	0055	3.0	.9
	0705	12.9	3.9		0715	13.9	4.2
TH	1220	8.8	2.7	FR	1230	9.6	2.9
JE	1835	12.9	3.9	VE	1805	14.2	4.3
2	0140	5.3	1.6	17	0140	2.6	.8
	0755	12.8	3.9		0820	13.9	4.2
FR	1325	9.6	2.9	SA	1445	10.4	3.2
VE	1850	12.6	3.8	SA	1845	13.9	4.2
3	0215	5.2	1.6	18	0240	2.7	.8
	0850	12.8	3.9		0920	13.8	4.2
SA	1455	10.3	3.1	SU	1600	10.9	3.3
SA	1910	12.2	3.7	DI	1940	13.2	4.0
4	0245	5.2	1.6	19	0330	3.2	1.0
	0955	12.7	3.9		1030	13.9	4.2
SU	1615	10.7	3.3	MO	1705	11.0	3.4
DI	1935	11.8	3.6	LU	2020	12.4	3.8
5	0340	5.3	1.6	20	0430	4.0	1.2
	1115	12.8	3.9		1150	14.0	4.3
MO	1730	10.9	3.3	TU	1835	10.6	3.2
LU	2000	11.5	3.5	MA	2150	11.6	3.5
6	0430	5.4	1.6	21	0535	4.8	1.5
	1215	12.9	3.9		1245	14.1	4.3
TU	1850	10.8	3.3	WE	1950	9.8	3.0
MA	2045	11.1	3.4	ME	2340	11.1	3.4
7	0535	5.4	1.6	22	0640	5.5	1.7
	1305	13.2	4.0		1335	14.2	4.3
WE	2000	10.5	3.2	TH	2055	8.9	2.7
ME	2235	10.8	3.3	JE			
8	0630	5.4	1.6	23	0105	11.3	3.4
	1350	13.3	4.1		0800	6.2	1.9
TH	2100	9.9	3.0	FR	1410	14.3	4.4
JE				VE	2145	7.9	2.4
9	0045	11.0	3.4	24	0205	11.6	3.5
	0725	5.2	1.6		0850	6.7	2.0
FR	1430	13.5	4.1	SA	1455	14.2	4.3
VE	2135	9.2	2.8	SA	2225	7.0	2.1
10	0150	11.5	3.5	25	0300	12.0	3.7
	0820	5.2	1.6		1000	7.3	2.2
SA	1500	13.6	4.1	SU	1525	14.1	4.3
SA	2155	8.3	2.5	DI	2255	6.2	1.9
11	0240	12.1	3.7	26	0400	12.4	3.8
	0915	5.3	1.6		1055	7.8	2.4
SU	1535	13.8	4.2	MO	1545	13.9	4.2
DI	2250	7.2	2.2	LU	2325	5.5	1.7
12	0345	12.8	3.9	27	0450	12.8	3.9
	0950	5.8	1.8		1140	8.6	2.6
MO	1600	14.0	4.3	TU	1620	13.6	4.1
LU	2305	6.0	1.8	MA	2345	4.9	1.5
13	0425	13.3	4.1	28	0530	13.0	4.0
	1030	6.5	2.0		1150	9.2	2.8
TU	1630	14.1	4.3	WE	1650	13.3	4.1
MA	2345	4.7	1.4	ME			
14	0525	13.7	4.2	29	0015	4.5	1.4
	1115	7.4	2.3		0610	13.2	4.0
WE	1705	14.3	4.4	TH	1250	9.8	3.0
ME				JE	1700	13.1	4.0
15	0030	3.7	1.1	30	0030	4.1	1.2
	0615	13.9	4.2		0700	13.4	4.1
TH	1150	8.5	2.6	FR	1345	10.3	3.1
JE	1740	14.4	4.4	VE	1730	12.8	3.9
				31	0105	4.0	1.2
					0750	13.5	4.1
				SA	1430	10.8	3.3
				SA	1750	12.5	3.8

NOVEMBER-NOVEMBRE

Day	Time	Ht/ft	Ht/m	Jour	Heure	H/pi	H/m
1	0145	4.1	1.2	16	0225	2.1	.6
	0835	13.5	4.1		0905	14.6	4.5
SU	1515	11.0	3.4	MO	1555	11.1	3.4
DI	1815	12.2	3.7	LU	1910	12.9	3.9
2	0220	4.4	1.3	17	0305	3.1	.9
	0935	13.6	4.1		1005	14.6	4.5
MO	1620	11.1	3.4	TU	1705	10.7	3.3
LU	1850	11.8	3.6	MA	2010	11.9	3.6
3	0250	4.7	1.4	18	0350	4.2	1.3
	1025	13.7	4.2		1100	14.7	4.5
TU	1725	10.9	3.3	WE	1815	10.0	3.0
MA	1930	11.3	3.4	ME	2150	11.0	3.4
4	0345	5.1	1.6	19	0450	5.5	1.7
	1115	13.8	4.2		1200	14.7	4.5
WE	1630	10.5	3.2	TH	1920	9.0	2.7
ME	2020	10.7	3.3	JE	2330	10.7	3.3
5	0430	5.5	1.7	20	0545	6.7	2.0
	1205	13.9	4.2		1245	14.7	4.5
TH	1925	9.8	3.0	FR	2015	7.8	2.4
JE	2220	10.3	3.1	VE			
6	0535	5.9	1.8	21	0105	10.8	3.3
	1250	14.1	4.3		0650	7.9	2.4
FR	2015	8.9	2.7	SA	1325	14.7	4.5
VE				SA	2100	6.7	2.0
7	0025	10.6	3.2	22	0220	11.4	3.5
	0625	6.3	1.9		0755	8.8	2.7
SA	1330	14.1	4.3	SU	1355	14.4	4.4
SA	2055	7.8	2.4	DI	2150	5.8	1.8
8	0135	11.3	3.4	23	0325	12.0	3.7
	0730	6.8	2.1		0905	9.6	2.9
SU	1400	14.2	4.3	MO	1430	14.2	4.3
DI	2145	6.6	2.0	LU	2220	4.9	1.5
9	0235	12.1	3.7	24	0405	12.6	3.8
	0820	7.4	2.3		1000	10.2	3.1
MO	1440	14.3	4.4	TU	1455	13.9	4.2
LU	2205	5.2	1.6	MA	2255	4.2	1.3
10	0340	13.0	4.0	25	0450	13.1	4.0
	0915	8.2	2.5		1055	10.6	3.2
TU	1510	14.5	4.4	WE	1520	13.5	4.1
MA	2250	3.8	1.2	ME	2320	3.7	1.1
11	0430	13.7	4.2	26	0540	13.5	4.1
	1005	9.0	2.7		1200	11.0	3.4
WE	1535	14.6	4.5	TH	1555	13.3	4.1
ME	2330	2.6	.8	JE	2345	3.3	1.0
12	0515	14.3	4.4	27	0610	13.8	4.2
	1030	9.8	3.0		1250	11.1	3.4
TH	1610	14.7	4.5	FR	1605	13.1	4.0
JE				VE			
13	0010	1.8	.5	28	0020	3.2	1.0
	0620	14.5	4.4		0650	14.0	4.3
FR	1245	10.4	3.2	SA	1330	11.3	3.4
VE	1650	14.7	4.5	SA	1630	12.9	3.9
14	0040	1.4	.4	29	0040	3.2	1.0
	0710	14.6	4.5		0740	14.1	4.3
SA	1355	10.9	3.3	SU	1405	11.3	3.4
SA	1735	14.3	4.4	DI	1715	12.6	3.8
15	0130	1.5	.5	30	0115	3.5	1.1
	0805	14.7	4.5		0815	14.1	4.3
SU	1445	11.2	3.4	MO	1510	11.2	3.4
DI	1815	13.7	4.2	LU	1755	12.3	3.7

DECEMBER-DECEMBRE

Day	Time	Ht/ft	Ht/m	Jour	Heure	H/pi	H/m
1	0130	3.8	1.2	16	0220	3.6	1.1
	0905	14.3	4.4		0940	15.2	4.6
TU	1600	11.2	3.4	WE	1645	10.2	3.1
MA	1835	11.7	3.6	ME	2005	11.6	3.5
2	0210	4.3	1.3	17	0310	5.0	1.5
	1000	14.4	4.4		1025	15.1	4.6
WE	1700	10.8	3.3	TH	1750	9.3	2.8
ME	1915	11.3	3.4	JE	2155	11.0	3.4
3	0250	4.9	1.5	18	0355	6.5	2.0
	1040	14.5	4.4		1115	14.9	4.5
TH	1800	10.2	3.1	FR	1855	8.4	2.6
JE	2025	10.7	3.3	VE	2325	10.7	3.3
4	0340	5.6	1.7	19	0435	8.0	2.4
	1120	14.6	4.5		1145	14.8	4.5
FR	1900	9.4	2.9	SA	1945	7.3	2.2
VE	2235	10.4	3.2	SA			
5	0435	6.4	2.0	20	0100	11.0	3.4
	1155	14.7	4.5		0525	9.2	2.8
SA	1955	8.2	2.5	SU	1230	14.6	4.5
SA				DI	2040	6.3	1.9
6	0005	10.7	3.3	21	0215	11.6	3.5
	0520	7.3	2.2		0620	10.3	3.1
SU	1235	14.8	4.5	MO	1310	14.4	4.4
DI	2030	6.9	2.1	LU	2110	5.3	1.6
7	0125	11.4	3.5	22	0335	12.4	3.8
	0615	8.3	2.5		0825	11.2	3.4
MO	1315	14.9	4.5	TU	1340	14.1	4.3
LU	2110	5.3	1.6	MA	2155	4.4	1.3
8	0240	12.3	3.7	23	0420	13.0	4.0
	0715	9.3	2.8		0955	11.7	3.6
TU	1340	15.0	4.6	WE	1405	13.8	4.2
MA	2150	3.7	1.1	ME	2225	3.7	1.1
9	0340	13.2	4.0	24	0505	13.5	4.1
	0805	10.2	3.1		1100	12.0	3.7
WE	1420	15.1	4.6	TH	1435	13.6	4.1
ME	2215	2.3	.7	JE	2255	3.2	1.0
10	0435	14.0	4.3	25	0535	13.8	4.2
	0905	11.0	3.4		1150	12.0	3.7
TH	1455	15.2	4.6	FR	1510	13.4	4.1
JE	2255	1.3	.4	VE	2330	2.8	.9
11	0520	14.7	4.5	26	0600	14.1	4.3
	1000	11.6	3.5		1240	12.0	3.7
FR	1535	15.1	4.6	SA	1540	13.2	4.0
VE	2330	.7	.2	SA	2345	2.7	.8
12	0615	15.0	4.6	27	0640	14.3	4.4
	1255	11.8	3.6		1300	11.8	3.6
SA	1615	14.8	4.5	SU	1600	13.0	4.0
SA				DI			
13	0015	.8	.2	28	0020	2.8	.9
	0710	15.3	4.7		0710	14.4	4.4
SU	1355	11.7	3.6	MO	1350	11.5	3.5
DI	1705	14.2	4.3	LU	1645	12.7	3.9
14	0105	1.3	.4	29	0035	3.1	.9
	0750	15.3	4.7		0745	14.6	4.5
MO	1445	11.4	3.5	TU	1445	11.2	3.4
LU	1800	13.5	4.1	MA	1740	12.4	3.8
15	0135	2.3	.7	30	0110	3.6	1.1
	0845	15.2	4.6		0825	14.7	4.5
TU	1545	10.9	3.3	WE	1550	10.8	3.3
MA	1900	12.6	3.8	ME	1815	12.0	3.7
				31	0130	4.3	1.3
					0910	14.8	4.5
				TH	1630	10.2	3.1
				JE	1925	11.5	3.5

Cross-sections evaluated at two sites (line 40 and line 60) shown in Appendix I, permit the computation of the stage height and flow occupancy of the estuary by a river flow of 350 m^3/sec. This analysis results in the following:

Line 40 (Appendix III)

A cross-section called Line 40 (Appendix I) was evaluated to ascertain the distribution of Campbell River flow through various segments of the estuary environment. The approximately 350 m^3/sec. flow on July 2, 1981, was at a stage height of 1.90 m in the area of Line 40 and the distribution of this flow (Appendix III) was as follows:

SECTION	DESCRIPTION	FLOW* m^3/sec.	% OF TOTAL FLOW
1	SW Channel	92.01	22.49
2	Booming Area	20.70	5.06
3	Booming Area	16.50	4.03
4	Main Channel	279.86	68.42
	Total	409.08	100.00

*Computed from measured velocities and cross-sectional areas.

The total computed discharge represents a flow of 59.08 m^3/sec. (~17%) over the flow estimate provided by B.C. Hydro and Power Authority. It is felt, however, that the analytical errors are sufficiently consistent that the flow distribution values are reasonable indicators of estuary utilization by river flows in the range of 300-400 m^3/sec.

Having computed the cross-sectional area of the estuary required by Campbell River to dispense a flow of about 350 m^3/sec. when no tidal effect exists, it is possible (assuming the velocities remain the same) to estimate the stage height requirement for the same flow at tides in excess of 1.25 m.

At a tide level of 1.25 m, a flow of about 350 m^3/sec. in the Campbell River would result in a stage height of about 2.25 m in the area of Line 40 in the Campbell River estuary. At a tide level of about 2.25 m a flow of about 350 m^3/sec, assuming lowered velocities due to the tide, could yield a stage height of about 3.0 m in the area of Line 40 in the Campbell River estuary.

Velocities measured during the 350 m^3/sec. flow are presented in Appendix II and interpretations of erosion potentials along Line 40 may be enhanced by referring to Figure 1.

Line 60 (Appendix IV)

An analysis of estuary occupancy by the 350 m^3/sec flow of Campbell River was conducted downstream of Line 40, at Line 60 (Appendix I). The approach taken in this analysis was to compute velocities based on the cross-sectional area at a measured stage height of 1.90 m for given sections of Line 60 and the computed sectional flows for Line 40. The results of the analysis (Appendix IV) are summarized as follows:

SECTION	DESCRIPTION	FLOW m^3/sec.	% OF TOTAL FLOW
1	SW Channel	92.02	22.49
2	Booming Area	20.70	5.06
3	Booming Area	16.50	4.03
4	Main Channel	279.86	68.42

These data are the same as for Line 40 since at a stage height of 1.9 m the channel sections are reasonably discrete and contiguous with those defined in Line 40.

As a consequence of expanded channel cross-sections, average velocities are lower along Line 60 than along Line 40.

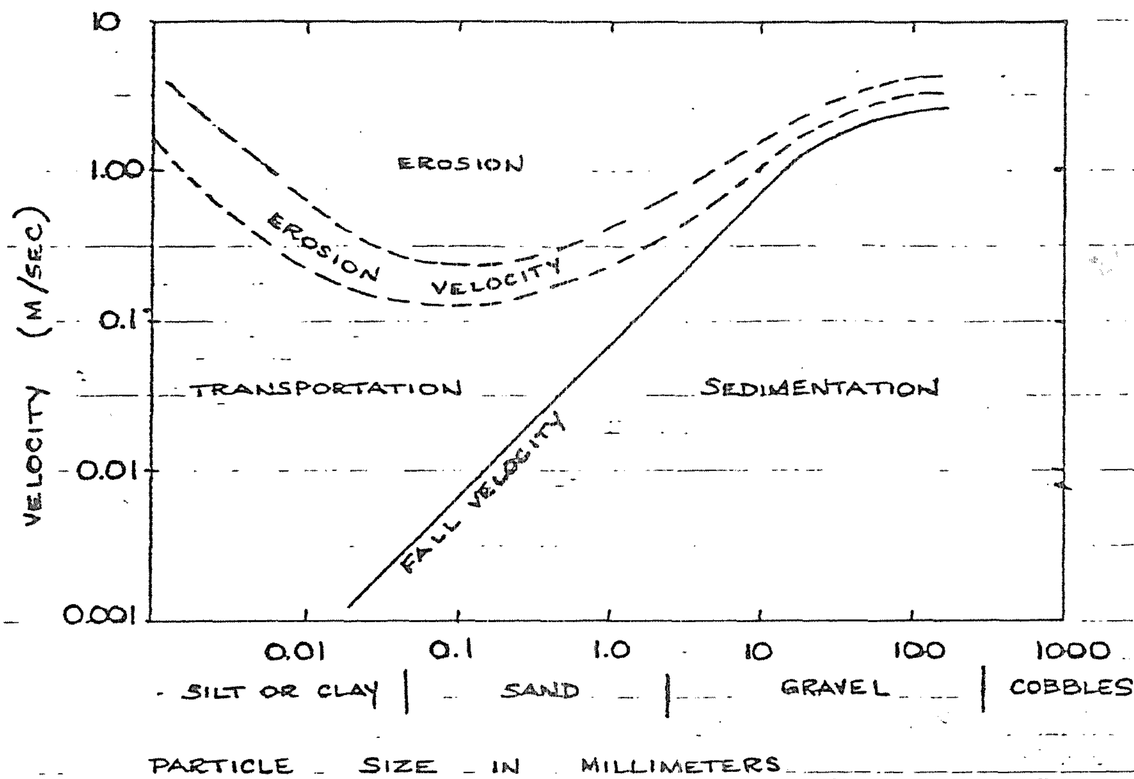
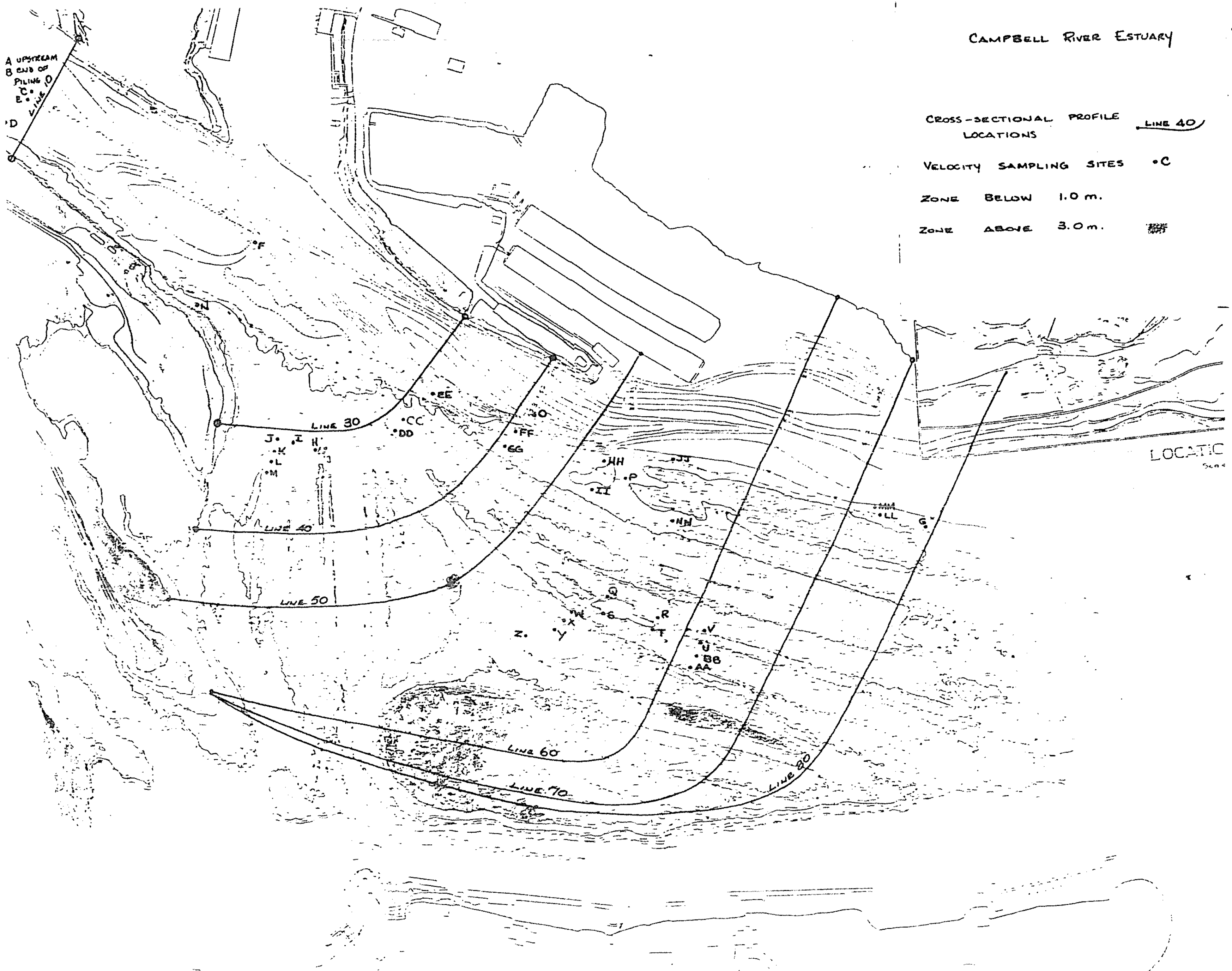


FIGURE 1. Curves of erosion and deposition for uniform material.*

*Redrawn from: HJULSTROM, F. (935. Studies of the morphological activity of rivers as illustrated by the River Fyris. Univ. Upsala Geol. Inst. Bull. 25. pp 221-527.) Original not seen - referred to by MORISAWA, M. 1968. Streams - their dynamics and morphology. McGraw-Hill. 175pp.

SUMMARY

Further data included is in Appendix V which contains all the cross-sectional profiles completed as per the locations shown in Appendix I. This report contains all the hydrological data collected by B.C. Forest Products Limited for the Campbell River estuary. There are no interpretations of these data with respect to estuary rehabilitation - that resting more appropriately with personnel from the Federal Department of Fisheries and Oceans.


Appendix 1
Campbell River Estuary
Cross-sectional profile locations
Line 40
Velocity sampling sites
•C
Zone below 1.0 m.
Zone above 3.0 m.
A upstream
B end of
Piling
Line 10
Line 30
Line 40
Line 50
Line 60
Line 70
Line 80
LOCATIC

APPENDIX II A. Velocity data measured on June 1, 1981 during a river flow of about 130 m^3/sec.

TIME	DEPTH M	MEAN M/SEC	SURFACE M/SEC	BOTTOM M/SEC	SITE	APPROX. TIDE M
1250	-	1.23	-	-	A	2.00
1300	-	1.50	-	-	A	2.05
1305	-	1.60	-	-	A	2.09
1308	-	1.60	-	-	B	2.10
1310	-	-	-	1.44	B	2.11
1312	-	-	2.05	-	B	2.15
1323	-	-	-	0.31	C	2.21
1331	-	-	0.33	-	C	2.25
1354	-	-	-	0.29	D	2.46
1356	-	-	0.65	-	D	2.46
1405	-	-	-	0.41	E	2.55
1410	-	-	0.65	-	E	2.60
1442	-	-	-	Ø	F	2.90
1446	-	-	-	0.16	C	2.95
1448	-	-	0.27	-	C	2.97
1507	-	-	0.09	-	H	3.13

APPENDIX II B. Velocity data measured on June 2, 1981 during a river flow of about 112 m^3/sec.

TIME	DEPTH M	MEAN M/SEC	SURFACE M/SEC	BOTTOM M/SEC	SITE	APPROX. TIDE M
1102	-	-	-	1.28	G	1.10
1104	-	1.07	1.34	-	G	1.09
1120	0.20	0.21	0.25	-	I	1.02
1122	0.20	0.17	-	-	J	1.01
1126	0.20	0.35	0.42	-	K	1.00
1130	0.20	0.67	0.80	-	L	1.00
1132	0.20	0.38	0.46	-	M	0.99
1200	-	-	-	0.35	C	0.93
1203	-	0.35	0.44	-	C	0.92
1210	-	-	-	0.56	E	0.91
1214	-	0.79	0.99	-	E	0.90
1226	-	-	-	1.16	G	0.90
1230	-	1.10	1.37	-	G	0.90
1242	-	0.16	0.19	-	I	0.91
1245	-	0.17	0.20	-	J	0.91
1247	-	0.42	0.50	-	K	0.91
1318	-	-	-	0.46	C	1.00
1322	-	0.42	0.52	-	C	1.01
1330	-	-	-	0.90	E	1.05
1333	-	1.07	1.16	-	E	1.06
1339	-	-	-	0.50	D	1.09
1342	-	0.53	0.66	-	D	1.11

APPENDIX XI

List of Publications Currently Available on Campbell River Research

Brown, T.J., McAllister, C.D., Levings, C.D., Kotyk, M., Chang, B.D. and J.S. Macdonald. 1984. Salmonid catch data from Campbell River and Discovery Passage 1983. Can. Data Rep. Fish Aquat. Sci. 444. iii + 97 p.

Brown, T.J., McAllister, C.D., Levings, C.D. and M. Kotyk. 1983. Salmonid catch data from Campbell River and Discovery Passage 1982. Can. Data Rep. Fish Aquat. Sci. 416. iii + 97 p.

Chang, B.D., Kotyk, M.S., Brown, T.J., Levings, C.D., McAllister, C.D and J.S. Macdonald. 1984. Length and weight data for unmarked juvenile salmon sampled in the Campbell River estuary and Discovery Passage, 1983. Can. Data Rep. Fish Aquat. Sci. 446 iii + 39 p.

Gordon, D.K., Kotyk, M.S., Brown, T.J., Levings, C.D. and C.D. McAllister. 1983. Data record on coded wire tags recovered from juvenile chinook at Campbell River estuary and Discovery Passage, 1982. Can. Data Rep. Fish. Aquat. Sci. 403. 111 + 57 p.

Kotyk, M.S., Chang, B.D., Brown, T.J., Levings, C.D., McAllister, C.D. and J.S. Macdonald. 1984. Data record on coded wire tags recovered from juvenile chinook at Campbell River estuary and Discovery Passage, 1983. Can. Data Rep. Fish Aquat. Sci. 457. 27p.

Kotyk, M.S., Chang, B.D., Brown, T.J., Levings, C.D. and C.D. McAllister. 1983. Length and weight data from unmarked juvenile salmon sampled in the Campbell River estuary and Discovery Passage, 1982. Can. Data Rep. Fish Aquat. Sci. 408. iii + 61p.

Levings, C.D., Kotyk, M.S., Brown, T.J., McAllister, C.D., Macdonald, J.S., Fagerlund, U. and J. McBride. 1984. An account of an experimental release of marked juvenile chinook to freshwater, estuarine and marine habitats near Campbell River, B.C. Can. Tech. Rep. Fish Aquat. Sci. 1240 V+35 p.

Levings, C.D. and M. Kotyk. 1983. Results of two boat trawling for juvenile salmonids in Discovery Passage and nearby channels, Northern Strait of Georgia. Can. Man. Rep. Fish. Aquat. Sci. 1730. iv + 55p.

Raymond, B.A., Wayne, M.M. and Morrison, J.A. 1981. Vegetation and Invertebrate Distribution and Fish Utilization of the Campbell River Estuary, British Columbia. Can. Man. Rep. Fish. Aquat. Sci. (unpublished; Habitat Management Division, DFO, Vancouver, B.C.).

Seki, H., Otsuki, A., Daigobo, S., Levings, C.D. and C.D. McAllister. 1984. Microbial contribution to the mesotrophic ecosystem of the Campbell River estuary during summer. Archiv. fur Hydrobiologie (in press).

APPENDIX II C. Velocity data measured on July 1, 1981 during a river flow of about 130 m^3/sec.

TIME	DEPTH M	MEAN M/SEC	SURFACE M/SEC	BOTTOM M/SEC	SITE	APPROX. TIDE M
1220	<.5	-	-	0.56	CC	0.25
1231	<.5	0.12	0.15	0.05	EE	0.25
1236	<.5	-	-	0.18	FF	0.26
1236	<.5	0.02	0.02	-	GG	0.26
1242	<.5	0.22	0.27	0.09	HH	0.27
1242	<.5	-	-	0.06	II	0.27
1248	<.5	-	-	0.11	NN	0.28
1250	0.15	-	-	0.17	P	0.28
1258	<.5	0.24	0.30	0.20	P	0.29
1303	<.5	0.35	0.44	0.21	JJ	0.29
1310	<.5	0.58	0.73	0.55	KK	0.30
1310	<.5	0.18	0.22	0.11	LL	0.30
1344	<.5	-	-	0.04	NN	0.42
1415	<.5	0.17	0.21	0.18	CC	0.60
1415	<.5	-	-	0.06	DD	0.60
1418	<.5	0.10	0.13	0.11	OO	0.65
1422	<.5	0.14	0.18	0.16	H	0.66
1423		-	-	Ø	K	0.66

APPENDIX II D. Velocity data measured on July 2, 1981 during a river flow of about 350 m^3/sec.

TIME	DEPTH M	MEAN M/SEC	SURFACE M/SEC	BOTTOM M/SEC	SITE	APPROX. TIDE M
1135		.86	1.07		O	.6
1140				.94	O	.59
1145		1.12	1.40		O	.55
1150				.40	L	.5
		1.36	1.72	1.19	O	
1155				.51	L	.5
				1.68	O	
1200				.73	L	.48
				1.34	O	
1205				.85	L	
		1.55	1.94	1.92	O	.45
	1.10	.42	.53	.34	P	
	.91	.78	.81	.35	S	
1210				1.09	L	
		1.78	2.22	2.01	O	.4
	1.10	.42	.53		P	
1215				1.14	L	
		1.73	2.16		O	
	1.10			.45	P	.4
		.56	.72	--	Q	
1220				1.37	L	
				2.04	O	
	1.10			.44	P	.35
	1.08	.51	.69	--	R	
1225				1.24	L	
		1.87	2.34		O	
	1.10	.38	.48	.44	P	.35
	1.08	.45	1.01	--	T	
1230				1.12	L	
		1.87	2.34	2.01	O	.32
	1.10	.38	.48		P	
1235				1.08	H	
		1.85	2.31	2.01	O	.32
	1.10	.39	.49	.46	P	
1240				1.13	H	
		1.86	2.32	2.04	O	
	1.10	.41	.51	.43	P	.3
	1.06	.37	--	--	Q	
1245				1.45	H	
				1.93	O	
	1.10	.42	.52	.44	P	.29
	1.15	--	--	.55	S	
1250				.158	H	
			1.32		N	
		1.84	2.30	1.85	O	.29
	1.10	.42	.52	.40	P	
1255			1.40		N	
		1.89	2.36	1.83	O	.27
	1.10			.43	P	
1300			1.34		N	
		1.86	2.32		O	
	1.10	.42	.53	.47	P	.25
	1.05	.62	.57	.62	W	

APPENDIX II D. (cont'd)

TIME	DEPTH M	MEAN M/SEC	SURFACE M/SEC	BOTTOM M/SEC	SITE	APPROX. TIDE M
1305		1.85	2.31	1.24	O	.25
	1.10	.40	.50	.45	P	
	.3	Ø			Y	
1310			1.68		N	.25
		1.86	2.33	1.39	O	
	1.10	.39	.49	.44	P	
	.49	.67	--	.48	X	
1315				1.31	O	.25
	1.10	.38	.48	.44	P	
1320			1.34		N	.25
		1.89	2.36	1.20	O	
	1.10	.38	.47	.49	P	
	.49	.25	--	.15	Z	
1325		1.89	2.36	1.25	O	.25
	1.10	.39	.49		P	
1330	.60	.76	--	.45	AA	.25
		1.86	2.33		O	
	1.10	.36	.45	.45	P	
1335	1.02	.90	--	.58	BB	.25
		1.77	2.21	1.53	O	
	1.10	.35	.44	.43	P	
1340				1.40	H	.25
		1.63	2.10	1.53	O	
	1.10			.40	P	
1345				1.53	O	.28
	1.10	.34	.42	.37	P	
	1.00	.58		.51	U	
1350		1.58	1.97	1.39	O	.3
	1.10	.31	.39	.34	P	
	1.00	.60		.52	S	
1355		1.44	1.80	1.15	O	.3
	1.10	.30	.38	.30	P	
1400		1.28	1.60		O	.3
	1.1	.49		.27	T	
1405	–			1.12	O	.3
1410	1.15	.30			Q	.32

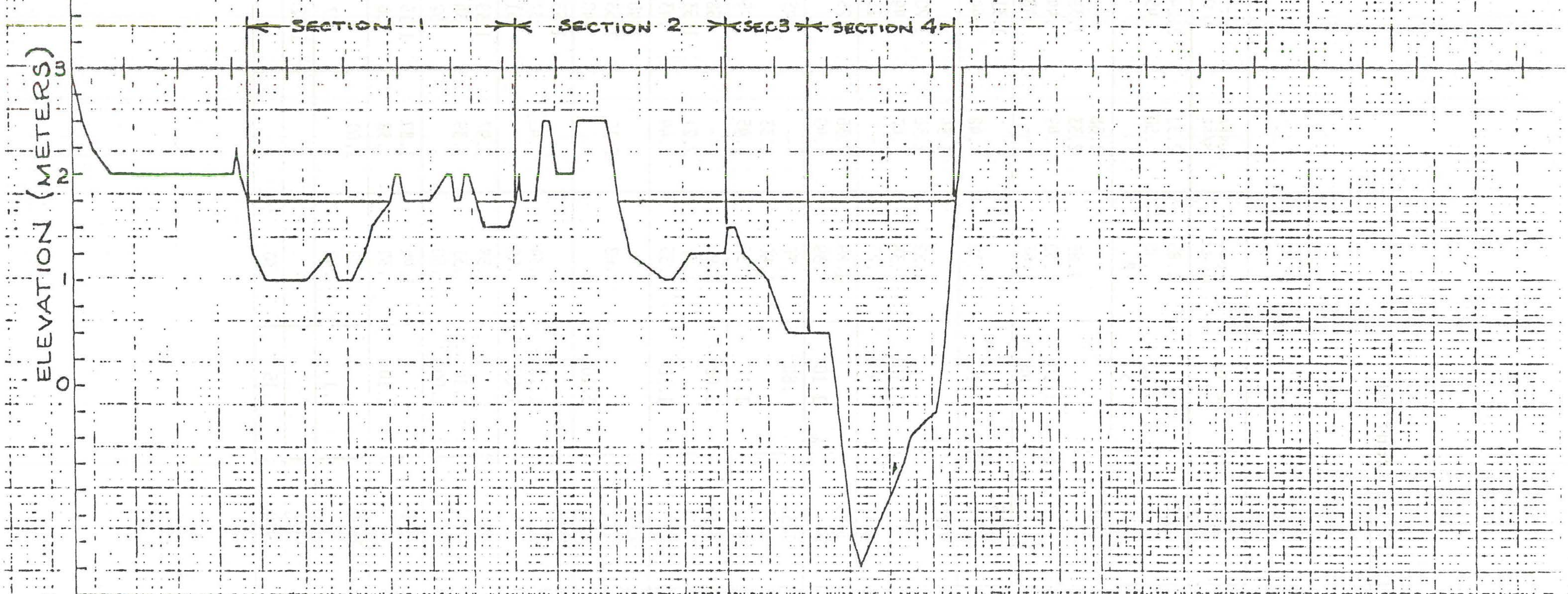
LINE40 TOTAL X-SECTION IS 719.82 / 0.00

HORIZONTAL TICS ARE 25 METERS APART

VERTICAL TICS ARE .25 METERS APART

FLOW DISTRIBUTION

SECTION	AREA M^2	VELOCITY M/S	FLOW M^3/S	% TOTAL
1	46.30	1.41	65.28	18.51
2	26.70	0.60	16.02	4.54
3	26.40	0.50	13.20	3.74
4	140.80	1.86	261.89	73.21
SUM	240.20		356.39	100.00



APPENDIX III A: CAMPBELL RIVER ESTUARY FLOW AT LINE 40 USING 1.75M. STAGE HEIGHT (LINE 40)

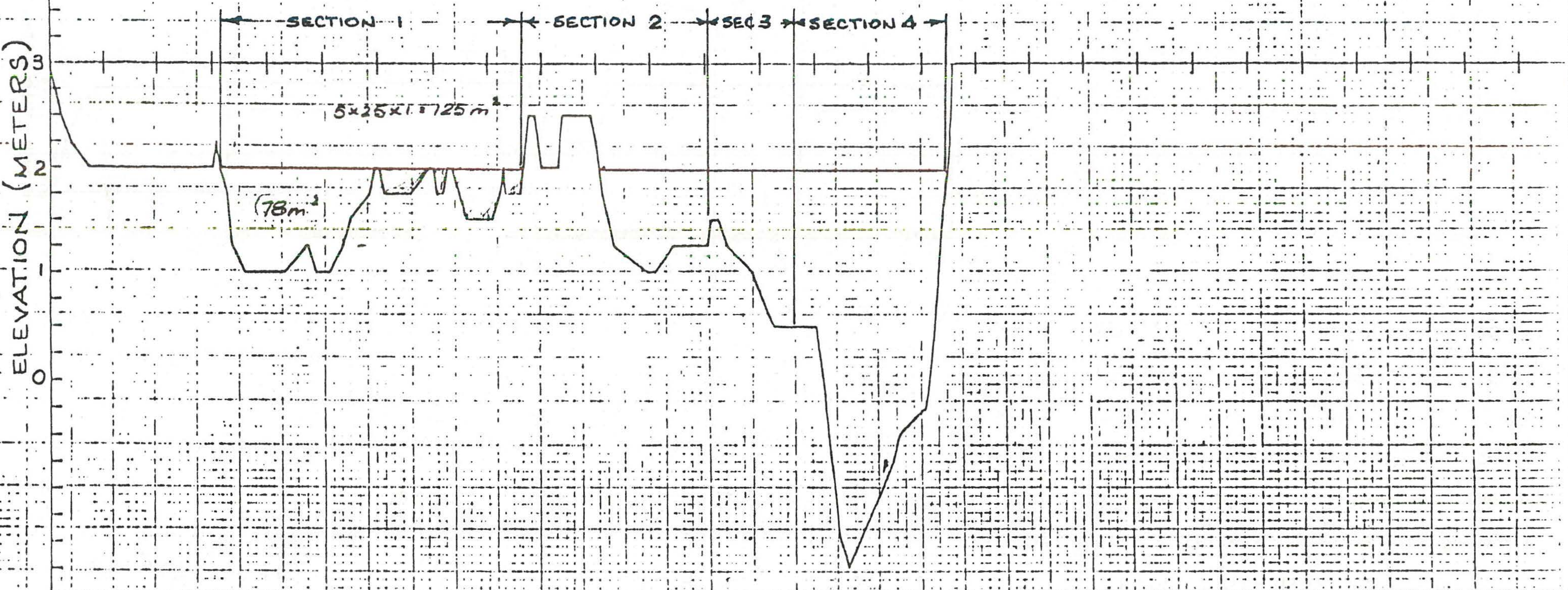
LINE40 TOTAL X-SECTION IS 719.82 / 0.00

HORIZONTAL TICS ARE 25 METERS APART

VERTICAL TICS ARE .25 METERS APART

FLOW DISTRIBUTION

SECTION	AREA M^2	VELOCITY M/S	FLOW M^3/S	% TOTAL
1	77.9	1.41	109.84	24.82
2	39.7	0.60	23.82	5.38
3	37.4	0.50	18.70	4.22
4	156.9	1.86	290.16	65.58
SUM	311.9		442.52	100.0



APPENDIX IIIB: CAMPBELL RIVER ESTUARY FLOW AT LINE 40 USING 2M STAGE HEIGHT.

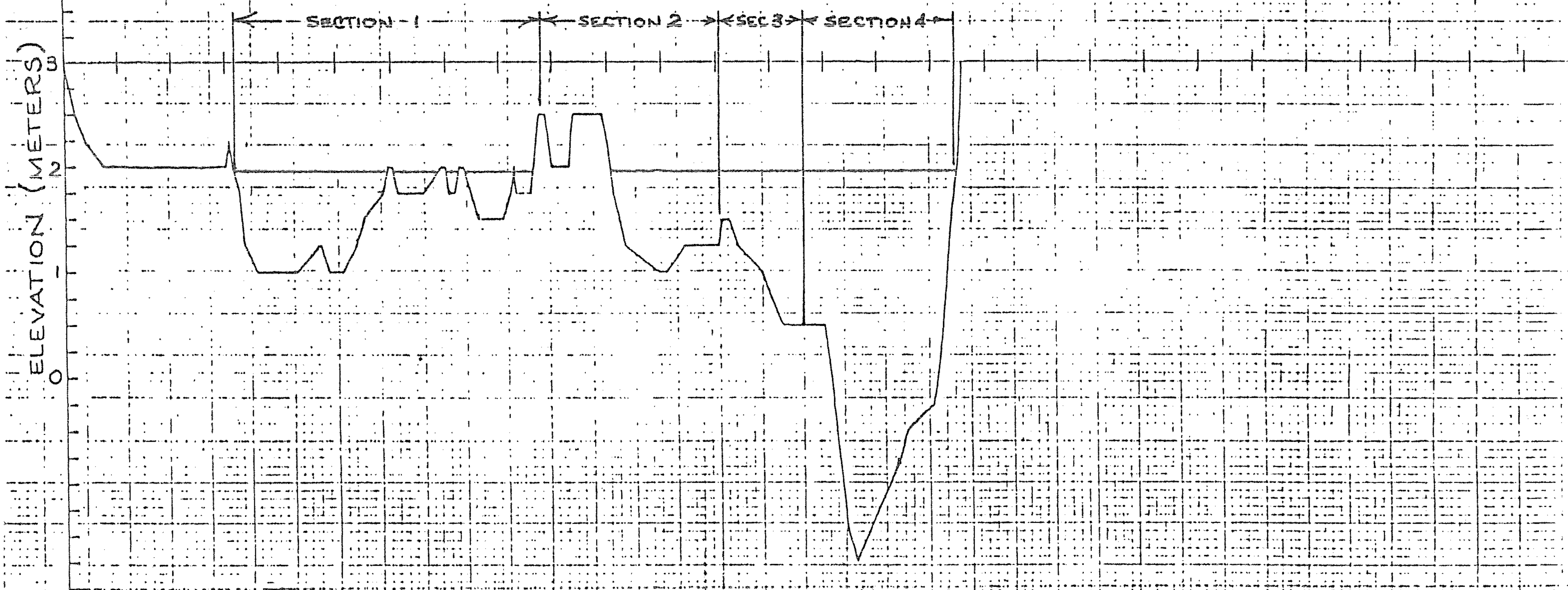
LINE40 TOTAL X-SECTION IS 719.82 / 0.00

HORIZONTAL TICS ARE 25 METERS APART

VERTICAL TICS ARE .25 METERS APART

FLOW DISTRIBUTION

SECTION	AREA M^2	VELOCITY M/S	FLOW M^3/S	% TOTAL
1	65.26	1.41	92.02	22.49
2	34.50	0.60	20.70	5.06
3	33.00	0.50	16.50	4.03
4	150.46	1.86	279.86	68.42
SUM	283.22		409.08	100.00



APPENDIX III C: CAMPBELL RIVER ESTUARY FLOW AT LINE 40 AT 1.9 M STAGE HEIGHT

LINE60 TOTAL X-SECTION IS 1052.06 / 33.48

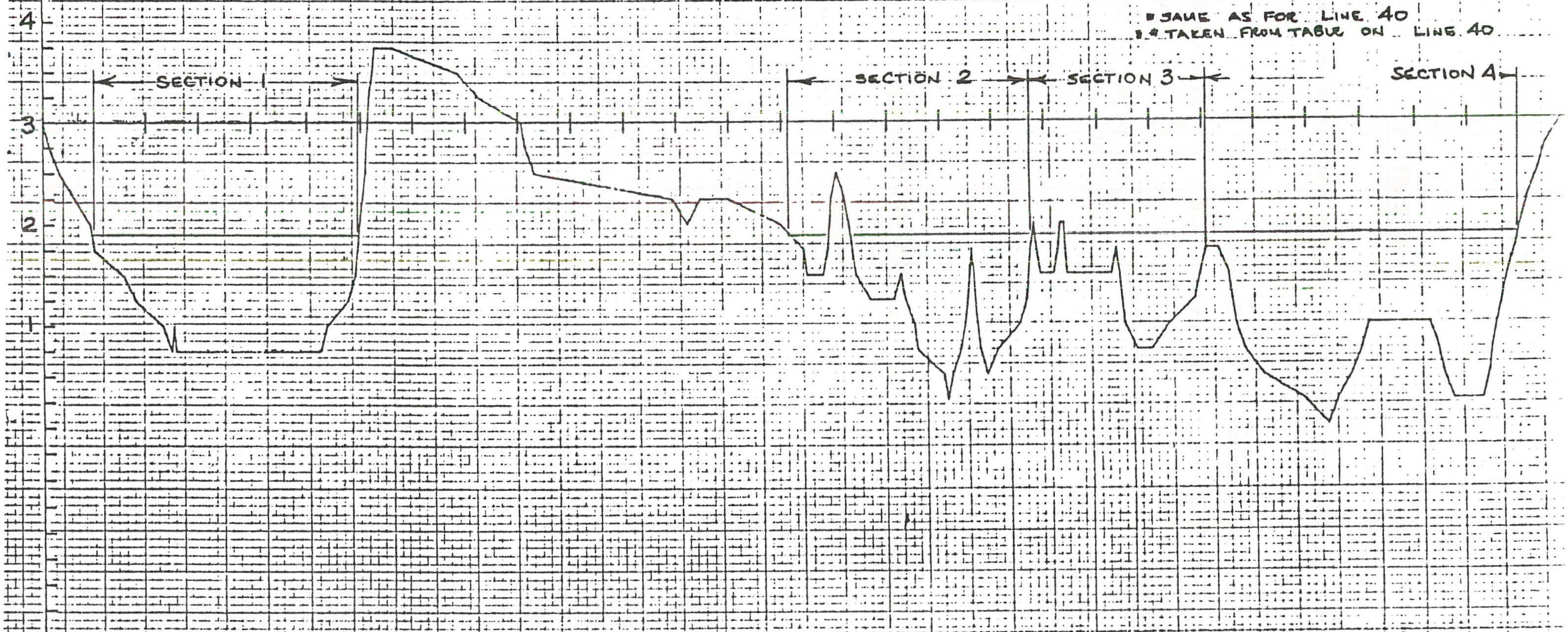
HORIZONTAL TICS ARE 25 METERS APART

VERTICAL TICS ARE .25 METERS APART

FLOW DISTRIBUTION

SECTION*	AREA M^2	VELOCITY M/S	FLOW** M^3/S	% TOTAL
1	110.00	0.84	92.02	22.49
2	74.25	0.28	20.70	5.06
3	44.37	0.37	16.50	4.03
4	171.19	0.61	279.86	68.42
SUM	399.81		409.08	100.00

* SAME AS FOR LINE 40
** TAKEN FROM TABLE ON LINE 40



APPENDIX IV CAMPBELL RIVER FLOW AT LINE 60 AT 1.9M STAGE HEIGHT

APPENDIX V.

Cross-sectional profiles at various locations across the Campbell River Estuary.

Legend: Horizontal line = 3.0 m

Cross-sectional areas i.e. 511.59 / 0.00

area below 3.0 m — area above 3.0 m

[Profiles available on DFO files]

Appendix VIII

Notes of a Campbell River estuarine review meeting

Br_sh Columbia
Forest Products Limited

BCFP

Inter-Office Memorandum

0 0 5 6 4 5

Revision of Memo dated October 8, 1982

To: E.R. Mattice

Date: November 10, 1982

TO: M. Brownlee

D/R

NOV 15 11 28 AM '82

FISHERIES & OCEANS
FISHERIES PACIFIC
FILE: 5903-85-C26-1

From: Mike Watkins

Subject: Campbell River Estuary Meeting
Review of 1982 - Plans for 1983

A workshop on the Campbell River Estuary was held in the Campbell River Office boardroom on October 6, 1982 with representatives from several agencies present (see attendance list attached). The purpose of the workshop was to have a general review of the efforts made to date to rehabilitate the old booming ground within our lease Lot 1486.

Each aspect of study was addressed separately with emphasis on date collection.

Construction procedures of the facility itself were briefly touched on through commentated slides.

A film photographed and produced by Richard Tomborello was presented and well received by all. The film showed our facility as it had been from 1904 to date illustrated with still photos, etc. from old International Timber Company and Elk River Timber Limited files. Campbell River as a resort/fishing town was the tone of the film with the enhancement of the estuary by B.C.F.P. under direction of Department of Fisheries & Oceans, being an integral step in ensuring the continuance of the salmon.

Department of Fisheries & Oceans funded the film and hope to have it become another Pacific Report or something of the like.

1982's EFFORTS

A) VEGETATION - Neil Dawe - Canadian Wildlife Service

- Planting of grasses was a 93% success for survival.
- 52 person days expended in data collection with an unspecified number on compilation.
- 22 species of flora recorded with Carex being dominant (present in 73% of plugs); Eleocharis palustris next in 53% and Juncus being third in 35% of plugs.
- Measurements of density, heights and number of flowers were taken on each of 23,302 plugs.

A) VEGETATION CONT'D.

- Density was comparable with Nunn's Island (used as control) while heights were approximately 50%.
- Measurements were taken during May, June, July and August.
- In May, an 18% mortality rate was observed, dropping to 7% in August with dramatic growth evidenced in color slides.
- Natural regeneration apparent in August.
- Natural regeneration of terrestrial plants evident on Island #4.
- Section D of Island #1 showed best growth with 100% survival.
- River flow and a takeover by algae gave Island #3 the worst growth with a 13% mortality rate.
- Some plugs inadvertantly planted wrong side up, due to darkness at time of planting, grew anyway.

B) BENTHOS - Bev Raymond - Contract Biologist to B.C.F.P.

- Sampling of each island done on three separate occasions with Nunn's Island as control.
- Sampling attempted to study macro and microbenthic fauna under changing conditions of vegetative influx over time.
- No variance in benthic densities between islands #1 and #4 although Nunn's Island had significantly higher numbers.
- Variance in benthic invertebrates densities between planted and unplanted sections of islands, depending on type of invertebrate.
- With most categories of benthos, sample dates did not affect densities indicating poor reproduction over summer.
- Fewer invertebrates in evidence in new marsh created on islands as compared to old established estuary, but it is hypothesized that detritus will be beneficial.

  - Bev Kask - Pacific Biological Station - Nanaimo

- Low productivity of epibenthic fauna on Island #3 or #4.
- New islands as productive with regard to epibenthos as the rest of the Campbell River estuary.
- Epibenthos only 10 - 20% as dense in "new" estuary as compared to Plumper Bay and Gowland Harbour.

C) FISH - Colin Levings - D.F.O. - West Vancouver Lab.

- Samples taken in estuarine, transitional and marine habitats.
- Sampling did and will take place from early April through late October.
- Young chinooks in evidence around islands compares in numbers to chinooks caught at old estuary stations before island constructions.
- First hatchery release (small fish in early April) are major estuary user with later releases heading directly to transition stations.

C) FISH - Colin Levings - Cont'd.

- Major users of island environment throughout summer were wild chinook stocks which tend to be much smaller than hatchery fish.
- Less than 1% of fish caught aroung islands from May onwards were hatchery fish, probably because bigger hatchery fish require deeper water (transition zones) while wild stocks use shallows around islands.
- With reference to Island #3, man-made channels experienced considerable useage with chinooks favouring upstream facing channels and chum favouring downstream.
- Both species favoured river side channels.

\- Tom Brown - D.F.O. - Vancouver

- 1,296 Beach seine's made in 18 trips requiring 63 days.
- Chinook salmon will and chum may benefit from islands.
- May and June are peak times for estuary useage in general with a steep decline in numbers caught thereafter in all three zones (estuary, marine and transitional) attributable to differences in ease of catching fish in estuary as opposed to marine zones.
- Mid-May peak time for island useage with 99% being wild stock.
- Transition zone experiences peak useage one month later than estuary with the marine zone peaking in late July.
- Fish use transition zone longer than estuary.
- Chum peak in estuary in April with a con-current marine zone peak (beach fry) while later transition and marine zone peaks are double indicating fish moving from estuary to outside creating one peak and one month later fish moving from other systems (probably Fraser) creating another.
- Pinks and coho were negligible in estuary (indicating larger fish moving straight through) but showed up in later months in outside zones with a double peak (created by outside system influx).
- Some chinook peaks had no correlation with hatchery releases (wild stocks).
- In general, hatchery fish were caught in same relative amounts as unmarked fish in all three zones.

\- Shawn Hamilton - D.F.O. - Vancouver

- On outside stations - objective of this summer's study was to delineate important fish use areas of the foreshore around the Campbell River system.
- Study areas ranged from Willow Point to Seymour Narrows and back to Cape Mudge on the Quadra Island side.
- Substrate, vegetative and benthic samples were taken.
- Boulder, Cobble-gravel and sand-mud sites were sampled.
- Deepest benthic samples were taken from minus 6 feet.
- Large benthic samples reported as far north as Menzies Bay up to mid-September.
- No conclusive results to date.

/4

D) WATERFOWL - Don Tretheway - C.W.S. - Vancouver

- We are under an international treaty obligation with the U.S. to study and report on waterfowl in their wintering and migration habitat.
- Last recorded observations in Campbell River estuary took place during winters of 1972 - 1974.
- Program of bird counting sketchily began again during winter of 1981 - 1982.
- Canadian Wildlife Service has a total of 35 staff to cover B.C. and the Yukon.
- C.W.S. now attempting to bring together Mittlenach Society to do bird counts, on weekly or bi-weekly basis, as C.W.S. does not have staff or funds.
- No documentation available from 1981 - 1982 observations.

E) PHYSICAL STUDIES - R.P. Willington - Crofton

- Physical aspects of estuary documented before any alteration on .25 m contour map (through air photo mapping and sub-marine echo sound mapping).
- Mapping will be re-done this winter utilizing new photos taken in late July, 1982 to show estuary as it presently exists.
- B.C. Hydro cannot release more than 620 m^3/sec. without causing flooding proximate to the Campbell River Lodge.
- Maximum water flow velocities are experienced between the islands at tides lower than one meter.
- In late June, there was no erosion in evidence around islands after a 230 m^3/sec. release at a 0.8 m tide (8000 cfs. @ 2.5').
- A planned test release of 10,000 cfs at zero tide this summer was cancelled. B.C. Hydro will re-schedule for this October and B.C.F.P. will test.
- Qualitative evaluations of island stability, river bedload movement and remaining piling performance will continue over this winter.
- Fresh-water induction culvert into sort area is performing as planned with flows ranging from 45 m^3/sec. down to zero depending on river stage/ tide stage correlation.
- Soil samples were collected from island sites and air-dried for subsequent nutrient analysis for C.W.S. Texture, pH and conductivity to be conducted on samples by B.C.F.P.

F) WATER QUALITY - S.L. Spencer - Crofton

- Samples were taken in July, August and September.
- Dissolved oxygen found to be at low levels on the bottom in bullpen/ storage area.
- Ready-mix Pool used as control with dissolved oxygen levels found to be higher than in storage areas.
- H_2S and suspended sediment samples for the August sampling period not analyzed at opting of Mike Nassichuck (D.F.O. Head of Water Quality).

F) WATER QUALITY CONT'D.

- Wood extractive samples taken in September, but will not be analyzed until a method has been developed.
- In September H_2S levels were sampled and found to be negligible.
- Macrobenthic samples were collected in August in new boom area and low fish food benthic fauna was found.

WATER QUALITY - HEAVY METALS - Alex McCarter - Professor of Environmental Toxicology - Univ. of Victoria

- Dramatic increase in zinc and copper in Buttle-Campbell system over last ten years except for recent drop which could be result of Westmin's new tailings handling system.
- Metals in the Campbell River are zinc, 40 pp billion, copper 2 - 2.25 ppb and cadmium 0.5 ppb: these levels are 4.23 times higher than a level deemed harmful/fatal to salmonids and trout over a short/extended period of exposure according to the Environmental Protection Agency.

  N.B. - Buttle Lake itself experiences concentrations of zinc at 180 ppb and copper at 10-20 ppb.
  - Domestic hot water flows with 700 ppb copper.
- Fish ingest heavy metals through their gills and not through food.
- Chinook hatchery fish are not affected by heavy metals because of their short exposure time, although wild chinooks could be.
- In general, the Campbell River itself is always toxic for steelhead - sometimes for chinook and never for Coho due to difference in tolerance level.

G) ESTUARY REHABILITATION - Mike Watkins

- See memo to C.H.G. Iverson dated August 26, 1982.

H) PLANTING - Gordon Burton

- See Campbell River Estuary Rehabilitation Report dated May 4, 1982.

SUMMARY

Mike Brownlee suggests that all information be gathered, data compiled and correlated and put under a cover before Christmas of this year. As a text, this will act as a reference much the same as Ministry of Lands Guidelines for Coastal Log Handling.

ACTIONS FOR 1983

A) VEGETATION

- Next year's studies depend on C.W.S. having funds for summer students.
- 200 person days required for data collection alone.
- Studies next year will include biomass investigations as well as individual plug assessment and natural vs planted regeneration assessment.

B) BENTHOS

- All studies should concentrate on benthic fauna that fish eat.
- Benthic quadrats will be investigated.
- Drift samples to be taken for insects.
- Mysids not in evidence - extra effort to find them including night samples.
- Sampling to be done monthly in spring, bi-monthly in summer.
- Closely investigate island colonization and see if it is happening as it should be.
- Zone stations to be assigned proper and consistent names.
- Continue sampling over next 3 - 5 years.

C) FISH

- Leving's department has been approached internally with the question "what is real benefit of an estuary?" To resolve, specific fry are to be put in different zones and seined by-weekly beginning in early April which will give more data on fry and smolt survival - ie: would chinook fry be just as well or better off to travel directly from hatchery to transitional or marine zones without stopping in an estuary?
- This year's program will also be repeated.
- Resolve, if possible, the reason large chinook are now using river pool at Lodge for holding rather than Ready-mix Pool. Buttle Lake lower metal levels on Island #1 construction could have altered fish response.
- Fish & Wildlife should take an interest in Steelhead and Cutthroat monitoring - Brownlee, to rattle Morrison's chain - AGAIN -.

D) WATERFOWL

- No funds in 1982 or 1983 for Canadian Wildlife Service.
- 4 person days per week ideally required.
- 2 people, 8 hrs/day - 4 days in row should also happen monthly.
- Want to relate finds and numbers of birds to habitat type.
- Perhaps people from S.E.P. could help.
- Egan to approach Naturalist Society of Comox re: assisting in Campbell River.
- Scientific principals will be compromised if a weekly count program is not implemented.

E) PHYSICAL STUDIES

- Update maps from new photos.
- Physical features noted by R.P. Willington and Rick Eliason (D.F.O.) to be mapped.
- B.C.F.P. and D.F.O. bench/reference marks to go on maps.
- Visual studies of material degradation or aggradation to continue this winter.

E) PHYSICAL STUDIES CONT'D.

- Soil samples from islands to be passed to Dawe (C.F.S.) for analysis as to nutrient content. PH levels texture classifications and conductivities to be conducted by B.C.F.P. this winter.
- Culvert performance evaluations to continue over winter.
- Decide next summer whether further physical studies are necessary.

F) WATER QUALITY

- Dissolved oxygen in booming area to be investigated while sort operating to determine if booming activity increases D/O.
- D/O and salinity monitoring to continue over winter in booming area.
- Water quality sampling to be streamlined to ensure sampling by B.C.F.P. and analysis by D.F.O. are compatable.
- Department of Fisheries & Oceans water quality department (Mike Nassichuk) Brownlee and B.C.F.P. to meet to set up winter quality monitoring program.
- Boom pocket area benthic sampling program to be evaluated and included in estuary island benthic sampling program.

WATER QUALITY - TOXICOLOGY

- University of Victoria will ask B.C. Science Council for funds to assist in 1983 work which will include:
    a) Effects of heavy metals on long-term smolt survival.
    b) Effects of heavy metals in secondary users - ie: mergansers eating contaminated smolts.
- Brownlee to supply letter of reference which McCarter can pass to B.C. Science Council stating validity and worth of project, in return hoping to "scoop" some University of Victoria grad students to assist in estuary studies.

G) CLEANUP

- Re-assessment in spring to see if high flows have removed small debris which is still a concern.
- River channel piles to remain possibly forever.
- River side piling rows adjacent to Island #3 to remain until all are convinced all is stabilized.
- Photos to be taken again next year with cost shared between D.F.O. and B.C.F.P.

H) BROWNLEE

- Supply approximately $5,000 for film.
- Continue work associated with operation of facility such as debris deposition, etc.
- A slow and uneventful winter projected.

/8

H) BROWNLEE CONT'D.

- In closing, Brownlee again suggested that all data should and would be compiled between now and year-end with the hope that works to date would form a text for any future developments and rehabilitative efforts on the B.C. Coast.

TENURE OF LEASE LOT #1486

- Egan stated that under new legislation the Provincial Government can now transfer land directly to the Federal Government or an agency.
- Brownlee to write to Egan immediately and set the wheels in motion.

FURTHER WORKS

- When directly asked by Egan "is there room and would there be more islands in Estuary?", Brownlee replied, "this is reason for 3 - 5 year study, it is a possibility."

Another meeting will be scheduled for early new year to review text and decide what will be done and who will do in 1983.

Mike Watkins

MW/me

CAMPBELL RIVER ESTUARY MEETING
REVIEW OF 1982
PROGRAM FOR 1983

NAME	REPRESENTING	FROM
Mike Brownlee	Dept. of Fisheries & OCeans	Vancouver
Ray Sheck	D.F.O.	Campbell River
Bill Masse	D.F.O.	Vancouver
John Payne	D.F.O.	Vancouver
Colin Levings	D.F.O.	West Vancouver Lab.
Tom Brown	D.F.O.	Nanaimo
Brian Tutty	D.F.O.	Vancouver
Tom Bird	D.F.O.	Vancouver
Norm Lemmen	D.F.O.	Campbell River
Ian Birtwell	D.F.O.	West Vancouver Lab.
Ron McNaughton	D.F.O.	Vancouver
Shawn Hamilton	D.F.O.	Vancouver
Bill McLean	D.F.O.	Quinsam Hatchery
Ben Covey	D.F.O.	Campbell River
Gordon Kosakoski	D.F.O.	Nanaimo
Jim Vantine	D.F.O.	Campbell River Hatchery
Richard Tomborello	Film Producer	Vancouver
James P. Egan	Ministry of Lands, Parks & Housing	Courtenay
Ron Diedericks	Fish & Wildlife	Nanaimo
Alec McCarter	Environment Toxicology	University of Victoria
Michael Rock	Environment Toxicology	University of Victoria
Mike Bradford	Simon Fraser University	Vancouver
Bev Kask	Pacific Biological Station	Nanaimo
Art Coburn	Pacific Biological Station	Nanaimo
Neil K. Dawe	Canadian Wildlife Service	Nanaimo
Don Trethewey	Canadain Wildlife Service	Vancouver
C.H.G. Iverson	B.C.F.P.	Campbell River
Ted Mattice	B.C.F.P.	Campbell River
Gordon Burton	B.C.F.P.	Campbell River
Mike Watkins	B.C.F.P.	Campbell River
S. Leigh Spencer	B.C.F.P.	Crofton
R.P. Willington	B.C.F.P.	Crofton
Bev Raymond	B.C.F.P(Consultant)	Nanaimo

----October 6th, 1982-----

Appendix IX

Campbell River Estuary -- soil analysis

CAMPBELL RIVER ESTUARY - SOIL ANALYSIS

JUNE 1983

R. SLACO
British Columbia Forest Products Limited
Resource Planning Group

TABLE OF CONTENTS

I. Introduction

As part of the acquisition of the Elk River Timber holdings by B.C. Forest Products Limited in 1980, a major reconstruction of the log sorting and booming grounds in the Campbell River Estuary was proposed. Associated with this plan was a rehabilitation program to enhance the fisheries resource within the intertidal zone of the estuary. This has mainly involved the construction of a series of man-made islands which were planted with marshgrass species. The work was completed during February, 1982.

Soil sampling of these man-made islands was undertaken as part of a large integrated project to monitor various biological and physical features associated with the rehabilitation of the estuary. Specifically, the objectives of the soil sampling were to:

- to identify and describe the various soil characteristics of the man-made islands as bench-mark soils information. (This information may be used to examine physical or chemical changes in the soil over time and thus provide a chronologic sequence of soil development).

- to compare the soil characteristics of the newly formed islands with that of an established natural island.

- to provide information for possible correlation with vegetation establishment on the islands.

Since there have been very few studies made on estuarine soils, there is limited information from which comparisons can be made.

II. Soil Sampling Procedure

Composite soil samples of the upper 30 cm. were taken at three different locations on each of the four man-made islands (Figure 1). In addition, composite soil samples of the 0 to 30 cm. depth and 30 to 50 cm. depth were made on Nunns Island which is an adjacent naturally established island (Figure 2).

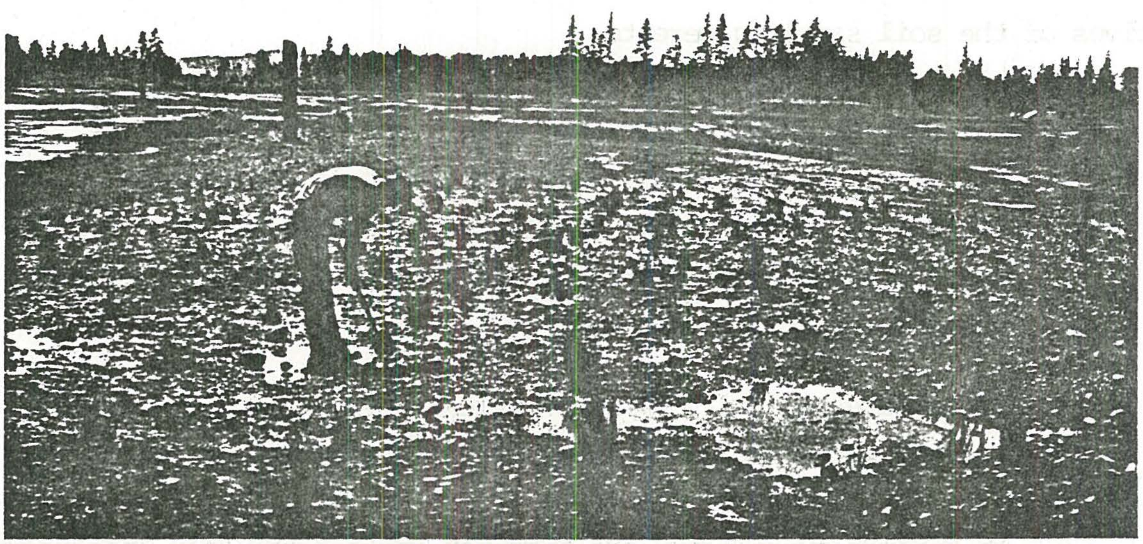


Figure 1. Soil sampling within the vegetated portion of Island #4.

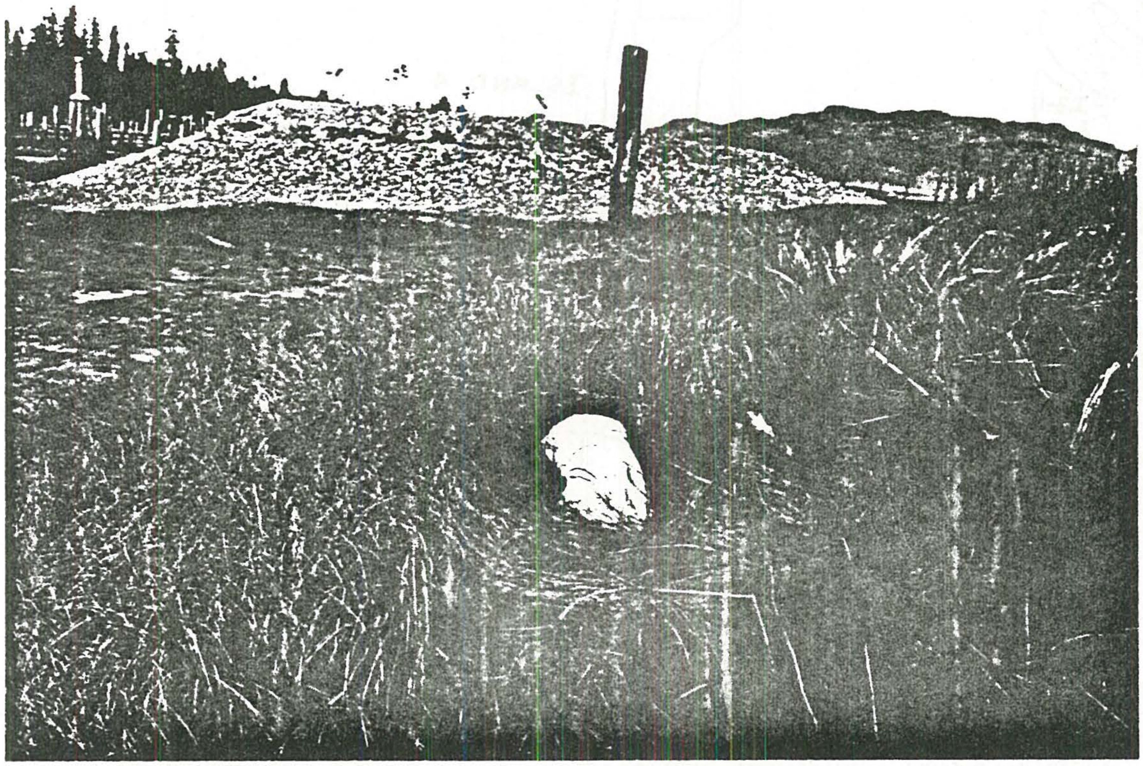


Figure 2. Soil sampling on Nunns Island.

Sampling was done on August 18, 1982, while the islands were exposed during a low tide of 0.1 meter. The soil-moisture content at the time of sampling was somewhere between saturation and field capacity. The approximate locations of the sampling sites are shown in Figure 3.

At each sampling site, approximately 8 to 18 kg. of soil was collected. The reason for collection of such a large sample size was due to the high coarse fragment content (Figure 4). A minimum of 1 kg. of the < 2 mm portion of soil was desired for the physical and chemical analyses.

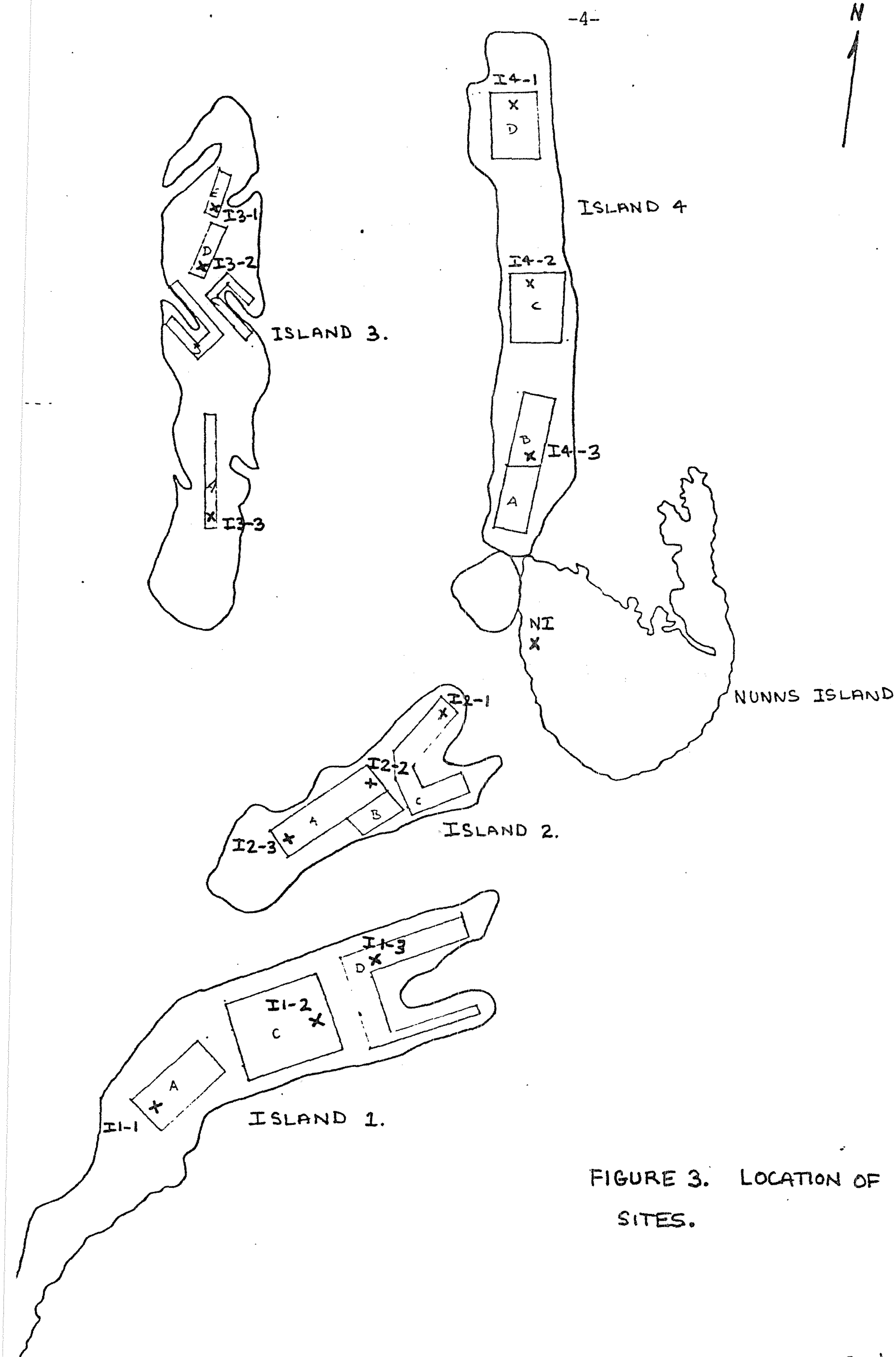


FIGURE 3. LOCATION OF SAMPLING SITES.

Approx. Scale 1:2400

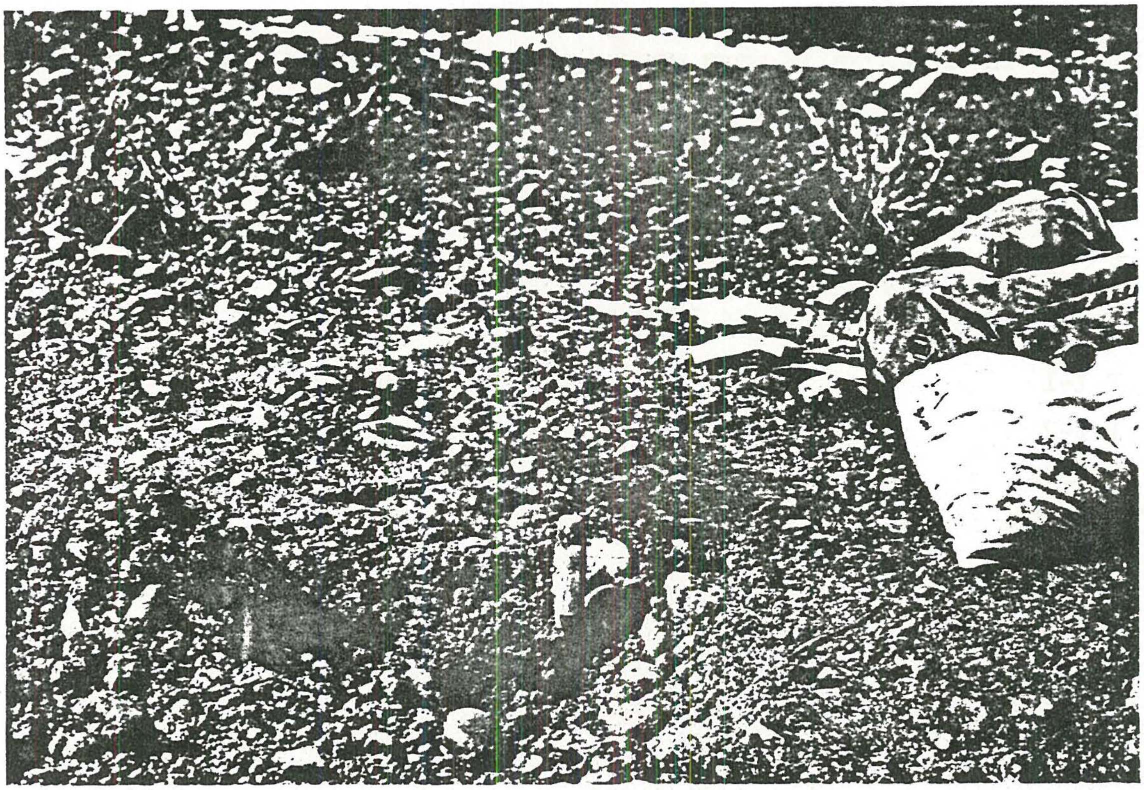


Figure 4. The material used to build the islands contained a high proportion of gravels and cobbles.

After the samples were collected they were air-dried in preparation for physical and chemical analysis.

III. Soil Analysis

a) Physical characteristics

Air-dried soils were passed through a series of sieves to determine particle size distribution (See Table 1 and Figure 5).

Table 1. Particle Size Distribution

Sample #	% did not pass #4 sieve (4.75 mm)	% did not pass #10 sieve (2.0 mm)	% less than (2.0 mm)
I 1-1	62	9	29
I 1-2	65	8	27
I 1-3	64	10	26
I 2-1	61	10	29
I 2-2	63	10	27
I 2-3	59	12	29
I 3-1	63	10	27
I 3-2	57	11	32
I 3-3	54	14	32
I 4-1	56	10	34
I 4-2	66	9	25
I 4-3	56	10	34
NI 0-30	-	-	100
NI 30-50	58	12	30

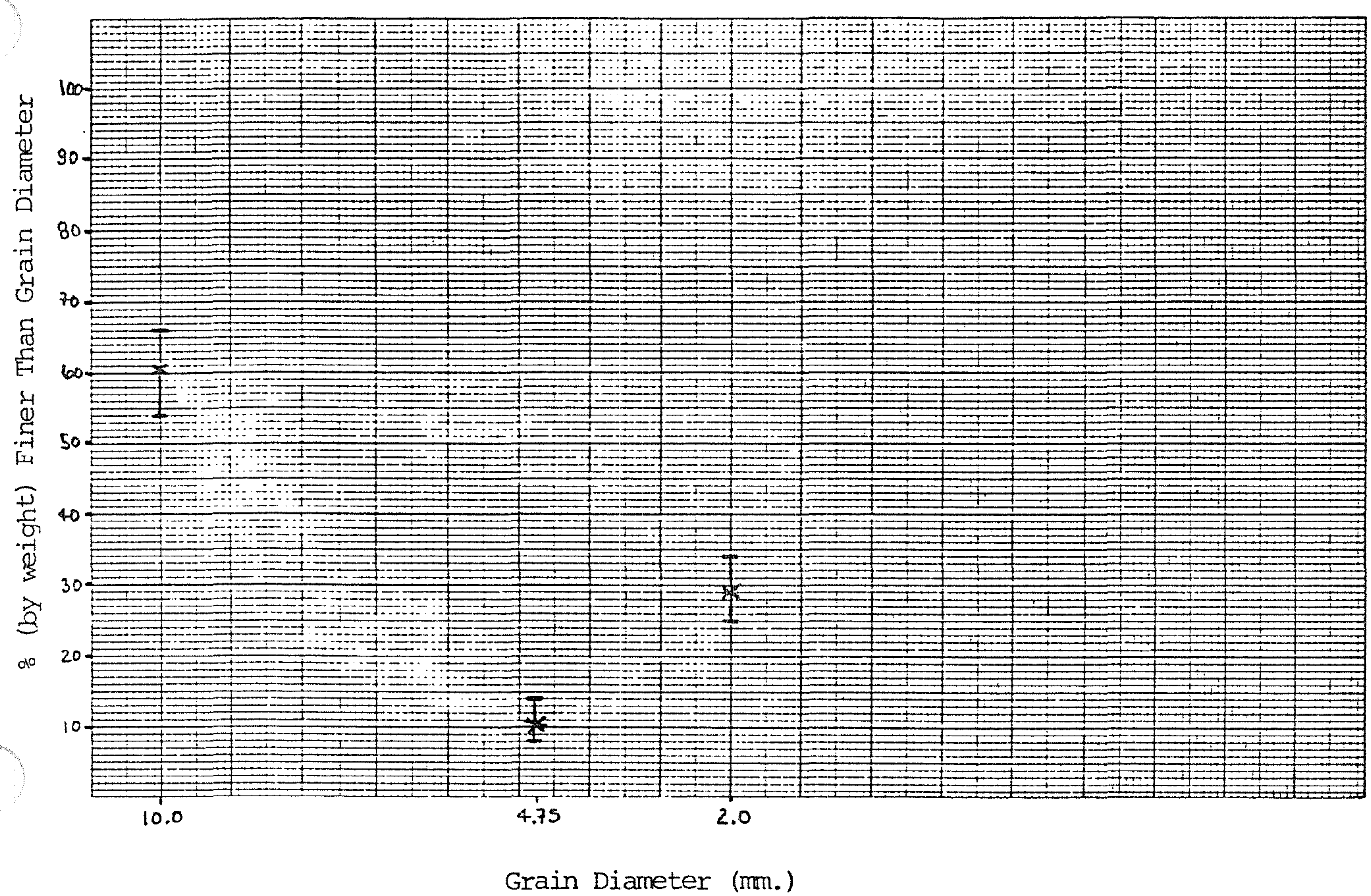


Figure 5. Average grain size diameter for the man-made islands

The particle size distribution of the fine fraction ($<$ 2 mm.) was determined using the hydrometer method (Table 2).

Table 2. Percent Sand, Silt and Clay and Textural Class.

Sample #	Percent (%)			Textural Class *
	Sand	Silt	Clay	
I 1-1	85	10	5	LS
I 1-2	80	15	5	LS
I 1-3	82	13	5	LS
I 2-1	88	7	5	S
I 2-2	85	10	5	LS
I 2-3	87	8	5	LS
I 3-1	81	16	3	LS
I 3-2	84	11	5	LS
I 3-3	84	13	3	LS
I 4-1	87	11	2	S
I 4-2	87	9	4	S
I 4-3	87	10	3	S
NI 0-30	54	42	4	SL
NI 30-50	92	5	3	S

* LS = Loamy Sand
SL = Sandy Loam
S = Sand

III. Soil Analysis

b) Chemical characteristics

The pH and conductivity were measured for each of the 14 samples. While nutrient analyses have not been done, a sufficient amount of sample has been sorted for future analyses, if required.

The procedure for determining pH and conductivity was made using the method described in Appendix I. In this method, a saturated soil paste is prepared from which a soil water extract is taken. The pH and conductivity were then determined from this extract using a Uniloc MD. #1070 pH probe and Uniloc MD. #770 conductivity meter (Table 3).

It should be noted that plants growing in salt-affected soils, respond to a salt concentration in solution which is dependent upon the water content of the soil. Therefore, to determine the relationship between plant growth and soluble salt content, the water content must be known. For estuarine soils the conductivity will change with the mixing of salt and fresh water, and with the fluctuation in soil-water content.

The actual salt concentration in parts per thousand (0/00) can be estimated by using the following equation (Black, 1965).[1]

$$\text{Salt Concentration (0/00)} = \frac{.64 \times \text{Conductivity}\,(\mu\text{mhos/cm})}{1000}$$

[1] Black, C.A., 1965. Methods of Soil Analysis Part 2. Agronomy No. 9. pp. 933-940.

Table 3. pH and Conductivity

Sample #	pH	Conductivity (μmhos/cm)	Salt Concentration (0/00)
I 1-1	4.4	3400	2.18
1-2	3.9	3400	2.18
1-3	4.1	3250	2.08
2-1	5.0	2300	1.47
2-2	5.2	1950	1.25
2-3	5.8	1700	1.09
3-1	5.1	3625	2.32
3-2	5.2	4700	3.01
3-3	4.5	3050	1.95
4-1	5.4	4200	2.69
4-2	4.8	2950	1.89
4-3	4.4	3950	2.53
NI 0-30	4.9	6700	4.29
NI 30-50	6.4	2225	1.42

IV. Discussion

The results of the soil particle size analysis indicate that all the man-made islands (I 1 - I 4) were very similar in both coarse fragment content and soil texture. In comparison with Nunns Island the particle size distribution of the lower soil material (NI 30-50) was found to be very similar to that of man-made islands. The upper soil on Nunns Island (NI 0-30) consisted of a much finer sandy-silty material with no coarse fragments. This material has resulted from the deposition of sediment and its entrapment by the natural vegetation. A considerable amount of organic matter was also present in this upper soil, however, its percent content has not been determined. The deposition of a similar fine textured material is expected to occur on the man-made islands. Its build-up will likely depend upon depositional and erosional process which affect the islands, as well as the establishment of the vegetation.

The results of pH measurements for the man-made islands showed an average pH of 4.8 with a range of 3.9 to 5.8. The within island variation of the 3 samples collected per island was less than 1.0 of 2 pH unit. Island #1 had the lowest average pH of 4.1 while Island #2 had the highest average pH of 5.3. The upper soil on Nunns Island (NI 0-30) had the highest pH of 6.4 while the lower soil (NI 30-50) had a pH of 4.4.

Soil conductivity is a measure of soluble salts. As mentioned earlier it will vary with water content, in particular with estuarine soils as the proportion of fresh water to salt water changes. Plants growing in these soils will therefore experience a wide range of salt concentrations. Since these soils were sampled at low tide, the concentration of salts in the soil will be lower than if measured when the soils are fully saturated. As the tide recedes, the fresh water which lies on the surface of salt water will be the last water that drains through the soil. This action will dilute the soluble salt concentrations within the soil.

IV. Discussion (Contd...)

The conductivity measured for the man-made islands averaged 3200 µmhos/cm with a range of 1700 to 4700 µ mhos/cm. Islands #3 and 4 had the highest average conductivity of 3792 and 3750 µmhos/cm. respectively. The lowest average conductivity measured was on Island #2 which was 1983 µmhos/cm.

In comparing conductivities of Nunns Island to the man-made islands, it was found that the upper soil on Nunns Island (NI 0-30) was higher while the lower soil (NI 30-50) was generally lower. The higher conductivity measured for NI 0-30 is likely the result of its organic matter content and fine texture.

The conductivities for all soils measured would likely increase as the soils become saturated with salt water during a high tide. Conductivities taken from water quality samples in the estuary measured up to 30,000 µmhos/cm.

V. Recommendations for Further Study

1. The determination of erosional and/or depositional patterns will play an important part in soil development on the islands. Therefore, it is recommended that cross-sectional profiles be done on an annual basis.

2. If deposition or erosion is occurring, the particle size of this material should be determined.

3. Nutrients measured in the soil will vary with water content at the time of sampling. A more meaningful measurement of nutrient status for the site may be determined by foliar analysis of the vegetation. The decision to determine nutrient levels either in the soils or vegetation should be based on clearly defined objectives.

APPENDIX I

pH AND CONDUCTIVITY MEASUREMENTS OF SOIL

NOTE:

this procedure is for determining both pH and conductivity from the same soil-water extract. A much simpler method can be used for determining pH alone (see pH of Soil procedure).

REAGENTS:

1. distilled water (demineralized water).

EQUIPMENT:

1. 300-600 ml beakers.
2. Filtration apparatus (aspirator, flask, funnel, graduated cylinder, etc.).
3. Whatman No. 1 filter paper to fit funnel.
4. pH meter.
5. Conductivity meter.

PROCEDURE:

1. weigh out approximate sample size of soil (300-500 g).
2. place in beaker and add distilled water to make a saturated soil paste.
3. let sit for 1 hour.
4. place in funnel with filter paper and suction off extract in graduated cylinder placed in bottom of flask.
5. transfer to sample bottles for pH and conductivity readings from meter. (Rinse funnel and cylinder and replace filter paper between samples).

Appendix X

Campbell River Estuary - water quality studies

AN INTERIM REPORT ON WATER QUALITY MONITORING OF BRITISH COLUMBIA FOREST PRODUCTS LTD. BOOMING AREA ADJACENT TO THE CAMPBELL RIVER ESTUARY

Robert P. Willington
Resource Planning Group

British Columbia Forest Products Limited initiated a water quality monitoring program in its booming area adjacent to the Campbell River Estuary on July 5, 1982 according to the outlined procedure provided by M.D. Nassichuk, Chief, Water Quality Unit Habitat Management Division of the Federal Department of Fisheries and Oceans in his memo of June 15th, 1982.

This report summarizes the results of this monitoring program to date in order to provide a basis for evaluating the disposition of any further water quality monitoring work to be conducted by B. C. Forest Products Ltd. in their Elk River Division booming ground adjacent to the Campbell River Estuary.

The Monitoring Program

The following outline of the monitoring program was provided by M.D. Nassichuk of D.F.O.:

1. The bottom contour (mid-channel) of the study area should be determined.

2. Three sub-areas within the dredged portion of the Study area and one location (control) outside the dredged area should be sampled.

3. Water column profiles of the following variables should be obtained at each location at high and low tide (some samples should also be collected with the culvert closed) once per month during late spring and summer beginning in 1982 prior to log storage:

   i) Dissolved oxygen
   ii) Temperature
   iii) Salinity
   iv) Suspended solids
   v) Organic carbon
   vi) Sulphides
   vii) wood extractives

4. Samples of bottom sediments should be obtained from each location and analyzed for:

   i) fibre content
   ii) organic carbon
   iii) in-site dissolved oxygen

5. Studies of benthic communities in one sub-area where maximum impacts are anticipated and in the control area should be conducted once/year.

6. Fish utilization of the study area over time should be monitored.

7. A photographic assessment of the study area (bottom) over time should be considered.

Further to this plan were some agreements worked out between Sally Leigh-Spencer (BCFP) and M.D. Nassichuk and Mike Brownlee of D.F.O. which included:

1. B.C. Forest Products Limited's major role in the program would be collecting samples and collecting data for those parameters amenable to field measurement.

2. D.F.O. would be responsible for water sample analysis of dissolved oxygen (as a check on field measurements), salinity, suspended solids, organic carbon, sulphides and, if possible, wood extractives.

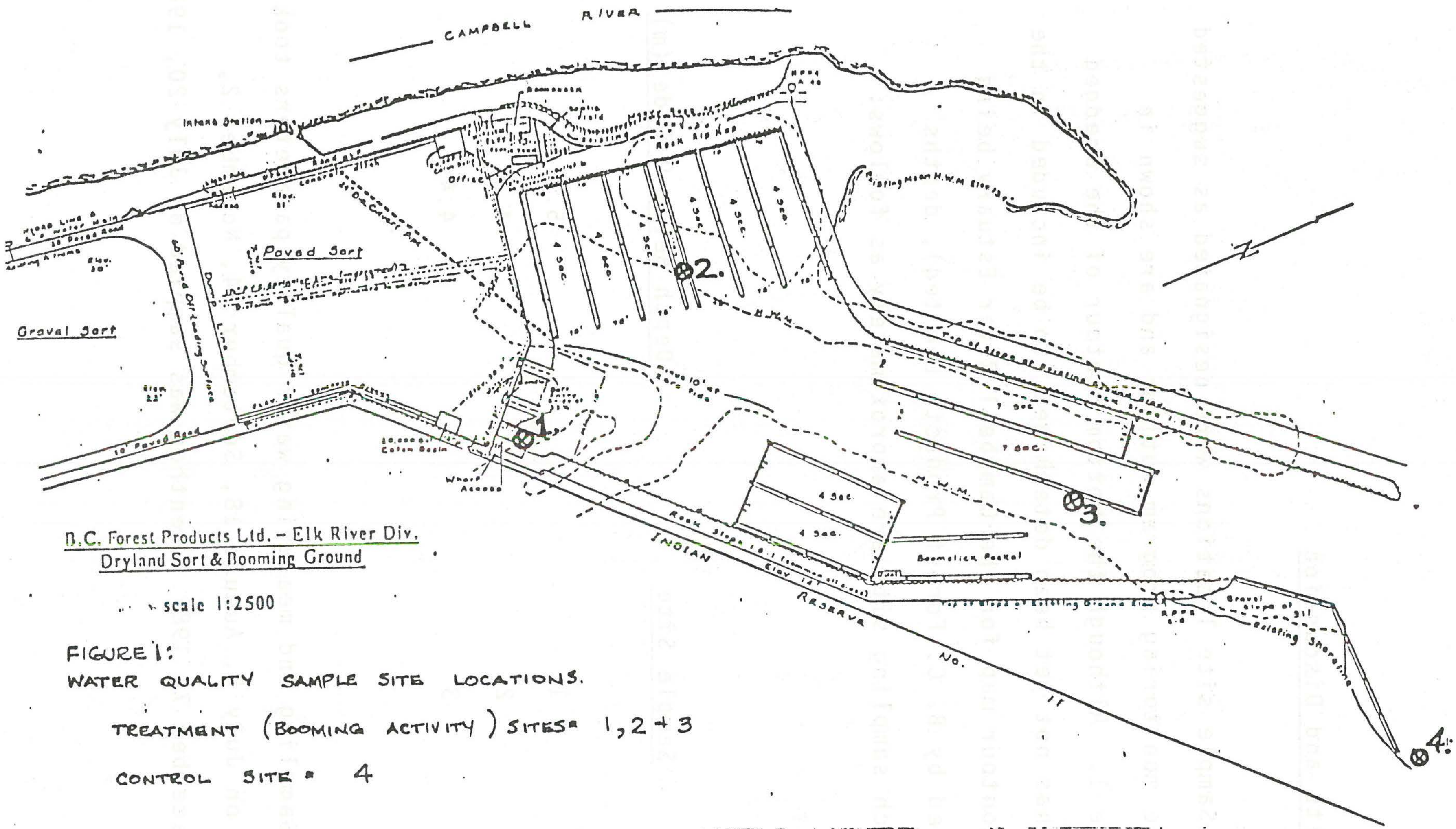
3. D.F.O. would be responsible for bottom sediment sample analysis of fibre content and organic carbon while BCFP would determine in-situ dissolved oxygen.

Results and Discussion

Sample site locations were designated as suggested in the monitoring program outline and are shown in Figure 1. Although the bottom contour of the dredged area has not yet been determined (to be included in the new contour map for the Campbell River Estuary being drafted by B. C. Forest Products Limited), depths at each sampling site are approximately as follows:

Sample Site	Depth Below 0 Tide (m)
1	5.7
2	4.5
3	4.4

Sampling and measuring water quality parameters took place on July 5, August 18, September 14, November 2, and December 7, 1982. Benthos was sampled on July 20, 1982.



B.C. Forest Products Ltd. – Elk River Div.
Dryland Sort & Booming Ground

scale 1:2500

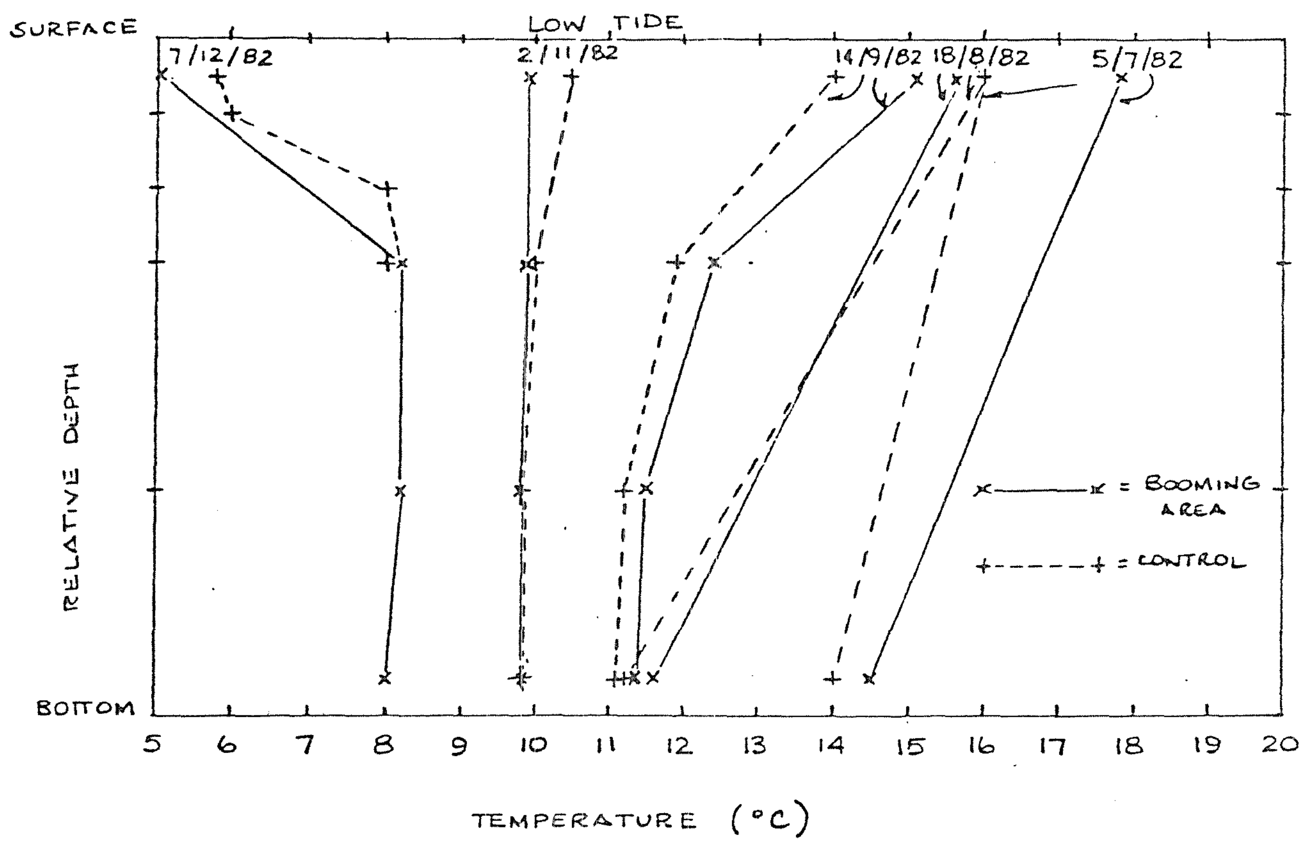
FIGURE 1:
WATER QUALITY SAMPLE SITE LOCATIONS.

TREATMENT (BOOMING ACTIVITY) SITES = 1, 2 + 3

CONTROL SITE = 4

Some of the collected data permits an evaluation of spatial and temporal variation of some aspects of water quality within the sampling period while other data serves as a benchmark of certain water quality parameters for comparison with subsequent years of data collection.

The temperature regime of the water column in the booming area and control varied over the sampling period and with depth (Figure 2). Tide difference appeared to have little significant effect on thermal water quality although some variation in surface water temperature was experienced, probably due to tidal redistribution of surface water the temperature of which was affected by air temperature regime. Figure 3 illustrates that little temperature variation existed between the control water column and the booming (average of Sites 1,2, and 3) area water column. Maximum variance existed in the surface layer which may be attributable to the input of Campbell River water by way of the diversion culvert (see discussion on salinity): warm river water input during the summer and cold river water input during late fall and early winter. Collected temperature data is presented in Appendix I.



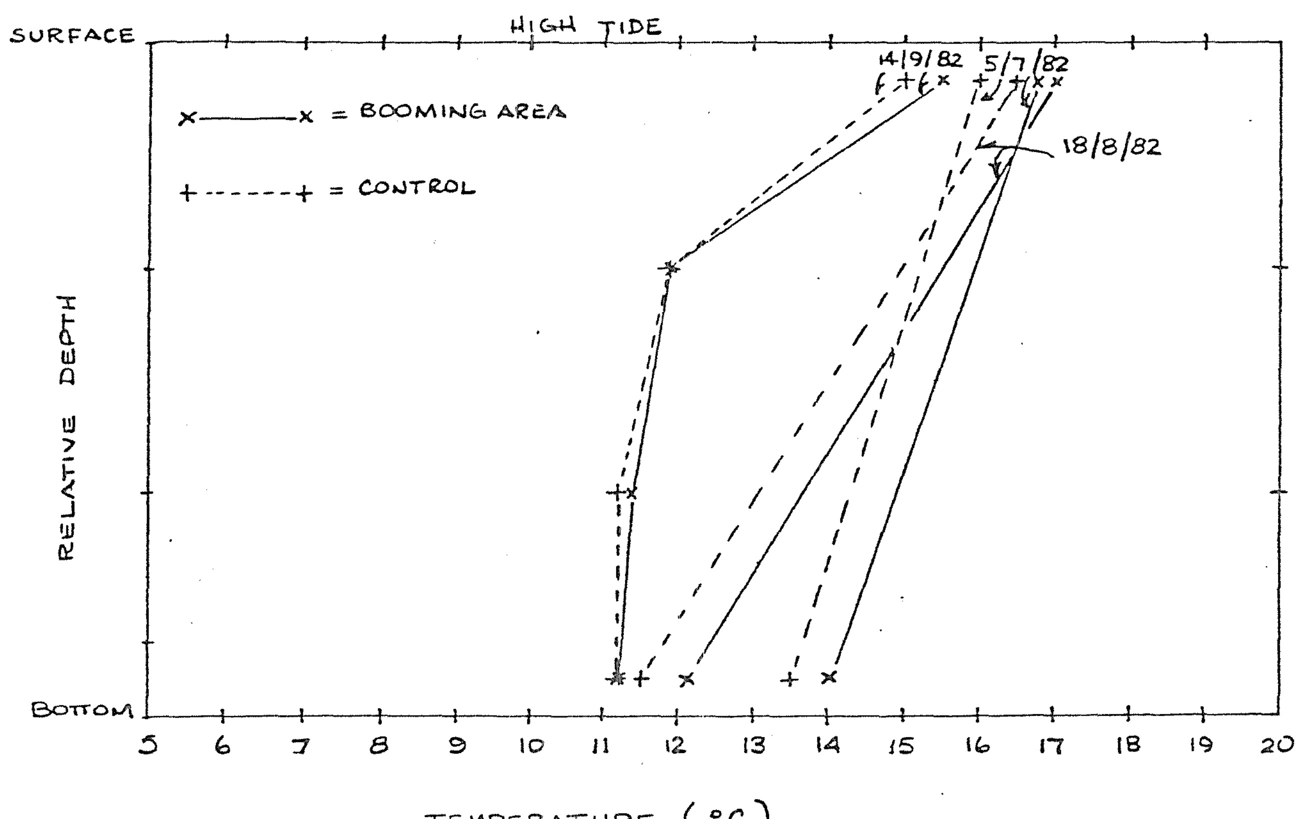


FIGURE 2: TEMPERATURE PROFILES BY DEPTH, TIME AND TIDE - ELK RIVER DIVISION BOOMING AREA - B.C.F.P. LTD.

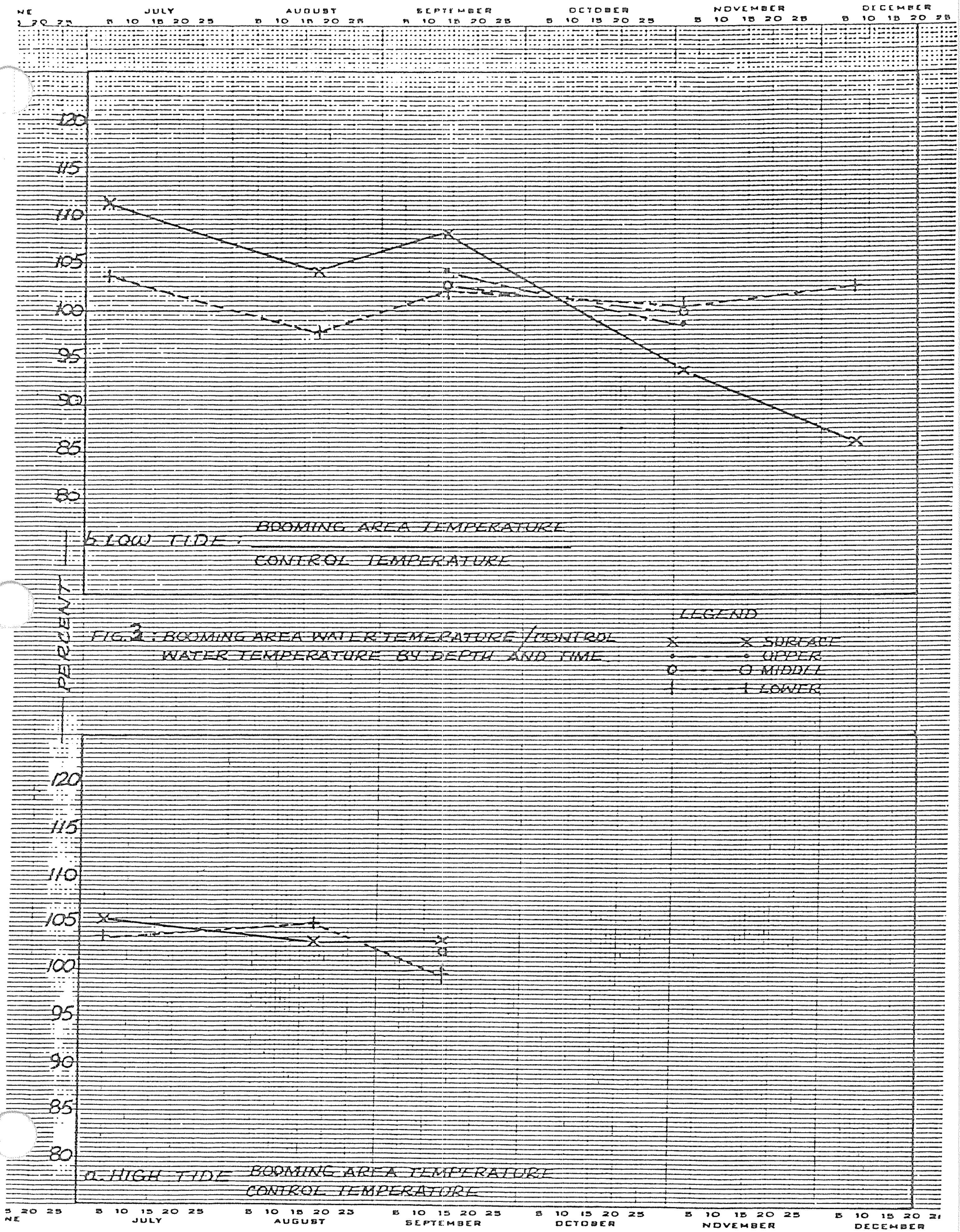


FIG. 3: BOOMING AREA WATER TEMPERATURE / CONTROL WATER TEMPERATURE BY DEPTH AND TIME

Water column salinity values (Appendix I) were derived from two sources. Those reported for the September 14, 1982 sampling were supplied by D.F.O. whereas the values for all other sampling dates were computed from measured conductivity using the following equation:

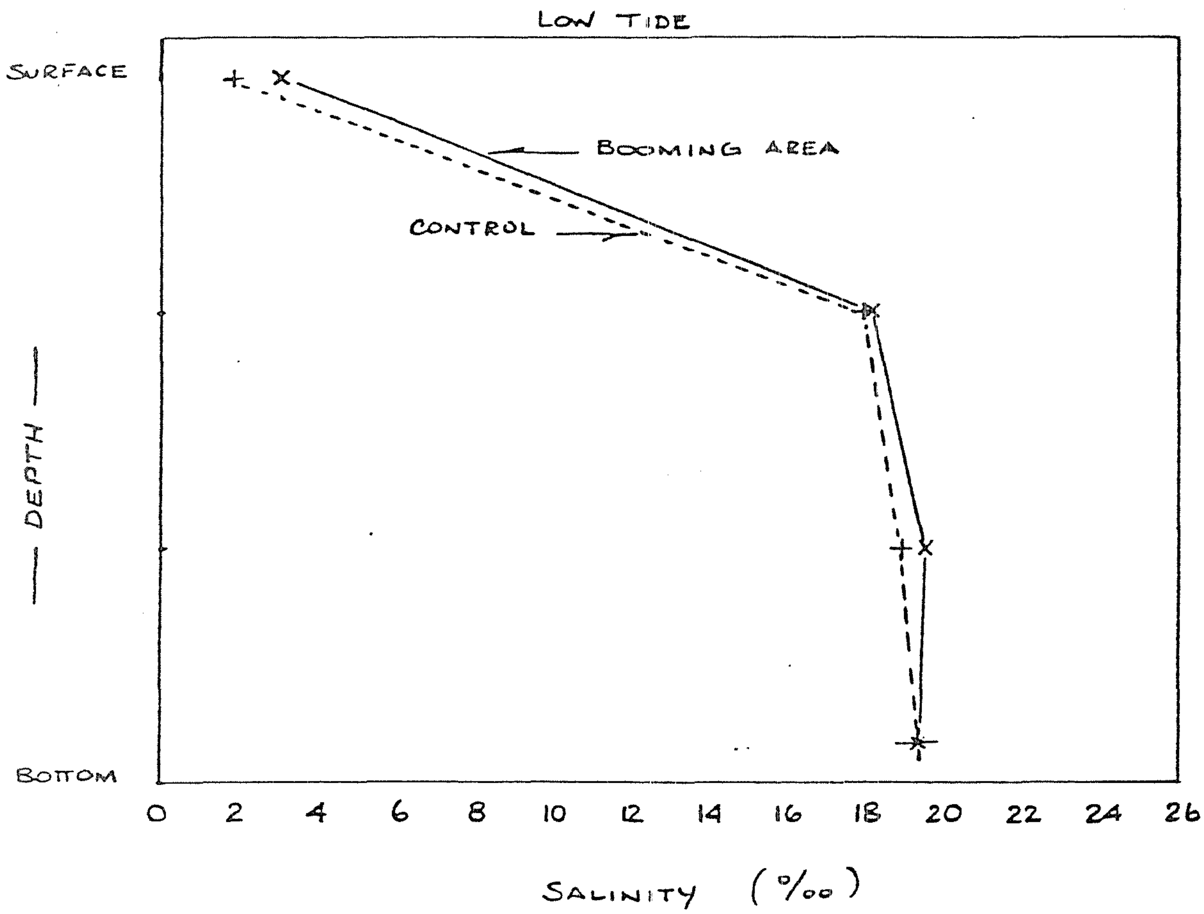
$$S = \frac{C \times 0.6}{1000}$$

where:

S = Salinity ($^{o}/_{oo}$)

C - Conductivity (uMhos/cm)

Figure 4 summarizes the salinity variation by depth for the booming area and control. The variation of salinity over time by depth is judged to be insignificent (see Appendix I). The most notable aspect of the salinity profiles in Figure 4 is the very low salinity of the surface waters. The rapid rate of vertical change from fresh surface water to saline subsurface waters indicates a low mixing rate with depth and a constant input



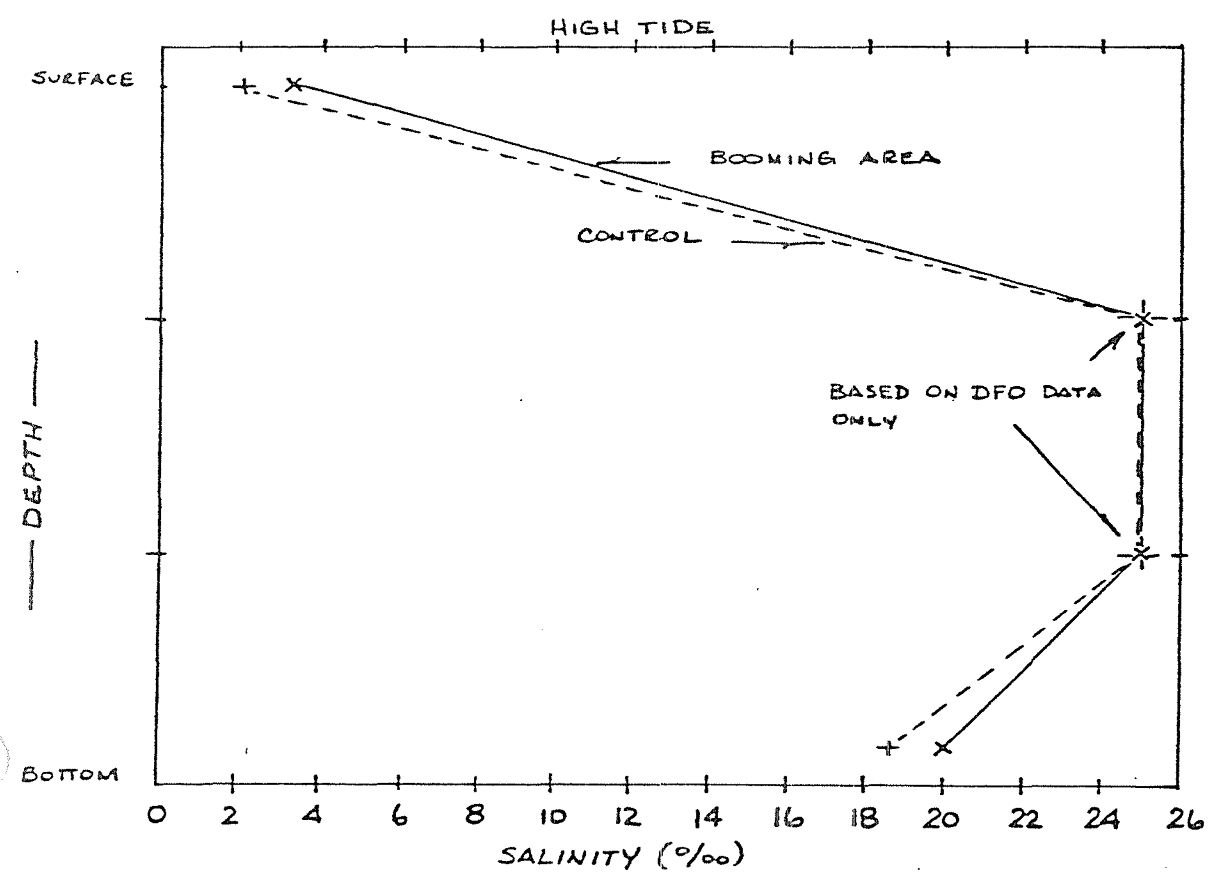


FIGURE 4: MEAN SALINITIES FOR BOOMING AREA AND CONTROL BY DEPTH AND TIDE – JULY 5 – DECEMBER 7, 1983.

of fresh water from the Campbell River. This fresh river water is introduced to the booming area by the diversion culvert (Figure I) and/or carried in by incoming tides although it is expected that the latter would yield a higher degree of vertical intermixing of fresh and saline waters than is indicated in Figure 4. It is interesting that surface water salinity does not vary significantly with tide, in view of the fact that the inflow of fresh Campbell River water through the diversion culvert only occurs at low tides (flow at high tides is minimal due to the reduction in hydraulic head). The effects of booming (propeller wash etc.) on vertical water mixing was not thoroughly investigated due to a low level of this activity during the monitoring period.

Saturated dissolved oxygen content varies with water temperature and salinity. Differences between the actual and predicted dissolved oxygen are , therefore, attributable to other characteristics of the water such as biological oxygen demand causing a reduction in dissolved oxygen from expected levels. Figures 5 and 6 summarize dissolved oxygen measurements, (Appendix I) corrected for salinity,

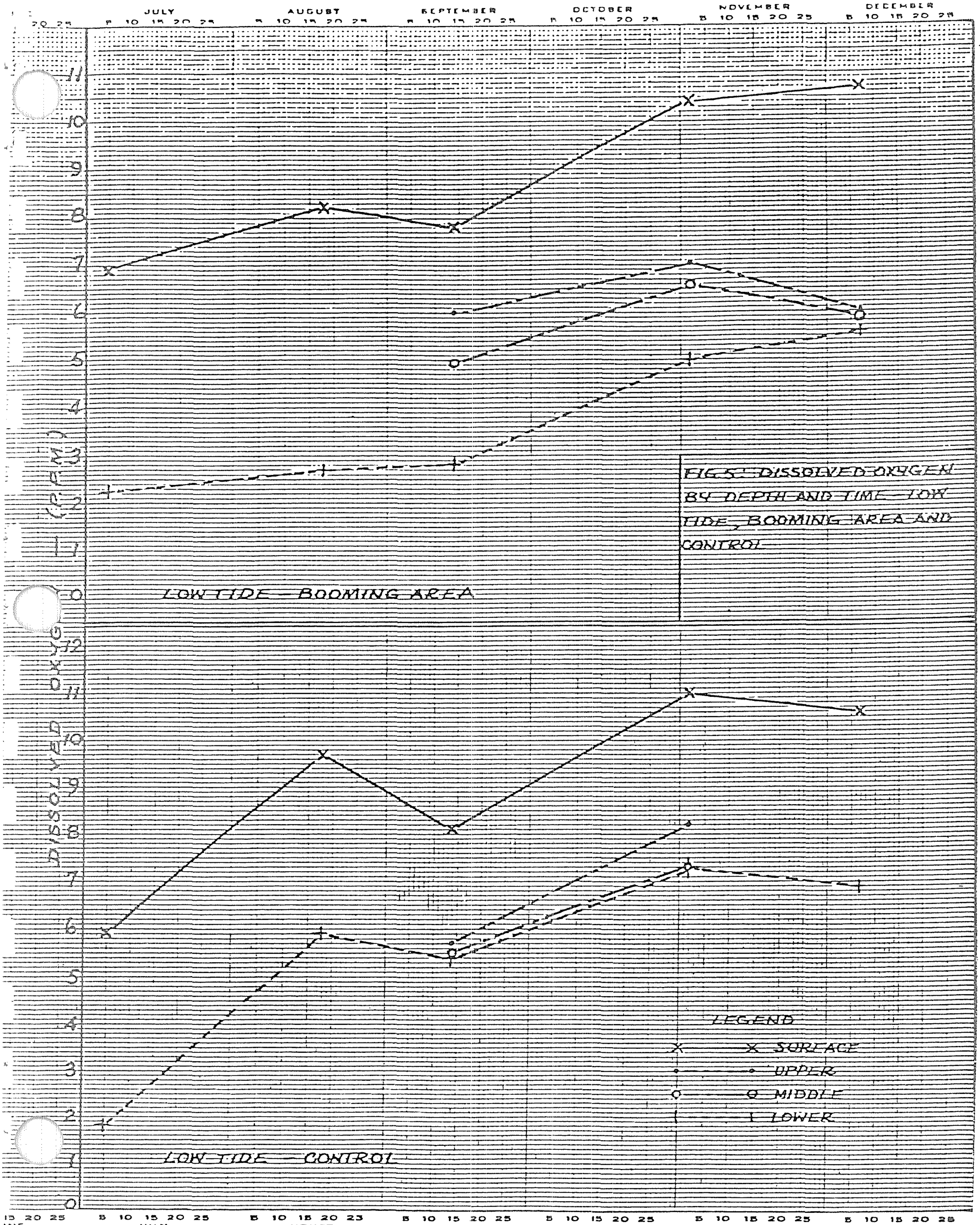


FIG. 5 DISSOLVED OXYGEN BY DEPTH AND TIME LOW TIDE, BOOMING AREA AND CONTROL

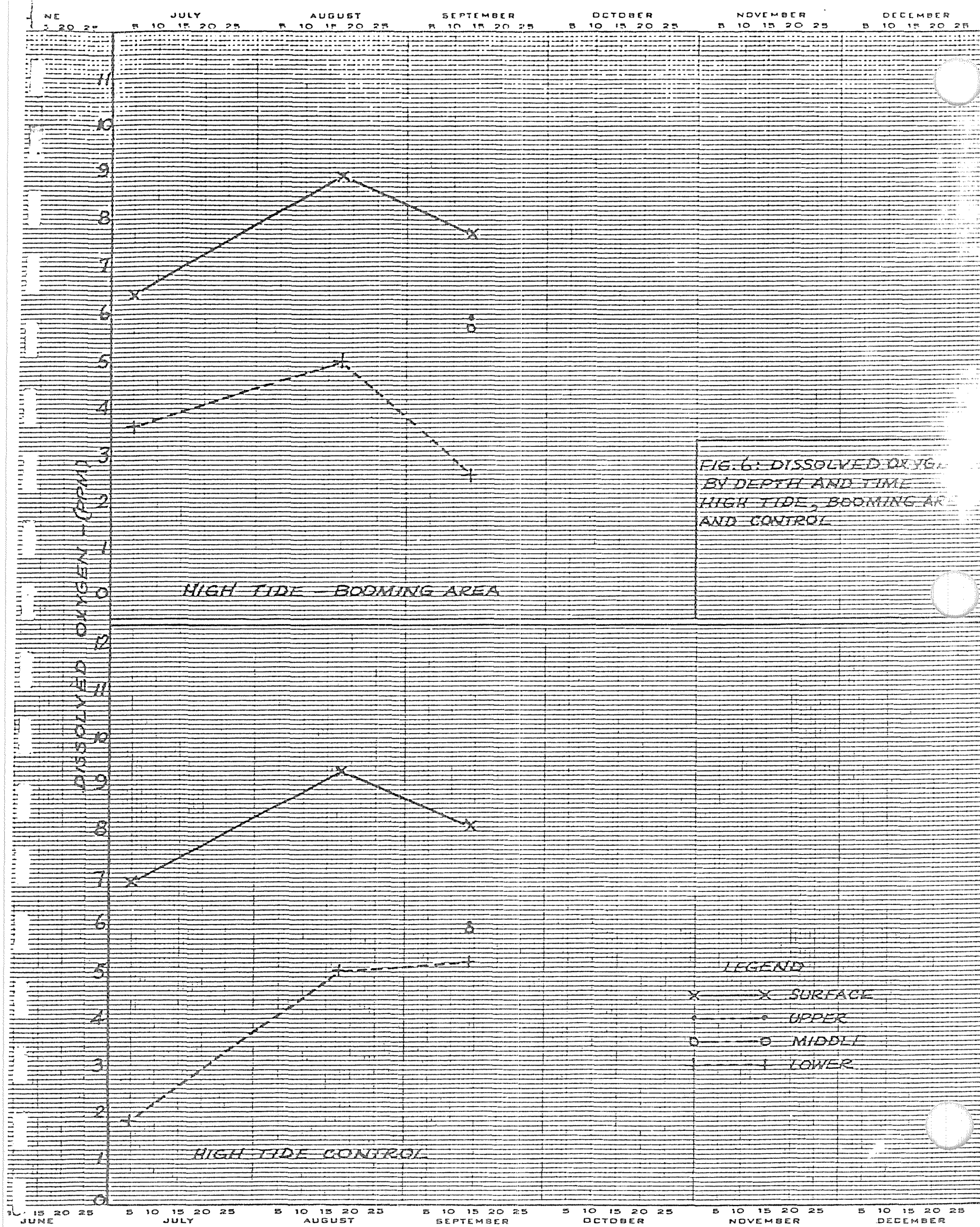


FIG. 6: DISSOLVED OXYG
BY DEPTH AND TIME
HIGH TIDE, BOOMING AR
AND CONTROL

conducted in the booming area and control. Corrections for salinity effects on measured dissolved oxygen were conducted using the following equation (from the Yellow Springs Instrument Company Instruction Manual - YS1 Models 54ARC and 54ABP Dissolved Oxygen Meters)

$$A = M \left[1.0 - \frac{(Cs/Co\ Sf - So)}{(Sf)} \right]$$

where:
A = Actual dissolved oxygen of sample (ppm)
M = Measured dissolved oxygen with instrument
Co = Salinity of ocean water (36.11 $^{o}/oo$)
Cs = Salinity of sample ($^{o}/oo$)
Sf = Dissolved oxygen of saturated fresh water at 760 mm pressure and at same temperature as sample (ppm).
So = Dissolved oxygen of saturated ocean water at 760 mm pressure and at same temperature as sample (ppm).

In general, trends in dissolved oxygen in both the booming area and control at high and low tide were a decrease with depth and an increase over time. The latter trend was largely due to falling water temperatures over time. The decrease of dissolved oxygen with depth is inadequately explained by the vertical water temperature over time and may be more a function of stagnation as is suggested by the salinity concentration over depth and the attendant interpretation of limited vertical water column mixing.

Figure 7 presents comparison of booming area dissolved oxygen levels with control dissolved oxygen by depth, time, and tide. At both tides at the surface, upper and middle depths over the sampling period, dissolved oxygen levels were similar for the booming area and control. At the bottom of the water column for both tides the dissolved oxygen in the booming areas was higher than the control on July 5, 1982, but by August 18, 1982, the trend had reversed and thereafter the dissolved oxygen in the booming area was lower than the control. This may reflect the construction - induced (suction dredging) oxygenation of the booming area which diminished over time through diffusion along the dissolved oxygen concentration gradient. The dissolved oxygen of

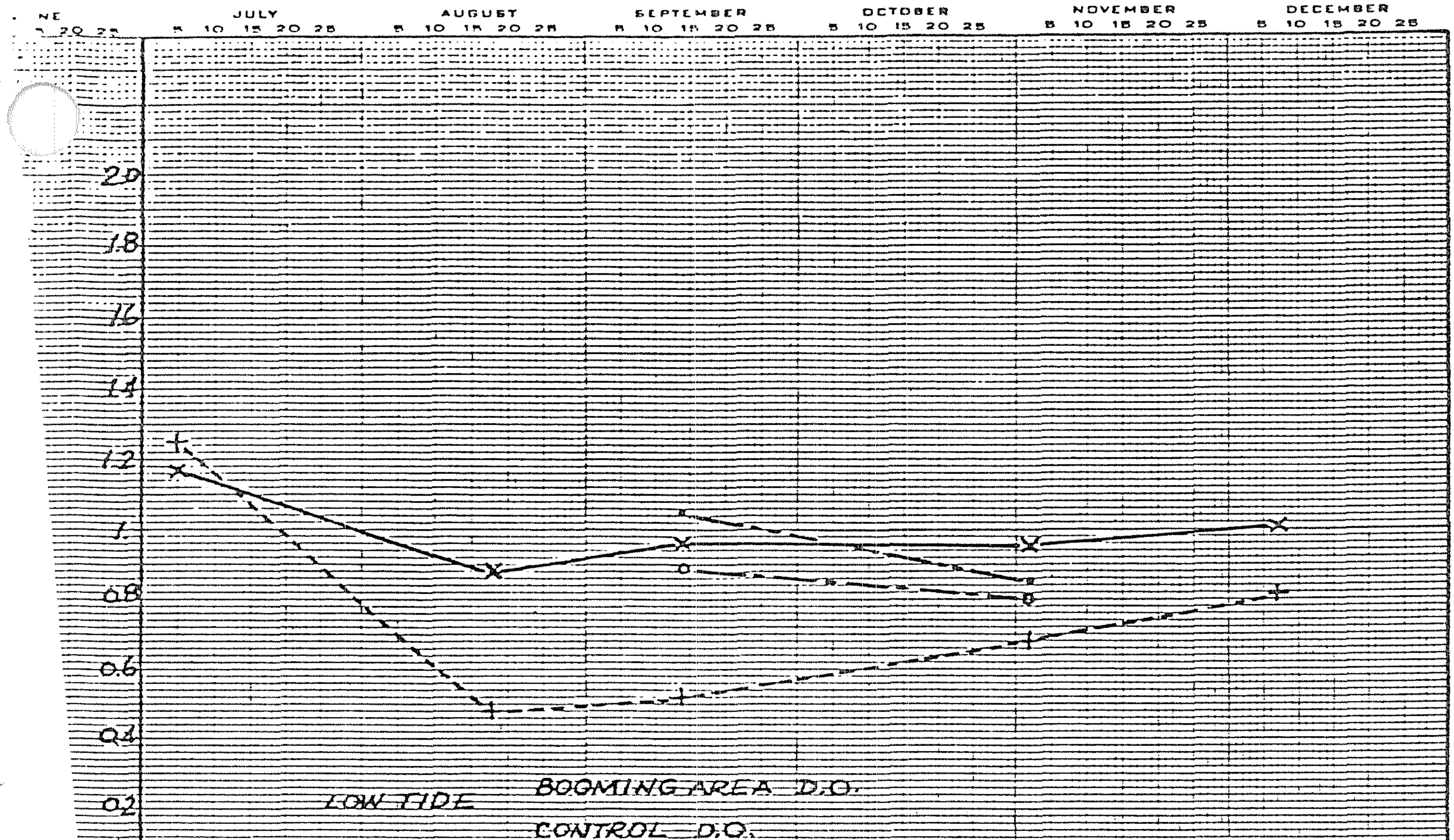
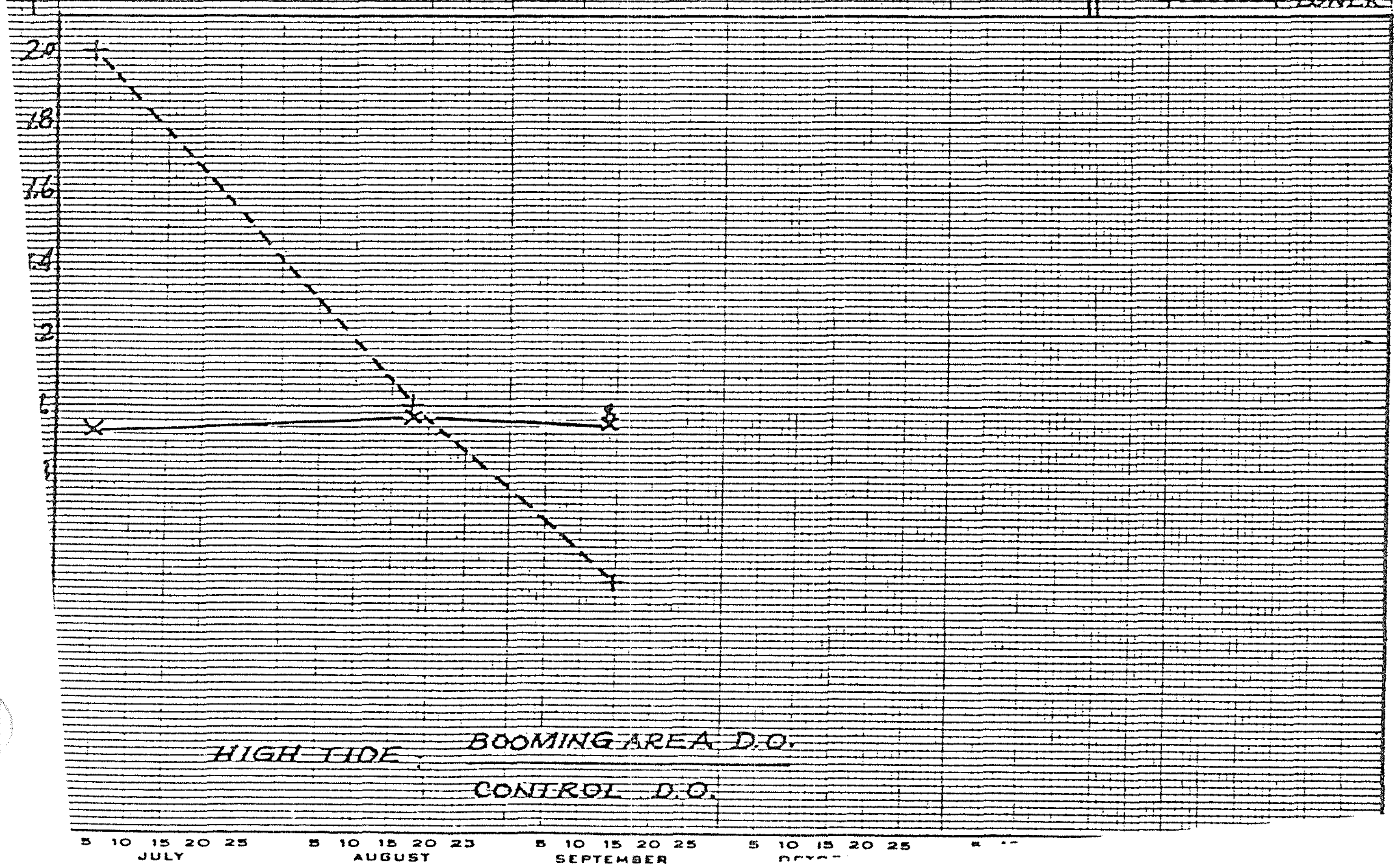


FIGURE 7: BOOMING AREA DISSOLVED OXYGEN / CONTROL DISSOLVED OXYGEN BY DEPTH, TIDE AND TIME

LEGEND
X——X SURFACE
•- - - -• UPPER
o——o MIDDLE
+- - - -+ LOWER



the bottom level in the booming area remained lower than the control area possibly as a result of the lower exchange rate with new ocean water. This low exchange rate is likely due to the location of the booming area relative to estuary salt water movements.

Subtidal benthos samples were sampled at each of the four sampling sites (Figure I) by SCUBA (Appendix II). Each sample was 0.3 m^3 and two samples were collected at each site and then amalgamated into one sample/site for analysis. Since the booming area benthos samples were subtidal and the benthos sampling in the islet environment of the estuary was intertidal, comparisons of benthos for the two areas are not possible.

Sample results indicate that the benthos at all four sites is not highly productive with respect to fish food value. Sites 1,2, and 3 had only two harpacticoids per site and the control (Site 4) sample contained only fourteen harpacticoids. The Site 1 sample was the lowest in total organisms including Oligochaeta, Polychaeta, and Nematoda, while the Site 1,2, and 3 samples contained relatively similar numbers of both Nematoda and Polychaeta. The Site 4 sample had the highest number of Nematoda.

Additional water quality analyses were conducted by the Federal Laboratory Service (EPS-FMS) (Appendix III). Analysis for sulphide indicated less than 0.05 ppm for all depths and tides in the booming area and control. The same similarity existed for colour with all samples having a value of 5. The results of the analyses of non-filterable residues indicates minimal variance between sites and depths at both low and high tides with the exception of bottom samples at high tide for Sites 2 and 4 which had values of 8 and 57 ppm respectively as compared with all other samples which had 5 ppm.

Summary and Recommendations

The objective of the 1982 booming area water quality and benthos monitoring program was to establish bench mark values of water quality and benthos against which subsequent data can be compared.

The degree to which the results meet this objective appears acceptable, but the final assessment needs to be conducted by the author of the program outline, Mr. M.D. Nassichuk, Department of Fisheries and Oceans.

RPW:rm
01/27/83

APPENDIX I

Temperature, Salinity, Measured and Corrected Dissolved oxygen data for all sampling dates.

CAMPBELL RIVER ESTUARY – ELK RIVER DIVISION BOOMING AREA.

TEMPERATURE AND DISSOLVED OXYGEN – JULY 5 /82

SAMPLE #	TEMP °C	MEAS. D.O. (M) P.P.M.	SALINITY ‰ (Cs)	Cs/Co	D.O FRESH H_2O (Sf) PPM	D.O SALT H_2O (So) PPM	Sf-So	D.O. CORR PPM (A)	% SAT.	DEPTH m	% SAT AS % OF CONTROL
LOWTIDE											
1	19.0	7.0	1.2	.03	9.3	7.5	1.8	6.9	75	.1	117
1	14.5	2.0	14.7	.41	10.3	8.2	2.1	1.8	19	7.6	100
2	18.5	7.0	1.2	.03	9.4	7.6	1.8	6.9	75	.1	117
2	15.0	3.0	15.0	.42	10.2	8.1	2.1	2.7	29	6.4	150
3	16.0	6.0	–	–	9.9	8.0	1.9		–	.1	
3	14.0	4.0	–	–	10.4	8.3	2.1		–	5.8	
4	16.0	6.0	.3	.1	9.9	8.0	1.9	5.9	61	.1	100
4	14.0	2.0	14.7	.41	10.4	8.3	2.1	1.8	19	7.6	100
HIGHTIDE											
1	17.5	6.0	–	–	9.6	7.8	1.8		–	.1	
1	14.0	1.0	–	–	10.4	8.3	2.1		–	8.8	
2	17.0	7.0	1.5	.04	9.7	7.8	1.9	6.9	72	0.1	100
2	14.0	4.0	18.3	.51	10.4	8.3	2.1	3.6	39	6.4	200
3	16.0	6.0	1.2	.03	9.9	8.0	1.9	5.9	60	.1	86
3	14.0	1.0	–	–	10.4	8.3	2.1	–	–	7.9	
4	16.0	7.0	1.8	.05	9.9	8.0	1.9	6.9	70	0.1	100
4	13.5	2.0	16.5	.46	10.5	8.4	2.1	1.8	19	7.9	100

CAMPBELL RIVER ESTUARY – ELK RIVER DIVISION BOOMING AREA.

TEMPERATURE AND DISSOLVED OXYGEN – AUGUST 18/82

SAMPLE #	TEMP °C	MEAS. D.O. (M) P.P.M.	SALINITY ‰ (C_s)	C_s/C_o	D.O FRESH H_2O (S_f) PPM	D.O SALT H_2O (S_o) PPM	$S_f - S_o$	D.O. CORR PPM (A)	% SAT.	DEPTH m	% SAT AS % OF CONTROL
LOW TIDE											
1	15.0	8.1	–		10.2	8.1	2.1	–	–	.1	
1	11.2	4.5	–		11.1	8.8	2.3	–	–	6.1	
2	15.0	8.3	5.1	.14	10.2	8.1	2.1	8.1	82	.1	84
2	11.8	3.1	18.9	.52	10.8	8.7	2.1	2.8	29	5.2	47
3	17.0	8.6	5.4	.15	9.7	7.8	1.9	8.3	88	.1	86
3	12.0	3.2	18.9	.52	10.8	8.6	2.2	2.5	26	5.5	42
4	16.0	9.8	1.2	.03	9.9	8.0	1.9	9.7	99	.1	100
4	11.2	6.5	18.0	.50	11.1	8.8	2.3	5.9	59	6.1	100
HIGH TIDE											
1	17.8	9.8	–	–	9.5	7.7	1.8	–	–	0.1	
1	12.1	4.2	–	–	10.8	8.6	2.2	–	–	7.3	
2	17.0	9.0	5.1	0.14	9.7	7.8	1.9	8.7	92	0.1	94
2	12.1	5.4	15.6	0.43	10.8	8.6	2.2	4.9	50	6.7	98
3	16.2	9.3	4.2	0.12	9.9	8.0	1.9	9.1	94	0.1	98
3	12.0	5.7	14.7	0.41	10.8	8.6	2.2	5.2	53	7.6	104
4	16.5	9.5	3.6	0.10	9.8	7.9	1.9	9.3	97	0.1	100
4	11.5	5.4	14.4	0.40	10.9	8.7	2.2	5.0	50	7.0	100

CAMPBELL RIVER ESTUARY – ELK RIVER DIVISION BOOMING AREA.
TEMPERATURE AND DISSOLVED OXYGEN – SEPT. 14/82

	SAMPLE #	TEMP °C	MEAS. D.O. (M) P.P.M.	SALINITY ‰ (Cs)	Cs/Co	D.O FRESH H_2O (Sf) PPM	D.O SALT H_2O (So) PPM	Sf-So	D.O. CORR. PPM (A)	% SAT.	DEPTH m	% SAT AS % OF CONTROL
	LOW TIDE											
	1	16.0	8.1	5	.11	9.9	8.0	1.9	7.9 (8.7)	82	0.1	103
	1	12.2	6.7	25	0.69	10.8	8.6	2.2	5.8 (3.4)	63	2.0	103
	1	11.1	4.7	25	0.69	11.1	8.8	2.3	4.0 (4.1)	42	4.0	72
	1	11.0	3.7	25	0.69	11.1	8.8	2.3	3.2 (4.0)	34	6.0	60
	2	15.0	8.4	5	0.14	10.2	8.1	2.1	8.1 (7.9)	82	0.1	103
	2	13.0	7.0	25	0.69	10.6	8.4	2.2	6.0 (4.0)	66	2.0	108
	2	11.9	6.5	22	0.61	10.8	8.6	2.2	5.7 (3.3)	60	4.0	103
	2	11.5	2.0	25	0.69	11.0	8.7	2.3	1.7 (2.7)	18	6.0	32
	3	14.5	7.5	5	0.14	10.3	8.2	2.1	7.3 (7.7)	73	0.1	91
	3	12.0	7.1	25	0.69	10.8	8.6	2.2	6.1 (3.1)	66	2.0	108
	3	11.5	5.9	25	0.69	11.0	8.7	2.3	5.1 (3.3)	54	4.0	93
	3	11.5	4.0	25	0.69	11.0	8.7	2.3	3.4 (2.5)	36	6.0	63
CONTROL	4	14.0	8.3	4	0.11	10.4	8.3	2.1	8.1 (9.8)	80	0.1	100
CONTROL	4	11.9	6.6	23	0.64	10.8	8.6	2.2	5.7 (3.6)	61	3.0	100
CONTROL	4	11.2	6.4	25	0.69	11.1	8.8	2.3	5.5 (3.7)	58	5.0	100
CONTROL	4	11.1	6.3	25	0.69	11.1	8.8	2.3	5.4 (4.2)	57	7.0	100

CAMPBELL RIVER ESTUARY – ELK RIVER DIVISION BOOMING AREA.

TEMPERATURE AND DISSOLVED OXYGEN – SEPT. 14/82

SAMPLE #	TEMP °C	MEAS. D.O. (M) P.P.M.	SALINITY ‰ (Cs)	Cs/Co	D.O FRESH H_2O (Sf) PPM	D.O SALT H_2O (So) PPM	Sf-So	D.O. CORR. PPM (A)	% SAT.	DEPTH m	% SAT AS % OF CONTROL
HIGH TIDE											
1	16.2	8.1	4	0.11	9.9	8.0	1.9	7.9 (7.7)	82	0.1	101
1	12.0	6.8	25	0.69	10.8	8.6	2.2	5.8 (3.6)	62	3.0	95
1	12.0	6.8	25	0.69	10.8	8.6	2.2	5.8 (3.3)	62	5.0	100
1	11.2	2.5	25	0.69	11.1	8.8	2.3	2.2 (2.4)	23	8.0	42
2	15.2	7.6	4	0.11	10.2	8.1	2.1	7.5 (9.3)	75	0.1	93
2	11.8	6.9	25	0.69	10.9	8.6	2.3	5.7 (4.9)	62	3.0	95
2	11.2	6.6	25	0.69	11.1	8.8	2.3	5.7 (2.7)	60	5.0	97
2	11.2	1.3	22	0.61	11.1	8.8	2.3	1.1 (3.3)	12	8.0	22
3	15.0	7.8	3	0.08	10.2	8.1	2.1	7.6 (8.6)	76	0.1	94
3	11.9	7.2	25	0.69	10.8	8.6	2.2	6.2 (2.8)	60	3.0	92
3	11.1	6.5	25	0.69	11.1	8.8	2.3	5.6 (2.8)	59	6.0	95
3	11.1	5.2	25	0.69	11.1	8.8	2.3	4.5 (3.1)	47	9.0	85
CONTROL 4	15.0	8.3	3	0.08	10.2	8.1	2.1	8.1 (8.7)	81	0.1	100
CONTROL 4	11.9	7.0	25	0.69	10.8	8.6	2.2	6.0 (3.3)	65	3.0	100
CONTROL 4	11.2	6.9	25	0.69	11.1	8.8	2.3	5.9 (3.0)	62	6.0	100
CONTROL 4	11.2	6.1	25	0.69	11.1	8.8	2.3	5.2 (2.4)	55	10.0	100

CAMPBELL RIVER ESTUARY – ELK RIVER DIVISION BOOMING AREA

TEMPERATURE AND DISSOLVED OXYGEN — NOV. 2/82

	SAMPLE #	TEMP °C	MEAS. D.O. (M) PPM	SALINITY ‰ (Cs)	Cs/Co	D.O FRESH H_2O (Sf) PPM	D.O. SALT H_2O (So) PPM	Sf-So	D.O. CORR. P.P.M. (A)	% SAT.	DEPTH m.	%SAT AS % OF CONT.
	LOW TIDE											
	1A	9.8	10.6	1.5	0.04	11.4	9.1	2.3	10.5	93	0.1	94
	1B	9.8	7.2	7.5	0.21	11.4	9.1	2.3	6.9	63	2.0	79
	1C	9.8	6.2	14.1	0.39	11.4	9.1	2.3	6.0	57	3.0	76
	1D	9.8	5.6	17.4	0.48	11.4	9.1	2.3	5.0	49	4.0	70
	2A	9.8	10.4	1.5	0.04	11.4	9.1	2.3	10.3	91	0.1	92
	2B	9.8	7.1	12.9	0.36	11.4	9.1	2.3	6.6	62	2.0	78
	2C	9.8	7.2	18.0	0.50	11.4	9.1	2.3	6.5	63	4.0	90
	2D	9.9	3.8	18.0	0.50	11.3	9.0	2.3	3.4	34	7.0	47
	3A	10.0	10.6	1.2	0.03	11.3	9.0	2.3	10.5	94	0.1	95
	3B	10.0	8.4	16.2	0.45	11.3	9.0	2.3	7.6	74	2.0	93
	3C	9.8	8.0	15.1	0.42	11.4	9.1	2.3	7.3	70	4.0	100
	3D	9.8	7.4	18.6	0.59	11.4	9.1	2.3	6.5	65	6.5	90
	4A	10.5	11.1	1.0	0.03	11.2	8.9	2.3	11.0	99	0.1	100
CONTROL	4B	10.0	9.0	15.6	0.43	11.3	9.0	2.3	8.2	80	2.0	100
	4C	9.8	8.0	16.2	0.45	11.4	9.1	2.3	7.3	70	4.0	100
	4D	9.8	8.2	19.5	0.54	11.4	9.1	2.3	7.3	72	6.0	100
	5A	9.9	9.3	–	–	11.3					0.1	
	5B	9.8	6.8	–	–	11.4					2.0	
	5C	9.8	5.8	–	–	11.4					4.0	
	5D	9.8	4.8	–	–	11.4					7.0	

CAMPBELL RIVER ESTUARY – ELK RIVER DIVISION BOOMING AREA.

TEMPERATURE AND DISSOLVED OXYGEN – DEC 7/82

SAMPLE #	TEMP °C	MEAS. D.O. (M) P.P.M.	SALINITY ‰ (Cs)	Cs/Co	D.O FRESH H_2O (Sf) PPM	D.O SALT H_2O (So) PPM	Sf-So	D.O. CORR. PPM (A)	% SAT.	DEPTH m	% SAT AS % OF CONTROL
1	5.0	10.7	0.9	0.02	12.8	10.1	2.7	10.7	84	0.1	101
1	8.2	6.6	15.3	0.42	12.3	9.7	2.6	6.0	56	4.0	87
1	8.2	6.6	16.8	0.47	12.3	9.7	2.6	5.9	53	6.0	
1	8.0	6.2	15.9	0.44	12.5	9.8	2.7	5.6	50	8.5	
SPIT	5.8	10.7	1.8	0.05	12.8	10.1	2.7	10.6	84	0.1	100
SPIT	6.0	11.1	1.4	0.04	12.5	9.8	2.7	11.1	90	1.0	100
SPIT	8.0	8.2	15.3	0.42	11.9	9.4	2.5	7.5	69	2.0	100
SPIT	8.0	7.6	15.6	0.43	11.9	9.4	2.5	6.9	64	3.0	100

APPENDIX II

Summary of benthos analysis - booming area and control.

Campbell River Estuary -- Results of analysis of subtidal macrofauna samples from the dry land sort log storage area, number of organisms per sample.

Taxa	I	II	III	IV
Nematoda	2	19	25	284
Pelecypoda				1
Oligochaeta				16
Polychaeta (unident.)	1	1		
Ampharete sp.			1	
Ampharetidae (unident.)			3	22
Aphroditoidea (unident.)		2		
Armandia brevis			2	5
Capitella capitata	47	147	128	9
Chaetozone setosa (?)				4
Cirratulidae (unident.)			1	
Cirratulus spectabilis (?)				10
Cossura sp.			1	5
Eteone longa	1			
Glycinde sp.			1	2
Harmothoe imbricata (?)			5	
Leitoscoloplos pugettensis (?)				1
Nereidae (unident.)			1	
Orbiniidae (unident.)			1	
Pholoe minuta	2		1	1
Prionospio (?) sp.				3
Syllidae (unident.)			3	9
Syllis (?) sp.				1
Terebellidae (unident.)			1	1
Harpacticoida		2	2	12
Gnorimosphaeroma oregonensis	2			
Corophium spinicorne				1
Eogammarus confervicolus				1
Hymenoptera adult		1		

APPENDIX III

Data from analysis of September 14th, 1983 samples - sulphide, colour, salinity, dissolved oxygen and non-filterable residue.

KEY TO APPENDIX DATA SHEETS

Site	Depth	Sample No.	Site	Depth	Sample No.
1	0.1 m	5	1	0.1 m	1
1	3 m	6	1	2 m	2
1	5 m	7	1	4 m	3
1	8 m	8	1	6 m	4
2	0.1 m	13	2	0.1 m	9
2	3 m	14	2	2 m	10
2	5 m	15	2	4 m	11
2	8 m	16	2	6 m	12
3	0.1 m	21	3	0.1 m	17
3	3 m	22	3	2 m	18
3	6 m	23	3	4 m	19
3	9 m	24	3	6 m	20
4	0.1 m	29	4	0.1 m	25
4	3 m	30	4	3 m	26
4	6 m	31	4	5 m	27
4	10 m	32	4	7 m	28

LABORATORY SERVICES (LPS-EMS)
CHEMISTRY

- ☐ Fresh Water
- ☒ Marine Water
- ☐ Effluent
- ☐ Sediment
- ☐ Biota
- ☐ Other

Location: Campbell River Estuary
Date Sampled: 8209.14
Sampled By: B.C.F.P.
Submitted By:
Send Report To: M. Nassichuk
Collator: 2820-648

Coordinator:
Quality Control ☐
Lab Number: 820871
Date Received: 8209.15

SAM. # (1, 2, 3 . . .)	I.D. & PRESERVATION (IF NECESSARY)	ANALYSIS REQUESTED	NUMBER OF BOTTLES
1-32		S=	32
		Resin Acid *	32
		DO	32
		NFR, S°/oo, Color	32

Return Equipment To: / Hold For:

Please return coolers

Phone

Checked By:
Date:

Remarks

*Hold Resin Acids-going to get sample from an active site to see if resin acids are there.

LABORATORY SERVICES (EPS-FMS)
CHEMISTRY

UNITS (Except Where Noted)	
☐ Fresh Water	mg/l
☐ Marine Water	mg/l
☐ Effluent	mg/l
☐ Sediment	mg/kg

Lab Number 820871

Date Received 82-09-15

Location CAMPBELL RIVER ESTUARY

✓	CONSTITUENTS	1	2	3	4	5	6	7	8	9	10	DATE	IN
	pH (080)												
	P. Alk. as $CaCO_3$ (006)												
	T. Alk. as $CaCO_3$ (006)												
	Sulfate (SO_4) (122)												
	Chloride (Cl) (024)												
	Fluoride (F) (050)												
	Ortho PO_4(P) (082)												
	Total PO_4(P) (086)												
	Nitrite (N) (072)												
	Nitrate (N) (072)												
	Nitrite + Nitrate (N) (072)												
	Ammonia (N) (058)												
	Silica (Si) (118)												
✓	Sulfide (S) (128)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	8209.21	RL
	Chlorophyll a (650)												
	Phaeopigments (650)												
✓	Color - Units (042)	5	5	5	5	5	5	5	5	5	5	8209.16	RL
	Turbidity - FTU (130)												
✓	Salinity - ‰ (114)	5	25	25	25	4	25	25	25	5	25	8209.16	RL
	Cond. - μmhos/cm (044)												
	Dil. Cond. μmhos/cm												
	Sam. Vol. - mls.												
	DI Vol. - mls.												
	DI Cond. - μmhos/cm												

REMARKS

1 — 32.

LABORATORY SERVICES (EPS-FMS)
CHEMISTRY

UNITS (Except Where Noted)

- ☐ Fresh Water — mg/l
- ☐ Marine Water — mg/l
- ☐ Effluent — mg/l
- ☐ Sediment — mg/kg

Lab Number: 820871
Date Received: 8209.15
Location: CAMPBELL RIVER

✓	CONSTITUENTS	11	12	13	14	15	16	17	18	19	20	DATE	IN
	pH (080)												
	P. Alk. as $CaCO_3$ (006)												
	T. Alk. as $CaCO_3$ (006)												
	Sulfate (SO_4) (122)												
	Chloride (Cl) (024)												
	Fluoride (F) (050)												
	Ortho PO_4(P) (082)												
	Total PO_4(P) (086)												
	Nitrite (N) (072)												
	Nitrate (N) (072)												
	Nitrite + Nitrate (N) (072)												
	Ammonia (N) (058)												
	Silica (Si) (118)												
✓	Sulfide (S) (128)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	8209.21	RL
	Chlorophyll a (650)												
	Phaeopigments (650)												
✓	Color - Units (042)	5	5	5	5	5	5	5	5	5	5	8209.16	RL
	Turbidity - FTU (130)												
✓	Salinity - ‰ (114)	22	25	4	25	25	22	5	25	25	25	8209.16	RL
	Cond. - µmhos/cm (044)												
	Dil. Cond. µmhos/cm												
	Sam. Vol. - mls.												
	DI Vol. - mls.												
	DI Cond. - µmhos/cm												

REMARKS

LABORATORY SERVICES (EPS-FMS)
CHEMISTRY

UNITS (Except Where Noted)

- ☐ Fresh Water mg/l
- ☐ Marine Water mg/l
- ☐ Effluent mg/l
- ☐ Sediment mg/kg

Lab Number 820871
Date Received 8209.15
Location CAMPBELL RIVER

✓	CONSTITUENTS	21	22	23	24	25	26	27	28	29	30	DATE	IN
	pH (080)												
	P. Alk. as $CaCO_3$ (006)												
	T. Alk. as $CaCO_3$ (006)												
	Sulfate (SO_4) (122)												
	Chloride (Cl) (024)												
	Fluoride (F) (050)												
	Ortho PO_4(P) (082)												
	Total PO_4(P) (086)												
	Nitrite (N) (072)												
	Nitrate (N) (072)												
	Nitrite + Nitrate (N) (072)												
	Ammonia (N) (058)												
	Silica (Si) (118)												
✓	Sulfide (S) (128)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	8209.21	RL
	Chlorophyll a (650)												
	Phaeopigments (650)												
✓	Color - Units (042)	5	5	5	5	5	5	5	5	5	5	8209.16	RL
	Turbidity - FTU (130)												
✓	Salinity - ‰ (114)	3	25	25	25	4	23	25	25	3	25	8209.16	RL
	Cond. - μmhos/cm (044)												
	Dil. Cond. μmhos/cm												
	Sam. Vol. - mls.												
	DI Vol. - mls.												
	DI Cond. - μmhos/cm												

REMARKS

LABORATORY SERVICES (EPS-FMS)
CHEMISTRY

UNITS (Except Where Noted)

- ☐ Fresh Water — mg/l
- ☐ Marine Water — mg/l
- ☐ Effluent — mg/l
- ☐ Sediment — mg/kg

Lab Number: 820871

Date Received: 8209.15

Location: CAMPBELL RIVER

✓	CONSTITUENTS	31	32									DATE	IN
	pH (080)												
	P. Alk. as $CaCO_3$ (006)												
	T. Alk. as $CaCO_3$ (006)												
	Sulfate (SO_4) (122)												
	Chloride (Cl) (024)												
	Fluoride (F) (050)												
	Ortho PO_4(P) (082)												
	Total PO_4(P) (086)												
	Nitrite (N) (072)												
	Nitrate (N) (072)												
	Nitrite + Nitrate (N) (072)												
	Ammonia (N) (058)												
	Silica (Si) (118)												
✓	Sulfide (S) (128)	<0.05	<0.05									8209.21	RL
	Chlorophyll a (650)												
	Phaeopigments (650)												
✓	Color - Units (042)	5	5									8209.16	RL
	Turbidity - FTU (130)												
✓	Salinity - ‰ (114)	25	25									8209.16	RL
	Cond. - µmhos/cm (044)												
	Dil. Cond. µmhos/cm												
	Sam. Vol. - mls.												
	DI Vol. - mls.												
	DI Cond. - µmhos/cm												

REMARKS

LABORATORY SERVICES (EPS-FMS)
CHEMISTRY

Remarks

UNITS (Except Where Noted)	
☐ Fresh Water	mg/l
☑ Marine Water	mg/l
☐ Effluent	mg/l
☐ Sediment	mg/kg

Lab Number 820871
Date Received 82-09-15
Location CAMPBELL RIVER ESTUARY

✓	CONSTITUENTS	1	2	3	4	5	6	7	8	9	10	DATE	IN
	Filterable R. (100)												
✓	Non-filterable R. (104)	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	82 09.23	DY RK
	Total R. (094)												
		11	12	13	14	15	16	17	18	19	20		
	Non-filterable R.	<5	<5	<5	<5	5	8	<5	<5	<5	<5	82 09.23	DY RK
		21	22	23	24	25	26	27	28	29	30		
	Non-filterable R.	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	82 09.23	DY RK
		31	32										
	Non-filterable R.	<5	57									82 09.23	DY RK
	Inorganic C (016)												
	CAOV (% C) (018)												
✓	DO (048)	1 / 87	2 / 3.4	3 / 4.1	4 / 4.0	5 / 7.7	6 / 3.6	7 / 3.3	8 / 2.4	9 / 7.9	10 / 4.0	82 09.16	Dy
		11 / 3.3	12 / 2.7	13 / 8.3	14 / 4.9	15 / 2.7	16 / 3.3	17 / 7.7	18 / 3.1	19 / 3.3	20 / 2.5		
		21 / 8.6	22 / 2.8	23 / 2.8	24 / 3.1	25 / 9.8	26 / 3.6	27 / 3.7	28 / 4.2	29 / 8.7	30 / 3.3		
		31 / 3.0	32 / 2.4										
	Total Soluable												
	Total Insoluable												
	Volatile Soluable												
	Volatile Insoluable												
	Particle Size (078)												
	Oils & Grease (725)												

REMARKS

1 — 32.

Appendix XI

List of publications currently available on Campbell River research