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GEOGRAPHICAL DISTRIBUTION OF CHLOROPHENOLS AND HABITAT TYPES IN THE FRASER RIVER ESTUARY

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GEOGRAPHICAL DISTRIBUTION OF CHLOROPHENOLS AND HABITAT TYPES IN THE FRASER RIVER ESTUARY

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ABSTRACT

Chlorophenol data in sediments, water and biological tissues, collected from the lower Fraser River and estuary, were compiled into a single database for a review of their geographical distribution within the study area. The data were obtained from both published and unpublished sources and cover the time period between 1973 and 1987.

The data were described in terms of chemical species (a total of 20 were identified), by analytical laboratory, and by sample medium, including sediments, water, fish muscle and fish liver (collectively and by species), and invertebrate organisms. For each sample medium, the geographical distribution of total chlorophenol concentration (described as the sum of all isomers of di-, tri-, tetra- and penta- chlorophenol reported for that sample) was displayed on maps showing the relationship between concentration and known or potential sources of chlorophenol (both existing and historical). Comparisons were also made with B.C. provisional water quality objectives, where appropriate.

Total chlorophenol concentration in sediments and in water were generally higher in samples collected adjacent to known chlorophenol sources, but decreased within a short distance downstream. The highest concentrations, frequently exceeding water quality objectives, were reported from the North Arm, which has the greatest number of sources along with lower river flows. In contrast, samples collected in the lower reaches of the Main Arm had much lower chlorophenol concentrations, and never exceeded the water quality objectives. However, the number of samples collected in the North Arm was much greater than elsewhere in the study area.

The collection of fish tissue samples was much more geographically uniform. The B.C. provisional objective for total chlorophenols in fish muscle was exceeded in 26% of the samples, but unlike sediment and water samples, the association with potential chlorophenol sources was not as apparent. There is no information on whether the present chlorophenol levels in fish tissue constitute a human health concern or represent chronic toxicity to fish.

The study also resulted in the preparation of detailed biophysical maps, identifying a total of 15 aquatic habitat types within the study area. Physical, chemical and biological information was summarized and the sensitivity of each habitat to the presence of chlorophenols was discussed. Several habitats were highlighted as having special features which may require special consideration in the development of water quality criteria, including those for chlorophenols. However, because the site descriptions in the original reports were often quite imprecise, we were unable to establish a relationship between the concentration of chlorophenols and biophysical characteristics.

Finally, these data represent a historical overview up to 1987. Improved waste management strategies such as the on-site reduction of contaminated runoff, a provincial stormwater regulation which effectively eliminated any allowable chlorophenol discharge, have since been implemented. In addition, there has been the elimination (in 1988) of chlorophenol products for sapstain fungus control (wood protection) by industries in the Fraser River estuary, although chlorophenol is still used in the preservation of some products such as pilings and railway ties. These measures, along with the short half-life of chlorophenol products, should result in decreased ambient levels within the estuary over time.

RESUME

Diverses données sur les chlorophénols dans les sédiments, l'eau et les tissus biologiques en provenance du bas-Fraser et de son estuaire ont été rassemblées dans une banque de données unique afin de passer en revue leur distribution géographique dans cette région. Les données en question avaient été publiées auparavant ou étaient encore du domaine privé; elles portaient sur la période allant de 1973 à 1987.

Les données ont été classées selon la structure chimique des chlorophénols (20 en tout ont été identifiées), selon le laboratoire d'analyse et selon le milieu d'échantillonnage, incluant les sédiments, l'eau, les muscles et le foie des poissons (collectivement et par espèce) et les invertébrés. Pour chaque milieu d'échantillonnage, la distribution géographique de la concentration totale en chlorophénols (égale à la somme des concentrations de tous les isomères de di-, tri-, tétra-, et penta- chlorophénols pour chaque échantillon) a été présentée sur des cartes montrant la relation entre ces concentrations et les sources de chlorophénols connues ou potentielles (passées ou présentes). De plus, des comparaisons ont été faites avec les objectifs provisoires de qualité des eaux de la Colombie-Britannique, lorsque cela était approprié.

Les concentrations totales en chlorophénols dans les sédiments et dans l'eau étaient généralement plus élevées dans les échantillons prélevés sur les lieux des sources connues de chlorophénols, mais elles diminuaient rapidement en aval. Les concentrations les plus élevées, qui excédaient fréquemment les objectifs de qualité des eaux, ont été retrouvées dans le bras nord de la rivière, où se retrouvent le plus grand nombre de sources de chlorophénols de même qu'un écoulement plus faible. Par contre, les échantillons recueillis dans le bas du bras principal de la rivière avaient des concentrations en chlorophénols nettement plus basses, qui ne dépassaient jamais les objectifs de qualité des eaux. Cependant, le nombre d'échantillons prélevés dans le bras nord était beaucoup plus élevé que partout ailleurs dans la région étudiée.

La cueillette des échantillons de tissus de poissons a été faite de façon nettement plus uniforme géographiquement. L'objectif provisoire de la Colombie-Britannique pour l'ensemble de chlorophénols dans le muscle de poisson a été dépassé pour 27% des échantillons, mais contrairement aux échantillons de sédiments et d'eau, il n'y avait pas d'association apparente avec les sources potentielles de chlorophénols.

On a aussi préparé des cartes biophysiques détaillées, qui permettent d'identifier 15 types d'habitat aquatique dans la région étudiée. Des informations sur la physique, la chimie et la biologie ont été résumées et la sensibilité de chaque habitat à la présence des chlorophénols a été considérée. Plusieurs des habitats ont été mis en évidence parce qu'ils présentent des caractéristiques particulières qui devraient être considérées de façon spéciale lors de l'élaboration de critères de qualité des eaux, dont ceux pour les chlorophénols. Cependant, comme la description des sites dans les rapports originaux était souvent imprécise, nous n'avons pas pu établir de relation entre la concentration des chlorophénols et les caractéristiques biophysiques.

Finalement, ces données constituent une revue historique allant jusqu'à 1987. Depuis lors, des stratégies améliorées de gestion des déchets ont été mises en oeuvre, comme par exemple la réduction à la source du ruissellement d'eaux contaminées et un règlement provincial sur les eaux pluviales qui interdit tout rejet de chlorophénol. De plus, en 1988, les industries situées dans l'estuaire du fleuve Fraser ont cessé d'utiliser les chlorophénols dans le traitement du bois; cependant, ces produits servent toujours à la préservation de certain matériaux comme les pilotis et les traverses de chemin de fer. Ces mesures, combinées à la courte demi-vie des chlorophénols, devraient résulter, avec le temps, en une réduction des niveaux observés dans l'estuaire.

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1.0 INTRODUCTION

Chlorophenols (CPs) are a major group of organic chemicals that are widely used as biocides and as precursors for the manufacture of other biocide agents. They include monochlorophenol (MCP), dichlorophenol (DCP), trichlorophenol (TCP), tetrachlorophenol (TTCP), and pentachlorophenol (PCP). A total of 19 CP isomers are available to industry, although 2,3,4,6-TTCP and PCP make up the greatest percentage in use (Jones, 1981). Chlorophenols are considered to be ubiquitous in the Canadian environment and have been detected in landfill leachate, sewage, urban and agricultural runoff, water, sediments and in aquatic and terrestrial organisms (NRCC, 1982).

The Water Quality Branch, Inland Waters Directorate, Environment Canada, has an ongoing program for assessing contaminants such as chlorophenols in aquatic ecosystems. They are also responsible for developing and/or revising ambient water objectives as part of the Fraser River Estuary Management Program. Water quality objectives are developed to protect designated water uses, such as drinking water, protection of aquatic life and wildlife, livestock watering, irrigation, and recreation. Objectives enable resource managers to evaluate the quality of a particular body of water, to assess the effectiveness of existing pollution control regulations and to provide an early warning about new or unexpected pollution problems.

Water quality objectives may be proposed for water, sediments, and/or biological tissues, and may include bioassays or other biological indicators. One facet in the process of developing objectives is to describe the existing conditions with respect to concentrations in the environment, particularly in relation to sources of contaminants. It is also important to determine the concentration in the various components of the ecosystem, especially when considering objectives for the protection of aquatic life and wildlife.

The Fraser River estuary is one of British Columbia's largest and most important aquatic habitats and is a critical staging and rearing area for many fish and wildlife species. The river is adjacent to the largest industrial region in the province, and numerous wood storage and sawmill operations, which use chlorophenols extensively for wood protection, are located along the banks. Thus, the potential exists for problems related to chlorophenol contamination of the aquatic environment.

This report describes the chlorophenol information that has been collected in the Fraser River estuary. Data from water, sediments and biological tissues, from over 300 separate sampling sites, have been compiled into a single database and summary statistics are provided. The report also describes 15 different aquatic habitat types in the estuary which were assessed for their sensitivity to the presence of chlorophenols. These habitats were also digitized into a computer-based mapping system which can be used to evaluate chlorophenol data from specific habitat types.

Chlorophenol data from the various habitat types are presented on maps and summarized in tables. Accompanying the report are printouts of the data and computer disks of the database and the digitized habitat map.

2.0 METHODS

2.1 Description of the database

2.1.1 Information sources

Over 60 references (including unpublished information) were reviewed for pertinent information. The data cover a time period between 1973 and 1987, although most of the information was collected after 1984. All chlorophenol data were entered into the database with related information, as available, such as moisture content of the tissues or sediments, and species weight, length and age. Data on PCBs were also coded but are not discussed in the report. The sources of the information are presented in Appendix 1. The number associated with each reference was used in the database as an unique identifier of the information source.

The availability of other environmental information (e.g., particle size, percent organic content) were coded as logical (true/false) fields.

2.1.2 Description of data file

The database was established using dBase III+. The database consists of 34 fields, described below. Codes used in the database are presented in Appendix 2.

MEASURE_ID - unique ID number for each result.

CHEM_SPECI - a code representing each chemical parameter (e.g. 2,3,4,5-tetrachlorophenol; 2,3,4,6- tetrachlorophenol; pentachlorophenol, etc.). A total of 30 different chemical species codes were used in the file.

CONC - the concentration measured. "ND" values (not detectable) were coded as "less than X" if the detection limit was known. If the detection limit was not reported the data were coded as "less than" zero. Missing data were coded as zero.

LESS_THAN - a logical field indicating measurements below the detection limit.

UNITS - the units were coded as reported (e.g., ug/g wet wt., ng/g dry wt., etc.). A total of 14 different unit codes were used.

STD_CONC - for data presentation, the CONC and UNITS fields were standardized to parts per billion (ppb): ug/L (water), ng/g wet weight (tissues), or ng/g dry weight (sediments).

REPLICATE - used to identify individual replicates when more than one sample was collected at the same place and time. Single samples were identified as replicate "1".

DAY_SAMPLE - day that the sample was collected.

MON_SAMPLE - month that the sample was collected.

YR_SAMPLE - year that the sample was collected.

DAY_ANA - day the sample was analyzed.

MON_ANAL - month the sample was analyzed.

YR_ANAL - year the sample was analyzed.

TIME - time (24 - hour) sample was collected.

(Where information on dates and times for sample collection and analysis was not available, the missing data were coded as zero.)

REFERENCE - unique number identifying information source. The number corresponds to the number in Appendix 1.

SITE_NO - unique site identification codes for the database.

THEIR_SITE - the site number as recorded in the original report.

LATITUDE - degrees North latitude for each site.

LAT_MIN - minutes (to two decimal places) for each site.

LONGITUDE - degrees West longitude for each site.

LON_MIN - minutes (to two decimal places) for site.

MEDIUM - a code identifying sample type as water (W), sediment (S), fish tissue (F), or invertebrate tissue (I).

SPECIES - each species is identified as a two letter code (Appendix 2).

TISSUE - the tissue analyzed (e.g., muscle, liver, whole animal) was identified as a two letter code (Appendix 2).

WEIGHT_GR - the weight of the individual (or composite sample weight), in grams.

LENGTH_MM - body length of the individual, in millimetres.

AGE - age or stage (e.g., juveniles, adults, etc.) was identified by a number or two letter code (Appendix 2).

COMPOSITE - logical field which identifies whether the analysis was done on a composite sample; e.g., more than one individual (tissues) or more than one field sample (sediments or water) combined.

MOIST_PC - percent moisture content of the tissues or of the sediments. Missing values were entered as zero.

SED_GRAIN - logical field which identifies whether sediment grain size information was reported.

SED_ORGAN - logical field which identifies whether the percent organic concentration was reported.

AUX_DATA - logical field which identifies whether other water quality data were reported.

2.2 Data summaries

2.2.1 Station locations

Latitudes and longitudes, standardized to degrees and decimal minutes, were used to describe the position of the sample sites. In some of the reports reviewed, sites were positioned on relatively small scale maps; these were transferred to the 1:25,000 scale base map as accurately as possible. Final positioning of each site was done directly on the digitized base map using the computer mapping routine ESLMap (see Section 2.2.4). Figures 1 - 5 show the location of the effluent sources and all sample sites (see Section 3.2). The numbers refer to the unique identifier assigned to each site (SITE_NO) in the database.

To facilitate interpretation, the data for several sites were combined into reaches, judged to be from the same biophysical region. The groupings were based on both habitat and water quality characteristics and correspond to the habitat types discussed in Section 2.3.2. The reaches include:

1.0	Main Stem (Freshwater Habitat)
1.1	Kanaka Creek to Pitt River, plus Pitt River
1.2	Pitt River to trifurcation
2.0	Main Arm (Estuarine Habitat)
2.1	Trifurcation to Deas Slough (Upper Estuarine Habitat)
2.2	Deas Slough to Steveston (Lower Estuarine Habitat)
3.0	North Arm (Estuarine Habitat)
3.1	Trifurcation to Mitchell Island (Upper Estuarine Habitat)
3.2	Mitchell Island (Upper Estuarine Habitat)
3.3	Mitchell Island to North Arm Jetty + Middle Arm (Lower Estuarine Habitat)
4.0	Outer Estuary and Marine Habitats
4.1	Offshore
4.2	Roberts Bank
4.3	Sturgeon Bank, south side Iona Jetty
4.4	Sturgeon Bank, north side Iona Jetty

Table 1 lists the actual stations included in each group.

2.2.2 Chemical species

The chlorophenol data were coded as reported in the original literature. The various species included:

Monochlorophenols: (MCP)	2-chlorophenol 4-chlorophenol (p-chlorophenol)
Dichlorophenols: (DCP)	dichlorophenol (unspecified) 2,3 - dichlorophenol 2,4 - dichlorophenol 2,6 - dichlorophenol

	3,4 - dichlorophenol
	3,5 - dichlorophenol
Trichlorophenols: (TCP)	trichlorophenol (unspecified)
	2,3,4 - trichlorophenol
	2,3,5 - trichlorophenol
	2,3,6 - trichlorophenol
	2,4,5 - trichlorophenol
	2,4,6 - trichlorophenol
	3,4,5 - trichlorophenol
Tetrachlorophenols: (TTCP)	tetrachlorophenol (unspecified)
	2,3,4,5 - tetrachlorophenol
	2,3,4,6 - tetrachlorophenol
	2,3,5,6 - tetrachlorophenol
	2,4,5,6 - tetrachlorophenol
Pentachlorophenol (PCP)	

2.2.3 Data analysis

Data analysis was done in three phases. First, all data were standardized to a common unit, parts per billion (ppb). The units for sediments were ng/g dry weight, water samples were reported as ug/L, while tissue samples were reported as ng/g wet weight.

In order to make comparisons between different regions of the study area, the data were then summarized by calculating "total chlorophenol". A wide variety of chemical species and isomers were recorded in the database. Total CP was based on the sum of all isomers (if measured) of DCP, TCP, TTCP, and PCP, as well as any data for which the specific isomer was not reported (e.g., TTCP rather than 2,3,4,5-TTCP). Data reported as "not detectable" were treated as zero. Note that total CP does not represent a true measurement of total chlorophenol but is simply the sum of all chlorophenol species reported.

The data are grouped into five categories, based on sample medium: 1) sediments; 2) water; 3) fish tissue (epaxial muscle or whole body analysis); 4) fish tissue (liver analysis); and 5) invertebrate tissue. Data are also reported for starry flounder, because of the large number of analyses for that species.

The final phase in our analysis was the calculation of descriptive statistics. It is important to recognize that a significant number of samples reported values as "less than" or "not detectable" and that these detection limits varied widely (Table 2). The data were also not normally distributed, as illustrated by the histograms in Figures 9 to 12, 14 and 15.

Percentiles are frequently used when data are not normally distributed, when a few very large (or small) values are present, or when a large number of samples reported as "less than" are included in the data set (Zar, 1974). All of these problems are apparent in the the chlorophenol database compiled in this study.

The median and other percentiles (10th, 25th, 75th and 90th) for the various components of the database and for different geographic regions (reaches) of the study area were calculated using all of the data, including "less than" values. Percentiles were not calculated if the sample size was less than six. For descriptive purposes, the mean, standard deviation, and upper limit of the 95% confidence interval were calculated using only values greater than detection because of the inherent problems associated with including large numbers of "less than" values. These statistics were only used in the preparation of the histograms referred to above. All interpretations and conclusions are based on the median and percentiles, which are not influenced by large numbers of "less than" values (Zar, 1974).

2.2.4 Mapping

Two different sets of mapping products were produced for this report: 1) aquatic habitat zones; and, 2) presentation of analytical results from the database.
The habitat maps were digitized as 15 separate layers (plus an additional layer for labels) over a base map originally prepared from 1:25,000 scale topographic maps. However, because the source maps were reproduced xerographically, which results in a 2% distortion, and because the boundaries of each habitat type were done in "thick line", the accuracy is limited to use at about the 1:50,000 scale. A description of each of the habitat types and information sources is given in Section 2.3.

The base map and habitat layers were prepared using AutoCAD, and are in data interchange format (DXF), which makes it compatible with most geographic information systems (GIS), including SPANS, and computer aided drafting (CAD) software. The file is approximately 16.5 MB (megabytes). This file accompanies this report, on 16 high density (1.2 MB) floppy disks (e.g., for use with an AT personal computer). The reference coordinates for the DXF file are presented below.

AUTOCAD		GEOGRAPHIC	
X	Y	Latitude (degrees N)	Longitude (degrees W)
34.2209	88.4112	49° 12.0'	123° 8.0'
133.6139	33.3540	49° 4.5'	122° 47.5'
180.8865	133.0716	49° 18.0'	122° 38.0'

Mapping of the chlorophenol data was performed using a software mapping package (ESLMap) developed by ESL Environmental Sciences Limited. This software allows the data and results of statistical analysis, using dBase III and Lotus files, to be interactively displayed on detailed maps.

The data are presented as symbols, which are sized in proportion to their concentration. The transformation of the data was done by setting the largest symbol size (height = 12 mm) for values which were greater than, or equal to, the concentration of the 90th percentile. The symbol height of the remaining data was then based on the ratio of concentration to the concentration of the 90th percentile, plus a constant to ensure a minimum height of 2 mm. Values in excess of the B.C. Ministry of Environment provisional water quality objectives were plotted as a circle, while the remaining data (>MDC) were plotted as squares. Values reported as <MDC were plotted as a "+". Black areas on some figures are a result of superimposed observations.

2.3 Fraser River estuary habitat information

2.3.1 Information sources

The information on habitats presented in the text and accompanying maps has been compiled from existing reports. The mapping is broadly based on the Fraser River Estuary - Estuary Habitat maps produced by the Ministry of Environment (Hunter and Howell-Jones, 1981). The aquatic habitats identified in the MOE series were combined and/or modified based on other habitat reports and from the authors' knowledge of the estuary. Water quality summaries were based on information from Drinnan and Clark (1980) and Drinnan and Hall (1983).

Detailed information on the Fraser River estuary can be found in the references listed in the "Bibliography of Scientific Information on Fraser River Estuary Water Quality"

(Inland Waters Directorate, 1986). References which were used in the habitat descriptions are presented in Appendix 1. In addition, information on the ecology of eelgrass meadows, estuarine channels and tidal marshes of the Pacific northwest was found in Phillips (1984), Simenstad (1983), and Seliskar and Gallagher (1983). While these are U.S. Fish and Wildlife Service reports, much of the material contained in them is applicable to the Fraser River estuary environment.

2.3.2 Habitat type designations

The estuary has been divided into 15 separate aquatic habitat types. These designations are based primarily on vegetation and water quality characteristics. The categories include:

- Freshwater - Intertidal, Vegetated (FIV)
- Freshwater - Intertidal, Non-Vegetated (FINV)
- Freshwater - Backchannel/Slough (FBC)
- Freshwater - Open (FO)

- Estuarine, Upper - Intertidal, Vegetated (EUIV)
- Estuarine, Upper - Intertidal, Non-Vegetated (EUINV)
- Estuarine, Lower - Intertidal, Vegetated (ELIV)
- Estuarine, Lower - Intertidal, Non-Vegetated (ELINV)
- Estuarine - Backchannel/Slough (EBC)
- Estuarine - Open (EO)

- Marine - High Intertidal, Vegetated (MHIV)
- Marine - High Intertidal, Non-Vegetated (MHINV)
- Marine - Low Intertidal, Vegetated (MLIV)
- Marine - Low Intertidal, Non-Vegetated (MLINV)
- Marine - Open (MO)

Each of the 15 habitat types has been digitized as a separate level or "layer" of the base map, which permits the mapping of any combination of habitat types.

3.0 DISTRIBUTION OF CHLOROPHENOL INFORMATION

3.1 General

This section provides a description of the chlorophenol results which have been incorporated into the database. It includes a description of chlorophenol sources of discharge into the Fraser River estuary; a discussion of the different chlorophenol species and their isomers; a breakdown of the contributions by analytical laboratory; and a review of the data from sediments, water, fish tissue, fish liver, and invertebrate tissues.

Data are available on DCP, TCP, TTCP, and PCP, as well as total CP, although the discussion will focus on total CP, with comments on the individual chemical species, where appropriate. It is important to note, however, that total CP is a calculation, derived by summing the concentrations of each individual chemical species that was reported, as described in Section 2.2.3. It is not a "true" total in that many of the analytical results reported exclude a number of chlorophenol species. However, virtually all the samples analyzed include TTCP and PCP, which made up 70 to 90% of the total CP when DCP and TCP were included in the calculation.

The distribution of total chlorophenol concentration is presented in a series of tables and figures for each of the sample media. In each case, data are presented on a map of the entire study area, as well as four larger scale maps which expand on four areas where most of the data have been collected: 1) Main Stem, from Pitt River to Annacis Island; 2) Mitchell Island, North Arm; 3) Sturgeon Bank off Sea Island (Iona Island Jetty); and Main Arm below Annacis Island. The data are displayed as symbols which are sized in proportion to their concentration.

There are few criteria against which these data can be compared. The closest are the provisional objectives recently established for the Fraser River for total chlorophenol (defined as the sum of TCP, TTCP, & PCP) for water, sediments and epaxial muscle tissue of fish (Swain and Holmes, 1985a). These criteria do not apply within the "Initial Dilution Zone", defined as 100 metres upstream and downstream of a point source. Because many of the data sources do not report sample locations with this accuracy it is not possible to determine whether or not they were collected within the IDZ. However, comparison of the database with these criteria is not intended to point out "compliance/non-compliance", in part because of the imprecise positioning information, because the short half-life of CPs reduces the concern associated with high historical data, and because recent waste management strategies have reduced CP inputs to the system. Rather, the use of these criteria is simply one of several yardsticks to place the existing data into perspective.

3.2 Sources of chlorophenols

Figure 1 shows an overview of the study area which also identifies potential sources of chlorophenols. Sources were identified from Krahn et al. (1987) and Garrett and Shrimpton (in prep.) (wood-storage and wood-treatment facilities), Cain et al. (1980) (industrial effluents, sewage treatment plants, and landfills) and Atwater (1980) (landfills). It should be noted that these represent historical sources and that a number may no longer be present.

Most chlorophenols are used as biocides by the forest products industry to prevent fungal growth on lumber products ("anti-sap stain" agents) or for wood protection on products such as fence posts and telephone poles. Industry generally uses a mixture of TTCP and PCP (in a ratio of 4:1) while PCP is the primary product used by the domestic market (Birtwell et al., 1985). However, it is believed that the latter constitutes only about 1% of the total (Jones, 1981).

A major source of chlorophenols to the Fraser River estuary is drainage from sawmill and lumber export sites. The chemical is leached from the treated wood during rain events and the resulting runoff has been shown to contain very high levels of TTCP and PCP, with concentrations up to 6600 ppb in runoff water from treated lumber (Krahn et al., 1987).

Many of the drainage systems from storage yards ischarge directly to the nearshore regions of the Fraser River. Krahn et al. (1987) found that during the flood stages of the tide, these discharges are blocked from entering the river by one-way gates and pooling of runoff water occurs. This pooled water (which may have chlorophenol concentrations in excess of 1000 ppb) is released during the ebb tide. Based on computer simulation models, chlorophenol concentrations of up to 100 ppb (well within the reported range of acute toxicity to salmoid fish) could occur as far as 60 m downstream of the discharge point (Krahn et al., 1987).

The annual total runoff generated at lumber storage yards in the study area is estimated to be between 165000 m^3 and 261000 m^3, with a total chemical loading that may exceed 900 kg per year (Krahn et al., 1987).

The sewage treatment plants (STP) in the study area were considered to be potential sources of chlorophenols because of domestic and industrial discharges into the municipal system. Treatment of sewage with chlorine may also result in the chlorination of phenolic compounds in the waste waters, although there is no evidence that chlorinated organics are formed as a result of the disinfection process (Birtwell et al., 1985; Fraser River Harbour Commission, 1987).

Analyses of various municipal effluents (Cain et al., 1980; Birtwell et al., 1985; Rogers et al., 1986) have found concentrations of up to 13 ppb for PCP and 28 ppb for TTCP.

However, the 1986 Effluent Monitoring Program by the Fraser River Harbour Commission (FRHC, 1987) found no evidence of PCP in the Iona, Lulu or Annacis Island sewage treatment plants, and tetrachlorophenols were detectable only in the sludge from the Iona plant. It is not known whether these differences represent a change in domestic or industrial use or a sampling artifact.

Leachate from landfills was also identified as a potential source of chlorophenols (Atwater, 1980; Jones, 1981). Known solid waste disposal sites, such as the Richmond landfill and Burns Bog landfill, were therefore included.

3.3 Distribution by chemical species

A total of 20 different chemical species were identified in the data set, as shown in Figure 6. There were considerable differences between the various data sources in the presentation of chlorophenol data. Some reported only dichlorophenol (DCP), trichlorophenol (TCP), or tetrachlorophenol (TTCP) without specifying which isomer(s) was analyzed, or whether the concentration was based on one isomer or the sum of several.

Monochlorophenol was measured in only nine sediment and nine fish tissue samples and all were below the detection limit. These data have been excluded from the rest of the discussion.

Dichlorophenol was measured in 31% of the samples. Over half (54%) of the observations were from fish tissue samples, while 41% were from water samples. Very few results were from sediments or invertebrate tissues. Two-thirds of the DCP observations were below the detection limit; most of the measurable concentrations were from fish tissues. 2,4-DCP was the most frequently measured isomer.

Trichlorophenol was measured in 66% of the samples with measurements distributed relatively evenly between sediments, water and fish tissue. Of the six isomers reported, 2,4,6-TCP was the most frequently measured.

Three tetrachlorophenol isomers were reported, but the principal one reported was 2,3,4,6-TTCP. Virtually all of the samples analyzed included some form of TTCP (98%) and pentachlorophenol (>99%).

3.4 Distribution by analytical laboratory

Figures 7 and 8 present the number of samples, by chemical species and by media respectively, which were analyzed by analytical laboratories. Some differences between the labs are apparent.

Most of the analyses of sediments were conducted by the Environmental Protection (EP) lab (37%) followed by the Ministry of Environment (MOE) (27%) and private labs (26%), the latter generally under contract to government agencies. In contrast, the Westwater laboratory, at the University of British Columbia, was responsible for the majority of water analyses (55%) but contributed only a few sediment or fish measurements. Fish tissue analyses were carried out by private labs (30%), and by Fisheries and Oceans (DFO), National Water Research Institute (NWRI) and EP labs (approximately 20% each). Invertebrate tissue data were conducted by private labs (49%) and by the MOE lab (44%).

3.5 Sediments

3.5.1 Overview

Results for the combined data set are presented in Table 3 and Figure 9. A total of 257 sediment samples were analyzed for chlorophenols, of which 53% had measurable concentrations. The maximum concentration for total CP was 180 ppb while the 90th percentile was 39.4 ppb. Eighty-two samples (32% of the total) had a total CP concentration which exceeded 10 ppb, the provisional water quality objective for sediments proposed by the B.C. Ministry of Environment (Swain and Holms, 1985a).

The mean total CP was 23.2 ppb, compared to a median concentration of 2 ppb. If the data were normally distributed, the mean and median would be expected to be reasonably close in value. The large differences between the two statistics in this data set illustrate the influence of a number of very large values plus the fact that the median includes "less than" values while the mean did not.

3.5.2 Geographical distribution (Table 4; Figures 16 - 20)

The Main Stem and North Arm of the Fraser River had higher concentrations of total CP in the sediments, compared to the Main Arm, reflecting the greater number of sources. Total CP was highest in the Main Stem between the Pitt River and the trifurcation, with a 50th and 90th percentile concentration of 16 ppb and 80 ppb, respectively. Mitchell Island in the North Arm had the next highest sediment concentration for total CP with 50th and 90th percentiles of 8 ppb and 46 ppb respectively. Both of these sections of the river have a number of large wood-treatment and storage facilities.

Many of the values in the Main Stem and North Arm exceeded 10 ppb, as illustrated by the number of ellipses on Figure 16. In most cases, the higher CP concentrations were measured in sediments collected adjacent to, or just downstream of, known sources. The concentration decreased, however, within a short distance from the source, as illustrated in Figure 17 by the reduction in symbol size, and change from ellipse to square. As was discussed in section 3.1, it was not possible to determine whether or not any of the samples were collected within the "Initial Dilution Zone" (IDZ). Therefore the possibility exists that some samples which exceeded provisional guidelines were collected within the IDZ, where the objective does not apply (L. Swain, pers. comm.). It also should be noted that the recent sediment data collected by the Ministry of Environment, which consists of a significant number of the total database (75 samples), all were within the objective. These data may be more representative of present "background" levels as they were collected away from known sources and consist of the most recent information (L. Swain, pers. comm.).

In contrast, the concentration of total CP in sediments collected from the Main Arm was much lower, with a 50th and 90th percentile of 2 ppb and 19 ppb for the upper estuarine section, and below detection (LD) and 3 ppb for the lower estuarine section. In fact, all values were less than 10 ppb except for one sample collected adjacent to a CP source, at the trifurcation (Figure 16).

Sediments collected on Sturgeon Bank and offshore were generally low. The median concentration and 90th percentile for total CP in the region south of the Iona Jetty was LD and 9 ppb respectively, while north of the Iona Jetty the 50th and 90th percentiles were LD and 4.0 ppb. Very few values exceeded 10 ppb (Figure 19) and the maximum concentration south and north of the Jetty was 23 ppb and 11 ppb, respectively.

Offshore, the concentration of total CP in sediments collected in the vicinity of the recently-installed Iona Island STP outfall was slightly higher than on Sturgeon Bank, with a 50th and 90th percentile of LD and 29.3 ppb and a maximum concentration of 39.4 ppb. While there were a greater number of results which exceeded 10 ppb, compared to measurements on Sturgeon Bank,it is worth noting that they all were collected in 1983; subsequent monitoring in 1986 reported sediment concentrations for total CP below 10 ppb.

3.6 Water

3.6.1 Overview

Chlorophenols were analyzed in 206 water samples, of which 178 (86%) had detectable values for total CP (Table 3 and Figure 10). The maximum concentration was 17.5 ppb, with a 90th percentile of 2.08 ppb.

The mean concentration for total CP was 0.85 ppb while the median was 0.15 ppb, again illustrating the influence of several high values when calculating the mean. Eighty-eight samples (42%) had a total chlorophenol concentration which exceeded the B.C. Ministry of Environment provisional water quality objective of 0.2 ppb; most were from a single data set collected near Mitchell Island (see next section).

3.6.2 Geographical distribution (Table 5; Figures 21 - 25)

Half of the water samples were collected near Mitchell Island, North Arm (Figure 23) while the remaining data were more equally distributed throughout the study area. The data from Mitchell Island are primarily those collected during a number of time series studies, each extending over a period of several days (Jacob, 1986). The area is adjacent to a number of wood-storage and treatment facilities.

Most of the samples from the Mitchell Island time series exceeded 0.2 ppb; the 25th percentile for total CP in water was 0.19 ppb while the median was 0.45 ppb. The 90th percentile was 2.77 ppb, an order of magnitude higher than the provisional water quality objective. A maximum of 17.5 ppb for total CP was reported.
Elsewhere in the study area, a few measurements for total CP exceeded 0.2 ppb, all from the Main Stem or the North Arm (Figures 21 and 22), and adjacent to known sources. None of the samples collected in the Main Arm or offshore had a concentration greater than 0.12 ppb.

3.7 Fish tissues

3.7.1 Overview

Fish samples were separated into two categories: 1) epaxial muscle or whole body analyses; and 2) liver analyses. Data for both are presented in Table 3 and Figures 11 and 12.

A total of 391 fish samples (250 epaxial muscle and 141 whole body) had measurable concentrations of chlorophenols. A comparison of the two groups showed no significant difference (student's z test, $p<0.05$). For the epaxial muscle, the maximum concentration was 6239 ppb, with a median and 90th percentile of 58 ppb and 280 ppb, respectively. Eighty-six samples (26% of the total) exceeded the B.C. provisional objective of 100 ppb wet weight. Eighty-four samples (not included in the statistics) were less than the detection limit.

Analyses were done on 93 liver samples, 75% of which had measurable chlorophenol concentrations. The maximum concentration for total CP was 1550 ppb with a 90th percentile of 286 ppb. The mean and median were 182 ppb and 78 ppb, respectively.

3.7.2 Geographical distribution

a) Fish muscle (Table 6; Figures 27 - 30)

Data for total chlorophenols in fish tissues are much more evenly distributed over the study area in contrast to sediment or water data (Figure 27). In addition, the higher concentrations of total CP in fish tissues, unlike sediments and water, do not appear to be as closely associated with effluent sources. Regionally, the lowest concentrations were from the Main Stem, upstream of the Pitt River, with a median concentration and 90th percentile of 20 ppb and 60 ppb, respectively. The highest values were from the section of the Main Stem downstream of the Pitt River (Table 6 and Figure 27). Data collected from the North Arm and the Main Arm were similar. The 50th and 90th percentiles for total CP in tissues collected in the three regions of the North Arm - trifurcation to Mitchell Island, Mitchell Island, and downstream of Mitchell Island - were 90 ppb and 280 ppb, 44 ppb and 260 ppb, and 50 ppb and 310 ppb, respectively. Total chlorophenols measured in fish tissues collected in the Main Arm had a median and 90th percentile of 60 ppb and 445 ppb in the upper estuarine reaches and 95 ppb and 400 ppb in the lower estuarine reaches.

In the offshore marine regions, total CP was generally below the MDC (37 of 41 values), except for several which had very high concentrations (maximum 5054 ppb).

There were also a few very high total CP concentrations in fish tissues elsewhere in the study area, with a maximum of 3700 ppb in the Main Stem, 6239 ppb and 4284 ppb from the upper and lower estuarine areas of the Main Arm, 2029 ppb near Mitchell Island, and 2324 ppb in the Middle Arm. These values are nearly an order of magnitude higher than the 90th percentile from the same area, and all originate from the same lab. However, a review of the analytical procedures provided in the report does not suggest any reason not to accept the data as valid.

b) Fish livers (Table 7; Figures 31 - 35)

Separate analyses of fish livers were carried out on 12 samples from the Main Stem, 24 samples from the Main Arm, and 19 samples from the North Arm. The median concentration for total chlorophenols was 205 ppb, 80 ppb, and 171 ppb, respectively, suggesting higher accumulated chlorophenols from regions where sources occur. It should be noted that while there were no detectable concentrations of TCP for most of the samples except starry flounder (collected near Mitchell Island), DCP was found in most of the livers.

3.7.3 Distribution by biological species

The fish tissue samples (muscle or whole body) were made up of 18 different species. The data are presented in Table 8 and Figure 13. Eulachon (81 samples) and starry flounder (78 samples) were the most frequently analyzed species, followed by northern squawfish (38 samples), prickly sculpin (27 samples), white sturgeon (25 samples) and staghorn sculpin (19 samples).

Six specimens each of chinook (0.7 to 11.5 kg) and sockeye salmon (2 to 4 kg), 8 cutthroat trout (.06 to 0.5 kg), 10 dolly varden trout (0.1 to 0.3 kg) and five rainbow trout (2-4 kg) were the only salmonid species analyzed. Detectable total CP was measured in one cutthroat (40 ppb), one dolly varden (20 ppb) and one rainbow trout (60 ppb).

Several species had a significant number of samples (n> 10) which exceeded the B.C. provisional objective for fish tissue of 100 ppb wet weight (muscle) including: eulachon (56% of the samples for that species), largescale sucker (44%), prickly sculpin (44%), northern squawfish (37%), and white sturgeon (36%).

Starry flounder was selected to show the distribution of chlorophenol data within a single species because of the comprehensive data set available, both in terms of number of samples and in the different chlorophenol species analyzed. The results are presented in Table 3, Figure 14 and Figures 36 to 40.

The mean concentration for total CP in starry flounder was 373 ppb, but this value was strongly influenced by seven results which were an order of magnitude larger than the rest of the data for this species (range 2029 ppb to 6239 ppb) (see Figure 14). The median, more representative of the central tendency, was 41.3 ppb while the 90th percentile was 190 ppb. Most of the data were collected near Mitchell Island (67%), with the remaining data from throughout the rest of the study area.

3.8 Invertebrates tissues

3.8.1 Overview

A total of 52 tissue samples was analyzed for various invertebrate species (Table 3 and Figure 15). Sixty percent had measurable concentrations and the overall mean, median, and maximum were 816 ppb, 10 ppb, and 9200 ppb, respectively. The 90th percentile (1380 ppb) was exceeded in 5 samples, all of which were made up of deposit or filter-feeding organisms (polychaetes, oligochaetes, or bivalves).

3.8.2 Geographical distribution (Table 9; Figures 41 - 45)

There were insufficient data to assess the distribution of chlorophenol data in other than the four main sections of the study area. The concentrations of total CP in tissues were similar for the freshwater and estuarine sections of the river. The median and 90th percentile for the Main Stem, Main Arm and North Arm were 90 ppb and 9200 ppb, 260 ppb and 4400 ppb, and 130 and 2200 ppb, respectively. In contrast, the median and 90th percentile for total CP data measured in invertebrates collected in the marine region of the study area were LD and 10 ppb, respectively. Note, however, that the sample size for this group was small, and that the marine samples did not include oligochaetes or polychaetes, the two groups which showed the highest CP values.

4.0 FRASER RIVER ESTUARY HABITAT INFORMATION

4.1 Freshwater habitats

4.1.1 General description

The geographic location of these habitats is upstream of the bifurcation of the Fraser River into the north and main arms (east of Lulu Island), and includes the Pitt River.

Tide

Magnitude of tidal range varies with discharge in Fraser River. Tidal range is 2.3 m at low flow (700 m/s) at Hope, B.C. and 1.0 m at high flow (8500 m/s). Geodetic elevation of the tide range also varies with discharge.

Water Quality

Conductivity is generally around 100 uS/cm (<0.1 parts per thousand {ppt}), with chloride concentrations of 5-10 mg/L. While the river will show tidal variation, the salt water wedge does not penetrate to these habitats. Concentration of dissolved ions is greatest during the winter (low flow period), decreasing during freshet.

The pH is generally around 7.5. Dissolved oxygen concentration ranges from a low of around 8-10 mg/L in the summer, to maximum values in winter of 10-12 mg/L. The percent saturation ranges between 80 and 100%.

Suspended sediment concentration is a function of river flow and mean monthly concentrations range between 10 mg/L during low flow to over 150 mg/L in freshet. Overall, the median concentration for suspended solids is between 35 and 40 mg/L.

4.1.2 Freshwater, intertidal, vegetated habitat (FIV)

This habitat is generally narrow bands of vegetation on river banks, although in some areas (i.e. the Pitt River) the bands are more extensive.

Physical descriptors

Sediments - fine mud/silts or organic peat.

Ecological descriptors

Vegetation - common plants include American great bulrush (Scirpus validus), sedges (Carex spp.), spikerush (Eleocharis spp.), horsetail (Equisetum spp.) and cattail (Typha latifolia). The distribution of these species can be discontinuous, although they can also occur in extensive mono-specific stands. Many herbaceous plants, grasses and shrubs are found at high or supra-tidal elevations.

Invertebrate fauna - available information is limited; insect and insect larvae (i.e. mayfly, stone fly and caddisfly nymphs) present.

Birds - foraging habitat of dabbling ducks, geese, swans and some shorebirds.

Mammals - feeding habitat for river otter, mink, muskrat and small rodents.

Fish - foraging habitat for juvenile salmon, char, whitefish, suckers and stickleback when inundated by the tide.

Sensitive Components

Waterfowl rearing (spring and summer).
Juvenile salmon rearing

4.1.3 Freshwater, intertidal, non-vegetated habitat (FINV)

This habitat is mud or gravel bars, often offshore in the river channels. Mud flats are generally found offshore of most intertidal marshes.

Physical descriptors

Sediments - sand/gravel or mud.

Ecological descriptors

Vegetation - occasional aquatic plants and algae.

Invertebrate fauna - information limited; insect and insect larvae (i.e. mayfly, stone fly and caddisfly nymphs) present.

Birds - feeding habitat for great blue herons and diving ducks when inundated; resting areas for gulls and feeding for shorebirds when exposed.

Mammals - feeding habitat for mink, muskrat, raccoon and small rodents.

Fish - foraging habitat for juvenile salmon, char, suckers and stickleback when inundated; eulachon may spawn on the gravel bars.

Sensitive Components

Waterfowl and shorebirds during feeding (spring, summer and fall).

Recreational fishing (bar fishing) during adult salmon migrations (fall).

Eulachon spawning (spring).

4.1.4 Freshwater, backchannel/slough habitat (FBC)

These habitats are side channels of the river, small tributaries or inundated drainage ditches. They are calm, gentle waters away from the main body of the river. Their use by fish can be limited by blocked access from the main river channel.

Physical descriptors

Sediments - mud/silt.

Ecological descriptors

Vegetation - open water may support aquatic species such as pondweed (Potamogeton spp.), duckweed (Lemna spp.) and waterweed (Elodea canadensis). Margins can be colonized by emergent vegetation: sedges (Carex spp.), rushes (Juncus spp.) and bulrushes (Scirpus spp.). These habitats are often overhung with shrubs and alders.

Invertebrate fauna - predominantly insect and insect larvae (i.e. mayfly, stone fly and caddisfly nymphs), also some benthic crustaceans (i.e. crayfish (Pacifastacus leniosculus)).

Birds - important resting areas for ducks; emergent vegetation utilized for nesting by dabbling ducks, coots, bitterns, rails and songbirds; open water used for feeding by kingfishers and herons.

Mammals - feeding habitat for raccoon, mink, river otter, muskrat, small rodents and beaver.

Fish - important habitat for juvenile salmonids, sturgeon, catfish, carp, trout and char. The use of these habitats can be restricted due to blockages which limit access from the main river channel.

Sensitive Components

Waterfowl rearing and nesting (spring and summer).

Rearing juvenile salmon, especially chum and chinook (spring and summer).

4.1.5 Freshwater, open habitat (FO)

This habitat is the main river channel. The banks of steep-sided channels are included in this category.

Physical descriptors

Sediments - variable: mud, sand, gravel, and/or boulders.

Ecological descriptors

Vegetation - limited to drift organisms and phytoplankton.

Invertebrate fauna - zooplankton (Bosmina spp. and Diaphanosoma spp.) and benthic invertebrates (i.e. crayfish (Pacifastacus leniosculus)) and oligochaete worms).

Birds - feeding areas for loons, mergansers, cormorants and gulls, especially during fish migrations; also resting habitat for Canada geese and dabbling ducks.

Mammals - foraging habitat for river otters and harbour seals.

Fish - most fish species found in the estuary will use this habitat at some point in their life cycle.

Sensitive Components

Eulachon spawning (spring).

Migrating salmon adults and juveniles (spring and fall).

Irrigation users.

Commercial gill net fishery, during adult salmon migrations (fall).

4.2 Estuarine and brackish water habitats

4.2.1 General description

These habitats are located downstream of the bifurcation of the Fraser River at the eastern end of Lulu Island. The water quality, especially salinity varies widely between the upstream reaches of the river and the foreshore area of this habitat section. However, the intertidal vegetation is not as variable as the water quality, and the plant communities are used to distinguish the two subzones: 1) an upper estuarine habitat, which includes the North Arm and Main Arm of the Fraser River downstream of the bifurcation to Steveston (Main Arm) and to McDonald Slough (North Arm); and, 2) a lower estuarine habitat, which includes the foreshore of Lulu, Sea, Reifel and Westham Islands, and the foreshore south of Canoe Passage to the coal terminal jetty.

Tide

Magnitude of the tidal range varies with discharge in Fraser River. Tidal range is 3.2 m at low flow (700 m/s) at Hope, B.C. and 2.1 m at high flow (8500 m/s). Geodetic elevation of the tide range also varies with river discharge.

Water Quality

Conductivity/salinity increases from values of 100-500 uS/cm (<0.5 ppt, salinity) in the upper reaches of the North Arm and Main Arm, to 25 ppt along the foreshore. The presence of salt water during the flood tide is a function of both the tidal amplitude and river flow. During low tide, the salt wedge will penetrate as far as Annacis Island. The increase in conductivity is most marked between Tilbury Island (median value of 8 uS/cm) and near the Ladner Marsh Islands (median, 500 uS/cm).

During flood tide, the salinity of foreshore areas can increase from essentially fresh water up to 25 ppt, as marine waters from Georgia Strait move over the tidal flats. Salinity is quite variable and is a function of the movement and magnitude of the Fraser River plume from both the Main Arm and North Arm.

Dissolved ions, especially chloride, increase from the upstream regions of these habitats (chloride 5-10 mg/L) to the area near the Ladner Marsh (10-100 mg/L) and much higher as the influence of the marine waters increases.

The pH is generally around 7.6-7.8, with slightly higher values in more saline waters. Dissolved oxygen ranges between 8-10 mg/L in summer, to 10-12 mg/L in winter.

Suspended solids begin to settle out in the lower reaches of this region, depositing on the islands and foreshores. The concentration of sediments in the water varies widely, between 10 and 150 mg/L.

The water quality of the backchannels, sloughs and tidal channels of the marsh islands, may differ from the main channels of the river. Frequently dissolved oxygen is lower and conductivity and pH are higher, reflecting the entrapment of more saline water. The differences are more prevalent during the summer. Tidal channels which drain the islands of the lower Fraser River estuary (e.g., Woodward and Duck Islands) show water quality characteristics similar to the main river during the higher stages of tide, but differing significantly as the water recedes. The most notable changes were increases in dissolved ions, particulate material, ammonia and organic nitrogen, and decreases in dissolved phosphorus and nitrate (Drinnan and Hall, 1983).

4.2.2 Estuarine, upper - intertidal, vegetated habitat (EUIV)

This habitat includes the marshes along the river banks. In general, the marshes increase in diversity with distance upstream from the mouth. Some areas, especially in the vicinity of Annacis Island, are dominated by annual plants. This may reflect the year to year mobility of the intertidal zone, as it varies vertically with river discharge.

Physical descriptors

Sediments - mud/silt; can be organic peat.

Ecological descriptors

Vegetation - generally dominated by horsetail (Equisetum spp.), sedges (Carex spp.) and grasses with many annuals and forbs.

Invertebrate fauna - supports a diverse community of adult and larval insects (esp. Hemipterans) and detrital feeding invertebrates, i.e. oligochaetes, mysids, harpacticoids and amphipods (Anisogammarus confervicolus and Corophium spp.).

Birds - important feeding habitat for dabbling ducks, foraging herons and songbirds.

Mammals - foraging habitat for mink, muskrat, raccoon and small rodents.

Fish - foraging habitat for juvenile salmonids and minnows.

Sensitive Components

Waterfowl feeding, migration staging, and over-wintering (all year).

Juvenile salmon rearing, especially chum and chinook (spring and summer).

4.2.3 Estuarine, upper - intertidal, non-vegetated habitat (EUINV)

This habitat includes the mud flats occurring below estuarine marshes, as well as beaches. Some of these areas have been incorporated into foreshore parks.

Physical Descriptors

Sediments - variable mud/silt to sand/gravel.

Ecological Descriptors

Invertebrate fauna - some oligochaetes, chironomid larvae, amphipods, adult and larval insects, and the occasional crayfish.

Birds - foraging habitat for shorebirds when exposed and diving ducks, herons, and mergansers when inundated by the tide.

Mammals - foraging areas for river otters and harbour seals.

Fish - foraging habitat for most juvenile and small fish of the estuary when inundated by the tide.

Sensitive Components

Juvenile salmon rearing, especially chum and chinook (spring and summer).

Waterfowl and shorebirds feeding (spring and summer).

Recreational fishing (bar fishing) during adult salmon migrations (fall).

4.2.4 Estuarine, lower - intertidal, vegetated habitat (ELIV)

These areas are the extensive marshes of the foreshore. This habitat is the only remaining remnant of the historical wetlands of the estuary. They are extremely productive and, therefore, important feeding areas for many fish, waterfowl and raptors.

Physical descriptors

Sediments - mud/silt, can be organic peat.

Ecological descriptors

Vegetation - dominated by Lyngbyei's sedge (Carex lyngbyei), with spikerush (Eleocharis palustris), American great bulrush (Scirpus validus), grasses (Deschampsis cespitosa, Agrostis alba, and Festuca spp.) and rushes (Juncus articulatus). Three-square bulrush (Scirpus americanus) is a common plant of the pioneer foreshore marsh. The high marsh also supports a relatively diverse community of annuals and forbs.

Invertebrate fauna - highly diverse and productive community of adult and larval insects (esp. Hemipterans) and other invertebrates (i.e. harpacticoids, amphipods, mysids, and oligochaetes).

Birds - important feeding and overwintering habitat for migratory waterfowl (notably trumpeter swans and snow geese), also extensively used by dabbling ducks, herons, songbirds, and raptors (notably northern harriers, red-tailed hawks, short-eared owls, and peregrine falcons).

Mammals - foraging habitat for mink and river otter, occasional harbour seal in the tidal channels.

Fish - foraging habitat for juvenile salmonids, sculpins, sea perch, and flounders.

Sensitive Components

Juvenile salmon rearing, especially chum and chinook (spring and summer).

Waterfowl - migration staging (winter); rearing and nesting (all year).

4.2.5 Estuarine, lower - intertidal, non-vegetated habitat (ELINV)

These areas are extensive mud or sand flats occurring below the marshes and beaches of the delta foreshore. The habitat is highly productive and forms important feeding areas for shorebirds, waterfowl, and many species of fish.

Physical descriptors

Sediments - mud/silt (mud flats), or sand (beaches).

Ecological descriptors

Invertebrate fauna - this habitat supports a large population of insects, worms and crustaceans (amphipods, copepods, and isopods).

Birds - important feeding habitat for shorebirds when exposed, and loons, cormorants, and mergansers when inundated by the tide.

Mammals - foraging habitat for river otters and harbour seals when inundated; haul out areas for harbour seals when exposed.

Fish - foraging habitat for most fish species of the estuary.

Sensitive Components

Juvenile salmon rearing, especially chum and chinook (spring and summer).

Waterfowl and shorebirds during feeding (spring and summer).

4.2.6 Estuarine, backchannel/slough habitat (EBC)

This habitat includes side channels of the river, small tributaries, or inundated drainage ditches. They are calm, gentle waters away from the main body of the river. Their use by fish can be limited due to restricted access from the main river channel.

Physical descriptors

Sediments - mud/silt.

Ecological descriptors

Vegetation - some aquatic vegetation; slough margins are often colonized by emergent vegetation similar to the estuarine marshes. They are often overhung with shrubs, red alder (Alnus rubra), and black cottonwood (Populus balsamifera).

Invertebrate fauna - dipteran insect larvae and nymphs, benthic invertebrates (i.e. crayfish, Pacifastacus leniosculus) and some marine zooplankton (i.e. copepods, and harpacticoids).

Birds - feeding and loafing habitat for dabbling ducks; feeding habitat for kingfishers and herons.

Mammals - foraging habitat for river otter, mink, raccoon, small rodents and occasional beaver.

Fish - foraging habitat for juvenile salmonids and most other small fish of the estuary.

Sensitive Components

Juvenile salmon rearing, especially chum and chinook (spring and summer).

Waterfowl rearing (spring and summer).

4.2.7 Estuarine, open habitat (EO)

This habitat is the deep water channels of the lower river. All steep sided river channels and the subtidal foreshore are included in this category.

Physical descriptors

Sediments - variable: mud, sand, gravel, and/or boulders.

Ecological descriptors

Vegetation - phytoplankton, drifting plant fragments.

Invertebrate fauna - zooplankton (cladocerans, copepods, and mysids (esp. Neomysis mercedis) in the river), benthic decapods (i.e. Dungeness crab (Cancer magister), on the foreshore), shrimp (Crangon spp.) and bivalves (Mytilus edulis and Macoma spp.).

Birds - diving ducks (scoters), loons, grebes (esp. western grebes), cormorants, and gulls.

Mammals - harbour seal, river otter, and the occasional killer whale may be present. Harbour seals and California sea lions use the outer Steveston jetty as a haul out area.

Fish - most fish species of the estuary will use this habitat at some point of their life cycle.

Sensitive Components

Migrating salmon (adults and juveniles) and foraging juveniles (spring, summer and fall).

Irrigation users (spring and summer).

4.3 Marine Habitats

4.3.1 General description

These habitats include the foreshore of Boundary Bay and of Roberts Bank, south of the coal terminal jetty.

Tide

The tidal range at Tsawwassen is 3.11 m on a mean tide and 4.69 m on a large tide.

Water quality

The Fraser River plume is significantly reduced in these habitats, and the water quality reflects the presence of the marine waters of Georgia Strait. Salinity is high, generally over 24 ppt. The pH ranges between 7.9 and 8.2, while dissolved oxygen ranges between 8-12 mg/L.

Suspended solids are generally lower than in habitats influenced by the freshwater plume of the Fraser River, with typical concentrations between 10 and 50 mg/L during the winter and summer, respectively.

4.3.2 Marine, high intertidal, vegetated habitat (MHIV)

This habitat includes the salt marshes found at elevations higher than mean sea level. They occur in Boundary Bay and are important areas for migratory shorebirds, waterfowl, and some raptors.

Physical descriptors

Sediments - mud/silt, may be organic peat.

Ecological descriptors

Vegetation - dominated in the lower elevations by saltgrass (Distichlis spicata) and glasswort (Salicornia virginica), merging into vegetation similar to the brackish marsh in the high marsh. Often drift Fucus distichus and Ulva lactuca occur in the lower reaches of the marsh.

Invertebrate fauna - large and diverse population of invertebrates - insects, worms (oligochaetes and polychaetes), amphipods (Anisogammarus confervicolus and Corophium spp.), isopods (Gnorimoshpaeroma spp.) and small crabs (Hemigrapsus oregonensis).

Birds - foraging habitat for raptors (i.e. marsh hawks, snowy owls, and short eared owls) and herons, also used by songbirds.

Mammals - mink, raccoon, and small rodents.

Fish - used by juvenile salmonids, sculpins, and sticklebacks for feeding when inundated by the tide.

Sensitive Components

Shorebirds and waterfowl - migration staging, feeding (spring through fall).

4.3.3 Marine, high intertidal, non-vegetated habitat (MHINV)

These areas are primarily the beaches or mud flats found along Boundary Bay, but also include the foreshore section of Roberts Bank between the coal port jetty and the ferry terminal jetty.

Physical descriptors

Sediments - silt/mud (mud flats) or sand (beaches).

Ecological descriptors

Vegetation - occasional occurrence of drift Fucus distichus and Ulva lactuca.

Invertebrate fauna - dominated by crustaceans (amphipods, isopods, and shore crabs (Hemigrapsus spp.)).

Birds - roosting habitat for gulls and shorebirds.

Mammals - foraging habitat for raccoon and mink.

Fish - foraging habitat for many species of small fish when inundated by the tide.

Sensitive Components

Shorebirds and waterfowl migration staging and feeding (summer and fall).

4.3.4 Marine, low intertidal, non-vegetated habitat (MLINV)

This habitat is primarily the sand flats that occur below mean sea level, which are extensive in Boundary Bay. They are intensively utilized by migratory birds.

Physical descriptors

Sediments - sand.

Ecological descriptors

Vegetation - occasional occurrence of drift Fucus distichus and Ulva lactuca.

Invertebrate fauna - this habitat supports a diverse and productive community of invertebrates, including the ghost shrimp (Callianassa spp.), lug worms (Abarenicola spp.), bivalves (Macoma spp. and Mya spp.) and many other burrowing or benthic gastropod and crustacean invertebrates (i.e. juvenile Cancer magister).

Birds - intensive use for feeding by migratory birds, especially shorebirds, gulls and dabbling ducks at low tide, and herons and diving ducks when inundated by the tide. The entire world population of the western sandpiper is thought to stopover in Boundary Bay twice yearly in the course of their migrations (CWS, 1988).

Mammals - mink and raccoon at low tide; river otter and harbour seal at high tide.

Fish - foraging habitat for juvenile sole, salmonids, and sculpins; smelt may spawn on sandflats.

Sensitive Components

Shorebird migration staging and feeding (summer and fall).

Commercial crab rearing (all year).

Recreational fishing for bivalves and crab (all year).

4.3.5 Marine, low intertidal, vegetated habitat (MLIV)

This habitat is primarily eelgrass beds. They are found from near the elevation of mean low tide and extend into the subtidal zone. They are highly productive habitats supporting a diverse community of periphyton (organisms growing on the eelgrass itself), and many fish and invertebrates.

Physical descriptors

Sediments - sand/silt.

Ecological descriptors

Vegetation - dominated by eelgrass (Zostera marina) and marine algae.

Invertebrate fauna - supports an extremely diverse and productive community of invertebrates, including Dungeness crab (Cancer magister), many gastropods, and bivalves (Clinocardium nutalli, Macoma spp., among others).

Birds - foraging habitat for diving ducks and, at low tide, brant and widgeon.

Mammals - harbour seals and river otter.

Fish - highly productive foraging habitat for juvenile salmonids and many other marine fishes; spawning habitat for herring.

Sensitive Components

Juvenile salmon (all species) rearing (spring through fall).

Commercial crab rearing and harvest (all year).

Diving ducks feeding and over-wintering (all year).

Shorebird feeding (fall and winter).

Herring - spawning (late winter - early spring); feeding (all year).

4.3.6 Marine, open habitat

This habitat includes the offshore regions in Boundary Bay and off Roberts Bank and Sturgeon Bank. The descriptors are those primarily found in the region out to the 10 m contour.

Physical descriptors

Sediments - variable sand/silt to boulders

Ecological descriptors

Vegetation - kelp (Nereocystis luetkeana) forms beds offshore of the Roberts Bank port and B.C. Ferry Tsawwassen terminal jetties and breakwater.

Invertebrate fauna - this habitat supports diverse zooplankton (including many larval fish and larval benthic invertebrates) and phytoplankton communities, and a diverse benthic fauna, including crustaceans (crabs and shrimp), worms, and bivalves.

Birds - utilized by diving ducks (mainly scoters), loons, grebes, cormorants, and murres. Kelp beds form foraging habitat for diving ducks, some dabbling ducks, and gulls.

Mammals - harbour seals and killer whales.

Fish - salmon, trout, sculpins, rockfish, dogfish, herring, and flounder. The kelp beds support a characteristic and diverse fish community.

Sensitive Components

Commercial crab harvest (all year).

Diving ducks feeding (all year, especially winter).

4.4 Sensitive habitat components

A number of areas within the estuary were identified as being of concern with respect to the potential impact of chlorophenols released to the environment. They include:

1) salmon enhancement projects;
2) overwintering habitat for trumpeter swans;
3) staging and wintering areas for shorebirds and waterfowl;
4) recreational bar fishing; and,
5) rearing areas for juvenile salmon.

The numbers (1 to 4) are used in Figures 47 - 50 to identify the sensitive habitats. Rearing areas for juvenile salmon are identified by habitat type. Areas where specific studies on utilization by salmon have been conducted are identified by the number "5".

4.4.1 Salmon enhancement projects

Hatcheries operated by, or under contract to, the Department of Fisheries and Oceans or community projects such as incubation boxes or release sites can be found at several locations within the study area (DFO, 1987a; 1987b; 1988). The habitats that would be most sensitive to environmental pressures include intertidal vegetated areas, backchannels and sloughs, and open water areas in the immediate vicinity, particularly during the period from May to July when juveniles are most likely to be present (Fraser River Estuary Study, 1978).

Salmon enhancement projects are presently found near the Alouette River, Kanaka Creek, Brunette River, Coquitlam River, Serpentine River, and Little Campbell River.

4.4.2 Overwintering habitat for the trumpeter swan

The trumpeter swan (Olor buccinator) is considered an endangered species (CWS, 1988) and although there has not been any identified risk from chlorophenols, there always exists some level of concern that should be recognized. The intertidal vegetated wetlands of the Pitt River, and the foreshore of Westham/Reifel and Lulu Islands, are the main overwintering (October to April) habitats for this species.

4.4.3 Staging and wintering areas for migratory waterfowl and shorebirds

The intertidal marshes of the lower estuary are staging and overwintering areas of many species of migratory waterfowl, including several of international significance. Internationally significant populations (as defined by Butler and Campbell, 1987) are those species in which a significant percentage of the total world population occur at some stage of the year and therefore the implication is that the population is at some risk with respect to environmental concerns. The species include the snow goose (Anser caerulescens), green-winged teal (Anas crecca), mallard (Anas platyrhynchos), american widgeon (Anas americana), canvasback (Aythya valisineria), greater scaup (Aythya marila), surf scoter (Melanitta perspicillata), white-winged scoter (Melinitta fusca), black scoter (Melinitta nigra), common goldeneye (Bucephala clangula), bufflehead (Bucephala albeola), common merganser (Mergus merganser), and ruddy duck (Oxyura jamaicensis).

The aquatic habitats most frequently utilized by the waterfowl are the lower estuarine intertidal marshes and estuarine backchannel/slough habitat. These habitats are in greatest use by the waterfowl in winter (October to April).

The intertidal sand and mud flats of Boundary Bay (low intertidal marine habitat, non-vegetated) are also staging areas for migratory shorebirds which use the bay during their annual migrations (September/October and April/May). Two species, the western sandpiper (Calidus mauri) and dunlin (Calidus alpina), are considered to be of international significance (Butler and Campbell, 1987).

4.4.4 Recreational bar fishing areas

All road-accessible riverine beaches and sandbars are potential fishing sites for the people of the lower mainland, and may be widely used especially during peak adult salmon migration periods. The concern is not with potential toxicity from eating fish contaminated with chlorophenols or from exposure or contact with waters with chlorophenols. It was identified as a use that may be affected by the presence of chlorophenols due to possible tainting, although this has not been reported for the Fraser River.

4.4.5 Rearing areas for juvenile salmon

It is generally accepted that estuarine habitats are critically important to juvenile salmonids. The residence time of individuals is to vary. Childerhose and Trim (1979) suggested that two weeks appears to be a reasonable estimate for all 5 species of salmon and steelhead trout. Work in the Nanaimo estuary (Healey, 1979; 1980) indicated that the average residence time for chinook fry was 25 days while chum fry were present between 0 and 18 days. In a more recent study in the marshes of the Fraser estuary, Levy and Northcote (1982) stated "...that chinook and chum fry resided temporarily in the marsh prior to migrating into the Pacific Ocean and returned to the same channel on several tidal cycles. Pink fry were abundant in the channels but appeared to be transient." The residence time for coho fry in the Squamish estuary varied from 3 to 10 days (Ryall and Levings, 1987), while chinook juveniles were present in the Campbell River estuary for 40 to 60 days (Levings et al., 1986). The following, based on information from Hart (1973), Northcote (1974), Levy et al. (1981) and Levy and Northcote (1981), summarizes the approximate seasonal occurrence of salmonids in the Fraser River estuary:

	Juveniles present in estuary	**Adult migration**
pink salmon (Oncorhynchus gorbuscha)	Feb - June	Sept - Oct
chum salmon (O. keta)	Mar - June	Oct - Nov
coho salmon (O. kitsutch)	April - June	Sept - Nov
sockeye salmon (O. nerka)	April - July	June - Aug
chinook salmon (O. tshawytscha)	Mar - July	Mar - Oct
steelhead trout (Salmo gairdneri)	April - June	June - Sept Nov - April
cutthroat trout (S. clarki clarki)	June	Nov - Feb

In this rewview, the freshwater intertidal vegetated (FIV), freshwater backchannel/slough (FBC), upper and lower estuarine intertidal vegetated (EUIV and ELIV), estuarine backchannel/slough (EBC), and marine lower intertidal vegetated (MLIV) habitats were identified to be particularly important for juvenile salmonids, although juveniles have also been found in non-vegetated habitat (Levings, 1982).

The designations are based on a series of detailed studies on marsh utilization by juvenile salmon in several areas including Duck, Woodward and Barber Islands, located near the mouth of the Main Arm of the Fraser River (Levy and Northcote, 1981; 1982; Levy et al., 1982); in Steveston Harbour (Anderson et al., 1981); Musqueam Marsh at the mouth of the North Arm and Swishwash Island at the mouth of the Middle Arm (Levy et al., 1982); and the foreshore area of Westham Island, mouth of the Main Arm (Levy et al., 1979). In addition, other studies, while less intensively sampled than the preceding, provided supporting information on the utilization of these habitats, particularly for the estuarine backchannels and sloughs. Juvenile salmon have been found in Tilbury and Deas Sloughs (Goodwin, 1975; Fisheries and Marine Service, 1978; Birtwell et al., 1987), Ladner Reach (Fisheries and Marine Service, 1978; Birtwell et al., 1987), and Annacis Channel (P. Harder and Associates Ltd., 1985a; 1985b). These study areas have been identified with a "5" on Figures 47 and 48.

Juvenile salmonids forage throughout the intertidal zone of the estuary, feeding on insect larvae, insect pupae and crustaceans (Levy et al., 1979). This activity extends deep into the vegetated intertidal and backchannel/slough habitats (Levy and Northcote, 1981; 1982). The fry move in and out of these habitats with the fluctuating tides and they undoubtedly forage over the adjacent sand and mud flats as they do so. Sibert (1979) and Healey (1979) indicate that the detrital food chain is the primary food source for chum fry in the Nanaimo estuary. Two of the sources of detritus to this food chain would be algal growth on mud/sand flats and intertidal vegetation. Thus, not only are these habitats of importance through direct utilization (foraging/shelter), they support the food web upon which juvenile salmonids depend.

5.0 DISCUSSION

Chlorophenols measured in sediments, water, fish tissues and invertebrates have been compiled into a single database, in order to review the distribution and concentrations in the Fraser River estuary. The database was linked with a biophysical map in order to display the data for the different regions of the study area. All data were standardized to parts per billion - ng/g dry weight for sediments, ug/L for water, and ng/g wet weight for biological tissues.

The chlorophenol compounds commonly in use by industry and in domestic markets are pentachlorophenol, 2,3,4,6-tetrachlorophenol and 2,3,4,5-tetrachlorophenol (Jones, 1981; NRCC, 1982), which were the three most commonly measured chemical species in the database. TTCP and PCP were reported in virtually all of the samples (>96% and >99%, respectively). Trichlorophenol is frequently one of the impurities in pentachlorophenol as well as a degradation product of TTCP and PCP (Jones, 1981). TCP was measured in 60% of the sediments, 72% of the water samples and 71% of the fish muscle samples, most frequently as 2,4,6-TCP and 2,4,5-TCP.

One difficulty with the number of compounds reported, which ranged from unspecified TTCP plus PCP values to over 15 different chemical species of DCP, TCP, TTCP, and PCP, is that it limits the extent to which comparisons can be made because the samples are not similar. In addition, when calculating a "total chlorophenol" value if the samples were not analyzed in a similar manner (i.e., unless all the CP species were reported), the total CP calculated may underestimate the true total.

The presence of a few very high values, frequent measurements below the detection limit, and a wide range in detection limits, resulted in a data set that was not normally distributed and parametric statistics were therefore not suitable. This was resolved by calculating the percentiles, with the 50th percentile (median) used as a measure of the "central tendency" of the data set, and the 90th percentile used to define the upper limits of the data set, without being unduly influenced by extreme values or "NDs".

Despite the limitations discussed above, when viewed graphically and presented on maps, several conclusions on chlorophenols in the sediments, water and fish tissues of the Fraser River estuary can be made from the database.

Total CP in water was generally highest in samples collected adjacent to known sources, but decreased within a short distance downstream. Dilution is likely responsible for this pattern. The high concentrations that are measured in water are likely from surface runoff from wood treatment facilities, which had pooled behind tidal gates and was released as the water level dropped. The discharge from these drainage ditches can have high concentrations of CP, particularly during the initial stages of a rainfall event. The intermittent release of this water would result in high ambient concentrations near the discharge point before being diluted by the main flow of the river. Time series data would more likely record these events, which would explain why of the water samples which exceeded B.C. provisional objectives of 0.2 ppb, most were measured during one such study.

An extensive review of acute or chronic toxicity information was not carried out for this report. The U.S. EPA has summarized chlorophenol data and calculated a fish acute toxicity value of 20 ppb, 24 ppb, and 25 ppb for 2,3,4,6-TTCP, 2,3,5,6-TTCP, and PCP, respectively (Jones, 1981). Water quality criteria published by the U.S. government recommend a maximum value of 5.5 ppb to protect against acute toxicity and 3.2 ppb to protect against chronic toxicity (USEPA, 1980). Acute toxicity concentrations (LC_{50}) for TTCP and PCP for salmonids range from 50 ppb to 200 ppm (Coastline, 1987). These criteria were generally met when compared with the 90th percentile from the present database, 2.08 ppb. However, tainting of fish tissues can occur at lower concentrations (1 - 2 ppb; USEPA, 1976).

Most of the wood treatment and processing facilities in the study area are located along the Main Stem, especially just upstream of the trifurcation, and along the North Arm. It was in these areas that the highest values for chlorophenols were measured. Water samples collected in the Main Arm, which does not have any sources of CP (except for possible contributions from the sewage treatment plants), were always below the B.C. provisional objectives.
Total chlorophenols in sediments were also highest in samples collected adjacent to known effluent sources, and the distribution was similar to that in water, with concentrations (median value) of 80 ppb, 40 ppb, and 46 ppb in the three areas with the highest density of wood processing facilities (Main Stem, downstream of Pitt River; upper section of the North Arm; and near Mitchell Island). By comparison, the upper and lower estuarine sections of the Main Arm had median concentrations of total CP of 19 ppb and 3 ppb, respectively.

Chlorophenols are rapidly adsorbed on organic matter and fine particulates and accumulation in the sediments near discharge points is expected (NRCC, 1982). The decrease in concentration short distances downstream suggests that the material is diluted or buried by the high natural sediment loading of the Fraser River, but that the discharge from the drainage ditches is sufficiently frequent to maintain higher concentrations near the source. Chlorophenols are not considered to be persistent chemicals; the half life in aquatic systems is thought to be about 5 days in many situations (NRCC, 1982). This is presumably for water and sediments; the data from this review illustrate that chlorophenols are accumulating in biological tissues.
Provisional water quality objectives for sediments have been set at 10 ppb maximum, based on the sum of TCP, TTCP, and PCP. This objective was exceeded in 32% of the samples; most of the samples were collected in areas adjacent to known sources. However, as was noted in Section 3.5.2 some of the samples which exceeded the provincial criterion may have been collected within the IDZ, within which the objectives were not intended to be applied.

The B.C. provisional objective for fish tissue (epaxial muscle) of 100 ppb wet weight, was exceeded in 26% of the samples, but unlike sediments and water, these high values were much less frequently associated with known sources of chlorophenols. The Main Arm, for example, did not appear to be different from areas in the North Arm or Main Stem that had higher concentrations of chlorophenols in water and sediments. The mobility of fish is one of the likely reasons for this pattern.

There was less apparent bias in the collection of fish samples than with sediments or water, and the data from the study area were more evenly distributed. The fish tissue data, however, do include information from a number of intensive sampling efforts for single species; over 80% of the starry flounder were collected at one site, while a second study was responsible for 79 of 81 analyses of eulachon.

A number of fish species were associated with high levels of CP, which exceeded the B.C. provisional objective - eulachon (56%), largescale sucker (44%), prickly sculpin (44%), and northern squawfish (37%). With the exception of eulachon, these species are generally not used as food, although species such as the squawfish and sucker may be eaten by some cultural groups, or used as pet food by local residents. Eulachon have traditionally been used by native groups as a source of food and they are also popular with many other residents of B.C. (Hart, 1973). There are no published criteria with respect to maximum concentrations for consumption by humans, but it is likely that odour and tainting of the tissues would render the flesh objectionable at lower concentrations than would be considered toxic (USEPA, 1976; NRCC, 1982).

Pentachlorophenol has been shown to bioaccumulate in numerous aquatic organisms to about 1000 times the concentration in water (NRCC, 1982). Carey et al. (1986) found concentrations in fish from 100 to 1400 times greater than in the North Arm of the Fraser River. For comparison, the median concentration of total CP in fish tissues (58 ppb) was 386 times the median concentration in water, in the database developed for this present study.

Total chlorophenol concentrations in invertebrates were very high for a number of species, predominately filter or deposit feeders such as oligochaetes, polychaetes, and bivalves. The 90th percentile for all invertebrates was 1380 ppb, which was nearly 8 times the maximum concentration found in sediments. The median concentration for invertebrates was 10 ppb compared with a median for sediments of 2 ppb total CP. The data suggest some bioaccumulation by some invertebrate organisms.
The only information from the study area for vertebrate species other than fish are data on blue heron eggs collected near University of British Columbia in 1983, which had a mean concentration of 2 ppb for both TTCP and PCP.

The biophysical maps present detailed information on the aquatic habitats which are found in the study area. A total of 15 different habitat types were incorporated into the maps, based on both water quality characteristics and biological (primarily vegetation) communities. The study area was separated into four broad habitat types: 1) freshwater; 2) upper estuarine; 3) lower estuarine; and, 4) marine. These in turn were separated into intertidal vegetated and non-vegetated zones, plus backchannels and sloughs. Several habitat zones were highlighted as having special features, which may require consideration in the development of water quality objectives, including objectives for chlorophenols. These features include: utilization by sensitive species (primarily juvenile salmonids); unique species such as the trumpeter swan; and populations of international significance (migrating and overwintering shorebirds and waterfowl). The habitats include the freshwater intertidal vegetated habitat; the freshwater backchannel/slough habitat; the upper and lower estuarine intertidal vegetated habitats; the estuarine backchannel/slough habitat; and the marine lower intertidal vegetated habitat.

There was insufficient information to establish any relationship between the concentration of total CP for water or sediments and biophysical characteristics. The main difficultly was that the data sources did not provide sufficient detail on the location of the sampling sites. As previously discussed, the higher values were all associated with samples collected adjacent to known effluent sources. Since the concentration of total CP in both sediments and water appears to decrease within a short distance of the effluent source, the habitats most immediately susceptible would be the intertidal vegetated zones and backchannels and sloughs adjacent to these discharges. Of greatest risk would be juvenile fish, and in particular salmonid juveniles, which may be exposed to partially diluted effluent during the initial periods of rainfall and the first flush of stormwater runoff from wood preservation facilities.

Elsewhere in the study area, away from chlorophenol sources, the concentration in water and in the sediments is much lower, with a correspondingly reduced risk in any of the aquatic habitats described. In fact, the lowest concentrations were measured in the largest areas utilized by many species of fish and birds, the marsh areas of Duck and Woodward Islands, in the lower estuarine region of the Main Arm, the Musqueam Marsh near the mouth of the North Arm, and the intertidal regions of Roberts and Sturgeon Banks, although it should be noted that there were fewer data collected in these habitats. There were no data for Boundary Bay with the exception of one fish sample (total CP < 100 ppb). There are no known sources of chlorophenols in this area and it is anticipated that the concentration of total CP in sediments and water would be low.

6.0 CONCLUSIONS AND RECOMMENDATIONS

A review of the chlorophenol data in sediments, water and biological tissues collected in the lower Fraser River has highlighted a number of conclusions regarding the distribution of these chemicals in the study area. Interpretation of the data set is limited, however, by the inconsistencies in the number of chemical species analyzed, by a wide range in detection limits, and by differing sampling strategies.

Most toxicity information and water quality objectives are based on total chlorophenol, which is calculated by summing the various chlorophenol compounds present in the sample. A significant number of samples were analyzed for only a few of the total number of chlorophenol compounds thus total CP may be underestimated. It is recommended that all analyses be standardized so that the same compounds are measured, include specifically the following chemical species: 2,4,5-TCP, 2,4,6-TCP, 2,3,4,5-TTCP, 2,3,4,6-TTCP, and PCP. These compounds are the major components of the known sources of chlorophenols to the study area, are the most frequently analyzed in the data set, and constitute over 95% of the total CP calculated (in those samples in which most of the chemical species were included in the analysis).

The minimum detectable concentration (MDC) should be lower than any of the criteria if comparisons are to be meaningful. While the detection limit will change for different chlorophenol species, the lowest MDC reported in the data set was similar for TCP, TTCP, and PCP. These were: sediments - 1 ng/g dry weight; water - 0.002 ug/L; and biological tissues - 0.05 ng/g wet weight. It is recommended that these detection limits be considered for future analyses.

Most of the higher concentrations for total CP measured in water and sediments were collected near known effluent sources. Samples collected some distance away were generally low in total CP. It is recommended that future programs include samples from sites in which there are no known sources nearby.

In the lower Fraser River, the collection of fish samples was much more geographically uniform than for water or sediments, with data available from most regions of the study area, both adjacent to effluent sources as well as in areas some distance away. It is therefore significant that a high number of samples (26%) exceeded the provisional objective set by the B.C. government. It is important to note that these objectives are not based on information on human health or toxicity effects from body burdens, but instead they reflect background values from relatively uncontaminated areas (Swain and Holms, 1985a). There is no information to suggest that the present chlorophenol levels in fish tissues constitute a human health concern or chronic toxicity to the fish. However, the data are indicative of elevated chlorophenol levels in the study area. Recent management strategies prohibiting the use of chlorophenols in the estuary should improve the situation.

There exist in the study area a number of aquatic habitats which include special features that should be considered in the development of water quality objectives. They fall into two categories - smaller, site specific micro-habitats (e.g., backchannels or sloughs) which occur throughout the region, and larger areas such as the lower estuarine vegetated habitats, and the marine intertidal regions of Roberts Bank, Sturgeon Bank, and Boundary Bay.

On the basis of the information in the database, the distribution of data for chlorophenols in sediments and water is source-related and no one habitat consistently showed higher or lower concentrations of chlorophenols.
For fish tissues, the data suggest a similarity between all habitats over the entire study area, with the possible exception of upstream of the Pitt River.

Future sampling should include areas within each of the biophysical habitats defined in this study, but at some distance (e.g. 1 - 2 km) from a known effluent source. Sampling should focus on sediments and fish tissues. Potential sites include:

1) Main Stem, upstream of Pitt River (freshwater habitat)
Stations 17 or 258

2) Main Arm, near Annacis Island (upper estuarine habitat)
Stations 41, 89, 264, or 281

3) Main Arm, near Steveston (lower estuarine habitat)
Stations 1, 42, 52, 251, or 92

4) North Arm, downstream of Mitchell Island (lower estuarine habitat)
Stations 26, 27, 45, or 194

5) Roberts Bank (marine habitat)
Stations 5 or 38

6) Sturgeon Bank, north of Iona Jetty (outer estuarine habitat)
Station 148

7) Boundary Bay (marine habitat)

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APPENDIX 2

FORMAT CODES FOR DATABASE

A. CHEMICAL SPECIES

01 - total chlorophenol
02 - dichlorophenol (DCP)
03 - trichlorophenol (TCP)
04 - tetrachlorophenol (TTCP)
05 - pentachlorophenol (PCP)
06 - PCB - AROCHLOR 1242 + 1254 + 1260
07 - dioxins
08 - 2,4-DCP
09 - 2,4,6-TCP
10 - 2,3,5-TCP
11 - 2,3,4-TCP
12 - 3,4,5-TCP
13 - 2,3,5,6-TTCP
14 - 2,3,4,6-TTCP
15 - 2,6-DCP
16 - 3,5-DCP
17 - 3,4-DCP
18 - 2,3,6-TCP
19 - 2,4,5-TCP
20 - 2,3,4,5-TTCP
21 - PHENOLS
22 - 2-CHLOROPHENOL
23 - 2,4,5,6-TTCP
24 - P-CHLOROPHENOL
25 - PCB - AROCHLOR 1254
26 - PCB - AROCHLOR 1242 + 1254
27 - PCB - AROCHLOR 1242
28 - PCB - (undesignated)
29 - PCB - AROCHLOR 1260
30 - 2,3-DCP

B. UNITS

01 - UG/G WET WEIGHT
02 - UG/KG WET WEIGHT
03 - UG/KG DRY WEIGHT
04 - UG/L
05 - NG/L
06 - NG/G WET WEIGHT
07 - NG/G DRY WEIGHT
08 - UG/G DRY WEIGHT
09 - PPB

10 - PPM
11 - PPB WET WEIGHT
12 - PPM DRY WEIGHT
13 - PPM WET WEIGHT
14 - PPB DRY WEIGHT

C. SAMPLING AGENCY

01 - Inland Waters Directorate, Vancouver
02 - National Water Research Institute, Burlington, Ontario
03 - Fisheries and Oceans, West Vancouver Laboratory
04 - Fisheries and Oceans, Habitat Protection, Vancouver
05 - Fisheries and Oceans, Research Branch, Vancouver
06 - Environmental Protection Service, West Vancouver
07 - B.C. Waste Management Branch, Lower Mainland Office, Surrey, B.C.
08 - B.C. Waste Management Branch, Head Office, Victoria
09 - B.C. Water Management Branch, Victoria
10 - Westwater Research Centre, University of B.C., Vancouver
11 - Greater Vancouver Regional District
12 - private consulting firms
13 - Seakem Oceanography Limited, Sidney, B.C.

D. ANALYTICAL LABORATORY

01 - Inland Waters Directorate, Vancouver
02 - National Water Research Institute, Burlington, Ontario
03 - Fisheries and Oceans, West Vancouver Laboratory
04 - Environmental Protection Service, West Vancouver
05 - B.C. Environmental Laboratory, U.B.C. campus, Vancouver
06 - E.V.S. Consultants Ltd., North Vancouver
07 - CanTest Ltd., Vancouver
08 - Westwater, University of British Columbia
09 - ASL, Vancouver
10 - Seakem Oceanography Limited, Sidney, B.C.

E. SAMPLE MEDIUM

W - water samples
T - biological tissues
S - sediment
E - effluent

F. BIOLOGICAL SPECIES

FISH

CK - chinook salmon
CH - chum salmon
CO - coho salmon
PK - pink salmon
SO - sockeye salmon
CT - cutthroat trout
PH - Pacific herring
DV - dolly varden trout
SS - staghorn sculpin
PS - prickly sculpin
LS - large-scale sucker
SF - starry flounder
NS - northern squawfish
EU - eulachon
PC - peamouth chub
WS - white sturgeon
SM - smelt
LA - lamprey
RT - rainbow trout
RS - Rex sole
ES - English sole
CA - Carp
MW - mountain whitefish
SD - speckled sanddab
ST - stickleback (spp.)
FS - flathead sole

INVERTEBRATES

LE - leeches
PO - polychaetes
AM - amphipods
CR - crustaceans
BI - bivalves
WO - worms
CM - Cancer magister (crab)
CY - crayfish
SR - shrimp (Crangon)
CI - chironomids
PE - pelecypods
OL - oligochaetes
SC - sea cucumber
PB - Pandalas borealis (shrimp)
MA - Macoma balthica (bivalve clam)
ME - Mytilus edulis (mussel)
OY - Crassostrea gigas (oyster)
CN - Clinocardium nuttalli (bivalve)
CC - Callianassa californiensis (ghost shrimp)
CP - Cancer productus (rock crab)

G. TISSUE TYPES

WT - whole animal (soft tissues)
EM - epaxial muscle
LI - liver
CM - chelaped muscle (crabs)
RE - residue (whole animal less liver)

H. AGE (FISH)

J - juvenile
S - smolts
F - fry
A - adult
0 - less than one year

1 to 9 - age in years

I. COMPOSITE SAMPLE

Yes or No

Tissues: several organisms of the same species combined before analysis.

Sediments: Several field samples (e.g. grabs) combined before analysis.

Water: Several field samples combined, usually collected over a period of time (several hours to several days).

J. REPLICATES (1 - 99)

Tissues: individuals of the same species, analyzed separately, but collected at the same place and time.

Sediments and water: more than one sample analyzed from the same place and time.

K. SEDIMENT TYPES: PARTICLE SIZE

Yes or No: Is there particle size information?

L. SEDIMENT TYPES: ORGANIC CONTENT

Yes or No: Is there organic content (% organic, TOC, etc.) information?

M. EFFLUENT

ST - stormwater
MU - municipal discharges
SM - sawmills and wood storage areas
AG - agricultural runoff
PM - paper mill
CH - chemical plant
LA - landfill site

N. AUXILIARY DATA

Yes or No: Are there additional water quality information available from the same time and place?

TABLE 1

STATION GROUPINGS, FRASER RIVER ESTUARY.
NUMBERS REFER TO SAMPLE SITES USED IN THE DATABASE AND IN THE FIGURES.

1.0 MAIN STEM
1.1 Main Stem - Kanaka Creek to Pitt River + Pitt River

47, 238 - 242, 258 - 260, 280

1.2 Main Stem - Pitt River to Bifurcation

6 - 19, 48, 78 - 82, 231 - 237, 255 - 257, 263

2.0 MAIN ARM
2.1 Main Arm - Bifurcation to Deas Slough

16, 41, 51, 88, 89, 214 - 217, 223 - 230, 248, 249, 264, 281

2.2 Main Arm - Deas Slough to Steveston

1, 3, 39, 42, 52, 90 - 92, 218 - 222, 250, 251, 261

3.0 NORTH ARM
3.1 North Arm - Bifurcation to Mitchell Island

2, 18, 34, 37, 49, 53, 54, 83, 84, 203 - 213, 246, 247, 262, 279

3.2 North Arm - Mitchell Island

30 - 33, 46, 55 - 57, 85, 86, 194 - 202, 252 -254, 271, 278

3.3 North Arm - Mitchell Island to N.A. Jetty + Middle Arm

4, 21 - 29, 43, 45, 50, 58, 59, 87, 190 - 193, 244, 265

4.0 MARINE
4.1 Offshore

93 - 98, 103 - 110, 243, 272 - 276

4.2 Roberts Bank

5, 38, 99 - 102

4.3 Sturgeon Bank - South Side of Iona Jetty

44, 157, 161, 164, 166, 167, 170, 172, 173, 176, 178, 179, 182 - 189

4.4 Sturgeon Bank - North Side of Iona Jetty

148 - 156, 158 - 160, 162, 163, 168, 169, 171, 174, 175, 177, 180-181

TABLE 2

RANGE OF DETECTION LIMITS (ppb)
REPORTED IN DATABASE
BY SAMPLE MEDIUM

MEDIUM	CHLOROPHENOL SPECIES			
	DCP	TCP	TTCP	PCP
Sediments (ppb dry wt.)	< 20	< 1	< 1	< 1
		< 5	< 2	< 2
		< 20	< 5	< 5
			< 10	< 10
Water (ppb)	< 0.001	< 0.01	< 0.002	< 0.002
	< 0.01	< 0.05	< 0.01	< 0.01
	< 0.015		< 0.05	< 0.05
	< 0.02			
Fish Tissue (ppb wet wt)	< 0.2	< 0.5	< 0.5	< 1
	< 0.5	< 1	< 5	< 5
	< 15	< 5	< 10	< 10
	< 20	< 15	< 20	< 20
	< 500	< 20		
	<2500	< 50		
		< 200		

TABLE 3

SUMMARY OF CHLOROPHENOL DATA
FROM THE FRASER RIVER ESTUARY[1]

NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb)
BY CHEMICAL SPECIES

		DCP	TCP	TTCP	PCP	TOTAL CP[2]
SEDIMENTS						
	n>MDC	0	16	132	129	137
	n<MDC	9	139	116	128	120
	$\bar{x}$ (n>MDC)	-	7.39	11.0	12.6	23.2
	SD	-	3.80	14.5	19.5	29.9
	MAX	-	15.1	90	107	180
	U.L.95% C.I.	-	9.25	13.4	15.9	28.3
	PERCENTILES					
	10th	LD	LD	LD	LD	LD
	25th	LD	LD	LD	LD	LD
	50th	LD	LD	1.00	1.00	2.00
	75th	LD	LD	6.00	5.00	14.0
	90th	LD	1.00	17.0	20.0	39.4
	n>OBJ(10ppb)	-	-	-	-	82
WATER						
	n>MDC	14	99	174	166	178
	n<MDC	109	49	32	40	28
	$\bar{x}$ (n>MDC)	0.018	0.024	0.705	0.159	0.852
	SD	0.039	0.021	1.66	0.326	1.94
	MAX	0.152	0.116	14.8	2.71	17.5
	U.L.95% C.I.	0.039	0.029	0.952	0.209	1.14
	PERCENTILES					
	10th	LD	LD	LD	LD	LD
	25th	LD	LD	0.010	0.009	0.040
	50th	LD	0.010	0.091	0.033	0.150
	75th	LD	0.023	0.481	0.090	0.583
	90th	0.033	0.047	1.70	0.372	2.08
	n>OBJ(0.2ppb)	-	-	-	-	88

TABLE 3 CONTINUED

NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) BY CHEMICAL SPECIES

	DCP	TCP	TTCP	PCP	TOTAL CP[2]
FISH (WHOLE/MUSCLE)					
n>MDC	69	88	292	311	315
n<MDC	49	174	65	54	55
$\bar{x}$ (n>MDC)	67.6	58.1	95.7	134	252
SD	131	193	269	344	699
MAX	736	1442	2522	3200	6239
U.L.95% C.I.	98.6	98.4	127	172	330
PERCENTILES					
10th	LD	LD	LD	LD	LD
25th	LD	LD	4.31	10.0	19.0
50th	5.05	LD	25.0	36.0	65.0
75th	17.4	3.19	61.0	81.0	165
90th	85.0	6.65	160	235	340
n>OBJ(100ppb)	-	-	-	-	101
FISH LIVER					
n>MDC	27	12	61	67	69
n<MDC	19	43	30	24	24
$\bar{x}$ (n>MDC)	44.8	19.8	67.0	105	182
SD	38.2	9.55	91.9	167	246
MAX	207	34.5	520	1030	1550
U.L.95% C.I.	59.2	25.2	90.1	145	242
PERCENTILES					
10th	LD	LD	LD	LD	LD
25th	LD	LD	LD	LD	LD
50th	24.5	LD	27.3	29.0	78.5
75th	35.2	LD	53.7	80.0	154
90th	54.5	20.1	89.0	160	286
INVERTEBRATES					
n>MDC	0	17	27	28	31
n<MDC	4	10	25	24	21
$\bar{x}$ (n>MDC)	-	225	388	392	816
SD	-	468	702	907	1830
MAX	-	2000	3000	4200	9200
U.L.95% C.I.	-	448	654	728	1460
PERCENTILES					
10th	LD	LD	LD	LD	LD
25th	LD	LD	LD	LD	LD
50th	LD	40.0	2.3	3.3	10.0
75th	LD	100.0	40.0	60.0	250.0
90th	LD	200.0	600.00	400.0	1380.0

TABLE 3 CONTINUED

NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb)
BY CHEMICAL SPECIES

	DCP	TCP	TTCP	PCP	TOTAL CP[2]
STARRY FLOUNDER					
n>MDC	59	67	75	75	76
n<MDC	10	8	2	2	1
$\bar{x}$ (n>MDC)	42.6	64.1	131	155	373
SD	106	217	427	477	1150
MAX	726	1442	2084	2329	6239
U.L.95% C.I.	69.8	116	227	263	631
PERCENTILES					
10th	LD	LD	2.17	5.70	19.0
25th	4.41	2.56	4.03	9.34	27.7
50th	10.2	4.61	7.77	16.6	41.3
75th	27.1	6.45	10.8	22.0	60.2
90th	77.2	11.6	140	55.0	195
n>OBJ(100ppb)	-	-	-	-	11

[1] The following abbreviations were used in Table 3:

n = number of samples
$\bar{x}$ = mean value of those samples which had detectable levels of chlorophenols
MDC = minimum detectable concentration or detection limit
SD = standard deviation
MAX = maximum concentration in group
U.L. 95% C.I. = upper limit, 95% confidence interval
n>OBJ = number of samples exceeding B.C. provisional water quality objectives.
LD = less than detectable (e.g., <MDC)

[2] Summaries of total chlorophenol data may not add up to the sum of the other four chlorophenol species (DCP, TCP, TTCP, & PCP) because each is based on a variable number of individual isomers.

TABLE 4

SUMMARY BY STATION GROUP OF CHLOROPHENOL DATA FOR SEDIMENTS, FRASER RIVER ESTUARY[1]

	STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb)				
			DCP	TCP	TTCP	PCP	TOTAL CP[2]
1.0	Main Stem, Kanaka Creek to Trifurcation (Freshwater Habitat)	n (>MDC)	0	5	37	36	38
		n (<MDC)	0	47	25	26	24
		x̄ (n>MDC)		5.2	20.0	21.1	40.1
		S.D.		3.12	19.1	20.1	33.7
		MAX		10	80	77	130
		U.L.95%C.I.		9.16	26.2	27.6	50.8
		PERCENTILES					
		10th		LD	LD	LD	LD
		25th		LD	LD	LD	LD
		50th		LD	3.0	5.0	11.0
		75th		LD	20.0	20.0	40.0
		90th		LD	30.0	30.0	80.0
1.1	Main Stem, Kanaka Creek to Pitt River + Pitt River (Freshwater Habitat)	n (>MDC)	0	1	7	8	8
		n (<MDC)	0	14	11	10	10
		x̄ (n>MDC)		1	9.14	14.1	22.2
		S.D.		-	5.24	12.8	16.5
		MAX		1	15	40	53
		U.L.95%C.I.		-	14.0	24.8	35.7
		PERCENTILES					
		10th		LD	LD	LD	LD
		25th		LD	LD	LD	LD
		50th		LD	LD	LD	LD
		75th		LD	5.0	9.0	13.0
		90th		LD	13.0	27.0	40.0
1.2	Main Stem, Pitt River to Trifurcation (Freshwater Habitat)	n (>MDC)	0	4	30	28	30
		n (<MDC)	0	33	14	16	14
		x̄ (n>MDC)		6.25	22.6	23.0	44.9
		S.D.		2.5	20.3	21.5	35.6
		MAX		10	80	77	130
		U.L.95%C.I.		10.2	29.8	31.4	57.6
		PERCENTILES					
		10th		LD	LD	LD	LD
		25th		LD	LD	LD	LD
		50th		LD	8.0	5.0	16.0
		75th		LD	30.0	29.0	55.0
		90th		5.0	40.0	40.0	80.0

TABLE 4 CONTINUED

STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP2
2.0 Main Arm, Trifurcation to Steveston (Estuarine Habitat)	n (>MDC)	0	0	25	23	26
	n (<MDC)	4	40	29	35	32
	$\bar{x}$ (n>MDC)	-	-	10.2	8.96	17.7
	S.D.	-	-	18.1	19.7	35.9
	MAX	-	-	90	90	180
	U.L.95%C.I.	-	-	17.7	17.5	32.2
	PERCENTILES					
	10th	-	LD	LD	LD	LD
	25th	-	LD	LD	LD	LD
	50th	-	LD	LD	LD	LD
	75th	-	LD	2.00	1.00	4.00
	90th	-	LD	12.0	5.00	17.0
2.1 Main Stem, Trifurcation to Deas Slough (Upper Estuarine Habitat)	n (>MDC)	0	0	20	18	21
	n (<MDC)	1	25	15	18	15
	$\bar{x}$ (n>MDC)	-	-	12.4	10.9	21.1
	S.D.	-	-	19.7	21.9	39.3
	MAX	-	-	90	90	180
	U.L.95%C.I.	-	-	21.6	21.8	39.0
	PERCENTILES					
	10th	-	LD	LD	LD	LD
	25th	-	LD	LD	LD	LD
	50th	-	LD	1.00	LD	2.00
	75th	-	LD	5.00	2.00	10.0
	90th	-	LD	18.0	5.00	19.0
2.2 Main Arm, Deas Slough to Steveston (Lower Estuarine Habitat)	n (>MDC)	0	0	5	5	5
	n (<MDC)	3	15	14	17	17
	$\bar{x}$ (n>MDC)	-	-	1.60	2.00	3.60
	S.D.	-	-	0.89	1.22	1.34
	MAX	-	-	3	4	5
	U.L.95%C.I.	-	-	2.71	3.52	5.14
	PERCENTILES					
	10th	-	LD	LD	LD	LD
	25th	-	LD	LD	LD	LD
	50th	-	LD	LD	LD	LD
	75th	-	LD	1.0	LD	LD
	90th	-	LD	2.0	2.0	3.0

TABLE 4 CONTINUED

STATION GROUP	STATISTIC	DCP	TCP	TTCP	PCP	TOTAL CP[2]
		NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb)				
3.0 North Arm, Trifurcation to N.A. Jetty + Middle Arm (Estuarine Habitat)	n (>MDC)	0	1	41	42	43
	n (<MDC)	3	50	23	25	24
	$\bar{x}$ (n>MDC)	-	1.00	7.76	12.5	19.7
	S.D.	-	-	6.22	22.5	25.7
	MAX	-	1.00	28	107	113
	U.L.95%C.I.	-	-	9.66	19.4	27.3
	PERCENTILES					
	10th	-	LD	LD	LD	LD
	25th	-	LD	LD	LD	LD
	50th	-	LD	4.0	3.0	6.0
	75th	-	LD	9.0	5.0	14.0
	90th	-	LD	14.0	18.0	28.0
3.1 North Arm, Trifurcation to Mitchell Island (Upper Estuarine Habitat)	n (>MDC)	0	1	14	14	15
	n (<MDC)	0	17	12	12	11
	$\bar{x}$ (n>MDC)		1.00	5.21	14.8	18.7
	S.D.		-	4.90	19.4	23.1
	MAX		1.00	19	56	75
	U.L.95%C.I.		-	8.04	26.0	31.5
	PERCENTILES					
	10th		LD	LD	LD	LD
	25th		LD	LD	LD	LD
	50th		LD	1.0	1.0	3.0
	75th		LD	6.0	5.0	16.0
	90th		LD	15.0	31.0	40.0
3.2 North Arm, Mitchell Island (Upper Estuarine Habitat)	n (>MDC)	0	0	11	11	11
	n (<MDC)	1	8	0	1	1
	$\bar{x}$ (n>MDC	-	-	7.82	14.9	22.7
	S.D.	-	-	7.37	30.9	32.3
	MAX	-	-	28	107	113
	U.L.95%C.I.	-	-	12.8	35.7	44.4
	PERCENTILES					
	10th	-	LD	3.0	1.0	3.0
	25th	-	LD	4.0	3.0	6.0
	50th	-	LD	5.0	3.0	8.0
	75th	-	LD	11.0	10.0	22.0
	90th	-	LD	12.0	18.0	46.0

TABLE 4 CONTINUED

STATION GROUP	STATISTIC	DCP	TCP	TTCP	PCP	TOTAL CP^2
		NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb)				
3.3 North Arm, Mitchell Island to N.A. Jetty + Middle Arm (Lower Estuarine Habitat)	n (>MDC)	0	0	16	17	17
	n (<MDC)	2	25	11	12	12
	$\bar{x}$ (n>MDC)	-	-	9.94	9.18	18.5
	S.D.	-	-	5.92	19.3	24.5
	MAX	-	-	28	84	112
	U.L.95%C.I.	-	-	13.1	19.1	34.1
	PERCENTILES					
	10th	-	LD	LD	LD	LD
	25th	-	LD	LD	LD	LD
	50th	-	LD	5.0	3.0	8.0
	75th	-	LD	10.0	5.0	14.0
	90th	-	LD	14.0	5.5	19.0
4.0 Marine	n (>MDC)	0	10	29	28	30
	n (<MDC)	2	2	39	42	40
	$\bar{x}$ (n>MDC)	-	9.13	4.60	4.58	11.8
	S.D.	-	2.99	4.40	4.36	11.1
	MAX	-	15.1	18.3	22.4	39.4
	U.L.95%C.I.	-	11.3	6.27	6.26	15.7
	PERCENTILES					
	10th	-	LD	LD	LD	LD
	25th	-	7.6	LD	LD	LD
	50th	-	9.1	LD	LD	LD
	75th	-	9.4	2.0	2.4	5.0
	90th	-	11.1	8.0	5.7	21.7
4.1 Marine Offshore	n (>MDC)	0	10	10	10	10
	n (<MDC)	0	0	14	14	14
	$\bar{x}$ (n>MDC		9.13	8.83	6.51	24.5
	S.D.		2.99	3.72	5.73	8.46
	MAX		15.1	18.3	22.4	39.4
	U.L.95%C.I.		11.3	11.5	10.6	30.5
	PERCENTILES					
	10th		7.6	LD	LD	LD
	25th		8.5	LD	LD	LD
	50th		9.4	LD	LD	LD
	75th		9.4	7.7	4.0	21.5
	90th		15.1	8.5	6.2	29.3

TABLE 4 CONTINUED

STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[2]
4.2 Marine, Roberts Bank	n (>MDC)	0	0	0	0	0
	n (<MDC)	1	1	3	3	3
	$\bar{x}$ (n>MDC)	-	-	-	-	-
	S.D.	-	-	-	-	-
	MAX	-	-	-	-	-
	U.L.95%C.I.	-	-	-	-	-
	PERCENTILES					
	10th	-	-	-	-	-
	25th	-	-	-	-	-
	50th	-	-	-	-	-
	75th	-	-	-	-	-
	90th	-	-	-	-	-
4.3 Sturgeon Bank, South Side of Iona Jetty	n (>MDC)	0	0	8	9	9
	n (<MDC)	1	1	11	11	11
	$\bar{x}$ (n>MDC)	-	-	3.50	4.11	7.22
	S.D.	-	-	4.00	3.26	6.44
	MAX	-	-	13	10	23
	U.L.95%C.I.	-	-	6.84	6.62	12.2
	PERCENTILES					
	10th	-	-	LD	LD	LD
	25th	-	-	LD	LD	LD
	50th	-	-	LD	LD	LD
	75th	-	-	2.0	3.0	6.0
	90th	-	-	4.0	9.0	9.0

TABLE 4 CONTINUED

STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[2]
4.4 Sturgeon Bank, North Side of Iona Jetty	n (>MDC)	0	0	11	9	11
	n (<MDC)	0	0	12	14	12
	$\bar{x}$ (n>MDC			1.55	2.89	3.91
	S.D.			1.21	2.93	3.42
	MAX			5	10	11
	U.L.95%C.I.			2.36	5.14	6.21
	PERCENTILES					
	10th			LD	LD	LD
	25th			LD	LD	LD
	50th			LD	LD	LD
	75th			1.0	2.0	3.0
	90th			2.0	2.5	4.0

[1] The following abbreviations were used in Table 4:

n = number of samples
$\bar{x}$ = mean value of those samples which had detectable levels of chlorophenols
MDC = minimum detectable concentration or detection limit
SD = standard deviation
MAX = maximum concentration in group
U.L. 95% C.I. = upper limit of 95% confidence interval
LD = less than detectable (e.g., < MDC)

[2] Summaries of total chlorophenol data may not add up to the sum of the other four chlorophenol species (DCP, TCP, TTCP, & PCP) because each is based on a variable number of individual isomers.

TABLE 5

SUMMARY BY STATION GROUP OF CHLOROPHENOL DATA FOR WATER
FRASER RIVER ESTUARY[1]

STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[2]
1.0 Main Stem, Kanaka Creek to Trifurcation (Freshwater Habitat)	n (>MDC)	0	6	12	14	14
	n (<MDC)	6	4	3	1	1
	x̄ (n>MDC)	-	0.018	0.030	0.051	0.084
	S.D.	-	0.004	0.033	0.098	0.126
	MAX	-	0.025	0.100	0.280	0.380
	U.L.95%C.I.	-	0.023	0.051	0.107	0.157
	PERCENTILES					
	10th	LD	LD	LD	0.01	0.01
	25th	LD	LD	0.01	0.01	0.02
	50th	LD	LD	0.015	0.01	0.04
	75th	LD	0.015	0.02	0.02	0.05
	90th	LD	0.02	0.10	0.28	0.38
1.1 Main Stem, Kanaka Creek to Pitt River + Pitt River (Freshwater Habitat)	n (>MDC)	0	0	3	4	4
	n (<MDC)	0	0	2	1	1
	x̄ (n>MDC)			0.017	0.012	0.025
	S.D.			0.006	0.021	0.013
	MAX			0.020	0.020	0.040
	U.L.95%C.I.			0.031	0.045	0.046
	PERCENTILES					
	10th			-	-	-
	25th			-	-	-
	50th			-	-	-
	75th			-	-	-
	90th			-	-	-
1.2 Main Stem, Pitt River to Trifurcation (Freshwater Habitat)	n (>MDC)	0	6	9	10	10
	n (<MDC)	6	4	1	0	0
	x̄ (n>MDC	-	0.018	0.034	0.066	0.108
	S.D.	-	0.004	0.038	0.113	0.144
	MAX	-	0.025	0.100	0.280	0.380
	U.L.95%C.I.	-	0.023	0.062	0.147	0.211
	PERCENTILES					
	10th	LD	LD	0.01	0.01	0.035
	25th	LD	LD	0.01	0.01	0.040
	50th	LD	0.015	0.015	0.01	0.045
	75th	LD	0.02	0.02	0.03	0.055
	90th	LD	0.025	0.10	0.28	0.38

TABLE 5 CONTINUED

STATION GROUP	STATISTIC	DCP	TCP	TTCP	PCP	TOTAL CP[2]
		NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb)				
2.0 Main Arm, Trifurcation to Steveston (Estuarine Habitat)	n (>MDC)	0	23	26	26	27
	n (<MDC)	24	5	2	2	1
	$\bar{x}$ (n>MDC)	-	0.016	0.014	0.024	0.051
	S.D.	-	0.005	0.009	0.022	0.025
	MAX	-	0.025	0.050	0.080	0.120
	U.L.95%C.I.	-	0.018	0.018	0.033	0.061
	PERCENTILES					
	10th	LD	LD	0.005	0.005	0.025
	25th	LD	0.01	0.01	0.01	0.035
	50th	LD	0.015	0.015	0.01	0.045
	75th	LD	0.02	0.015	0.04	0.065
	90th	LD	0.02	0.02	0.06	0.085
2.1 Main Arm, Trifurcation to Deas Slough (Upper Estuarine Habitat)	n (>MDC)	0	11	13	13	14
	n (<MDC)	12	4	2	2	1
	$\bar{x}$ (n>MDC)	-	0.017	0.015	0.018	0.045
	S.D.	-	0.005	0.012	0.016	0.026
	MAX	-	0.025	0.050	0.070	0.120
	U.L.95%C.I.	-	0.021	0.023	0.028	0.060
	PERCENTILES					
	10th	LD	LD	LD	LD	0.01
	25th	LD	LD	0.005	0.01	0.025
	50th	LD	0.015	0.01	0.01	0.035
	75th	LD	0.02	0.02	0.02	0.05
	90th	LD	0.02	0.02	0.025	0.065
2.2 Main Arm, Deas Slough to Steveston (Lower Estuarine Habitat)	n (>MDC)	0	12	13	13	13
	n (<MDC)	12	1	0	0	0
	$\bar{x}$ (n>MDC	-	0.015	0.013	0.030	0.057
	S.D.	-	0.005	0.003	0.025	0.024
	MAX	-	0.020	0.020	0.080	0.105
	U.L.95%C.I.	-	0.018	0.015	0.045	0.072
	PERCENTILES					
	10th	LD	0.01	0.01	0.005	0.035
	25th	LD	0.01	0.01	0.01	0.04
	50th	LD	0.015	0.015	0.02	0.045
	75th	LD	0.02	0.015	0.05	0.075
	90th	LD	0.02	0.015	0.060	0.085

TABLE 5 CONTINUED

STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[2]
3.0 North Arm, Trifurcation to N.A. Jetty (Estuarine Habitat)	n (>MDC)	14	70	136	126	137
	n (<MDC)	79	35	9	19	8
	$\bar{x}$ (n>MDC)	0.018	0.028	0.896	0.199	1.09
	S.D.	0.039	0.024	1.84	0.364	2.16
	MAX	0.152	0.116	14.8	2.71	17.5
	U.L.95%C.I.	0.041	0.033	1.21	0.263	1.45
	PERCENTILES					
	10th	LD	LD	0.009	LD	0.029
	25th	LD	LD	0.07	0.012	0.10
	50th	LD	0.003	0.22	0.05	0.278
	75th	LD	0.035	0.953	0.183	1.20
	90th	0.006	0.049	1.97	0.452	2.50
3.1 North Arm, Trifurcation to Mitchell Island (Upper Estuarine Habitat)	n (>MDC)	3	10	14	14	15
	n (<MDC)	6	4	7	7	6
	$\bar{x}$ (n>MDC)	0.005	0.030	0.143	0.051	0.202
	S.D.	0.002	0.009	0.214	0.105	0.252
	MAX	0.001	0.040	0.580	0.400	0.870
	U.L.95%C.I.	0.009	0.036	0.267	0.112	0.342
	PERCENTILES					
	10th	LD	LD	LD	LD	LD
	25th	LD	LD	LD	LD	LD
	50th	LD	0.028	0.015	0.01	0.06
	75th	0.003	0.035	0.02	0.015	0.094
	90th	0.006	0.035	0.47	0.05	0.48
3.2 North Arm, Mitchell Island (Upper Estuarine Habitat)	n (>MDC)	9	52	109	100	109
	n (<MDC)	67	28	1	10	1
	$\bar{x}$ (n>MDC	0.024	0.029	1.08	0.238	1.31
	S.D.	0.048	0.028	2.01	0.399	2.37
	MAX	0.152	0.116	14.8	2.71	17.5
	U.L.95%C.I.	0.061	0.036	1.46	0.316	1.76
	PERCENTILES					
	10th	LD	LD	0.06	0.003	0.084
	25th	LD	LD	0.153	0.03	0.192
	50th	LD	0.002	0.37	0.069	0.449
	75th	LD	0.043	1.47	0.268	1.83
	90th	0.004	0.058	2.27	0.591	2.77

TABLE 5 CONTINUED

STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[2]
3.3 North Arm, Mitchell Island to N.A. Jetty + Middle Arm (Lower Estuarine Habitat)	n (>MDC)	2	8	13	12	13
	n (<MDC)	6	3	1	2	1
	$\bar{x}$ (n>MDC)	0.014	0.019	0.157	0.052	0.219
	S.D.	0.009	0.005	0.274	0.035	0.298
	MAX	0.020	0.031	1.06	0.140	1.20
	U.L.95%C.I.	0.093	0.024	0.323	0.074	0.399
	PERCENTILES					
	10th	LD	LD	0.027	LD	0.055
	25th	LD	LD	0.04	0.019	0.094
	50th	LD	0.015	0.08	0.045	0.135
	75th	0.008	0.02	0.1	0.05	0.16
	90th	0.02	0.02	0.2	0.09	0.25
4.3 Marine	n (>MDC)	0	0	0	0	0
	n (<MDC)	0	0	18	18	18
	$\bar{x}$ (n>MDC)			-	-	-
	S.D.			-	-	-
	MAX			-	-	-
	U.L.95%C.I.			-	-	-
	PERCENTILES					
	10th			LD	LD	LD
	25th			LD	LD	LD
	50th			LD	LD	LD
	75th			LD	LD	LD
	90th			LD	LD	LD

[1] The following abbreviations were used in Table 5:

n = number of samples
$\bar{x}$ = mean value of those samples which had detectable levels of chlorophenols
MDC = minimum detectable concentration or detection limit
SD = standard deviation
MAX = maximum concentration in group
U.L. 95% C.I. = upper limit of 95% confidence interval
LD = less than detectable (e.g., < MDC)

[2] Summaries of total chlorophenol data may not add up to the sum of the other four chlorophenol species (DCP, TCP, TTCP, & PCP) because each is based on a variable number of individual isomers.

TABLE 6

SUMMARY OF CHLOROPHENOL DATA BY STATION GROUP
FOR FISH TISSUES (MUSCLE AND WHOLE BODY)
FRASER RIVER ESTUARY[1]

	STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[2]
1.0	Main Stem, Kanaka Creek to Trifurcation (Freshwater Habitat)	n (>MDC)	0	2	35	41	41
		n (<MDC)	5	39	10	6	6
		$\bar{x}$ (n>MDC)	-	62.5	57.5	183	235
		S.D.	-	24.7	85.1	494	571
		MAX	-	80	500	3200	3700
		U.L.95%C.I.	-	285	85.7	334	410
		PERCENTILES		-			
		10th	-	LD	LD	LD	LD
		25th	-	LD	3.00	10.0	20.0
		50th	-	LD	25.0	54.0	100
		75th	-	LD	55.0	170	215
		90th	-	LD	100	265	335
1.1	Main Stem, Kanaka Creek to Pitt River + Pitt River (Freshwater Habitat)	n (>MDC)	0	0	11	16	16
		n (<MDC)	0	11	9	6	6
		$\bar{x}$ (n>MDC)		-	56.7	224	203
		S.D.		-	147	794	917
		MAX		-	500	3200	3700
		U.L.95%C.I.		-	156	666	752
		PERCENTILES					
		10th		LD	LD	LD	LD
		25th		LD	LD	LD	LD
		50th		LD	3.0	15.0	20.0
		75th		LD	20.0	30.0	40.0
		90th		LD	20.0	54.0	60.0
1.2	Main Stem, Pitt River to Trifurcation (Freshwater Habitat)	n (>MDC)	0	2	24	25	25
		n (<MDC)	5	22	1	0	0
		$\bar{x}$ (n>MDC)	-	62.5	57.8	156	217
		S.D.	-	24.7	35.9	105	128
		MAX	-	80	140	405	545
		U.L.95%C.I.	-	285	151	200	270
		PERCENTILES					
		10th	-	LD	13.0	14.0	94.0
		25th	-	LD	30.0	80.0	140
		50th	-	LD	50.0	140	200
		75th	-	LD	70.0	200	275
		90th	-	LD	110	300	406

TABLE 6 CONTINUED

STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[2]
2.0 Main Arm, Trifurcation to Steveston (Estuarine Habitat)	n (>MDC)	3	6	88	91	91
	n (<MDC)	10	89	30	29	34
	x̄ (n>MDC)	371	435	133	173	343
	S.D.	349	541	319	362	871
	MAX	736	1442	1908	2329	6239
	U.L.95%C.I.	1238	1003	200	248	522
	PERCENTILES					
	10th	LD	LD	LD	LD	LD
	25th	LD	LD	LD	160.0	LD
	50th	LD	LD	36.0	42.0	86.0
	75th	LD	LD	60.0	100	160
	90th	337	LD	190	290	445
2.1 Main Arm, Trifurcation to Deas Slough (Upper Estuarine Habitat)	n (>MDC)	1	1	28	29	29
	n (<MDC)	5	46	25	25	25
	x̄ (n>MDC)	736	1442	108	256	435
	S.D.	-	-	319	429	1130
	MAX	736	1442	1732	2329	6239
	U.L.95%C.I.	-	-	231	419	847
	PERCENTILES					
	10th	LD	LD	LD	LD	LD
	25th	LD	LD	LD	LD	LD
	50th	LD	LD	20.0	35.0	60.0
	75th	41.0	LD	45.0	235	280
	90th	736	LD	80.0	365	445
2.2 Main Arm, Deas Slough to Steveston (Lower Estuarine Habitat)	n (>MDC)	2	5	60	62	62
	n (<MDC)	5	43	5	4	9
	x̄ (n>MDC)	189	234	145	135	300
	S.D.	209	249	321	323	726
	MAX	337	519	1908	2182	4284
	U.L.95%C.I.	2069	544	226	215	481
	PERCENTILES					
	10th	LD	LD	15.0	30.0	LD
	25th	LD	LD	30.0	40.0	60.0
	50th	LD	LD	50.0	50.0	95.0
	75th	LD	LD	80.0	70.0	154
	90th	337	LD	210	160	400

TABLE 6 CONTINUED

STATION GROUP	STATISTIC	DCP	TCP	TTCP	PCP	TOTAL CP[2]
		NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb)				
3.0 North Arm, Trifurcation to N.A. Jetty + Middle Arm (Estuarine Habitat)	n (>MDC)	64	78	164	176	178
	n (<MDC)	33	76	20	12	12
	$\bar{x}$ (n>MDC)	49.2	18.0	58.1	76.3	155
	S.D.	97.3	73.2	101	141	279
	MAX	460	547	952	1093	2324
	U.L.95%C.I.	73.1	34.3	73.6	97.2	196
	PERCENTILES					
	10th	LD	LD	LD	4.35	15.2
	25th	LD	LD	5.2	10.6	29.3
	50th	6.24	0.410	11.5	22.0	56.0
	75th	17.4	4.72	70.0	70.0	170
	90th	77.2	6.81	170	180	308
3.1 North Arm, Trifurcation to Mitchell Island (Upper Estuarine Habitat)	n (>MDC)	4	10	74	82	84
	n (<MDC)	18	59	17	12	12
	$\bar{x}$ (n>MDC)	68.8	7.96	64.2	90.6	149
	S.D.	42.4	8.9	55.9	99.7	145
	MAX	114	26.2	260	480	740
	U.L.95%C.I.	128	13.8	76.9	112	180
	PERCENTILES					
	10th	LD	LD	LD	LD	LD
	25th	LD	LD	5.2	9.9	20.9
	50th	LD	LD	40.0	40.0	90.0
	75th	LD	LD	70.0	110	200
	90th	69.0	3.31	145	210	285
3.2 North Arm, Mitchell Island (Upper Estuarine Habitat)	n (>MDC)	56	59	66	67	67
	n (<MDC)	8	8	1	0	0
	$\bar{x}$ (n>MDC)	48.3	6.89	34.2	45.1	125
	S.D.	103	10.9	121	123	289
	MAX	460	69.0	952	933	2029
	U.L.95%C.I.	75.3	9.68	63.4	74.6	195
	PERCENTILES					
	10th	LD	LD	2.19	7.28	22.3
	25th	4.99	2.56	4.11	9.37	30.5
	50th	11.2	4.30	7.80	18.1	44.8
	75th	30.6	6.37	11.5	22.7	75.1
	90th	77.2	7.96	76.0	110	260

TABLE 6 CONTINUED

STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[2]
3.3 North Arm, Mitchell Island to N.A. Jetty + Middle Arm (Lower Estuarine Habitat)	n (>MDC)	4	9	24	27	27
	n (<MDC)	7	9	2	0	0
	$\bar{x}$ (n>MDC)	43.5	102	105	110	244
	S.D.	47.2	204	133	245	489
	MAX	94	547	587	1093	2324
	U.L.95%C.I.	119	259	161	207	438
	PERCENTILES					
	10th	LD	LD	5.00	12.0	15.6
	25th	LD	LD	10.0	15.5	25.5
	50th	LD	0.46	20.0	30.0	50.0
	75th	6.0	2.30	170	60.0	270
	90th	73.3	357	194	180	310
4.0 Marine	n (>MDC)	1	1	4	2	4
	n (<MDC)	1	2	37	39	37
	$\bar{x}$ (n>MDC)	217	602	542	1080	1297
	S.D.	-	-	1029	1457	2506
	MAX	217	602	2084	2111	5054
	U.L.95%C.I.	-	-	2179	14174	5283
	PERCENTILES					
	10th	-	-	LD	LD	LD
	25th	-	-	LD	LD	LD
	50th	-	-	LD	LD	LD
	75th	-	-	LD	LD	LD
	90th	-	-	LD	LD	LD

[1] The following abbreviations were used in Table 6:

n = number of samples
$\bar{x}$ = mean value of those samples which had detectable levels of chlorophenols
MDC = minimum detectable concentration or detection limit
SD = standard deviation
MAX = maximum concentration in group
U.L. 95% C.I. = upper limit of 95% confidence interval
LD = less than detectable (e.g., < MDC)

[2] Summaries of total chlorophenol data may not add up to the sum of the other four chlorophenol species (DCP, TCP, TTCP, & PCP) because each is based on a variable number of individual isomers.

TABLE 7

SUMMARY BY STATION GROUP OF CHLOROPHENOL DATA FOR FISH LIVER
FRASER RIVER ESTUARY

STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[2]
1.0 Main Stem, Kanaka Creek to Trifurcation (Freshwater Habitat)	n (>MDC)	4	0	12	12	12
	n (<MDC)	4	12	0	0	0
	$\bar{x}$ (n>MDC)	79.5	-	75.7	144	246
	S.D.	816	-	86.4	166	253
	MAX	207	-	320	600	920
	U.L.95%C.I.	216	-	131	250	407
	PERCENTILES					
	10th	LD	LD	2.0	3.00	5.00
	25th	LD	LD	25.4	67.3	92.7
	50th	27.7	LD	60.4	113	205
	75th	57.8	LD	95.7	140	388
	90th	207	LD	128	319	448
1.1 Main Stem, Kanaka Creek to Pitt River + Pitt River (Freshwater Habitat)	n (>MDC)	0	0	3	3	3
	n (<MDC)	1	3	0	0	0
	$\bar{x}$ (n>MDC)	-	-	8	48.7	56.7
	S.D.	-	-	10.4	79.1	89.4
	MAX	-	-	20	140	160
	U.L.95%C.I.	-	-	33.8	245	279
	PERCENTILES					
	10th	-	-	-	-	-
	25th	-	-	-	-	-
	50th	-	-	-	-	-
	75th	-	-	-	-	-
	90th	-	-	-	-	-
1.2 Main Stem, Pitt River to Trifurcation (Freshwater Habitat)	n (>MDC)	4	0	9	9	9
	n (<MDC)	3	9	0	0	0
	$\bar{x}$ (n>MDC	79.5	-	98.2	176	309
	S.D.	85.7	-	89.2	179	261
	MAX	207	-	320	600	920
	U.L.95%C.I.	216	-	167	313	510
	PERCENTILES					
	10th	LD	LD	25.4	29.0	68.2
	25th	LD	LD	43.8	87.8	159
	50th	27.7	LD	82.4	113	229
	75th	51.8	LD	95.7	140	388
	90th	207	LD	320	600	920

TABLE 7 CONTINUED

STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[2]
2.0 Main Arm, Trifurcation to Steveston (Estuarine Habitat)	n (>MDC)	9	0	24	24	24
	n (<MDC)	7	16	0	0	1
	$\bar{x}$ (n>MDC)	24.4	-	68.1	159	263
	S.D.	11.9	-	101	223	309
	MAX	54.5	-	520	1030	1550
	U.L.95%C.I.	38.5	-	111	254	394
	PERCENTILES					
	10th	LD	LD	LD	16.7	10.0
	25th	LD	LD	21.9	26.6	59.9
	50th	19.7	LD	34.4	32.5	79.2
	75th	27.4	LD	55.0	35.7	103
	90th	39.7	LD	60.9	155	145
2.1 Main Arm, Trifurcation to Deas Slough (Upper Estuarine Habitat)	n (>MDC)	3	0	7	7	8
	n (<MDC)	4	7	0	0	0
	$\bar{x}$ (n>MDC)	42.9	-	40.5	33.8	81.1
	S.D.	10.4	-	21.5	13.8	53.7
	MAX	54.5	-	71.3	54.6	150
	U.L.95%C.I.	68.7	-	60.4	46.6	126
	PERCENTILES					
	10th	LD	LD	10.0	9.0	9.0
	25th	LD	LD	21.9	28.1	68.7
	50th	LD	LD	40.6	34.2	82.5
	75th	39.7	LD	60.9	41.7	145
	90th	54.5	LD	71.3	54.6	150
2.2 Main Arm, Deas Slough to Steveston (Lower Estuarine Habitat)	n (>MDC)	6	0	7	9	9
	n (<MDC)	3	9	2	0	0
	$\bar{x}$ (n>MDC	22.6	-	36.9	35.2	78.9
	S.D.	4.24	-	16.3	25.3	31.6
	MAX	27.4	-	577	101	136
	U.L.95%C.I.	27.1	-	51.9	54.6	103
	PERCENTILES					
	10th	LD	LD	LD	16.7	27.6
	25th	LD	LD	12.4	25.4	59.9
	50th	19.7	LD	32.9	27.2	79.2
	75th	23.9	LD	42.1	32.5	98.9
	90th	27.4	LD	57.7	101	136

TABLE 7 CONTINUED

STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[2]
3.0 North Arm, Trifurcation to N.A. Jetty (Estuarine Habitat)	n (>MDC)	14	12	16	18	19
	n (<MDC)	8	12	2	0	0
	$\bar{x}$ (n>MDC)	44.9	19.8	68.3	51.1	126
	S.D.	24.5	9.55	109	105	201
	MAX	110	34.5	470	470	940
	U.L.95%C.I.	59.0	25.9	126	109	223
	PERCENTILES					
	10th	LD	LD	14.4	40.6	78.5
	25th	LD	LD	27.3	56.6	128
	50th	28.6	LD	50.9	74.2	171
	75th	37.9	16.6	74.0	162	286
	90th	70.7	29.6	140	470	760
3.1 North Arm, Trifurcation to Mitchell Island (Upper Estuarine Habitat)	n (>MDC)	8	0	11	11	11
	n (<MDC)	1	11	0	0	0
	$\bar{x}$ (n>MDC)	39.4	-	65.0	166	259
	S.D.	14.4	-	29.5	169	184
	MAX	70.7	-	140	620	760
	U.L.95%C.I.	51.5	-	84.8	278	383
	PERCENTILES					
	10th	LD	LD	45.0	57.2	144
	25th	28.6	LD	50.9	60.2	149
	50th	32.1	LD	53.7	100	181
	75th	37.9	LD	74.0	188	313
	90th	70.7	LD	96.0	300	396
3.2 North Arm, Mitchell Island (Upper Estuarine Habitat)	n (>MDC)	6	12	13	13	13
	n (<MDC)	7	1	0	0	1
	$\bar{x}$ (n>MDC	52.1	19.8	70.8	154	267
	S.D.	34.1	9.55	137	269	393
	MAX	110	34.5	520	1030	1550
	U.L.95%C.I.	87.9	25.9	154	316	504
	PERCENTILES					
	10th	LD	5.69	12.2	40.6	64.1
	25th	LD	11.3	17.8	50.7	91.5
	50th	LD	16.6	27.3	65.1	146
	75th	35.2	28.7	41.9	88.6	203
	90th	76.8	31.3	108	224	315

TABLE 7 CONTINUED

STATION GROUP	STATISTIC	DCP	TCP	TTCP	PCP	TOTAL CP[2]
		NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb)				
3.3 North Arm, Mitchell Island to N.A. Jetty + Middle Arm (Lower Estuarine Habitat)	n (>MDC)	0	0	2	2	2
	n (<MDC)	0	2	0	0	0
	$\bar{x}$ (n>MDC)		-	246	237	514
	S.D.		-	274	329	603
	MAX		-	470	470	940
	U.L.95%C.I.		-	2741	3192	5933
	PERCENTILES					
	10th		-	-	-	-
	25th		-	-	-	-
	50th		-	-	-	-
	75th		-	-	-	-
	90th		-	-	-	-
4.0 Marine	n (>MDC)	0	0	9	13	14
	n (<MDC)	0	1	28	24	23
	$\bar{x}$ (n>MDC)		-	50.0	33.7	63.4
	S.D.		-	29.9	33.8	48.9
	MAX		-	126	110	206
	U.L.95%C.I.		-	73.0	52.1	91.6
	PERCENTILES					
	10th		-	LD	LD	LD
	25th		-	LD	LD	LD
	50th		-	LD	LD	LD
	75th		-	LD	12.0	43.0
	90th		-	43.0	28.0	83.0

[1] The following abbreviations were used in Table 7:

n = number of samples
$\bar{x}$ = mean value of those samples which had detectable levels of chlorophenols
MDC = minimum detectable concentration or detection limit
SD = standard deviation
MAX = maximum concentration in group
U.L. 95% C.I. = upper limit of 95% confidence interval
LD = less than detectable (e.g., < MDC)

[2] Summaries of total chlorophenol data may not add up to the sum of the other four chlorophenol species (DCP, TCP, TTCP, & PCP) because each is based on a variable number of individual isomers.

TABLE 8

NUMBER OF OBSERVATIONS EXCEEDING THE MINIMUM DETECTABLE CONCENTRATION (MDC) AND TOTAL NUMBER OF CHLOROPHENOL MEASUREMENTS FOR SELECTED FISH SPECIES.

		MUSCLE TISSUE OR WHOLE BODY ANALYSIS			LIVER TISSUE	
SPECIES	CODE	NUMBER OF SAMPLES (n)	n>MDC	n>OBJ (% TOTAL)	NUMBER OF SAMPLES (n)	n>MDC
CHINOOK	CK	6	0	0	6	0
SOCKEYE	SO	6	0	0	6	0
CUTTHROAT TROUT	CT	8	1	0	0	0
DOLLY VARDEN	DV	10	1	0	1	1
STAGHORN SCULPIN	SS	19	13	2 (11%)	3	2
PRICKLY SCULPIN	PS	27	27	12 (44%)	8	8
LARGESCALE SUCKER	LS	57	50	25 (44%)	0	0
STARRY FLOUNDER	SF	78	77	11 (14%)	12	12
NORTHERN SQUAWFISH	NS	38	32	14 (37%)	0	0
EULACHON	EU	81	76	45 (56%)	30	30
PEAMOUTH CHUB	PC	16	11	3 (19%)	0	0
WHITE STURGEON	WS	25	18	9 (36%)	0	0
SMELT	SM	1	1	0	0	0
LAMPREY	LA	5	5	4 (80%)	0	0
RAINBOW TROUT	RT	5	3	0	1	1
REX SOLE	RS	12	1	1 (8%)	12	12
ENGLISH SOLE	ES	12	0	0	12	2
CARP	CA	1	1	1	0	0

TABLE 9

SUMMARY BY STATION GROUP OF CHLOROPHENOL DATA FOR INVERTEBRATES
FRASER RIVER ESTUARY

STATION GROUP	STATISTIC	NUMBER OF SAMPLES (n) AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[2]
1.0 Main Stem, Kanaka Creek to Trifurcation (Freshwater Habitat)	n (>MDC)	0	6	6	7	9
	n (<MDC)	0	3	4	3	1
	$\bar{x}$ (n>MDC)		400	551	637	1129
	S.D.		786	667	1571	3028
	MAX		2000	3000	4200	9200
	U.L.95%C.I.		1225	1251	2090	3457
	PERCENTILES					
	10th		LD	LD	LD	5.0
	25th		LD	LD	LD	60.0
	50th		40.0	30.0	30.0	90.0
	75th		80.0	40.0	60.0	250
	90th		2000	3000	4200	9200
2.0 Main Arm, Trifurcation to Steveston (Estuarine Habitat)	n (>MDC)	0	6	7	7	7
	n (<MDC)	0	0	1	1	1
	$\bar{x}$ (n>MDC)		137	344	447	909
	S.D.		144	536	908	1556
	MAX		400	1500	2500	4400
	U.L.95%C.I.		288	840	1287	2347
	PERCENTILES					
	10th		3.0	LD	LD	LD
	25th		30.0	20.0	40.0	140
	50th		100	100	100	260
	75th		200	500	200	770
	90th		400	1500	2500	4400
3.0 North Arm, Trifurcation to N.A. Jetty (Estuarine Habitat)	n (>MDC)	0	5	12	12	12
	n (<MDC)	4	5	0	0	0
	$\bar{x}$ (n>MDC)	-	122	396	281	728
	S.D.	-	71.6	558	380	945
	MAX	-	200	1700	1000	2500
	U.L.95%C.I.	-	211	751	522	1328
	PERCENTILES	-				
	10th	-	LD	2.3	3.2	5.6
	25th	-	LD	3.7	5.0	9.4
	50th	-	60.0	20.0	40.0	130
	75th	-	80.0	900	800	1500
	90th	-	200	1000	800	2200

TABLE 9 CONTINUED

STATION GROUP	STATISTIC	NUMBER OF SAMPLES AND CHLOROPHENOL CONCENTRATION (ppb) DCP	TCP	TTCP	PCP	TOTAL CP[1]
4.0 Marine	n (>MDC)	0	0	2	2	3
	n (<MDC)	0	2	20	20	19
	$\bar{x}$ (n>MDC)		-	13.0	9.50	15.0
	S.D.		-	11.3	6.36	5.57
	MAX		-	21.0	14.0	21.0
	U.L.95%C.I.		-	115	66.7	28.8
	PERCENTILES					
	10th		-	LD	LD	LD
	25th		-	LD	LD	LD
	50th		-	LD	LD	LD
	75th		-	LD	LD	LD
	90th		-	LD	LD	10.0

[1] The following abbreviations were used in Table 9:

n = number of samples
$\bar{x}$ = mean value of those samples which had detectable levels of chlorophenols
MDC = minimum detectable concentration or detection limit
SD = standard deviation
MAX = maximum concentration in group
U.L. 95% C.I. = upper limit of 95% confidence interval
LD = less than detectable (e.g., < MDC)

[2] Summaries of total chlorophenol data may not add up to the sum of the other four chlorophenol species (DCP, TCP, TTCP, & PCP) because each is based on a variable number of individual isomers.

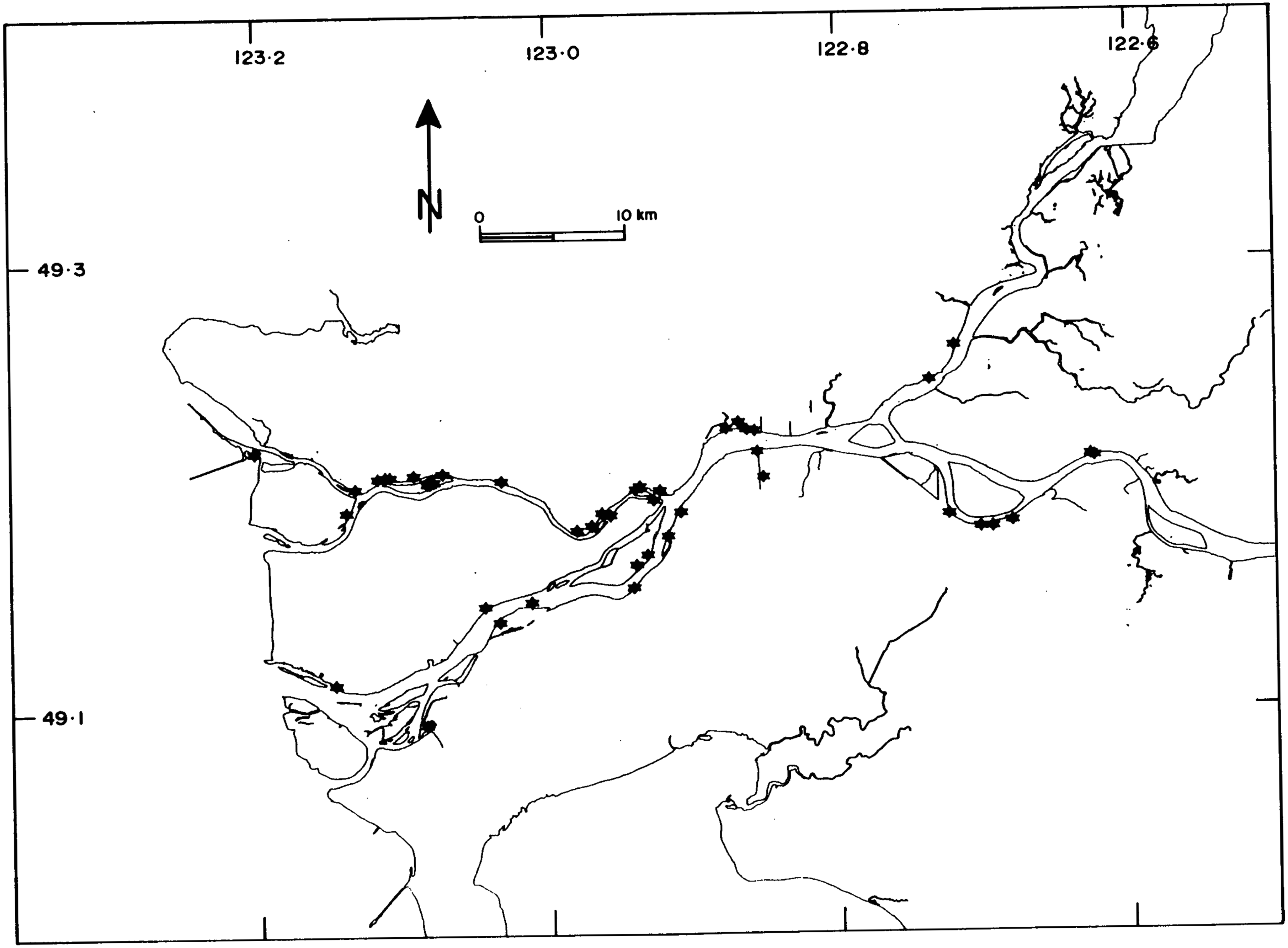

FIGURE 1. OVERVIEW OF STUDY AREA SHOWING LOCATION OF SOURCES OF CHLOROPHENOLS.

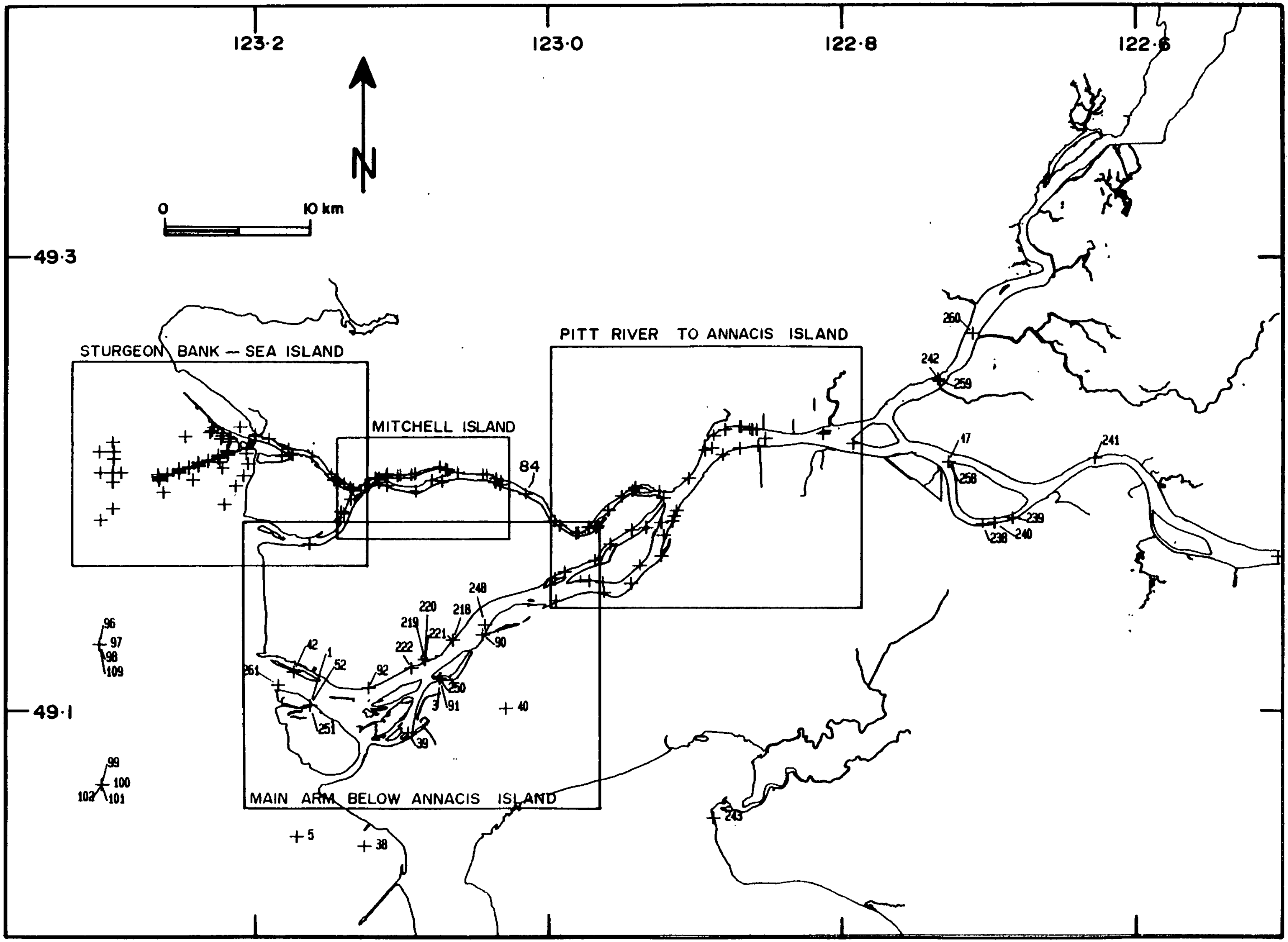

FIGURE 2. SAMPLING LOCATIONS, CHLOROPHENOL DATA, FRASER RIVER ESTUARY. AREAS WHERE SITES ARE CLOSELY GROUPED ARE OUTLINED AND PRESENTED ON SEPARATE FIGURES.

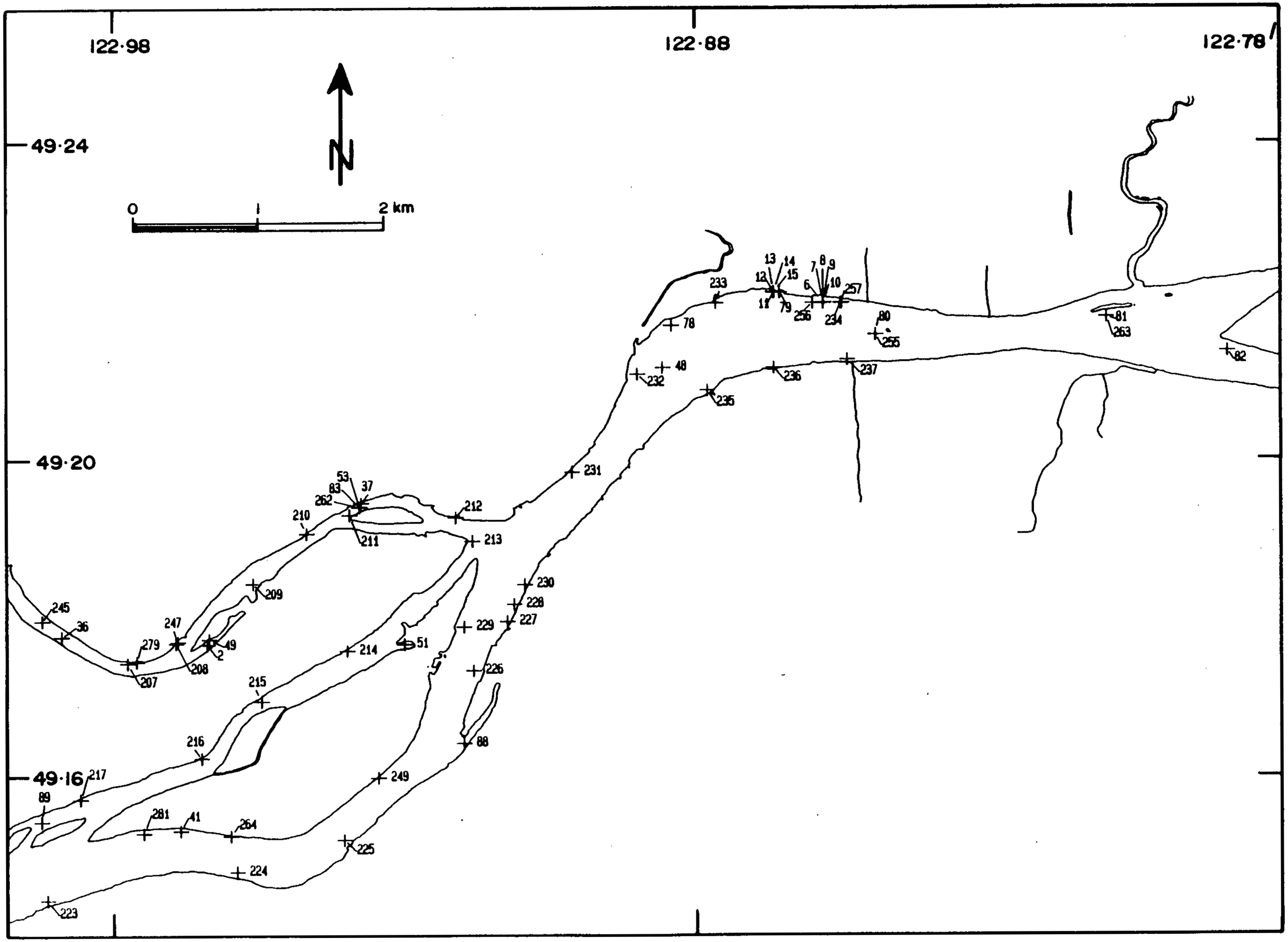

FIGURE 3. SAMPLING LOCATIONS, CHLOROPHENOL DATA. PITT RIVER TO ANNACIS ISLAND, FRASER RIVER ESTUARY.

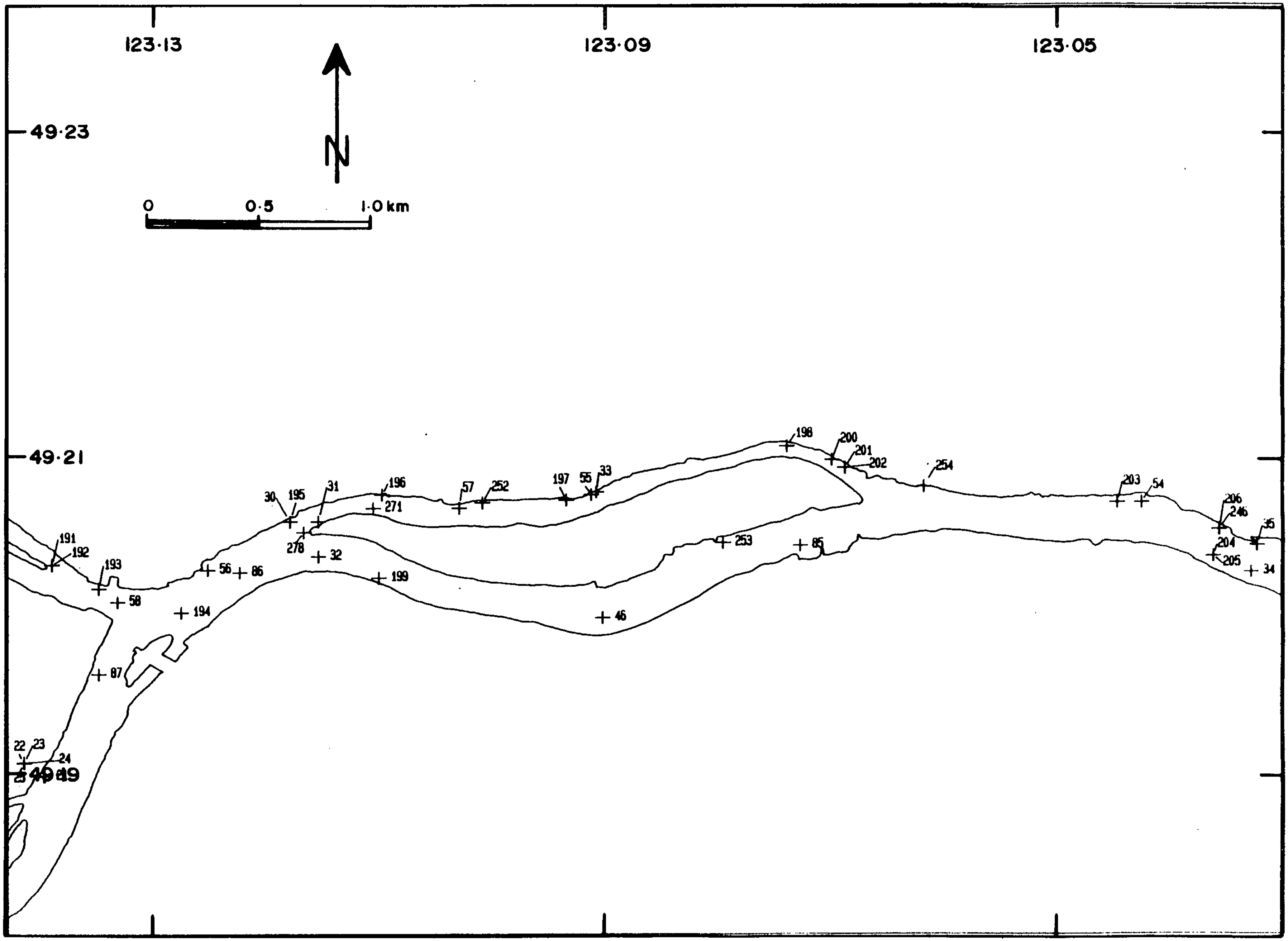

FIGURE 4. SAMPLING LOCATIONS, CHLOROPHENOL DATA. MITCHELL ISLAND, NORTH ARM, FRASER RIVER ESTUARY.

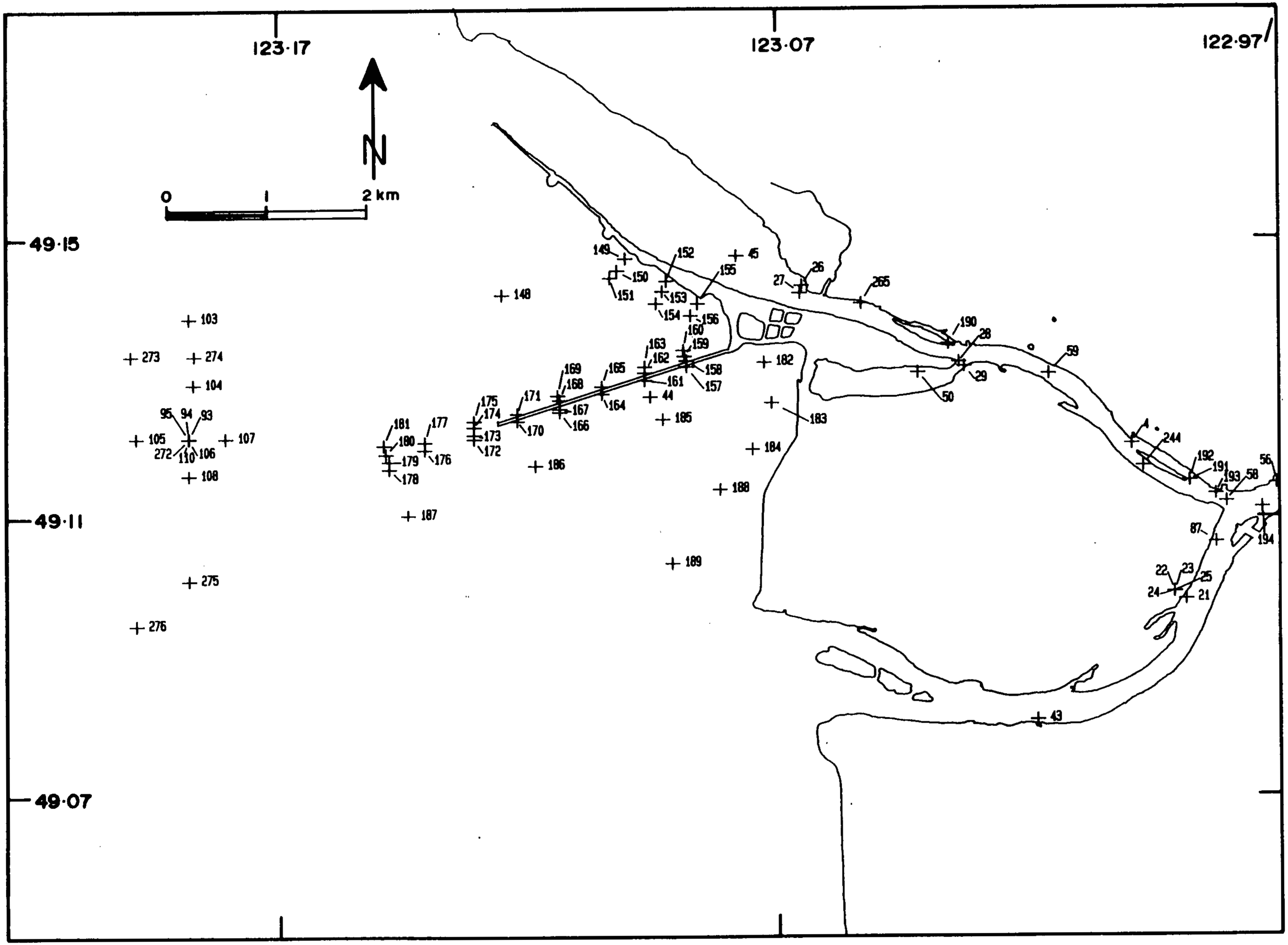

FIGURE 5. SAMPLING LOCATIONS, CHLOROPHENOL DATA. STURGEON BANK - SEA ISLAND, FRASER RIVER ESTUARY.

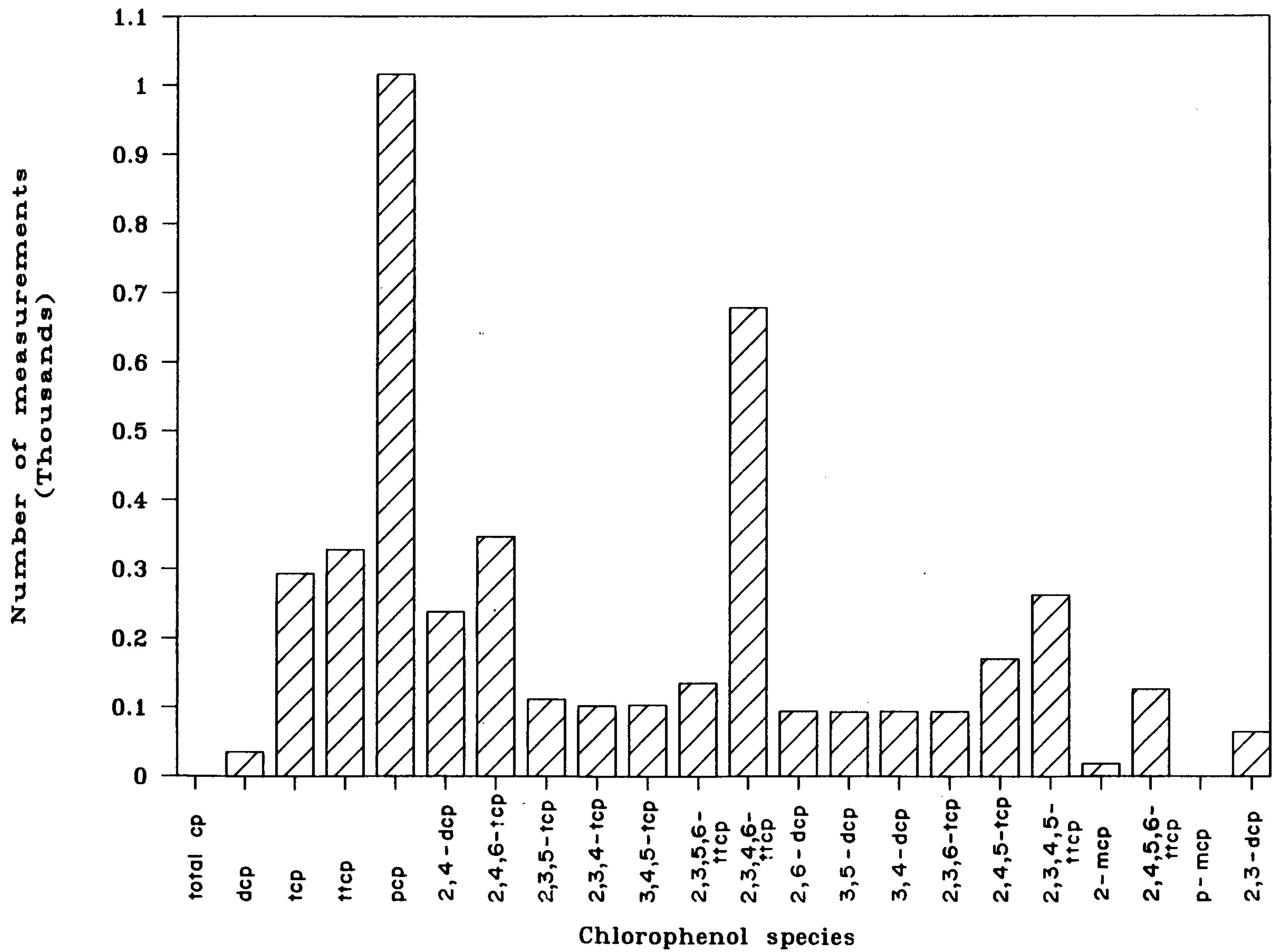

FIGURE 6. FREQUENCY DISTRIBUTION OF CHLOROPHENOL OBSERVATIONS BY CHEMICAL SPECIES, FRASER RIVER ESTUARY. CHEMICAL SPECIES CODES ARE DESCRIBED IN TEXT.

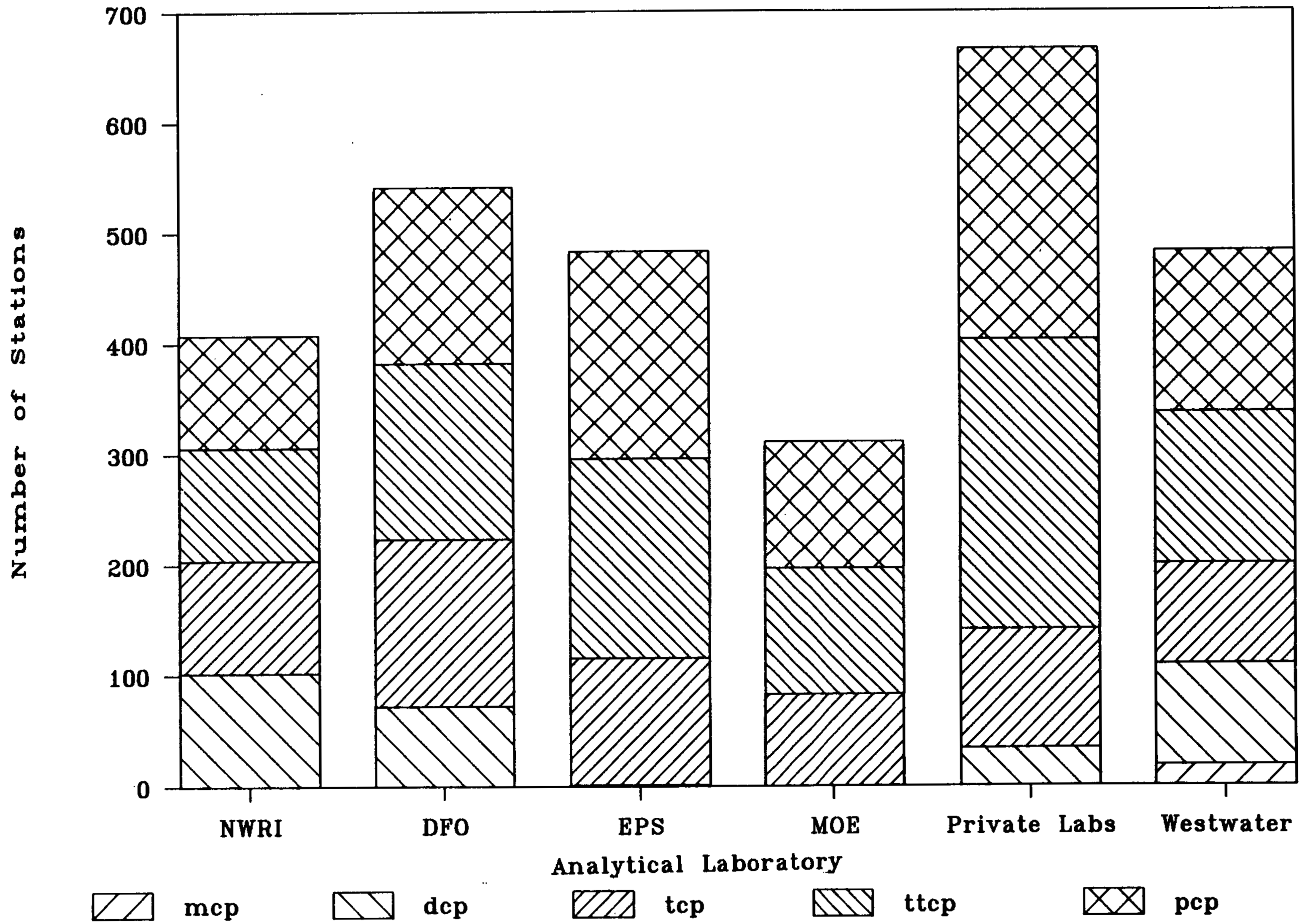

FIGURE 7. FREQUENCY DISTRIBUTION OF CHEMICAL SPECIES FOR CHLOROPHENOL DATA BY ANALYST, FRASER RIVER ESTUARY. NUMBER OF STATIONS REFERS TO NUMBER OF UNIQUE STATION - DATE - TIME MEASUREMENTS.

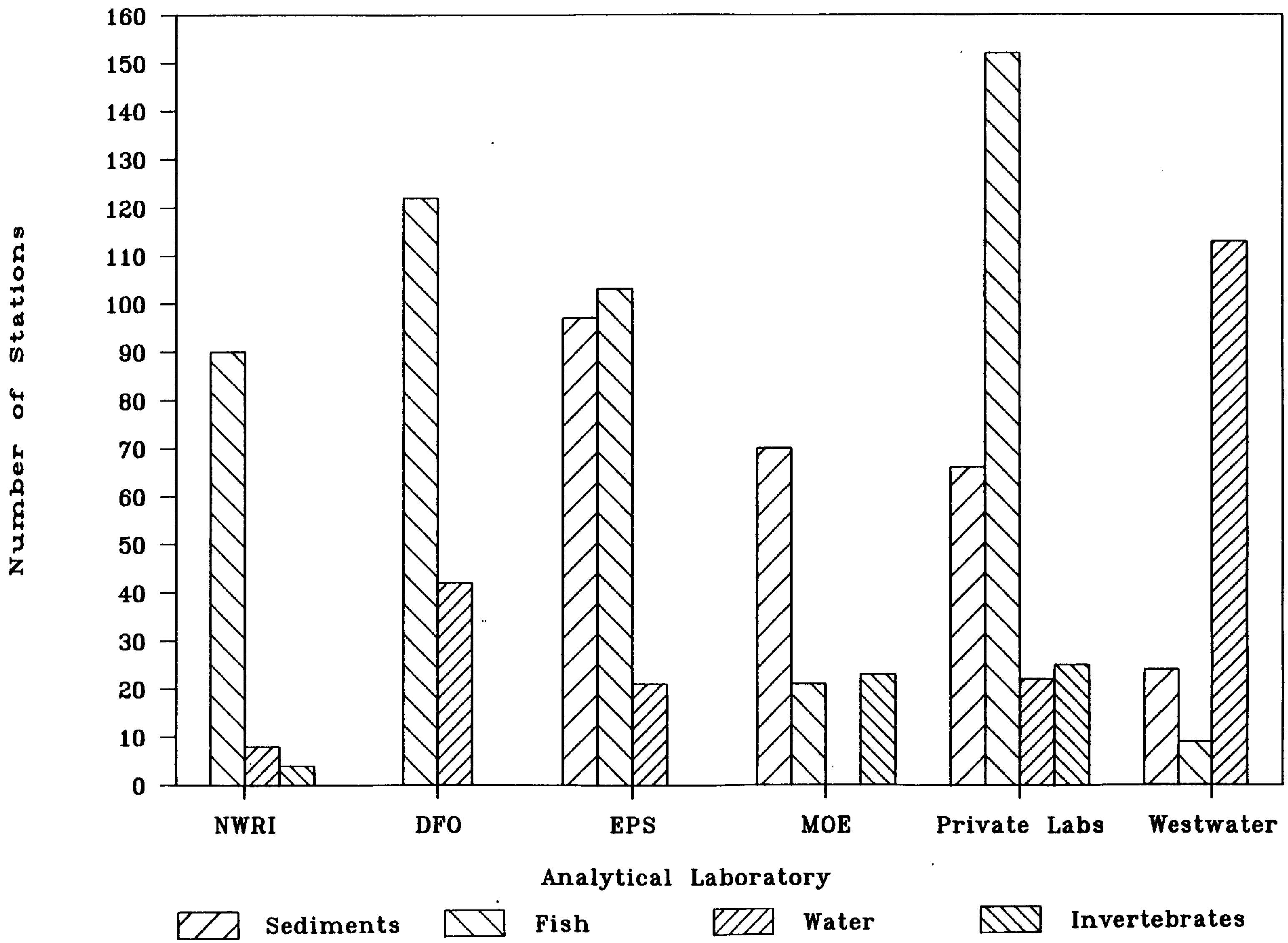

FIGURE 8. FREQUENCY DISTRIBUTION OF CHLOROPHENOL DATA FOR EACH SAMPLE MEDIUM BY ANALYST, FRASER RIVER ESTUARY. NUMBER OF STATIONS REFERS TO NUMBER OF UNIQUE STATION - DATE - TIME MEASUREMENTS.

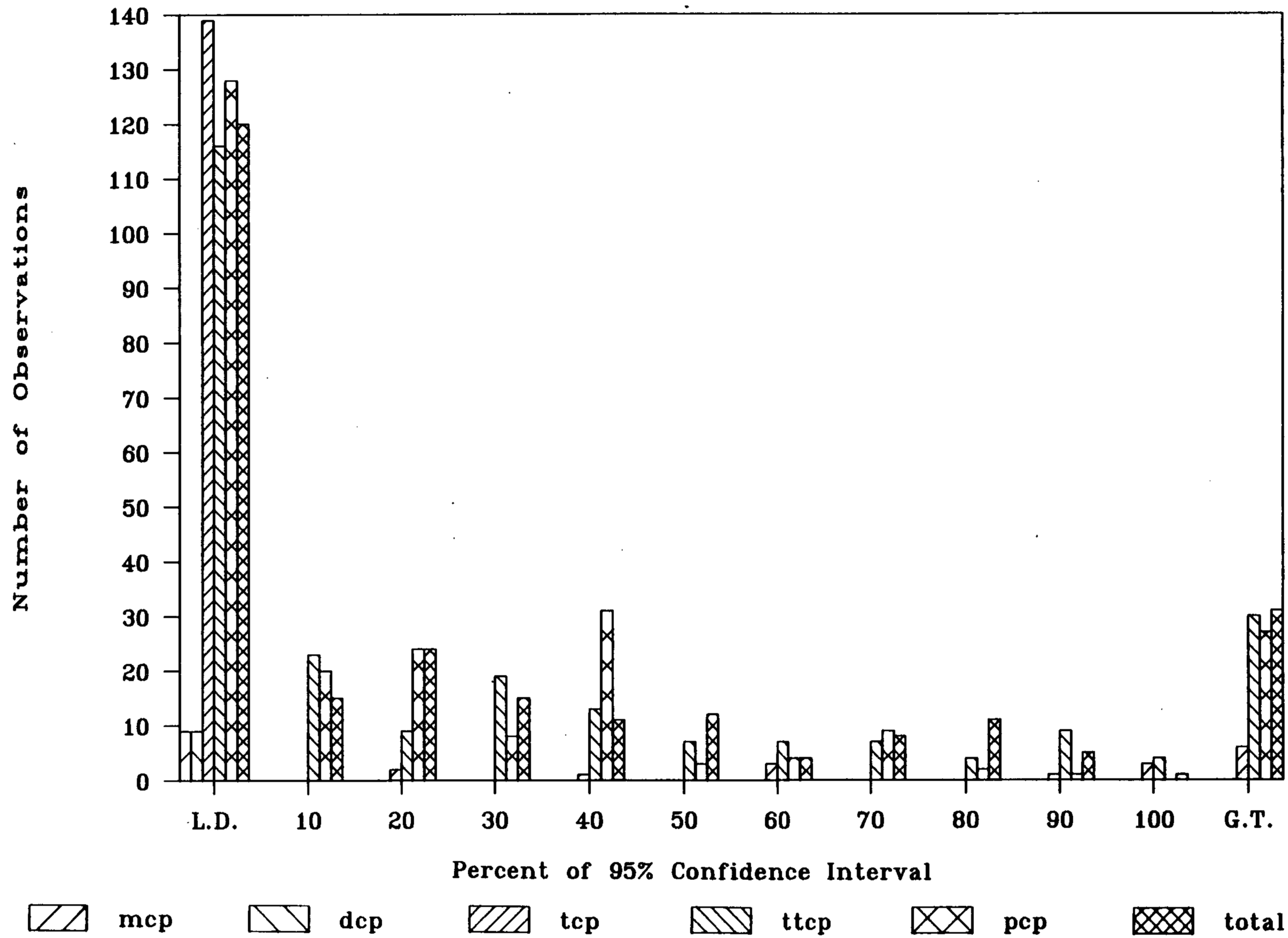

FIGURE 9. FREQUENCY DISTRIBUTION OF CHLOROPHENOL OBSERVATIONS IN SEDIMENTS, FRASER RIVER ESTUARY. GT IS GREATER THAN THE UPPER LIMIT, 95% CONFIDENCE INTERVAL (28.3 PPB).

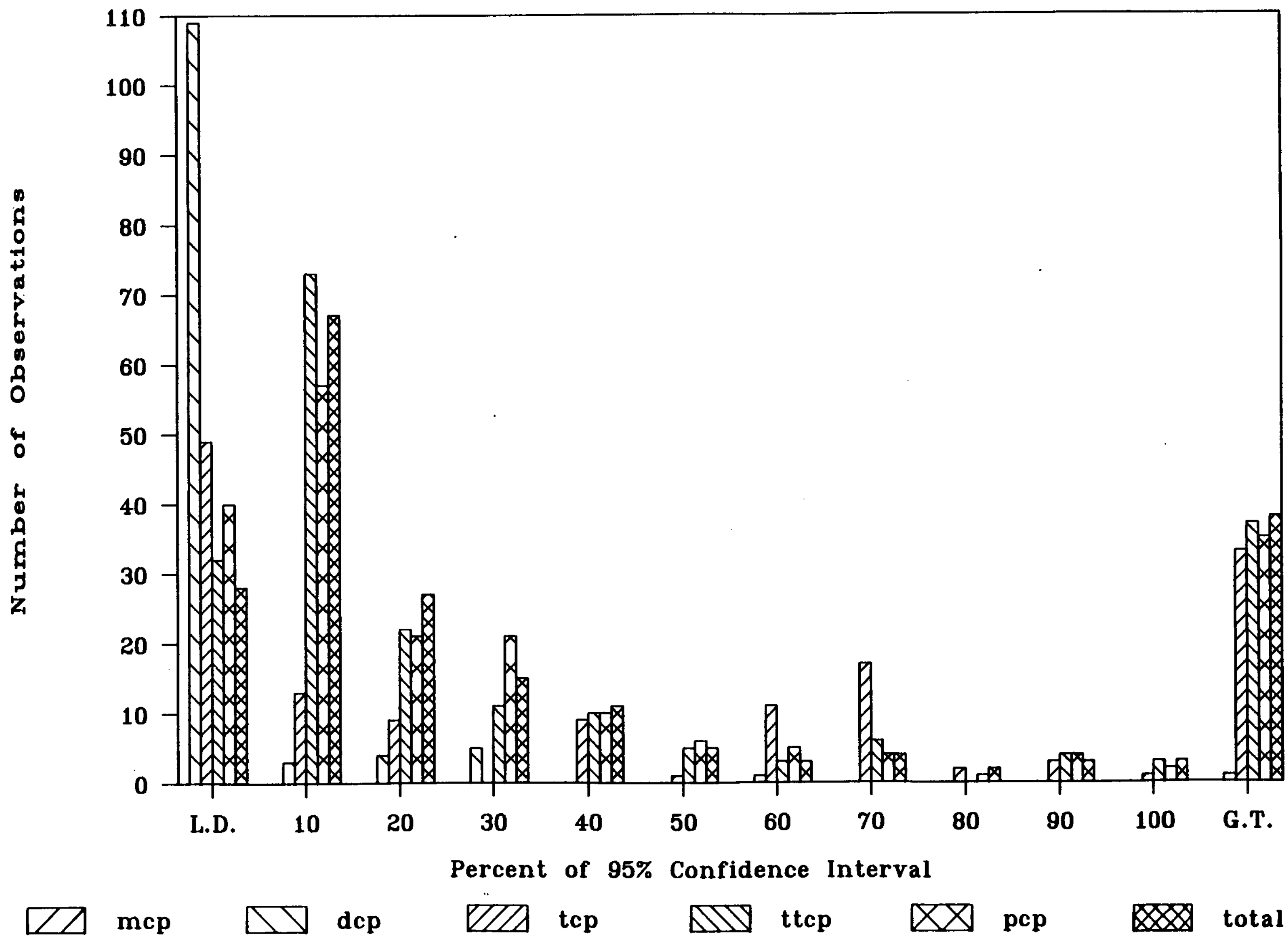

FIGURE 10. FREQUENCY DISTRIBUTION OF CHLOROPHENOL OBSERVATIONS IN WATER, FRASER RIVER ESTUARY.
GT IS GREATER THAN THE UPPER LIMIT, 95% CONFIDENCE INTERVAL (1.14 PPB).

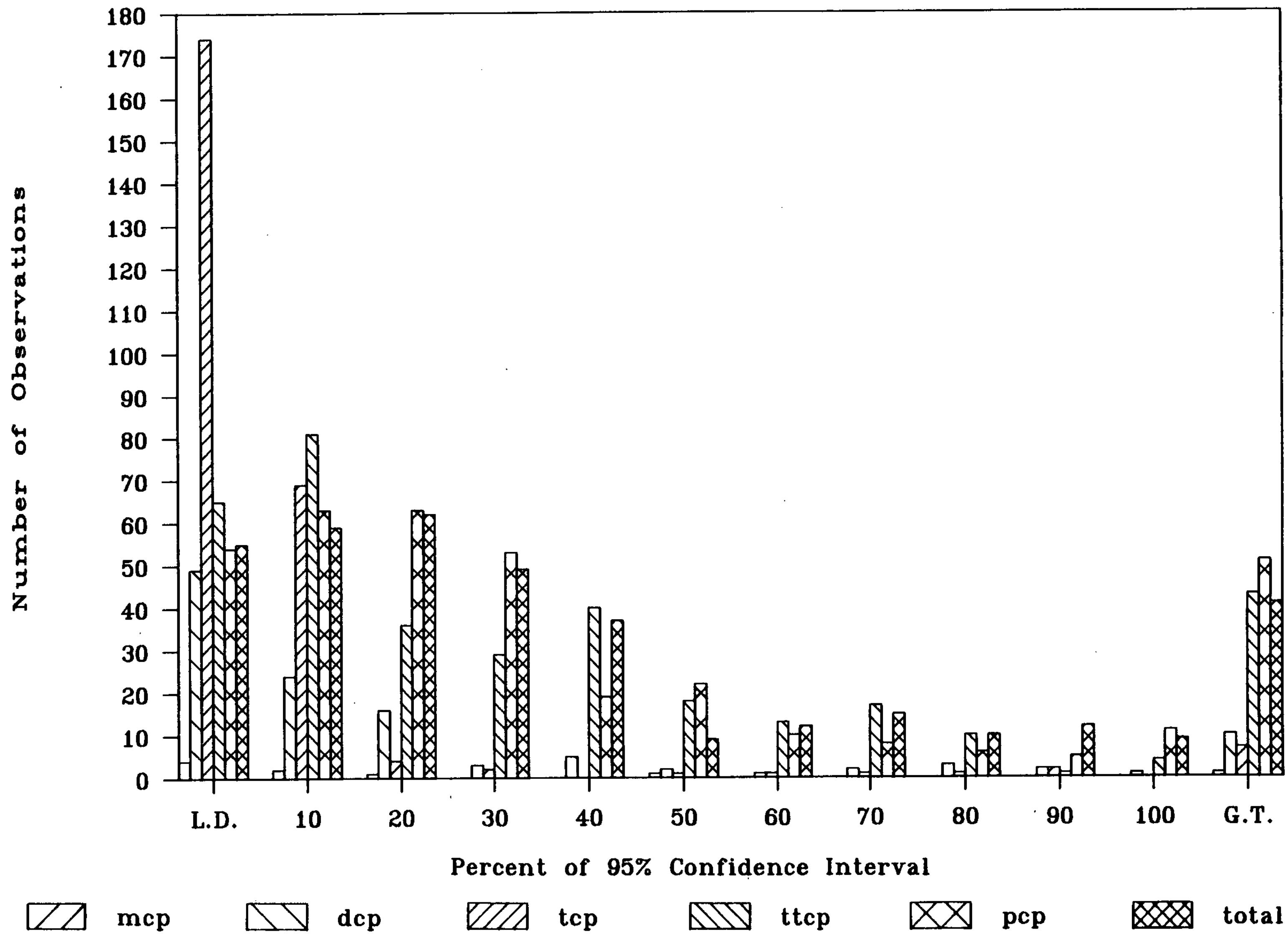

FIGURE 11. FREQUENCY DISTRIBUTION OF CHLOROPHENOL OBSERVATIONS IN FISH MUSCLE, FRASER RIVER ESTUARY. GT IS GREATER THAN THE UPPER LIMIT, 95% CONFIDENCE INTERVAL (330 PPB).

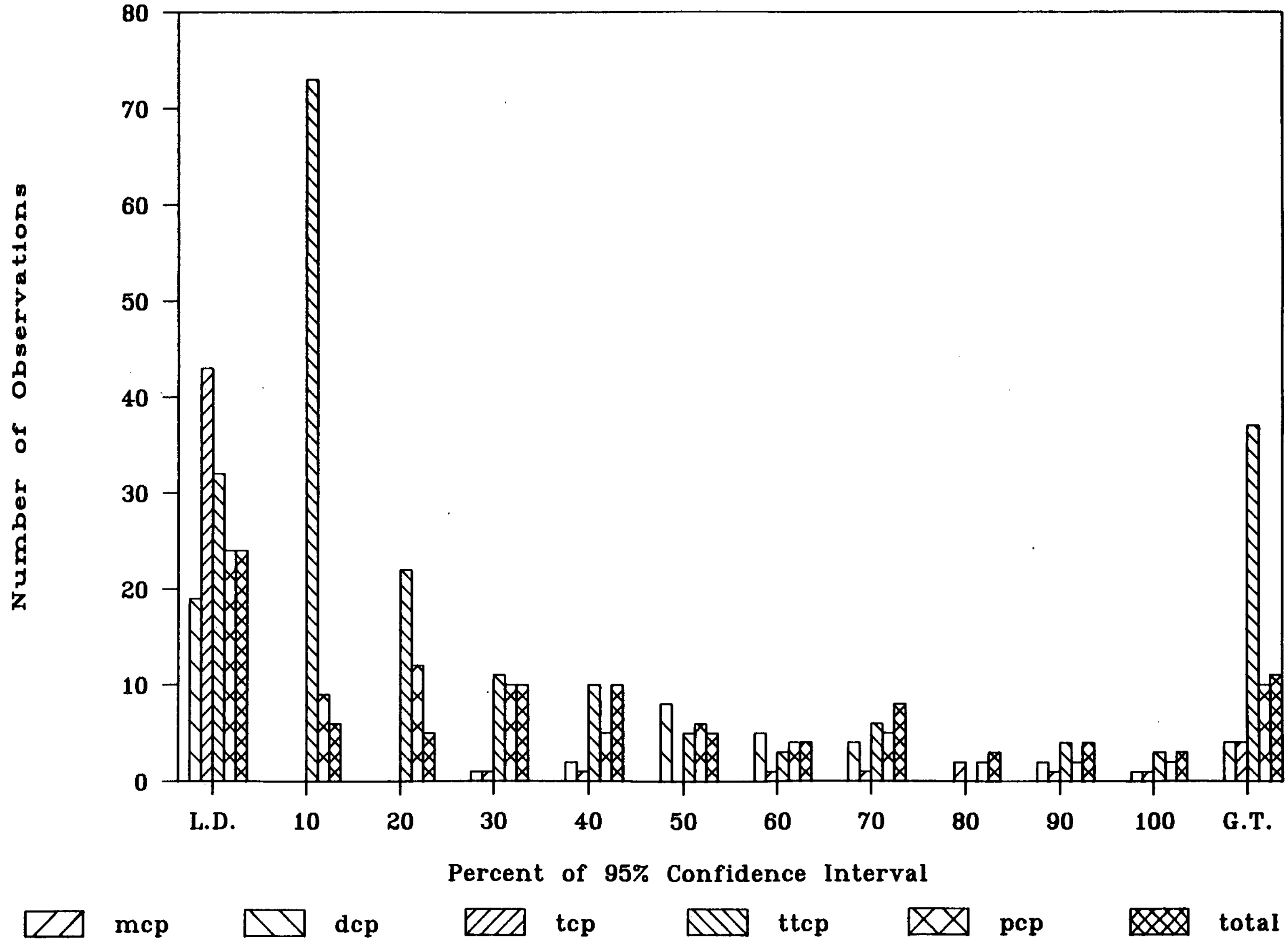

FIGURE 12. FREQUENCY DISTRIBUTION OF CHLOROPHENOL OBSERVATIONS IN FISH LIVERS, FRASER RIVER ESTUARY. GT IS GREATER THAN THE UPPER LIMIT, 95% CONFIDENCE INTERVAL (242 PPB).

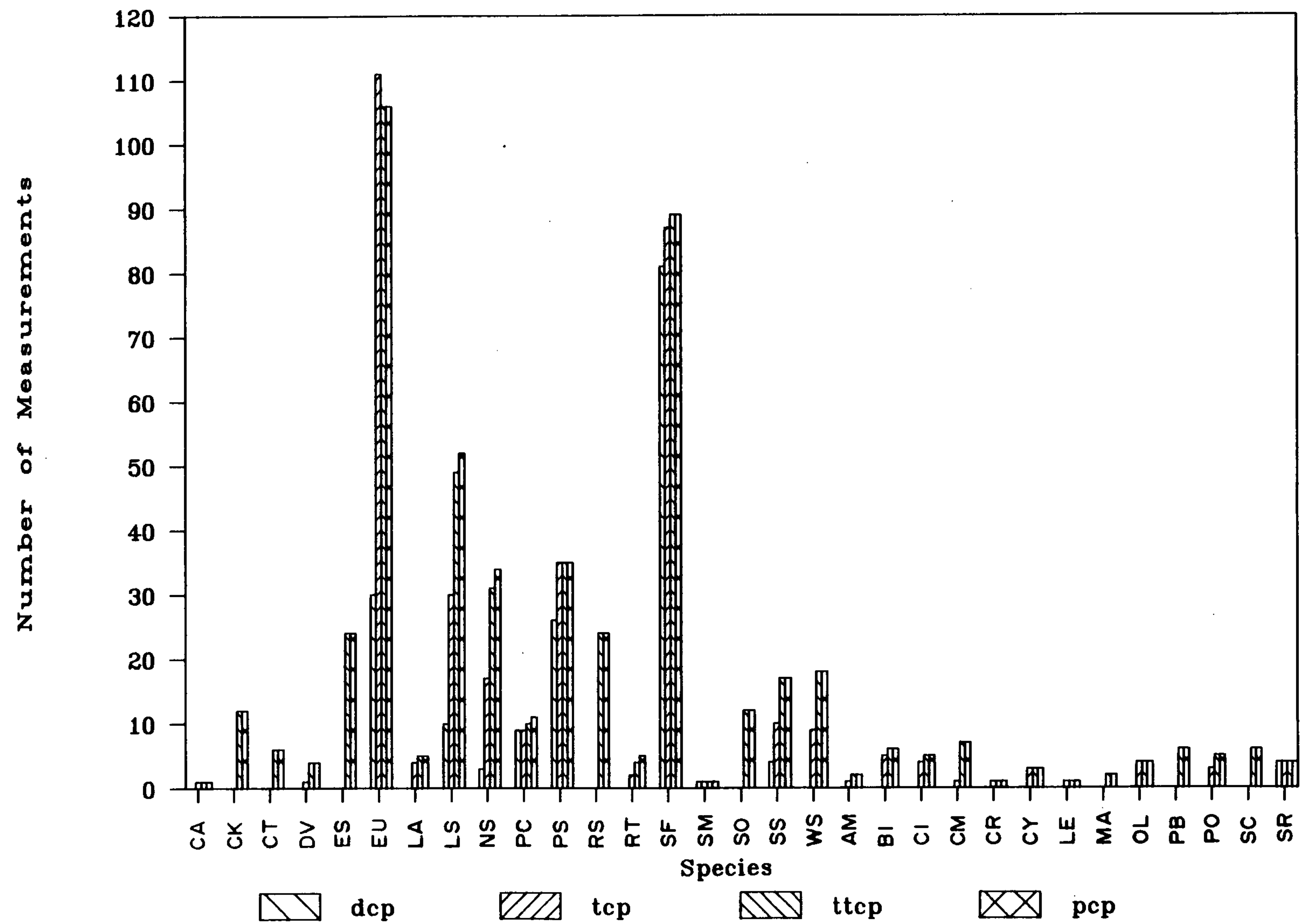

FIGURE 13. FREQUENCY DISTRIBUTION OF CHLOROPHENOL OBSERVATIONS FOR FISH AND INVERTEBRATES, FRASER RIVER ESTUARY. SPECIES CODES ARE GIVEN IN APPENDIX 2.

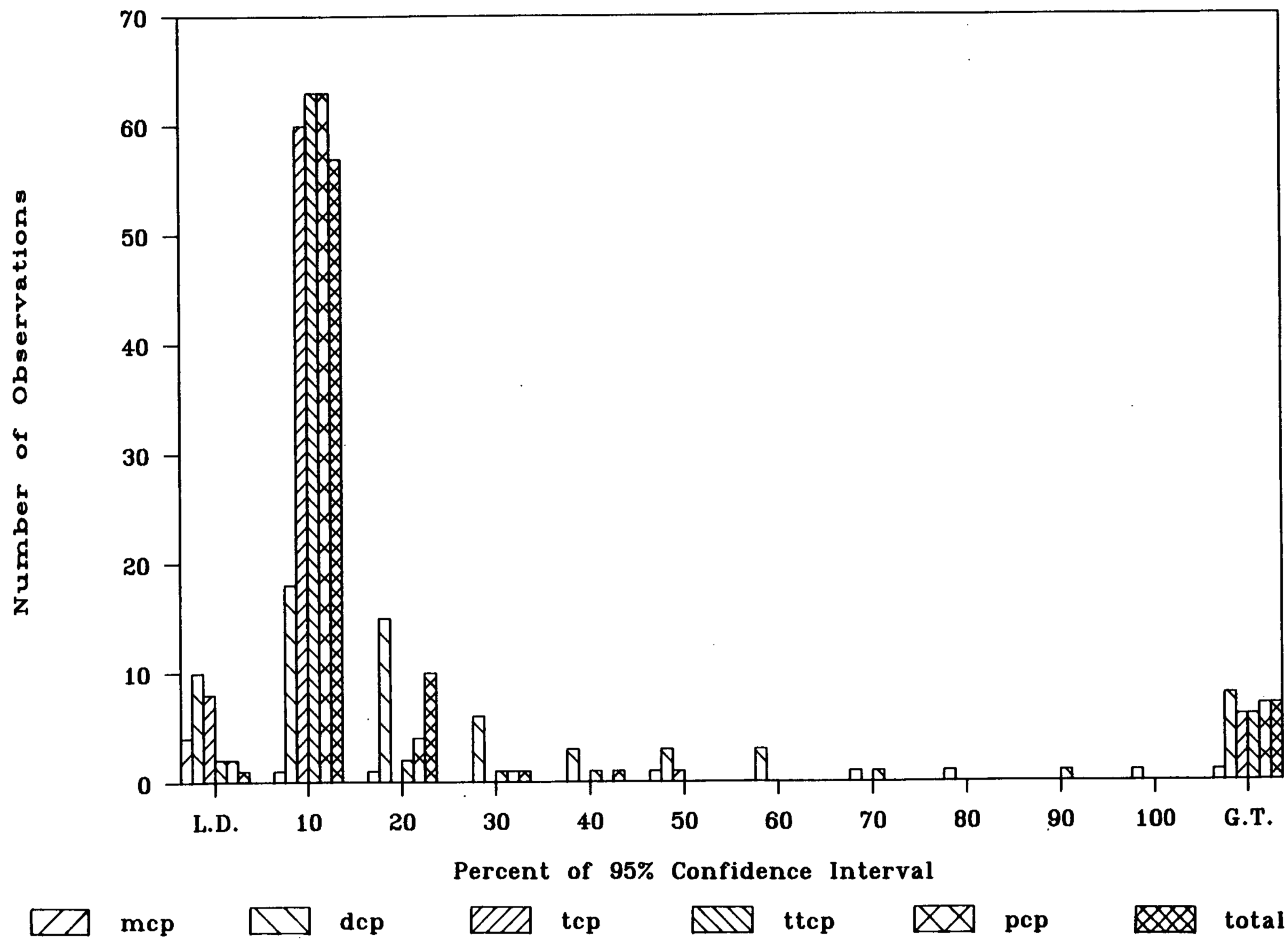

FIGURE 14. FREQUENCY DISTRIBUTION OF CHLOROPHENOL OBSERVATIONS IN STARRY FLOUNDER, FRASER RIVER ESTUARY. GT IS GREATER THAN THE UPPER LIMIT, 95% CONFIDENCE INTERVAL (631 PPB).

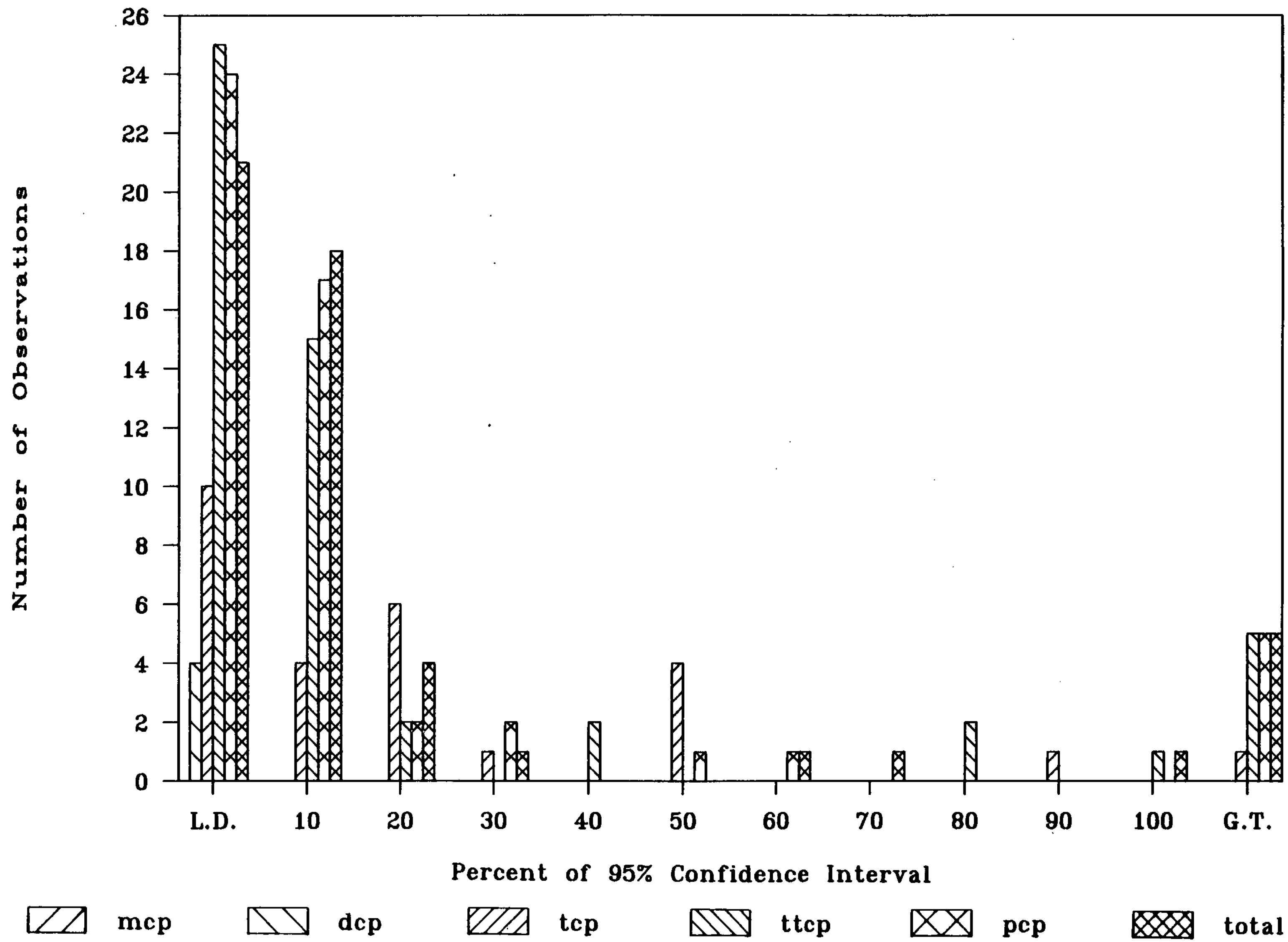

FIGURE 15. FREQUENCY DISTRIBUTION OF CHLOROPHENOL OBSERVATIONS IN INVERTEBRATES, FRASER RIVER ESTUARY. GT IS GREATER THAN THE UPPER LIMIT, 95% CONFIDENCE INTERVAL (1460 PPB).

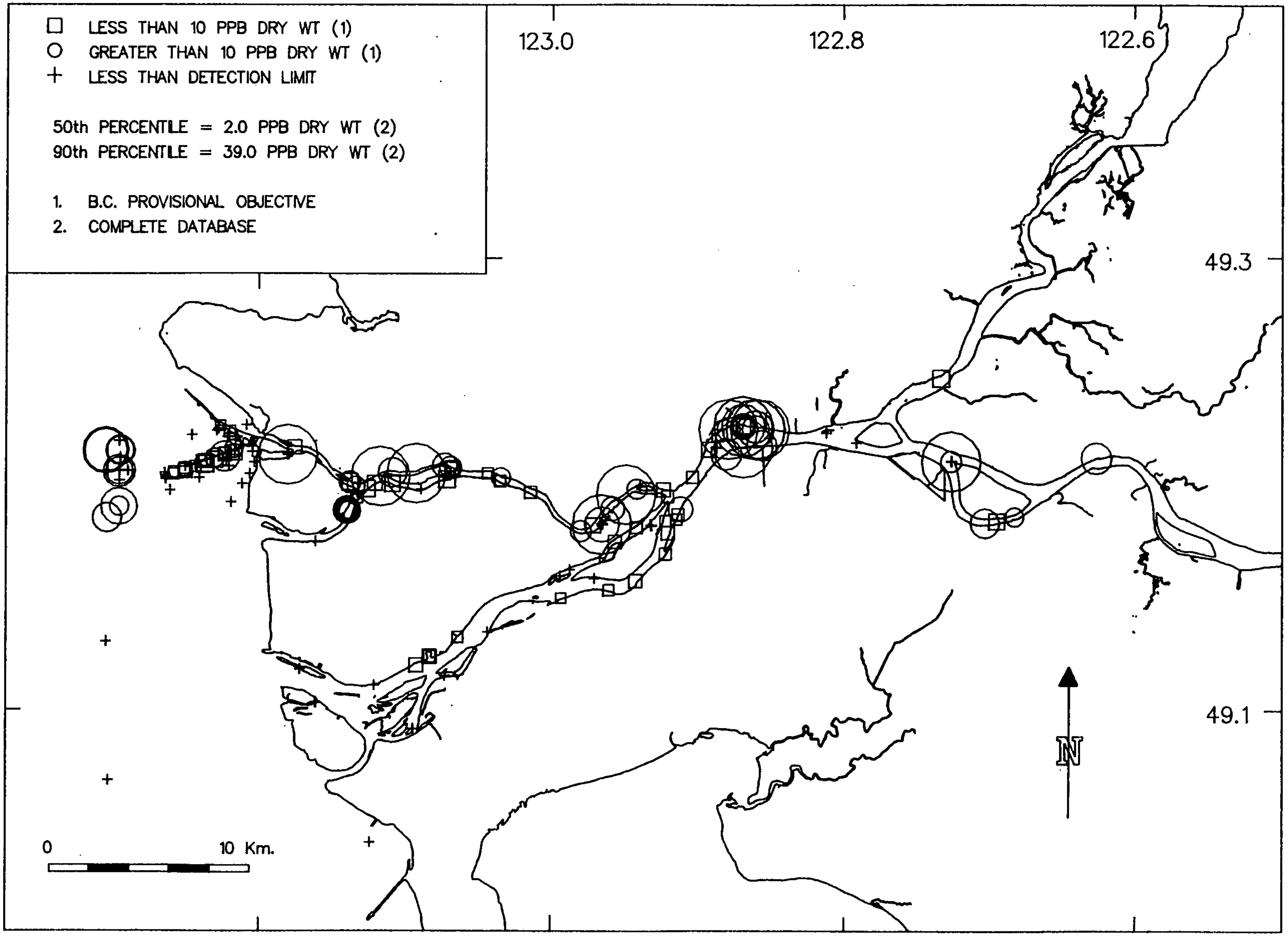

FIGURE 16. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN SEDIMENTS, FRASER RIVER ESTUARY.
Size of symbol proportional to concentration (ppb dry wt).

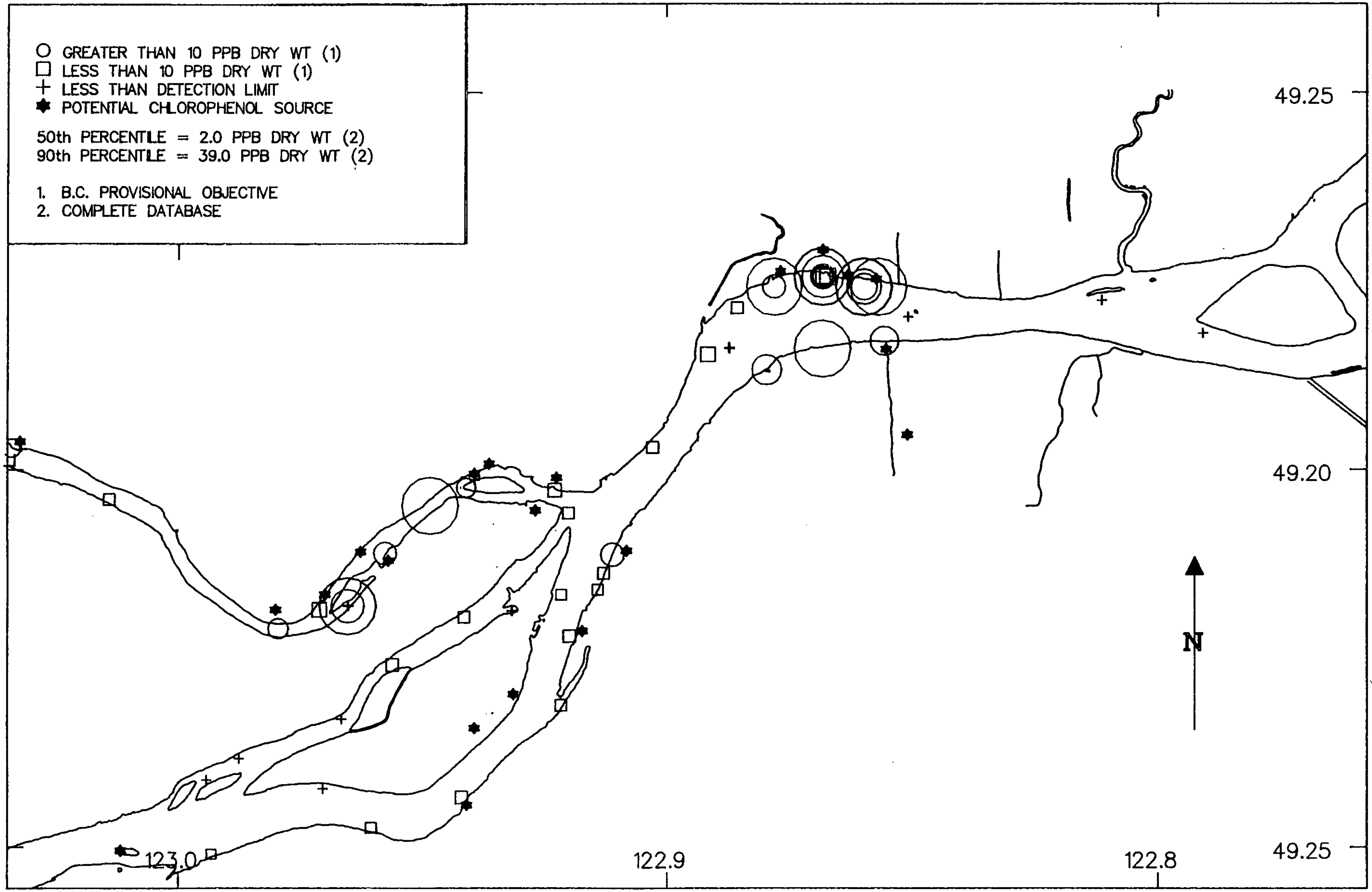

FIGURE 17. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN SEDIMENTS, PITT RIVER TO ANNACIS ISLAND.
Size of symbol proportional to concentration (ppb dry wt).

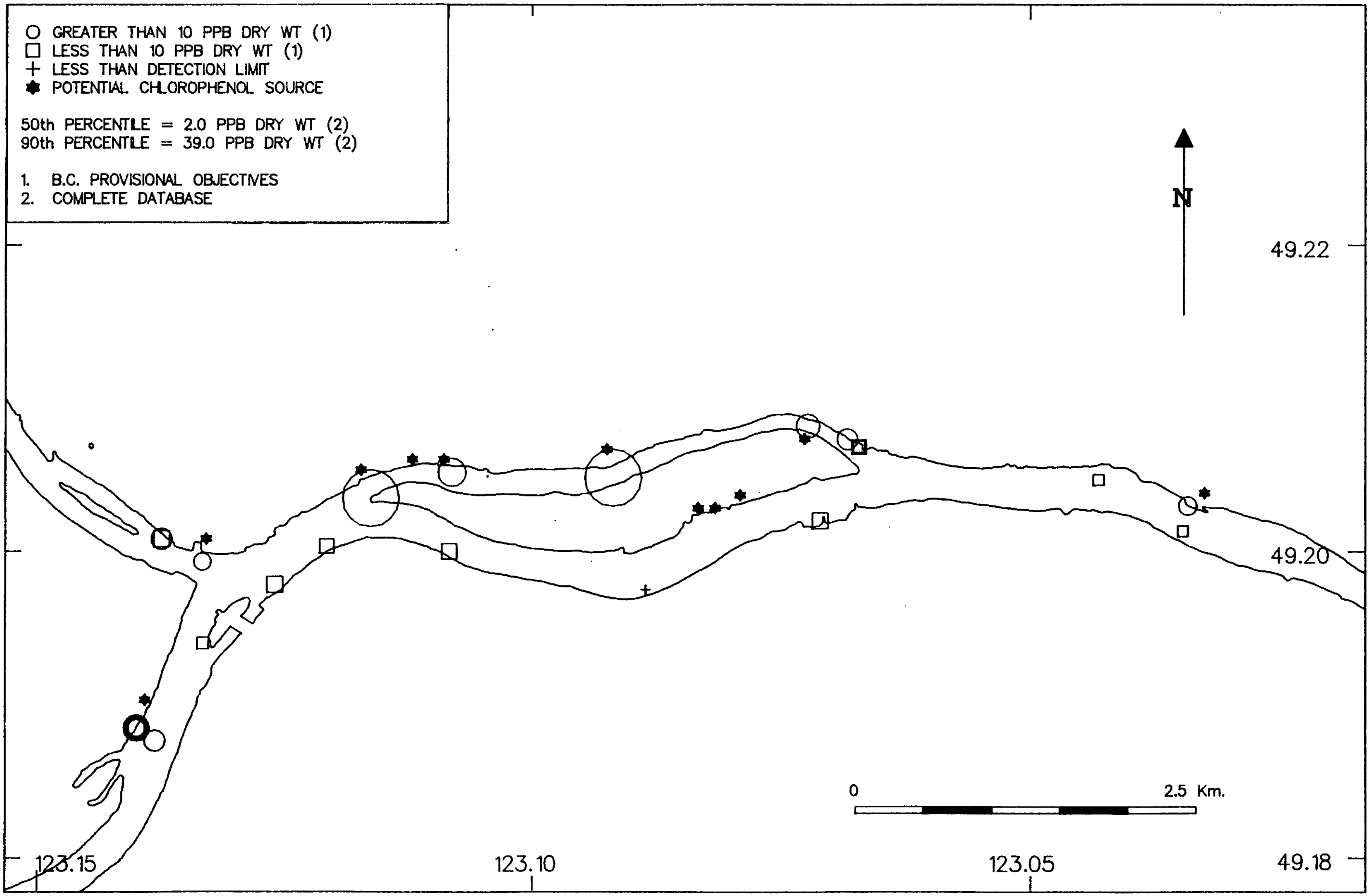

FIGURE 18. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN SEDIMENTS, MITCHELL ISLAND.
Size of symbol proportional to concentration (ppb dry wt).

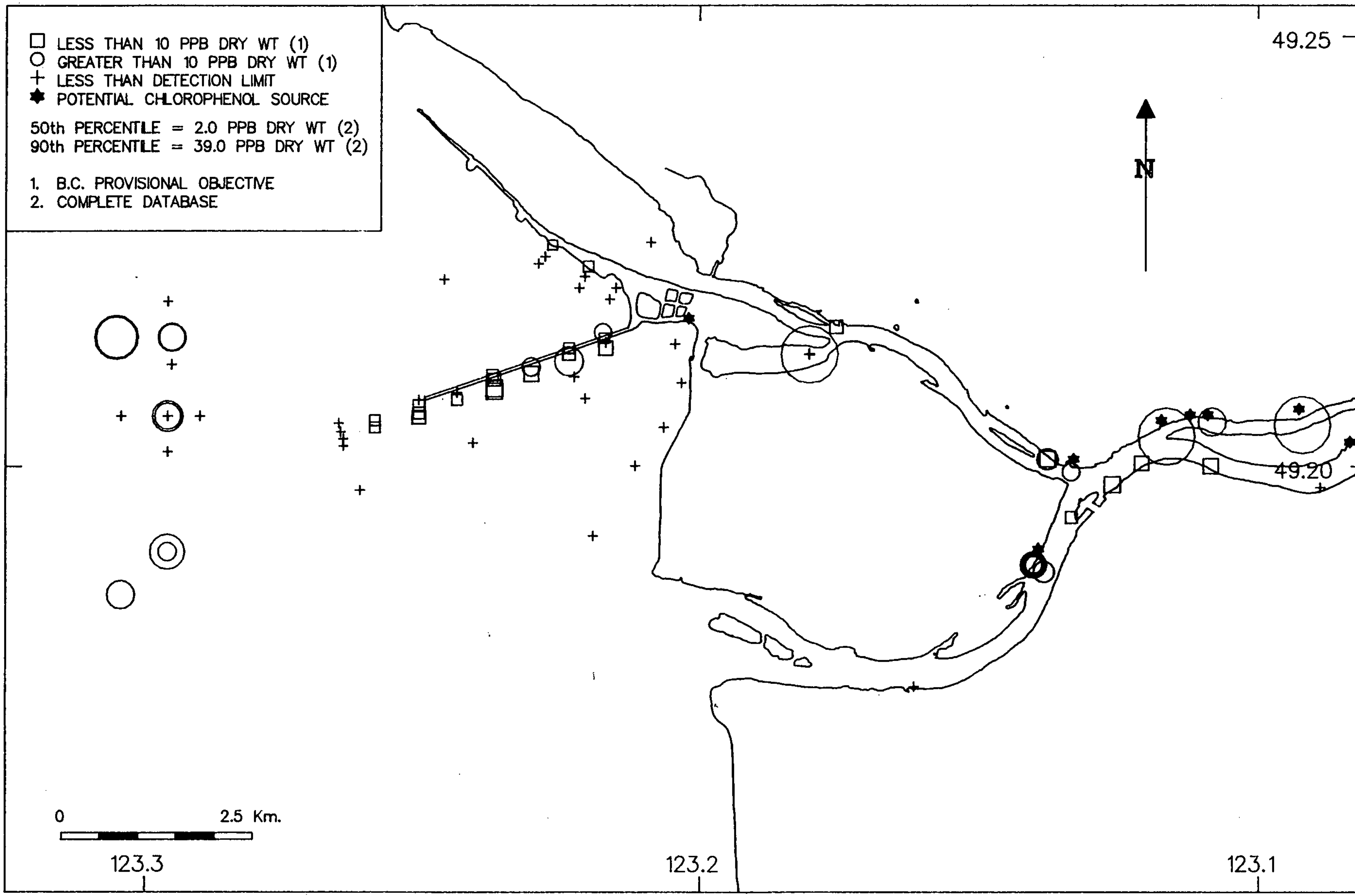

FIGURE 19. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN SEDIMENTS, STURGEON BANK TO SEA ISLAND.
Size of symbol proportional to concentration (ppb dry wt).

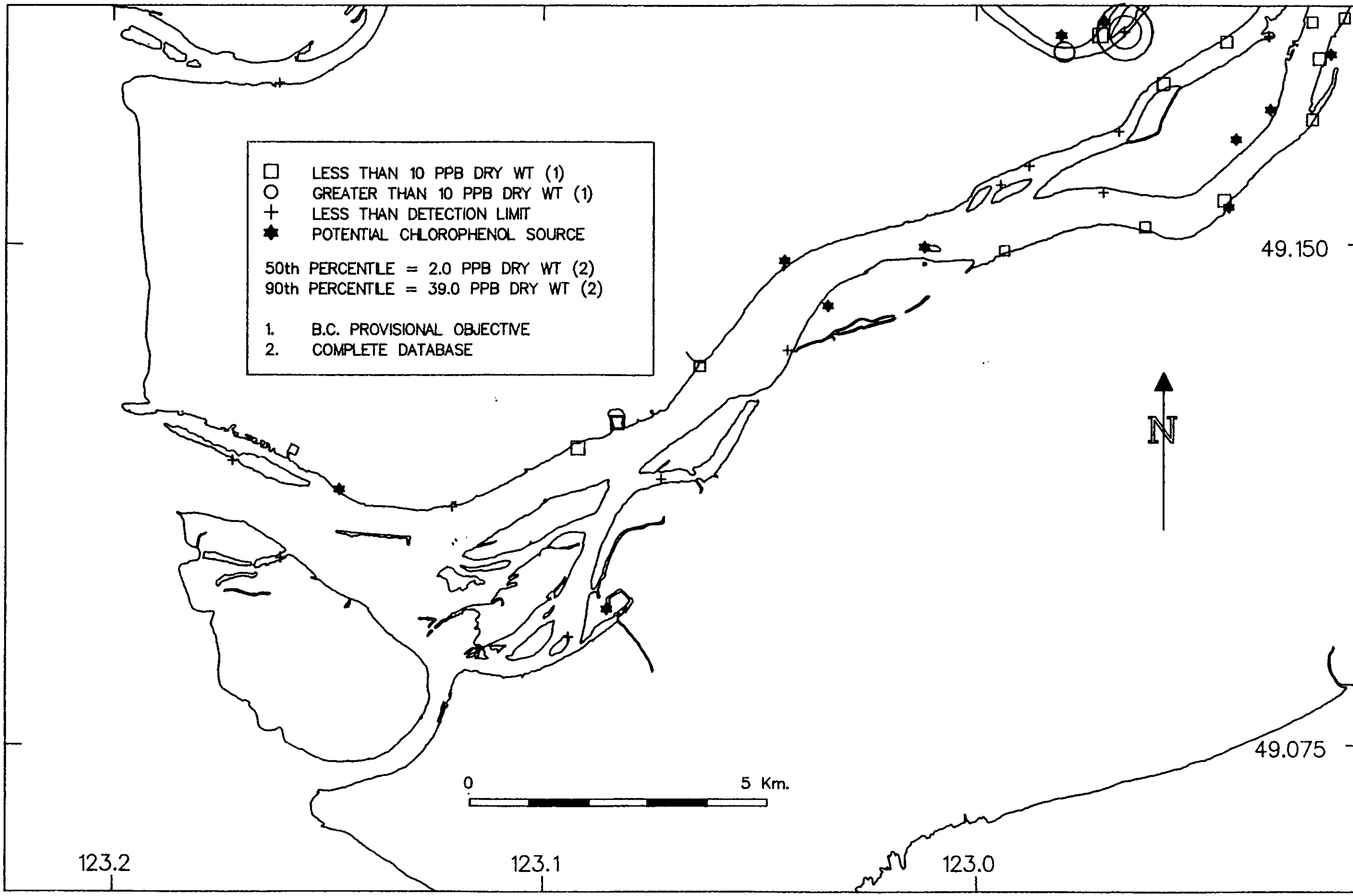

FIGURE 20. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN SEDIMENTS, MAIN ARM BELOW ANNACIS ISLAND.
Size of symbol proportional to concentration (ppb dry wt).

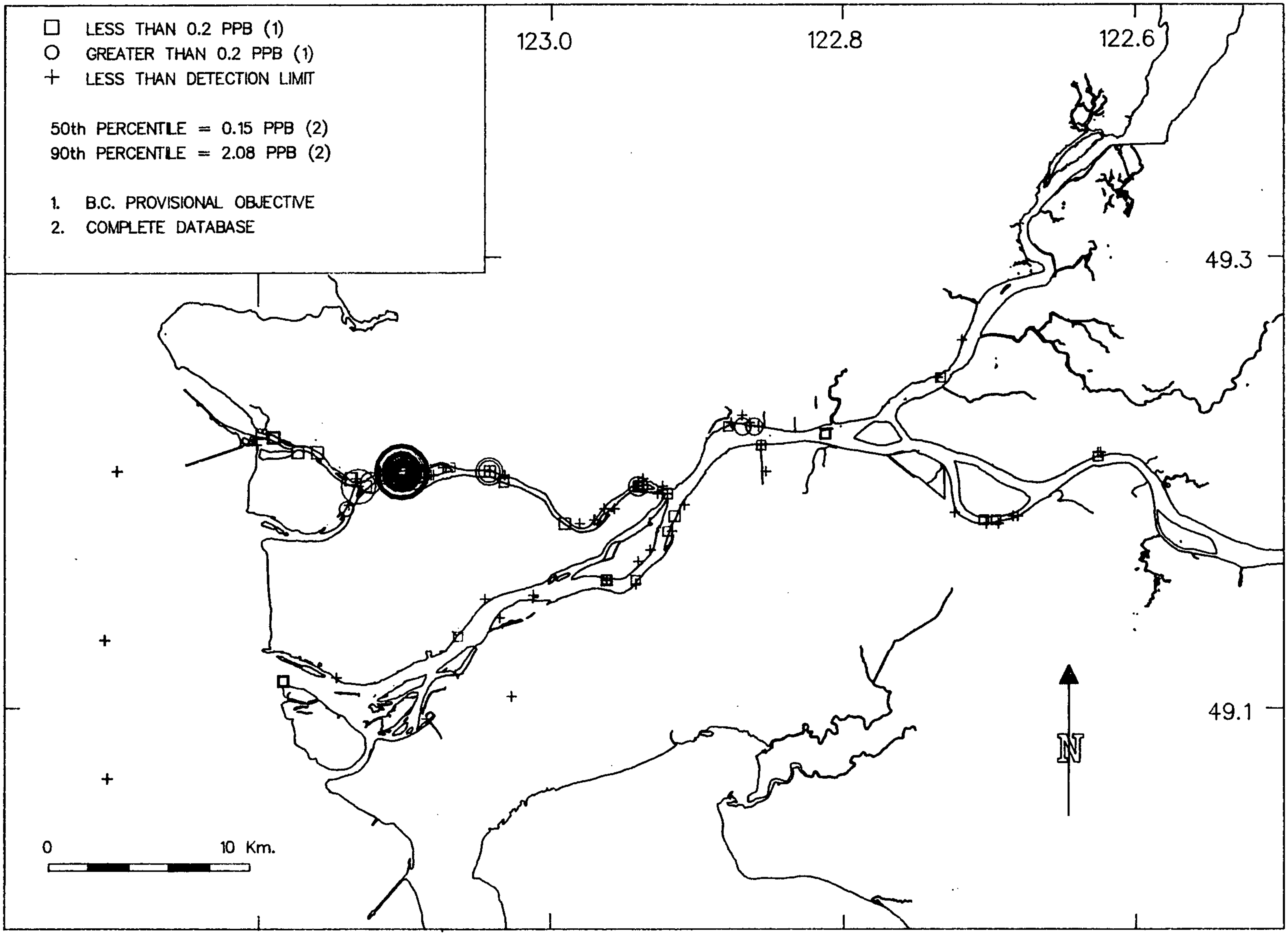

FIGURE 21. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN WATER, FRASER RIVER ESTUARY.
Size of symbol proportional to concentration (ppb).

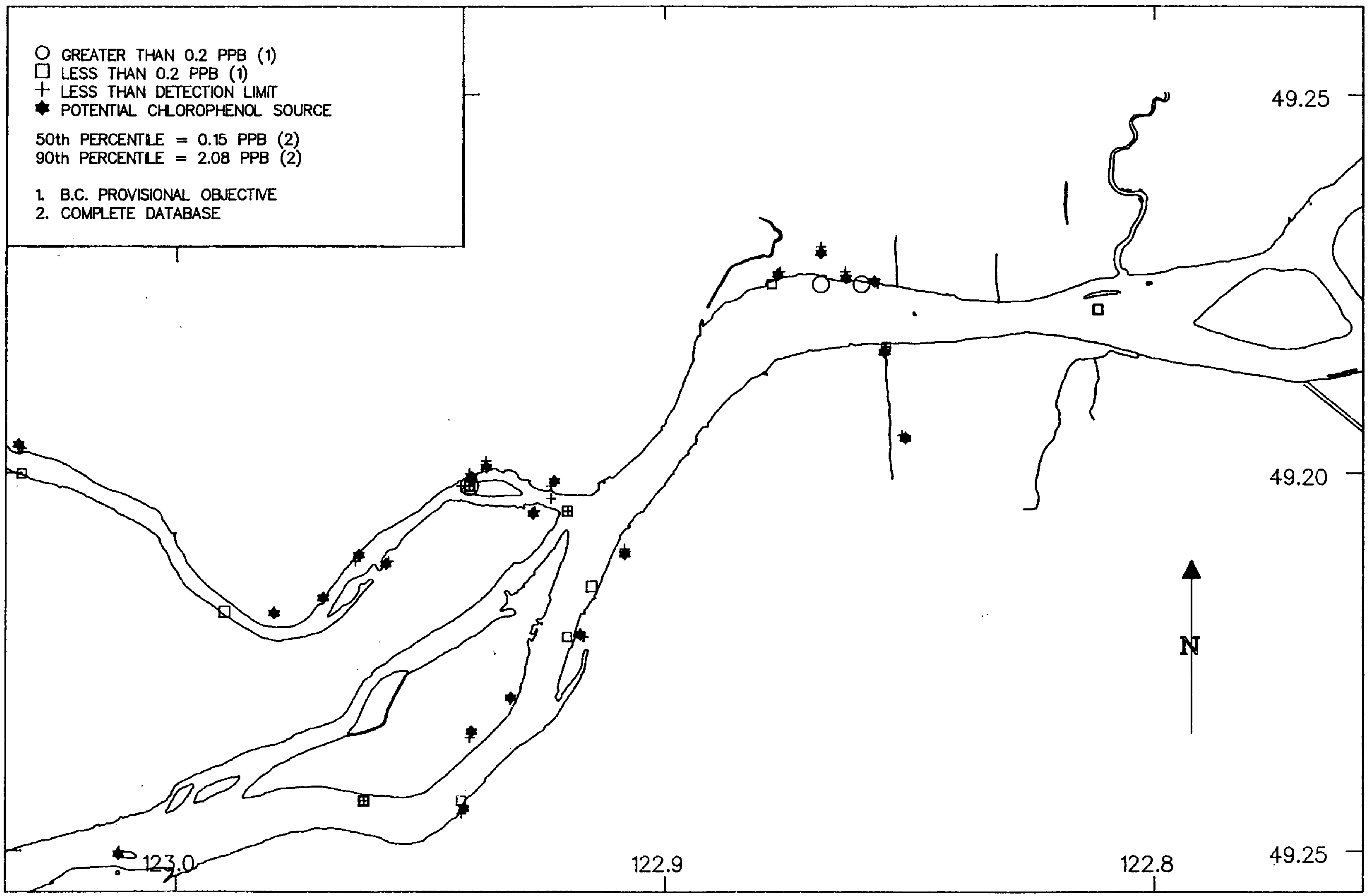

FIGURE 22. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN WATER, PITT RIVER TO ANNACIS ISLAND.
Size of symbol proportional to concentration (ppb).

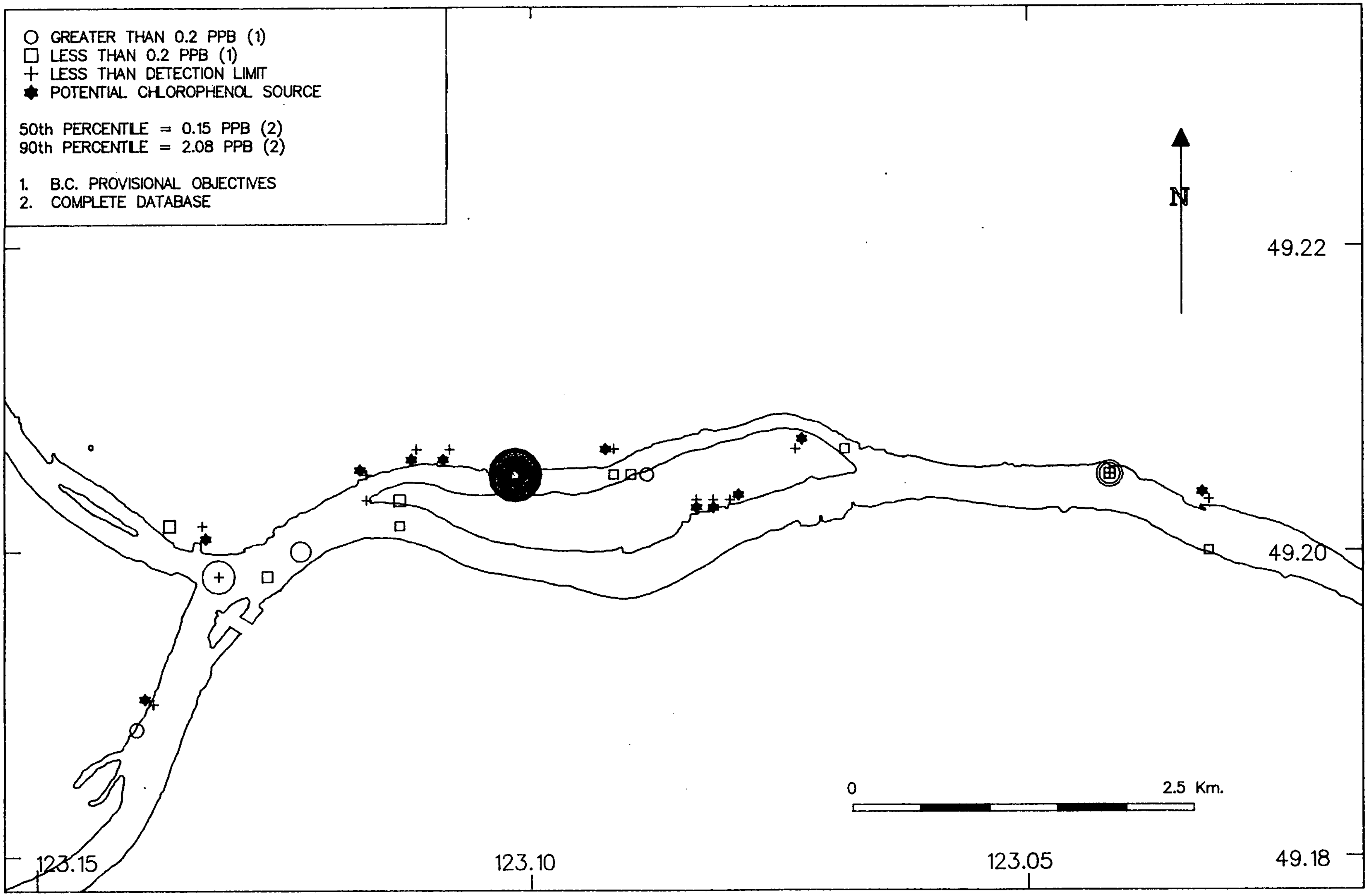

FIGURE 23. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN WATER, MITCHELL ISLAND.
Size of symbol proportional to concentration (ppb).

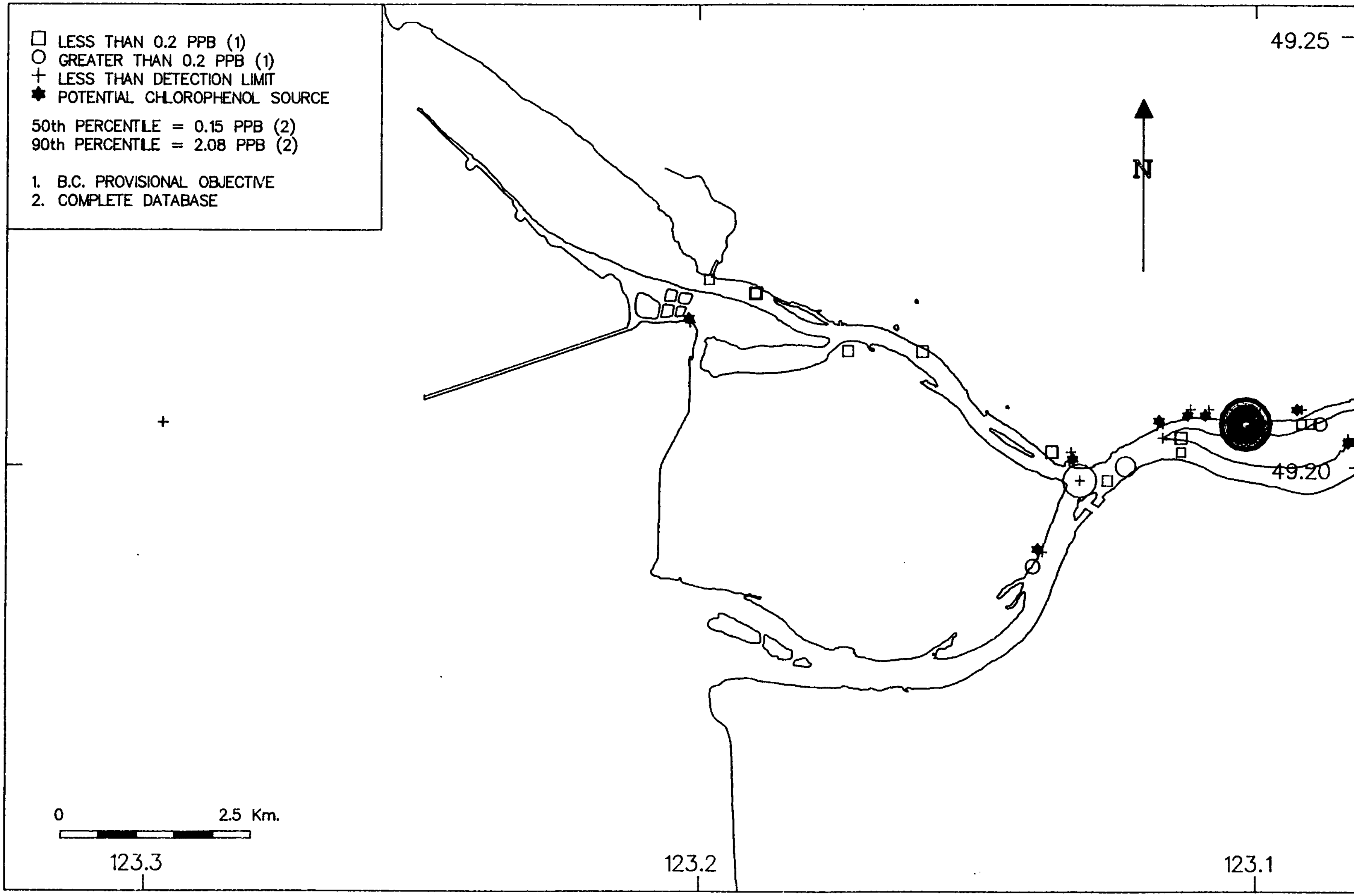

FIGURE 24. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN WATER, STURGEON BANK TO SEA ISLAND.
Size of symbol proportional to concentration (ppb).

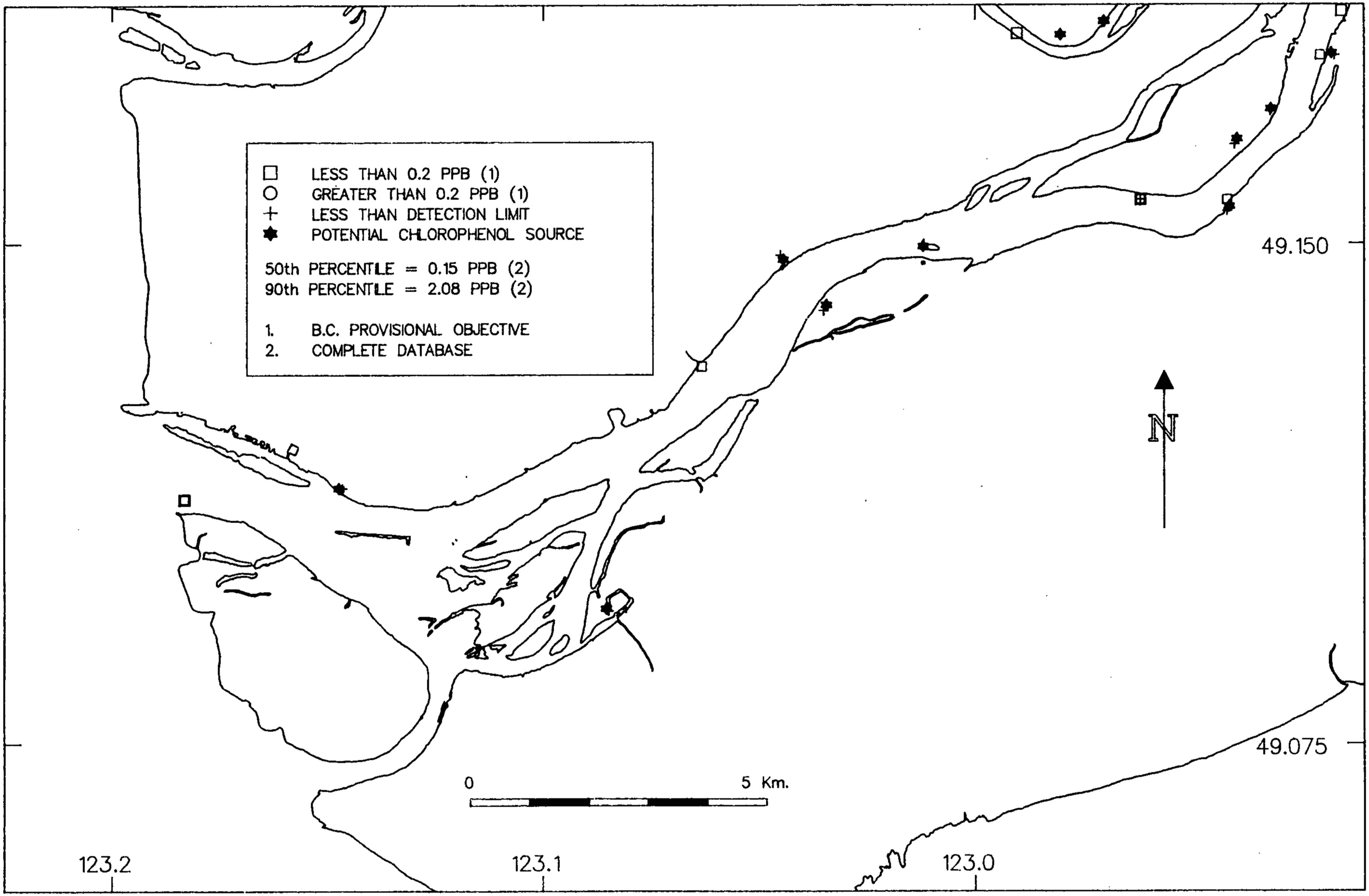

FIGURE 25. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN WATER, MAIN ARM BELOW ANNACIS ISLAND.
Size of symbol proportional to concentration (ppb).

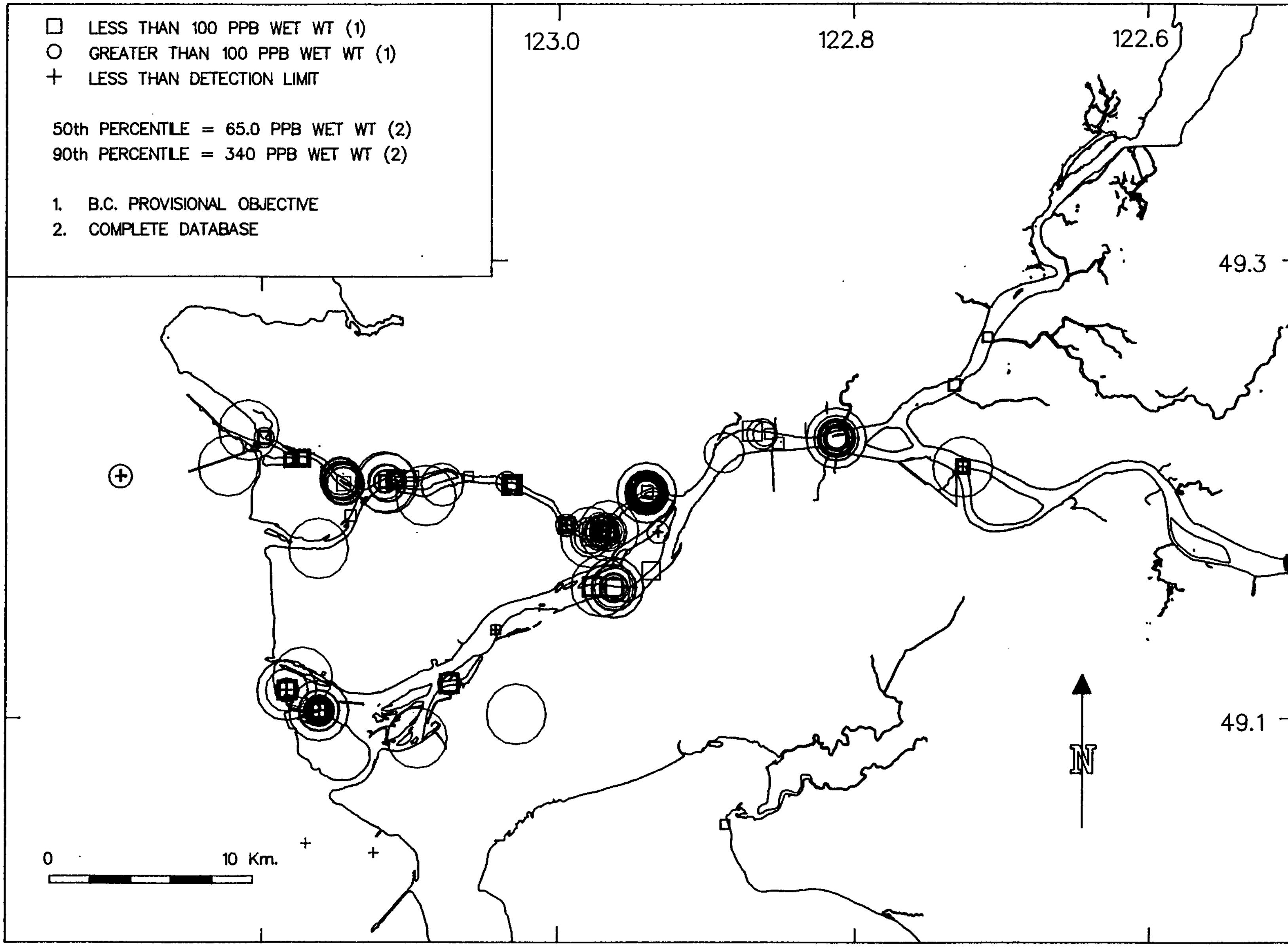

FIGURE 26. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN FISH MUSCLE, FRASER RIVER ESTUARY.
Size of symbol proportional to concentration (ppb wet wt).

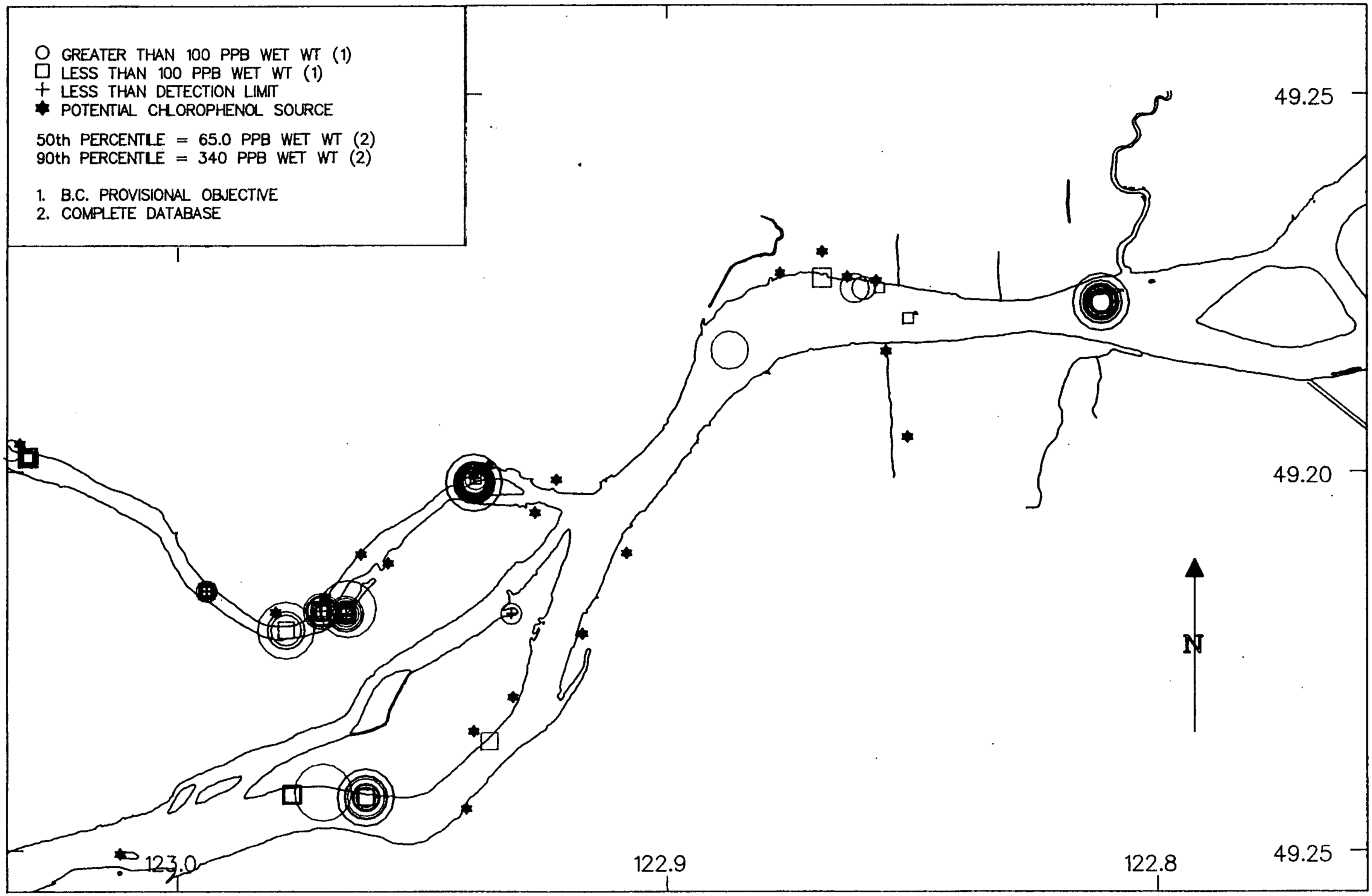

FIGURE 27. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN FISH MUSCLE, PITT RIVER TO ANNACIS ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

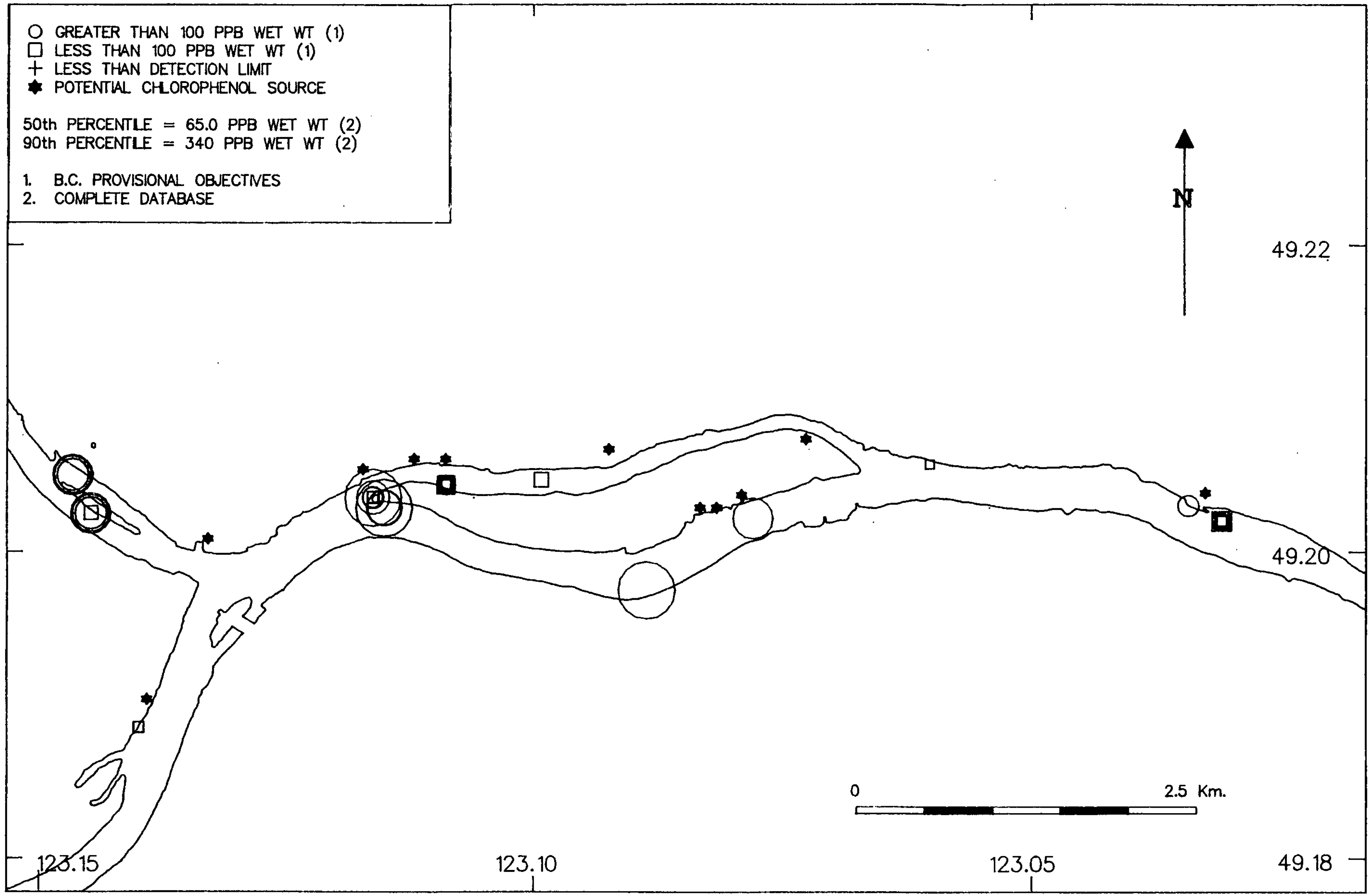

FIGURE 28. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN FISH MUSCLE, MITCHELL ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

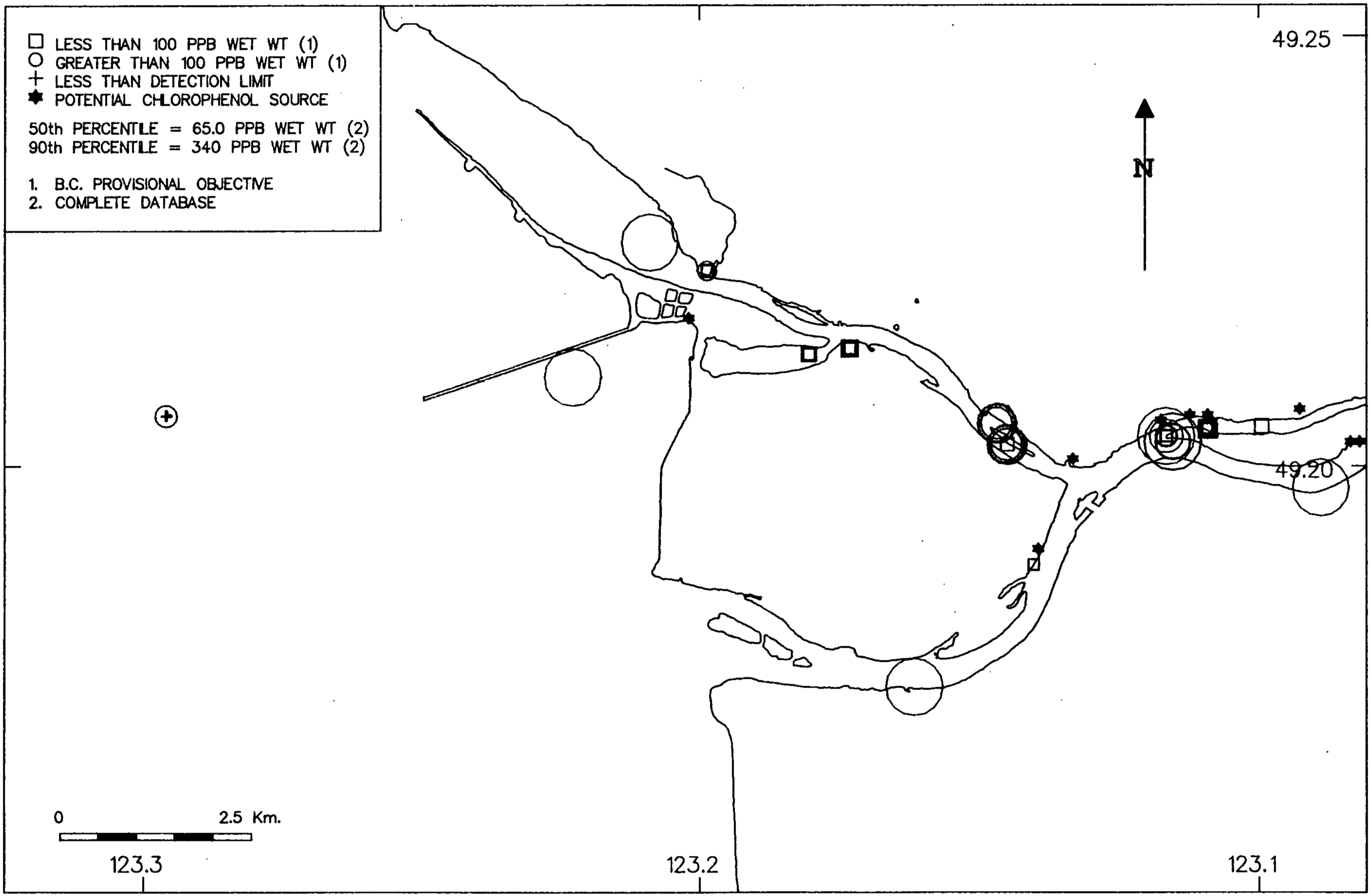

FIGURE 29. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN FISH MUSCLE, STURGEON BANK TO SEA ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

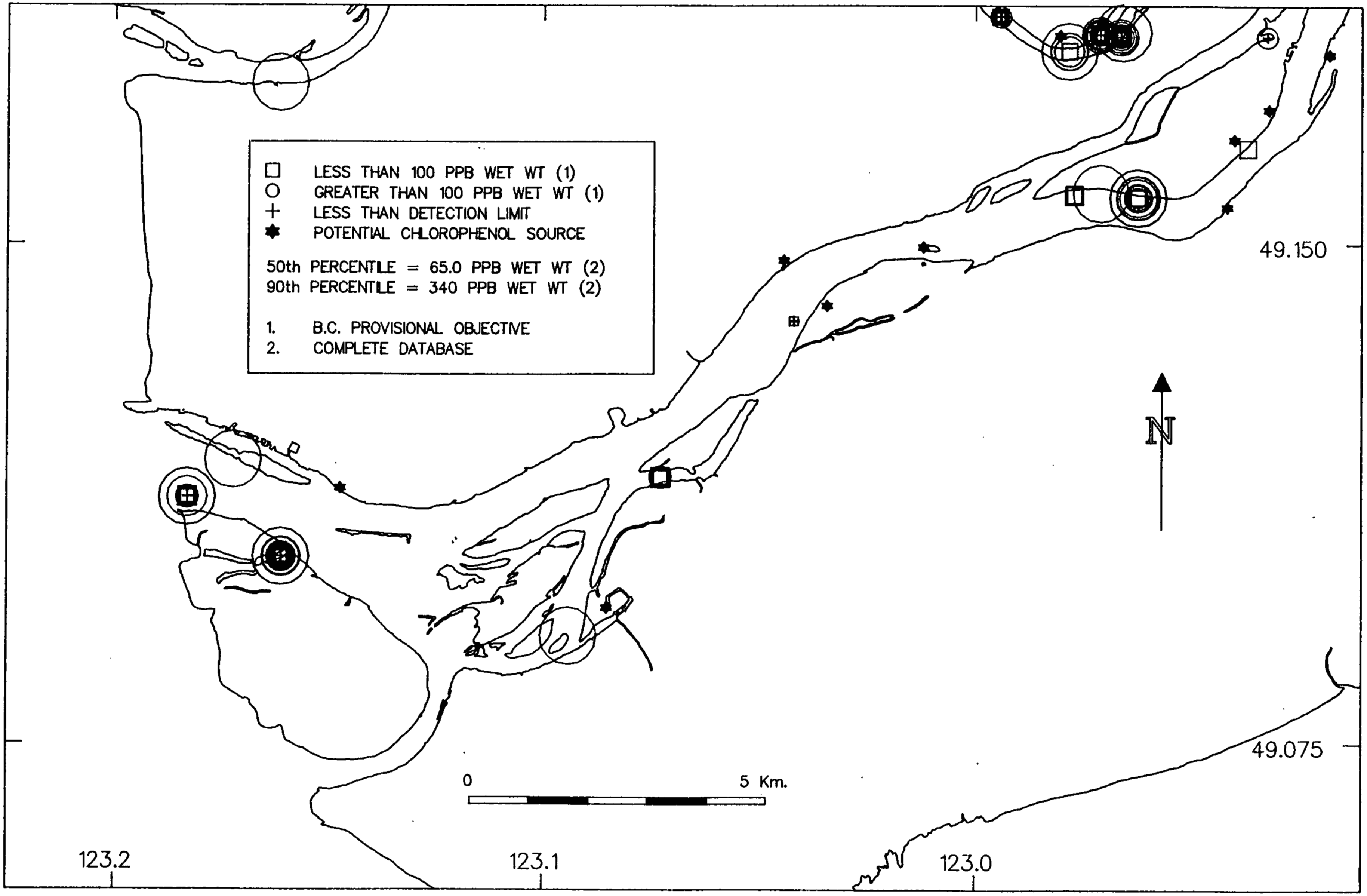

FIGURE 30. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN FISH MUSCLE, MAIN ARM BELOW ANNACIS ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

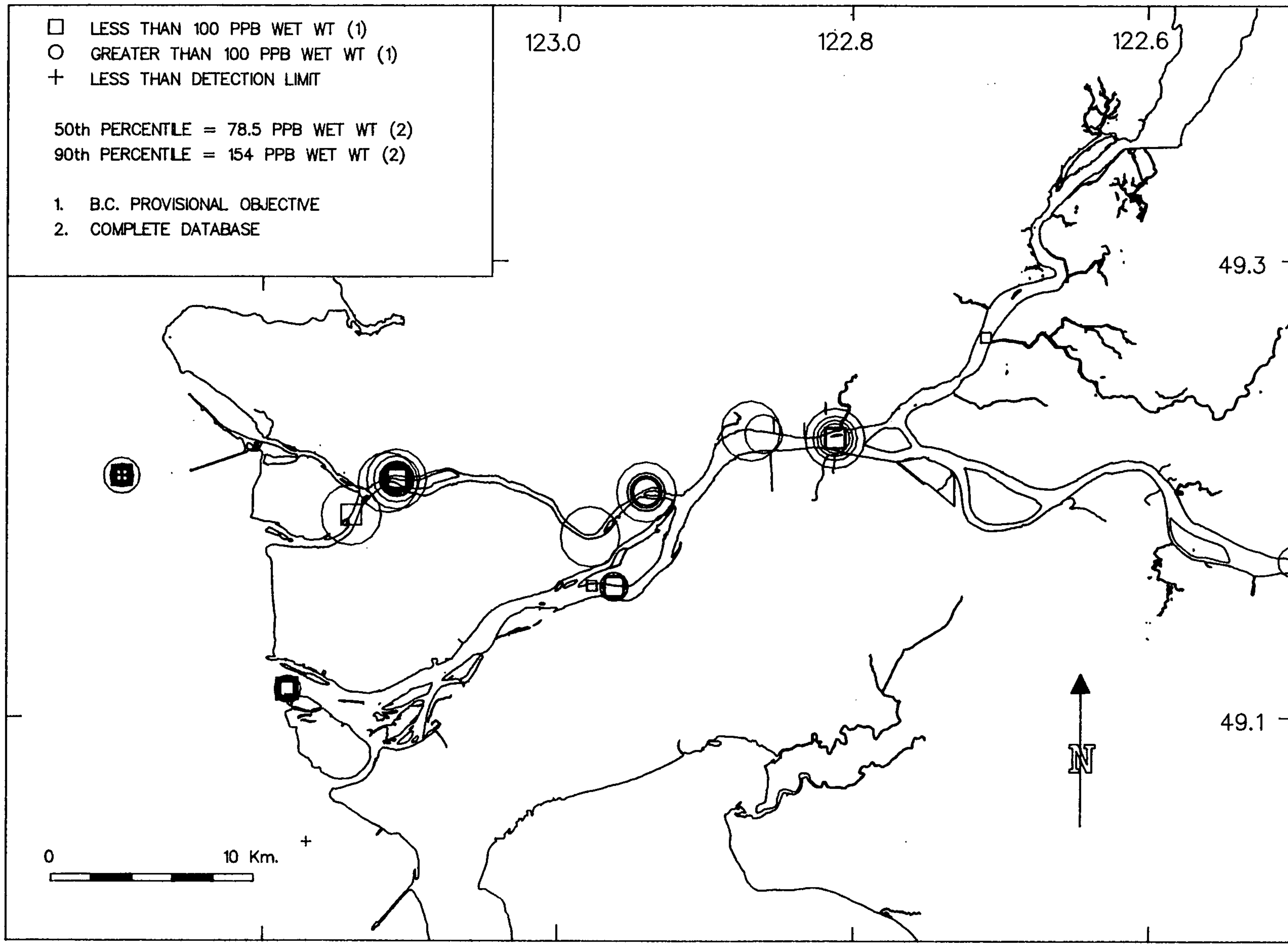

FIGURE 31. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN FISH LIVER, FRASER RIVER ESTUARY.
Size of symbol proportional to concentration (ppb wet wt).

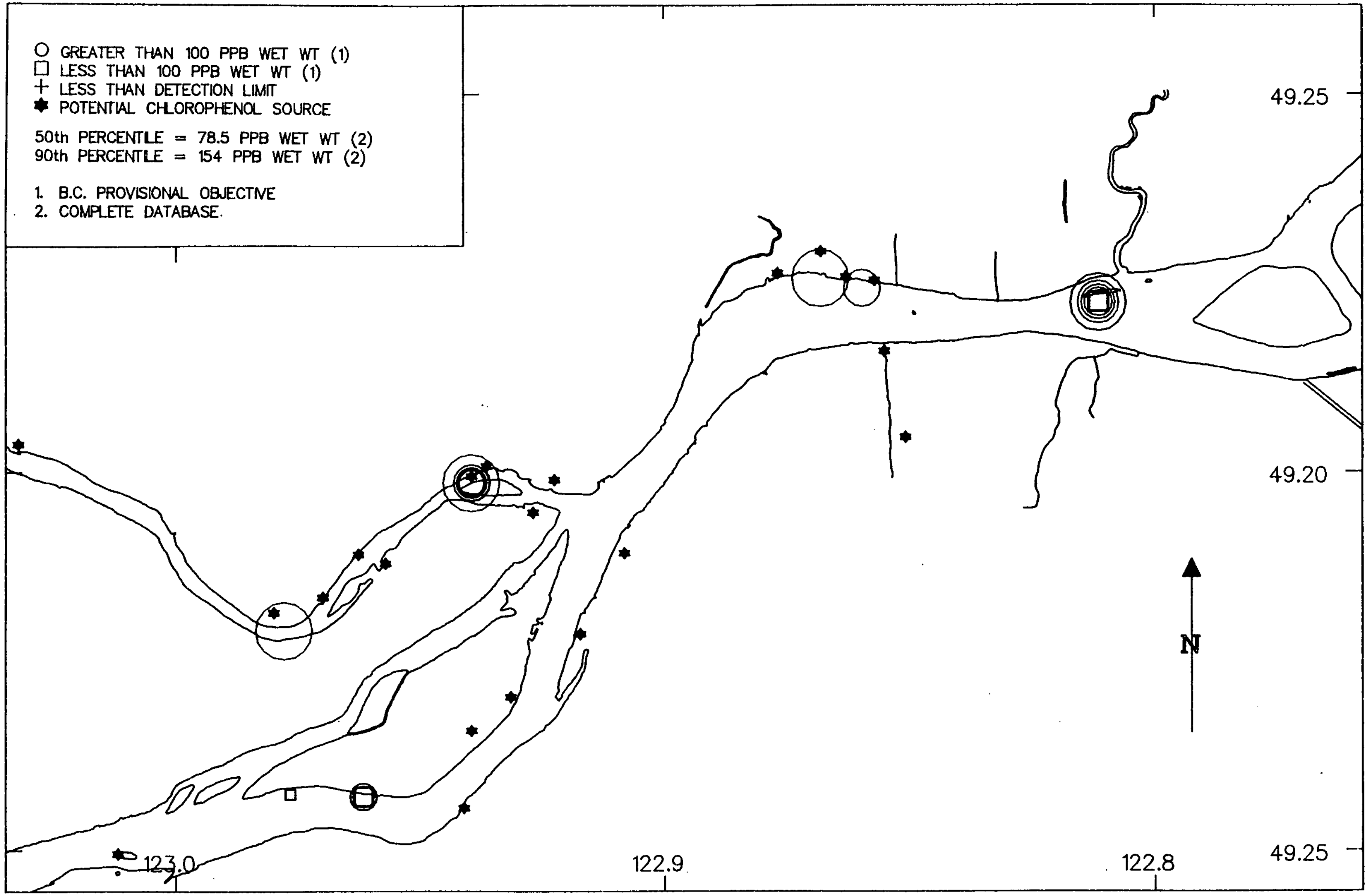

FIGURE 32. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN FISH LIVER, PITT RIVER TO ANNACIS ISLAND
Size of symbol proportional to concentration (ppb wet wt).

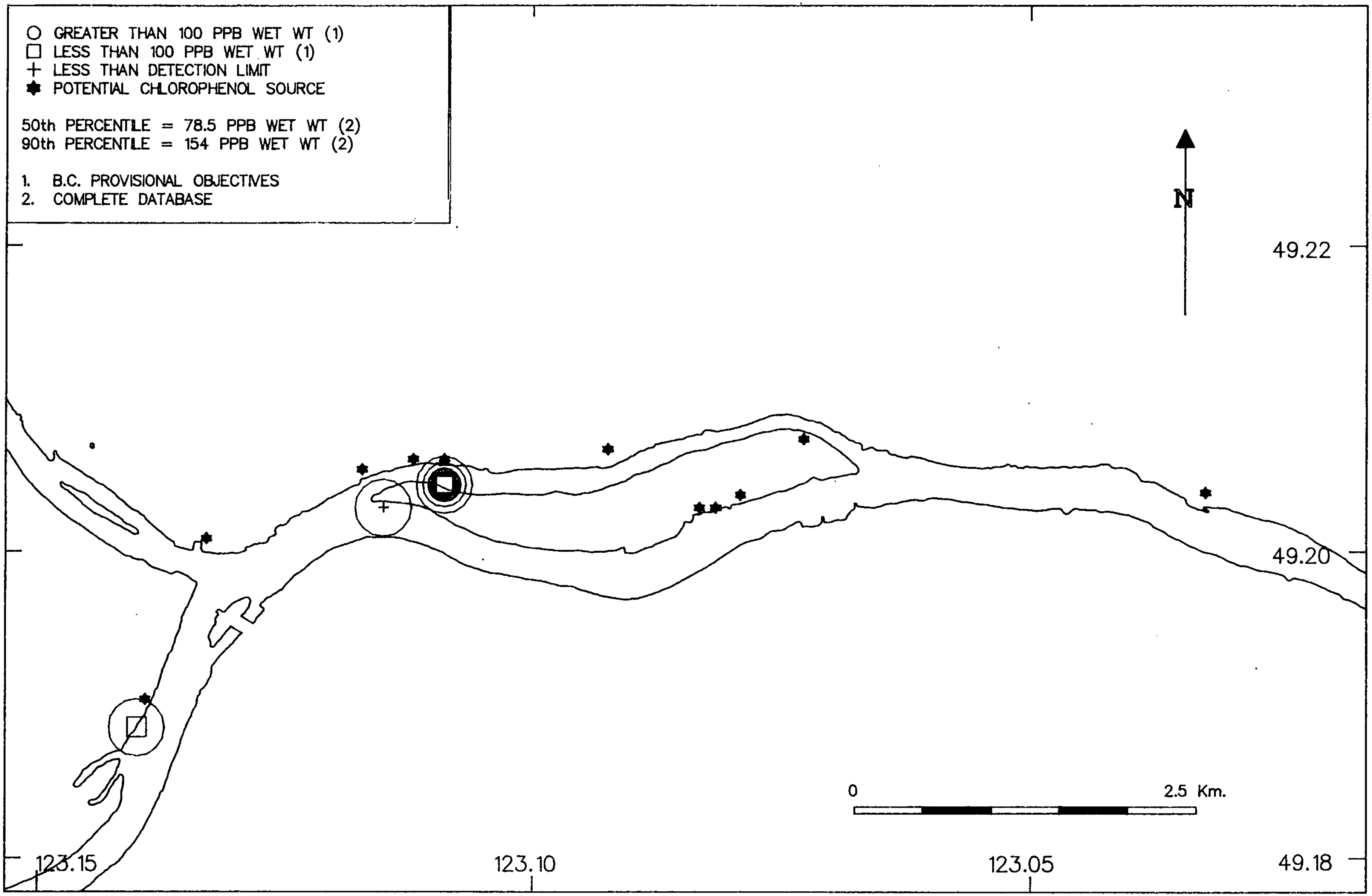

FIGURE 33. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN FISH LIVER, MITCHELL ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

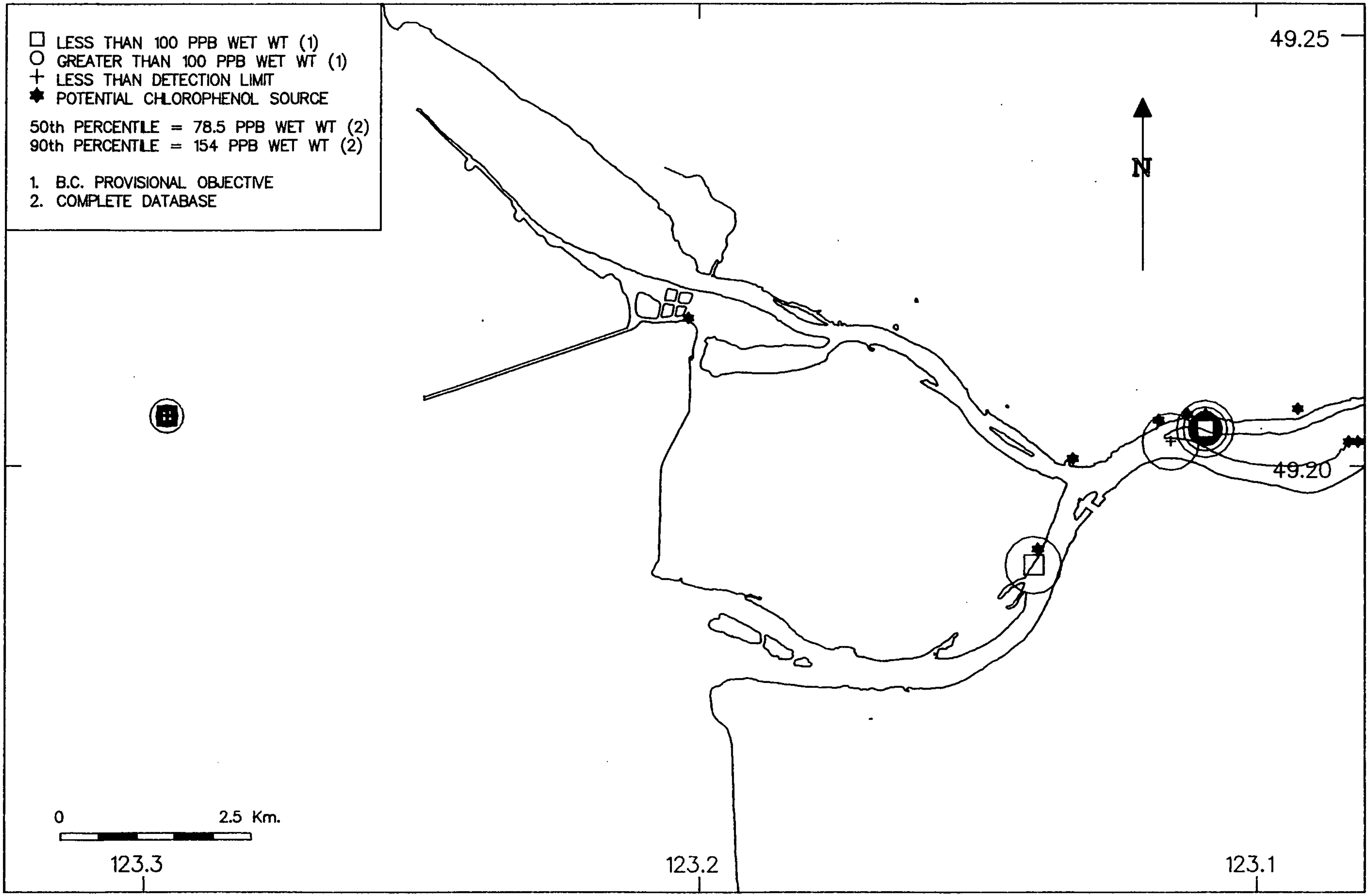

FIGURE 34. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN FISH LIVER, STURGEON BANK TO SEA ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

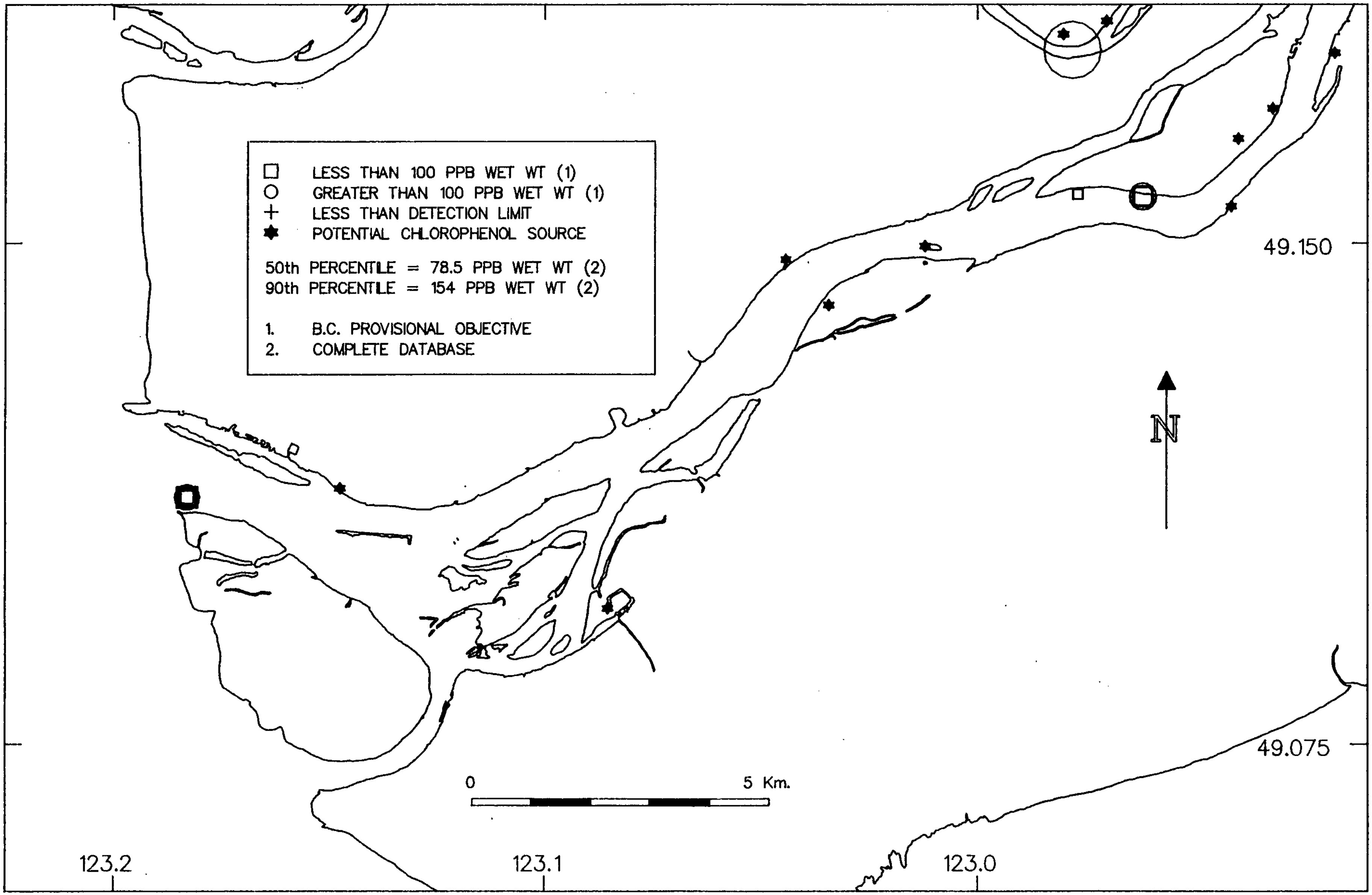

FIGURE 35. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN FISH LIVER, MAIN ARM BELOW ANNACIS ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

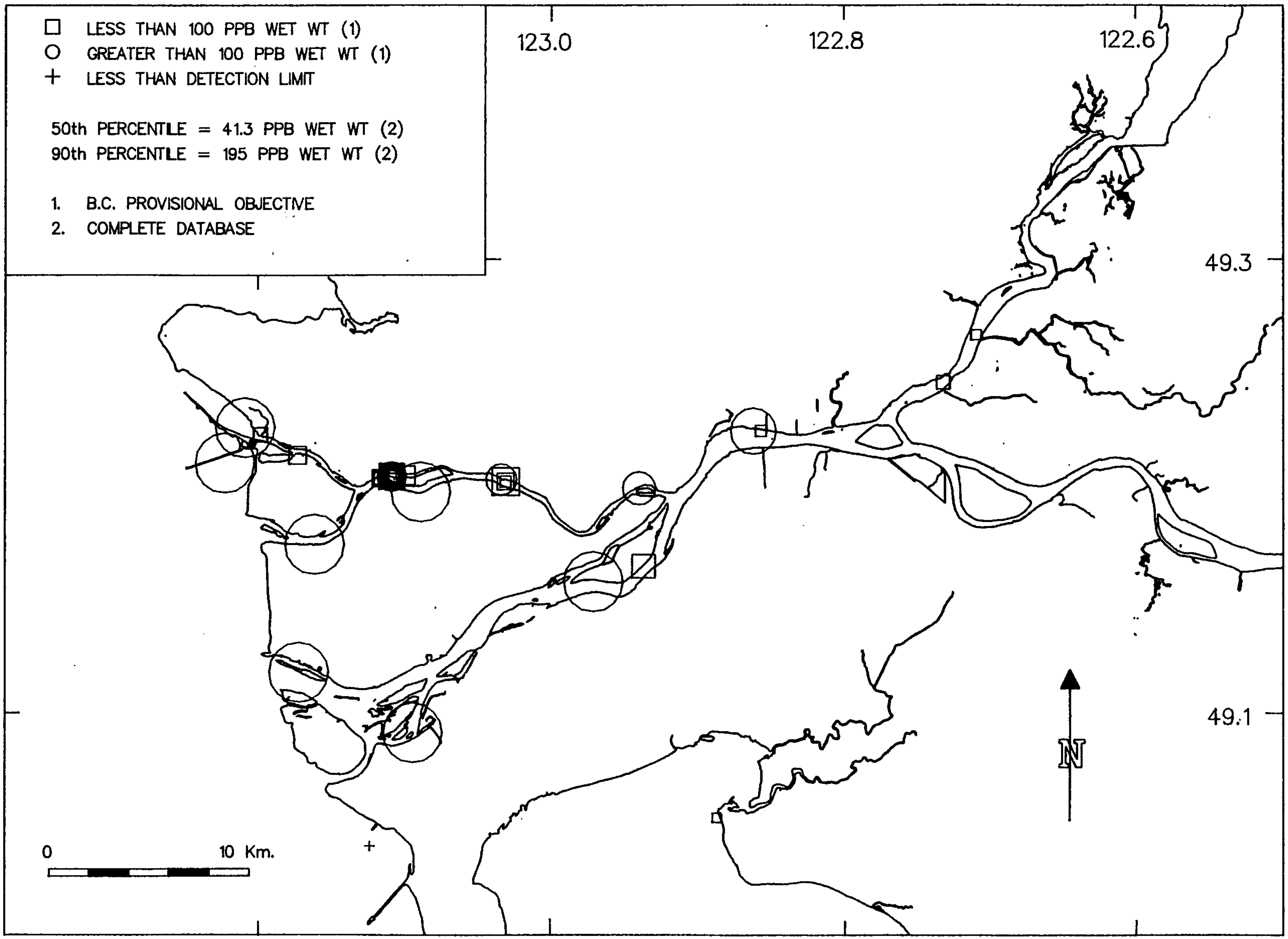

FIGURE 36. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN STARRY FLOUNDER, FRASER RIVER ESTUARY.
Size of symbol proportional to concentration (ppb wet wt).

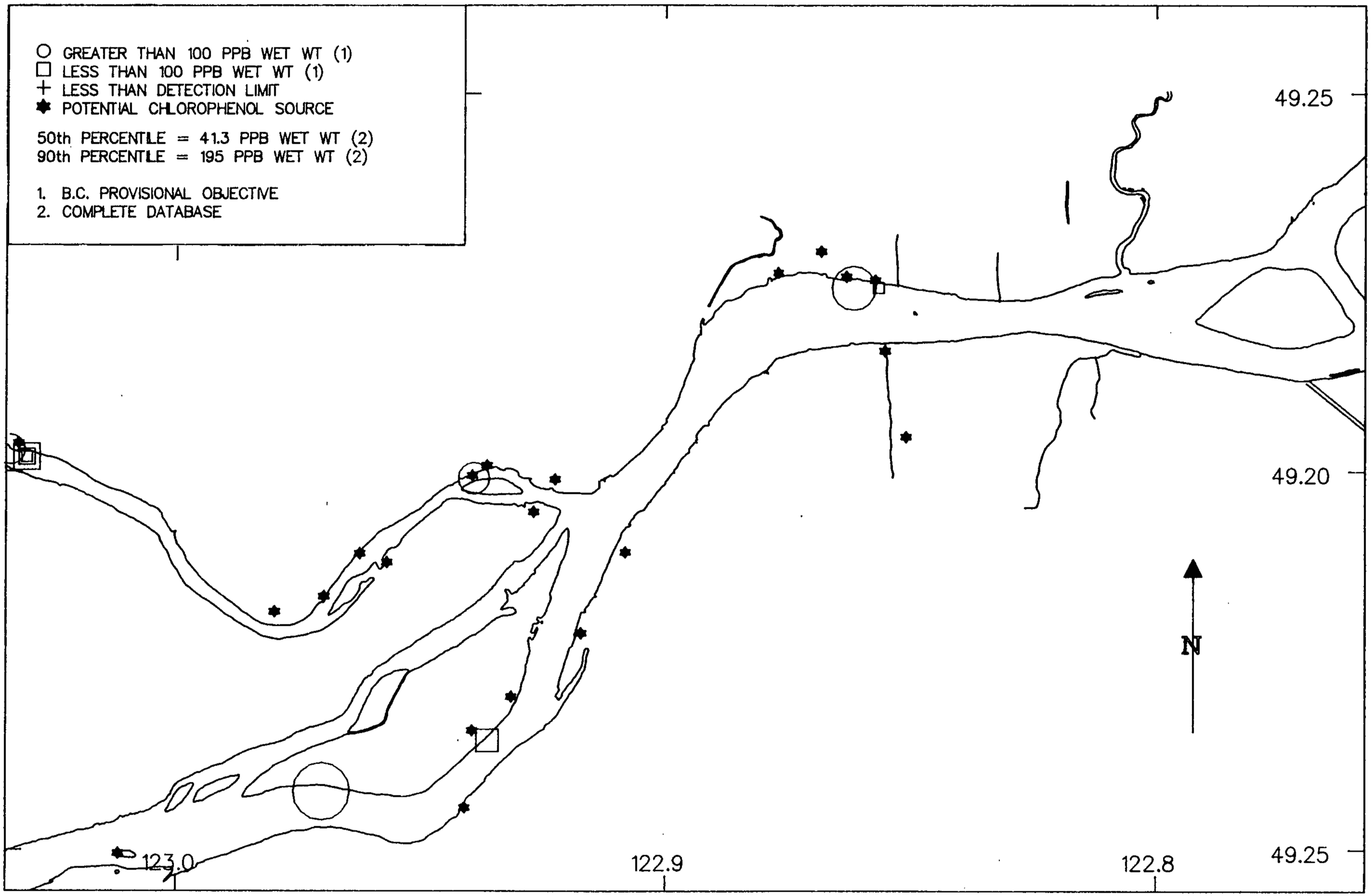

FIGURE 37. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN STARRY FLOUNDER, PITT RIVER TO ANNACIS ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

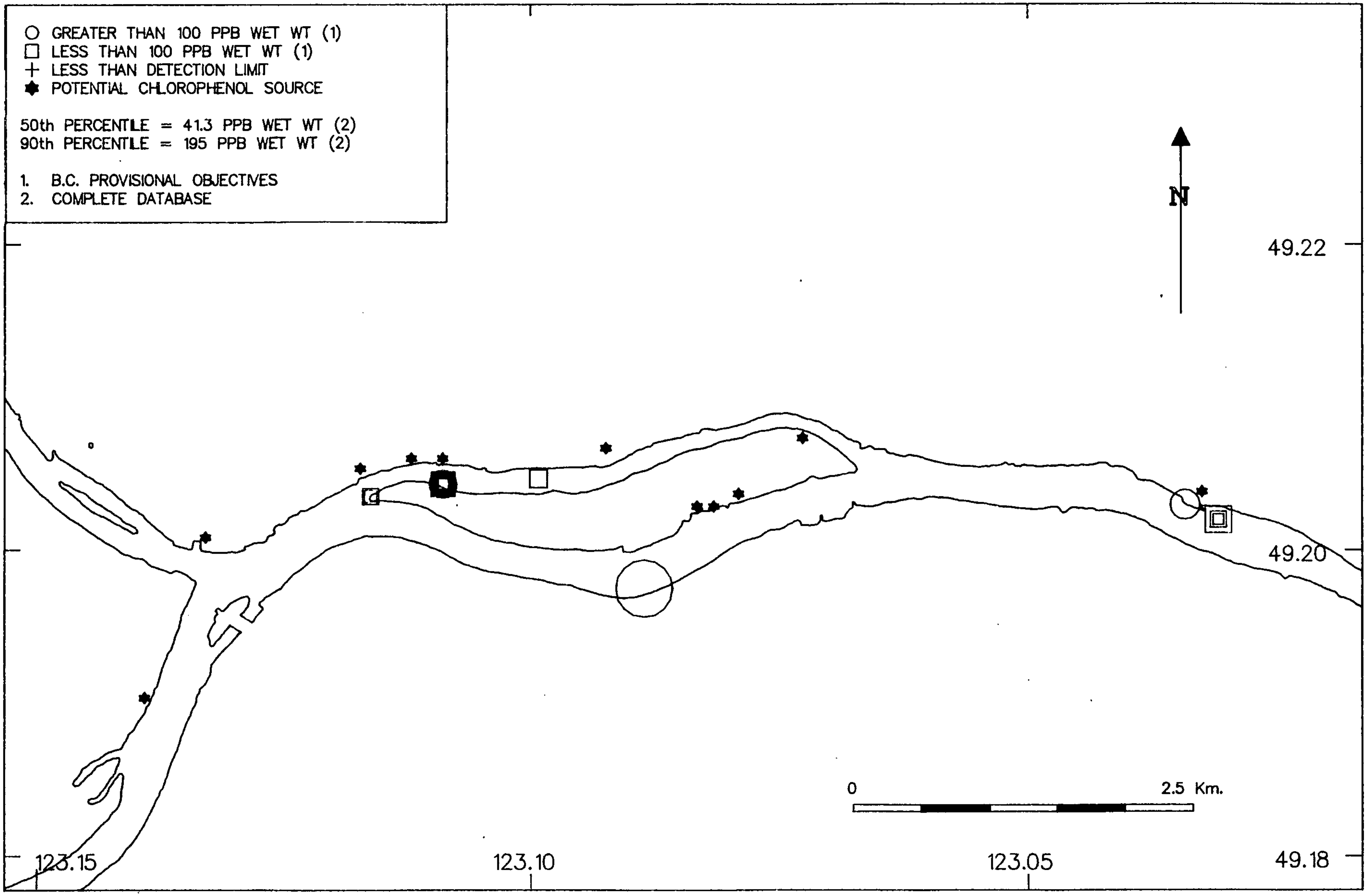

FIGURE 38. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN STARRY FLOUNDER, MITCHELL ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

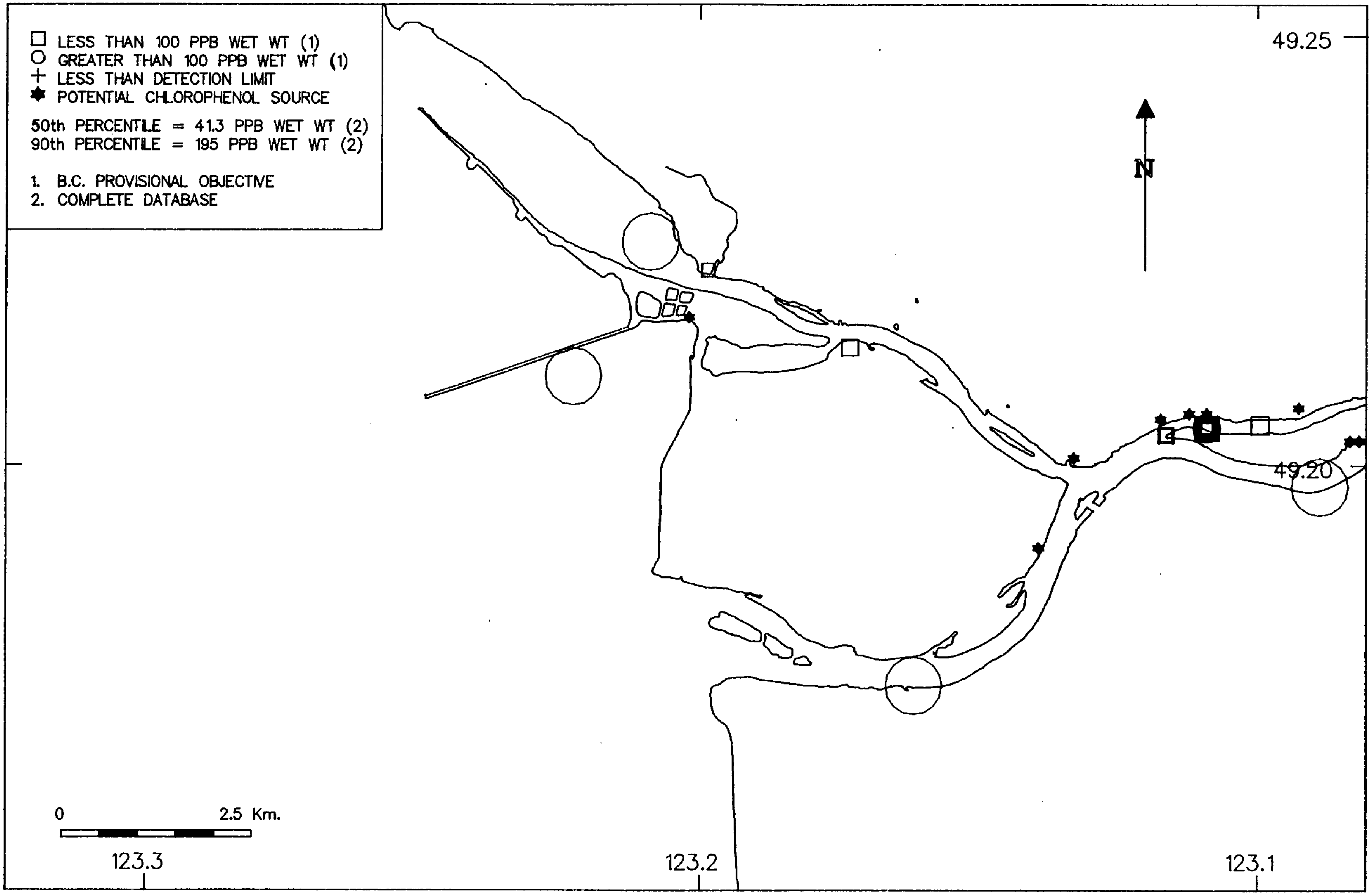

FIGURE 39. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN STARRY FLOUNDER, STURGEON BANK TO SEA ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

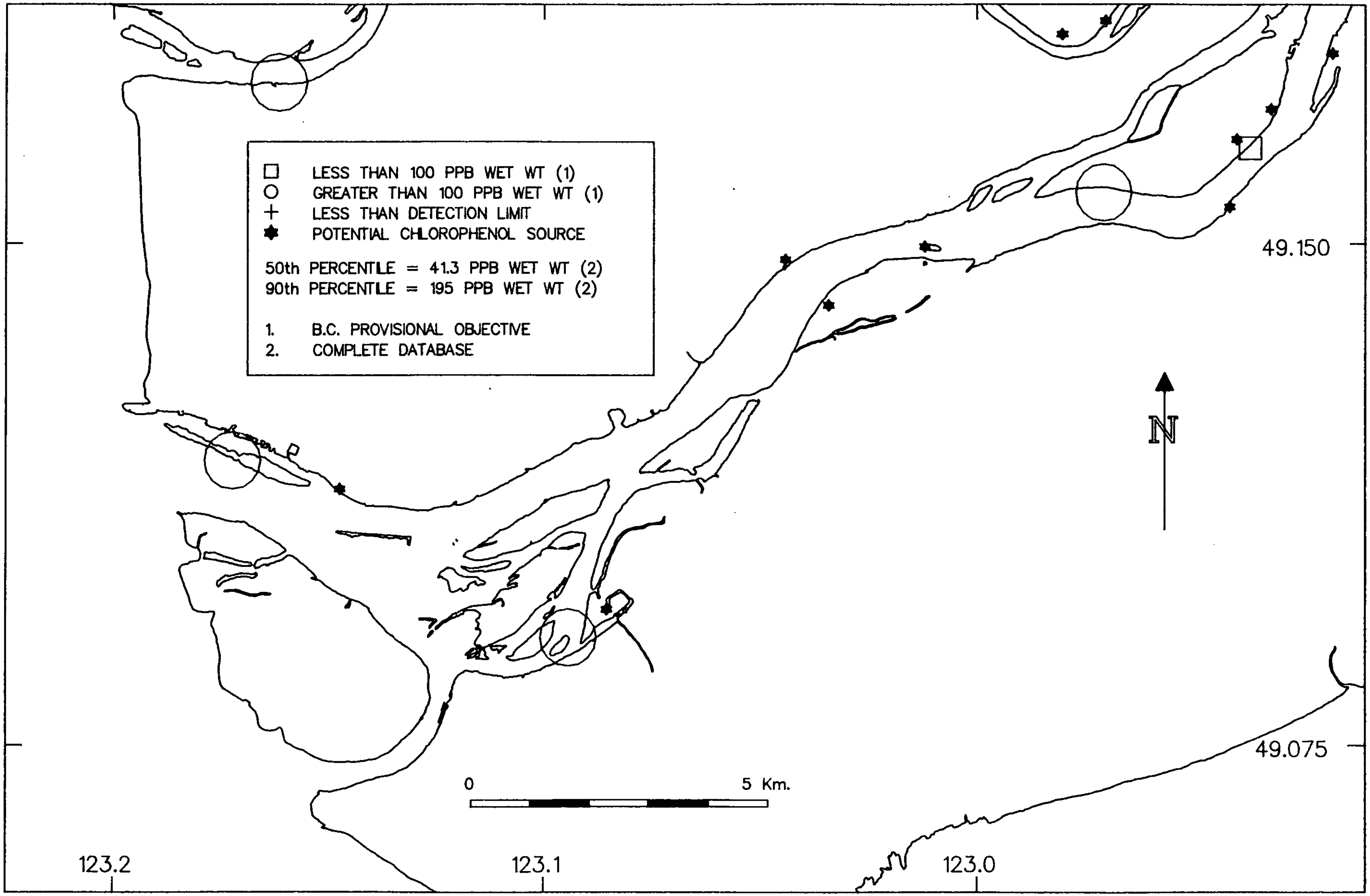

FIGURE 40. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN STARRY FLOUNDER, MAIN ARM BELOW ANNACIS ISLAND. Size of symbol proportional to concentration (ppb wet wt).

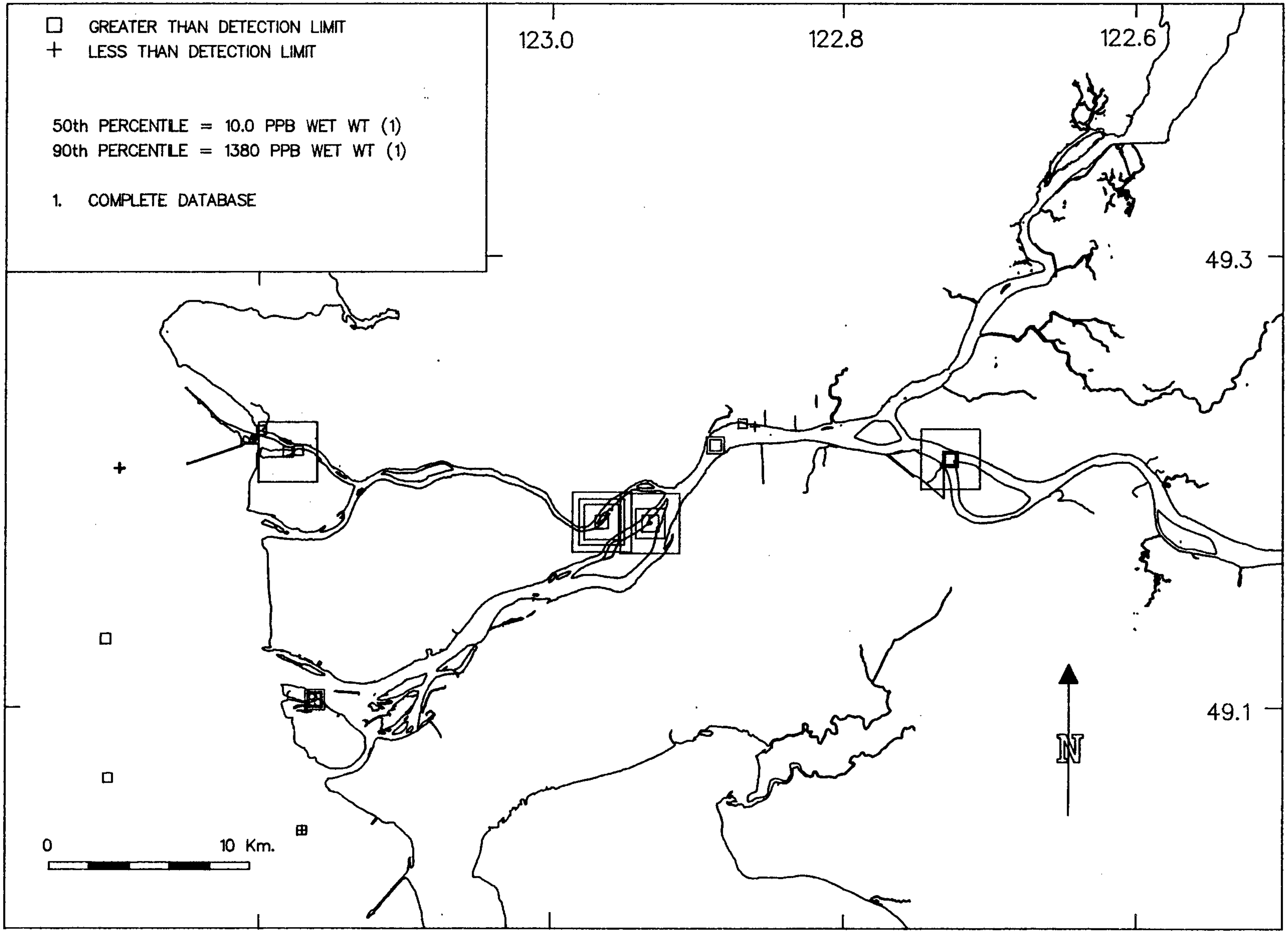

FIGURE 41. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN INVERTEBRATES, FRASER RIVER ESTUARY.
Size of symbol proportional to concentration (ppb wet wt).

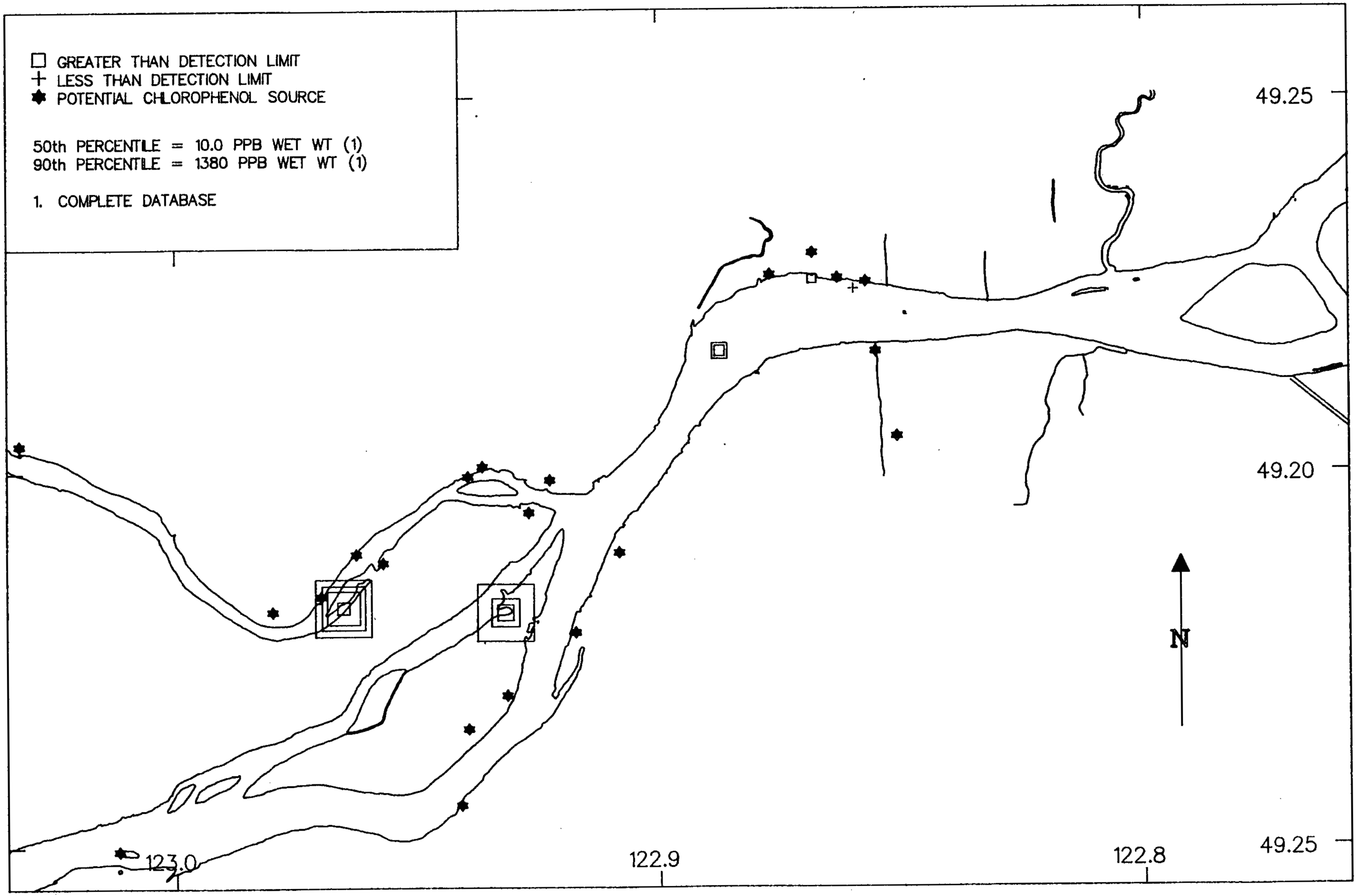

FIGURE 42. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN INVERTEBRATES, PITT RIVER TO ANNACIS ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

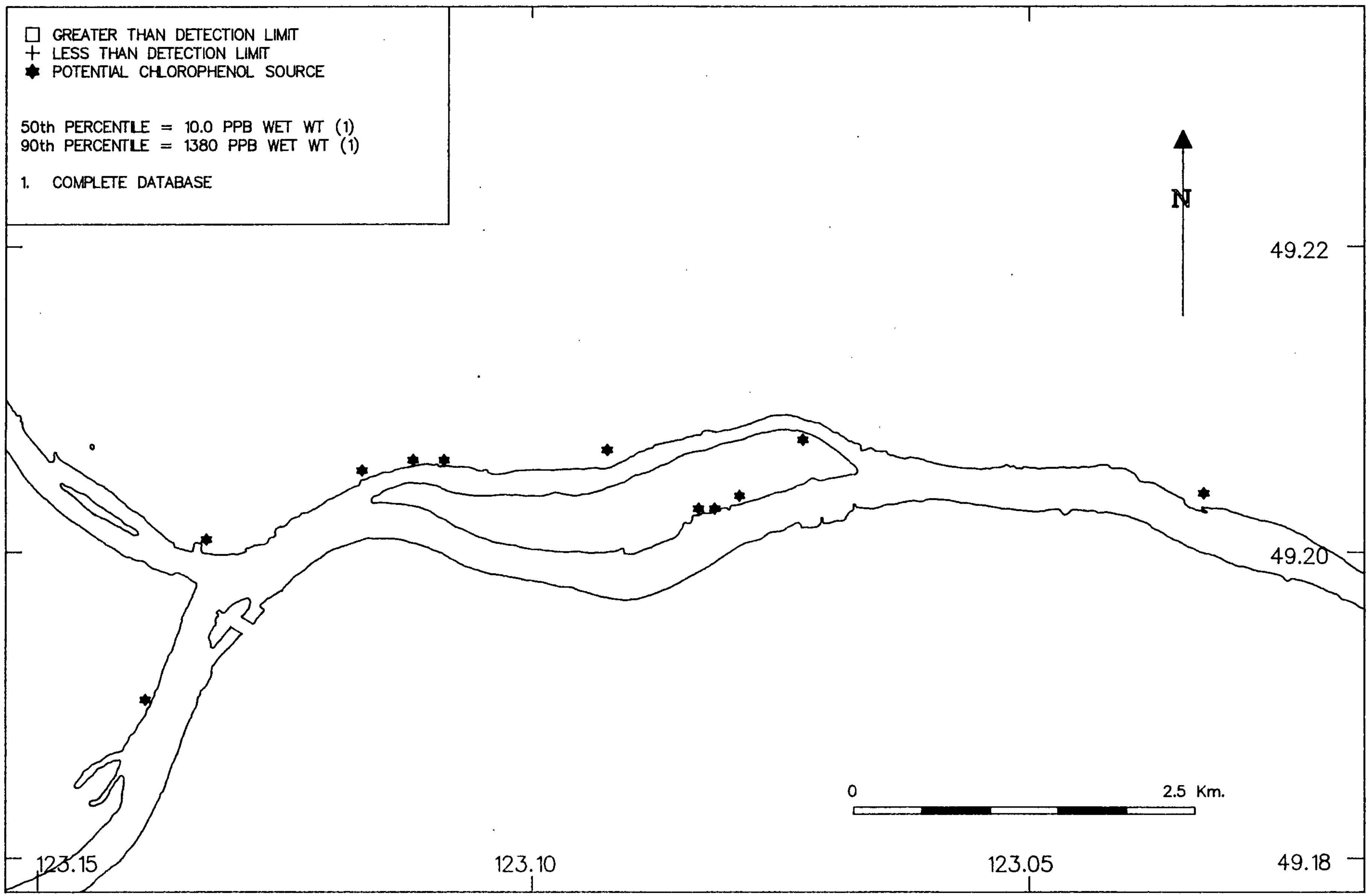

FIGURE 43. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN INVERTEBRATES, MITCHELL ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

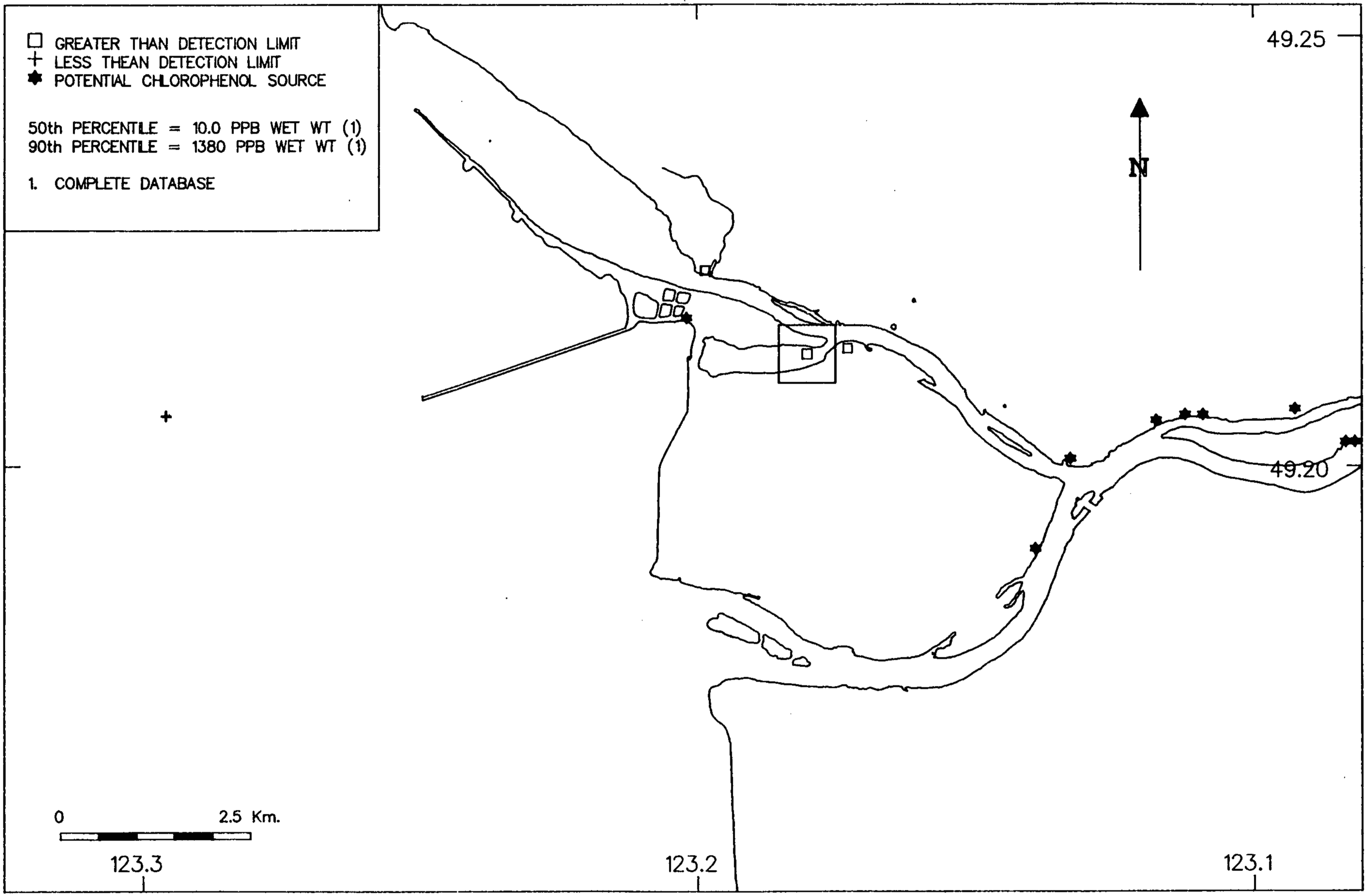

FIGURE 44. DISTRIBUTION OF TOTAL CHLOROPHENOLS IN INVERTEBRATES, STURGEON BANK TO SEA ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

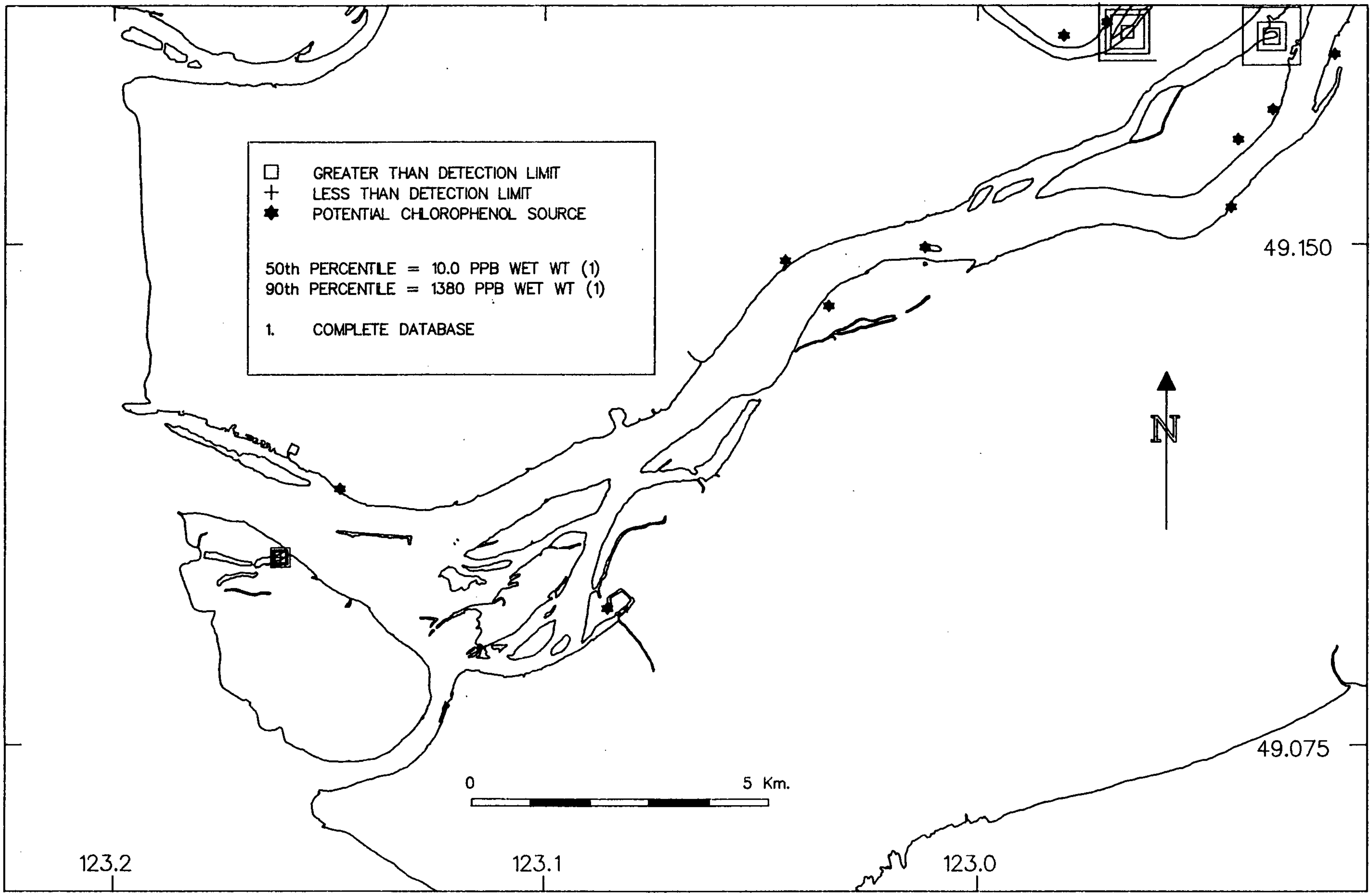

FIGURE 45. DISTRIBUTION OF TOTAL CHLORPHENOLS IN INVERTEBRATES, MAIN ARM BELOW ANNACIS ISLAND.
Size of symbol proportional to concentration (ppb wet wt).

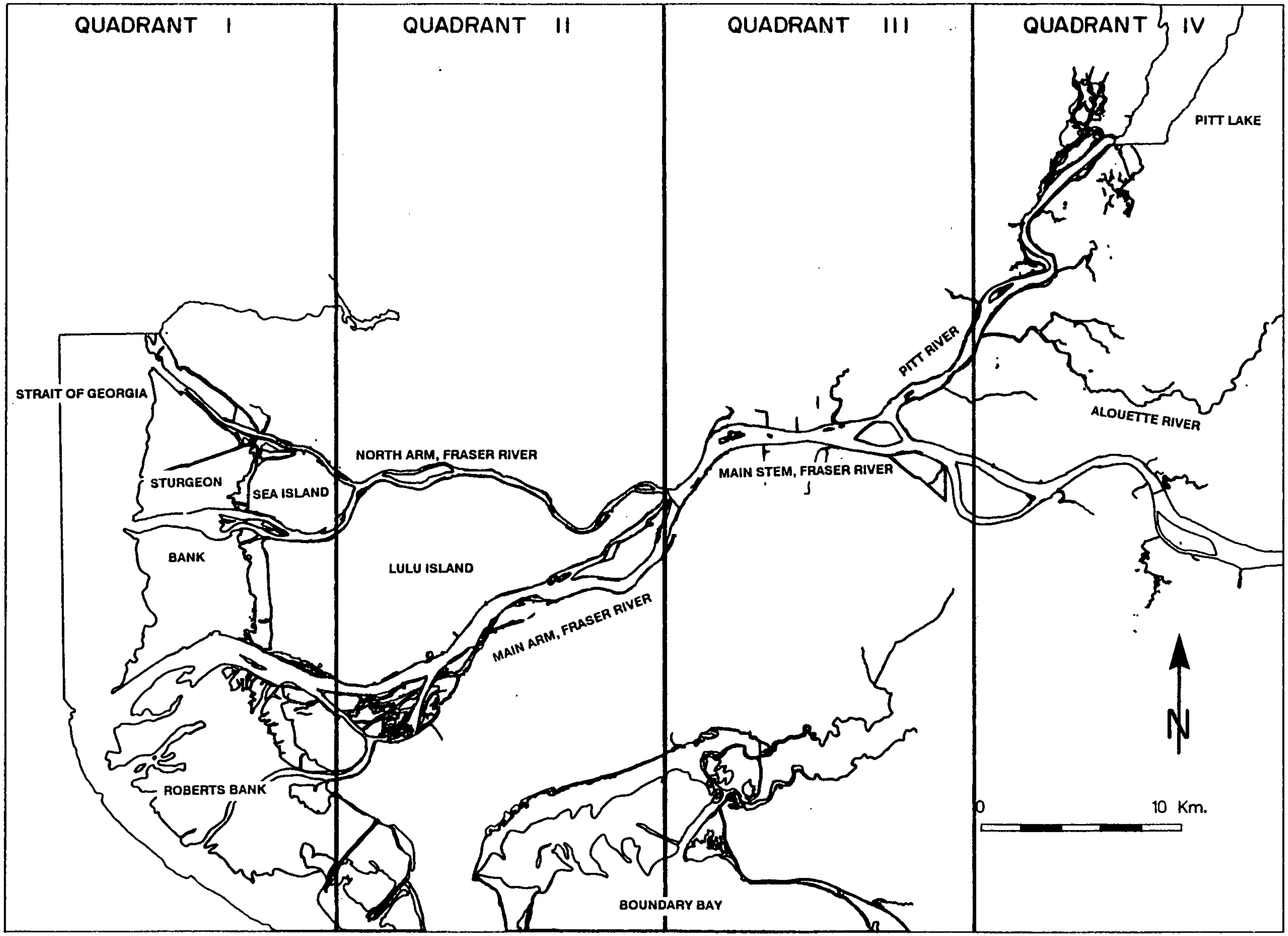

FIGURE 46. OVERVIEW OF AQUATIC HABITAT ZONES, FRASER RIVER ESTUARY.

FIGURE 47.
AQUATIC HABITAT ZONES, FRASER RIVER ESTUARY.
QUADRANT I.

FIV	Freshwater - Intertidal, Vegetated*
MHIV	Marine - High Intertidal, Vegetated
MHINV	Marine - High Intertidal, Non-Vegetated
MLIV	Marine - Low Intertidal, Vegetated*
MLINV	Marine - Low Intertidal, Non-Vegetated
MO	Marine - Open
EUIV	Estuarine, Upper - Intertidal, Vegetated*
EUINV	Estuarine, Upper - Intertidal, Non-Vegetated
ELIV	Estuarine, Lower - Intertidal, Vegetated*
ELINV	Estuarine, Lower - Intertidal, Non-Vegetated
EBC	Estuarine - Backchannel/Slough*
EO	Estuarine - Open
(star symbol)	Potential Chlorophenol Sources
FINV	Freshwater - Intertidal, Non-Vegetated
FBC	Freshwater - Backchannel/Slough*
FO	Freshwater - Open
1	Salmon Enhancement Projects
2	Trumpeter Swan Overwintering Habitat
3A	Staging Areas of International Significance - Shorebirds
3B	Staging and Overwintering Areas of International Significance - Waterfowl
4	Recreational Bar Fishing Areas
5	Juvenile Salmon Rearing Areas, Study Sites
*	Habitats Known to be Important for Juvenile Fish

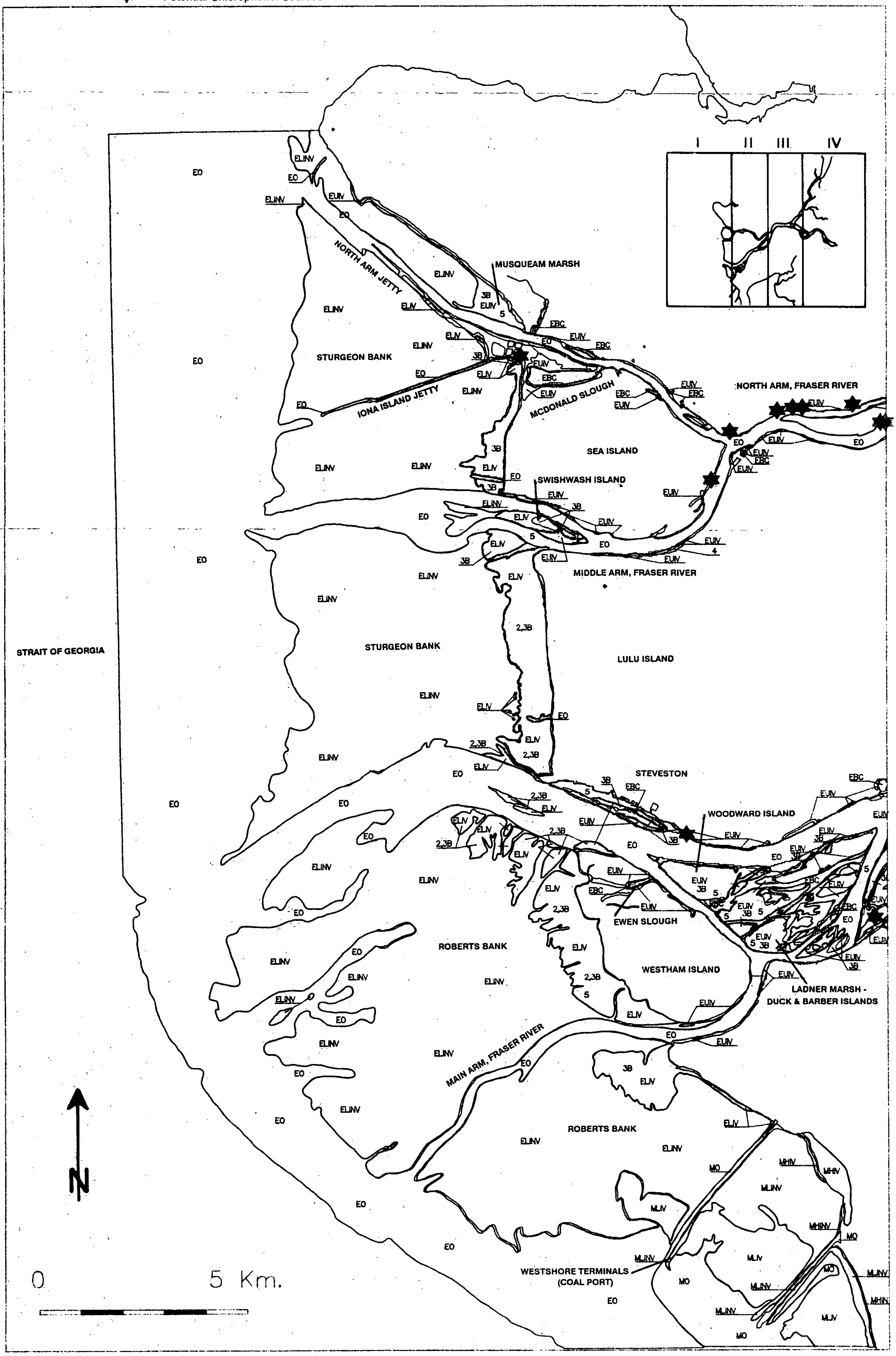

FIGURE 48.
AQUATIC HABITAT ZONES, FRASER RIVER ESTUARY.
QUADRANT II.

FIV	Freshwater - Intertidal, Vegetated*
MHIV	Marine - High Intertidal, Vegetated
MHINV	Marine - High Intertidal, Non-Vegetated
MLIV	Marine - Low Intertidal, Vegetated*
MLINV	Marine - Low Intertidal, Non-Vegetated
MO	Marine - Open
EUIV	Estuarine, Upper - Intertidal, Vegetated*
EUINV	Estuarine, Upper - Intertidal, Non-Vegetated
ELIV	Estuarine, Lower - Intertidal, Vegetated*
ELINV	Estuarine, Lower - Intertidal, Non-Vegetated
EBC	Estuarine - Backchannel/Slough*
EO	Estuarine - Open
★	Potential Chlorophenol Sources
FINV	Freshwater - Intertidal, Non-Vegetated
FBC	Freshwater - Backchannel/Slough*
FO	Freshwater - Open
1	Salmon Enhancement Projects
2	Trumpeter Swan Overwintering Habitat
3A	Staging Areas of International Significance - Shorebirds
3B	Staging and Overwintering Areas of International Significance - Waterfowl
4	Recreational Bar Fishing Areas
5	Juvenile Salmon Rearing Areas, Study Sites
*	Habitats Known to be Important for Juvenile Fish

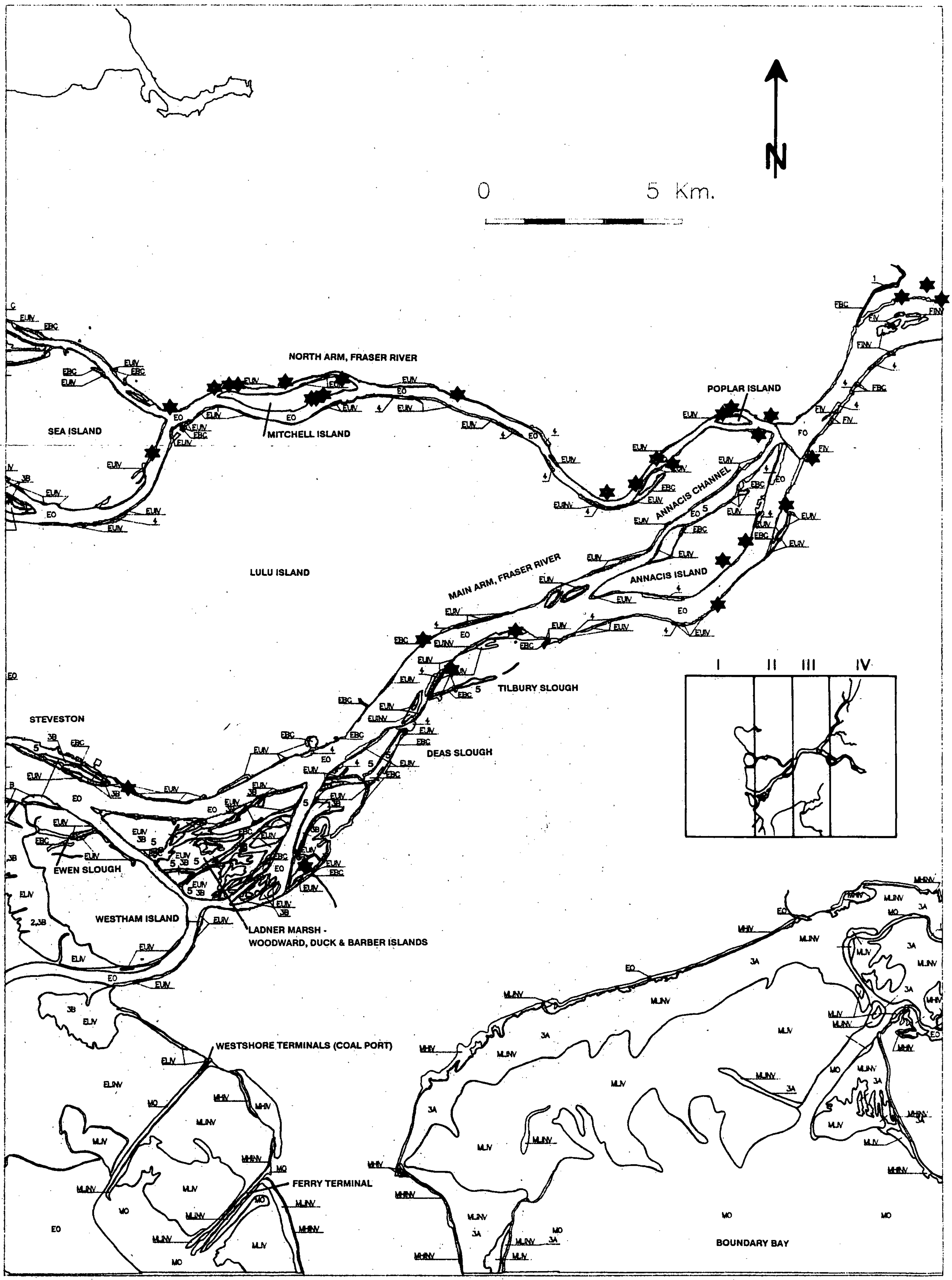

FIGURE 49.
AQUATIC HABITAT ZONES, FRASER RIVER ESTUARY.
QUADRANT III.

FIV	Freshwater - Intertidal, Vegetated*
MHIV	Marine - High Intertidal, Vegetated
MHINV	Marine - High Intertidal, Non-Vegetated
MLIV	Marine - Low Intertidal, Vegetated*
MLINV	Marine - Low Intertidal, Non-Vegetated
MO	Marine - Open
EUIV	Estuarine, Upper - Intertidal, Vegetated*
EUINV	Estuarine, Upper - Intertidal, Non-Vegetated
ELIV	Estuarine, Lower - Intertidal, Vegetated*
ELINV	Estuarine, Lower - Intertidal, Non-Vegetated
EBC	Estuarine - Backchannel/Slough*
EO	Estuarine - Open
★	Potential Chlorophenol Sources
FINV	Freshwater - Intertidal, Non-Vegetated
FBC	Freshwater - Backchannel/Slough*
FO	Freshwater - Open
1	Salmon Enhancement Projects
2	Trumpeter Swan Overwintering Habitat
3A	Staging Areas of International Significance - Shorebirds
3B	Staging and Overwintering Areas of International Significance - Waterfowl
4	Recreational Bar Fishing Areas
*	Habitats Known to be Important for Juvenile Fish

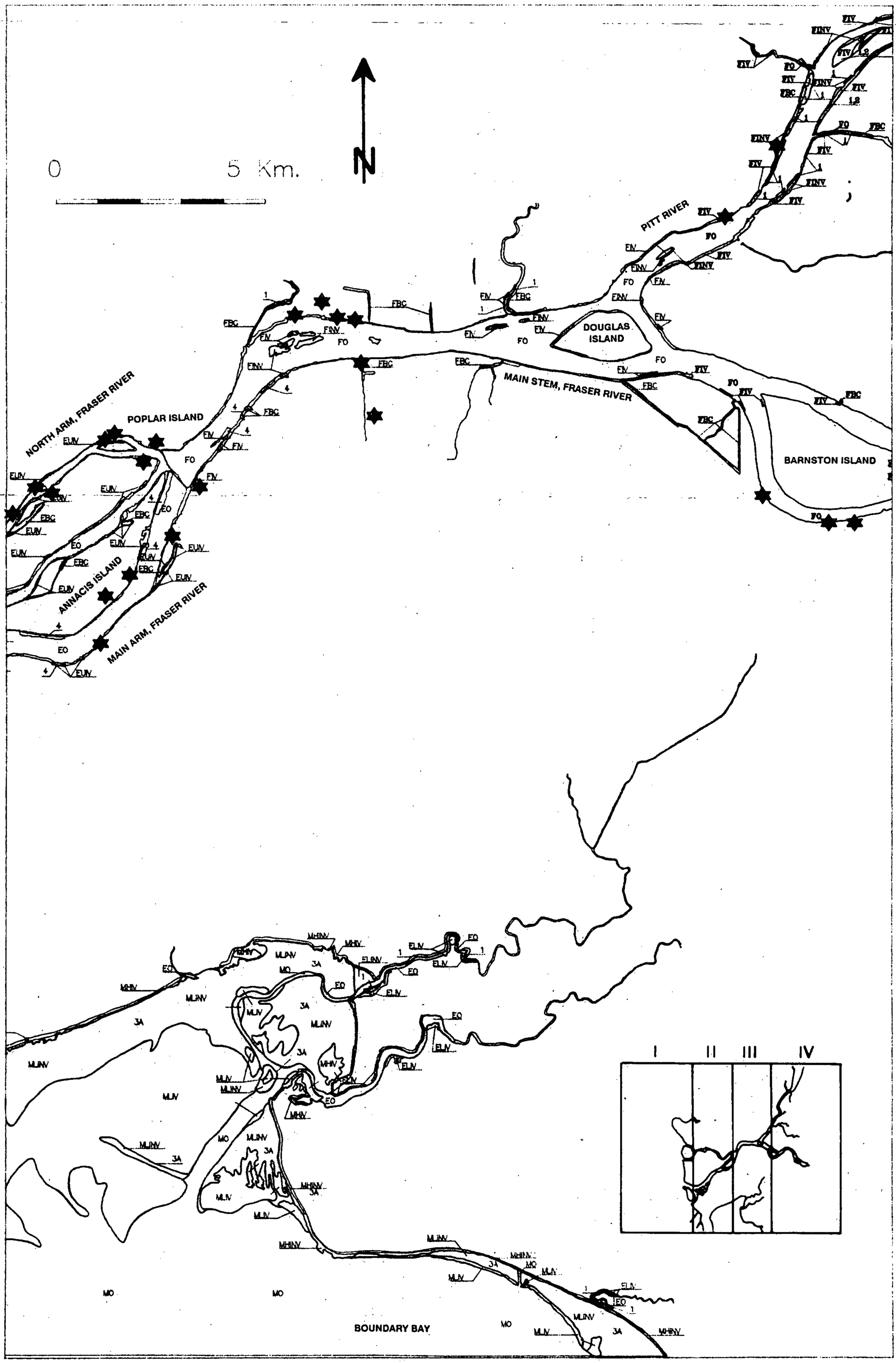

FIGURE 50.
AQUATIC HABITAT ZONES, FRASER RIVER ESTUARY.
QUADRANT IV.

FIV	Freshwater - Intertidal, Vegetated*	FINV	Freshwater - Intertidal, Non-Vegetated
MHIV	Marine - High Intertidal, Vegetated	FBC	Freshwater - Backchannel/Slough*
MHINV	Marine - High Intertidal, Non-Vegetated	FO	Freshwater - Open
MLIV	Marine - Low Intertidal, Vegetated*		
MLINV	Marine - Low Intertidal, Non-Vegetated	1	Salmon Enhancement Projects
MO	Marine - Open	2	Trumpeter Swan Overwintering Habitat
		3A	Staging Areas of International Significance - Shorebirds
EUIV	Estuarine, Upper - Intertidal, Vegetated*		
EUINV	Estuarine, Upper - Intertidal, Non-Vegetated	3B	Staging and Overwintering Areas of International Significance - Waterfowl
ELIV	Estuarine, Lower - Intertidal, Vegetated*		
ELINV	Estuarine, Lower - Intertidal, Non-Vegetated	4	Recreational Bar Fishing Areas
EBC	Estuarine - Backchannel/Slough*		
EO	Estuarine - Open	*	Habitats Known to be Important for Juvenile Fish
✱	Potential Chlorophenol Sources