Chapter 7

Conclusions

As mentioned on numerous occasions in this report there are challenges in attributing shoreline water and offshore sediment quality impairment in the Cape Town outfalls study area solely, or even predominantly to effluent discharged through the Green Point, Camps Bay and Hout Bay outfalls. This is because there are many land- and sea-based sources of contaminants other than effluent to the marine environment off the Atlantic seaboard of Cape Town. Also, the shoreline faecal indicator bacteria monitoring is too infrequent to identify the frequency of bacterial impairment of water quality and potential sources of the bacteria. It is, however, illogical and indeed irresponsible to imply that effluent discharged through the outfalls is not impacting on the marine receiving environments or posing a potential human health risk. Indeed, the notion of no impact to a marine receiving environment in the context of effluent discharge is unfounded. This is a price that must be acknowledged for the privilege of using the sea (and any other aquatic ecosystem) as a receptacle for wastewater. The critical question is whether effluent discharge through the Green Point, Camps Bay and Hout Bay outfalls is having a major adverse impact on the ecosystem functioning of the marine receiving environments and is posing a major risk to the health of humans that use and/or extract and consume resources from these environments.

It is not the prerogative or the responsibility of the scientists that prepared this report to decide on what constitute major ecological impacts and human health risks in the context of effluent discharge since this may differ from one person to another. Nevertheless, based on the findings of the surveys documented in this report these scientists are of the opinion no immediate ecological disaster is imminent as a result of effluent discharge through the Cape Town outfalls. This does not mean there are no ecological impacts and human health risks associated with this practice, but rather that no major ecological impacts could be detected through the monitoring approach followed in this study. This does not mean these scientists are not concerned about the practice of discharging wastewater into the marine environment, but under the status quo it provides a practical solution to the management of waste-water generated in parts of the City of Cape Town if properly managed. The strategy of disposing wastewater into the marine environment must also be considered in the context of impacts to rivers and estuaries were the wastewater to be treated at an inland wastewater works.

Based on the physical and chemical characteristics of effluent discharged through the Green Point, Camps Bay and Hout Bay outfalls and an assumed minimum initial dilution of 200 for each outfall, it would appear most effluent constituents are likely to be diluted in the marine receiving environments to concentrations protective of direct plume effects to marine fauna and flora shortly after discharge (*i.e.* within a small distance of points of effluent discharge). This does not, however, appear to be the case for ammonia in some samples and total suspended solids in a large proportion of samples. These constituents require much greater dilution to meet water quality targets than other effluent constituents, and under calm conditions and high concentrations in the effluents might not be effectively diluted in the marine receiving environments such that water quality targets are met at the margin of the zone of initial dilution. It is the high total suspended solids concentration and associated discolouration that makes the effluent visible when it reaches the sea surface (and indeed beneath the surface when the sea is clear).

The toxicity testing of seawater samples collected at the sea surface in the greater vicinity of the outfalls revealed a single incidence of very low magnitude toxicity, even though some seawater samples were collected in the effluent plume at the sea surface. This supports the notion that most contaminants in the effluents are likely to be sufficiently diluted shortly after discharge to limit

the incidence of acute toxicity.

There also appears to be no significant acute toxic risk posed by chemical concentrations in sediment in the Table Bay, Camps Bay and Hout Bay areas. Thus, despite the over 115 year history of discharging partially treated wastewater into the marine environment off Cape Town there has been no significant accumulation of effluent-derived contaminants in the sediment with time. Although sediment in parts of the Cape Town outfalls study area is contaminated by metals, hydrocarbons and polychlorinated biphenyls, apart from the latter it is not possible to attribute these as having an effluent source.

Mussels and rock lobsters collected from the shoreline and nearshore along the Atlantic seaboard of the Cape Peninsula were not found to be accumulating effluent-derived contaminants in their tissue, at least not to concentrations that could be discriminated from concentrations in mussels and rock lobsters collected at 'clean' sites. Sessile or slow moving marine organisms living at or near the points of effluent discharge may, however, be accumulating effluent-derived contaminants in their tissue and this warrants investigation in the future.

The measurement of faecal indicator bacteria in surface seawater samples collected in the greater vicinity of the outfalls provided clear evidence of effluent reaching the sea surface in some surveys, but there was no clear evidence the bacteria (and thus presumably other effluent constituents) were reaching the shoreline. There is indirect evidence from faecal indicator bacteria counts in seawater samples collected at many sites along the Cape Town shoreline over an extended period that effluent is possibly, even if infrequently, reaching the shoreline. The uncertainty in this regard stems from the fact that stormwater runoff may be a significant source of faecal indicator bacteria to the shoreline, as is the case in most cities. These uncertainties make it difficult to estimate the risk posed by effluent discharge to the health of recreational users of nearshore and shoreline waters and represents perhaps the most important uncertainty that should be addressed through further research and monitoring. Regardless of the source of the bacteria their counts in shoreline water samples at many sites were, at varying frequencies depending on the site, high enough to suggest a significant periodic risk to humans recreationally using nearshore and shoreline waters.

The conclusion that effluent discharge through the Green Point, Camps Bay and Hout Bay outfalls is not having an immediate major ecological impact in the Cape Town outfalls study area might be surprising to the public considering recent debate on the practice of discharging partially treated wastewater to the marine environment off Cape Town appears to have created the impression that major ecological impacts and health risks should intuitively be associated with this practice. As discussed above, this does not mean there are no impacts associated with this practice, but that the assimilative capacity of the marine receiving environments for the Green Point, Camps Bay and Hout Bay outfalls has not, at this time, been exceeded. It is nevertheless clear the world cannot use the marine environment as a waste receptacle in perpetuity and opportunities for improved and economically and environmentally feasible waste-water treatment, and the feasibility of using alternate strategies for disposing of wastewater to the marine environment should be investigated by the City of Cape Town (and other municipalities).

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Glossary of Terms and Acronyms[1]

Abiotic factors	The physical, chemical and other non-living components of the environment that an organism lives in. These factors include all aspects of climate, geology, and atmosphere that affect ecological systems.
Acceptable risk	The maximum level of individual lifetime carcinogenic level risk considered 'acceptable' by risk managers.
Acute toxicity test	A method used to determine the concentration of a substance that produces a toxic effect on a specified percentage of test organisms in a short period of time.
Acute toxicity	The discernible adverse effects induced in an organism within a short period of time of exposure to a chemical. For aquatic animals, this usually refers to continuous exposure to the chemical in water for a period of up to four days.
Adsorption/Adsorb	Bonding of chemicals onto the surfaces of suspended particles by way of physical, chemical and biological processes.
Aliquot	A sub-sample of the original sample.
Ammonia (NH_3)	A chemical combination of nitrogen and hydrogen that occurs extensively in nature. It is a water-soluble gas that behaves as a weak base. It can exert toxic effects on aquatic life.
Ammonium (NH_4^+)	The protonated form and conjugate acid of ammonia. It predominates under low-pH conditions.
Anthropogenic	Made and/or introduced into the environment by humans, especially pertaining to contaminants/pollutants.
Aquatic ecosystem	All the living and non-living material interacting within an aquatic system (*e.g.* pond, lake, river, ocean).
Assimilative capacity	The amount of contaminant load that can be discharged to a specific water body without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a water body to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.
Bacteria	Bacteria are single-celled, small organisms that reproduce generally by fission. Some are pathogenic (cause disease), but most are free-living, with most being saprophytic (feed on dead or decaying organic matter).
Bathymetry	Bathymetry is the water depth relative to sea level. From bathymetry data, an understanding of the seafloor topography can be gained.
Benthic invertebrate community	The assemblage of various species of sediment-dwelling organisms that are found within an aquatic ecosystem.
Benthic	Pertaining to the environment inhabited by organisms living on or in the ocean bottom.
Bioaccumulation	General term describing a process by which certain chemicals are taken up by a plant or animal either directly from exposure to a contaminated medium (soil, sediment, water) or by eating food containing the chemical. Compounds of a certain type can accumulate in living things when they are taken up and stored faster than they are broken down (metabolised) or excreted. Certain compounds are easily broken down and do not bioaccumulate.
Bioavailable	A substance in a chemical and physical form that allows it to affect organisms or be accumulated by them.
Biomagnification	Sequence of processes in an ecosystem by which higher *concentrations* are

[1] This glossary of terms and acronyms was compiled from numerous sources, which are available from the CSIR on request.

	attained in organisms at higher trophic levels (at higher levels in the food web); at its simplest, a process leading to a higher concentration of a substance in an organism than in its food.
Biota	The living organisms within a habitat or region.
Biotic	Relating to life or living things.
Bivalve	Mollusc with a shell in two parts, hinged together (*e.g.* mussel).
Byssus threads	The fine fibres or bundle of silky threads secreted by a gland found in the foot of some bivalves by which they attach themselves permanently to rocks or other solid objects.
Cancer slope factor (CSF)	A value assigned to a cancer causing chemical that is used to estimate its ability to cause cancer in humans.
Carcinogen	Any substance that causes cancer.
Chronic toxicity	The response of an organism to long-term exposure to a chemical substance. Among others, the responses that are often measured in chronic toxicity tests include lethality, decreased growth, and impaired reproduction.
Chronic	Multiple exposures occurring over an extended period of time, or a significant fraction of the organism's life-time; effects from chronic exposure, or long-term effects from high short-term exposures.
Coliform bacteria	A group of bacteria primarily found in human and animal intestines and wastes. These bacteria are widely used as indicator organisms to show the presence of such wastes in water and the possible presence of pathogenic (disease-producing) bacteria. Escherichia coli (*E. coli*) is one of the faecal coliform bacteria widely used for this purpose.
Colony forming unit (cfu)	A unit (measurement) of density used to estimate bacteria concentrations in ocean water. The number of bacterial cells that grow to form entire colonies, which can then be quantified visually.
Community	Any group of organisms belonging to a number of different species that co-occur in the same habitat or area.
Concentration	The quantifiable amount of a substance in water, food or sediment.
Contaminants	Biological or chemical substances or entities, not normally present in a system, capable of producing an adverse effect in a biological system, seriously injuring structure or function.
Control site	A geographic location that is far enough from a known pollution source (*e.g.* ocean outfall) to be considered representative of an undisturbed environment. Information collected within control sites is used as a reference and compared to impacted sites.
Crustacea	A group (Phylum) of marine invertebrates characterised by jointed legs and an exoskeleton (*e.g.* crabs, shrimps, and crayfish).
CSIR	Council for Scientific and Industrial Research
Cumulative effects	Effects on the environment resulting from actions that are individually minor but that add up to a greater total effect as they take place over a period of time.
Day grab	A mechanical device designed to collect bottom sediment samples. The device consists of a pair of hinged jaws and a release mechanism that allows the opened jaws to close and entrap a 0.25 m^2 sediment sample once they touch bottom.
Dissolved oxygen (DO)	The oxygen that is freely available in water. Certain amounts are necessary for life processes of aquatic animals. The oxygen is supplied by the photosynthesis of plants and by aeration. Oxygen is consumed by animals, plants, and bacteria that decompose dead organic matter and some chemicals.

Dose	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect.
Dose-response	The relationship between the amount or magnitude of exposure (dose) and the biological response or toxic injury produced by the chemical.
Echinodermata	A group (phylum) of marine invertebrates characterized by the presence of spines, a radially symmetrical body, and tube feet (*e.g.* sea stars, sea urchins, and sea cucumbers).
Ecosystem	An interrelating complex of plant and animal communities and their associated non-living environment.
Effective Concentration (EC)	A point estimate (statistically derived) of the toxicant concentration that would cause a quantal ('all or nothing') effect, such as death or lack of fertilisation, in a given time, for example, 96 hr EC_{50}.
Effluent	The discharge to a body of water from a defined or point source, generally consisting of a mixture of waste and water from industrial or municipal facilities.
Endpoint	A measured response of a receptor to a stressor. An endpoint can be measured in a toxicity test or in a field survey.
Enterococci	Any Streptococcus bacteria that inhabit the intestines of warm-blooded animals. In the intestines, enterococci are normal and do not cause disease. They can be pathogenic if they enter tissues, the bloodstream, or the urinary tract.
Eutrophication	A condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae (*e.g.* phytoplankton). Algal decomposition may lower dissolved oxygen concentrations. Although eutrophication is a natural process in the aging of lakes and some estuaries, it can be accelerated by both point and non-point sources of nutrients.
Exposure assessment	An identification and evaluation of the human population exposed to a toxic agent that describes its composition and size and the type, magnitude, frequency, route, and duration of exposure.
Exposure pathway	The physical course a chemical or pollutant takes from its source to the organism exposed.
Exposure scenario	A combination of facts, assumptions, and inferences that define a discrete situation where potential exposures may occur. These may include the source, the exposed population, the time frame of exposure, microenvironment(s) and activities. Scenarios are often created to aid exposure assessors in estimating exposure.
Exposure	Contact made between a chemical, physical, or biological agent and the outer boundary of an organism. Exposure is quantified as the amount of an agent available at the exchange boundaries of the organism (*e.g.* skin, lungs, gut).
Far-field effects	Effects of an activity that are observed far away from that activity.
Grab sampler	A device that is used to collect surficial sediments through a scooping mechanism.
Guideline	A numerical concentration limit or narrative statement recommended to support and maintain a designated water use.
Habitat	A place where the physical and biological elements of ecosystems provide an environment and elements of the food, cover and space resources needed for plant and animal survival.
Heavy metal	An imprecise term with no sound terminological or scientific basis, used loosely to

	refer to metals that are toxic.
Hypoxia	The condition of low dissolved oxygen in aquatic systems (typically with a concentration <2 $mg.l^{-1}$ but >0.5 $mg.l^{-1}$).
Impact site	A geographic location that has been altered by the effects of a pollution source, such as a wastewater outfall.
Impact	A change in the chemical, physical or biological quality or condition of a waterbody caused by external sources.
Impairment	A detrimental effect on the biological integrity of a water body caused by an impact.
Indicator	Characteristics for the environment, both abiotic and biotic, that can provide quantitative information on environmental conditions.
Infauna/infaunal animals	Those animals that live within the sediments of the sea floor.
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way.
Ingestion rate	The amount of an environmental medium that could be ingested typically on a daily basis.
Inorganic	Any compound lacking carbon.
Intraspecific variability	Differences between individuals of a single species.
Invertebrate	An animal without a backbone (*e.g.* a starfish, crab, or worm).
Lethal Concentration (LC)	Toxicant concentration producing death of test organism. For example, a 96 hr LC_{50} would be the test concentration killing 50% of exposed organisms after 96 hrs of exposure.
Macrofauna	Epifaunal or infaunal benthic invertebrates that are visible with the naked eye. These animals inhabit soft-bottom marine habitats and are retained on a 1 mm mesh screen.
Meal consumption limits	Recommended restrictions on the frequency of fish meals based on chemical concentrations found in fish tissue. Meal consumption limits are set to keep amounts of chemicals eaten in fish at or below levels believed to cause no adverse health effects.
Meiofauna	Small interstitial (i.e. occurring between sediment particles) animals that pass through a 1 mm mesh sieve but are retained by a 0.045 mm mesh.
Method detection limit	The minimum concentration of a substance that can be measured and reported with 99% confidence that the concentration is greater than zero.
Minimum Acceptable Toxicant Dilution (MATD)	The dilution needed to render an effluent non-toxic, or at least no different to the controls.
Mollusca	A taxonomic group (phylum) of invertebrates characterized as having a muscular foot, visceral mass, and a shell. Examples include snails, clams, and octopuses.
Multivariate analysis	Statistical methods (*e.g.* ordination or discriminant analysis) for analysing physical and biological community data using multiple variables.
Near-field	Effects of an activity that are observed adjacent or close to that activity.
Nitrate	A compound containing nitrogen that can exist in the atmosphere or as a dissolved gas in water. Nitrates in water can cause adverse effects on humans and animals and act as a nutrient for plants.
Nitrite	An intermediate in the bacterial transformation of ammonia or ammonium to nitrate.
Nitrogen	A key nutrient for aquatic and terrestrial plants and occurring in various forms.

Non-carcinogen	A chemical or substance that causes non-cancer health effects
Normalise	Perform a data calculation in order to express results in terms of a reference parameter or characteristic.
Nutrients	Essential chemicals (*e.g.* nitrogen and phosphorus) needed by plants for growth. Excessive amounts of nutrients can lead to degradation of water quality by promoting excessive growth, accumulation, and subsequent decay of plants, especially algae (phytoplankton).
Outfall	Discrete location where quantities of water and/or waste are discharged into lakes, streams, or oceans, generally through a pipe.
Parameter	One of a set of properties whose values determine the characteristics of a waterbody. Examples include dissolved oxygen, temperature, and salinity.
Pathogen	An agent such as a virus, bacterium or fungus that can cause diseases in humans. Pathogens can be present in municipal, industrial, and non-point-source discharges.
Phosphorus	An important nutrient utilized by aquatic and terrestrial plants.
Physicochemical	Measurement of both physical properties (*e.g.* temperature, salinity) and chemical determinants (*e.g.* metals and nutrients) to characterise the state of an environment.
Phytoplankton	Free-floating, single-celled, microscopic plants that live in water (also called unicellular algae). Can make the water appear cloudy or coloured.
Pollution	The terms 'pollution' and 'contamination' are often confused. The term 'pollution' is clearly defined in several of the international conventions, but in everyday language the term is used in another sense. The Paris Convention, for instance, defines pollution as the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as hazards to human health, harm to living resources and to marine ecosystems, damage to amenities or interference with other legitimate uses of the sea. On the other hand, 'contamination' is caused by substances not normally present in the marine environment (or present in higher concentration than normal) that do not apparently cause ill effects.
Polychaeta	A taxonomic group (Class) of, mainly marine, invertebrates characterised by having wormlike features, segments, and bristles or hairs. They are very variable in form and lifestyle and are good environmental indicators.
Polychlorinated Biphenyls (PCBs)	A group of closely related and manufactured chemicals made up of carbon, hydrogen, and chlorine. Due to their non-flammability, chemical stability, high boiling point and electrical insulating properties they have wide industrial and commercial applications. PCBs can persist for a long time in the environment and they can bioaccumulate and biomagnify in aquatic food webs and are suspected of causing cancer in humans. They are an example of an organic contaminant.
Polycyclic aromatic hydrocarbons	Substances that occur through incomplete burning of organic substances such as wood, and are also manufactured and used in medicines or to make dyes, plastics and pesticides.
Population	An aggregate of interbreeding individuals of a biological species within a specified location.
Primary treatment	The first stage of wastewater treatment involving removal of debris and solids by screening and settling.
Receiving environment	A river, stream, lake or other body of surface water into which wastewater or treated effluent is discharged.

Reference dose (RfD)	An estimate (with uncertainty spanning perhaps and order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.
Reference toxicant	A chemical used to access the constancy of response of a given species of test organisms to that chemical. It is assumed that any change in sensitivity to the reference substance will indicate the existence of some similar change in degree of sensitivity to other chemicals/effluents whose toxicity is to be determined.
Replicate	Taking more than one sample or performing more than one analysis.
Risk	The chance of something happening that will have a (generally adverse) impact on plants, animals, ecosystems or humans. It is measured in terms of likelihood.
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing (inhalation), eating or drinking (ingestion), or contact with the skin (dermal contact).
Salinity	A measurement of the amount of salt in water. Frequently reported as parts per thousand (i.e. grams of salt per 1 000 g of water) and abbreviated as ppt, but technically has no measurement units.
Sediment	Mud, sand, silt, clay, shell debris, and other particles that settle on the bottom of rivers, lakes, estuaries, and oceans.
Sensitivity	The condition whereby adverse health effects that occur from exposure to a chemical contaminant are determined by quantitative differences; a chemical can produce the same effect in infants, children, or adults, but the magnitude of effect differs.
Shell hash	Sediment composed of shell fragments.
Site	A sampling location within a study area or site, where physical, chemical, or biological sampling and/or testing occurs.
Sorting	The range of grain sizes that comprise marine sediments. Also refers to the process by which sediments of similar size are naturally segregated during transport and deposition according to the velocity and transporting medium. Well sorted sediments are of similar size (such as desert sand) while poorly sorted sediments have a wide range of grain sizes (as in a glacial till).
Species	A category of biological classification ranking immediately below the genus, comprising related organisms potentially capable of interbreeding. A species is identified by a two part name; the name of the genus followed by a Latin or Latinised un-capitalised noun agreeing grammatically with the genus name.
Stockholm Convention	An international convention established to address global concerns about persistent organic pollutants. It aims to reduce/eliminate production, use, and/or release of key persistent organic pollutants under the support of the United Nations Environment Programme (UNEP).
Susceptibility	The condition whereby adverse health effects from exposure to a chemical contaminant are due to qualitative differences; such as, unique processes of growth and development in the exposed organism, particularly in young, not fully matured individuals, changes due to aging, state of health, nutritional status, or genetic predisposition to harm.
Taxon (taxa)	Any group of organisms considered to be sufficiently distinct from other such groups to be treated as a separate unit (*e.g.* species, genera, families).
Thermocline	The zone in a thermally stratified body of water that separates warmer surface water from colder deep water. At a thermocline, temperature decreases rapidly over a short depth.
Total Suspended Solids	Insoluble solids that either float on the surface of or are in suspension in water or

(TSS)	wastewater. TSS is a measure of the amount of particulate matter in an aqueous sample. May also be referred to as suspended solids (SS).
Toxic	Poisonous, carcinogenic, or otherwise directly harmful to life.
Toxicant	A chemical capable of producing an adverse response (effect) in a biological system, seriously injuring structure or function or producing death (*e.g.* pesticides and metals).
Toxicity	A measure of the impact on a chosen biological process or condition.
Trace metal	A metal found in low concentration, in mass fractions of ppm (µg) or less, in some specified source (*e.g.* sediment, tissue).
Trophic level	A portion of the food web at which groups of animals have similar feeding strategies.
Turbidity	A measure of the clarity of water.
Uncertainty	Uncertainty occurs because of a lack of knowledge. It is not the same as variability. For example, a risk assessor may be very certain that different people drink different amounts of water but may be uncertain about how much variability there is in water intakes within the population. Uncertainty can often be reduced by collecting more and better data, whereas variability is an inherent property of the population being evaluated. Variability can be better characterized with more data but it cannot be reduced or eliminated. Efforts to clearly distinguish between variability and uncertainty are important for both risk assessment and risk characterization.
Upwelling	The process by which deep, cold, nutrient-laden water is brought to the surface, usually by wind divergence of equatorial currents or coastal winds that push water away from the coast.
Wastewater	Spent or used water of a community or industry, including runoff water and combined sewer overflow.
Water column	The area of water contained between the surface and the bottom of a waterbody.
Water quality guideline	A value, not to be exceeded, set for a specific water quality constituent in a defined water body portion or a water body, to ensure with a given measure of reliability, its agreed fitness for use. This is an achievable value determined by considering the water quality requirements of recognised water users as well as relevant physical, technological, economic and socio-political issues.
Weight of evidence approach	Use of multiple lines of evidence to evaluate an issue or risk; evidence can be scientific in nature or inclusive of other disciplines (*e.g.* socio-economic, political and legal).
Whole effluent toxicity	The total toxic effect of an effluent measured directly with a toxicity test.
Zone of Initial Dilution (ZID)	An area in the immediate vicinity of a marine outfall discharge where there is rapid mixing of the effluent with sea water as a result of jetting and buoyant rise. An allocated impact area, or mixing zone, in a water body where numeric water quality criteria can be exceeded as long as acutely toxic conditions are prevented.