ENVIRONMENTAL AUDIT

OF THE EAST BAYFRONT/PORT INDUSTRIAL AREA

PHASE 2

Technical Paper

QUALITY OF LIFE AND HEALTH

DRAFT

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for

THE ROYAL COMMISSION ON THE FUTURE

OF THE TORONTO WATERFRONT

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INTRODUCTION (CH)

During Phase 1 of the Environmental Audit of the East Bayfront/Port Industrial Area, the study area was investigated by separating the environment into five components: air, surface water, soils and groundwater, built heritage and natural heritage. Each of these was studied separately. It quickly became clear that as well as examining these components in more detail, Phase 2 should explore the relationships between them and develop an ecosystem framework for the area. It also became obvious that it was impossible to examine the study area in isolation from its surroundings.

One way of achieving this integration is to look at the quality of life and health that the area provides not only for humans, but also for other organisms. The environmental review undertaken during Phase 1 and many of the submissions to the Environment and Health Hearings raised questions about the quality of the environment for people, but it also affects other non human biota, such as plants and animals. For example, different parts of the East Bayfront/Port Industrial Area are quite different from each other. The open spaces adjacent to the Lake offer views, cool breezes, relatively good habitats for plants and animals and opportunities for humans to observe them. The water quality along Cherry Beach is usually good enough to permit swimming for most of the summer. In contrast, much of the industrial portion of the area is perceived as noisy, barren, smelly and dusty and provides relatively poor habitat for plants and animals. Thus, the environmental conditions in the area are heterogenous and generalisations may not be valid. Environmental conditions affect non human biota at least as much as they influence people.

Bearing these points in mind, the objectives of this report are:

- To examine the East Bayfront/Port Industrial Area as an ecosystem, emphasising the relationships between its different components, as well as between the ecosystem and its surroundings;
- To assess the ecosystem health of the East Bayfront/Port Industrial Area; and
- To provide some suggestions on how ideas about ecosystem health could be incorporated into redevelopment plans for the area.

Much of the data and information discussed in this report are taken from the Technical Papers prepared for Phases 1 and 2 of the Environmental Audit. They are referenced accordingly in the Bibliography.

1. THE EAST BAYFRONT/PORT INDUSTRIAL AREA AS AN ECOSYSTEM (CH)

DEFINITIONS AND CONCEPTS OF ECOSYSTEMS (A)

Traditionally, the term ecosystem has been used to describe any selected unit of nature where the biotic and abiotic components exchange materials and energy (Odum 1971; Tansley 1935, 284-307; Knight and Swaney 1981, 991-992). Thus, ecosystems are primarily functional units, although it is possible to analyse them in structural as well as functional terms (Cairns and Pratt 1986, 725-786). This definition implies spatial proximity and interactions, although the boundaries are drawn to encompass the particular interactions and components under study. Therefore, the prescribed boundaries of an ecosystem are always somewhat arbitrary, although they are usually based on biological, physical or chemical criteria. Ecosystems can vary from relatively simple systems, involving a small geographic area and a few species, to very complex systems. Ultimately, the entire biosphere is itself one ecosystem. Ecosystems are open systems, usually receiving and returning energy and materials to other ecosystems. Thus, they are dependant on each other and can be seen as forming a continuum that extends to encompass the whole biosphere.

In contrast, the concept of environment emphasises structures and components. For example, the Canadian Environmental Protection Act defines environment as "the components of the Earth". Environment also denotes one's surroundings. The Oxford English Dictionary defines the environment as "the objects or region surrounding anything. The conditions under which any person or thing lives or is developed; the sum total of influences which modify and determine the development of life or character". (Oxford English Dictionary 1979). These definitions encourage us to see the environment as an assemblage of distinct, static units which surround us, but which are separate from us. It is quite different from the concept of ecosystem which encourages us to think of dynamic, interconnected systems, of which humans are integral components.

In recent years, the concept of ecosystem has become widely accepted, even though it has not yet permeated our environmental decision-making entirely. In 1978, the federal governments of Canada and the U.S. formally adopted an ecosystem approach for the management of the Great Lakes in the Great Lakes Water Quality Agreement. The Agreement states that "restoration and enhancement of the boundary water cannot be achieved independently of other parts of the Great Lakes Basin Ecosystem with which these waters interact." A further commitment to an ecosystem approach can be seen in Article II: "The purpose of the Parties is to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem. In order to the Parties agree to make a maximum effort to develop programs, practices and technology necessary for a better understanding of the Great Lakes Basin Ecosystem and to eliminate or reduce to the maximum extent practicable the discharge of pollutants in the Great Lakes System."

The steps that led to the adoption of an ecosystem approach by the federal governments are described in a special report to the International Joint Commission by the Great Lakes Research Advisory Board (Great Lakes Research

Advisory Board 1978). The adoption of a basinwide ecosystem approach to the management of the Great Lakes was very important because it recognised that actions taken by one jurisdiction are likely to affect the whole system, that therefore programs should be coordinated and that from an ecosystem perspective and provincial, national state boundaries are arbitrary (Caldwell 1988, 1-30).

Within any ecosystem there are many levels of biologic organisation. These can be described in several different ways. Two common ways are to examine the levels of organisation that can be affected by stressors and to consider the system in terms of its trophic structure. Dixon et al. (1985) have proposed a classification scheme describing the levels of biologic organisation that can be affected by stressors. This is shown in Table 1. The six levels are not independent of each other. For example, exposure to a toxic chemical could cause DNA-adduct formation and inhibit cell-to-cell communication, causing developmental effects that could reduce population size and change the trophic structure of the food web.

An ecosystem's trophic structure is determined by several factors including the habitat and the species diversity. Energy and nutrients are transferred from plants (source) through several species by eating and being eaten, although a large proportion of the potential energy is lost at each transfer. Therefore, the number of steps is usually limited to four or five (Odum 1971). This transfer of energy and nutrients is called a food chain, but because food chains are usually interconnected with each other, the term food web is more common. Food webs have been reviewed by Pain (Pain 1980, 667-685). Species whose food is obtained from plants by the same number of steps are at the same trophic level. In many terrestrial ecosystems, there are four or five common trophic levels:

· Green plants (producer level)	first trophic level
· Herbivores (primary consumer level)	second trophic level
· Carnivores (secondary consumer level)	third trophic level
· Secondary carnivores (tertiary consumer level)	fourth trophic level

There are two biological phenomena that are often associated with food webs which are exposed to persistent toxic chemicals. These are biomagnification and bioaccumulation. Bioaccumulation is the process by which some substances, including persistent toxic chemicals, are ingested or absorbed by an organism and retained in its tissues. The amount of bioaccumulation depends on many factors including the concentration of the substance in the food or prey, the amount consumed and the length of exposure. Biomagnification is the process by which the substance is concentrated at successively higher trophic levels by eating and being eaten. Many persistent toxic chemicals are known to bioaccumulate and biomagnify, including DDT, dieldrin, dioxins, PCBs and mercury. For example, the concentration of total PCBs in surface water is approximately 0.0000025 micrograms/gram and in plankton it is approximately 0.001 micrograms/gram, but the concentration in herring gulls is about 51 micrograms/gram.

TABLE I: CLASSIFICATION OF LEVELS OF BIOLOGIC ORGANISATION

LEVEL	EXAMPLES OF EFFECTS
Molecular	DNA-adduct formation, enzyme induction or inhibition
Cellular	Inhibition of cell-to-cell communication, cell proliferation
Tissue/Organ	Lung cancer, chloracne, anencephalus and other developmental effects
Individual	Mortality, premature aging, size
Population	Disease incidence and prevalence, reproductive success rates, size
Community	Reduction in species diversity; changes in trophic structure of food webs

Unlike the classification of biologic organisation, food webs are based on function, rather than structure. A species, for example, humans, may occupy oneor more than one trophic level, according to its food sources. It is important to note that this classification does not contain any levels for microbial organisms that breakdown dead and decaying tissue. These types of organisms are essential to the healthy functioning of ecosystems because they facilitate nutrient and energy cycling through the system.

Several models have been developed to predict the flow of energy, nutrients and toxic chemicals through ecosystems. One of these is the fugacity model which uses mathematical modelling techniques to predict the likely behaviour of chemicals in real and constructed environments (see for examples, Clarke et al. 1988, 120-127).

Although when we think of ecosystems, we tend to visualise rural, natural systems, many ecosystems involve artificial structures, such as roads and buildings, and humans in cities and other communities. The importance of the relationships between humans, the built environment and the more natural components of ecosystems have been recognised in the Canadian Healthy Communities Project and the World Health Organisation's Healthy Cities Project. These Projects are intended to improve and enhance human and ecosystem health. A healthy city should provide:

- A clean, safe, high quality physical environment;
- An ecosystem that is stable now and sustainable in the long term;
- A strong, mutually supportive and non-exploitive community;
- A high degree of participation and control by the public over affecting their lives, health and well-being;
- Basic needs (food, water, shelter, income, safety and work);
- Access to a wide variety of experiences and resources;
- Connectedness with the past (cultural and biological heritage);
- An optimum level of appropriate public health and sick care services acceptable to all; and,
- High health status (high levels of positive health and low levels of disease.

Although these attributes are expressed in anthropocentric terms, they have implications for ecosystems and their health.

THE EAST BAYFRONT/PORT INDUSTRIAL AREA AS AN ECOSYSTEM (A)

The East Bayfront/Port Industrial Area does not constitute an naturally-defined ecosystem. The spatial boundaries were established by the declaration of

Provincial Interest made by the Province of Ontario under the <u>Planning Act</u> on 17 October 1989, rather than by any consideration of the natural integrity of the area. Thus, the boundaries were arbitrarily defined by jurisdictional issues, rather than by physical, chemical or biological interactions. As a result, the concept of the East Bayfront/Port Industrial Area as an ecosystem is somewhat problematic. Nevertheless, it is possible to apply the principles of an ecosystem approach to the area and to an assessment of its health.

To apply the principles of an ecosystem approach to the East Bayfront/Port Industrial Area, it is necessary to understand how nutrients and toxic chemicals flow in the area, as well as how they enter and leave it. To do this, a scheme showing some of the possible interactions is shown in Table II. The available environmental data can then be seen in the context of an ecosystem approach. This emphasises the relationships between the different components as well as where information is lacking. Obviously, there is a large number of interactions in most ecosystems. Fortunately, there is usually only a relatively small number of key interactions. This scheme identifies the key interactions in the East Bayfront/Port Industrial Area, allowing the effects of human activities to be managed more effectively.

TRANSFERS OF NUTRIENTS AND TOXIC CHEMICALS WITHIN THE ECOSYSTEM AND BETWEEN THE ECOSYSTEM AND ITS SURROUNDINGS (A)

This section of the report describes the conditions in the East Bayfront/Port Industrial Area from an ecosystem perspective. Thus, it draws very heavily on published data. In contrast to standard data interpretations however, it describes the links between prevailing conditions in different media and relates data sets from different media wherever possible. This is difficult because the data are incomplete.

Six media have been examined. They are:

- Air;
- Soils and groundwater;
- Sediments;
- Surface water;
- Terrestrial biota; and
- Aquatic biota.

Air and sediments are usually regarded as the most important indirect sources and sinks of nutrients and toxic chemicals because they act as virtually limitless reservoirs. However, surface water and soils and groundwater can also be significant sources and sinks.

At the beginning of each section, the loadings to the medium are summarised.

TABLE II TRANSFERS OF NUTRIENTS AND TOXIC CHEMICALS WITHIN THE ECOSYSTEM AND BETWEEN THE ECOSYSTEM AND ITS SURROUNDINGS

MEDIA	LOADINGS TO MEDIA	TRANSFERS WITHIN MEDIA	EFFLUX FROM MEDIA
Air	LOCAL POINT AND NON POINT SOURCES	Lrtap	DEPOSITION ONTO SOILS/DUST, PLANTS AND WATER
	VOLATILISATION FROM SOILS/DUST and surface water	Mixing in air column	Inhalation by terrestrial animals
Soils/groundwater	LOCAL POINT AND NON POINT SOURCES	MOVEMENT OF GROUNDWATER	Ingestion/uptake by terrestrial biota
	DEPOSITION FROM AIR	Transfers from groundwater to soils and vice versa	Volatilisation to air and resuspension to dust
	Decay of terrestrial biota		INFILTRATION OF GROUNDWATER TO SURFACE WATER
Sediments	LOADINGS OF SEDIMENTS		INGESTION/ UPTAKE BY AQUATIC BIOTA
	Deposition from surface water and suspended solids	Sediment burial	RESUSPENSION INTO WATER BY DREDGING ETC.
	Decay of aquatic biota	Sediment movement	
Surface Water	LOCAL POINT AND NON POINT SOURCES	Mixing in water column	Deposition to sediments
	DEPOSITION FROM	Mixing of	Adsorption to

	AIR	nearshore and offshore water	particulates
	INFILTRATION FROM GROUNDWATER		Ingestion/uptake by aquatic biota
	RESUSPENSION FROM SEDIMENTS		Volatilisation to air
	Decay of aquatic biota		
Terrestrial biota	Inhalation of air	Transfers up the terrestrial food web	Decay to soils/groundwater
	Ingestion/uptake from surface water and groundwater	Transfers within species (prenatal and postnatal)	Excretion
	Ingestion/uptake from soils/groundwater		
	Ingestion of aquatic biota		
Aquatic Biota	Ingestion/uptake from surface water	Transfers up the aquatic food web	Ingestion of aquatic biota by terrestrial biota
	INGESTION/ UPTAKE FROM SEDIMENTS	Transfers within species (prenatal)	Decay to water and sediments
			Excretion

Note: PATHWAYS IN CAPITAL LETTERS MEAN THAT DATA ON THE EAST BAYFRONT/PORT INDUSTRIAL AREA ARE AVAILABLE, underlined pathways mean that data from elsewhere are available and lower case pathways mean that no data are available.

Then its current status is examined, including any mixing or transfers occurring within it. Finally, the effluxes from each medium are outlined. Degradatory pathways have not been examined in great detail. These include the chemical, physical and biological processes by which toxic chemicals are broken down. In general, little research has been done on the persistence and fate of nutrients and toxic chemicals in ecosystems.

The Phase 1 and 2 reports for the Environmental Audit were used extensively to prepare this section (Shenfield 1990 a,b; Intera Kenting 1990a,b; Dobos and Chan 1990; Natural Heritage Workgroup 1990a,b). In addition, the Stage 1 of the Remedial Action Plan for Metro Toronto was very helpful (Environment Canada et al. 1988).

Air (B)

Loadings (C)

There are two main types of loadings to the atmosphere of the East Bayfront/Port Industrial Area. These are anthropogenic point and non point sources and volatilisation from soil, dust and surface water. Obviously, air quality in the East Bayfront/Port Industrial Area is influenced by sources inside and outside the geographic area itself.

The anthropogenic point and non point sources affecting air quality have been described in the Phase 1 report on the atmospheric environment. Redpath Sugar is probably the major anthropogenic source of SO_2, NOX and CO, while Canada Malting is the major source of particulates and the Main Sewage Treatment Plant is the major source of VOC. In the surrounding areas, the east half of the Gardiner Expressway is the major source of NOX, CO and VOC while Canada Metal is the main source of SO_2 and particulates.

It is important to note that the data shown in the Phase 1 report are for 1985 and that the Commissioners Street incinerator, the Oil Canada Company and the TTR plants are not in operation at present. There are also other sources of dust and odours that affect air quality including scrap metal industries, oil tank farms, oil processing plants and asphalt production facilities. Emissions of toxic chemicals from the study area and its surroundings have not been thoroughly quantified, except that it has been estimated that Canada Metal emits approximately one tonne of lead a year.

Some chemicals can volatilise from soil, dust and water. In addition, soil particles can become suspended as dust. There is no information available on the nature and extent of volatilisation from surface water. The extent of volatilisation and resuspension from soil will depend on the proportion of land that is built on, paved or covered with vegetation and the prevailing climatic conditions. Since soil contamination is a problem in the study area, it is possible that volatilisation and resuspension are important sources of contaminants to the atmosphere, although only a small proportion of the study area is bare soil. Research conducted during Phases 1 and 2 has indicated that there are volatile chemicals present at several sites. These include petroleum product sites where organic vapour from the low parts per million range to greater than the 100% lower explosive limit, indicating an explosion hazard in soil air. Volatile chemicals such as benzene, toluene and xylene were also detected.

Status and Internal Transfer (C)

Air quality in the study area have been described in the Phase 1 report. In summary:

- Sulphur dioxide and nitrogen dioxide are not a problem in the Toronto Waterfront at present. Nitrogen dioxide could become a problem if the orientation of new buildings confine air movement in the vicinity of the Gardiner Expressway and Lakeshore Boulevard;

- Carbon monoxide, suspended particulates and dustfall are a problem in close proximity to the Gardiner Expressway and Lakeshore Boulevard, especially near the exit ramps;

- Dustfall is a problem in the Port Industrial Area in the vicinity of the coal, sand and gravel piles, and in the vicinity of the landfill trucking operations;

- Lead is likely to have contaminated the soil along the Expressway and Lakeshore Boulevard as well as in the eastern Port Industrial Area;

- Odours are a problem;

- Noise is a problem in the East Bayfront as well as in the Port Industrial Area, in the vicinity of the Gardiner Expressway and Lakeshore Boulevard;

- Air quality is affected by ground level ozone and fine particulates composed of sulphates and nitrates that are perceived as haze, are a problem on warm, sunny days in late spring and summer.

Within the atmosphere, mixing or dispersion of toxic chemicals and gases such as SOX and NOX can occur vertically in the air column and horizontally (including the long range transportation of air pollutants - LRTAP). There is no information available on vertical mixing and dispersion in the study area. Toxic chemicals and gases from local sources in the study area and its surrounding will mix with those from remote sources. The major factors that influence the contribution of remote sources to local air quality include the magnitude and composition of the remote emissions, the distances involved and the prevailing climatic conditions. The airshed or atmospheric region of influence for the Great Lakes Basin, and hence for the study area, has been defined as extending as far as Hudson Bay (north), the Dakotas (west), central Georgia (south) and New Brunswick (east) (Summers and Young 1987).

The concept of LRTAP implies that the East Bayfront/Port Industrial Area could be a source of pollutants to remote areas. However, since the emissions in the study area constitute only a small proportion of the total atmospheric loadings in Metropolitan Toronto, it is unlikely to contribute to LRTAP significantly.

Effluxes (C)

Pollutants can be lost from the air by deposition onto dust, soils, plants and surface water and by inhalation by terrestrial animals. Dry and wet deposition occur. Dry deposition occurs via dust and wet deposition occurs via rain, snow and hail.

There are some data that have estimated the atmospheric deposition of chemicals to the Toronto Waterfront. They suggest that deposition to water is likely to be relatively small contributor of chemicals to surface water, and that deposition to land is more significant. This can be seen in Table III.

The Environment Ontario Air Resource Branch has recently established a deposition and monitoring site on the Toronto Islands. This will provide information on the deposition of persistent toxic chemicals, such as PCBs, DDT, cadmium and lead that will be helpful in estimating atmospheric loadings.

Terrestrial animals inhale air. Particulates can remain in the lungs and chemicals can be absorbed into the bloodstream. Some chemicals, such as CO, are easily absorbed, while others are not. But even if chemicals and particulates are present at low concentrations, the large volumes of air inhaled can expose terrestrial animals to relatively large amounts. The average person inhales approximately 20m^3 a day. If a chemical is present at 1 microgram/litre in air, a human would be exposed to 0.02 grams/day. Nevertheless, the amounts of chemicals and particulates lost from the atmosphere through inhalation are likely to be insignificant in terms of the total amounts present.

Soils and Groundwater (B)

Loadings (C)

There are three main sources of nutrients and toxic chemicals to soils and groundwater in the East Bayfront/Port Industrial Area. These are anthropogenic point and non point sources, atmospheric deposition and the decay of terrestrial biota. Soils and groundwater in the study area are affected mainly by local sources, except for the atmospheric deposition which can be local or remote.

Anthropogenic point sources include previous or current land use activities that could contaminate the area. These are described in the Phase 1 and 2 reports on soils and groundwater quality. Thirty-nine of 123 identified sites have or had land uses as coal storage or distribution sites and thirty-eight have had uses as petroleum product storage, refining or distribution sites. Coal storage and distribution can result in slightly elevated levels of some heavy metals and PAHs in soil and high levels of sulphate and low pH in groundwater. Petroleum product storage, refining or distribution typically results in spills and leaks. In addition to oil and gasoline contamination, such industrial land use often results in contamination of soils and groundwater with VOCs, such as benzene, toluene and xylene, phenols and PAHs.

Anthropogenic non point sources include the lakefill that created much of the area, including the reclamation of Ashbridges Bay, the foot of Cherry Street and the area between Yonge and Parliament. Some of this material could itself have been contaminated by previous industrial uses.

Atmospheric deposition in the East Bayfront/Port Industrial Area has already been discussed (see Table III). It is likely that atmospheric deposition is a significant source of contaminants to soils.

Decay of terrestrial plants and animals can contribute nutrients and toxic chemicals to soils and groundwater. This is an important component of ecosystem cycling. No data are available on the magnitude of the pathway for the East Bayfront/Port Industrial Area or elsewhere.

Status and Internal Transfers (C)

Soils and groundwater quality vary across the East Bayfront/Port Industrial Area. Portions of all sites for which data are available exceed relevant clean-up criteria for one or more guideline parameter for residential/parkland use and portions of most sites for which data are available exceed one or more of the provincial guideline parameters for commercial/industrial use. Most of the sites for which data are available exceed either the Provincial Water Quality Objectives or the irrigation criteria for oils and grease, phenol, one or more metals and the VOCs, benzene, toluene and xylene. Most exceed level C of the Quebec soil quality criteria for benzene and xylene. Sites that are particularly contaminated include the National Iron Works (site 22), the former Domtar site (sites 28,29), the Texaco site (site 71), the Esso Petroleum site (site 53) and the Canron site (site 23).

The main internal transfers are through the movement of groundwater. While regional flows are directed towards Lake Ontario, flow on any particular site is influenced by buried utilities, such as sewers (groundwater frequently infiltrates sewers), pipelines and watermains that are often backfilled with granular, high permeability materials that act as a drain. There is also likely to be considerable exchange between moving groundwater and water absorbed to soil particles.

Effluxes (C)

The main effluxes of nutrients and toxic chemicals from soils and groundwater are ingestion or uptake by terrestrial biota, volatilisation to the air, resuspension to dust and infiltration of groundwater to surface water.

Plants can take up nutrients and soluble contaminants via their roots. There are some data available on plant uptake particularly for food crops, but little on the species found in the study area. However, uptake will be influence by several factors including the species, the concentrations present in soils and groundwater and the prevailing climatic conditions. Terrestrial animals are also exposed to toxic chemicals in soil. Animals and humans inadvertently ingest soil or inhale dust. It has been estimated that children between 18 months and 3½ years old can ingest up to 10 grams of soil a day through normal playing and mouthing activities (Kimbrough 1987, 177–184). Since much of the East Bayfront/Port Industrial Area is paved or built on, these pathways are unlikely to be important, except where contaminated soil is open and accessible.

TABLE III ATMOSPHERIC LOADINGS OF CHEMICALS TO THE TORONTO WATERFRONT

Parameter	To Water[1] (kg/y)	To Land[2] (kg/y)
Lead	300	18,860
Zinc	230	14,460
Cadmium	7	440
Copper	56	3,520
Nickel	23	1,450
PCDDs/PCDFs	0.001	0.060
PCBs	0.1	0.6
Chlorobenzenes	0.002	0.130

(1) Based on $30Km^2$ and APIOS loading rates

(2) Based on $1886Km^2$ and APIOS loading rates

Volatilisation from soil and resuspension from dust have already been discussed in the section on air. Since soil contamination is a problem in the study area, it is possible that there are important sources of contaminants to the atmosphere, although only a small proportion is bare soil.

Contaminated groundwater from the study area infiltrates Lake Ontario. This could occur either directly, because regional groundwater flows are towards the Lake, or indirectly through storm sewers draining the area. (Insert information from Phase 2 final soils/Groundwater report when available).

Sediments (B)

Loadings (C)

The sediments in the Toronto Waterfront are derived mainly from shoreline erosion, especially from the Eastern Beaches, discharges of tributaries, urban runoff and lakefilling activities. Major sources of sediments to the East Bayfront/Port Industrial Area include storm sewers, the discharge from the Main Sewage Treatment Plant, lakefilling and the Don River. The effects of lakefilling activities are normally localised to the immediately adjacent area.

Some of these sources generate relatively uncontaminated, nutrient-poor sediments while others produce contaminated nutrient-rich ones. Sediments resulting from shoreline and bluff erosion along the eastern beaches are likely to be relatively clean, while those from the Don River and the lakefilling activities are more contaminated. The most heavily contaminated and nutrient-rich sediments are those from the storm sewers and the discharge from the Main Sewage Treatment Plant. They are likely to contain toxic organic chemicals, such and PCBs and VOCs, heavy metals, such as lead and cadmium, and nitrogen and phosphorus.

Hutchinson and Fitchko (1974) have outlined the numerous factors that determine the concentration of contaminants in sediments. The first order factors refer to the amount of contaminant input, which is in turn dependent on the magnitude and proximity of the sources. The second order factors include contaminant uptake and retention by sediments. Bacteria, nutrients and chemical contaminants adsorb to sediment particles, especially fine ones that have a high surface area to volume ratio. Often these carrier particles are themselves composed of organic nutrients, clay minerals or the hydrous oxides of iron or manganese. They are often suspended and then settle out, taking their loadings of nutrients and contaminants with them.

Another pathway through which contaminants and nutrients can enter sediments is by the decay of aquatic biota. When benthos, zooplankton, algae, aquatic plants and fish decay on the lake bottom, nutrients and contaminants are recycled to the sediments. This pathway is likely to be an important means of immobilising contaminants out of active circulation in the ecosystem when conditions are eutrophic.

There are no data available on loadings of nutrients and contaminants to the East Bayfront/Port Industrial Area sediments or on the loadings of sediments to the area. However, estimates of projected sediment loads from the Don River were prepared as part of the 1983 Keating Channel Environmental Assessment. These are unlikely to be accurate because of recent extensive development in the regional municipality of York.

Status and Internal Transfers (C)

Surveys across the Toronto Waterfront have shown that the Inner Harbour contains the most heavily contaminated sediments. In contrast, the Outer Harbour is only moderately contaminated. Table IV shows the mean concentrations of chemical parameters in sediments and the open water disposal guidelines.

In the Inner Harbour, the most common contaminants are total phosphorus, total kjeldahl nitrogen, copper, lead, zinc and PCBs. Others include mercury and nickel. Contamination in the Outer Harbour is mainly in the form of heavy metals. Sediment quality varies in both the Inner and Outer Harbours. In the Inner Harbour the most heavily contaminated areas are the boat slips. In the Keating Channel, the most contaminated sediments are at the west end. The sediments in the deeper portions of the Outer Harbour consist of fine contaminated material that may have originated from the Inner Harbour. Sediment quality around the Eastern Headland also varies. The area to the south of the headland contains moderately contaminated sediments, while the quality is better in the area to the east. Sediment quality in the Eastern Waterfront is relatively good. The Ashbridges Bay area is the most contaminated with sediments containing total kjeldahl nitrogen, total organic carbon, oil and grease, chromium, copper, zinc, total phosphorus, mercury and lead.

Sediment quality has also been assessed by examining the degree of contaminant mobilisation. For example, a highly mobile contaminant present at low concentrations may cause greater environmental problems than an immobile contaminant present at low concentrations. Two tests have been used, an elutriation test and a percolation test. They have shown that large concentrations of lead and ammonia are probably released to the water columnduring dredging operations and that when dredgeate is dewatered lead, copper and zinc are not likely to be present in the leachate. These tests, however, do not provide information on the mobilisation of contaminants under normal anoxic conditions.

The suspension and transport of sediments is facilitated by wind-generated waves and currents, predominantly from east to west. The Inner and Outer Harbours are relatively sheltered and water circulation is relatively poor, so lateral sediment movement is probably minimal. There is some information available on sediment movement in the disposal cells of the Eastern Headland. Successive layers of sediment are buried and the burial rate is dependent on the magnitude of, and the distances from, the sediment sources. In the Toronto Waterfront, sedimentation rates require dredging of the navigational channels and the Keating Channel. Dredging resuspends sediments and contaminants adsorbed to them and prevents normal burial processes.

Efflux (C)

There are two major routes by which contaminants can be lost from sediments,

TABLE IV MEAN CONCENTRATIONS OF CHEMICAL PARAMETERS IN SEDIMENTS AND THE OPEN WATER DISPOSAL GUIDELINES

(All values are parts per million dry weight, except of LOI%)

Parameter	Toronto Harbour	Eastern Headland	Eastern Waterfront	Open Water Disposal Guideline
Lead	271	83	17	50
Zinc	339	129	35	100
Copper	90	38	9	25
Iron	26,700	21,500	13,150	10,000
Manganese	493	358	296	--
Chromium	92	46	19	25
Total Kjeldahl Nitrogen	2,100	900	400	2,000
Total Phosphorus	1,810	900	1,040	1,000
Total Organic Carbon	29,200	ND	4,920	1,000*
Solvent Extractable	5,689	1,926	602	1,500
Mercury	0.47	0.17	0.02	0.3
Cadmium	3.93	1.54	0.36	1.0
Arsenic	6.90	5.00	0,40	8.0
LOI%	7.26	3.22	1.59	6
PCBs	0.32	0.13	0.02	0.05

* = Internal Guideline (MOE)

other than by burial. These are resuspension of contaminants into the water column, either in solution of more usually, absorbed to carrier particles, and ingestion or uptake by aquatic biota.

As mentioned above, dredging activities contribute significantly to resuspension of contaminants in the Inner Harbour and the Keating Channel. Wave action can also resuspend sediments and contaminants. This occurs in exposed, erosional areas, such as the eastern beaches, and also during storm events.

Aquatic biota that can ingest contaminants from suspended and bottom sediments include benthos, zooplankton, algae and fish. Ingestion occurs through swallowing contaminants and nutrients in sediments. Contaminant uptake depends largely on its form in the sediment. This is particularly true for heavy metals where only a small proportion may be geochemically available. Data from sequential extraction analysis of sediment samples from the Toronto Waterfront demonstrate that there is a strong relationship between most metals (not iron or manganese) and the organic content of sediments (Persuad et al. 1987).

Surface Water (B)

Loadings (C)

Sources of contaminants and nutrients to the Toronto Waterfront in general, and the East Bayfront/Port Industrial Area in particular include storm sewers, combined sewers, sewage treatment plants (especially the Main Sewage Treatment Plant), sediments, atmospheric deposition, infiltration from groundwater and the decay of aquatic biota. Nearly all of these have been discussed in the Phase 1 report on the aquatic environment. Contaminants in groundwater have been discussed in the Phase 1 and 2 reports on soils and groundwater. There is some information available on most of these sources, although it is not complete. There is no information on the decay of aquatic biota. This is unlikely to contribute significantly to loadings of toxic chemicals. Although eutrophic conditions promote algal growth and so would tend to increase the amount of decaying algae, this has not been significant in the study area until recently, even though it is a eutrophic area.

Status and Internal Transfers (C)

The Phase 1 report on the aquatic environment discussed the current status of water quality in the East Bayfront/Port Industrial Area.

Contaminants and nutrients can be mixed vertically in the water column and there is also lateral mixing between nearshore and offshore water. Concentrations of nutrients and contaminants can vary with depth, so sampling depth should always be recorded. For example, turbidity and total suspended solids associated with the lakefilling activities are greater at subsurface depths.

Efflux (C)

There are four pathways by which nutrients and contaminants can be lost from surface water. These are deposition to sediments, adsorption to particulates, ingestion or uptake by aquatic biota and volatilisation to air.

As mentioned above, nutrients and contaminants are either soluble or adsorbed to particulates, which can settle out. This pathway is likely to be important. In addition, aquatic biota can ingest or take up nutrients and contaminants from water. Ingestion occurs via swallowing, while uptake can occur across cell membranes, such as fish gills. Ingestion and uptake of nutrients and contaminants from surface water is discussed in the section on aquatic biota. There is no information available on volatilisation to air.

Terrestrial Biota (B)

Loadings (C)

Plants and animals can be exposed to nutrients and toxic chemicals via food, air and water. Plants are exposed by atmospheric deposition and by uptake from groundwater. Many of the plants identified in the Port Industrial Area have relatively shallow root systems. Animals are exposed by inhalation of air, and ingestion of surface water and soil/dust and sometimes by consumption of aquatic biota. For humans, it has ben estimated that the majority (approximately 85%) of exposure to persistent organochlorines occurs through food, with drinking water and air being only minor contributors (approximately 10% and 5% respectively).

Inhalation and ingestion of soil/dust have already been discussed in the section on air and soils and groundwater respectively. All biota need to ingest water to survive. Humans need approximately two litres a day. Non' human biota in the study area will obtain their drinking water from puddles and the nearshore area of the lake. In contrast, humans obtain their drinking water from the municipally treated supply. Many species in the study area are likely to be exposed through consuming aquatic biota, such as fish. These include fish eating birds. These include gulls, terns and herons. In addition, several species of mammals in this study area, such as raccoons, may ingest aquatic biota. Humans catch a small number of fish in the study area and may occasionally consume them. This is discussed in the section on the status of aquatic biota.

Status and Internal Transfers (C)

The major types of terrestrial biota are plants, invertebrates, reptiles and amphibians, birds and mammals. Nine different types of habitat have been mapped and descried in the East Bayfront/Port Industrial Area (need to relate habitat location to soils/groundwater data). These are:

- Mature cottonwood woodland;
- Overgrown field part way through the process of succession from old field to mature cottonwood woodland;
- Open field with good drainage;
- Recent fill and other semi-bare ground;

- Aquatic habitat with submerged plants;
- Marshland and wet meadow, flooded at least seasonally;
- Sand or gravel beach and shoreline;
- Willow thickets; and
- Manicured lawns and gardens.

These are described in the Phase 2 report on natural heritage. The Phase 2 report also contains a list of vascular plants that have been identified in the Port Industrial Area. In addition, fourteen regionally or provincially rare plant species have been identified in the Port Industrial Area, including two unusual non-native species. Some of the species identified are known to be pollution-tolerant (e.g., of salt, metals or herbicides).

There are no data available on toxic contaminants in vegetation on the study area. Invertebrates in the study area include butterflies and the main reptiles and amphibians include:

- American toad;
- Northern leopard frog;
- Common snapping turtle;
- Painted turtle;
- Map turtle;
- Common garter snake; and
- Brown snake.

Their current status and distribution i discussed in the Phase 1 report on natural heritage. There are no data available on contaminants in these species in the study ares, although there is information on the effects on snapping turtles in the Hamilton Harbour. This indicates that turtles eggs from Hamilton Harbour have a lower hatchability and the young experience more deformities than an equivalent turtle population in Algonquin Park.

There is a lot of information on the effects of contaminants on birds in the Great Lakes. Eight species have been studied in detail. These are:

- Double crested cormorant;
- Black crowned night heron;
- Bald eagle;

- Herring gull;
- Ring billed gull;
- Caspian tern;
- Common tern, and
- Forster's tern.

Of these, five are common in the East Bayfront/Port Industrial Area, two are unusual and one is abundant. Populations declined throughout the Great Lakes, in the early 1970s. Since then, they have increased. The increase in numbers has meant that in some areas effects are more commonly observed than in the 1970s. An example of this is the double-crested cormorant whose population crashed to approximately three pairs on Lake Ontario in the mid/late 1970s. Since then, it has exploded and anomalies such as club feet, cross bills and eye and skeletal deformities are now being observed in some locations around the Great Lakes. The population crash was caused by DDE-induced eggshell thinning and embryonic mortality. Double-crested cormorant populations are particularly susceptible to eggshell thinning because they stand on their eggs to incubate them. Population increases are associated with the lower levels of many organochlorines in the Great Lakes ecosystem. There are no data available on contaminant-related effects on bird populations in the study area, but there is information available on birds on Mugg's Island (herring gulls, ring-billed gulls and common terns). For example, levels of contaminants in herring gull eggs have been measured since 1980. Levels of DDE, Mirex, HCB and PCBs have decreased significantly, but levels of dieldrin and 2,3,7,8-TCDD have remained approximately the same. Effects have also been investigated. These include leg deformities in ring-billed gulls and crossed bills in common tern chicks. These are discussed in chapter 2.

Thirteen mammalian species have been recorded in the study area. These are:

- Bats (species unknown);
- Eastern cottontail;
- European hare;
- Eastern grey squirrel;
- Beaver;
- Meadow vole;
- Muskrat;
- Norway rat;
- Coyote;

- Red fox;
- Raccoon, and
- Striped skunk.

These are discussed in Phase 1 report on natural heritage. An inventory of small mammals in the East Bayfront/Port Industrial Area was conducted in August 1990 for the Phase 2 report on natural heritage. The results show that house mice were found to the west of Cherry Street, close to the eastern gap and that meadow voles were found at the other two locations studied, south of Unwin Avenue. There are no data available on contaminant concentrations or effects in small mammals, although the Royal Commission is considering conducting a study on residue levels in the meadow vole, the most abundant small mammal.

Nutrients and contaminants are transferred in several ways in terrestrial biota. Obviously, transfers occur to successively higher trophic levels in the food web. This has been discussed in the section on definitions and concepts of ecosystems. In addition, toxic chemicals can be transferred within species either prenatally or post-natally via lactation and nursing. It is becoming apparent that in many cases exposure of adult populations to toxic chemicals causes effects in the offspring rather than in the exposed adults. Developing embryos are often more sensitive to toxic chemicals than adults. Developmental effects include physical abnormalities such as crossed bills, oedema, skeletal and leg deformities in birds, low birth weight, small head circumference in humans and leg deformities in snapping turtles and behaviourial abnormalities, such as reduced nest attentiveness in birds and poorer usual recognition and short term memory in humans. Mammals can also transfer contaminants through lactation and nursing their young. Although larger amounts of contaminants are transferred post-natally than prenatally, human data suggests that individuals are less sensitive to the effects of contaminants after birth then before. Lactation is the major depuration mechanism for females.

Efflux (C)

Terrestrial biota can lose nutrients and contaminants by excretion or when the decay. In either case, the loss occurs to soils and groundwater. No data are available on these pathways.

Aquatic Biota (B)

Loadings (C)

Aquatic biota in the East Bayfront/Port Industrial Area include benthos, phytoplankton (algae), zooplankton, and fish. Loadings to these diverse life forms occurs via ingestion and uptake from water and sediments. Ingestion and uptake from water can occur via swallowing or across cell membranes, such as fish gills. Ingestion and uptake from sediments can occur in similar ways. Benthos, attached algae, some zooplankton and bottom feeding fish are likely to receive the majority of their loadings from contaminated sediments, while phytoplankton (free, unattached algae), some zooplankton and other fish are likely to receive their loadings from water. Gill transfer may be an important exposure pathway because although concentrations of toxic chemicals in water are often low, large volumes of water flow over fish gills. The bioavailability of contaminants in sediments is discussed on the section of sediments.

Status and Internal Transfers (C)

Studies of benthic invertebrates in the Toronto Waterfront have shown that species and numbers vary depending on the environmental conditions. Areas along the north shore of the Inner Harbour, in Ashbridges Bay and Mimico Creek are organically polluted and the benthic communities consist primarily of oligochaetes and chronomids. Thus, species diversity is reduced, although the numbers of individuals of a species are increased. Observations that some contaminants have a low bioavailability in sediments are supported by data on contaminant levels in benthos. However, contaminated benthos are found in areas such as Ashbridges Bay. These studies are discussed further in the Stage 1 Remedial Action Plan.

Studies have also been conducted on phytoplankton and algae. Measurements on the size of algae communities are often used as a measure of the primary productivity of an ecosystem or as a measure of nutrient availability in a water body. But although conditions in the study area are eutrophic algal growth is not a significant problem because of wave action and because there are limited substrates available for algal attachment. Research on the effects of dredging and other activities on carbon assimilation by algae indicates that the rate was inhibited by dredging and ship movement, but enhanced by dredgeate disposal. There are insufficient data to permit an assessment of zooplankton in the Toronto Waterfront in general or the study area in particular.

Freshwater clams have been used to test for the bioavailability of contaminants adjacent to Tommy Thompson Park in 1988 and 1989. The results show that clams accumulated detectable residues of many heavy metals, PAHs and gamma chlordane at levels higher than those in control clams from Balsam Lake.

Fish populations and their habitats have been investigated extensively. Table V shows the numbers of species that have been observed in the East Bayfront/Port Industrial Area and its surrounding. They are identified and discussed in the Phase 1 report on natural heritage. Brown trout and rainbow trout are stocked in the vicinity of the Toronto Waterfront. In 1987, brown trout were stocked in Bluffers Park (20,000) and Ashbridges Bay (15,000).

The species diversely reflects the relative quality of the habitat provided by each location. Factors contributing to the poor habitat in the Lower Don, the Keating Channel and the Ship Channel are poor water quality, concrete walls and dredging. The Hearn Outfall, the Eastern Headland and Ashbridges Bay provide better habitat. A survey conducted in 1990 as part of the Phase 2 report on natural heritage identified twenty species in the study area.

The best fish community in the study area was the wave zone north shore of the Outer Harbour. This provides good thermos protection and spawning habitat. The fish communities in the Keating Channel and the turning basin are the most

TABLE V NUMBERS OF SPECIES THAT HAVE BEEN OBSERVED IN THE EAST BAYFRONT/PORT INDUSTRIAL AREA AND ITS SURROUNDINGS

Location	Number of Species
Lower Don	11
Keating Channel	12
Ship Channel	12
Hearn Outfall Bay	29
Headland-Lagoons Pond	40
Ashbridges Bay	35

degraded and limited communities along the waterfront. Coatsworth Cut is adversely affected by stormwater discharges from the Main Sewage Treatment Plant.

Fish habitat in the survey area has been investigated in scuba reconnaissance survey. The area was primarily silt and sand with areas of gravel, which had sporadic coverings of attached algae and aquatic macrophages. Areas of boulder, cobble and gravel were found adjacent to the eastern gap.There is some recreational fishing in the study area, particularly around the Hearn Outfall and Ashbridges Bay, although the Hearn plant is currently not in use and so the cooling water that attracted fish species is not in circulation. The Phase 2 report on natural heritage contains details on angler effort, harvest, catch rate and consumption in the study area. The numbers of fishermen using the study area is likely to be about one hundred and the Toronto area is thought to provide about 7,000 angler days per year and a harvest of about 3,500Kg a year. Surveys conducted by Environment Ontario of Ontario anglers have shown that the most common fishing frequencies are once every two weeks and more than once a week. Many fish caught by Ontario anglers are consumed. (insert information on fish consumption in the study area). Approximately half of the respondents to province-wide surveys ate fish once a month or more and the mean meal size was 284g (Cox et al. 1987). This is considerably more than the 114g used by Health and Welfare Canada to calculate consumption guidelines.

Levels of contaminants have been measured in benthos and fish. Data on concentrations of metals and organics in benthic tissue from the East Bayfront/Port Industrial Area and its surroundings are shown in Tables 3.10 and 3.11 of the Stage 1 Remedial Action Plan. Levels in fish have been determined as part of Environment Ontario's Nearshore Juvenile Fish Contaminants Surveillance Program (young-of-the-year spottail shiners) and the Sport Fish Contaminant Monitoring Program. These programs have shown that concentrations of many contaminants, including PCBs, DDT and its metabolites, BHC and chlordane are decreasing in fish, although they can still be detected. The Sport Fish Program has provided information published in the 'Guide to Eating Ontario Sport Fish'. Consumption advisories have been issued for eleven locations along the Toronto Waterfront, of which three are in or adjacent to the study area. These are shown in Table VI. Concentrations of contaminants in fish from the Toronto Waterfront are discussed extensively in the Stage 1 Remedial Action Plan.

Transfers of nutrients and contaminants can occur up the aquatic food web. For example, benthos, phytoplankton and algae are commonly eaten by fish. This is likely to be a significant pathway for the fish species involved and information on the Great Lakes aquatic food web is available. In addition, prenatal transfer could also occur, although it has not been studied extensively.

Efflux (C)

There are three main pathways by which nutrients and contaminants can be lost from aquatic biota. These are the ingestion of aquatic biota by terrestrial biota, decay to water and sediments and excretion. Fish consumption has already been discussed above. As mentioned in the section on sediments, the decay of aquatic biota can be an important pathway for immobilising chemical contaminants in

TABLE VI. CONSUMPTION ADVISORIES RELEVANT TO THE EAST BAYFRONT/PORT INDUSTRIAL AREA

Location	Species*
Hearn Generating Station Outer Harbour	Carp
	White Bass
	Yellow Perch
	Gizzard Ahad
	Northern Pike
Toronto Island - Inner Harbour	White Sucker
	Northern Pike
	Carp
Scarborough Bluffs	Lake Trout

* Advisories may be for specific sizes only

sediments if eutrophic conditions promote algal growth. Excretion is unlikely to represent a major pathway.

Conclusions (B)

This section of the report has described the East Bayfront/Port Industrial Area as a ecosystem. Information on loadings of nutrients and toxic chemicals to the environmental media in the study area is relatively good. The most important loadings to the ecosystem are:

- To the air (from local and remote sources);
- To the surface water (from the Main Sewage Treatment Plant and storm and combined sewers); and
- To soils and groundwater (from previous and current land use activities).

These and other loadings have resulted in detectable residues of toxic chemicals in all media (air, surface water, sediments, soils and groundwater, terrestrial biota and aquatic biota). In addition, there have been effects reported on terrestrial and aquatic biota. Birds have experienced reproductive failure and fish are also unable to reproduce normally. Information on transfers within media is relatively poor. This reflects our general lack of knowledge about how nutrients and toxic chemicals cycle in ecosystems. Information about how nutrients and toxic chemicals leave individual media is also relatively poor for the same reason. One of the major pathways by which contaminants are removed from the ecosystem, sediment burial, has been disrupted by dredging activities which resuspend contaminants in the water column, further exposing aquatic biota. For humans, the most important exposure pathway to contaminants in the ecosystem is the consumption of contaminated fish, although consumption of fish from the study area is probably minimal.

2. ECOSYSTEM HEALTH (CH)

APPLYING CONCEPTS AND DEFINITIONS OF HEALTH TO ECOSYSTEMS (A)

Concepts of human health have changed over time and are different in different societies. In 1967, the World Health Organisation defined it as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organisation 1967, 29). This definition recognised the importance of the non-physical aspects of health. More recently, the World Health Organisation's Regional Office for Europe expanded this definition to "the extent to which an individual or group is able, on the none hand, to realise aspirations and satisfy needs: and, on the other to change or cope with the environment. Health is therefore seen as a resource for everyday living, not the objective of living; it is a positive concept emphasising social and personal resources, as well as physical capacity" (World Health Organisation 1984). This definition has been accepted by both the federal and provincial governments and was endorsed by the Environment and Health Work Group in its report (Royal Commission on the Future of the Toronto Waterfront Environment and Health Workgroup 1989, 23).

These broad definitions recognise that it is important not only to protect health by minimising or eliminating risks, but also to promote and enhance it. Until recently, western societies have focused on health protection, rather than health promotion although this situation is now changing. For example, in medical practice physicians usually focus on diagnoses of ill health, rather than enhancing or even sustaining good health.

Recently concepts and definitions of health have been applied to ecosystems. In the last few years, several papers have been published on ecosystem health (for example, Rapport, Regier and Hutchinson 1985; Kuchberg 1985; Schaeffer, Herricks and Kerster 1988 and Rapport 1989). But just as in humans, good health in ecosystems is often taken as the absence of adverse physical effects. Studies have examined physical effects at different trophic levels and at different levels of biologic organisation. This raises the question of when is an adverse effect a health effect. Clearly, adverse effects at the tissue/organ, individual, population and community levels of organisation can be seen as health effects, but what about adverse effects at the molecular and cellular levels? Are these health effects or just adverse effects? Can we talk about the health of a molecule or a cell?

Most studies on ecosystem health have only explored the physical aspects of health and have not used the broad concepts embodied in WHO definitions. This can be seen in the characteristics of ecosystem health described below. Few studies have examined the psychological and social aspects of ecosystem health. There are, however, some notable exceptions where effects on social and psychological health are being investigated in humans, laboratory animals and wildlife exposed to environmental stressors. In humans, this includes the ongoing epidemiological study of the offspring of women who consumed relatively large amounts of fish from Lake Michigan. Initially, the study showed that the children exhibited behaviourial and neurodevelopmental deficits at birth (Jacobson et al. 1984, 523-532) and subsequently deficits in cognitive functioning were reported in the children at four years of age (Jacobson et al. 1990, 38-44). In a study of laboratory rats fed diets containing salmon from Lake Ontario, researchers demonstrated an increase in reactivity to aversive events, such as mild electric shock (Daly et al. 1989, 1356-1365). Behaviourial effects have also been observed in several bird species in the Great Lakes Basin. The most common effect is nest inattentiveness. This has been observed in herring gulls (for example, Fox et al. 1978, 477-483), Forster's tern ((Kubiak et al. In press). In addition, polygyny has been reported in herring gulls from the Great Lakes (Shugart 1980, 426-429). Lake trout fry have demonstrated abnormal behaviour associated with DDT including "loss of equilibrium, abnormal swimming, laying on their sides at the bottom of tanks, lethargy, cessation of feeding and eventual death" (Mac 1986).

Since humans are integral components of many ecosystems, human health can be seen as a subset of ecosystem health. Of course, human definitions of human health are not necessarily transferable to ecosystems and their health. Ultimately human health is self-defined. So how can human definitions of ecosystem health be valid? Human perceptions about what makes an ecosystem healthy and desirable may not reflect the biocentric realism of what makes an ecosystem healthy. Inevitably, the criteria used to judge whether an ecosystem is healthy or not are influenced by human values. These values are dependent on prevailing social and cultural norms that change over time and are different in different societies. Just as human health is a relative concept, so ecosystem health means different things to different people.

It is easy to trace the links between current characteristics of ecosystem health and the prevailing values of our western, developed society (Rapport 1989, 120-132). For example, the notion that a healthy ecosystem is a productive one can be related to our orientation towards achieving high levels of economic well-being. Similarly, in a society in which normality and stability are valued, it is not surprising that stability and the ability to damp undesirable oscillations are seen as desirable characteristics for ecosystem health.

Concepts of ecosystem health often depend on perceptions of the usefulness or value of the ecosystem to humans. For example, acidified lakes are attractive to swimmers because there are no algae, but few would judge them to be healthy. Similarly, a productive, commercially viable forest may be seen as healthy, but may be a virtual monoculture, providing suitable habitat and food for only a few species. In addition, many degraded ecosystems may be economically viable in the short term, although natural capital is being lost. Such deteriorations are often not obvious in the short term because of artificial nutrients inputs, e.g., fertilisers or other additions.

A related consideration is the notion of valued ecosystem components. What is it that we value about ecosystems and why are we concerned about them? Beanlands and Duinker identified the following factors that determine how the public values ecosystems (Beanlands and Duinker 1983, 45):

- The relationship between human health and the environment is of utmost importance;

- Concern about losses of important commercial species or commercially available production. Similarly, a concern about an increase in undesirable species;

- A high value is placed on recreational and aesthetic considerations;
- Rare or endangered species are valued highly;
- Concern about loss of habitat, because it represents a narrowing of future options;
- Perceived imbalances between supply and demand of species or habitats.

These factors represent societal values and may not reflect the values of all individuals and groups within society. For example, some may agree that ecosystems should be left undisturbed and that recreational opportunities damage their health. However, they can be used to develop anthropocentric criteria for a healthy ecosystem in the East Bayfront/Port Industrial Area. This is discussed later in this chapter.

No discussion about human values and ecosystem health would be complete without mentioning deep ecology. The term deep ecology was coined by Arne Naess in 1973 (Naess 1973). The essence of deep ecology is an attempt to adopt a biocentric or ecosystems approach to life, rather than an anthropocentric one. Devall and Sessions have described the basic principles of deep ecology as follows (Devall and Sessions 1985):

- Life (human and non human) has value in itself, independent of the usefulness of the non human world for human purposes;
- The richness and diversity of life forms contribute to the realisation of this value and are also values in themselves;
- Humans have no right to reduce this richness and diversity except to satisfy vital needs;
- The flourishing of human life and cultures is compatible with a substantial decrease of the human population. The flourishing of non human life requires such a decrease;
- Present human interference with the non human word is excessive and worsening;
- Policies affecting economic, technological and ideological structures must be changed;
- The necessary ideological change is to appreciate the quality of life, rather than an increasingly higher standard of living;
- Those who subscribe to these principles have an obligation to try to implement the necessary changes.

Many deep ecologists have gained prominence through their non-violent direct action campaigns that are usually designed to disrupt human exploitation of the non human world. But however laudable it may be to attempt to adopt a biocentric (or ecosystem) perspective, we are human and it is impossible to dismiss the unique attributes that differentiate us from all other species of life on earth. We cannot ever wholly step outside the human framework and entirely embrace a biocentric approach. But although we can never completely supersede an anthrogenic perspective, we can acknowledge its weaknesses and compensate for them by valuing individual ecosystems, and ultimately the whole biosphere more highly than human desires and greed.

This discussion has implications for this report. First, only the physical aspects of ecosystem health in the East Bayfront/Port Industrial Area can be assessed with relative ease. Second, the identification and measurement of risk factors and characteristics of a healthy ecosystem in the East Bayfront/Port Industrial Area represent human values, rather than how the ecosystem itself might perceive of its health and well-being. The remainder of this report should be considered in the context of these two points.

CUMULATIVE EFFECTS (A)

As the pace, scale and complexity of development have increased, it has become apparent that the combined effects of multiple actions on the ecosystem can cause irreversible changes to ecological and social systems that can be different in nature and extent from those caused by any single activity. These types of effects are called cumulative effects, and they exist within a range of spatial and temporal dimensions. Several environmental problems provide examples of the ways in which many small, repeated actions cumulatively produce significant consequences. These include ozone depletion, loss of wetlands, degradation of Great Lakes water quality and the decline of fish stocks. Cumulative effects on ecosystems can be classified in many different ways. One example is shown in Table VII (Sonntag et al. 1987).

Clearly, there are cumulative ecosystem effects in the East Bayfront/Port Industrial Area. The types of cumulative effects that are the most common are time and space crowding, triggers and thresholds and indirect effects. Of course, an effect can fit into more than one of these categories. Effects which can be considered as cumulative include the contamination of soil, water and sediments, dustfall, habitat deterioration, and the numbers, types and diversity of terrestrial and aquatic species. Contamination of soil, water and sediments can be seen as a consequence of loadings that are time and space crowded, compounding and indirect. Dustfall is mainly a result of time crowding in the vicinity of coal, sand and gravel piles and the lakefilling operation. Habitat deterioration probably reflects most of the issue types. The primary causes are the construction of buildings, paving of land and lakefilling. The numbers, types and diversity of terrestrial and aquatic species have been affected habitat deterioration.

Several methodologies have been proposed for assessing cumulative effects, particularly in wetlands and freshwater aquatic ecosystems. However, it is generally recognised that is extremely difficult to develop broadly applicable methodologies because of the many problems associated with assessing cumulative effects. These include defining temporal and spatial boundaries, determining the

TABLE VII: CLASSIFICATION OF CUMULATIVE ECOSYSTEM EFFECTS

ISSUE TYPES	MAIN CHARACTERISTICS	EXAMPLES
Time Crowding	Frequent and repetitive impacts on a single environmental medium	Wastes sequentially discharged into rivers, or watersheds
Space Crowding	High density of impacts on a single environmental medium	Habitat fragmentation in forests, estuaries
Compounding Effects	Synergistic effects due to multiple sources on a single environmental medium	Gaseous emissions into the atmosphere
Time Lags	Long delays in experiencing impacts	Carcinogenic effects
Space Lags	Impacts resulting some distance from source	Major dams; gaseous emissions into the atmosphere
Triggers and Thresholds	Impacts to biological systems that fundamentally change system behaviour	Effects of changes in forest age on forest fauna
Indirect	Secondary impacts resulting from a primary activity	New road developments opening frontier areas

value of different effects, accounting for non-additive effects, dealing with information gaps and ensuring scientific rigour and consistency. It will also be important to develop methodologies to examine the cumulative effects in the methodologies to examine the cumulative effects in the whole of the Greater Toronto Bioregion especially as existing land use planning processes do not assess cumulative effects. These methodologies should be integrated into the land use planning and development control process for the area.

APPROACHES TO IDENTIFYING AND MEASURING ECOSYSTEM HEALTH (A)

There are two approaches that have been used to assess ecosystem health. These are:

- Identifying and measuring risk factors; and,
- Identifying and measuring characteristics that differentiate healthy ecosystems from unhealthy ones.

Risk factors determine the expression of the characteristics that differentiate healthy ecosystems from unhealthy ones.

These two approaches have also been used to assess human health. Risk factors that have been identified and measured include exercise, nutritional status, poverty, housing, employment and the use of alcohol and cigarettes. Characteristics that have been identified and measured include disease prevalence and incidence and mortality rates. Clearly, however, there are differences between the types of risk factors and characteristics that are appropriate to assess ecosystem health, as compared with human health. These are explored at the end of this section.

Identifying and Measuring Risk Factors (B)

Ecosystem health can be assessed by identifying and measuring the stressors that are known, or are likely to cause adverse effects on ecosystems. There are probably two main types of risk factors: physical ones and non-physical ones. Physical risk factors can be either anthropogenic (e.g., persistent toxic chemicals), natural (e.g., hurricanes, earthquakes) or both (e.g., radiation, mercury). One particularly interesting risk factor is the introduction of exotic species (i.e., species not native to the ecosystem). Exotic species can be accidentally or deliberately introduced and can be desirable or undesirable. Two well-known examples of exotic species in the Great Lakes are lamprey and zebra mussels. These have both had negative effects on the Great Lakes ecosystem.

Non-physical risk factors include government policies and economic factors. For example, the policy of sewer separation adopted by Metropolitan Toronto many years ago has probably improved ecosystem health, in that bacterial levels entering the Toronto Waterfront from combined sewers are likely to be lower than previously. Economic factors that are also risk factors for the East Bayfront/Port Industrial Area include the pressures for redevelopment. New industries and perhaps housing are needed to generate tax revenues and provide jobs. But these activities will affect the health of the ecosystem, either by improving it or further degrading it.

Some ecosystems are dependent on periodic stressors, or risk factors. For example, many boreal forests depend on fire to regenerate nutrients and annual flooding increases the productivity of nearshore ecosystems. Thus, risk factors are not necessarily negative. They can also enhance ecosystem health.
This approach of identifying and measuring risk factors is implicit in the majority of environmental monitoring programs that determine the levels of stressors in the ecosystem. Examples include programs that monitor levels of bacteria in drinking water, concentrations of SOX and NOX in air and the levels of persistent toxic chemicals in water, sediments, soil and biota. Most of the environmental data on the East Bayfront/Port Industrial Area are in this category.

Characteristics of Healthy/Unhealthy Ecosystems (B)

Although ecosystem health, like human health, has been assessed largely through diagnoses of ill health, more generic screening approaches are being developed. These screening approaches involve the use of systemic indicators of an ecosystem's functional and structural integrity. While there is not widespread consensus on what constitutes an ecosystem's vital signs, a relatively small number of indicators are emerging as being appropriate to differentiate unhealthy and stressed ecosystems from healthy and unstressed ones. These critical functions and structures are common to all types of ecosystems and so can be applied to the East Bayfront/Port Industrial Area to assess its ecosystem health, just as they can be applied to a tropical rain forest.

The functions and structures that are critical to ecosystem health include:

- An adequate circulating nutrient pool to support desired organisms, especially long-lived, larger species;
- An adequate flow of energy to maintain the trophic structure;
- Maintaining a diverse species base, especially long-lived, larger species. In turn this requires:
    - Suitable habitat for all stages in the life cycle and for all critical activities (e.g., reproduction, shelter and ingestion of food and water);
    - A food web appropriate for the species base.
- Feedback mechanisms to damp undesirable oscillations such as the ability to respond to exposure to toxic chemicals by decomposing, transferring, or chelating them so that they are no longer toxic or their circulation in the ecosystem is minimised. This has also been called ecosystem resilience (Westman 1978, 705-711);
- Low disease prevalence and incidence rates.

Similarly, there are several characteristics of unhealthy and stressed ecosystems (Regier 1988 a,b). These include:

- Reduced primary productivity (except when the stressor is a nutrient loading, such as phosphorus in Lake Erie in the 1960s);
- Loss of nutrients e.g., loss of organic matter in soil. This can be masked by additions of nutrients, such as fertilisers);
- Loss of sensitive species and a reduction in species diversity. This usually involves the replacement of long-lived large species with small, short-lived ones and the emergence of large numbers of the few stress tolerant species (e.g., oligochaetes);
- High disease prevalence and incidence rates, accompanied by reproductive failure;
- Increase instability in numbers of individuals in a species (i.e., population explosions and crashes); and
- Increased cycling of contaminants through ecosystem media.

Complete information on these characteristics is hardly ever available. This is true for the East Bayfront/Port Industrial Area where there is little information available on these characteristics.

Example of Assessing Ecosystem Health (B)

One example of the assessment of ecosystem health is the monitoring and surveillance programs in the Great Lakes Basin. For many years, state and provincial government agencies have measured levels of persistent toxic chemicals in the water, sediments, air and biota of the Great Lakes Basin. This is an example of identifying and measuring physical risk factors to determine ecosystem health.

Recently, more emphasis has been placed on monitoring the effects of persistent toxic chemicals on the biota of the Great Lakes Basin systematically. In some respects, it is surprising that systematic effects monitoring is only now being implemented because it has been evident for many years that numerous species of fish and wildlife experience adverse health effects from exposure to chemical contaminants. Effects monitoring is thus an example of measuring the characteristics of ecosystem health.

Another indicator of ecosystem health in the Great Lakes was developed by the International Joint Commission and has been proposed in the 1987 Amendments to the 1978 Great Lakes Water Quality Agreement. It is for Lake Superior and is defined in terms of two organisms: a fish (lake trout) at the top of the food web and a benthic species (*Pontoporeia hoyi*) at the bottom. The indicator includes measures of each organism's abundance and adds that the lake should be comprised of stable, self-producing stocks of lake trout that are free from contaminants at concentrations that adversely affect the trout themselves or the quality of the harvested trout. Both species require clear, cold water, clean sediments and undisturbed habitat. The International Joint Commission's Science Advisory Board has also proposed walleye and mayfly as indicators of a healthy mesotrophic system (Science Advisory Board 1989).

Recently, the health of the entire Great Lakes Basin Ecosystem has been assessed in two publications. These are the book entitled "Great Lakes, Great Legacy?" prepared by the Conservation Foundation and the Institute for Research on Public Policy (Conservation Foundation and the Institute for Research on Public Policy 1990) and the report entitled "Toxic Chemicals in the Great Lakes and Associated Effects," (Environment Canada et al. 1990). The Conservation Foundation/Institute for Research on Public Policy book identifies fifteen indicators of ecosystem health in the Great Lakes Basin. These are:

- Air quality
- Surface water quality
- Contaminated sediments
- Groundwater
- Body burdens of toxics
- Population status
- Habitat
- Fisheries
- Forests
- Wetlands
- Soil erosion
- Agricultural Productivity
- Shorelines
- Human health, and
- Economic conditions.

Clearly, these indicators are structural, rather than functional measures of ecosystem health. In contrast, this report and most researchers in the field advocate the use of functional indicators. Nevertheless, structural notions of ecosystem health can also be helpful.

Risk Factors and Characteristics Used to Assess Human Health (B)

Although this report focuses on ecosystem health in the East Bayfront/Port

Industrial Area, humans are a part of the ecosystem and so a brief discussion of the risk factors and characteristics that can be used to assess human health is appropriate.

The Ottawa Charter for Health Promotion identifies nine prerequisites for human health (Ottawa Charter for Health Promotion 1986). The absence of these could be seen as risk factors. They are: peace, shelter, education, food, income, a stable ecosystem, sustainable resources, social justice and equity. Like the risk factors for ecosystem health, some of these are physical and others are not. Although there are differences in the types of risk factors for human and ecosystem health, in many cases they are compatible. This notion that what is good for ecosystem health is also good for human health underlies the concept of sustainable development.

The main characteristics used to assess human health are symptoms of disease or ill health in individuals and prevalence and incidence data (especially life expectancy and infant mortality) in communities. These characteristics represent a proportion of the characteristics that are used to asses ecosystem health.

CRITERIA FOR A HEALTHY EAST BAYFRONT/PORT INDUSTRIAL AREA (A)

Two types of criteria for a healthy East Bayfront/Port Industrial Area have been developed. These are first an ecosystem (or biocentric) perspective, as interpreted by humans, and second a purely anthropocentric perspective. They are summarised in Table VIII.

Ecosystem Criteria (B)

Two types of ecosystem criteria have been developed. These are risk factor criteria and characteristics criteria. Some criteria are both risk factors and characteristics, including the quantity and quality of habitat and the nature of the food web. Habitat and food webs are risk factors for species diversity, stable population numbers, disease incidence and prevalence and the ability to respond to stressors. The physical risk factors that can be used to determine the health of the East Bayfront/Port Industrial Area include:

- Habitat quantity and quality for fish and wildlife that are not appropriate for some or all the stages of life cycle or for all critical activities (e.g., reproduction, shelter and the ingestion of food and water) of the species present;

- The presence of toxic chemicals (either from anthropogenic or natural sources) in the ecosystem;

- An inadequate food web to support upper trophic level species, either because there is an inadequate number of food and prey species or because the numbers of individual organisms are inadequate;

- Development of the East Bayfront/Port Industrial Area including expansion upgrade of the Main Sewage Treatment Plant;

TABLE VIII : SUMMARY OF CRITERIA FOR A HEALTHY EAST BAYFRONT/PORT INDUSTRIAL AREA

ECOSYSTEM CRITERIA	ANTHROPOGENIC CRITERIA
Risk Factors:	· Fish and wildlife advisories
· Habitat	· Habitat
· Food Web	· Valued Species
· Development	· Beach Postings
· Exotic Species	· No Algae
· Redevelopment Plans	· Clean Industries
· Sewer Separation Policy	· No Dead or Decaying Biota
	· Recreational Opportunities
Characteristics:	· Absence of Undesirable Species
· Habitat	
· Circulating Nutrients	
· Species Diversity	
· Stable Population Numbers	
· Response to Stressors	
· Food Web	
· Low Rates of Adverse Effects	

- Introduction of exotic species.

The non physical risk factors that can be used to determine the health of the East Bayfront/Port Industrial Area include:

- Plans for the redevelopment of the East Bayfront/Port Industrial Area;

- The policy of sewer separation.

The characteristics that can be used to determine the health of the East Bayfront/Port Industrial Area include:

- Habitat quality and quantity that are suitable for all stages of the life cycle and for all critical activities (e.g., reproduction, shelter, ingestion of food and water);

- A circulating nutrient pool of N, P and C with no artificial additions or removals;

- The presence of diverse species of aquatic biota (benthos, zooplankton, phytoplankton, reptiles, amphibians, mammals and birds), and especially sensitive, long-lived, larger species that are characteristic of upper trophic level organisms;

- Stable population numbers with no explosions or crashes (e.g., double-crested cormorants). This implies reproductive success e.g., minimal egg loss, eggshell thinning or embryo loss;

- The ability to respond to undesirable stressors in the ecosystem. This includes the ability to respond to toxic chemicals by detoxification or by minimising their circulation. Mechanisms include metabolic processes (e.g., induction of AHH enzymes) and the burial of contaminated sediments with cleaner ones;

- An adequate food web to support higher trophic level organisms in terms of the numbers of food and prey species available and the numbers of organisms present;

- Low incidence and prevalence of adverse effects in biota. This includes fish tumours, eggshell thinning, developmental problems, biomarkers outside normal range etc.

Anthropogenic Criteria (B)

The criteria that humans might select to measure the health of the East Bayfront/Port Industrial Area are in some cases different. Anthropogenic criteria can be inferred from the factors identified by Beanlands and Duinker (1983) and discussed at the beginning of Chapter 2. They include:

- No advisories on fish or wildlife consumption;

- Abundant, high quality habitat for fish and wildlife;

- The presence of valued species of fish and wildlife (e.g., bald eagle);
- No beach postings;
- No algal growth;
- Clean industries with no apparent discharges to the environment (some would argue for no industries);
- No dead or decaying plants, animals or fish;
- Recreational opportunities e.g., paths, water sport activities;
- The absence of undesirable species e.g., lamprey and rats.

THE HEALTH OF THE EAST BAYFRONT/PORT INDUSTRIAL AREA ECOSYSTEM (A)

Ecosystem Criteria (B)

Risk Factors (C)

Habitat (D)

The quantity and quality of habitat varies throughout the study area. There is a good diversity of terrestrial habitats and some are of a relatively good quality. However, much of the Port Industrial Area is paved or built on, providing suitable habitat for only a few species, such as the house mouse. Aquatic habitat is generally of poor quality partly because of anthropogenic activity and partly because of natural factors, such as rapid temperature changes in the Lake. There is also a poor diversity of aquatic habitats.

Toxic Chemicals (D)

Toxic chemicals have been detected in all biotic and abiotic media investigated. Although data from the study area itself are scarce, information on biota from the surrounding areas suggest that concentration of several contaminants have decreased in recent years.

Food Web (D)

The terrestrial food web in the East Bayfront is relatively good and supports a variety of medium and higher trophic level species. The food web in the Port Industrial Area is poor and supports only three species of small mammals that are all foraging animals. An important feature of the aquatic food web is the large numbers of pollution-tolerant chronimids and oligochaetes. In addition, the fish community is dominated by forage fish which are medium, rather than high, trophic level species. High trophic level species i.e., predator fish are rare.

Development and Redevelopment Plans (D)

Past development in the study area has limited the quantity, quality and diversity of available habitats and resulted in the presence of toxic chemicals. Redevelopment plans have the potential to improve or further deteriorate ecosystem health. This is discussed in the next section on moving towards a healthier ecosystem.

Introduced Species (D)

There are several exotic species of aquatic and terrestrial (plant) life in the study area. They include purple loosestrife which invades wetlands and displaces native plant species and lamprey which preys on fish. Some introduced species are also undesirable from an anthropogenic perspective.

Sewer Separation (D)

Sewer separation has probably improved water quality somewhat especially in terms of microbiological parameters. However, a shortage of data and changes in sampling methodologies make it difficult to ascertain the extent of the improvement. Information on beach postings indicate that the frequency has not been reduced significantly in recent years.

Characteristics (C)

Habitat (D)

This has already been discussed above.

Nutrient Pool (D)

The most obvious feature of the nutrient pool in the East Bayfront/Port Industrial Area is the high organic content of some of the sediments, particularly in the Inner Harbour and Ashbridges Bay. This is maintained by organic inputs from sewer overflows and outflows and the discharge from the Main Sewage Treatment Plant. These large artificial additions are unhealthy for the ecosystem but they cannot be eliminated. The extension of the Main Sewage Treatment Plant outfall pipe may improve the situation in the nearshore zone, but it will affect other parts of the lake ecosystem. In addition, phosphorus levels across the Toronto Waterfront often exceed Environment Ontario's aquatic guideline of 20 micrograms/litre. As a whole, the Toronto Waterfront is usually characterised as eutrophic.

Species Diversity (D)

The diversity of aquatic species is relatively poor. As mentioned above, there are large numbers of a few pollution-tolerant benthic species and upper trophic level fish are almost entirely absent. Densities of benthos have decreased in recent years, suggesting an improvement. The diversity of fish species in the study area has changed over time. This can be seen from the results of the Metro Toronto Waterfront Fisheries Survey conducted by the MTRCA. These are presented in the Phase 2 report on natural heritage and summarised in Table IX. The diversity of terrestrial species in the East Bayfront is relatively good, but it is relatively poor in the Port Industrial Area.

Population Numbers (D)

Little is known about the stability of population numbers over time. There is no information available on terrestrial species. In contrast, there is some information on aquatic biota, although it is mainly in terms of yield or biomass. The Ontario Ministry of Natural Resources has estimated that Lake Ontario waters fronting Toronto could produce over half a million kilograms of fish a year. In comparison fishing along the shore, in streams and in urban ponds in recent years has produced approximately 3,500 kilograms of fish a year (Environment Canada et al. 1988).

The Phase 2 report on natural heritage uses an index that combines the number of species caught and the total number of individuals collected to compare fish collections. This index is:

$$\frac{S - 1}{(\log n)}$$

where S = total number of species caught

n = total number of individuals collected.

Responses to Stressors (D)

Most of the biota in the East Bayfront/Port Industrial Area have evolved biochemical mechanisms to detoxify toxic chemicals. These include enzyme induction. However, as a whole the study area is relatively poor at responding to loadings of toxic chemicals. This is because the main method of immobilising contaminants i.e., burial in sediment cannot function normally in parts of the study area. Dredging activities in and around the Keating Channel, the eastern gap and the Inner Harbour resuspend sediments and contaminants increasing their bioavailability. It could be argued that the removal of dredgeate to the disposal cells in the Eastern Headland is a valid method of removing contaminants from the area, but it is not a natural phenomenon and causes significant effects itself.

Food Web (D)

This has been discussed above.

Prevalence and Incidence of Adverse Effects (D)

There are not many data available on adverse effects on biota in the study area.

TABLE IX NUMBERS OF FISH SPECIES CAUGHT BY THE MTRCA AS PART OF THE METRO TORONTO WATERFRONT FISHERIES SURVEYS

Year	Number of Species
1982	25
1983	13
1989	15
1990	19

However, there are some data on biota in the surrounding area.

Fish populations in the Toronto Waterfront appear to be healthy, showing evidence of fungal infections and lamprey scars only (Environment Canada et al. 1988). In the late 1960s and 1970s, reproductive success of fish eating birds on Lake Ontario was relatively poor and there were reports of developmental effects. Crossed bills in common tern chicks and leg deformities in ring-billed gulls both from Mugg's Island were reported in the early 1970s. Since then, reproductive rates have improved. There have been no recent reports of congenital effects in birds on Mugg's Island. Thus, it is likely that this aspect of ecosystem health has improved in recent years. This is probably a result of decreases in the levels of organochlorines in the Great Lakes Basin Ecosystem.

Anthropogenic Criteria (B)

Advisories on Fish and Wildlife Consumption (C)

These have been discussed in Chapter 1 in the section on aquatic biota.

Habitat (C)

This has been discussed above.

Beach Postings (C)

All of Metro Toronto's waterfront beaches have been intermittently posted in recent years because of high levels of fecal coliform. Beach postings usually increase as the summer progresses because of increased bacterial survival in sediments related to warm temperatures, constant dry weather loadings and higher rainfall frequency. Beach postings have remained relatively constant in recent years. This may suggest that the effects of sewer separation are less than might have been expected. Cherry Beach is usually posted less frequently, compared with other beaches and only towards the end of the summer.

Algal Growth (C)

Algal growth can be expected in eutrophic conditions, such as those in the study area. However, algae have not been a large problem, probably because of a shortage of suitable material to which the can attach and because of wave action. In the last two years, there have been complaints about increased algal growth and the fouling of boat hulls and propellers in the vicinity of Ashbridges Bay. The reason for this is unknown.

Clean Industries (C)

At present the study area is dominated by light and heavy industrial uses. Current and previous industrial land uses have resulted in soils and groundwater contamination. Industries in and around the study area could not be described as clean, however, they are probably cleaner now than in previous years.

Built Form (C)

Much of the built form in the East Bayfront/Port Industrial Area is aesthetically unpleasant. A transition to more pleasing forms would require substantial redevelopment which would have negative short term effects on ecosystem health.

Dead or Decaying Biota (C)

Dead or decaying biota return nutrients to abiotic media. Breakdown and decay processes are essential for nutrient cycling and ecosystem health. Despite this, dead or decaying biota are not aesthetically pleasing from an anthropogenic perspective. This demonstrates a difference between the ecosystem and the anthropogenic criteria.

Recreational Opportunities (C)

The East Bayfront/Port Industrial Area already provide some recreational opportunities including walking and bicycling, water contact sports, fishing and the observation of wildlife. Increasing the availability of recreational opportunities may have negative effects on ecosystem health. In recent years, recreational opportunities in the Toronto Waterfront have increased dramatically, partly through the construction of new marinas, such as that in the Outer Harbour. Future possibilities that could affect the study area include car access, car parks, an interpretive centre and sailing club facilities proposed in the current master plan for Tommy Thompson Park. This is a possible conflict between the ecosystem and the anthropogenic criteria.

Undesirable Species (C)

There are several undesirable species in the study area. They include lamprey, which prey on fish, and possibly rats. The zebra mussel is rapidly approaching the Toronto Waterfront from the west.

Conclusions (B)

This section has attempted to assess the health of the East Bayfront/Port Industrial Area. Several conclusions can be drawn:

- It is extremely difficult to generalise about the health of the study area because of its diversity. It may be more appropriate to divide the area into at least three sub-areas: the East Bayfront, the Port Industrial Area and the aquatic environment;

- The overall ecosystem health status of the East Bayfront is better than that of the Port Industrial Area or the aquatic environment. It can be classified as fair. The Port Industrial Area and the aquatic environment can be classified as relatively poor;

- Nevertheless, the health of the entire study area has improved over the last twenty years. This is partly because until recently it has ben somewhat ignored in terms of redevelopment and natural habitat regeneration and succession processes have been allowed to proceed. This is not true for the aquatic environment. It is also because of initiatives to regulate, and in some cases ban, the manufacture, use and disposal of some persistent toxic chemicals in Canada and the U.S.

MOVING TOWARDS A HEALTHIER ECOSYSTEM IN THE EAST BAYFRONT/PORT INDUSTRIAL AREA (A)

Current Plans for the Area (B)

The East Bayfront/Port Industrial Area is covered by the Central Waterfront Plan, approved by City Council in June, 1988. It designates the East Bayfront as light industrial and the Port Industrial Area as light and heavy industrial. This section describes general trends in plans for the study area. It does not outline specific development projects, except where they are large enough to affect a large proportion of the study area.

In the spring of 1989 there were several proposals for housing in the East Bayfront and the Port Industrial Area that were associated with the City's bid for the 1996 Olympic Games. Initially, there was a proposal for housing west of Cherry Street and south of the Ship Channel and subsequently there was a proposal for housing in the East Bayfront. City Council rejected both of these options because of the implications for the industrial base in the city and because of the soil and landscape remediation that would be required. Thus, it appears unlikely that the city would consent to housing in the study area.

After these proposals, the idea of re-aligning the Don River was put forward. This idea had originally been suggested by the MRTCA in the late 1970s. The current version would be to straighten the Don River so that it flowed south into the Outer Harbour, rather than turning west into the Keating Channel. This could provide a continuous green space link between the Eastern Headland and the Don Valley. However, it would also result in large amounts of relatively contaminated sediments being deposited in the comparatively clean Outer Harbour. It would also constitute a significant engineering project as large amounts of soil and sediments would have to be excavated and dredged. The environmental effects of the project itself would be considerable, aside from the long term problems associated with sediment deposition mentioned above. These would involve disposal of the excavated, and presumably contaminated, soil and the resuspension of contaminants in sediments caused by the excavation activity on the river bank.

More recently, this idea has been further developed by the Gardiner Lakeshore Task Force. The Task Force has suggested that the Don River would be straightened out to the Ship Channel and the width of the new river bed would be increased to approximately five times its current width. This would create a retention pond for the sediments coming down the Don River and a wetland habitat for terrestrial and aquatic biota. While this option is extremely attractive from an ecosystem perspective and from an anthropogenic aesthetic perspective, there would be significant engineering and environmental problems associated with the project itself, including those outlined above.

At present, the City's Planning and Development Department is conducting an area-wide study of the East Bayfront. This is being conducted because of an application for an Official Plan Amendment to change the land use from industrial to residential and because there were twelve objectives to the Central Waterfront Plan for the East Bayfront. It is premature to speculate about the type of housing, densities and built form that may be permitted in the area.

There are several proposed developments that would affect a large proportion of the study area. These are the expansion/upgrade of the Main Sewage Treatment Plant, the construction of a hydro sub-station, the construction of a concrete batching plant (McCord) and an aggregate recycling facility (Harkow Aggregates) and the construction of a Port Industrial Park (THC). In addition Ataratiri, the joint City-provincial housing project, is located to the north of the Port Industrial Area.

Sustainable Redevelopment of the East Bayfront/Port Industrial Area (B)

Any redevelopment of the East Bayfront/Port Industrial Area is likely to have several objectives. These include creating jobs and providing tax revenues and possible housing. However, another vitally important objective will probably be to enhance the health of the area. Assuming that land use planning reflects prevailing societal values, ecosystem remediation will inevitably be a priority in any redevelopment scheme.

It is also likely that an important consideration will be balancing the short term, but possibly large, disturbances to the area during redevelopment caused by excavation, construction and other activities against the potential long term benefits to ecosystem health when redevelopment has been completed. Such balancing will require value judgements and ultimately political decisions because it will be impossible to weigh all the factors scientifically. However, it will be important to remember that the area is currently quite degraded and that human intervention could improve it much more rapidly than normal ecosystem successional processes.

Ecosystem health in the East Bayfront/Port Industrial Area could be improved on a long term basis by implementing two key ideas. These are:

- Improving habitats

  It will be important to improve the quality and quantity of terrestrial and aquatic habitats in the area. There is already a variety of different habitats, which is in itself healthy. The quality and quantity of terrestrial habitat could be improved by adopting the recommendations contained in the Phase 2 report on natural heritage. The quality and quantity of aquatic habitat would be more difficult to improve. However, it may be possible to provide more spawning habitat for different types of fish and minimising disturbances caused by dredging activities. It is recognised that upwelling events caused by wind effect seiche activity destabilises water temperatures along the nearshore zone probably making it difficult to establish stable, warm water fish communities.

  Habitat improvement would lead to an overall improvement in ecosystem health because it would attract a diversity of species which would in turn ensure an adequate food web for medium and higher trophic level organisms and a circulating pool of nutrients. It would also contribute to stable population numbers and improve the ability of biota to respond to stressors.

- Reducing or eliminating emissions of toxic chemicals

The reduction or elimination of emissions of persistent toxic chemicals is already the goal of two programs that are relevant to the East Bayfront/Port Industrial Area. These are the 1978 Great Lakes Water Quality Agreement, as amended in 1987, and Environment Ontario's Municipal Industrial Strategy for Abatement (MISA).

Reducing or eliminating emissions of toxic chemicals to the air, water and soil of the East Bayfront/Port Industrial Area would have the following effects on ecosystem health:

- Reduce fish consumption advisories in the area;
- Reduce adverse effects on fish, wildlife and plants;
- Reduce body burdens of contaminants in terrestrial and aquatic biota;
- Reduce levels of toxic chemicals throughout the ecosystem.

It is recognised, however, that it is probably not feasible to eliminate emissions entirely, especially because the Main Sewage Treatment Plant is located in the area and there are many sewer overflows and outfalls.

An important vehicle for improving the ecosystem health of the East Bayfront/Port Industrial Area will be the Remedial Action Plan. Although implementation of the Plan is probably still a year or more away, its potential should not be underestimated. Clearly, any remedial actions proposed in the Plan should be implemented into any redevelopment plans requiring municipal or provincial approval under the Planning Act or the Environmental Assessment Act. Thus, the Remedial Action Plan, the Planning Act and the Environmental Assessment Act will be important in improving the ecosystem health of the East Bayfront/Port Industrial Area. Unless, remedial and preventative measures, as proposed in the Remedial Action Plan, are required as part of all redevelopment plans, the success of the Plan will be only limited.

Ongoing Monitoring of Ecosystem Health in the East Bayfront/Port Industrial Area (B)

The East Bayfront/Port Industrial Area is a jurisdictionally defined ecosystem. Therefore, it is probably desirable to integrate any ongoing monitoring of ecosystem health in the area with programs already in place along the rest of the Toronto Waterfront. Also, it is likely that monitoring will be required to evaluate the success of remedial actions initiated as part of the Remedial Action Plan. Current and future monitoring programs are, and will probably continue to be, conducted by Environment Ontario, Environment Canada and the Metropolitan

Toronto and Region Conservation Authority.

Ideally, a program to monitor ecosystem health in the Toronto Waterfront in general and the East Bayfront/Port Industrial Area in particular should address the range of risk factors and characteristics identified in the section on criteria for a healthy ecosystem in the East Bayfront/Port Industrial Area. Current programs focus on levels of persistent toxic chemicals in abiotic (water and sediments in particular) and biotic (fish, freshwater clams, benthos) media. This represents only a portion of the criteria for healthy ecosystems. While it may not be feasible to initiate a monitoring program covering all of the criteria listed above, some could be incorporated.

Future programs should recognise the importance of biomonitoring more fully. This could include coordinated effects monitoring at the different levels of biologic organisation. Some examples of possible parameters are shown in Table I. Another approach would be to develop ecosystem indicators for the Toronto Waterfront similar to the one developed by the International Joint Commission's Science Advisory Board for Lake Superior. However, it would be necessary to address terrestrial, as well eutrophic aquatic ecosystem indicators. This approach is probably more feasible than measuring all of the criteria for a healthy ecosystem, however, it may be an oversimplification of a very complex ecosystem and so not represent its health accurately. Obviously, all monitoring programs will benefit from improved collaboration between the agencies involved and from synthesising the results more fully.

3. DIFFICULTIES IN ASSESSING ECOSYSTEM HEALTH (CH)

This chapter describes some of the general difficulties in assessing ecosystem health. Difficulties associated with assessing the effects of long term, low level, multiple exposures to persistent toxic chemicals are emphasised because of their relevance to the East Bayfront/Port Industrial Area. The problems can be classified into two broad areas:

- Scientific limitations; and
- Institutional arrangements.

These are discussed in further detail below.

SCIENTIFIC LIMITATIONS (A)

Ecosystems have been studied using the scientific method for approximately three hundred years. This investigation has proceeded largely by using a reductionistic approach in which an 'external', 'objective' experimenter or observer formulated a hypothesis usually about a component of the system, tested it by manipulating and observing the system and then reformulating the hypothesis based on the information collected. This approach owes much to Descartes and Newton who perceived nature in mechanistic terms. The scientific method, as it has been practised, has used the principle of causality i.e., that effects or events can be attributed to specific causes. Science has become very good at investigating unicausal relationships, where an effect can be attributed to a particular cause. In ecosystems, however, effects are rarely, if ever, unicausal.

The Nature of Ecosystem Health Effects (B)

Ecosystem health effects are usually complex because ecosystems consist of many interacting components that are mutually dependent on each other. Stressors can effect health directly or indirectly. Indirect effects are more common. For example, CFCs are essentially non-toxic and so do not cause direct health effects on humans, but they are depleting the stratospheric ozone layer and this is probably causing health effects.

It is often difficult to establish temporal and spatial boundaries for exposed populations and individuals. For example, to predict the human health effects resulting from exposure to a toxic chemical emitted from a point source, such as an incinerator, it is necessary to know its concentration in the environment and its distribution. Effects can occur at locations remote from the original source. For example, acid rain is known to cause environmental effects at locations remote from its sources. In addition, effects can occur immediately or after a latency period. For example, the effects of noise are often immediate, whereas the effects of exposure to ionising radiation may take decades to become apparent.

Ecosystem health effects are frequently non-specific. The same effect can be caused by several factors, only some of which may be environmental. For example, liver cancer can be caused by several carcinogenic chemicals and by many non-chemical factors. Thus, it is usually almost impossible to attribute an effect to a specific cause.

Ecosystems are exposed to many chemicals and other stressors simultaneously so it is virtually impossible to attribute a specific health effect to a particular stressor. Also, chemicals and other stressors interact with each other so that the combined effects may be less than (antagonism), equal to (additivity), or greater than (synergism) the effects of the individual stressors.

Biological variability is another confounding variable. Populations are extremely heterogenous and respond to stressors to differing degrees. It is therefore very difficult to predict the severity of health effects in individuals. As a result, population-based approaches to estimating risk assessment are often used. However, within heterogenous populations there may be more sensitive subpopulations. Some people may be more sensitive because they are more highly exposed than average (e.g., workers and their families and people who eat relatively large amounts of fish from the Great Lakes and their offspring), because their physiology and metabolism is less robust than average (e.g., developing fetuses and the elderly) or both (e.g., nursing infants).

The interaction and complexity of the factors discussed above means that it is extremely difficult to establish that a particular stressor caused a particular effect i.e., it is difficult to establish cause and effect relationships. In response to this, researchers are developing probabilistic models, such as quantitative risk assessment. This difficulty in proving causality means that prediction and assessment of health effects can never be entirely precise, except in a probabilistic sense.

Methodological Problems (B)

Ecosystem health effects have traditionally been investigated using epidemiology and toxicology. Epidemiology has been defined as "the study of the distribution and determinants of health-related states and events in defined populations, and the application of this study to the control of health problems" (Last 1983). Most epidemiologic studies have investigated human populations, although recently epidemiologic techniques have been applied to wildlife populations. Toxicology has been defined as "the study of the adverse effects of chemical agents on biological system" (Klaassen et al. 1986). Ecosystem health has been investigated using three sub-disciplines of toxicology:

- Wildlife toxicology;
- Plant toxicology; and,
- Clinical toxicology using experimental animals.

Although epidemiology and toxicology are helpful in assessing ecosystem health, they are not particularly well-suited to answer complex questions associated with long term, low level exposures to multiple stressors and the subtle effects they cause.

Factors which limit the usefulness of epidemiology in assessing ecosystem health include:

- It is a diagnostic, rather than a predictive technique;
- Environmental epidemiology has concentrated on studying gross health effects, such as mortality, cancer and congenital anomalies. Research is needed on more subtle indicators of health, such as neurotoxic and immunotoxic effects, functional impairments, biological markers, subtle developmental effects and reproductive success;
- It is usually necessary to correct for multiple stressors;
- It is often difficult to identify unexposed controls that can be used for comparative purposes because all ecosystems are exposed to stressors;
- Environmental exposures are often difficult to measure and predict and may vary over time or within an exposed population. Sometimes, epidemiological studies do not measure exposures. Similarly, it is difficult to define the target population spatially and temporally;
- Large sample sizes are often needed to detect rare health effects;
- Prospective studies can take many years to complete, so migration becomes important. However, prospective studies can be useful for post audit investigations;
- Retrospective studies rely on historical record which may not be accurate;
- Often, the increase in relative risk levels between the exposed and control populations are very small.

These problems limit the usefulness of environmental epidemiology. Unfortunately, however, little research has been done to describe the criteria that govern when environmental epidemiological studies are likely to be useful and conversely when such studies are likely to produce equivocal results or results that are not informative. In many cases, studies of the health effects of environmental stressors are inconclusive, so it may not always be helpful to conduct such investigations.

Factors which limit the usefulness of toxicology include:

- Effects in laboratory animals are extrapolated to predict effects in humans. This can never be entirely accurate because of metabolic and physiological differences between animals and humans;
- Laboratory animals are usually exposed to large doses of a single stressor through a single exposure pathway. Ecosystem populations are usually exposed to small doses of multiple stressors through multiple exposure pathways; and
- The results of wildlife toxicological studies have not been systematically compared with the results of laboratory toxicology studies. Similarly, little

attention has been paid to relating the results of wildlife toxicology studies to human health.

These problems are unlikely to be resolved although methodological improving are occurring. For example, the development and application of biological markers to chemically exposed populations is allowing us to measure subtle effects, although they are non specific for exposures and are not necessarily predictive of clinical health effects.

Data and Information (B)

As mentioned above, the two basic sciences used to assess ecosystem health are toxicology and epidemiology. However, although both have considerable databases they are still inadequate.

In 1984, the U.S. National Research Council and the National Academy of Sciences published a study on the nature and extent of available toxicological information. The study investigated a subset of the 65,725 substances of possible concern to the U.S. National Toxicology Program (U.S. National Research Council and National Academy of Science 1984). It found that there were insufficient data available to permit a health hazard assessment for the vast majority of chemical investigated. For the best studied group of chemicals, drugs and excipients in drug formulations, sufficient toxicological information was available on only 18% to permit a complete health hazard assessment. For pesticides, which are environmental chemicals, these was sufficient information available on only 10% to permit a complete assessment. There were insufficient data available on all chemicals in commerce studied to permit a complete assessment. The study also found that almost half of the chemicals studied were considered to have widespread human exposure and available physicochemical data on 20% of the chemicals led to a high concern that they could have adverse human health effects.

There is a similar shortage of environmental epidemiological data. An unpublished preliminary survey of Canadian studies on long term, low level exposure to chemicals in the environment and potential human effects identified a total of 43 studies (Davies and Gully 1989). They included six case studies, ten exposure studies, twelve ecological studies, seven case control studies and eight cohort studies. Of these 43 studies, nine demonstrated an association between exposure and effects, but only two demonstrated a high degree of association. This could be because of study design, sampling problems or because environmental exposure did not play a significant role in the human health effects investigated. Before it is possible to assess how ecosystem health is affected by stressors it is important to understand the pre-existing ecosystem health status or at least the health status of comparable ecosystems. Unfortunately, however, there is often not much information available on human or wildlife population health status. For example, data on human mortality are reasonably good, even though there are problems with defining 'causes of death' on death certificates. But information on morbidity is scarce. Hospital admission records can be an important source, as can 'sentinel physician' systems but information on health conditions for which physicians are often not consulted e.g., colds, flu, minor allergies, rashes etc. is almost entirely lacking, except where special health-status surveys have been conducted. The shortage of baseline health data is compounded by the shortages of environmental epidemiological and toxicological data discussed above. Baseline environmental data are more common, as many government environmental agencies routinely monitor air, food and water quality. Related issues are the separate collection and storage of information on environmental quality and human health and the need for information to be interpreted for its biological significance. In recent years, analytical detection levels have fallen by several orders of magnitude, but our ability to understand the biological significance of stressors such as low concentrations of chemicals has not kept pace. The trend towards effects monitoring, should resolve this problem.

INSTITUTIONAL, LEGISLATIVE AND JURISDICTIONAL ARRANGEMENTS (A)

A second difficulty with assessing ecosystem health is the institutional/legislative/jurisdictional ecosystem that we have constructed to manage the physical ecosystem and its health. This organisational ecosystem is an artifact of human values and concepts. Just as prevailing social and individual values determine the importance we assign to different ecosystems and their components (and how we assess their health), so the organisational ecosystem is based on the importance we assign to different components of the world around us. Existing arrangements are largely based on the assumption that ecosystems can be divided into components and managed separately. For example, humans are integral components of many ecosystems, but human health is usually managed separately from the health of the environment. For centuries, the Judeo-Christian tradition has emphasized the separation between, and superior nature of, humans over the environment. At worst, this belief has been used to justify the exploitation of 'natural resources' while at best it provides a justification for human stewardship of the biosphere. It is not realistic to think that humans can manage the biosphere or even act as its stewards. It is more appropriate to think in terms of managing the effects of human activities on the ecosystem, which is what most environmental management programs are designed to do.

Institutions and agencies rarely work collaboratively to assess ecosystem health and do not often agree about how the effects of human activities should be managed. There are four general problems that hinder collaboration. These are:

- Different institutions often have conflicting perceptions of their responsibilities. Sometimes, responsibilities are not clearly defined and sometimes more than one agency is responsible;

- Different institutions have different priorities and organisational values;

- Political power and influence is often related to the extent of the resources (budget and human) allocated to individual agencies. Frequently, departments or ministries at the same level of government must compete against each other for these resources;

- Institutions have long memories so that reorganisations involving transfers of resources (and hence power) from one institution to another are not quickly forgotten.

While it may not be feasible or desirable to abolish the existing institutional/legislative/jurisdictional ecosystem, it should be possible to ameleriorate it so that ecosystem health can be assessed and improved. This will require a change in values, so that ecosystems and their health are seen as being more important than the narrow jurisdiction or concerns of single institutions.

4. CONCLUSIONS (CH)

1. The East Bayfront/Port Industrial Area does not constitute a naturally defined ecosystem. Nevertheless, it is possible to apply the principles of an ecosystem approach to the area and to an assessment of its health.

2. There are many pathways through which nutrients and toxic chemicals enter the study area and our information on loadings is relatively good. Some of these pathways involve local sources and others involve remote sources. The most important ones are:

   - To the air (from local and remote sources);
   - To the surface water (from the Main Sewage Treatment Plant and storm and combined sewers);
   - To soils and groundwater (from previous and current land use activities).

3. Nutrients and toxic chemicals are exchanged between different media in the study area and between the study area and its surroundings. Our information on transfers within individual media and between different medial is relatively poor. This reflects our lack of knowledge about how nutrients and toxic chemicals cycle in ecosystems.

4. One of the major pathways by which contaminants are removed from the ecosystem, sediment burial, has been disrupted by dredging activities which resuspend contaminants in the water column, further exposing aquatic biota.

5. The criteria used to judge whether an ecosystem is healthy or not are inevitably influenced by human values. Nevertheless, it is possible to develop separate sets of criteria for ecosystem health in the East Bayfront/Port Industrial Area that represent the biocentric and anthropocentric perspectives.

6. Many of the effects observed in the East Bayfront/Port Industrial Area are cumulative i.e., they are not caused by a single activity in temporal and spatial isolation from other activities. There is a need to develop methodologies to assess the cumulative effects in the whole of the Greater Toronto Bioregion and to integrate them into the land use planning and development control processes in the area.

7. From a biocentric perspective, ecosystem health can be determined by identifying and measuring risk factors and by identifying and measuring the characteristics of healthy/unhealthy ecosystems.

8. From and anthropogenic perspective, ecosystem health can be determined by identifying and measuring factors that reflect how the public values ecosystems. These factors include the relationship between human health and the environment and concern about losses of important commercial species or commercially available production.

9. From a biocentric perspective, risk factors for the East Bayfront/Port Industrial Area include the quantity, quality and diversity of habitat, the presence of toxic chemicals, the adequacy of the food web, development and redevelopment plans, the introduction of exotic species and the policy of sewer separation. Characteristics include the quantity, quality and diversity of habitat, a circulating nutrient pool, the presence of diverse species, especially upper trophic level organisms, stable population numbers, the ability to respond to undesirable stressors, an adequate food web and a low incidence and prevalence of adverse effects in biota.

10. From an anthropogenic perspective, criteria include no fish or wildlife consumption advisories, abundant high quality habitat, no beach postings, no algal growth, clean industries, aesthetically pleasing built form, no dead or decaying biota, recreational opportunities and the absence of undesirable species.

11. Several conclusions can be drawn about the health of the East Bayfront/Port Industrial Area:

- It is extremely difficult to generalise about the health of the study area, because of its diversity. It may be more appropriate to divide the area into at least three sub-areas: the East Bayfront, the Port Industrial Area and the aquatic environment;

- The overall ecosystem health of the East Bayfront is better than that of the Port Industrial Area or of the aquatic environment. It can be classified as fair. The Port Industrial Area and the aquatic environment can be classified as relatively poor;

- Nevertheless, the health of the entire study area has improved over the last twenty years. This is partly because until recently it has been somewhat ignored in terms of redevelopment and natural habitat regeneration and succession processes have been allowed to proceed. This is not true for the aquatic environment. It is also because of initiatives to regulate, and in some cases ban, the manufacture, use and disposal of some persistent toxic chemicals in Canada and the U.S.

12. Assuming that land use planning reflects prevailing societal values, ecosystem remediation will inevitably be a priority in any redevelopment schemes for the area.

13. Ecosystem health in the East Bayfront/Port Industrial Area could be improved on a long term basis by implementing two key ideas. These are:

- Improving the quantity, quality and diversity of habitats; and

- Reducing or eliminating emissions of toxic chemicals.

14. There are two main difficulties in assessing ecosystem health. They are:

- Limitations related to science and its ability to answer questions about interactions in complex ecosystems; and

- Problems associated with institutional, legislative and jurisdictional arrangements.

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