ASSESSMENT OF FACTORS INFLUENCING THE QUALITY OF SURFACE AND GROUND WATER IN THE HOUT BAY RIVER CATCHMENT

by

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ABSTRACT

An investigation into the quality of surface water and ground water was conducted during 1988 in the 38,8 km^2 Hout Bay River catchment near Cape Town. The main objective of the study was to determine those areas and activities which constitute a pollution source and to ascertain the relative proportion which each contributes to the pollution problem and health risk of the surf zone of the beach at Hout Bay. The objective was achieved by monitoring the chemical and microbiological attributes of the Hout Bay River, its tributaries and stormdrains in wet and dry conditions on a routine basis and during storm events.

Hout Bay is a rapidly developing residential area in which sewage disposal occurs by means of septic tank soakaway systems. Ground water quality was monitored to investigate the contribution to contamination by septic tank effluent. Results showed that stormdrain effluent in dry and wet conditions and surface runoff during rainfall were the main vectors of pollution. Although the pollution concentration was high during dry conditions the greatest pollution discharge to the surf zone of Hout Bay occurred during storm events.

In view of the proposed residential development it is imperative that pollution control measures be undertaken so as to secure the future recreational and aesthetic value of Hout Bay.

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Aerial view of Hout Bay, below Victoria bridge.

CHAPTER 1

INTRODUCTION

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1.1 Context of the research project

Hout Bay, south west of Cape Town (figure 1), has over the past eight years changed from a low density area into a rapidly developing residential area with a population of 10 000 people in 1986. The capacity population is an estimated 26 000 people.

The beach and surf zone of Hout Bay are microbiologically polluted. The pollution problem prompted this investigation into the natural and imported water induced hydrodynamics of the Hout Bay catchment in order to establish pollution source areas and vectors.

1.2 Study objective

The main objective of the study is to determine those areas and activities which constitute a pollution source and to ascertain the relative proportion which each contributes to the pollution of the surf zone in Hout Bay.

The study objective comprises four specific aims:

(i) Determination of the magnitude, characteristics and variability of chemical and microbiological pollution.

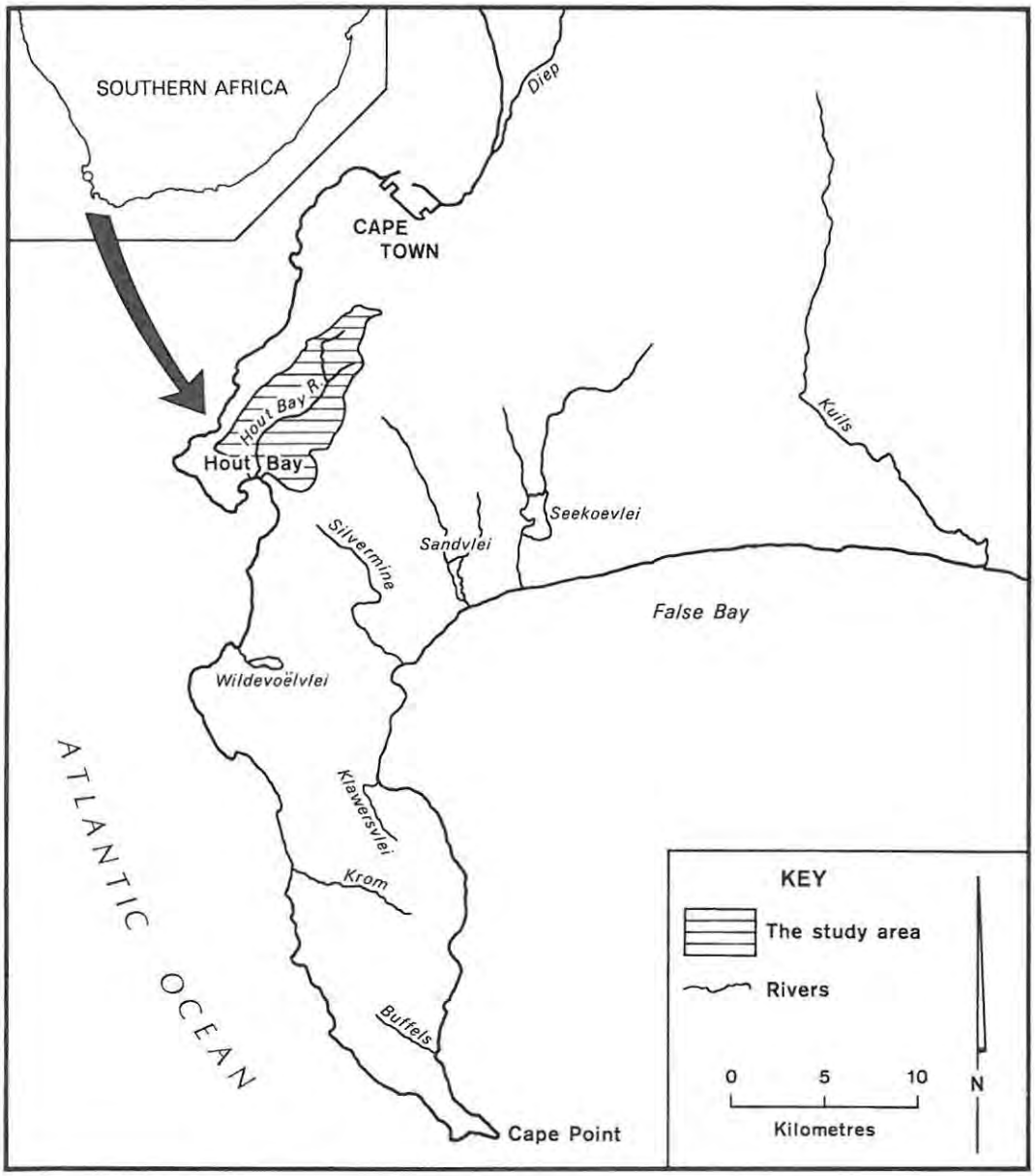

Figure 1: Location of Hout Bay

(ii) Identification of the point and non-point sources and vectors of pollutants.

(iii) Recommendation of control measures or preventive measures against further pollution.

(iv) Determination of the expected effect which the implementation of a reticulated sewerage system will have on the water quality of the Hout Bay surf zone.

1.3. Hypotheses

The following hypotheses are based on an extensive literature review and provide the framework of the study:

(i) Inefficient septic tank systems are the major source of pathogenic pollutants in the surf zone of Hout Bay.

(ii) The total pollution load of the Hout Bay River system increases during the rainy season because of flushes of pollutants from stormdrains.

(iii) The total pollution load of the Hout Bay River system increases during the rainy

season because of increased hydrodynamics of the ground water system.

(iv) The ground water discharge direct to the beach zone represents a minor contribution to the total pollution load.

1.4 Research studies in water pollution

1.4.1 Previous research in Hout Bay

A number of recent research publications have been related to various aspects of Hout Bay including the physical aspects of the beachfront (Hill Kaplan Scott (HKS), 1984; Fromme, 1985), flood characteristics (HKS, 1985), land use patterns and river channel degradation (Grindley, 1984) and the ecological status of the river (King and Grindley, 1982).

The proposed construction of a sewage outfall off Badtamboer Point, below the Sentinel (figure 2) stimulated research along the Hout Bay coastline investigating anticipated effluent levels and associated water quality (Toms, 1985), current, wind and wave patterns (CSIR 8611, 1986) and anticipated effluent dilution (CSIR 8613, 1986). Pollution monitoring along Hout Bay beach and surf zone was conducted by the Division of Earth Marine and Atmospheric Science and Technology (DEMAST) (formerly the

National Research Institute for Oceanology (NRIO)) in 1979, 1980, 1981 and 1985 (Taljaard et al., 1985). Samples taken from eleven sites stretching from Badtamboer Point, below the Sentinel, to the old jetty, below Chapmans Peak Drive, revealed that samples obtained in the surf zone from the east and west beaches were relatively free from microbiological pollution whereas enumeration of indicator organisms in samples obtained in the surf zone at the river mouth exceeded those limits recommended for the South African coastal zone by Lusher (1984) at least 50 percent of the time over which it was monitored (Tworeck et al., 1986).

Western Cape Regional Services (WCRSC) has been monitoring the water quality at three points on the Hout Bay River on a three monthly basis since April 1979 (King, pers. comm.).

Apart from the surveys related to the proposed outfall much of the work done in Hout Bay was on a monitoring level only and failed to investigate sources and factors influencing the pollution. The surveys did however emphasize the need for an in-depth pollution study of the Hout Bay River and it is on this basis that the research project was formulated.

1.4.2 South African research studies

Only recently has the severity of marine pollution aroused concern in South Africa. Grabow (1987) draws attention to the

hazard associated with viruses entering the marine environment. Bowmaker et al., (1987) refer to a number of surveys involved in monitoring the disposal of sewage and bacteriological pollution along the Natal coastline. In the Cape Peninsula similar studies investigating marine pollution from a land based origin were carried out at Camps Bay (Eagle et al., 1977) and False Bay (DEMAST; DWT). Other areas presently being investigated include Green Point (DWT; Cape Town Municipality), Three Anchor Bay (CPA; DEMAST) and a number of points along the False Bay coastline (Department of Environmental Affairs; DEMAST; DWT).

1.4.3 Worldwide research studies

Much of the literature (in English) on pollution of coastal waters reports on areas in the United States of America, United Kingdom and Europe. Researchers such as Cabelli et al., (1983) (USA), Evison, (1982) (UK, Mediterranean) and Hodgkiss and Chan, (1986) (Hong Kong) make specific reference to bacteriological pollution and the associated health threat.

Prevention of marine pollution involves control of pollution sources of a land based origin and control over the means through which the pollutants enter the marine environment. A number of studies concentrating on individual aspects of the greater pollution problem include those by Griffin et al. (1980) on the export of microbiological and chemical pollution from two small catchments in northern Virginia (USA) and Rimer et al. (1980) on the effect which different land use has on stormwater runoff.

OECD (1986) produced a general report on the mechanisms, problems and management strategies relating to urban run-off. Investigations into the contamination of ground water by septic tank effluent has been widely covered by researchers Viraraghavan and Warnock (1976) in Ottawa, Canada, Lewis et al. (1980) referring to problems in developing countries such as India and the Far East, Sinton (1984) working in Canterbury Plains, New Zealand and Reddy and Dunn (1986) in North Carolina (USA).

In addition to sources of pollution, factors influencing the pollutants are important such as the movement of chemical pollutants through soil (Brown et al., 1984; Whelan and Barrow, 1984), microorganisms in soil (Brown et al., 1979; Siegrist, 1987) and factors influencing the survival of bacteria in soil (Hegedorn et al., 1981) and surface water (Gerba and McLeod, 1976; McCambridge and McMeekin, 1981; Rhodes et al., 1983).

The next chapter provides a descriptive background of the characteristics of the study catchment area.

CHAPTER 2

THE STUDY AREA

2.1 Location

2.2 Relief

2.3 Geology

2.4 Soils

2.5 Hout Bay River system

2.6 Climate

2.7 Water supply and waste disposal

2.8 Proposed residential development

CHAPTER 2

THE STUDY AREA

2.1 Location

The Hout Bay River catchment (figure 2), which comprises the study area, extends over an area of 33,8 square kilometres. Hout Bay is situated 22 kilometres south south-west of Cape Town (figure 1) between longitude $18^{o}18'$ and $18^{o}26'$ east and latitude $33^{o}58'$ and $34^{o}04'$ south.

2.2 Relief

As shown in figure 2 the catchment is bounded by mountain ranges with the Twelve Apostles forming the western catchment boundary, the Constantiaberge the eastern boundary and the Back Table in the north. Maclear's Beacon at aheight of 1085,9 metres above sea level is the highest point in the catchment. Despite the prominence of the mountain ranges over 50 percent of the catchment has an altitude below 500 metres.

Figure 3 shows the relief profile of the Hout Bay River which is a short, steep gradient river, highly susceptible to flooding and erosion.

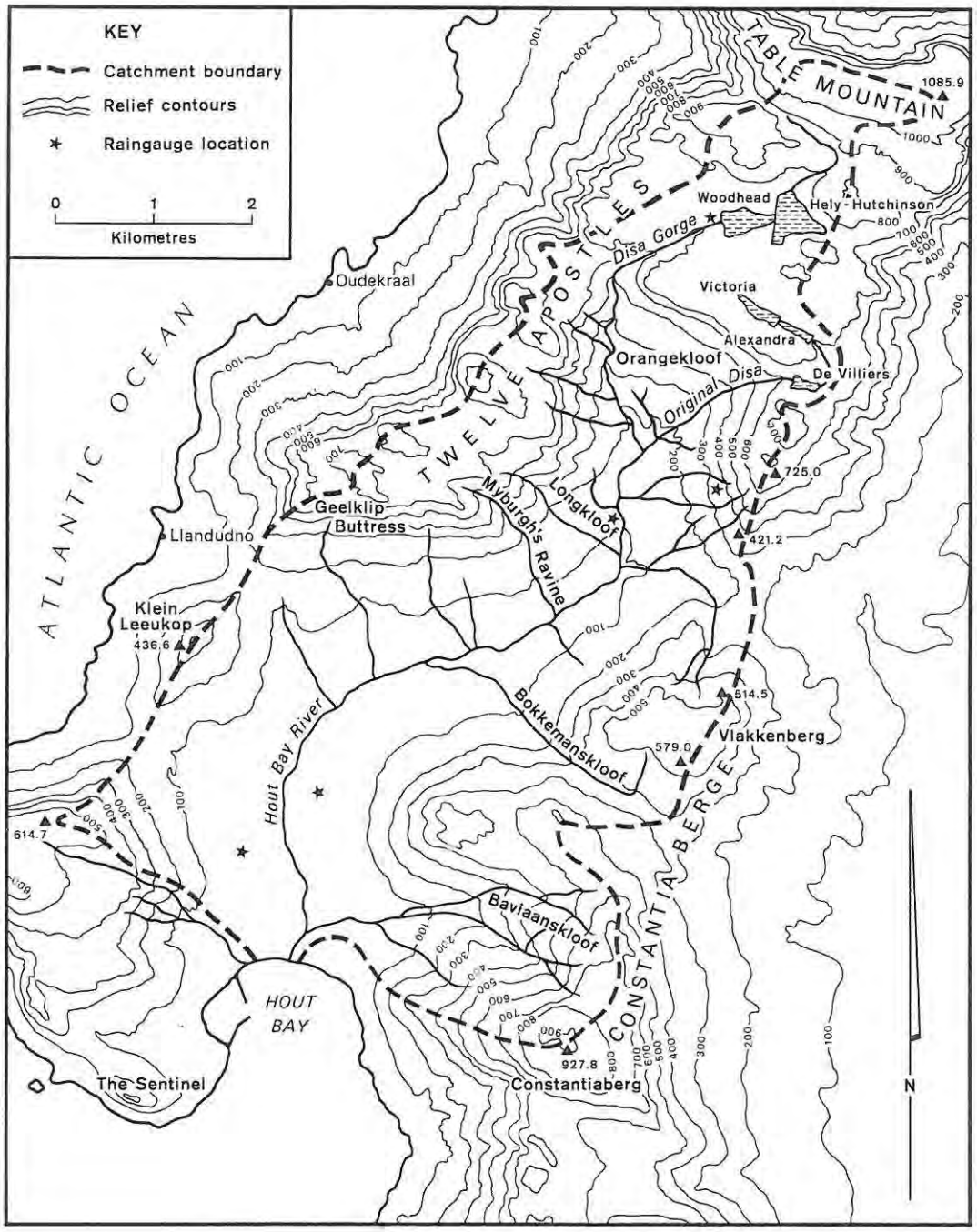

Figure 2: Relief map and Hout Bay River System

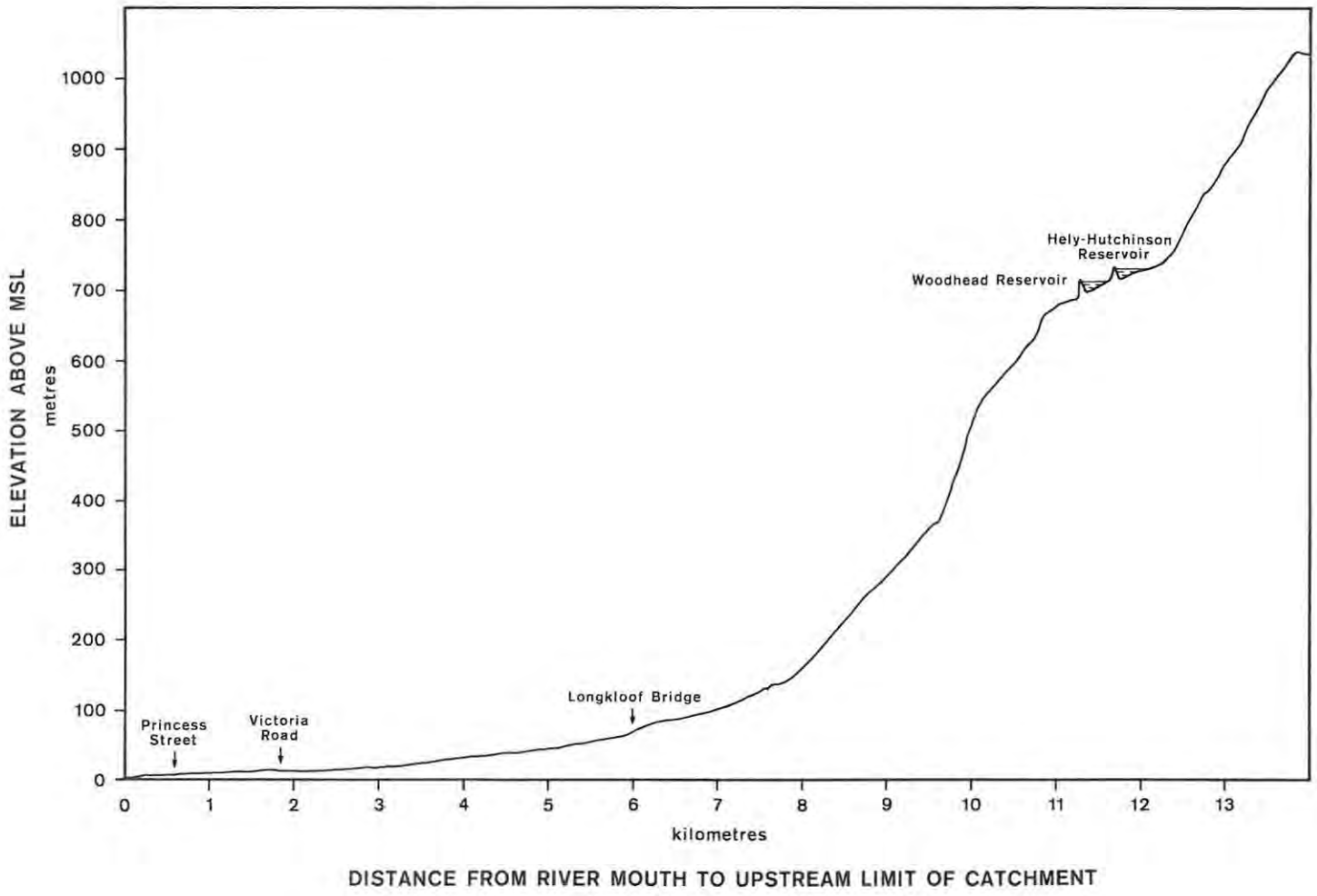

Figure 3: Relief profile of the Hout Bay River (HKS, 1985)

2.3 Geology

A geological map of Hout Bay is given in figure 4. The main stratigraphic groups are the Cape Granite Suite (igneous) of Cambrian origin and the Table Mountain Group of the Cape Supergroup (sedimentary) of Ordovician origin. Dolerite dykes (igneous intrusions) occurred during the Carboniferous to Jurassic periods. Quaternary geology comprises semi consolidated sedimentary deposits.

Cape Granite Suite

The Cape Granite, dated at 553 +/- 8 My (Borchers, 1979) is a grey coarse-porphyritic granite. Quartz veins, pegmatite dykes and aplite veins of NNE-SSW orientation intersect the granite. The Cape Granite appears as gently rounded boulders in parts of the Hout Bay River valley and the Hout Bay coastline.

Table Mountain Group

The Cape Granite is unconformably overlain by the Table Mountain Series which, in the northern part of the catchment occurs at approximately 274 metres above sea level. The Table Mountain Series consists of the lower basalt shales of the Graafwater Formation overlain by the Peninsula Formation. The Graafwater Formation comprises thinly bedded reddish mudstone, siltstone and

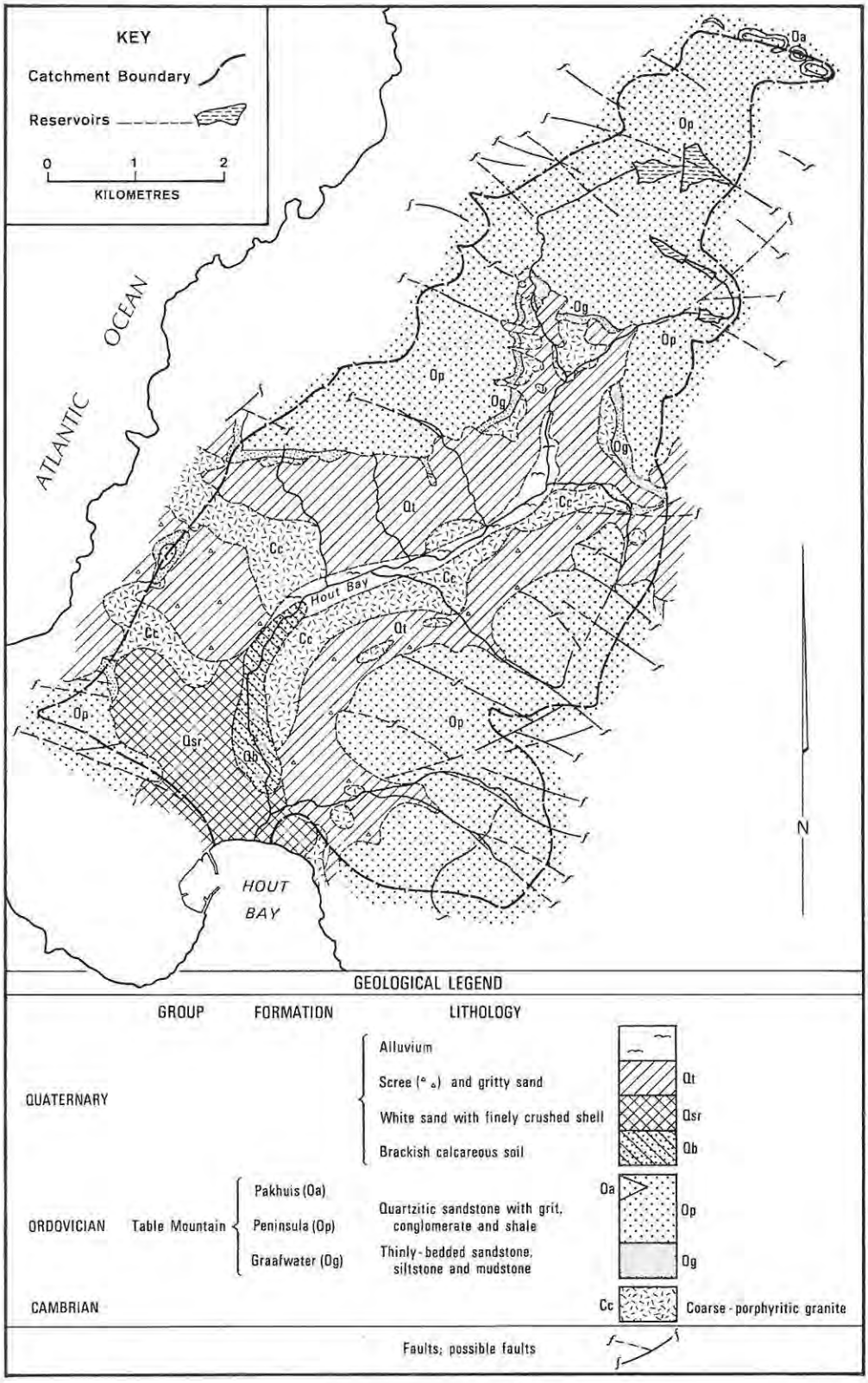

Figure 4: Geology of the study area (Director of Surveys and Mapping, 1984)

sandstone. The Peninsula Formation comprises well bedded, uniform, medium to coarse-grained quartzitic sandstone with thin lenses of green siltstone, conglomerate and grit (Director of Surveys and Mapping, 1984; Wilson et al., 1987).

Faults

Numerous faults mostly of a WNW-ESE orientation intersect the Table Mountain Group. Displacements across these scissor, strike slip and simple step faults range from 10 to 100 metres (Wilson et al., 1987).

2.4 Soils

All the information on soils in the Hout Bay region was obtained from the soil map of the Cape Peninsula, produced by the Soil and Irrigation Research Institute (Smith-Bailie et al., 1976).

Deep alluvial deposits border the Hout Bay River and its tributaries. Alluvial deposits are of the Dundee, Oakleaf and Westleigh forms (according to the Macvicar et al., 1977 classification). Apart from the alluvial deposits, soils are generally shallow (300 to 800 mm effective depth) and stony.

Two broad belts of red and yellow apedal soils of the Avalon, Bainsvlei, Clovelly and Hutton forms, having a clay content of less than 15 percent, border the alluvial deposits on the lower

eastern region of the catchment and on the west side of the river in the mid-catchment area above Victoria Road bridge.

Bordering the alluvial deposits on the steeper slopes of the Orangekloof forest reserve, soils are also of the Avalon, Bainslei, Clovelly and Hutton forms but have a clay content of greater than 15 percent.

Shallow non-hydromorphic soils on weathered rock or on clayey substrata of the Glenrosa, Swartland and Sterkspruit forms are found in the area east of the Longkloof and Disa River Road crossings (Smith-Baillie et al., 1976).

The open drift sand area between Hout Bay and Sandy Bay has since 1968 diminished with the spread of alien vegetation and residential development (Fromme, 1985). In this area deep hydromorphic (Fernwood and Vilafontes forms) and deep non-hydromorphic (Fernwood and Constantia forms) grey sandy soils are found.

Soils become more shallow (less than 300mm) on the steeper slopes with the predominance of rocky outcrops along the mountainous catchment boundary (Smith-Baillie et al., 1976).

2.5 Hout Bay River system

The Hout Bay river originates in the mountains at the Back Table as the Original Disa Stream and the Disa Stream (in Disa Gorge)

as shown in figure 2. After the confluence of the two mountain streams the river is referred to as the Hout Bay River (Grindley, 1984). The headwaters of the Disa stream are dammed in two reservoirs - the Hely-Hutchinson and the Woodhead reservoirs. The Alexandra and Victoria Reservoirs dam the headwaters of the Original Disa stream with excess flow leading into a third reservoir - the De Villiers reservoir.

No water is released from the reservoirs to the river during the dry summer months. In winter when reservoirs are full, excess water is released into the Original Disa and Disa Streams (Singels, pers. comm.) The flow of the river is supplemented by a number of permanent and seasonal tributaries.

2.6 Climate

Hout Bay experiences a Mediterranean-type climate with rainfall mainly from May to September and a hot dry summer.

Rainfall

Orographic effects influence rainfall distribution which is highly variable throughout the catchment as shown in table 1, the location of the raingauges is shown in figure 2.

RAINGAUGE LOCATION	APPROX. ELEVATION (METRES ABOVE MEAN SEA LEVEL)	MEAN ANNUAL RAINFALL	NUMBER OF YEARS OF RECORD
Woodhead	735	1 590	94
De Villiers	620	1 519	76
Orangekloof	160	1 230	59
Forest Station (WCRSC)	50	750	10

Table 1: Spatial variability in rainfall within the Hout Bay catchment (Cape Town Municipality; WCRSC).

An average of 12 to 15 rain days per month occurs during winter (mainly cyclonic rain) and 4 to 5 rain days per month is the average for summer.

Occasionally during winter or early spring, snow of short duration, has fallen on Table Mountain. Hail in the south-western Cape is rare (Schulze, 1979).

Wind

Windy conditions are experienced for 75 percent of the year with spring and summer being windier than autumn and winter. South-easterly winds predominate (40 percent occurence) and can reach wind speeds of up to 72 kilometres per hour.

North-westerly winds (30 percent occurence) predominate in winter

and have relatively low speeds (mean 27 kilometres per hour). South-easterly winds are normally associated with dry weather and north-westerly winds with rain (Fromme, 1985; Toms, 1986). Hot, dry berg (föhn) winds are fairly common.

Temperatures

Daily temperature ranges are mainly influenced by cloud cover. The average maximum daily temperatures recorded for Cape Town are 28°C in summer and 17°C in winter reaching extremes of 43°C and 30°C respectively. The average minimum temperatures are 15°C (summer) and 6°C (winter) reaching extremes of 4°C and -5°C respectively (Schulze, 1979).

2.7 Water supply and waste disposal

The average daily water consumption in Hout Bay is 300 to 400 litres per person in winter and 700 to 1100 litres per person in summer (Cape Town Municipality, pers. comm.). At present there is no reticulated sewerage system in Hout Bay thus a large percentage of the water supplied to each household will form an output via septic tank systems and hence contributes to ground water flow (the longitudinal section of a septic tank system is illustrated in figure 5). In South Africa the average per capita sewage effluent volume for the middle to higher income group is between 130 and 180 litres per day. Figures are significantly lower for the lower income groups ranging from 60 to 90 litres per person per day (Drews, 1986).

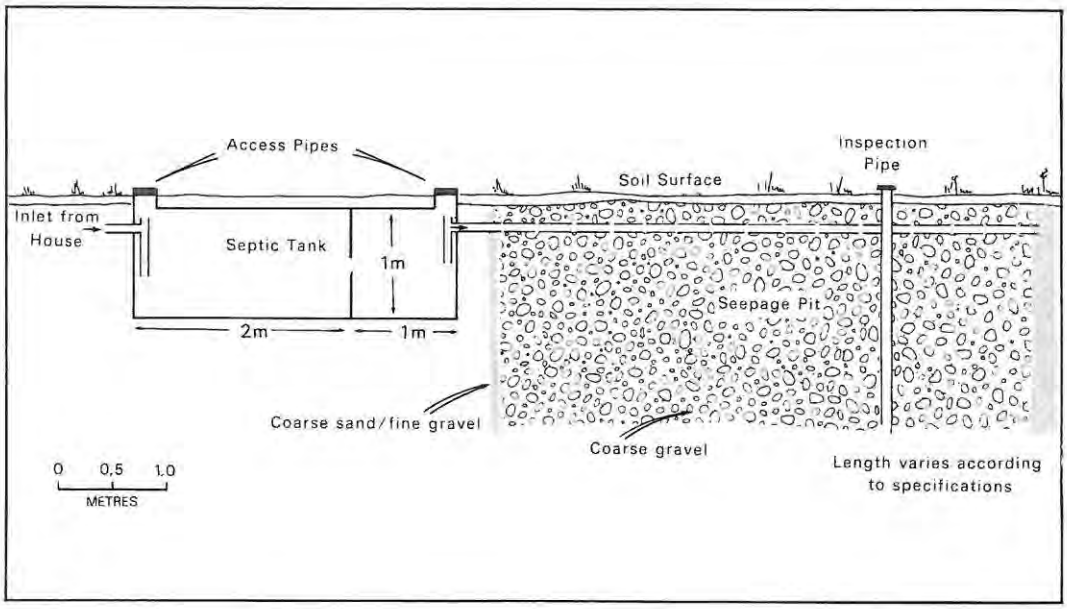

Figure 5: Diagram of a septic tank and soakaway system

Sewerage pipes have been laid in some of the streets of Hout Bay but are not connected to any household or disposal pipe. A new marine sewage outfall is planned (WCRSC) but it will be a number of years before the system is operational. Microbiologically, septic tank effluent has the same potential danger to public health as raw sewage (Mahdy, 1979; Drews, 1986), for this reason there are set regulations regarding the installation of septic tank systems. As the sewage effluent passes through the subsurface soil system pathogenic organisms may be removed by

adsorption onto soil particles or natural die-off. However, in non-homogenous soils, in saturated flow (pipeflow) or where soils are rich in organic matter or nutrients the organisms may enter the river in large numbers (Van Donsel et al., 1967).

The efficiency of a septic tank system is influenced by design, construction and maintainance, hydraulic loading, physical and chemical properties of soil, local geology and topography (Cotteral and Norris, 1969). An inefficient septic tank system (hypothesis (i), page 4) is one which does not function as it is designed. Unsuitable soil drainage conditions or a high watertable may result in the failure of the soil to purify the effluent. Inadequate capacity for the number of amenities serving the system, clogging of the soakaway by bacterial slime or sludge accumulation may result in the emergence of the effluent at the soil surface (Viraraghavan, 1982).

Some of the requirements for the installation of septic tanks and soakaways in the Western Cape (WCRSC, 1972) include:

- a constant and sufficient water supply
- a minimum of 900 square metres in which to install the system
- suitable soil conditions
- combined sewer and greywater drainage is allowed, provided adsorption conditions are adequate and are subject to approval by a Health Official

- dimensions of soakaways are regulated by on site conditions, soil properties and the volume of wastewater and sewage being treated.

2.8 Proposed residential development

In 1986 Hout Bay was only 32 percent developed with a population of 10 000, the capacity population is an estimated 26 000 people thus much development can be expected in the Hout Bay local area. It is the aim of the Western Cape Regional Services Council to accommodate the development whilst maintaining the character of Hout Bay. Figure 6 shows the existing land use (1986) and the proposed residential development including the population distribution expected at maximum development. The lower income group live in the area behind the harbour. Most development is likely to occur in the higher income areas as indicated in figure 6. Hout Bay is a popular and favoured residential area of the Cape Peninsula.

The next chapter discusses the various techniques which were adopted for the research investigation and provides some background to the constituents present in surface and ground water.

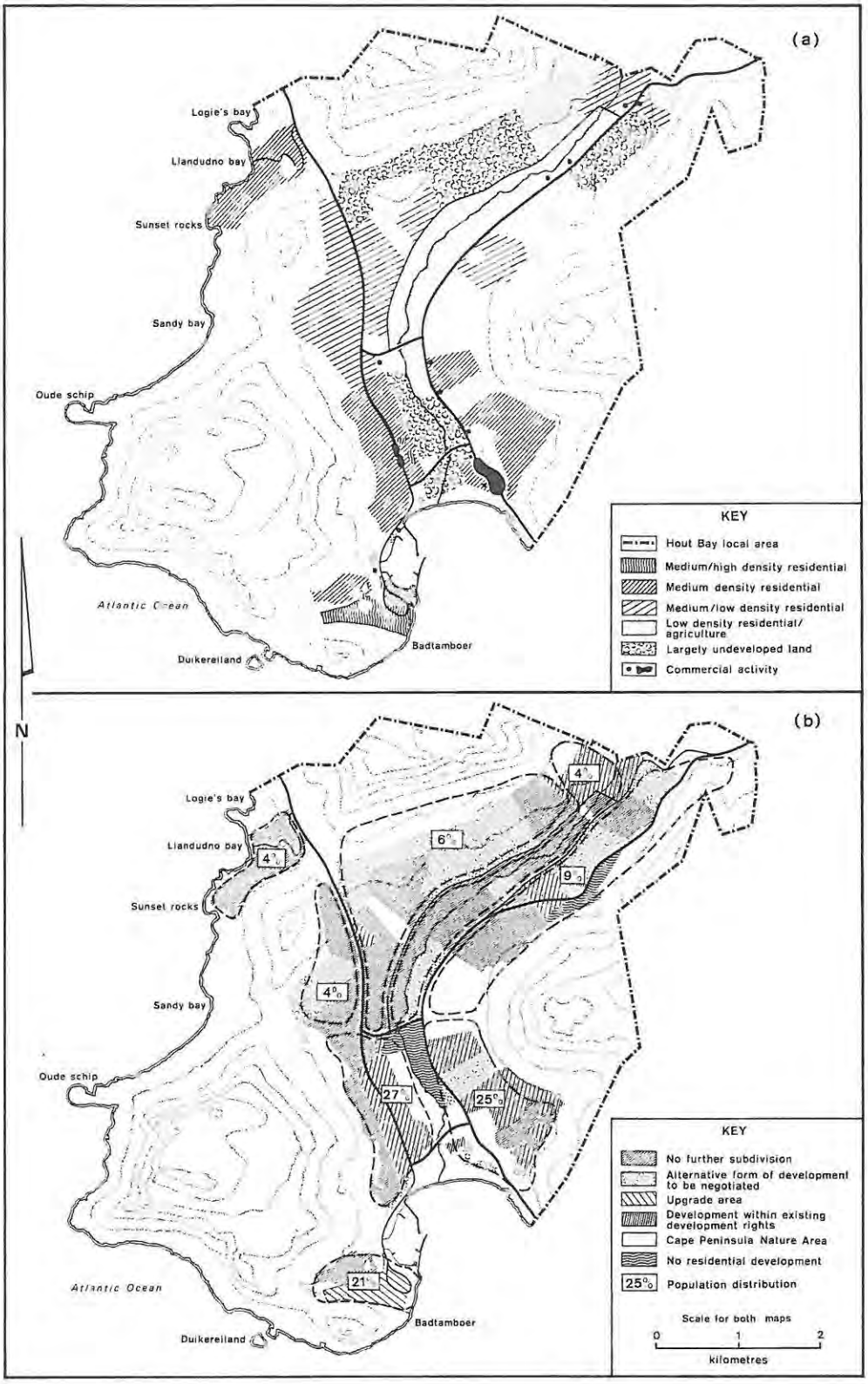

Figure 6 : (a) Existing land use of Hout Bay local area, (b) proposed residential development (after Blandy, 1986)

CHAPTER 3

HYDROLOGICAL INVESTIGATION TECHNIQUES

CHAPTER 3

HYDROLOGICAL INVESTIGATION TECHNIQUES

3.1 Approach to the hydrological investigation

To establish a conceptual three dimensional hydrodynamic model of the Hout Bay catchment various components of the hydrological system, represented in figure 7 were isolated and studied as 4 separate entities.

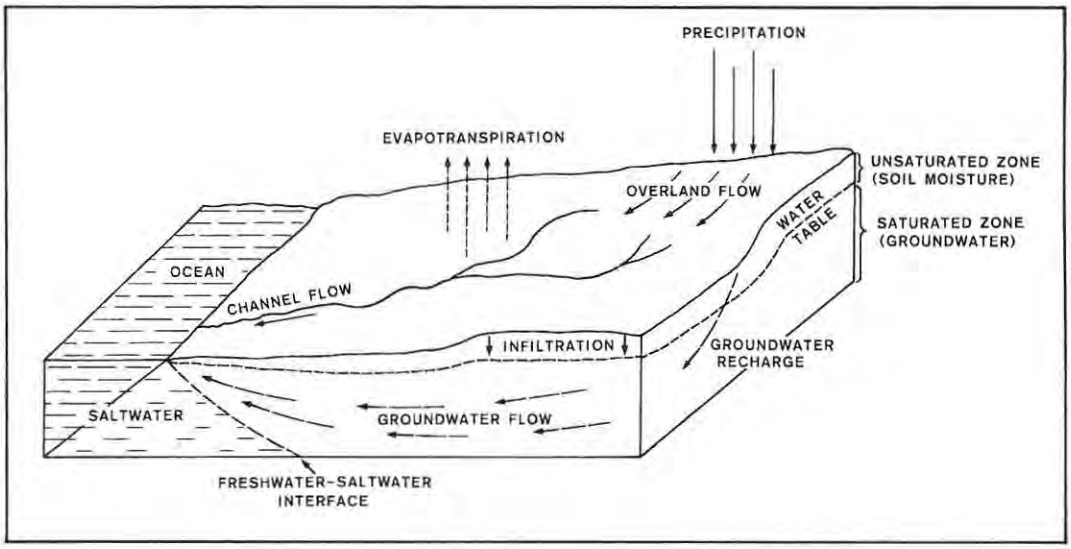

Figure 7: Systematic representation of the hydrological cycle.

These 5 entities comprise the main practical objectives designed to test the hypotheses stated in section 1.3. The laboratory and field techniques used are discussed in sections 3.4, 3.5 and 3.7 to 3.9 . For ease of discussion the findings of each component are discussed in separate chapters (4 to 7) as outlined below:

Hydrological properties of **surface water** (chapter 4)

Samples were obtained from various points along the Hout Bay River, its tributaries and stormdrains discharging into the river and marine environment. Results of the routine microbiological and chemical analyses are discussed in conjunction with river and stormdrain flow rates.

Storm event river sampling (chapter 5)

Samples obtained prior to, during and following a storm event were analysed to describe the catchment response to rainfall with regard to waterborne pollutants.

Water table fluctuations together with the associated hydrochemical and microbiological indices are discussed in:

Hydrological properties of **ground water** (chapter 6)
in relation to land use at four sites and in

Subsurface water in the **beach zone** (chapter 7)

An integration of the findings discussed in chapters 4 to 7 gives an overview of the functioning of the Hout Bay hydrological system from which the study hypotheses (section 1.3) are tested (chapter 8) and conclusions drawn (chapter 9).

3.2 Water quality criteria

According to Brown (Lord et al., 1984; page 35) "there is no aspect of the lives of marine organisms which is immune to the effects of pollution", from the human health aspect water quality criteria are also important.

Lusher (1984, page 1) referring specifically to the coastal zone, defined water quality criteria as "those limits which must not be exceeded in order to maintain the chemical, physical and biological characteristics of a selected portion of the sea or estuary" the definition can be extended to include dams and rivers and applied to the various beneficial uses of water as shown in tables 2 and 3. Water quality criteria are not enforced standards but serve as guidelines. These guidelines vary throughout the world (Bouwer, 1978) and according to water use (Kempster et al., 1980).

CHEMICAL PARAMETER	MEAN RECOMMENDED VALUE ACCORDING TO BENEFICIAL USE OF WATER		
	UNIT	RIVER/DAM	DRINKING WATER*
Electrical conductivity	mS/m		70
pH	pH units	6,5-9,0	6,0-9,0
Chloride	mg/l	50-400	250
Sodium	mg/l	500	100
Potassium	mg/l	50	200
Sulphate	mg/l	1400	200
Calcium	mg/l	1000	150
Alkalinity (as $CaCO_3$)	mg/l	720	300
Magnesium	mg/l	1500	70
Nitrate + Nitrite (as N)	mg/l		6
Aluminium	mg/l	100-1500	0,15

Table 2: Water quality criteria (chemical) for specified beneficial use (after Kempster et al., 1980; *Kempster and Smith, 1985)

MICROBIOLOGICAL PARAMETERS	DRINKING WATER *	DIRECT CONTACT	AQUATIC LIFE FOR FOOD FILTER + NON FILTER FEEDERS
Faecal coliforms (per 100 ml)			
50%	0	100	15
90%		400	45
99%		2000	-
Faecal Streptococci (per 100 ml) (median value)	20	200	-

Table 3: Microbiological parameters for specified beneficial use (* Kempster et al., 1980; Lusher, 1984).

3.3 Indicator organisms of faecal contamination

Indicator organisms are organisms normally associated with faecal pollution and the presence of pathogens, a positive growth of indicator organisms thus indicates a potential health threat (Barrow, 1977). Indicator organisms are detected in preferance to a spectrum of pathogenic organisms so that large numbers of samples can be processed within a few hours of collection using simple techniques (Bonde, 1974). Ideally indicator organisms are those which cover the spectrum of waterborne pathogens, are present in all water types, abundant, unable to reproduce in water and should have a direct correlation to the extent of

faecal pollution (Scarpino, 1974; Barrow, 1977).

The methods used for detection and enumeration of indicator organisms should provide easy isolation, accurate identification and good reproducibility of results (Bonde, 1974; Barrow, 1977). The main indicator organisms used in microbiological investigations include Escherichia coli, faecal coliforms, faecal Streptococci and bacteriophages. Direct correlation between various indicator organisms and the presence of pathogens have been confirmed by a number of researchers (Bonde, Scarpino, 1974; Kenard and Valentine, 1974; Grabow et al., 1984). It is therefore important not only to report the presence or absence of indicator organisms (qualitative test) but enumeration thereof will give an indication as to the magnitude of pollution (quantitative test) (Drinking Water Supplies, 1984).

3.4 Microbiological methods

The membrane filter technique as specified by Standard methods for the examination of water and wastewater (APHA, 1985) was used for the enumeration of total coliforms, faecal coliforms and faecal Streptococci. APHA methods have been used by numerous researchers (Viraraghavan 1978; Reneau, 1978; Wilson et al.,1982; Sinton, 1986) for the detection of indicator organisms (see section 3.3) in both surface and ground water. Different methods and growth media have been tested to determine their accuracy, reliability and efficiency (Grabow et al., 1981).

Coliphage enumeration was done in this study using the double agar layer method originally described by Adams (1959). Despite the validity of bacteriophage as indicators of human faecal contamination (Scarpino, 1974) the limited number of studies involving the enumeration thereof is partly attributable to the expense and sensitivity of detection techniques. Grabow et al., (1984) (South Africa) and Wentsel et al., (1982) (United States) give positive appraisals of coliphage as indicators of water quality.

3.5 Hydrochemical constituents

Although past monitoring of pollution in the Hout Bay River (mentioned in section 1.4.1) has indicated that chemical pollution is less severe than microbiological pollution it is necessary to monitor chemical pollution of the river for two reasons:

(i) chemical parameters such as potassium, phosphate, nitrate, ammonia, organic carbon and dissolved oxygen content are indicators of contamination with sewage (Luce and Welling, 1983; Reddy and Dunn, 1984).

(ii) chemical parameters are more stable than microbiological counts which tend to be highly variable (Morrison, pers. comm.).

A brief theoretical background and the method used to quantify the chemical and physical parameters in the water samples is presented in sections 3.5.1 to 3.5.13.

3.5.1 Electrical conductivity (EC) and total dissolved solids (TDS)

A Radiometer CDM3 conductivity meter was used to determine the electrical conductivity of samples. Electrical conductivity, usually expressed in micromhos per centimetre (μmhos) or millisiemens per metre (mS/m) is a measure of the total quantity of dissolved solids present. The relationship between total dissolved solids (TDS) and conductivity depends on the particular ions in solution but is generally given as:

$$EC\ (mS/m) \times 6.5 \simeq TDS\ (mg/l)$$ (Kempster et al., 1980)

TDS or EC alone do not provide an adequate description of water quality - more specific chemical analyses are required in addition to these values.

3.5.2 pH

pH values are not stable and determinations are best done in the field (Driscoll, 1986). pH was thus determined on site and confirmed in the laboratory using an E488 Metrohm pH meter.

pH affects the solubility of aluminium and the toxicity of ammonia. The pH of most natural waters ranges from 6,0 to 8,5 (Hem, 1970).

3.5.3 Sodium

Sodium content of water was determined by atomic absorption spectrophotometry.

In natural waters sodium is mainly derived from feldspars, which in Hout Bay are plentiful in the granite. A limited quantity of sodium is absorbed onto clay minerals in the soil. When water containing calcium and magnesium ions passes through the soil cation exchange occurs resulting in a high sodium content in ground water (Matthess, 1982).

In humid climates natural groundwater may contain between 1 and 20 mg of sodium per litre. In Hout Bay the sodium content of the inland well points ranged from 52,2 (4B) to 199,5 mg per litre (3B) and ground water in the beach zone ranged from 57,0 (BBH3) to 326 mg per litre (BBH4) with a mean of 115,8 mg per litre. Groundwater at sites 2,3, 5B and 5E had sodium-potassium contents in excess of 60 percent of their total ionic composition.

3.5.4 Potassium

Atomic absorption spectrophotometry was used to determine potassium in the water samples.

The potassium content of natural water (less than 5 mg per litre) is usually lower than that of sodium, this difference may be attributable to the fact that potassium forms part of the clay structure and is more resistant to weathering than sodium (Davis and De Wiest, 1966).

The potassium content of the Hout Bay River and its tributaries was below 2,0 mg per litre whereas stormdrains discharging into the river had a mean potassium content of 8,56 mg per litre. Potassium content of ground water from the inland well points (5,73 mg per litre) was comparable to that of beach well points 1,2 and 3 (5,73 mg per litre). Beach well points 4, 5, 6, 7 and 8 had a mean potassium value of 12,70 mg per litre, which is more than double that of beach holes 1, 2 and 3.

3.5.3 Calcium

Calcium in water samples was determined using the atomic absorption spectrophotometer.

Calcium, present in sedimentary, metamorphic and igneous rocks, is the most common cation in natural ground water and usually varies between 10 and 100 mg per litre (Davis and De Wiest,

1966). In Hout Bay calcium values exceeded 100 mg per litre in all the beach well points and in inland well points 5D, 5C and 5G. In sandstone areas stormwater is often high in calcium as the sediment which is washed into the river goes into solution (Hem, 1970). During stormevents the highest calcium values were recorded in stormdrain discharges. Stormdrain 14 yielded a maximum of 131,6 mg per litre and stormdrain 16 124,1 mg per litre otherwise the highest recorded calcium value during a storm event was 28,3 mg per litre at Princess Street bridge.

3.5.6 Magnesium

Magnesium was determined using an atomic absorption spectrophotometer.

Although most magnesium compounds are more soluble than calcium compounds, magnesium content in natural waters is normally lower than calcium, usually below 40 mg per litre. Dolomite is a common source of magnesium (Davies and De Wiest, 1966), however as there is no dolomite in Hout Bay magnesium was low in both surface and ground water.

3.5.7 Chloride

Chloride was determined using the automated ferricyanide method (APHA, 1985).

Sodalite and apatite are chloride containing igneous and metamorphic rocks. Ground water containing high sodium and chloride concentrations may indicate contact with water of marine origin (Bouwer, 1978). The chloride content of natural waters varies depending on climate, geology and other conditions. Chloride has the tendency to accumulate as it is not easily removed by natural processes and is not significantly influenced by exchange, adsorption and biotic activity (Davis and De Wiest, 1966).

3.5.8 Sulphate

Sulphate was determined by the automated methylthymol blue method (APHA, 1985).

Sulphates in natural water may be derived from sedimentary rocks particularly organic shales. Sulphate is particularly high in natural waters which have been in contact with clay but vary considerably depending on conditions. In low oxygen conditions sulphate is reduced by bacteria resulting in the release of hydrogen sulphide (H_2S). Thus ground water characterized by the smell of H_2S is indicative of the absence or minimal presence of dissolved oxygen (Holden, 1970).

In Hout Bay ground water which smelled strongly of hydrogen sulphide gas (which is released by sulphide reducing bacteria) during pumping had the lowest sulphate values - as occurred in beach well points 2 and 3 and inland well points, 5E, 5F and 5G.

Ground water in beach holes 2 and 3 had mean sulphate values of 55,0 and 48,8 mg per litre respectively compared to the mean of 119,4 mg per litre for the remaining beach holes. The lowest sulphate content occurred at 5F (7,3 mg per litre), low values also occurred in well points 5E (61,8 mg per litre), 5G (60,8 mg per litre), site 4 (22,3 mg per litre) and site 3 (62,0 mg per litre excluding 3B which was 143,4 mg per litre).

When organic matter and sulphate are present the production of sulphide can be the result of sulphate reducing bacteria or general bacterial decomposition (Holden, 1970).

3.5.9 Nitrite and nitrate

Nitrite is unstable and is readily oxidized to nitrate. Nitrite and nitrate were determined together by the automated cadmium reduction method (APHA, 1985) and results given as nitrogen in mg per litre.

Nitrogen generally does not have a geological origin although some volcanic rocks contain nitrogen. Nitrogen fixing bacteria present in root nodules of leguminous plants produce nitrate which being highly soluble is readily leached from the root zone. Atmospheric nitrogen, human and animal excrement, decaying plant matter and agricultural fertilizers are the major sources of nitrate in surface and ground water (Hem, 1970; Driscoll, 1986).

The recommended concentration limit of nitrate (as nitrogen) in drinking water is 6 mg per litre for South Africa (Kempster and Smith, 1985). Average nitrate (as nitrogen) values above 6 mg per litre occurred in well points BBH1, 2B, 2E, 3A and 5C, nitrate values between 4 and 6 mg per litre occurred in well points 2A, 4B, 4C, 4F, 5A and 5B. On average the nitrate content of the Hout Bay River and its tributaries was low whilst that of stormdrains did not exceed 2,65 mg per litre. Storm event sampling revealed that high but variable nitrate values occurred in stormdrain 14 (mean value 5,2 mg per litre with a standard deviation of 4,7 mg per litre).

3.5.10 Ammonia

Ammonia, reported as nitrogen (mg per litre), was determined in water by the automated phenate method (APHA, 1985).

Ammonia nitrogen is adsorbed onto soil particles and can only be leached from the soil once oxidized by nitrifying bacteria into the nitrate form (Bouwer, 1978). The toxicity of ammonia is determined by the pH of the solution. Sources of ammonia in surface and ground water are the same as those for nitrite and nitrate (section 3.5.9). The concentration of ammonia (as nitrogen) in the marine environment should not exceed 600 µg per litre (Lusher, 1984).

In Hout Bay high ammonia values occurred in ground water at well points 5D, 5F, 5G (discussed in section 7.6), BBH4, BBH5 and to a

lesser extent in 3B, 5E, BBH6, BBH7 and BBH8. On average the ammonia value obtained for the Hout Bay River and its tributaries was less than 0,05 mg per litre.

High ammonia values were obtained in stormdrains 28 (27,47 mg per litre) and 32 (20,37 mg per litre) whereas in 23 values were variable ranging from less than 0,05 mg per litre on 23 May to 34,38 mg per litre on 20 June (both during wet conditions). The septic tank overflow running down the street at the Hout Bay Hotel cottages (19-C) on 20 June had an ammonia content of 44,14 mg per litre and that alongside the carpark (19) 40,92 mg per litre.

3.5.11 Phosphate

Phosphate as phosphorus (mg per litre) was determined by the automated ascorbic acid method specified by APHA (1985).

The low solubility of apatite (the natural source of phosphorus) and adsorption of phosphates onto clay structures result in low phosphate values in ground water (Matthess, 1982). Natural ground water usually contains less than 0,1 mg per litre (Bouwer, 1978) as was found in Hout Bay, surface water also had very low phosphate values. Where phosphate values were high so too were ammonia values as occurred in the stormdrains discussed in the previous paragraph.

3.5.12 Alkalinity

Alkalinity given as $CaCO_3$ (mg per litre) was determined by potentiometric titration to pH 4,5 (APHA, 1985).

Bicarbonate and carbonate ions produce alkalinity. Atmospheric carbon dioxide and the release of carbon dioxide from bacterial and other activites in the soil are sources of alkalinity. Alkalinity is not affected by the presence of chloride, nitrate or sulphate (Hem, 1970). The alkalinity of groundwater normally varies between 50 and 400 mg per litre (Davis and De Wiest, 1966).

3.5.13 Dissolved organic carbon (DOC)

Dissolved organic carbon as carbon (mg per litre) was determined by automated infra-red carbon dioxide measurement following potassium persulphate and ultra violet digestion (CSIR, 1974).

The recommended concentration limit of DOC in drinking water is 5 mg per litre. Sewage and industrial effluents as well as harmless humic acids of plant and soil origin are the major sources of dissolved organic carbon in surface waters (Kempster and Smith, 1985). DOC values in the Hout Bay River were generally greater during wet conditions than dry as follows:

SAMPLING POINT	DOC mg per litre	
	Wet conditions	Dry conditions
Orangekloof weir	8,45	3,88
Longkloof weir	8,12	3,80
Victoria bridge	7,82	5,60
Princess Street bridge	8,04	6,35
Hout Bay River mouth	7,97	5,73

During storm events peaks in DOC, as monitored at Princess Street bridge, occurred when the mountain runoff reached the bridge. DOC peaks occurred after the microbiological peaks associated with local runoff. Such DOC peaks can be attributed to humic acids from the densely vegetated Orangekloof reserve whereas the high DOC content found in stormdrains (12,27 mg per litre) when considered in the light of other parameters (faecal coliforms, potassium) can be attributed to both sewage effluent and humic acids.

3.6 Trilinear diagrams

The hydrochemical indices can be used to further classify and identify water types by means of trilinear diagrams (figures 16, 17 and 21) and bar charts (figure 20). Trilinear diagrams facilitate comparison between numerous samples (Matthess, 1982). The trilinear diagram proposed by Piper is not based on actual quantities but considers the proportion of anions and cations relative to the total anion and cation composition. As a result

of the presentation of hydrochemical data in percentage composition, types of water can be identified and the relative composition is a fingerprint indicative of specific influences on water quality.

The Piper trilinear diagram comprises a cation triangle, an anion triangle and the resultant plot on the diamond. Total cations comprise (i) sodium plus potassium, (ii) calcium and (iii) magnesium. The total anions comprise (i) sulphate (ii) chloride and (iii) carbonate and bicarbonate, all ions are expressed as a percent of total equivalents per million. Figure 8 shows the demarcation of water types.

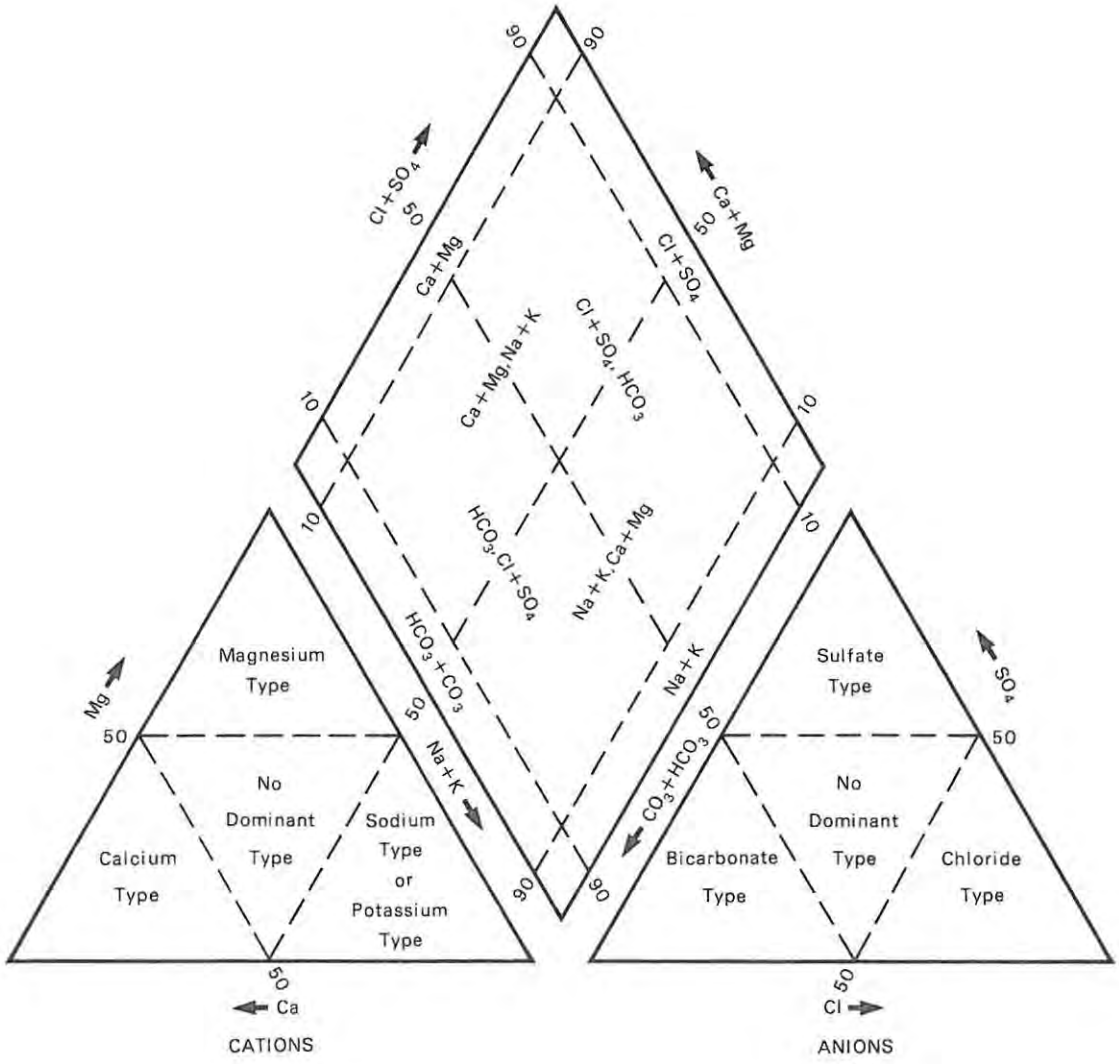

Figure 8: Water analysis diagram showing hydrochemical facies (after Back; 1966, page 14).

3.7 Flow measurements

There are no flow gauging stations at any point along the Hout Bay River and flow rates have not been monitored systematically or for any length of time. Grindley (1984) devoted a chapter to the application of the Pitman, SCS and Rational rainfall-runoff models to the Hout Bay River catchment.

In this study measurement of flow rates during dry conditions, light rainfall and storm events was necessary to quantify pollutant loads. The velocity-area technique was used to determine discharge at 9 points along the Hout Bay River, 7 tributaries and 5 stormdrains. Measurement sites were chosen according to characteristics recommended by Shaw (1983) which are:

(i) a straight channel

(ii) uniform slope and cross-section

(iii) free from obstructions including vegetation

Discharge, in cubic metres per second, can be calculated from the equation:

$Q = VA$ where V is flow velocity (metres per second) and A is the cross-sectional area (square metres). Methods are described in Gregory and Walling (1973) and Shaw (1983) among others.

The Hydrometry Division, Department of Water Affairs, measured discharge below Victoria bridge on a fortnightly basis (from 14 July 1988 to 26 October 1988) using a rod mounted propeller current meter, discharge was calculated by the velocity-area technique.

Routine river gauging was conducted according to the availability of the rod mounted propeller current meter from DEMAST or by measuring surface velocity (float method).

3.8.1 Surface velocity

Flow velocity varies vertically and horizontally according to the depth of water and effects of friction in the river channel. The relationship between velocity and depth of flow is given as:

$$\frac{V}{Vm} = (c + 1)\left(\frac{y}{d}\right)^{c}$$

where V is the velocity at point y above the river bed (metres per second), Vm the mean velocity over the vertical, c a coefficient normally taken to be 1/6 but which varies between 1/5 and 1/8, y the height above the river bed (metres) and d the depth of flow (metres). For surface floats y = d thus the mean velocity is 0,86 of the surface velocity. Discharge is therefore the product of mean velocity and cross-sectional area (Muller, 1987).

3.7.2 Current gauging

A rod mounted Braystoke (Valeport) BFM 002 miniature current flow meter with a 1178 series impellor was used to determine velocity at 0,6 of the water depth (Muller, 1987). Discharge was calculated by the Mid-section method as described in Gregory and Walling (1973).

3.7.3 Measurement of flow from stormdrains

In low flow conditions baseflow from stormdrains was measured by recording the time to fill a container of known volume.

The discharge from stormdrains during high flow conditions was calculated using the Manning equation which is easier to use than the Darcy equation although more suitably applied to turbulent flow in open channels. The open end of the stormdrains were calibrated at 0,05 metre intervals to facilitate stage readings during storm events to be used in stage-discharge computations.

The Manning equation is given as:

$$Q = A\bar{V} = \frac{AR^{2/3} S^{1/2}}{n}$$

where A is the cross-sectional area, R the hydraulic radius, S the slope of the channel floor, that is tan θ where θ is the

slope angle and $\frac{D}{4}$ is the roughness factor (Muller, 1987).

The hydraulic radius R is given as $\frac{ab}{2(a+b)}$ for rectangular and for circular pipes where D is the internal diameter of the pipe (Perry and Chilton, 1973). The n value for smooth concrete is 0,012 and for rough concrete 0,018 (Chow, 1964). As the Manning equation gives discharge from circular pipes at full capacity the proportional discharge from partly full stormdrains was calculated using the tables given in Bruges (1969).

The data obtained from flow measurements is presented in Appendix B and the relationship between flow and water quality is discussed in sections 4.2, 4.3, 4.4 and 5.1.

3.8 Rainfall monitoring

The main purpose of recording rainfall was to relate rainfall to the storm event hydrograph after storm event sampling (results discussed in chapter 5). Rainfall data were also used to determine the number of dry days preceding routine sampling (section 4.1, page 53). Rainfall characteristics are briefly discussed in section 2.6 (Climate).

Rainfall was recorded at 5 sites in the Hout Bay River catchment (as located on figure 2). Rainfall has been recorded on a daily basis since 1892 at Woodhead Reservoir and since 1927 at Constantia Nek purification works.

A Casella autographic raingauge was established in the low relief area at Orangekloof forest station and at the Western Cape Regional Services Council road station for the duration of the study period. The raingauges were secured at a standard height of 1,2 metres above the ground surface with a clearance of 30^{o} (Weather Bureau Standards (South Africa), 1986). The Casella raingauges were fitted with a recording chart which was changed on a weekly basis.

3.9 Well points

3.9.1 Well point installation

Twenty nine well points were installed inland at 5 locations in configurations shown in figures 15 and 18 and 8 well points installed in the beach zone as shown in figure 19.

The well points were jetted in by the Western Cape Regional Services Council using a fresh water (mains) supply. On withdrawal of the 63 mm galvanized iron pipe used during the jetting process - PVC casing with screen in the lower portion and a capped end was placed down the hole. The annular space between the jetted hole and the PVC casing was backfilled using clean, coarse river sand. Where necessary a metal sleeve encased in concrete with a locking metal cap was installed around the PVC casing to prevent vandalism and contamination.

Installation of the beach well points differed slightly from the inland holes in that polyflip a non-toxic bio-degradable bipolymer was used. Poly-flip prevents hole collapse and excessive loss of water in beach sands during jetting thereby facilitating installation of the casing. Some of the problems associated with using poly-flip are discussed in relation to the well point data in section 7.6.

Although jetting is a cheap and easy way of installing well points it has the disadvantages that core samples are not recovered, there is contamination by mains water and obstructions such as rock or a stony layer dictate the depth of the hole. The minimum depth occurred at points 1D, 2B and 2C where coarse gravel prevented the holes from exceeding 3,5 metres, a maximum depth of 6,6 metres was achieved at well point 5D, 5E and 5F where alluvial sands were encountered. Screen lengths ranged between 1,1 metres (well point 1E) and 2,4 metres (well points 4A and 4B). The depth and screen lengths of the 37 well points are given in Appendix C.

3.9.2 Well development

The aim of well development is to improve the yield of the well by clearing the screen of blockages such as soil particles or caked drilling fluid. A variety of methods are available for well development these include surging, jetting, pumping, the use

of explosives or various chemical treatments as discussed in British Standards Institution (1983) and Driscoll (1986).

Air surging was the technique of choice for the Hout Bay well points. This method of well development was used by Stone and Reynders (1984) after the installation of abstraction boreholes on the Eastern Cape coast (South Africa).

3.9.3 Water level measurements and sampling

Depth to rest water level in the well points (Appendix D) was measured with a graduated tape and attached electrical dip meter. A battery operated submersible pump (Whale superline 99 model, with a maximum output of 11,36 litres per minute from a 12 volt battery) (Munster Simms Engineering, ref. 729-41) was used to obtain ground water samples. Output from the pump decreases with an increase in head because of the additional power required to lift water from a greater depth, for example with a 2 metre head the pump delivers water at a rate of 10 litres per minute whereas with a 4 metre head only 7,3 litres per minute is delivered. When obtaining a ground water sample the head and volume of water in the well casing was taken into consideration and the pumping time calculated according to the delivery rate of the pump. Each well was pumped long enough to remove the standing water and to ensure that the sample obtained was from induced flow into the hole.

In the next chapter the microbiological and chemical attributes of surface waters in Hout Bay are considered in the light of environmental conditions and related to the total pollution load of the Hout Bay River.

CHAPTER 4

HYDROLOGICAL PROPERTIES OF SURFACE WATERS

CHAPTER 4

HYDROLOGICAL PROPERTIES OF SURFACE WATER

4.1 Monitoring water quality

The aims of the study as stated on pages 2 and 4 include (i) determination of the magnitude, characteristics and variability of chemical and microbiological pollution and (ii) identification of point and non-point sources and vectors of pollutants. Sampling of the Hout Bay River, its tributaries and stormdrains discharging into the river on a regular basis thus comprise a major part of the study.

Sampling was conducted on a routine basis at the sampling points shown on figures 9 and 10 from January to November. Microbiological results obtained from the January and February sampling runs were variable and thus resulted in an increase of sampling frequency to a fortnightly basis (March to August).

In the ensuing discussion wet and dry conditions do not refer to the summer or winter season (see section 2.6). Long dry periods preceded certain sampling days in winter as well as summer. Dry conditions refer to those sampling runs which were preceded by ten days in which there was no rainfall (with the exception of 4 July where 2,5mm was followed by 7 dry days prior to sampling). Wet conditions refer to those samples collected during or the day following rainfall of at least 4 mm. The definition of dry and wet refer only to this study and were determined in retrospect by

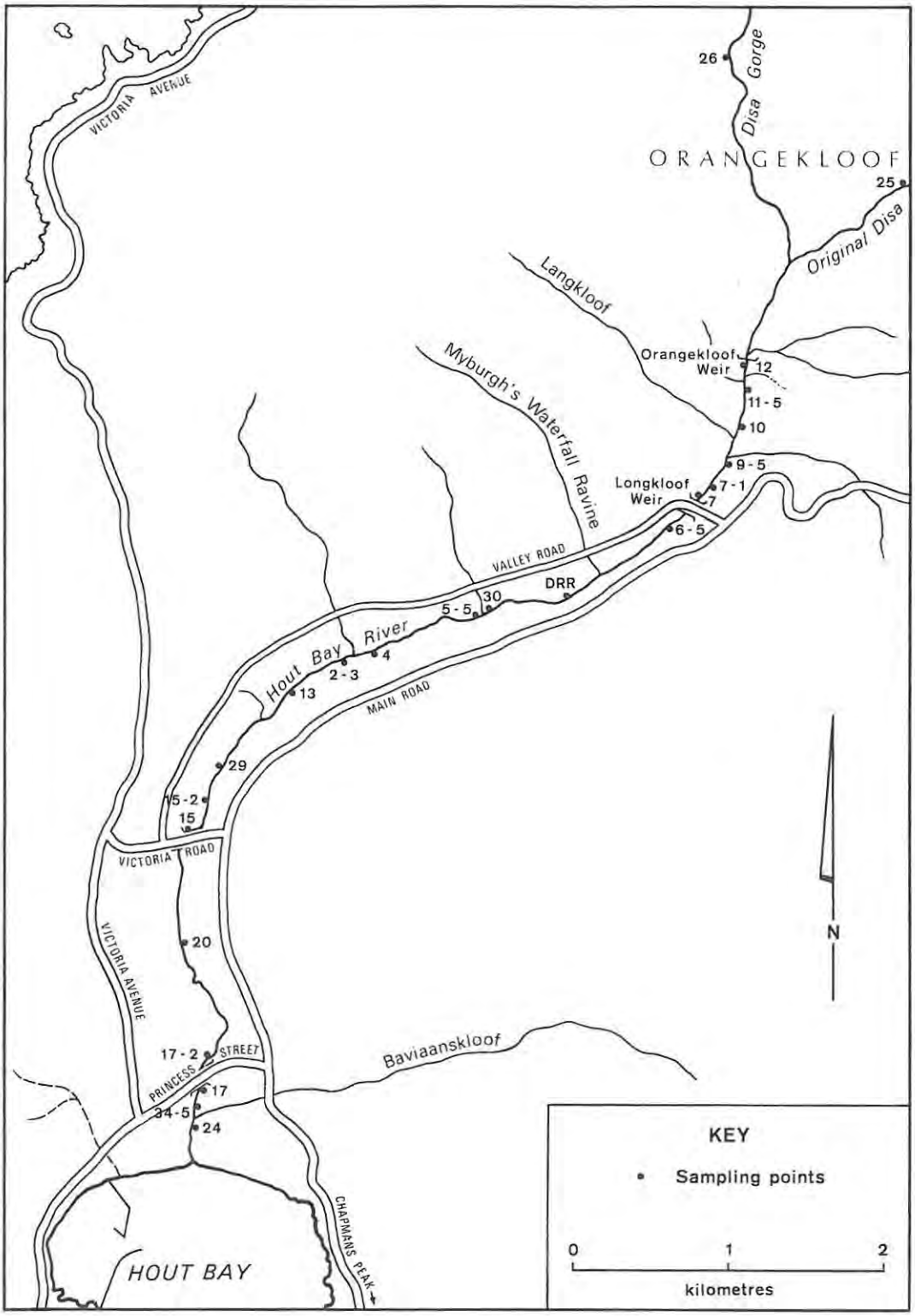

Figure 9: Location of sampling points along the Hout Bay River

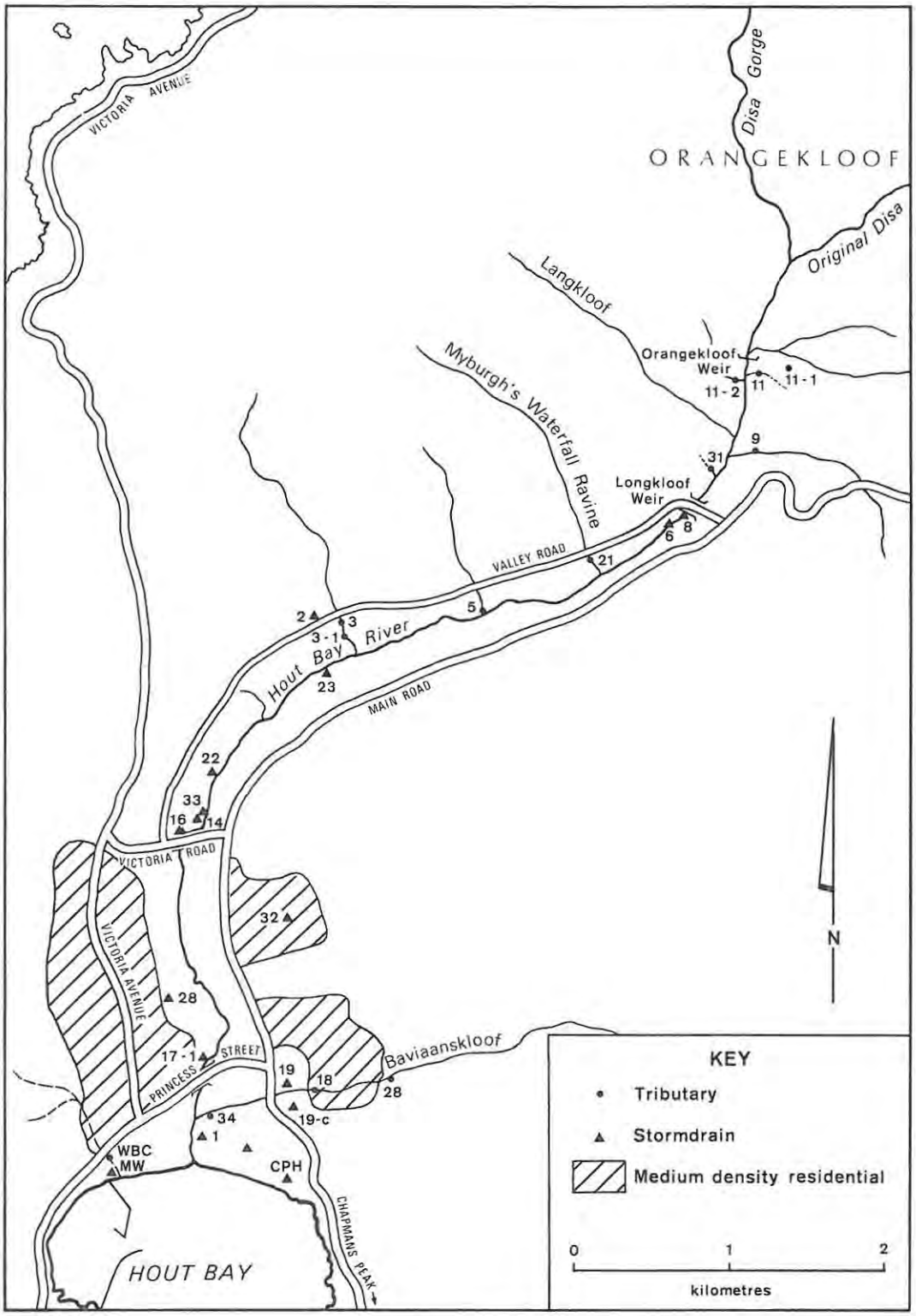

Figure 10: Location of tributary and stormdrain sampling points

the conditions associated with each sampling run. Samples collected during the 4 storm events are discussed in chapter 5. The discussion of surface water includes stormdrains, tributaries, natural earth drains and the Hout Bay River. Data were obtained at 53 sites located in figures 9 and 10, 24 of which were obtained at various points along the Hout Bay River (figure 9).

Surface water quality is discussed on the basis of sampling points under the headings of:

river samples (4.2)
tributaries (4.3), and
stormdrain effluent (4.4)

The distinction is however not always straight forward because in many areas stormdrains discharge into tributaries and thus form a combined input to the river.

4.2 River samples

Figures 11 and 12 show the change in concentration of faecal coliforms and faecal Streptococci respectively at 21 points along the Hout Bay River from the Disa Gorge (Orangekloof forest reserve) to the river mouth. The microbiological quality of the river depends on conditions and land use activities close to the sampling point and varies spatially (figures 11 and 12) and

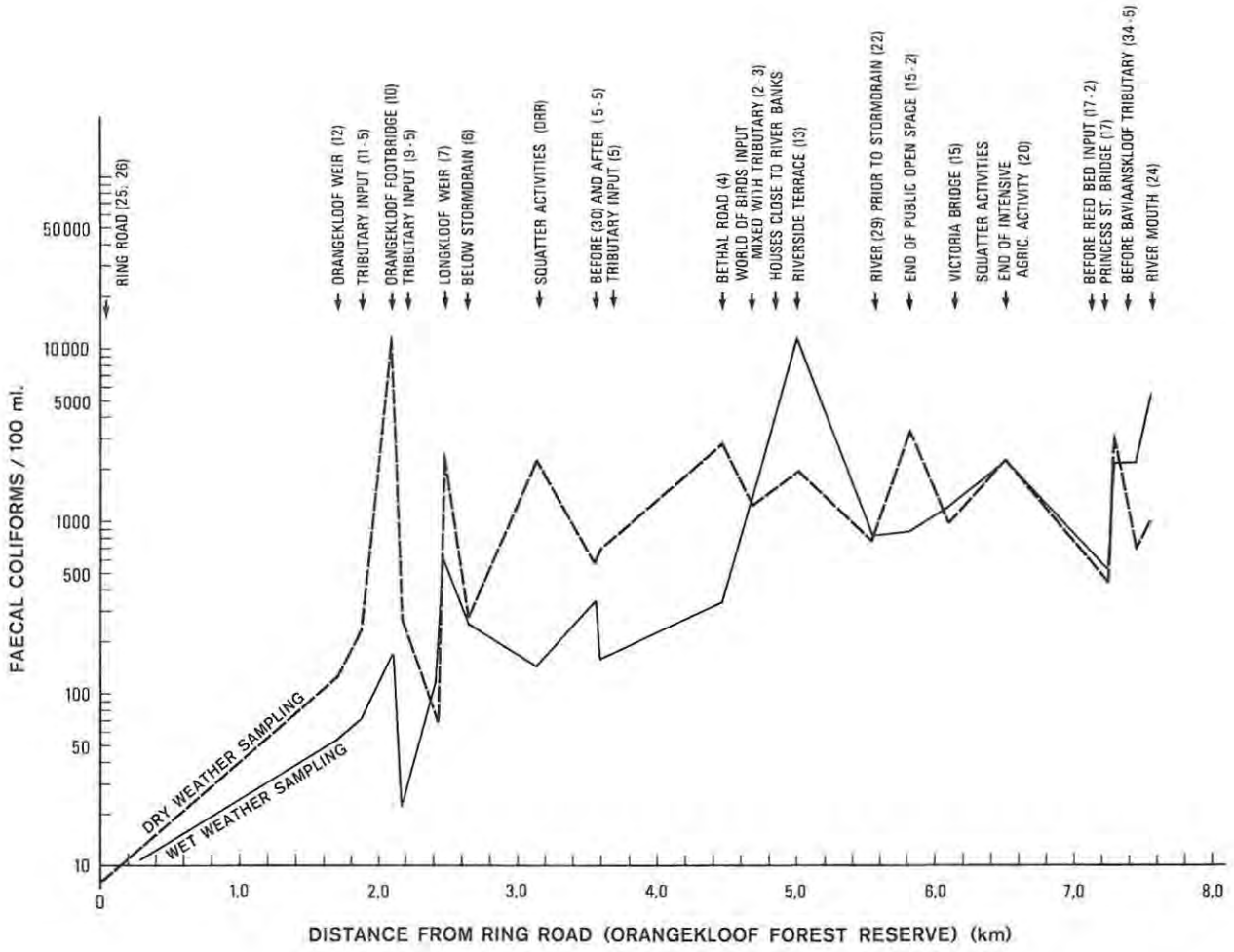

Figure 11: Wet and dry weather variation in faecal coliform concentration along the Hout Bay River

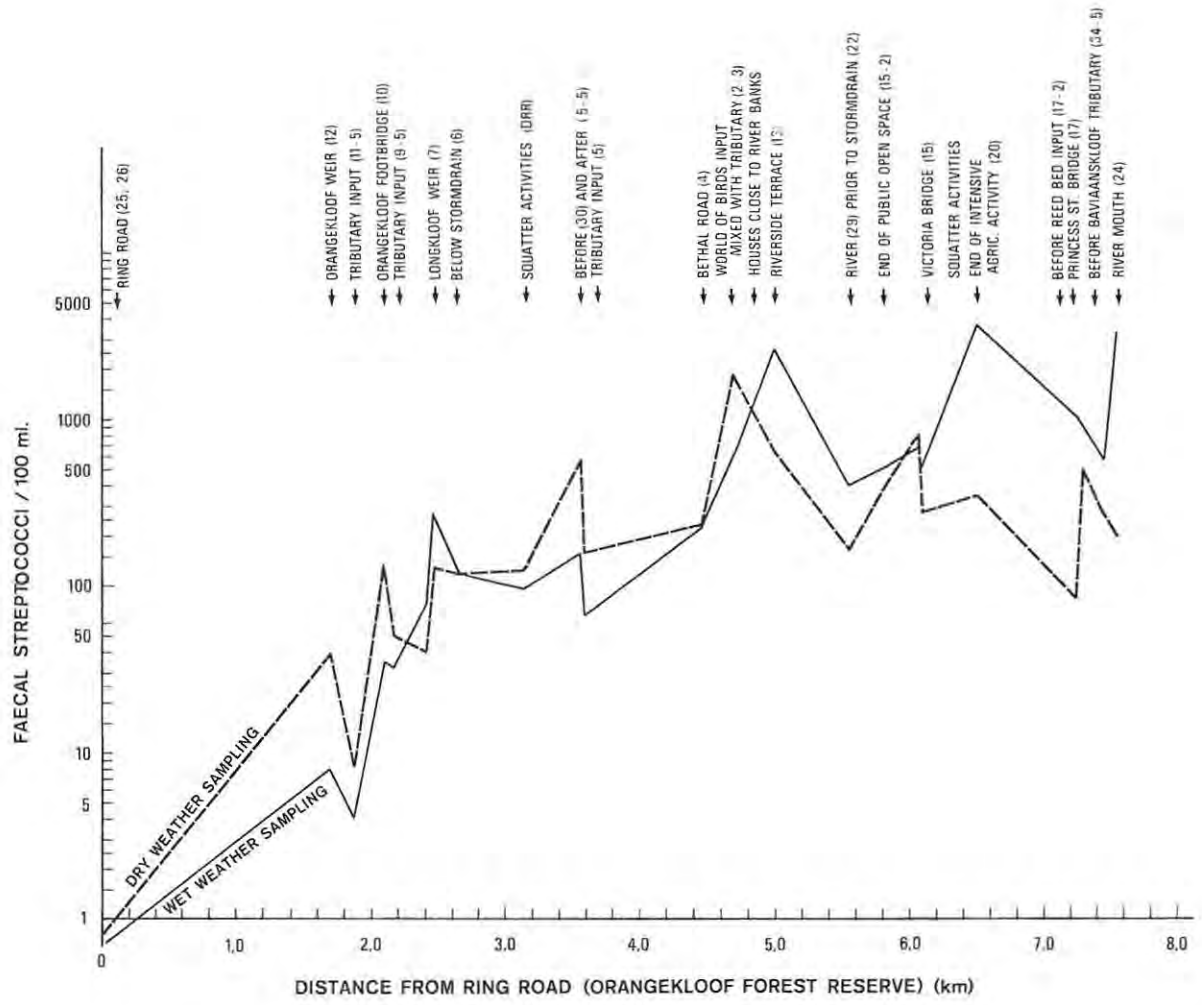

Figure 12: Wet and dry weather variation in faecal Streptococci concentration along the Hout Bay River

temporally as seen from the range of faecal coliforms, faecal Streptococci and coliphage enumerated at each site (see tables A-1 and A-2, Appendix A). Although concentration of organisms is important the total bacteriological and viral load depends on the rate of flow (see plates 1 and 2, page 90). The impact of faecal pollution on the marine environment and the associated health hazards are related to the pollution load entering the sea.

Table 4 shows that the load of faecal coliforms was greater during wet conditions than dry conditions.

SAMPLING POINT	FAECAL COLIFORM DISCHARGE PER SECOND	
	DRY CONDITIONS	WET CONDITIONS
Orangekloof weir	$6{,}00 \times 10^4$	$1{,}17 \times 10^5$
Longkloof weir	$6{,}80 \times 10^5$	$1{,}30 \times 10^6$
Victoria bridge	$1{,}02 \times 10^7$	$1{,}14 \times 10^7$
Princess Street bridge	$1{,}53 \times 10^6$	$2{,}75 \times 10^7$
Hout Bay River mouth	$1{,}88 \times 10^6$	$1{,}82 \times 10^7$

Table 4: Median faecal coliform loads at 5 points along the Hout Bay River

At Hout Bay River mouth not only was the pollution load greater during wet conditions than dry conditions $1{,}87 \times 10^7$ (wet) versus $1{,}88 \times 10^6$ (dry) faecal coliforms per second but during the wet winter months the river mouth is open providing an outlet to the

beach zone whereas in the summer months the river mouth is closed by wind blown sand. The exit to the sea is opened manually by the Western Cape Regional Services Council (road station division), as requested by a farmer, when the build up of dissolved salts in the river prevents its use for irrigation between Victoria and Princess Street bridges.

Bacterial counts in the surf zone at the river mouth were higher during wet conditions than dry regardless of the time of year. Hout Bay River water had relatively low concentrations of those chemical constituents indicative of contamination by sewage as shown in table 5. At no sampling point on the Hout Bay River did phosphate exceed 0,05 mg per litre.

SAMPLING POINT	CHEMICAL CONSTITUENT mg per litre							
	$NO_2 + NO_3$ as N		NH_4 as N		DOC		K	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Orangekloof weir	0,10	0,10	0,05	0,05	3,42	8,45	0,96	0,70
Longkloof weir	0,10	0,10	0,05	0,05	3,8	8,12	1,38	0,86
Victoria bridge	0,10	0,13	0,05	0,05	4,76	7,82	2,64	2,68
Princess Street bridge	0,16	0,10	0,10	0,08	6,35	8,04	3,23	1,80
Hout Bay River mouth	0,10	0,10	0,11	0,08	5,73	7,97	3,27	1,97

Table 5: Nitrogen, DOC and potassium values at 5 points along the Hout Bay River

The DOC content of the Hout Bay River was greater during wet conditions (7,69 mg per litre) than during dry (4,66 mg per litre). The higher DOC may be attributable to both humic acids and faecal organic matter in surface runoff and ground water input to the river system. DOC values were slightly higher in tributaries during wet weather, than during dry weather being 5,47 mg per litre, and 4,18 mg per litre respectively. Table 5 also shows higher wet weather DOC values at points along the Hout Bay River.

Potassium levels increased towards the river mouth 0,96 mg per litre was the average wet weather value at Orangekloof weir whereas 3,27 mg per litre was the value at the river mouth. The down-the-river rise in potassium corresponds with the increasing faecal coliform counts along the river (table 4).

Calcium values were low compared to those of stormdrains and tributaries, with sampling point 1 showing a maximum value of 68,4 mg per litre (wet conditions). The EC of river water was low averaging 20,9 mS/m (wet) and 29,7 mS/m (dry conditions).

4.2.1 Factors influencing microbiological quality of the Hout Bay River

The following 3 pages contain a discussion of those factors influencing the microbiological quality of the Hout Bay River. Some of the factors responsible for increases in bacteria and

viruses along the river include:

- squatter activities
- presence of animals
- stormdrain discharge (section 4.4)

Factors resulting in a decrease in bacterial concentration include:

- undisturbed tributary inputs
- natural die-off of microorganisms

Squatters living in make-shift shanties use the river for washing and as a latrine. The main contamination was by faecal coliforms and coliphage. Faecal coliform concentrations were higher during dry conditions at the places frequented by the squatter community, when it is raining the river is not used by the squatters to the same extent which may account for the difference in faecal coliform contamination during dry and wet weather.

There is a large domestic animal population in Hout Bay concentrated mainly between Longkloof weir and Victoria bridge. Horses and dogs predominate but cows and ducks are also numerous. The impact of the World of Birds aviary on the Hout Bay River is discussed in section 4.4.1. Animals contribute to the microbiological pollution of the river in a diffuse manner (non-point source pollution) by means of surface run-off contaminated with animal excrement and by direct contact of animals with the

river. Animals graze alongside the river in the public open space north west of Victoria bridge and cross the river at points where landowners have grazing on both sides of the river. It was reported that the river was being used as a dumping ground for animal wastes - this was clearly evident from the large amount of dog excrement dumped on the river bank at the lower end of Baviaanskloof tributary.

Geldreich et al. (1968) give median levels of total coliforms ($2,3 \times 10^7$), faecal coliforms ($2,3 \times 10^7$) and faecal Streptococci ($9,8 \times 10^8$) per gram of dog faecal matter. These quantities indicate the magnitude of bacterial pollution which could occur during storm events when faecal matter is washed into the Hout Bay River and discharged into the marine environment.

Between Longkloof weir and Victoria bridge the average daily increase in faecal coliform load is $2,28 \times 10^7$ for every 100 metres in dry conditions and $2,42 \times 10^8$ per 100 metres in wet conditions. Similarly the average daily increase in faecal Streptococci for every 100 metres between Longkloof weir and Victoria bridge is $2,88 \times 10^7$ in dry conditions and $1,97 \times 10^8$ in wet conditions.

Excrement from seagulls feeding in the lagoon, river mouth and surf zone may contribute to the bacterial populations at these points.

Bacteriological die-off is influenced by temperature, pH, nutrients available, predator organisms, solar radiation and a combination thereof. McCambridge and McMeekin (1981) working in controlled laboratory conditions found that the combined effect of solar radiation and the presence of predator organisms resulted in a greater mortality of *Escherichia coli*, than each factor independently. Faecal coliforms and faecal Streptococci have been found to survive longer in lower temperatures (7° to 10°C) than temperatures of 20°C or above in surface water (Clausen et al., 1977) and soil (Van Donsel et al., 1967). Die-off rates also differ for different bacteria depending on environmental conditions, some pathogens survive longer than the indicator organisms.

Generally (depending on environmental conditions) faecal Streptococci survive longer than faecal coliforms (Van Donsel et al., 1967; Clausen et al., 1977). The differences in die-off rates are taken into consideration in this study when comparing faecal coliform and faecal Streptococci concentrations on a seasonal (dry versus wet) basis (page 59).

Bacterial numbers may also drop as a result of sedimentation of bacteria in slow moving waters. During high flow conditions resuspension of organisms from sediments may result in elevated numbers in storm event samples (as discussed in section 5.2.1).

4.3 Tributaries

The mean values of the chemical constitutents monitored in tributaries discharging into the Hout Bay River were similar to the mean values obtained for the Hout Bay River. The mean potasium content of tributaries was 1,95 mg per litre, that of the Hout Bay River 1,98 mg per litre and stormdrains 8,56 mg per litre. The DOC content of tributaries was slightly lower (4,58 mg per litre) than that of the river (5,84 mg per litre) whereas sodium (32,94 mg per litre) and total dissolved solids (193 mg per litre) were slightly more than that of the Hout Bay River (28,6 mg per litre and 172 mg per litre respectively).

The microbiological quality of tributaries differed from that of the Hout Bay River although counts were in the same order of magnitude in both waters as shown in table 6.

The chemical and bacteriological differences between different tributaries were quite large in certain areas and thus a discussion of water quality of tributaries in general (using mean and median values) can be misleading. For example, tributary 11 showed a much higher degree of pollution than tributary 11-2 and tributary 31 and are therefore discussed separately in sections 4.3.1, 4.3.2 and 4.3.3 respectively.

WATER BODY	WEATHER CONDITIONS	50% OF OBSERVATIONS HAVING ORGANISMS EQUAL TO OR LESS THAN :	90% OF OBSERVATION HAVING ORGANISMS EQUAL TO OR LESS THAN :
FAECAL COLIFORMS/100ml			
Hout Bay River	Dry	$8,10 \times 10^2$	$5,20 \times 10^3$
	Wet	$4,90 \times 10^2$	$9,30 \times 10^3$
Tributaries	Dry	$4,90 \times 10^2$	$1,37 \times 10^4$
	Wet	$6,90 \times 10^2$	$1,2 \times 10^4$
Stormdrains	Dry	$1,4 \times 10^4$	$4,50 \times 10^7$
	Wet	$4,4 \times 10^4$	$1,50 \times 10^6$
FAECAL STREPTOCOCCI/100 ml			
Hout Bay River	Dry	$1,85 \times 10^2$	$7,40 \times 10^2$
	Wet	$2,16 \times 10^2$	$1,62 \times 10^3$
Tributaries	Dry	$1,60 \times 10^2$	$8,20 \times 10^2$
	Wet	$3,50 \times 10^2$	$1,70 \times 10^3$
Stormdrains	Dry	$2,30 \times 10^3$	$1,80 \times 10^5$
	Wet	$8,60 \times 10^3$	$1,85 \times 10^5$
COLIPHAGE/10ml			
Hout Bay River	Dry	4	77
	Wet	2	32
Tributaries	Dry	0	46
	Wet	0	30
Stormdrains	Dry	0	$1,00 \times 10^4$
	Wet	77	$1,35 \times 10^4$

Table 6: Microbiological quality of the Hout Bay River, tributaries and stormdrains

4.3.1 Constantia Nek purification works

The sludge waste produced from the water purification process is sprayed (rotating jet sprinkler) in a forest clearing below the purification works. Little infiltration occurs and a large proportion of the spray runoff forms a direct input into a tributary (sampling point 11) entering the Hout Bay River approximately 200 metres south of Orangekloof weir (figure 10).

The microbiology of the sludge spray runoff (11-1) is as follows:

faecal coliforms/100 ml	336
faecal Streptococci/100 ml	245
coliphage/10 ml	<1

The purification works at Constantia Nek receives water from mountain reservoirs which are free from anthropogenic pollution and thus the indicator organisms in the sludge spray appear to be abnormally high. However, the chemistry of the sludge spray shows the absence of faecal contamination in that the ammonia, nitrate-nitrite and phosphate content were less than 0,1 mg per litre and potassium measured only 0,75 mg per litre. A possible explanation for the high bacterial counts could be that forest animals introduced the faecal organisms into the water and the highly favourable nutrient conditions provided by means of the sludge, are capable of maintaining the bacterial population.

The sludge spray runoff then joins runoff from residences

occupied by forest reserve and purification plant employees and enters tributary 11 which discharges into the Hout Bay River at an average of 13 litres per second. The indicator organisms in tributary 11 are as follows:

	MEDIAN VALUES	RANGE
faecal coliforms/100ml	$2,0 \times 10^3$	$61 - 9,8 \times 10^4$
faecal Streptococci/100 ml	$1,4 \times 10^2$	$16 - 9,6 \times 10^2$
coliphage/10ml	2	$0 - 3,6 \times 10^2$

Faecal Streptococci counts were less at sampling point 11 than at the sludge spray runoff, whereas faecal coliforms and coliphage were greater. The potassium content (1,65 mg per litre) and nitrate-nitrite content (0,23 mg per litre) were greater at sampling point 11. These increases are indicative of contamination by human sewage. When the pollution of tributary 11 is considered in the context of the small number of residences in the area it indicates the potential which exists for pollution from household effluent.

4.3.2 Tributary 11-2

Tributary 11-2 discharging into the Hout Bay River opposite tributary 11 showed minimal faecal contamination although bordered by a few residences. The slope of the land is such that drainage would occur away from or parallel to tributary 11-2. Sampling was only conducted on two occasions thus the consistency of bacterial numbers at 11-2 is unknown. During wet conditions 70 faecal coliforms per 100ml and 8 faecal

Streptococci per 100 ml were enumerated, in dry conditions 4 faecal coliforms per 100 ml were enumerated. No faecal Streptococci were present in the dry weather sample and coliphage was not detected on either occasion. The chemical quality of the water was comparable to that of Longkloof tributary and the Hout Bay River at Orangekloof weir which are discussed in section 4.3.3.

4.3.3 Tributary 31

Longkloof tributary (sampling point 31) had the lowest faecal coliforms (43 per 100 ml), faecal Streptococci (7 per 100 ml) and coliphage (absent) of the tributaries monitored. These results are comparable to those characteristic of Orangekloof weir during wet conditions that is 39 faecal coliforms per 100ml, 11 faecal Streptococci per 100 ml and an absence of coliphage.

The chemical quality of Longkloof tributary was also very similar to that at Orangekloof weir, potassium values were low (0,6 and 0,9 mg per litre respectively) as were ammonia, phosphate (less than 0,05 mg per litre) and nitrate-nitrite (less than 0,1 mg per litre). The chemistry of the water indicates the absence of any sewage input in the waters. The higher organic carbon contents 7,6 mg per litre in Longkloof tributary and 5,6 mg per litre at Orangekloof weir are most probably of plant origin. The cationic and anionic composition of water at each sampling point is as follows:

CATIONS (meq %)	LONGKLOOF TRIBUTARY	ORANGEKLOOF WEIR
sodium + potassium	80,9	81,4
magnesium	9,1	9,3
calcium	10,0	9,3
ANIONS (meq %)		
chloride	77,5	73,0
sulphate	14,5	19,9
carbonate + bicarbonate	8,0	7,1

There are very few houses in the vicinity of Longkloof tributary and the similarity of water quality to that of Orangekloof weir (where there are no houses) indicates the quality of fresh, unpolluted mountain runoff prior to the influence of man. The low faecal indicator organisms may be attributable to the input from animals (wild) living in the mountain forests.

4.3.2 Baviaanskloof tributary

The length of the Hout Bay River, diversity of activities and potential sources of pollution make it difficult to ascertain the origin of pollution entering the river. For this reason Baviaanskloof tributary, a smaller, predominantly residential area, was monitored to determine the pollution input from residential activities alone. The three points at which the water quality was monitored are shown on figure 13, that is at

the top of Skaife Road (27), 478 metres downstream at Darling Street (18) and at the end of Melkhout Crescent (34) which is 474 metres downstream of Darling Street. There are few houses above sampling point 27, between 27 an 18 the tributary passes through a built up medium density residential area as shown in figure 13. After sampling point 18 the tributary is channelized alongside the Hout Bay Hotel, is bordered by a common, a restaurant and about 8 houses before passing through a reed bed into the lagoon area of the Hout Bay River.

The median values of the indicator organisms at the three sampling points (27, 18, 34) and in the Hout Bay River before (34-5) and after (24) the tributary input are given in table 7.

The chemical quality of Baviaanskloof tributary varied with weather conditions and pollutants increased downstream. Chemical concentrations were greater at Darling Street sampling point (18) than at the Skaife Road sampling point (27) with potassium and calcium differing the most. During dry conditions potassium measured 0,36 mg per litre at Skaife Road but 2,75 mg per litre at Darling Street, and calcium measured 2,96 and 15,7 mg per litre respectively. Less variation occurred between the remaining chemical constitutents and during wet conditions. During dry conditions water quality (chemical) improved between Darling Street and the end of Baviaanskloof tributary whereas in wet conditions potassium (0,75 versus 0,90 mg per litre), calcium (4,90 versus 6,10 mg per litre) and dissolved organic carbon

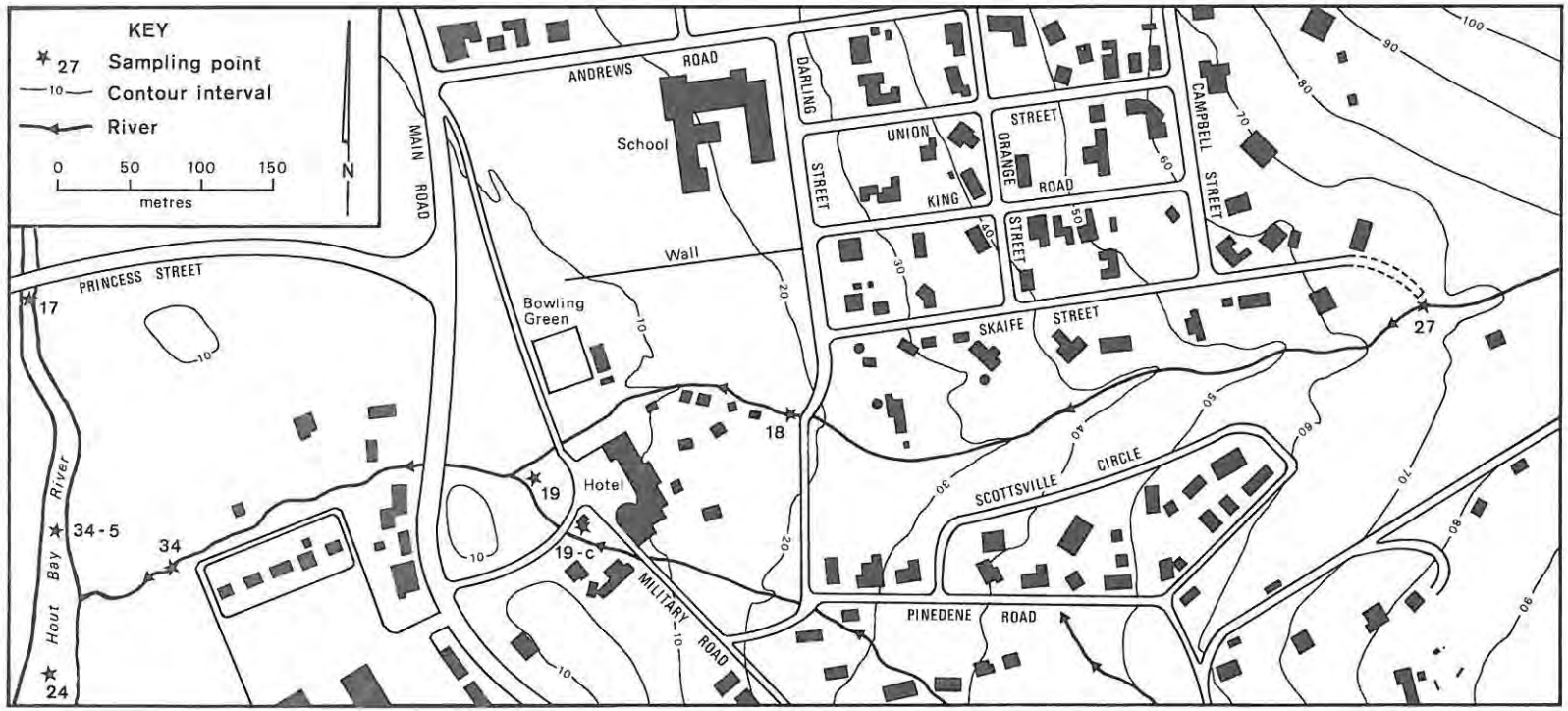

Figure 13: Location of sampling points along Baviaanskloof tributary.

SAMPLING SITE	MEDIAN VALUE OF: FAECAL COLIFORMS per 100ml	FAECAL STREPTOCOCCI per 100 ml	COLIPHAGE
Skaife Road (27)	$1,03 \times 10^2$	14	0
Darling Street (18)	$8,50 \times 10^3$	$6,72 \times 10^2$	2
Melkhout Crescent (34)	$1,47 \times 10^7$	$1,20 \times 10^3$	4
Hout Bay River before tributary input (34-5)	$7,75 \times 10^2$	$2,80 \times 10^2$	14
Hout Bay River after tributary input (24)	$1,16 \times 10^3$	$3,80 \times 10^2$	7

Table 7: Microbiological quality of Baviaanskloof tributary and the Hout Bay River before and after the tributary input

(4,10 versus 5,40 mg per litre) were greater at 34 than at Darling Street (18). Where water quality improved it may be a function of dilution.

The difference in water quality between 27 and 18 emphasizes the impact which a medium density residential area can have on water quality. Apart from the above mentioned chemical constituents, no other chemical pollution occurred between points 18 and 34, however, microbiological pollution was greater at 34 than at 18. These results indicate that chemical pollutants are mainly derived from street runoff as occurs in a medium density

residential area whereas bacteriological pollution will occur where there are inefficient septic tanks regardless of the density of housing (assuming that not all the septic tanks in an area are contributing to the pollution problem). On a number of occasions during the rainy season the septic tank behind a popular restaurant, bordering the tributary, was seen to overflow directly into the tributary. Remedial action was then taken by the restaurant in that a new septic tank system with a greater capacity was installed. As the tributary transects a popular common it is also possible that it was used as a local latrine as well as a dumping ground for animal wastes (as mentioned in section 4.2.1).

4.4 Stormdrain effluent

Stormdrain discharge in both dry and wet conditions is a major contributor to the pollution of the Hout Bay River as shown in table 6 which gives the 50 and 90 percentile values of indicator organisms in the Hout Bay River, its tributaries and stormdrains. A number of specific source areas of pollution are discussed in the following paragraphs.

4.4.1 World of Birds aviary

The effluent from the World of Birds (sampling point 2) was a small but highly contaminated discharge averaging approximately 2 litres per second during wet conditions. Flow was not measured

during dry conditions but was estimated at less than 1 litre per second. The microbiology of the effluent was as follows:

	MEDIAN VALUE	RANGE
faecal coliforms/100ml	$1,6 \times 10^5$	$1,4 \times 10^4 - 8,3 \times 10^7$
faecal Streptococci/100ml	$3,5 \times 10^4$	$3,0 \times 10^2 - 8,6 \times 10^5$
coliphage/10ml	$9,1 \times 10^3$	$12 - 1,7 \times 10^4$

Field observations and chemical analyses of samples confirm the origin of the pollution as faecal. Potassium values averaged 10,03 mg per litre, ammonia 7,34 mg per litre, nitrate-nitrite and phosphate 1,69 and 1,91 mg per litre respectively.

The effluent from the aviary flows into tributary 3 which then borders a number of small holdings (with domestic animals) before discharging into the Hout Bay River (sampling point 2-3) south of Bethal Road (point 4).

The microbiological quality of tributary 3 is comparable to that of the collective median values obtained for tributaries in Hout Bay. Chemical pollution however exceeded that characteristic of tributaries - tributary 3 had an average total dissolved solids concentration of 322 mg per litre compared to 193 mg per litre for tributaries collectively. Of the faecal indicators potassium (4,61 mg per litre compared to 1,95 mg per litre) and ammonia (0,22 mg per litre compared to <0,05 mg per litre) were greater in tributary 3. Median values of indicator organisms in tributary 3 prior to the input of the aviary effluent are as

follows:

faecal coliforms/100ml	320
faecal Streptococci/100ml	310
coliphage/10ml	0

The tributary was sampled at point 3-1 which included the avian effluent. As the mixture was only sampled once during dry conditions and once during wet conditions, the validity of data from 3-1 are questionable but give an indication of the water quality after the aviary input. Indicator organism enumeration yielded the following results:

	Dry conditions	Wet conditions
faecal coliforms/100ml	$2,8 \times 10^3$	$3,5 \times 10^4$
faecal Streptococci/100ml	$5,4 \times 10^4$	$2,8 \times 10^4$
coliphage/10ml	$2,8 \times 10^2$	$4,6 \times 10^2$

The average flow rate of tributary 3 after the aviary input was 12 litres per second in dry conditions giving a daily discharge of $2,9 \times 10^{10}$ faecal coliforms, $5,6 \times 10^{11}$ faecal Streptococci and $2,9 \times 10^{10}$ coliphage. During wet conditions the flow rate was 61 litres per second giving a daily discharge of $1,8 \times 10^{13}$ faecal coliforms, $1,5 \times 10^{12}$ faecal Streptococci and $2,4 \times 10^{11}$ coliphage.

4.4.2 Stormdrain effluent within residential areas

Surface overflow from septic tanks is a fairly common occurrence

mainly in winter, in a number of different areas in Hout Bay. In the event of septic tank overflow the sewage services (WCRSC) will pump the septic tank for a fee of R100. Some residents are however, reluctant to pay for the service and allow their septic tank to overflow continually. In situations where soil drainage is poor or the septic tank is undersized continual septic tank overflow may necessitate reconstruction of the septic tank system.

Where septic tank overflow was clearly visible samples were not obtained. Of the numerous stormdrain flows only 4 points were sampled, numbers were restricted by the project budget and limited to those places where flow was of uncertain origin.

Samples were obtained from Liverpool Road (28), Barry Road (32), Hout Bay Hotel cottages (19-C) and alongside Hout Bay Hotel carpark (19) as shown on figures 10 and 13. Results from chemical and microbiological analyses showed that the discharges were characteristic of raw sewage. Faecal coliform and coliphage numbers were as follows:

SAMPLING POINT	FAECAL COLIFORMS per 100ml	COLIPHAGE per 100ml
28	$1,17 \times 10^6$	$4,10 \times 10^2$
32	$3,40 \times 10^7$	$3,70 \times 10^4$
19-C	$1,15 \times 10^7$	$2,10 \times 10^4$
19	$2,28 \times 10^9$	$8,80 \times 10^4$

The ammonia content at the 4 points ranged from 20,37 mg per litre at sampling point 32 to 44,14 mg per litre at 19-C. Thus ammonia values were lower than that characteristic of raw sewage (45,9 mg per litre) but greater than that of secondary effluent (11,6 mg per litre). Total alkalinity values were similar to that of secondary effluent (224 mg per litre), that is 180 mg per litre at 32, 190 and 229 mg per litre at 19 and 19-C respectively and 394 mg per litre at 28. Total dissolved solids (TDS), chloride and phosphate values were lower than average values of secondary effluent. TDS ranged from 416 mg per litre at 19 to 692 mg per litre at 28, chloride from 48 mg per litre (19) to 72 mg per litre (28) and phosphate from 4,62 mg per litre (19) to 9,86 mg per litre (28) - the mean phosphate value of secondary effluent is 10,5 mg per litre.

Surface overflow from inefficient septic tanks (hypothesis (i) page 4) therefore provides a small but continuous volume of highly polluted effluent into the Hout Bay River. The severity of the problem of septic tank overflow is highlighted when examined in the context of the infective dose of certain pathogens as shown in table 11 (page 95). The infective dose of pathogens (Shigella species) which could cause bacillary dysentery is less than 10^4 organisms whilst the level of viruses which could cause diarrhoea, meningitis and poliomyelitis is less than 10^2 organisms (Olivier and Newman, 1984). In Finland the virus responsible for the poliomyelitis outbreak in 1984 was subsequently isolated from sewage water in 13 different locations

in the Helsinki region and in 13 other towns in Finland (Pöyry et al., 1988).

4.4.3 Stormdrains discharging into the Hout Bay River

Stormdrains carry the runoff from residential areas, wet weather discharge contains street runoff contaminated by animal excrement (horses and dogs), litter which has accumulated during the period preceding rainfall and septic tank overflow. Stormdrain discharge during dry weather is low (mainly runoff from residential uses) but highly polluted. For example the faecal coliform load discharging from the large centre stormdrain (16) immediately north of Victoria bridge was of the same order of magnitude during dry and wet conditions, that is $1,09 \times 10^5$ and $9,68 \times 10^5$ faecal coliforms per second whereas the mean flow rates were 0,78 litres per second in dry conditions and 2,20 litres per second in wet conditions.

Microbiological pollution in stormdrains tended to remain high throughout storm events whereas chemical attributes varied most during storm events as discussed in section 5.2.3. The microbiological quality of stormdrain effluent varied most during routine sampling (dry and wet conditions). In the stormdrain discharging into the Hout Bay River 100 metres north of Victoria bridge (sampling point 14, figure 10) faecal coliforms ranged between $2,3 \times 10^3$ and $6,7 \times 10^5$ organisms per 100ml with the highest value ($2,0 \times 10^6$ faecal coliforms per 100ml) being

recorded during the 7 August storm event. Minimum and maximum faecal Streptococci values (per 100ml) were $6,3 \times 10^2$ and $2,3 \times 10^5$ respectively with a high of $1,7 \times 10^6$ being recorded during the 7 August storm event and coliphage ranged from 0 to $6,6 \times 10^2$ per 10ml. The range of the three indicator organisms monitored in 6 stormdrains are given in table 8.

SAMPLING POINT	FAECAL COLIFORMS per 100 ml	FAECAL STREPTOCOCCI per 100 ml	COLIPHAGE per 10 ml
6	$1,6x10^2$-$3,4x10^4$	$2,4x10^1$-$2,8x10^6$	0-$4,7x10^2$
8	$7,0x10^2$-$4,5x10^5$	$1,0x10^2$-$4,5x10^5$	0-$1,4x10^3$
14	$2,3x10^3$-$6,7x10^5$	$6,3x10^2$-$2,4x10^4$	0-$6,6x10^2$
16	$1,1x10^3$-$8,4x10^4$	$4,1x10^2$-$2,3x10^4$	0-$1,1x10^2$
22	$1,0x10^4$-$5,9x10^5$	$1,6x10^3$-$3,0x10^5$	0-$6,0x10^3$
33	$1,1x10^3$-$3,7x10^6$	$3,5x10^2$-$1,6x10^5$	0-$2,7x10^2$

Table 8: Variation in microbiological quality of 6 stormdrains

The average concentration of the chemical constitutents analysed were greater in stormdrains than the Hout Bay River or its tributaries. Potassium values averaged 8,56 mg per litre in stormdrains compared to 1,95 mg per litre in tributaries and 1,98 mg per litre in the Hout Bay River. DOC content was 12,27 mg per litre in stormdrains, the second highest average occurred in the Hout Bay River during wet conditions (7,69 mg per litre) and the lowest value occurred in tributaries (4,58 mg per litre).

Wet weather and dry weather TDS values were very similar being 427 and 422 mg per litre respectively. The total TDS load entering the Hout Bay River however depends on the rate of flow of stormdrains, for example, although stormdrain 6 had a higher TDS concentration during dry conditions (213 mg per litre) than during wet conditions (177 mg per litre) the average daily discharge of TDS (taking into consideration the rate of flow) was 0,37 kg and 82,94 kg in dry and wet conditions respectively.

During dry conditions stormdrain flow was erratic as flow was related more to land use activities in the vicinity than to rainfall. Stormdrains 6 and 23 were found to be dry on numerous sampling runs. Stormdrain discharge was also variable during wet conditions, the average discharges ranged from 0,5 litres per second in stormdrain 22 to 5,4 litres per second in stormdrain 6.

4.4.2 Stormdrains discharging onto Hout Bay beach

Two stormdrains discharge directly onto the east beach, one at the Chapmans Peak Drive (CPH) end and the other at the end of Beach Road as shown on figure 10. On the west beach a culvert (WBC) and stormdrain (MW) near Mariners Wharf discharge directly onto the beach. Beach stormdrains were sampled on an ad hoc basis.

An obvious and very serious contributor to marine pollution was the stormdrain near Chapmans Peak Drive (CPH). The stormdrain outlet was covered by a thin metal sheet to prevent blockage by

beach sand. During high tide sea water entered the stormdrain. Stormdrain discharge, containing washings from the Chapmans Peak Hotel rubbish bins and other effluent, was dammed up behind the metal sheet with slow seepage from the sides. This stagnant, nutrient-rich water supply favoured multiplication of bacteria in the time between stormdrain openings. The sand blocking the stormdrain was cleared on a weekly basis and the metal sheet lifted to allow the pungent effluent to drain directly into the sea.

Quantification of the flow on one occasion (22 January 1988) revealed that a volume of 40,46 cubic metres was released in half an hour, with a load of $1,45 \times 10^5$ faecal coliforms, $8,90 \times 10^{15}$ faecal Streptococci and $1,50 \times 10^{12}$ coliphage being discharged into the sea. Other microorganisms would be present in large numbers but only the 3 indicator organisms were enumerated. The phosphate, chemical oxygen demand (COD) and ammonia values of the stormdrain effluent exceeded those characteristic of raw sewage. The phosphate concentration in the stormdrain sample was 12,5 mg per litre. COD was 2238 mg per litre and ammonia (as nitrogen) 25,2 mg per litre. Analytical data as obtained from the Muizenberg sewage treatment plant gave a phosphate concentration of 9,0 mg per litre, a COD of 695 mg per litre and 42,5 mg per litre ammonia (as nitrogen).

The health threat and shockloading effect of the sudden release of a highly contaminated effluent into the sea are exacerbated

because of the sheltered nature of Hout Bay (see frontispiece photograph). Wave-dynamics along the beach do not facilitate rapid dispersion and dilution of any effluent entering the surf zone.

The problem of the stormdrain was taken up by the Water Quality Division (WCRSC) in February 1988 and action taken to prevent further pollution in this manner. The stormdrain was sampled again during the 17 July storm event, although the different conditions hinder an accurate comparison of the two data sets, microbiological results obtained on the 22 January and 17 July are as follows:

	22 January	17 July
faecal coliforms /100 ml	$3,6x10^9$	$7,8x10^5$
faecal Streptococci /100 ml	$2,2x10^8$	$3,6x10^3$
coliphage /10 ml	$3,7x10^5$	$7,0x10^1$

In the water sample obtained from the stormdrain on the 17 July less than 0,05 mg per litre of ammonia and phosphate was found and the total dissolved solids content was 104 mg per litre. As these results are very low for a stormdrain (as compared to others in Hout Bay) it is possible that the main flush of pollutants had occurred prior to sampling.

West beach stormdrain

Samples obtained from the culvert on the west beach (WRC) during dry weather had a faecal coliform count of 70 organisms per 100

ml and during the 17 July storm event 2,30 x 10^3 faecal coliforms per 100 ml. Similarly faecal Streptococci counts were greater during the storm event (2,80 x 10^3 per 100 ml) than dry conditions (1,04 x 10^2 per 100 ml), coliphage was absent from both samples.

4.5 Application of the faecal coliform to faecal Streptococci ratio

The ratio of faecal coliforms to faecal Streptococci (FC/FS) has been used to give an indication of the source of pollution, that is a ratio of less than 0,7 is indicative of pollution by animal excrement whereas a ratio above 4 indicates pollution of human origin (Geldreich et al., 1968). The ratio merely gives an indication of the origin and is only valid for recent faecal contamination of under 24 hours (Clausen et al., 1977).

In Hout Bay calculation of the FC/FS ratio did not give conclusive evidence as to the origin of the faecal pollution. For example areas having a predominant animal activity did not always yield a FC/FS ratio below 0,7. However, it is possible that human contamination is so predominant that it overshadows the pollution by animals, or that local conditions affecting die-off of organisms (see page 64) prevent the application of the FC/FS ratio.

4.6 Environmental impact of pollution

Pollution entering the bay will affect the marine environment by (i) an accumulation effect and (ii) shockloading. The accumulation effect occurs where the pollution discharge into the sea is a continuous moderate level of contamination which results in the gradual depletion of marine life. Pollution loads carried down the river during wet conditions and to a lesser extent dry conditions produce a population of contaminated filter feeders and die-off of certain populations.

Shockloading occurs when a very high pollution load is released into the bay in a short period such as during storm events (Chapter 5). Organisms have no time to adapt to the sudden toxic conditions and rapid die-off of marine organisms occurs. An investigation into the shockloading impact on the marine environment did not form part of this study but is recommended for future research in Hout Bay.

This chapter has given a detailed account of surface water quality during routine sampling in wet and dry conditions, the next chapter deals with water quality during storm events.

CHAPTER 5

STORM EVENT HYDROLOGY

CHAPTER 5

STORM EVENT HYDROLOGY

5.1 Rainfall and flow characteristics

The time delay between rainfall and peak flow is influenced by a number of factors such as: (i) land cover, as demonstrated by Rimer et al. (1978) studying stormwater runoff from high and low activity rural, commercial and residential areas in the Piedmont region of North Carolina; (ii) antecedent moisture conditions as shown by Green et al. (1986) in a study of stormwater runoff from a developed downtown area and a residential area in Johannesburg (South Africa). Green also found that the discharge of pollutants from each catchment was proportional to the volume of runoff; (iii) stormwater management practices and structures (Stephenson, 1981).

The first storm event of the 1988 season, 10 mm on the 7 March, produced a maximum discharge of 0,60 cubic metres per second about 8 hours after the initial onset of rain. However, the storm event on 7 August (15 mm) which like that on 7 March was preceded by 16 rain-free days produced a maximum discharge of 1,16 cubic metres 2 hours 45 minutes after the onset of rain. More than double the quantity of rain was recorded on 19 May (53 mm) as on 17 July (25 mm) and yet the maximum recorded discharges were 4,40 and 4,16 cubic metres per second respectively. The rainfall totals, number of preceding dry days and maximum

discharge for the four storm events are summarized in table 9. Table 9 shows the variation in rainfall quantity at the 5 raingauge sites, the locations of which are shown on figure 2.

RAINFALL (mm)	DATE OF STORM EVENT			
AT:	7 March	19 May	17 July	7 August
Albert Ave. **	10,0	53,0	25,0	15,0
Road Stat.	-	-	19,5	13,0
Orangekloof	-	-	36,5	24,5
Constantia Nek *	14,0	89,5	38,5	28,0
Woodhead *	14,0	80,0	37,0	27,5
Max. Discharge (m^3/S)	0,60	4,40	4,16	1,16
No. dry days preceding storm event	16	1	3	16

Table 9: Rainfall, maximum discharge and number of dry days preceding the 4 storm events

* Rainfall records, Cape Town Municipality

** Rudings, pers. comm.

\- No data available

On the 20 July a discharge of 32,45 cubic metres per second was recorded at Princess Street bridge following 29 mm of rain and a flow of 56,17 cubic metres per second was recorded 3 hours later after an additional 4 mm of rain. Although only 1 dry day preceded the storm event of 19 May(table 9) a total of 19 mm of rain had been recorded for May (up to 18 May) whereas for the 20

July storm event, less rainfall (33 mm) produced a much greater discharge (4,40 versus 56,17 cubic metres per second) but the total rainfall for July (up to 19 July) was 108 mm. Antecedent moisture conditions and reservoir overflow were probably the main factors responsible for the high flow shown in plate 1 taken on 20 July after 33 mm of rainfall. By means of contrast plate 2 is included to show the average flow characteristic of dry conditions taken a month later.

5.2 Magnitude of pollution

5.2.1 Microbiological quality of stormwater

Figure 14 shows the faecal coliform and TDS discharge during the 7 August storm event. Peak faecal coliform discharges as measured at Princess Street bridge (table 10) were extremely high exceeding those characteristic of secondary sewage effluent which is in the order of $1,2 \times 10^3$ faecal coliforms per 100 ml, often approaching values characteristic of raw sewage ($2,0 \times 10^7$ faecal coliforms per 100 ml).

DATE OF STORM EVENT	MAXIMUM FAECAL COLIFORM CONCENTRATION (per 100ml)	MAXIMUM FAECAL COLIFORM DISCHARGE (per second)
7 March	$5,60 \times 10^6$	$2,24 \times 10^{10}$
19 May	$2,87 \times 10^5$	$1,26 \times 10^{10}$
17 July	$1,40 \times 10^5$	$2,84 \times 10^9$
7 August	$2,22 \times 10^6$	$1,10 \times 10^{10}$

Table 10: Maximum recorded faecal coliform concentration and discharge during storm events

Plate 1: River flow at Victoria bridge after 33 mm of rain (20 July 1988)

Plate 2: Low flow at Victoria bridge during dry conditions (mid-August 1988)

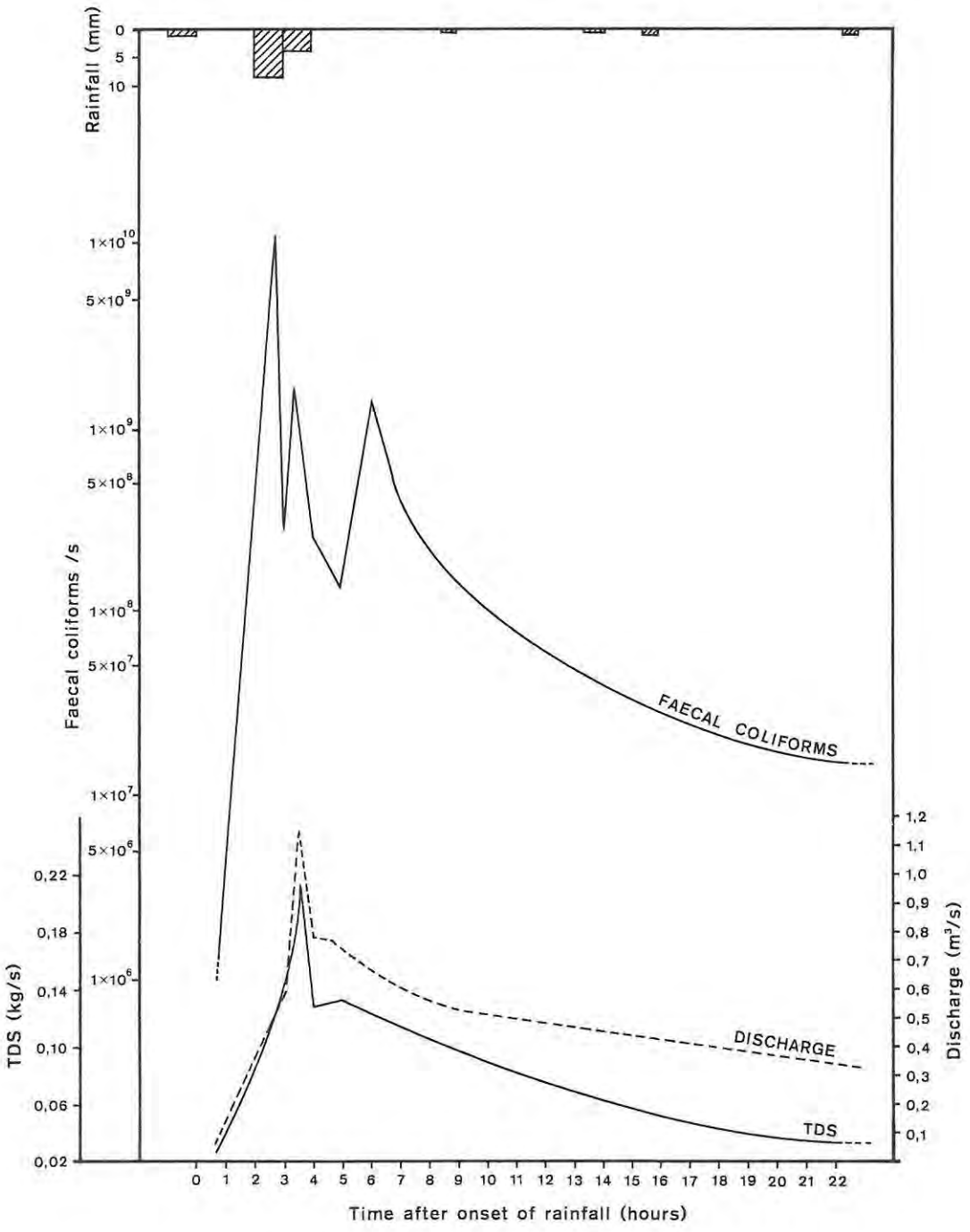

Figure 14: Faecal coliform and TDS discharge at Princess Street bridge during the 7 August storm event

Urban storm water studies in Sydney and Baltimore (Maryland) by Cordery (1977) and Olivieri (1981) respectively showed that faecal coliform concentrations in stormwater runoff approached magnitudes characteristic of raw sewage.

Faecal coliform discharge from the Hout Bay River

Using rainfall data for the hydrological year ending on 31 September 1988, mean faecal coliform concentrations for wet and dry conditions and mean wet and dry river discharge the total faecal coliform loads are given as:

	FAECAL COLIFORMS	(%)
Total load during dry conditions:		
286 dry days	$7,39 \times 10^{13}$	(5,8)
Total load during wet conditions:		
56 days with rainfall between 1 and 10mm	$2,27 \times 10^{14}$	(17,8)
Total load during storm events:		
12 rain days of between 10 and 15mm	$6,55 \times 10^{14}$	(51,2)
11 rain days exceeding 15mm	$3,22 \times 10^{14}$	(25,2)
Total load for 1988 (hydrological year)	$1,27 \times 10^{15}$	

The faecal coliform balance shows that storm events are the major cause of faecal contamination in the Hout Bay River. Storm events, exceeding 10mm of rainfall, were responsible for over 76 percent of the total annual faecal coliform load. Twelve days having between 10mm and 15mm of rain produced 51,2 percent of the

total load whereas 286 dry days contributed only 5,8 percent.

The importance of storm event pollution along the South African coastline has been stressed by researchers such as Grabow (1987) and Lord (1988).

In Hout Bay river sediments may be a significant source of pollution during storm events when the greater volume and turbulence of river flow cause resuspension and subsequent discharge of microorganisms. Matson et al. (1978) investigated the occurrence of indicator organisms in river sediments in the Shetucket River in northeastern Connecticut. Following the 3 year study the authors concluded that high densities of indicator organisms occur in river sediments and are resuspended during high runoff resulting in an increase in organisms in the discharge.

5.2.2 Health hazard

Rhodamine WT was used to trace the path of the river water discharging into the surf zone. The dye was introduced into the Hout Bay River and the path of flow into the sea observed, observations were not quantified.

Dilution and dispersion of polluted effluent, entering the bay from the Hout Bay River, depends on predominating winds and currents (Toms, 1986). During storm events the movement of water entering the bay from the Hout Bay River could be observed as the

sediments and suspended matter gave the river discharge a brown turbid appearance. Similarly the Rhodamine WT dye which was introduced into the river remained as a coherent body for about 30 minutes (approximately 100 ml of dye was used) and tended to move along the shallow breakers to the east and west of the river mouth after entering the surf zone. Observation of storm event discharge and tracer movements indicate that any pollution entering the sea from the Hout Bay River will remain in the surf zone for extended periods with little dilution and dispersion. Although there is a natural die-off or organisms (discussed in section 4.2.1) when very high concentrations of organisms enter the sea (as occurs during storm events) the health risk is also high. Many pathogenic and non-pathogenic bacteria and viruses are carried in storm water runoff. To give an indication of the magnitude of microorganism discharge the mean daily discharge of faecal coliforms was $2,58 \times 10^{11}$ on a dry day and $4,06 \times 10^{12}$ on a wet day. Table 11 shows the infective dose of a number of pathogenic organisms, that is the number of organisms which if ingested could result in infections such as hepatitis or gastroenteritis or surface infections and septicaemia resulting from physical contact with the organisms (Olivier and Newman, 1984).

BACTERIA	INFECTIVE DOSE
E. coli (enteropathogenic)	$>10^6 - 10^7$
Salmonella	10^6
Shigella	$10^2 - 10^4$
Vibrio	$10^4 - 10^6$
Leptospira	$<10^2$
VIRUSES	
Enteroviruses	$<10^2$
Hepatitis A virus	$<10^2$

Table 11: Infective dose of waterborne pathogens (Olivier and Newman, 1984)

The number of microorganisms present in stormwater runoff is high but varies with the amount and type of pollution on the land surface, the amount of rainfall, runoff and antecedent moisture conditions.

5.2.3 Chemical quality of stormwater

Princess Street bridge was the main sampling point during storm events and the following discussion on chemical quality of stormwater refers specifically to results obtained from Princess

Street bridge.

As the environmental conditions, amount of rainfall and moisture conditions differ for each storm event, interpretation of results are treated with some reserve as it may be a specific combination of factors producing such results.

As expected a greater TDS load (15 tonnes) was discharged into the marine environment during the 25 mm storm event on 17 July than during the 15 mm storm event on 7 August (9,8 tonnes). Conversely a smaller faecal coliform load corresponded with the greater rainfall, that is 2,93 x 10^{13} faecal coliforms were discharged during the 25 mm storm event and 5,46 x 10^{13} faecal coliforms during the 15 mm storm event (7 August). These results are in keeping with the general findings discussed in literature on storm event sampling. That is where contaminants can be eroded and transported to the river by runoff - the greater the runoff the greater the capacity for pollution. In the short term period such as a storm event, bacteriological pollution is of a finite nature in that once faecal matter has been washed into the river, additional pollution must then occur to increase the load as indicator organisms do not multiply in the water environment. Thus the runoff can only transport what pollution is present on the land surface (Geldreich et al., 1968) which is the reason researchers such as Qureshi and Dukta (1979) found little relationship between the amount of rainfall and microbiological pollution.

Time lapse to peak concentrations

On 7 August the highest concentration of DOC, EC, potassium, phosphate, ammonia, calcium and total alkalinity occurred 2,75 hours after the onset of rainfall. Nitrate-nitrite had a maximum value of 0,4 mg per litre after 2,75 hours, 4,50 and 8 hours after the onset of rainfall.

On 7 March peak values of DOC, potassium, phosphate, nitrate-nitrite and ammonia occurred 3 hours after the onset of rainfall. The highest TDS value (260 mg per litre) occurred 1,83 hours after the onset of rainfall, the mean TDS value at Princess Street bridge was 239,6 mg per litre with values ranging from 195 to 260 mg per litre. Peak concentrations varied during the 19 May and 17 July storm events with maximum TDS concentrations recorded 1,58 and 2,33 hours after the onset of the respective storm events. Peak DOC values occurred 25 hours after the onset of rainfall on the 19 May and 11,25 after the start of the 17 July storm event.

Range of chemical constituents

The mean value and range of EC, DOC and potassium (K) at Princess Street bridge during the 4 storm events are given in table 12.

DATE OF STORM EVENT	EC mS/m		DOC mg/l		K mg/l	
	Range	Mean	Range	Mean	Range	Mean
7 March	30,0-40,0	36,8	6,3-13,8	8,5	3,3-5,7	4,2
19 May	11,0-27,5	18,9	3,1-9,1	4,6	1,9-4,0	2,9
17 July	13,0-31,0	20,7	4,0-13,5	8,7	1,1-3,0	1,9
7 August	25,0-39,0	30,1	5,9-11,5	7,4	1,8-3,9	2,6

Table 12: EC, DOC and potassium values at Princess Street bridge during storm event sampling

The highest EC values recorded during storm events occurred in the 2 stormdrains monitored. Stomdrain 14 had a maximum of 137 mS/m and a minimum of 7,8 mS/m both on 19 May. In stormdrain 16 a maximum of 103 mS/m occurred on 17 July and low of 8 mS/m on 19 May, the mean EC value at stormdrain 16 for the 4 events was 55,8 mS/m with a standard deviation of 34,5 mS/m.

DOC values also varied during storm events, for example 2,3 mg per litre occurred 1,33 hours after the onset of rainfall in stormdrain 14 and 20,0 mg per litre was recorded the following morning in the same stormdrain.

TDS discharge from the Hout Bay River

Using mean total dissolved solids (TDS) values and discharge volumes the TDS loads for 1988 were as follows:

	TONNES TDS	(%)
TDS load during dry conditions:		
286 days	1 429	(59,5)
TDS load during wet conditions:		
56 days with rainfall between 1mm and 10mm	679	(28,3)
TDS load during storm events:		
12 rain days of between 10 and 15mm	118	(4,9)
11 rain days exceeding 15mm	175	(7,3)
Total TDS load for 1988 (hydrological year)	2 401 tonnes	

Contrary to the faecal coliform balance (page 92) in which storm events were the major causative factor in contamination of the bay, dry conditions contribute the highest loads of total dissolved solids - being responsible for 59,5 percent of the total annual load. The same storm events which produced 52,4 per cent of the total coliform load produced only 4,9 per cent of the annual TDS load.

5.3 First flush effect

The first flush effect is the terminology commonly used to refer to the phenomenon in which the main pollution load occurs in the initial stages of a storm event, building up to a peak and then dropping off to base level. The pollution build up, peak and drop usually occurs in a coherent manner within a short space of time.

Cordery (1977), collecting storm water samples in three urban catchments in Sydney, Australia, found an initial flush of suspended solids, BOD and coliforms within the first hour of storm events. Similarly Simpson (1987) working in an urban catchment in Natal, South Africa confirmed an initial flush of pollutants such as lead, nitrogen, phosphorus and suspended solids.

In Hout Bay samples were collected at the onset, during and the day following each storm event. Pollution loads, as measured at Princess Street bridge, did not occur as a single flush but as a number of pollution peaks followed by a steady decline to a level slightly higher than that measured at the onset of the storm event. These findings are similar to those of Qureshi and Dukta (1979) who investigated stormwater runoff at three locations in Southern Ontario, Canada and found that microbiological pollution in particular remained very high throughout the event in contrast to a predominant first flush effect.

In Hout Bay the multiple pollution peaks which did not always correspond to peak flows can be related to the following factors:

(i) rainfall characteristics

(ii) mountain runoff

(iii) clearing of stormdrains

(i) Rainfall characteristics

Intermittent rain which occured as two or more periods of intense rain followed by very light drizzle or complete cessation of rainfall resulted in two seperate pollution peaks - the magnitude of each depending on rainfall quantity. The 19 May and 17 July storm events showed such rainfall related peaks.

(ii) Mountain runoff

The time delay for mountain runoff to reach the flow gauging stations in the lower valley varied with the quantity of rainfall, antecedent moisture conditions and release of water from Woodhead reservoir. Peak flows resulting from the delay of mountain runoff to reach the bridges in the lower valley (where flow was monitored) can also be related to rainfall characteristics. Observation during storm events in Hout Bay showed that it was common for rainfall to continue in the Back Table area (figure 2) after it had ceased in the southern part of the catchment. Although the river stage increased with the mountain runoff there was no corresponding increase in faecal contaminants. During the 17 July storm event the pollution peak occurred at a discharge of 2,033 cubic metres per second whilst the recorded maximum discharge of 4,159 cubic metres per second produced no additional increase in faecal coliform discharge. The concentration of faecal coliforms at 2,033 and 4,159 cubic metres per second were $1,40 \times 10^5$ and $5,00 \times 10^2$

organisms per 100 ml respectively. Conversely the greatest dissolved organic carbon load (55,7 grams per second) corresponded to the mountain run-off peak whereas the load at 2,033 cubic metres per second was 13,8 grams per second.

(iii) Clearing of stormdrains

During the storm events of the 19 May and 7 August the second faecal coliform peaks and the first (07/08) and second (19/05) total dissolved solids (TDS) pollution peaks were directly related to the sudden discharge of the unpaved stormdrain discharging into the river just north of Princess Street bridge. The stormdrain not only transported a high faecal coliform load but also brought down large quantities of litter particularly plastic containers and beverage tins.

5.4 Sources of pollutants

During the 7 August storm event faecal coliform discharge from stormdrain 16 comprised approximately 3,5 percent of the total faecal coliform load deposited in the sea. Approximately 2 percent of the total dissolved solids load entered the Hout Bay River by means of stormdrain 16. Although this appears to be a relatively small proportion there are 19 functioning stormdrains which discharge directly into the Hout Bay River - this number does not take into consideration those tributaries which also receive stormdrain effluent. Assuming each stormdrain contributed 2 and 3,5 percent of the TDS and faecal coliform load

respectively - then stormdrain effluent alone would account for 38 percent of the TDS and 66,5 percent of faecal coliforms entering the marine environment by means of the Hout Bay River. Stormdrain contribution to the TDS load is much greater during storm events than during dry and wet (less than 10 mm of rainfall) conditions. It is estimated that 2,8 percent and 12,5 percent of the total TDS load can be attributed to stormdrain discharge during dry and wet conditions respectively.

It is difficult to trace the exact origin of stormdrain pollutants, however stormdrain discharge generally comprises street runoff, domestic animal wastes, surface runoff from driveways, pavements and septic tank overflow (where it occurs). Septic tank overflow predominates during wet conditions as soil drainage is further retarded by water logged soils. Pollution by septic tank overflow is discussed in section 4.4.2. Surface runoff from paddocks, stables, duck ponds and grazing fields is difficult to quantify but may be highly contaminated by animal faecal matter. River banks are washed by rising water during storm events thus any animal or human excrement deposited along the river banks will contribute to the pollution load.

Having examined the surface water quality in Hout Bay, the next chapter discusses ground water quality at 5 different sites in the study area.

CHAPTER 6

HYDROLOGICAL PROPERTIES OF GROUNDWATER

CHAPTER 6

HYDROLOGICAL PROPERTIES OF GROUND WATER

6.1 Contamination by septic tank effluent

Hypothesis (i) (page 4) states that inefficient septic tank systems are the major source of pathogenic pollutants in the surf zone of Hout Bay. The word "inefficient" is used to define the condition of a septic tank system not operating as designed and which releases pathogen charged effluent. In most cases "inefficiency" results from overloading of systems and sewage appears at the ground surface.

Complete removal of microorganisms from septic tank effluent depends on the physical characteristics of the soil around the percolation system such as porosity, infiltration capacity and saturation. A reduction in microorganisms in ground water occurs by physical removal such as filtration and adsorption, dilution with uncontaminated ground water and natural die-off (Hagedorn et al., 1981; Corapcioglu and Haridas, 1984). Although the potential for ground water contamination in unsewered areas is high most outbreaks of diseases from drinking borehole water have been associated with nearby septic tank inputs. Given the appropriate conditions soil is effective in removing pathogens from septic tank effluent (Lewis et al., 1980).

During a 2 year study Alhajjar et al. (1988) found that although

indicator organisms were not present in ground water near septic tank systems, viruses were present. The viral numbers increased with distance from septic tank systems. This was attributed to decreasing ionic attraction between viruses and sediments with increasing distance from the drainfield. Sinton (1982) working in Yaldhurst, an unsewered semi-rural area in Christchurch, New Zealand found that the presence of septic tanks had no adverse affect on the microbiological quality of ground water. Viraraghavan and Warnock (1976) examined the bacteriological and hydrochemical quality of sewage effluents in controlled conditions, Brown et al. (1979) and Hagedorn et al. (1981) monitored the movement and reduction in bacteria and viruses on passage through soil and found that in unsaturated soil conditions faecal coliforms were almost completely removed within a short distance from the sewage effluent loading point.

Similarly in Hout Bay it was found that bacterial counts were highest in monitoring well points situated adjacent to percolation systems but were substantially lower a few metres away from the percolation system. The location of the 5 sites at which ground water was monitored are shown in figure 15 and results are discussed on a site by site basis in sections 6.2 to 6.6.

Generally the ground water chemistry at each site varied little over the period in which they were monitored (May to August 1988). Water levels fluctuated slightly with sites 2, 3 and 5 showing a drop in water levels in August when dry conditions

predominated. Water levels and ground water quality were monitored for 3 days following a rainfall event to determine the effect of rainfall on ground water quality. On the 18 and 19 May 10 mm and 53 mm of rain was recorded respectively, ground water samples were obtained on 20, 21 and 24 May. A decrease in faecal coliforms occurred between the first and fifth day after rain in 13 of the 15 well points which had a positive faecal coliform count. According to Wellings et al. (1974) as reviewed by Virarhagavan (1982) the number of viruses in ground water may increase rapidly following rainfall as changes occurring in the soil result in the mass desorbtion of viruses from soil particles. This was found to occur in the ground water in Hout Bay following the rainfall on the 19 May. Maximum coliphage values recorded at each site occurred on the 20 May in 21 of the 24 well points with the remaining 3 well points (2B, 2D and 5C) showing maximum values on the fifth day after rain.

Phosphates, normally indicative of faecal contamination and the presence of detergents (see page 39) were consistently low in all well points except 4B, 5F and 5G, a maximum recorded value of 0,35 mg per litre occurred in 5F. Nitrate-nitrite (as nitrogen) ranged from less than 0,1 mg per litre to 25,0 mg per litre (3A). Total dissolved solids in ground water ranged from 286 mg per litre (2D) to 1 072 mg per litre (5D) with a mean of 560 mg per litre.

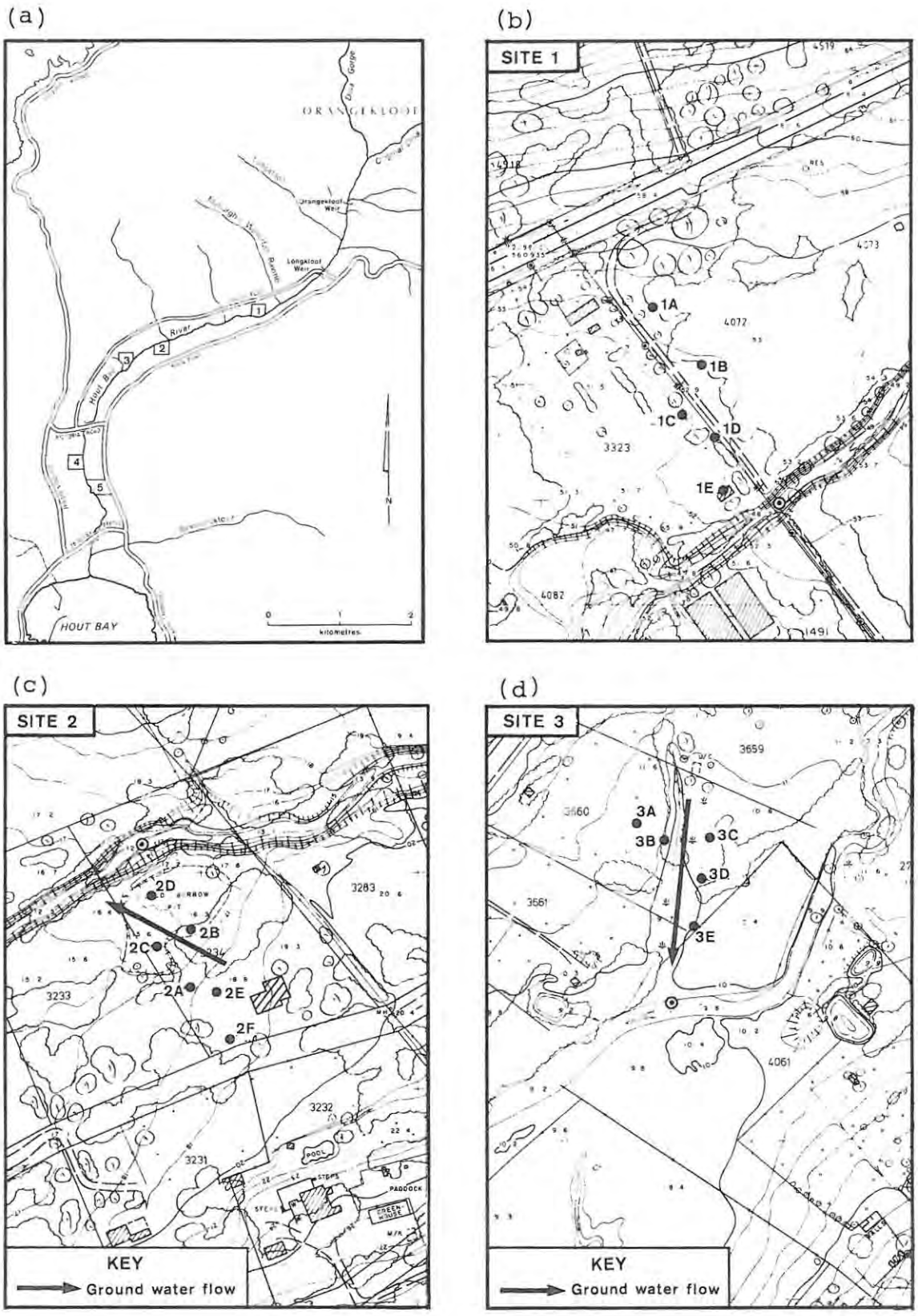

Figure 15: (a) Location of ground water study sites

(b) Site 1, (c) Site 2, (d) Site 3

6.2 Site 1 - Disa River Road

Site 1 (figure 15-b) was chosen as a control site to obtain background values of ground water in Hout Bay. Well points at site 1 were not situated next to septic tank systems, stables or other distinctive land uses. However well points remained dry throughout most of the sampling period. A vertical electrical-sounding (sounding 8) (the location of which is shown on figure E-1, Appendix E) done across the river from well point site 1 showed that weathered granite, occurred at 5,8 metres below the ground surface. The maximum depth reached by the jetting process (section 3.9.1) at site 1 was 5,07 metres (1E). Where sufficient water was obtained at holes 1A, 1C and 1E samples were muddy and samples too infrequent (maximum of twice) for valid discussion of results.

6.3 Site 2 - Riverside Terrace

The trilinear plot of hydrochemistry (figure 16) shows that ground water at site 2 (figure 15-c) is chloride-sulphide type water (with the exception of 2D) and is relatively saline. Ground water at site 2 was acidic (pH 5,7) compared to the ground water at sites 3,4 and 5 which had a mean pH of 6,9, the acidity of ground water at site 2 may be attributed to underlying granitic rocks. The hydrochemistry of river water obtained at site 2 is also shown in figure 16 and indicates that water in well point 2D is influenced by the Hout Bay River. The gradient from the river surface to the rest water level in well point

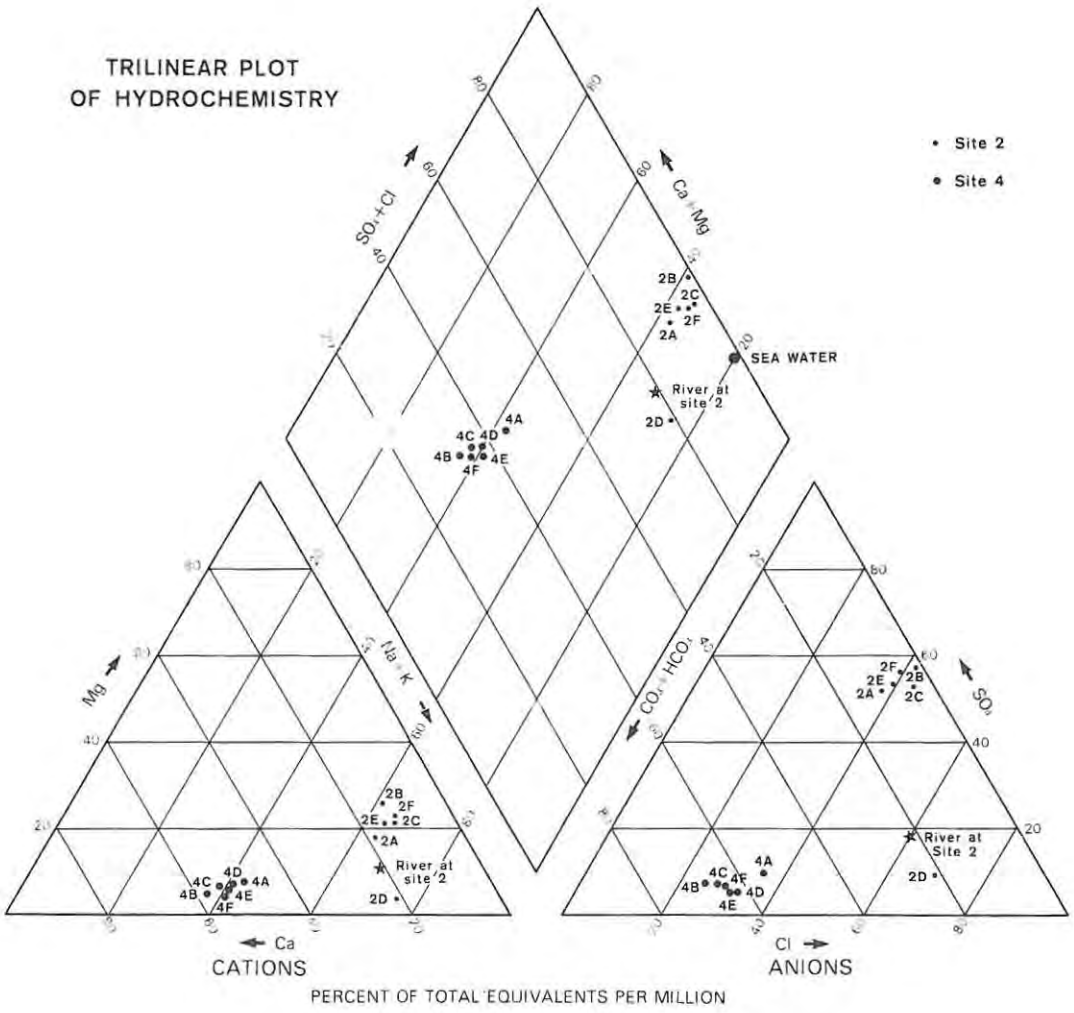

Figure 16: Trilinear plot of ground water chemistry at sites 2 and 4

2D (as determined on 3 August) was 1 to 0,0007 metres.

The mean electrical conductivity of well points A, B, C, E and F was 73,0 mS/m, that of the river 23,0 mS/m and at 2D measured 47,6 mS/m. Well point 2D also had the highest median faecal coliform count of 470 organisms per 100 ml compared to 33 faecal coliforms per 100 ml which is the median value for the 24 inland well points.

Evidence of faecal contamination was obtained from well points A, E and B. Well point E situated adjacent to the septic tank percolation system had a nitrate-nitrite nitrogen content of 11,47 mg per litre and DOC of 3,64 mg per litre. Twelve metres south of E, A had a nitrate-nitrite nitrogen value of 4,16 mg per litre, a DOC of 8,26 mg per litre and a median faecal coliform count of 105 organisms per 100 ml. The median faecal coliform count in the ground water adjacent to the percolation system (2E) and well points B, C and F was zero. Ground water at 2B had a nitrate-nitrite nitrogen content of 6,30 mg per litre and a DOC of 5,04 mg per litre. Thus soil conditions at site 2 appear suitable for the removal of microorganisms from ground water and in this area septic tanks do not constitute a pollution source.

6.4 Site 3 - off Valley Road

The Piper diagram in figure 17 shows that ground water at site 3

is fairly saline, the movement of ground water towards the Hout Bay River is indicated in figure 15-d. Of the 24 well points only 3A, B, C and E had positive faecal Streptococci counts (18, 4, 84 and 2 faecal Streptococci per 100 ml respectively). Although 3C had the highest bacteriological contamination of 140 faecal coliforms per 100 ml and 84 faecal Streptococci per 100 ml (median values) the nitrate-nitrite nitrogen content in ground water was low (0,45 mg per litre). High nitrate-nitrite nitrogen values occurred in well points A (19,88 mg per litre) and B (2,54 mg per litre) which also showed high potassium (8,37 and 8,73 mg per litre respectively) and DOC values (12,30 and 9,77 mg per litre respectively).

6.5 Site 4 - Milner Road

Ground water at site 4 (figure 18) can be classified as potable ground water according to the plot of ground water chemistry on the trilinear diagram in figure 16. Results of vertical electrical-soundings at site 4 (Appendix E) show that about 20 metres of alluvium overlies the fractured granite in the area. According to the geological map of Hout Bay (figure 4) the Quaternary deposits are classified as brackish calcareous soils. From the results of ground water analysis at site 4 although the water cannot be classified as brack (the mean TDS was 485,7 mg per litre whereas the TDS of brack water ranges from 1 000 to 10 000 mg per litre) the water had a high calcium content. The mean calcium content in ground water at sites 4 and 5 was 90,0 mg per litre compared to 21,1 mg per litre at sites 2 and 3.

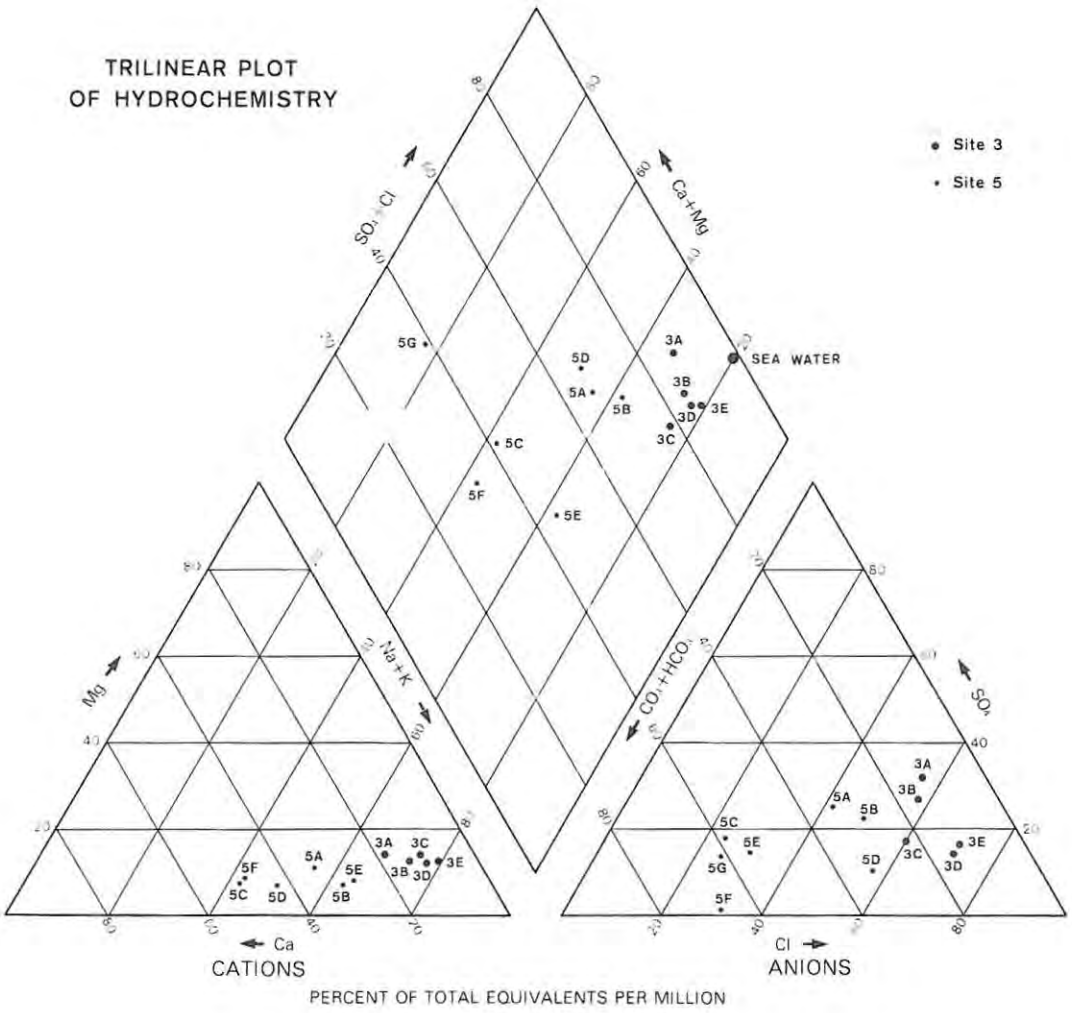

Figure 17: Trilinear plot of ground water chemistry at sites 3 and 5.

Examination of the ionic composition of ground water at site 4 showed that calcium comprised between 49,7 and 57,0 percent of the cations present.

Ground water at A, D and E has a greater chloride content (in excess of 105 mg per litre) than that of B (78,6 mg per litre), C (83,1 mg per litre) and F (89,1 mg per litre). The recommended chloride value which should not be exceeded in drinking water is 250 mg per litre (table 2, page 28). The difference in chloride content and depth to rest water level indicate the general direction of ground water movement which is shown in figure 18.

The only well point at site 4 having a median faecal coliform count above zero was 4A (120 faecal coliforms per 100 ml) which was situated adjacent to a septic tank percolation system. Median faecal Streptococci and coliphage values were zero in the ground water at site 4. Well point 4A had a very low water yield which showed no improvement after well development (methodology discussed in section 3.9.2). It is possible that a build up of bacterial slime hindered the free flow of water through the screen as the remaining 4 well points in the area yielded water freely when pumped. Although the presence of microorganisms was low, nitrate-nitrite nitrogen content was indicative of septic tank effluent throughflow, values were as follows:

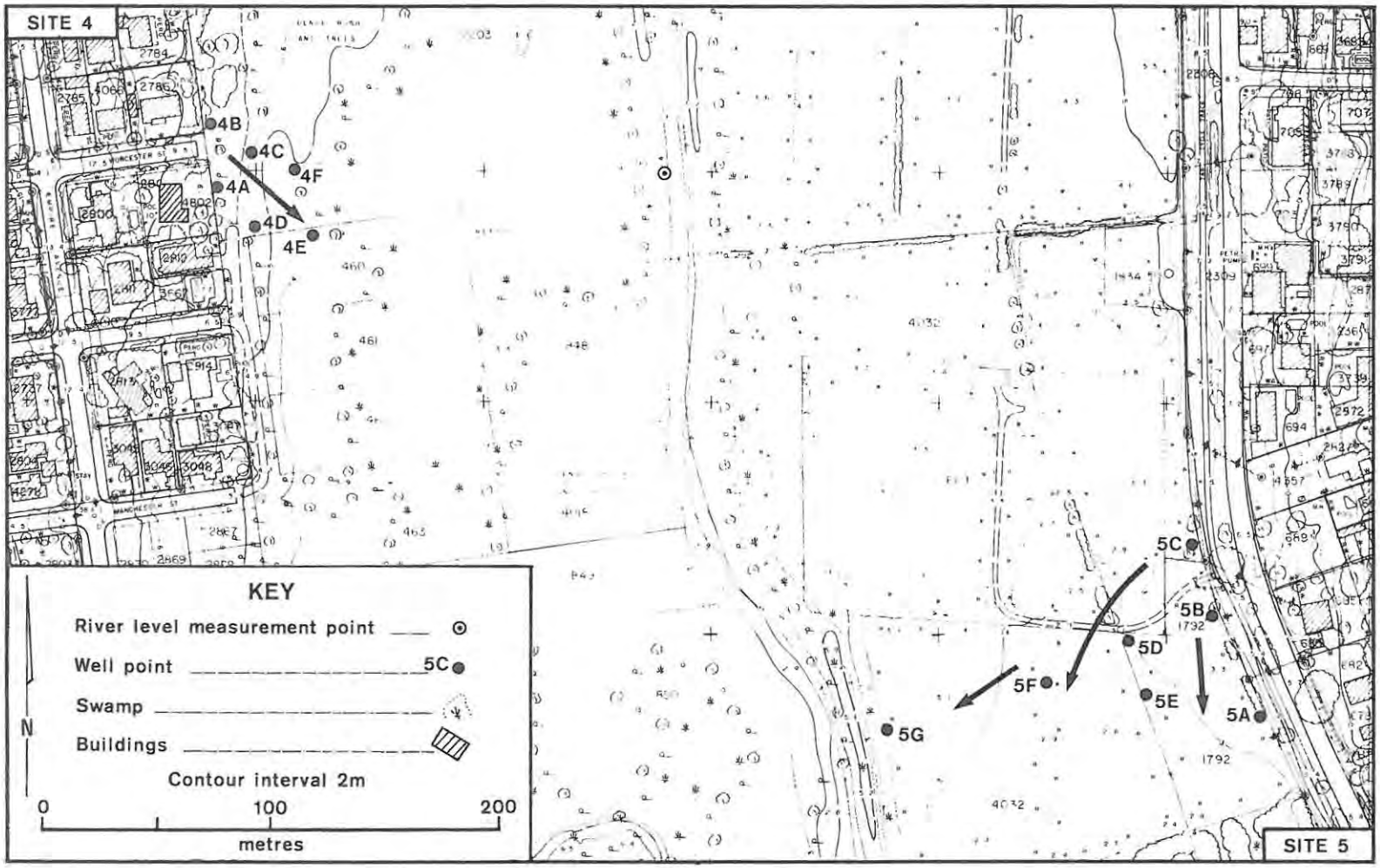

Figure 18: Well points at site 4 and 5 in relation to land use

Well Point at site 4	Nitrate-nitrite nitrogen (mg per litre)
A	1,24
B	4,46
C	4,24
D	2,91
E	2,40
F	5,84

The absence of faecal indicator organisms but presence of nitrate indicates that septic tank effluent at site 4 does not contribute to the bacteriological pollution of the Hout Bay River.

6.6 Site 5 - Main Road

Examination of the material encountered at depth at each well point during installation showed that soils varied from well point to well point at site 5 (figure 18) as shown in table C-1, Appendix C. The vertical electrical-sounding (sounding 7, Appendix E) at site 5 showed that a clay layer was overlain by 46 metres of alluvium. Sounding 13 (500 metres up slope of sounding 7 - figure E-1) showed a clay layer 6 metres thick 4,2 metres below the ground surface.

The residential area up slope of site 5 was the area of choice at the start of the study, however the presence of boulders

prevented drilling. Ground water chemistry at well points 5A to 5G is not only influenced by subsurface drainage from the residential area but also by farming activities (see frontispiece photograph) and road runoff. The trilinear plot of ground water hydrochemistry (figure 17) is quite scattered indicating different water types. The difference in ground water chemistry may be partly influenced by local soil conditions, the direction of ground water flow and land use. The direction of ground water flow, as indicated by ground water chemistry, is shown on figure 18. Large portions of the fields were marshy during the sampling periods and standing water in ditches between fields may also have influenced hydrochemistry.

The three well points closest to septic tanks had the highest nitrate-nitrite nitrogen values that is 9,07 mg per litre (5C), 5,07 mg per litre (5B) and 4,25 mg per litre (5A) and low ammonia-nitrogen values. Conversely well points D and F had high ammonia nitrogen values (1,99 and 3,24 mg per litre respectively) and low nitrate-nitrite nitrogen content. Although the presence of ammonia is indicative of fresh faecal contamination, it is not so at site 5 as well points D and F are further from potential sewage sources than A, B and C. The high ammonia values in D and F may be attributed to anaerobic conditions and high organic carbon content which together prevent the oxidation of ammonium to nitrate (Holden, 1970). Potassium values ranged from less than 5,5 mg per litre (in well points E, F and G) to 14,3 mg per litre (5D).

Bacteriological and viral contamination of ground water was low with only 33 faecal coliforms per 100 ml and 4 faecal coliforms per 100 ml (median values) recorded for well points 5C and 5A respectively.

At sites 4 and 5 an expanse of reed beds and standing water occurs between the Hout Bay River and each study site. Shallow ground water will therefore encounter the standing water before the river. At site 5 ground water movement may occur semi parallel to the Hout Bay River.

6.7 Seasonal variation in rest water levels

Generally the ground water level was higher during May and June and dropped to a low during the dry period of late July and August (see tables D-1 and D-2, Appendix D) the water level fluctuations did not show any distinct correlation to rainfall. Water levels at site 4 showed the least range of movement, varying by around 0,20 metres between dry and wet periods. Sites 3, 4 and 5 varied at each well point showing a water level fluctuation between 0,30 and 0,60 metres in dry and wet conditions.

The next chapter is a continuation of the discussion on ground water quality but focuses on the beach zone of Hout Bay.

CHAPTER 7

SUBSURFACE WATER IN THE BEACH ZONE

CHAPTER 7

SUBSURFACE WATER IN THE BEACH ZONE

7.1 Introduction

Pollution surveys examining surf zone and interstitial water quality along the beach of Hout Bay were carried out by Fricke et al. (1979), Eagle et al. (1980), Bartlett (1981) and Taljaard et al. (1985). Water samples were analysed for salinity, phosphate, nitrate, ammonia, silicate, dissolved oxygen and dissolved organic carbon. Sediment samples underwent particle size analysis and meiofauna examination. Increasing organic contamination of the beach and low meiofauna numbers indicated that the beach was in a stressed condition (Taljaard et al., 1985). The beach surveys were not done on a routine basis but enabled a general year by year comparison of organic pollution of the beach.

In the present study 8 permanent monitoring well points were installed along the beach in the configuration shown in figure 19. In the above mentioned surveys along Hout Bay beach interstitial water samples were obtained at a depth of 1 metre whereas in the present study the depth of well points ranged from 4,61 metres (hole 5) to 8,70 metres below the ground surface (hole 3). The purpose of the well points in the present study was to investigate ground water quality in the beach zone in relation to the total pollution load entering the bay (hypothesis

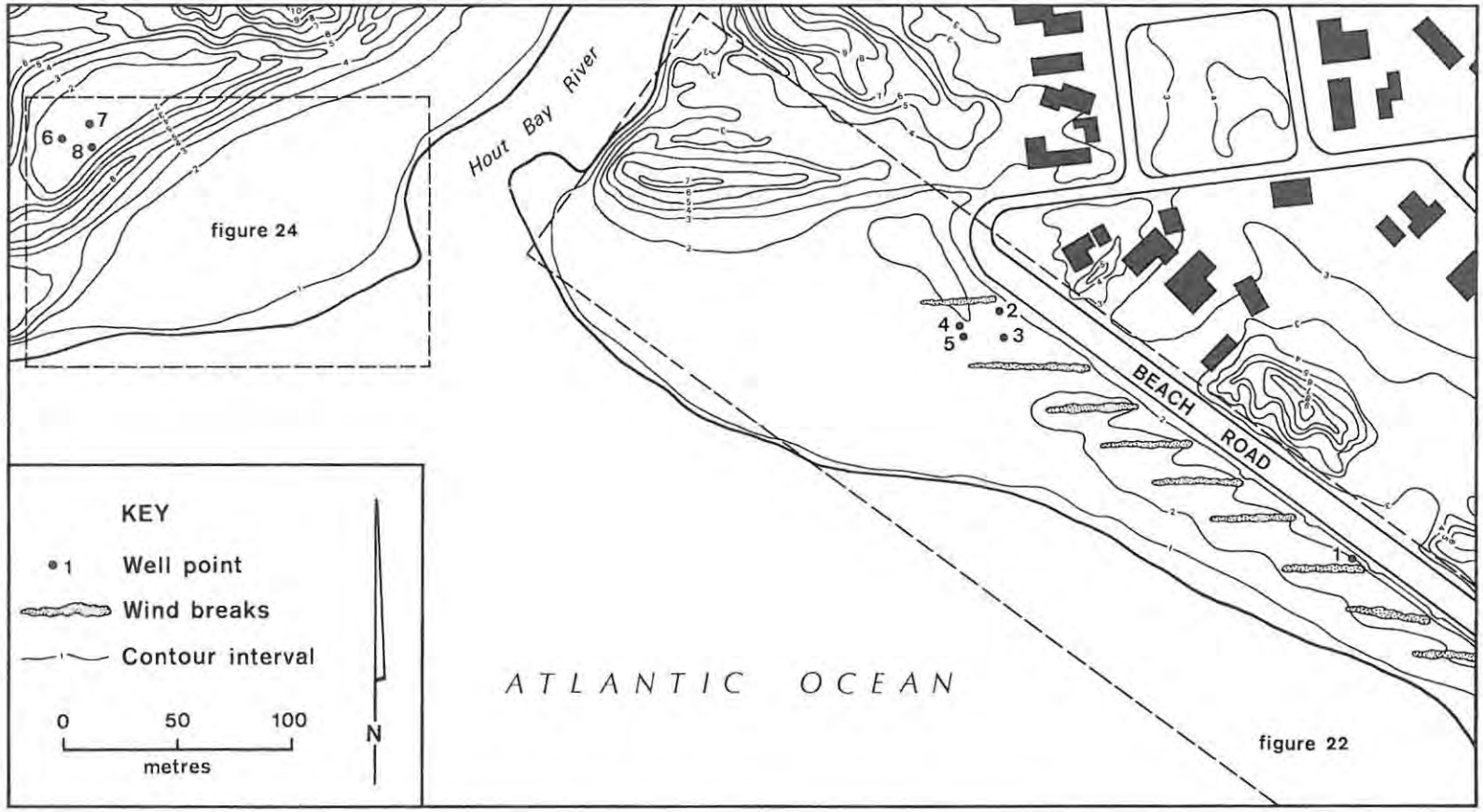

Figure 19: Location of beach well points

(iv) page 5) and not as a continuation of previous surveys. The depths of each well point, length and position of screen are given in Appendix C.

A geophysical survey was conducted along the Hout Bay beach to determine the depth to bedrock in the area of the river mouth. the 6 vertical electrical-soundings (Appendix E) showed highly conductive layers which indicates that the layers were saturated with sea water. The findings of the survey were inconclusive as it is difficult to determine which electrical layer represents bedrock.

7.2 Hydrochemistry of ground water in the beach zone

The mean TDS value of ground water at each well point is given below the bar charts in figure 20. TDS and EC of subsurface beachwater is partly influenced by the proximity of the sampling point to the sea (see section 7.3),on the east beach well points 4 and 5, the closest to the sea, had the highest EC values. The most distant well points, 2 and 3, had the lowest EC values that is 90 mS/m and 87 mS/m respectively.

To determine whether ground water quality varied with depth well points 4 and 5 were installed about a metre apart and the screen placed at different depths in each of the two well points. However, there was too much overlap with regard to the water level tapped as the screen position of well point 5 extended from a depth of 2,11 metres to 4,61 metres below the beach surface and that of well point 4 from 2,51 metres to 6,50 metres below the

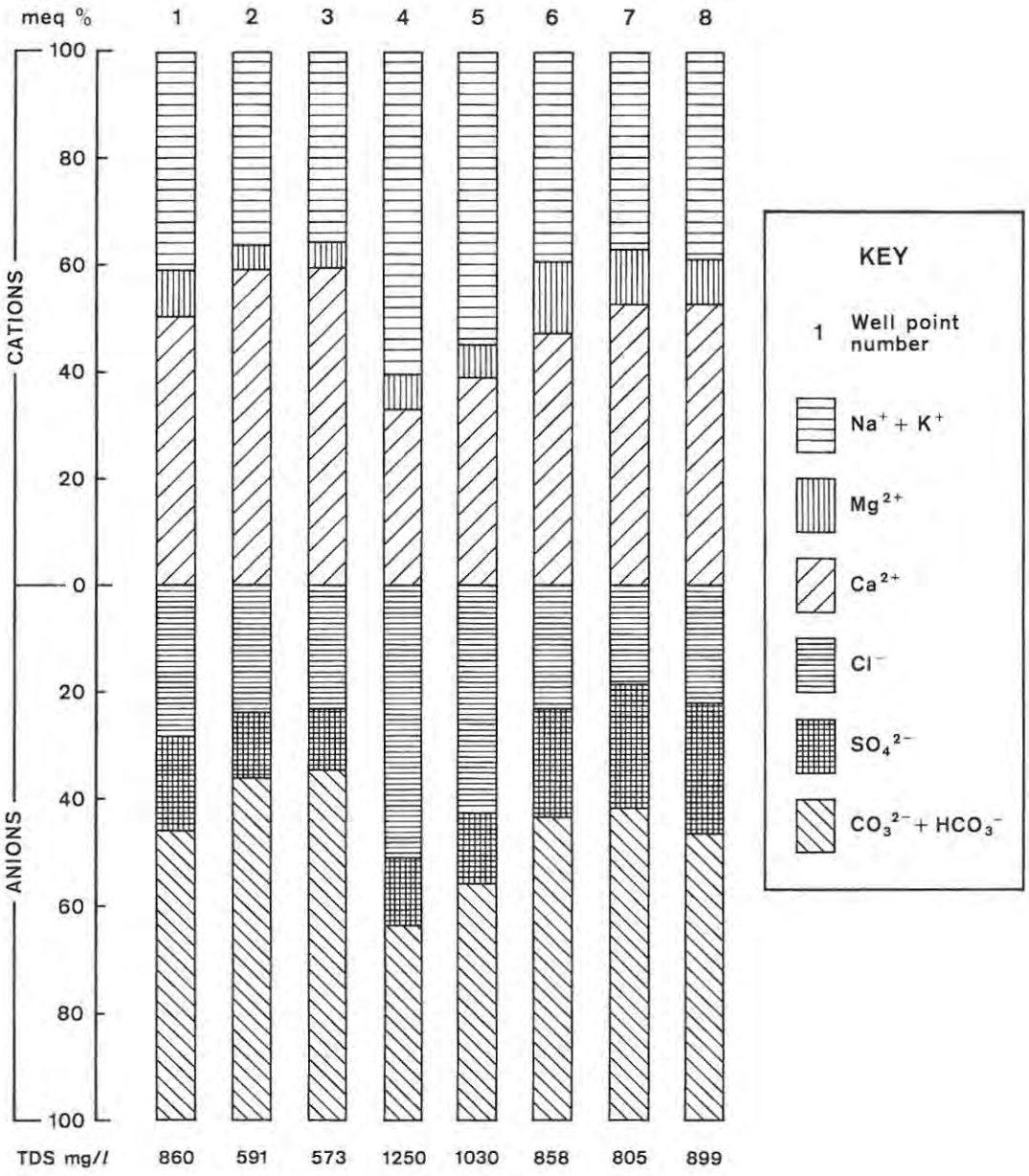

Figure 20: Bar charts showing ionic composition of ground water in the beach zone

beach surface. The difference in electrical conductivity at the well points can be attributed to the differences in sodium, chloride and sulphate, the mean values are as follows:

CHEMICAL CONSTITUENT	WELL POINT 4	WELL POINT 5
EC (mS/m)	202,0	182,0
sodium (mg/l)	231,7	173,4
sulphate (mg/l)	99,0	87,4
chloride (mg/l)	400,0	290,0

Down-the-hole EC profiles did not show much difference with depth, well points 6 and 7 for example increased by less than 5 mS/m between 2,30 and 6,00 metres. EC increased by 15 mS/m between 1,38 metres (rest water level) and 6,38 metres in well point 8 but decreased 3 mS/m between rest water level and the bottom of well point 1.

The bar charts in figure 20 show cationic (Na+K, Mg, Ca) and anionic (Cl, SO_4, CO_3 + HCO_3) composition of ground water at each well point. Well points 4 and 5 had the highest EC values, differing slightly from the other 6 well points in that both comprised over 55 percent sodium and potassium and had high chloride contents 51 and 43 percent respectively.

The plot of beach zone ground water on the Piper diagram in figure 21 is similar to the hydrochemistry of ground water at

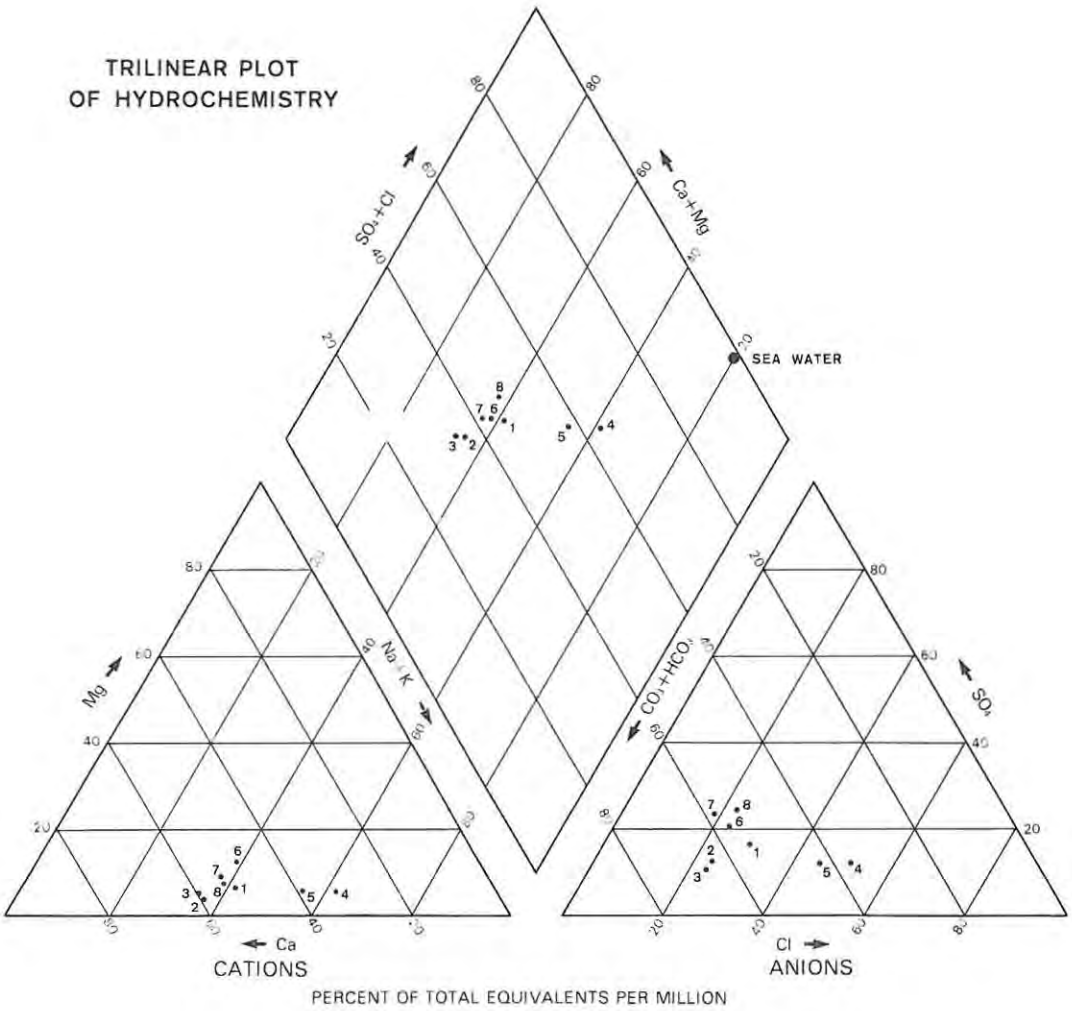

Figure 21: Trilinear plot of ground water chemistry in the beach zone

site 4 (inland well points) shown in figure 16. As seen on the geological map of Hout Bay (figure 4) site 4 and the beach zone comprise white sands with finely crushed shells as the two sites have a similar ground water composition - it appears that geology and not land use has the predominating influence on ground water quality in these areas.

Chemical constituents varied little during the period in which they were sampled, which was fortnightly from June to August. Dissolved organic carbon (DOC) and alkalinity were however, higher on 10 July and 26 July. The mean DOC for the beach well points was 8,9 mg per litre whereas that of ground water further inland was 6,6 mg per litre.

Nitrate-nitrite and ammonia

Well point 1 had the highest nitrate-nitrite concentration (6,29 mg per litre) but the lowest ammonia content (0,30 mg per litre). Well points 6 and 7 had nitrate-nitrite values of 0,95 mg per litre and 0,80 mg per litre respectively and fairly low ammonia content: 0,37 mg per litre and 0,35 mg per litre respectively. The greatest concentrations of ammonia were found in well points 4 (1,38 mg per litre) and 5 (1,59 mg per litre) where nitrate-nitrite values were very low (less than 0,1 mg per litre). High ammonia content in ground water is indicative of a fresh sewage input, nitrate-nitrite and phosphorus are also associated with

sewage input however the subsurface beach water had low phosphate values showing little correlation to nitrate-nitrite or ammonia content of the water.

Sulphate

Groundwater in holes 2, 3, 4 and 5 smelled strongly of hydrogen sulphide (H_2S) and had correspondingly low sulphate values (72,5 mg per litre) compared with well points 1, 6, 7 and 8 (135,4 mg per litre). The liberation of H_2S gas can be attributed to the activity of sulphate reducing bacteria (see page 36).

7.3 Conductivity profile of the east beach

Shallow holes were dug along the east beach at the locations shown in figure 22. The depth of the holes varied between 0,3 and 1,5 metres according to the depth at which water was encountered. The holes were deep enough to allow immersion of the conductivity probe for EC readings to be taken. Conductivity measurements were made the day after 17mm of rainfall and repeated at the same 26 sites (shown in figure 22) after 5 days of dry weather. EC values were lower after 5 dry days than after 17mm of rainfall in 19 of the 26 holes. In dry weather EC ranged from 8,4 mS/m (site R) to 4 750 mS/m (site B) and after rainfall from 17,7 mS/m (site N) to 1 745 mS/m (site B).

The profile revealed areas with very low EC values bordered by

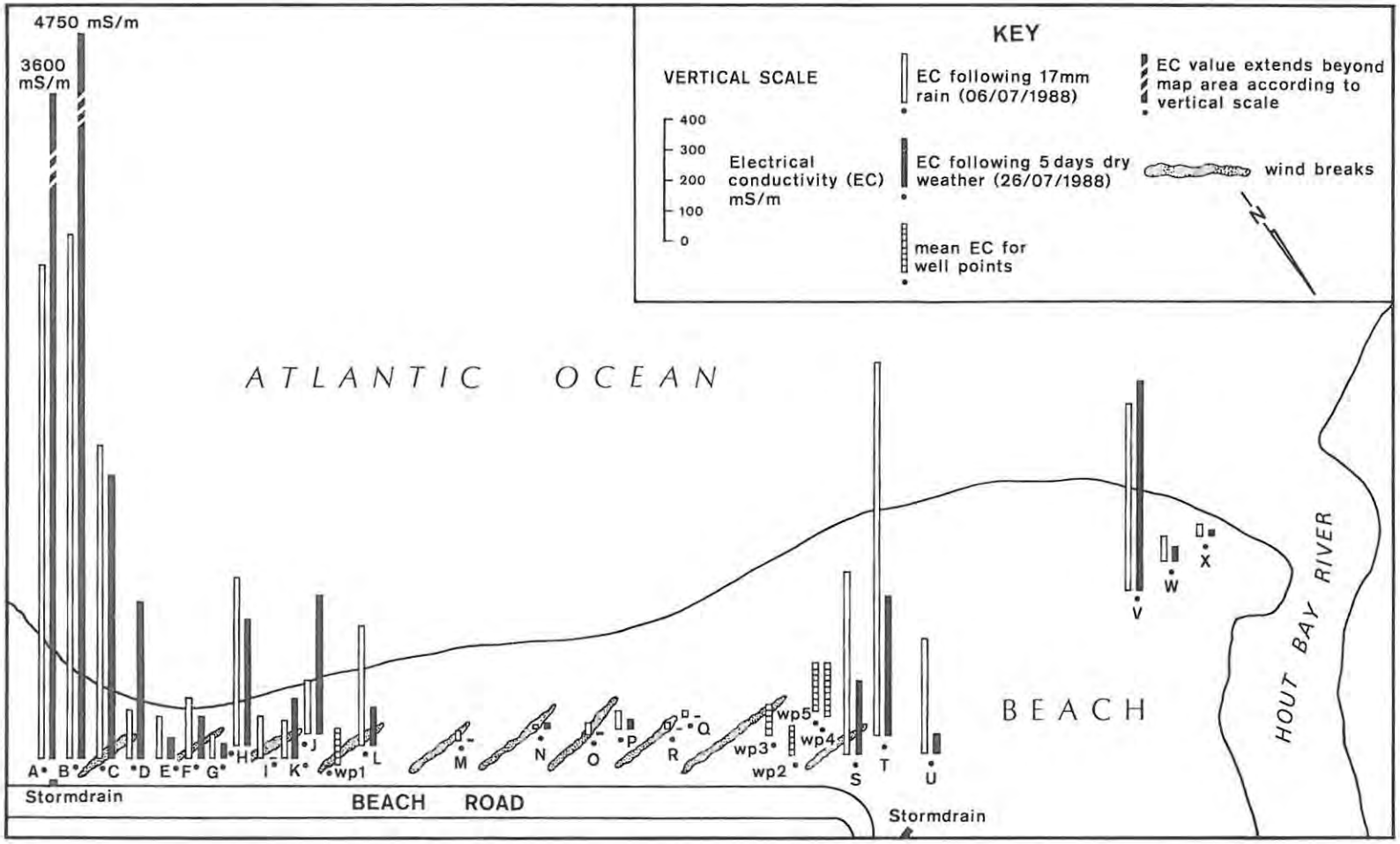

Figure 22: Electrical conductivity profile of east beach

much higher conductivities indicating the movement of water from inland through the beach zone into the sea. The dry weather EC at sites M-N-O were 16,0; 20,3 and 17,0 mS/m respectively and at Q and R 10,9 and 8,4 mS/m respectively. Wet weather values at the same sites were 22,8; 17,7; 43,7 and 21,0 and 20,8 mS/m.

Such low EC values can be attributed to 3 factors:

(i) a natural unpolluted freshwater input to the sea possibly of Baviaanskloof origin. The low EC values at the above mentioned sites are comparable to those found in tributaries to the Hout Bay River (mean 29,7 mS/m) and the upper reaches of the river at Orangekloof weir (12,4 mS/m) and in the Disa Stream (11,5 mS/m) and Original Disa stream (8 mS/m).

(ii) water of municipal supply origin. Household effluent could have low EC values but be microbiologically polluted. Only EC readings were taken at each site, as no other analyses were conducted there is little conclusive evidence as to the history and origin of the ground water passing through the beach zone. The lowest EC in the beach well points was 82 mS/m at BBH2 and in the inland well points was 33 mS/m at 1A.

(iii) natural ground water recharge by rainfall in the dune belt may also contribute to the fresh water throughput in the beach zone. Figure 19 shows a greater open dune area

behind sites M to R than behind the sites which had higher EC values. The two holes W and X adjacent to the river mouth also had relatively low EC values: 47,6 and 32,3 mS/m (dry weather) compared to that of the river on the same day (70 mS/m). The slightly higher conductivity values such as those at E (68,8 - dry; 128 - wet), F (134 - dry; 209 - wet) and G (89,3 - dry; 134 - wet) may be indicative of :

(i) a greater degree of mineralization of natural ground water, or

(ii) septic tank effluent throughflow.

The mean ammonia content of ground water at well points 4 and 5 was 1,38 mg per litre and 1,59 mg per litre respectively. The mean EC at 4 was 192 mS/m and at 5 was 158 mS/m. Sewage is a source of ammonia and nitrate (see pages 37 and 38) thus the high ammonia values at well points 4 and 5 are indicative of a sewage effluent throughflow.

7.4 Saltwater - freshwater interface

The saltwater - freshwater interface does not exist as a distinct boundary but as a zone of dispersion the shape and movement of which is controlled by freshwater and saltwater hydrodynamics. Tidal changes, water table fluctuations and to a lesser degree molecular diffusion influence the zone of dispersion (Todd,

1980). The projection of the saltwater tongue inland also varies according to on site storage capacity, permeability, transmissivity and vertical and horizontal anisotropy of the aquifer (Essaid, 1986). The results obtained in the EC beach profile (figure 22) can be explained in terms of saltwater-freshwater hydrodynamics particularly those at H and G and well points 2 and 4 which are further clarified by the three dimensional illustration in figure 23.

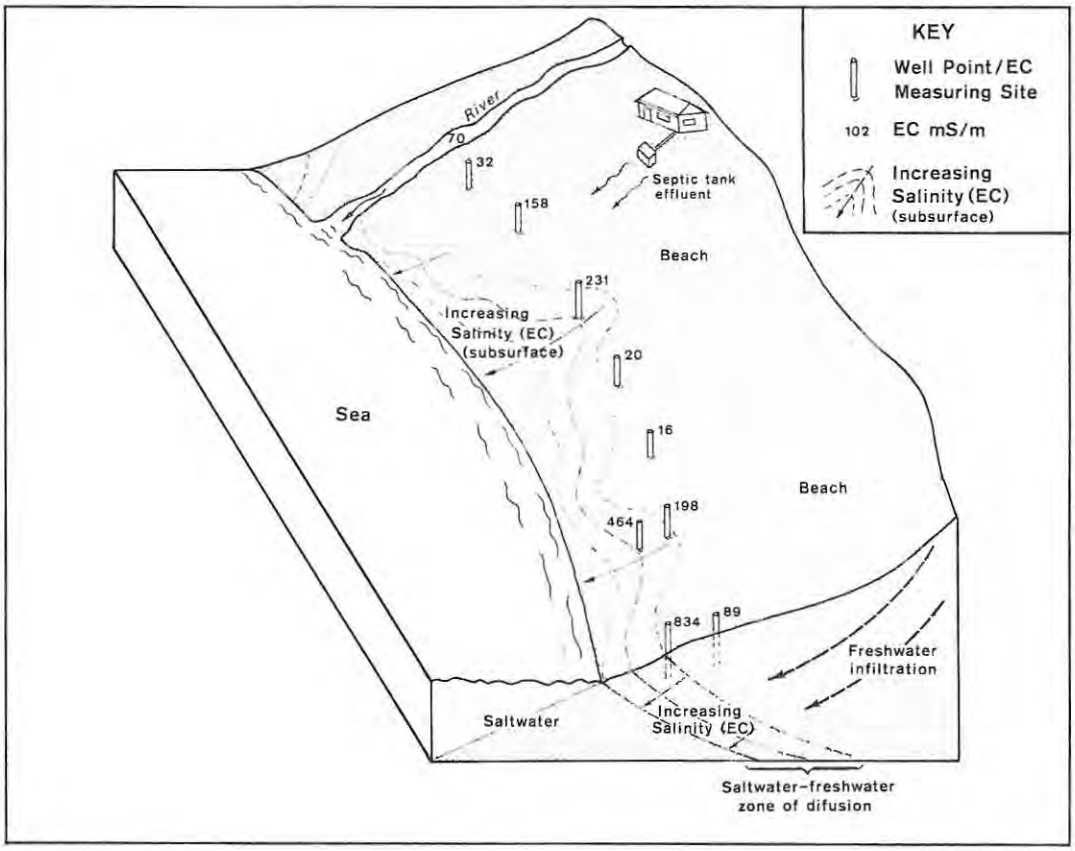

Figure 23: Schematic representation, based on east beach findings, on the effect of saltwater-freshwater zone of diffusion on electrical conductivity

7.5 Conductivity profile of the west beach

An isogram map of the west beach is given in figure 24 based on the electrical conductivity at 33 sites.

Factors influencing subsurface water quality on the west beach include:

(i) unpolluted, natural ground water input

(ii) characteristics of the saltwater-freshwater interface (illustrated in figure 23)

(iii) past river course (discussed below)

From the isogram map it appears that the electrical conductivity of subsurface water in this area is influenced by old river sediments. The area in which the survey was conducted was the path followed by the Hout Bay River since 1965 and was more recently the site of a lagoon which formed during summer when the river mouth was closed. Salts and sediment transported down the river are deposited in the lower reaches of the river particularly in the closed lagoon. These sediments raise the salinity of subsurface water according to salt deposits present in the sediment.

7.6 Microbiology of well points

Poly-flip a non-toxic, modified galactomannan was used in the jetting process during the installation of the beach well points.

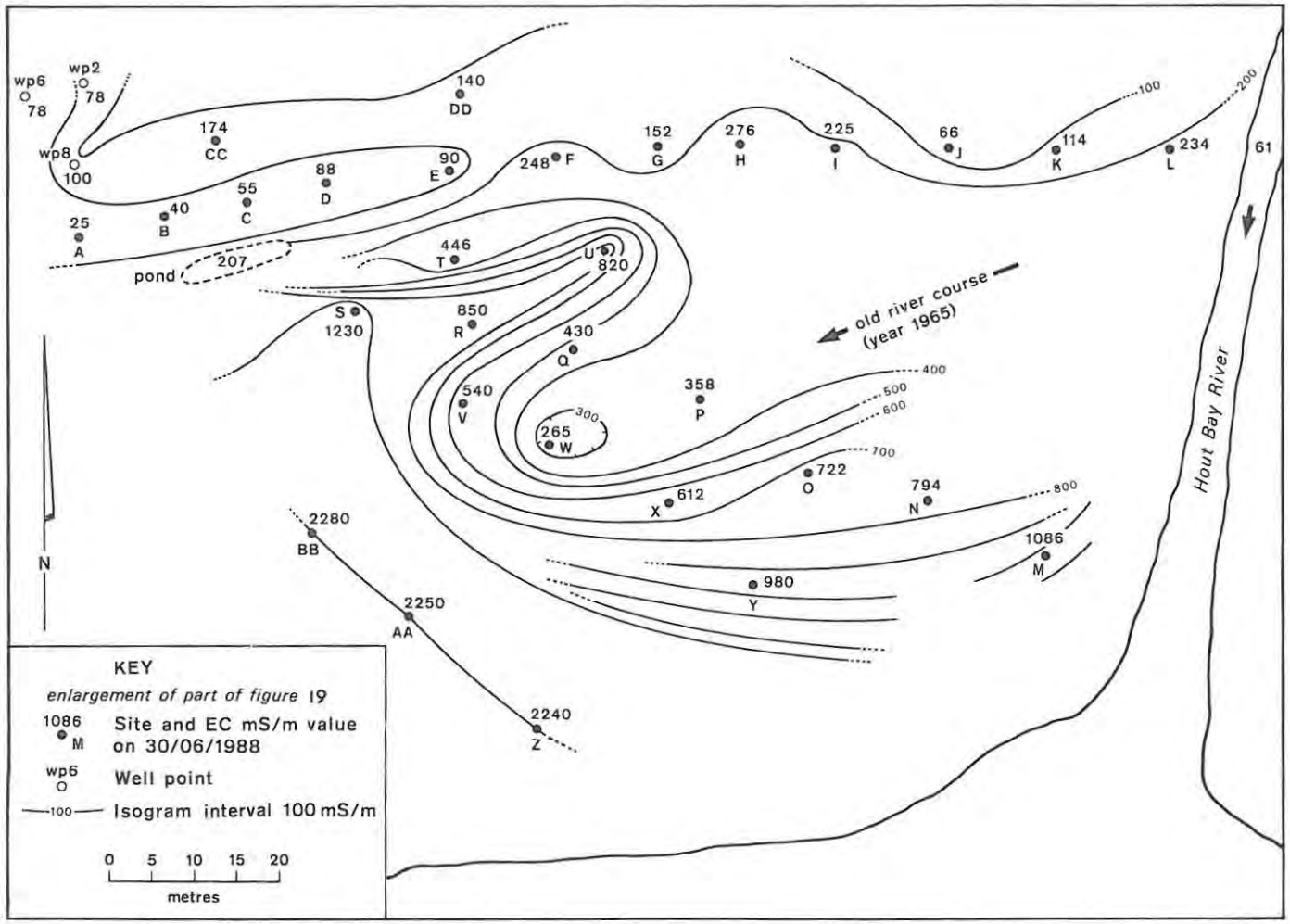

Figure 24: Isogram map of the west beach

The constituents of poly-flip act as nutrients for bacteria and although poly-flip reverts to a water-like constituency after 72 hours (SANCHEM specifications) microbiological analyses were only conducted a month after installation to avoid results that had been modified by remnants of poly-flip.

The well points showed a progressive decrease in faecal coliforms over the sampling period, microbiological data are given in table A-17, Appendix A. Possible explanations for the microbiological characteristics of the beach well points include:

(i) dilution with an increased throughflow of ground water during the rainfall season

(ii) a direct relationship between bacteriological activity and nutrient availability

(iii) true microbiological quality of ground water masked by the influence of poly-flip.

(i) It is unlikely that natural dilution related to the throughput of ground water in the beach zone is the cause of the attenuation of faecal coliforms as the chemical constituents (table A-18, Appendix A) did not indicate a similar trend.

(ii) Bacterial activity as related to nutrient availability could account for the spatial variability in faecal coliforms as could the presence of septic tank effluent. However if

this were the case faecal coliform numbers would have remained high over the sampling period as nutrients are replenished by the continued throughflow of ground water. Examination of the temporal decline of faecal coliforms indicates that the microbiology of the well points was influenced by factors other than nutrients or sewage effluent.

The presence of faecal Streptococci and coliphage in the subsurface beach water was scarce, only holes 6 and 7 had notable counts. The numbers of faecal Streptococci ranged from zero to 104 per 100ml and zero to 92 per 100 ml in well points 6 and 7 respectively. Coliphage was only present in three of the six sampling runs, well point 6 yielded a maximum of 32 organisms per 10 ml and well point 7 25 organisms per 10 ml but on separate dates.

(iii) Poly-flip, a galactomannan, is a nutrient source to bacteria. It is possible that bacteria are attracted to the nutrient source (chemotaxis) (Corapcioglu and Haridas, 1984) resulting in artificially high bacterial activity in the well points where poly-flip was used. With pumping (prior to sampling), well development (section 3.9.2) and gradual depletion of the nutrient source through the degradation of poly-flip the bacterial populations would decrease accordingly. Well points 1, 3, 4 and 5 decreased to a zero faecal coliform count as did faecal Streptococci and coliphage in all 8 well points. Results are

inconclusive and it is recommended that microbiological and chemical analyses be continued on the ground water in the beach zone over a longer period.

The next chapter draws together the findings of the preceeding 4 chapters to test the hypotheses stated in chapter 1.

CHAPTER 8

HYPOTHESIS TESTING AND DISCUSSION

8.1 Hypothesis testing

8.2 Discussion

8.3 Recommended control and preventive measures against further pollution of the Hout Bay River and surf zone

CHAPTER 8

HYPOTHESIS TESTING AND DISCUSSION

8.1 Hypothesis testing

Each of the hypotheses stated in section 1.3 (restated below) is examined in the context of the results obtained and accepted or rejected accordingly.

Hypothesis (i)

Inefficient septic tank systems are the major source of pathogenic pollutants in the surf zone of Hout Bay.

The average daily per capita sewage flow is between 130 and 180 litres per day (section 2.7). Using the 1986 population statistics (Blandy, 1986) the sewage flow from the Hout Bay residential area (excluding the harbour area) is an estimated 698 cubic metres per day. The average discharge of the Hout Bay River was $2,25 \times 10^4$ cubic metres per day during dry conditions and $1,24 \times 10^5$ cubic metres per day during wet conditions. Inputs to the Hout Bay River include rainfall, tributaries, stormdrain effluent and ground water. The throughflow from the shallow alluvial aquifers comprise septic tank effluent, infiltrated rainfall and irrigation return flow. Sewage effluent throughflow to the Hout Bay River is less than 4 percent of the total daily discharge of the river into the surf zone

during dry conditions and less than 1 percent during wet conditions.

In the areas in which ground water quality was monitored results showed that indicator organisms, which are normally found in primary sewage water, were not transported to ground water more than a few metres from septic tank systems (sections 6.3, 6.5 and 6.6). Such systems were functioning according to design (section 2.7) and are therefore not referred to as inefficient septic tank systems.

Surface overflow from septic tanks was observed on numerous occasions and sampling was conducted at 4 of the observed sites. Enumeration of faecal indicator organisms showed that effluent was highly contaminated and chemical analysis showed extreme values of nitrate-nitrite and ammonia (section 4.4.2). The highly polluted septic tank overflow was found to be one of the major sources of potential pathogens in the Hout Bay River and thus also in the surf zone of Hout Bay. The exact proportion of pollutants from stormdrains, septic tank overflow and runoff from roads and pastures is unknown. Hypothesis (i) is accepted with the following clarification:

Inefficient septic tank systems are <u>one</u> of the major sources of <u>potential</u> pathogens in the surf zone of Hout Bay.

Hypothesis (ii)

The total pollution load of the Hout Bay River system increases during the rainy season because of flushes of pollutants from stormdrains.

The concentration of chemical and microbiological pollutants in stormdrain effluent exceeded that of the Hout Bay River and its tributaries (section 4.4). Estimated values of the contribution by stormdrains to the total faecal coliform load of the Hout Bay River was 66,5 percent during a minor (15mm) storm event, 2 percent during wet conditions (less than 10mm rainfall) and 1 percent during dry conditions. The contribution by stormdrains to the TDS load of the Hout Bay River was estimated at 38 percent during a minor storm event, 12,5 percent during wet conditions and 2,8 percent during dry conditions (section 5.4). The hypothesis is therefore accepted.

The effect of residential development (section 2.7) is an increase in the pollution load of stormdrain effluent. Evidence obtained from monitoring the water quality along Baviaanskloof tributary showed a greater concentration of both chemical and microbiological pollutants downstream of the medium-density residential area than in the undeveloped area in the upper reaches of the same tributary (section 4.3.4). Thus not only does the total pollution load of the Hout Bay river system increase during wet conditions because of flushes of pollutants from stormdrains but it increases with an increase in residential

development.

Hypothesis (iii)

The total pollution load of the Hout Bay River system increases during the rainy season because of increased hydrodynamics of the ground water system.

Water levels in the inland well points did not show a direct response to rainfall. However, the water table was between 0,2 metres and 0,6 metres higher during the wet May - June period than during the dry period of late July and August (section 7.7). According to Darcy's law: $Q = KAS$ (Davis and De Weist, 1966) where Q is the rate of flow, K the hydraulic conductivity, A the cross-sectional area at right angles to the flow direction and $S = -\frac{dh}{dl}$. Thus transmission of an aquifer depends on the hydraulic conductivity and saturated thickness of the aquifer (Heath, 1983). In Hout Bay the elevated water table during the wet period results in a great transmissivity of ground water to the Hout Bay River system.

Monitoring of ground water quality at 4 study sites yielded evidence of throughflow of septic tank effluent in the alluvial layers overlying the weathered granite. Although there was evidence of effluent throughflow the ground water showed little microbiological contamination but where present contamination was highest adjacent to septic tank systems. According to the Piper

trilinear plot of hydrochemistry ground water at site 4 and at well points 5F and 5G had an ionic composition similar to that of potable ground water whereas ground water at sites 2,3 and well points 5A and 5E was saline (sections 6.2 to 6.6). The pollutant load transported by means of ground water flow to the Hout Bay River system thus varies from site to site according to land use (which governs the magnitude of the pollutant source), soil characteristics (which determine the removal of certain pollutants from ground water) and the rate of ground water flow (which increases during the wet period). Hypothesis (iii) is therefore accepted.

Hypothesis (iv)

The ground water discharge direct to the beach zone represents a minor contribution to the total pollution load.

In Hout Bay water enters the marine environment via the Hout Bay River (section 4.2), stormdrains discharging directly onto the beach (section 4.4.4) and ground water flow. The total ground water input comprises natural ground water free from anthropogenic influences, household effluent throughflow and natural recharge from rainfall. The geophysical survey along the beach zone was inconclusive (page 122) but the marine geophysical survey conducted by Wilson et al. (1987) in the area of the proposed sewerage outfall pipe south of the Sentinel showed that sediments reached a maximum of 26 metres. The deep soundings conducted by Kantey and Templer (1963) in the vicinity

of Princess Street bridge showed 22,8 metres comprising mainly sands. It is in the alluvial and weathered granite layers, which overly bedrock, where the ground water throughflow to the marine environment occurs. It was therefore necessary to monitor both the surface water and ground water quality in the beach zone.

Considering the magnitude of pollution discharging into the surf zone of Hout Bay via the Hout Bay River (table 4 and section 5.2), the pollutants transported by means of ground water flow (section 7.2 and 7.6) into the marine environment thus represent a minor contribution to the total pollution load.

Hypothesis (iv) is therefore accepted.

The decline in number of faecal coliforms, faecal Streptococci and coliphage in ground water in the beach zone was attributed to the presence of poly-flip (section 7.6 (iii)) however this aspect requires further investigation.

8.2 Discussion

In establishing a conceptual three dimensional hydrodynamic model of the Hout Bay catchment (section 3.1) various components of the hydrological cycle (shown in figure 7) were studied as separate entities. The hydrological system is however greater than the sum of the individual components, which are inter-related and

given the climate, geology, relief and land use patterns specific to Hout Bay together comprise a hydrodynamic system unique to Hout Bay. Thus the findings of this study are limited to the conditions of Hout Bay, however, the general principles governing the generation, transport, deposition and attenuation or exacerbation of pollutants in surface waters, ground water and the marine environment can be extrapolated to other hydrological investigations of a similar nature.

This study showed that surface water and not ground water was the major cause of pollution in the surf zone of Hout Bay. The aquifer system contributing to the baseflow of the Hout Bay River comprises a shallow alluvial aquifer and a deeper weathered granite aquifer. Recharge, by rainfall, to the weathered granite occurs mainly in the upper mountain slopes which are dominated by rocky outcrops and where there is little anthropogenic pollution. Conversely the ground water in the alluvial layers is largely influenced by mans activities.

Results of the geophysical survey (Appendix E) showed that on average the weathered granite occurred 9 metres below the ground surface and was overlain by alluvium. The maximum depth of the monitoring well points was 6,6 metres (as limited by the jetting method of installation), thus all the monitoring well points tapped the alluvial aquifer. The discussion of ground water quality in this study is therefore only applicable to the alluvial aquifer. The alluvial and weathered granite aquifers discharge into the Hout Bay River system or directly into the

marine environment. Ground water obtained from the well points showed little microbiological and chemical pollution. The pollutants transported to the Hout Bay River by means of shallow ground water flow thus constitute a minor part of the total pollution load of the river.

Section 8.3 lists a number of control measures against further pollution of the Hout Bay River and surf zone. The recommended measures are also aimed at preventing further degradation of the river through flooding and maintaining the quality of life of residents in Hout Bay.

8.3 Recommended control and preventive measures against further pollution of the Hout Bay River and surf zone

(i) The implementation of a reticulated sewerage system in Hout Bay may control further microbiological pollution particularly in view of the proposed residential development in the area.

(ii) As it will be a number of years before the sewerage system is operational, in the interim period conservancy tanks or compulsory pumping of septic tanks should be enforced where septic tank overflow is a recurring problem.

(iii) Where structurally feasible and in areas where microbiological pollution is particularly high stormdrains should be connected to the sewerage network and not discharge directly into the Hout Bay River.

(iv) The existing reed beds should not be cleared and the presence of new reed beds alongside the river should be encouraged for the following reasons:

- reed beds act as a buffer zone retarding the entry of stormwater into the river thereby reducing or staggering pollution peaks. Numerous smaller pollution peaks in stead of one large peak would in turn have less of a shockloading impact on the marine environment (page 85).

- by retarding the flow of storm water into the river bank erosion and river bed scour, as caused by the rapid entry of large volumes of water into the river, are thus prevented.

In view of the proposed development and with the limited space available, development within the 50 year floodplain (as delineated by HKS (1985)) has already taken place in certain areas. It is recommended that the reed beds be maintained and areas within the 50 year floodplain be kept as green zones to prevent flood damage.

(v) More frequent street cleaning particularly in medium to high density residential areas would reduce the pollutant load caused by road runoff during rainfall.

(vi) Control of dumping in the river by imposing heavy fines on the guilty party, this includes polluted effluent running into the river, tributaries and stormdrains.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

9.2 Recommendations for future research

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The main objective of the study was to determine the areas and activities which constitute a pollution source in Hout Bay and to ascertain the relative proportion which each contributes to the pollution of the surf zone. The objective was fulfilled and the study has provided greater insight into the pollution problems in Hout Bay and provided a detailed description of surface and ground water quality in the area.

In 1986 Hout Bay was only 32 percent developed, in view of the evidence of increases in microbiological pollution from residential areas and considering the proposed residential development installation of a reticulated sewerage system in Hout Bay is necessary. Although septic tank systems are not a pollution source to ground water, surface overflow from inefficient septic tank systems are a source of pollution and the pollutant load of the Hout Bay River would increase with residential development. As inefficient sep tic tank systems are one of a number of sources of pollution the installation of a reticulated sewerage network may control additional pollution to the Hout Bay River rather than solve the problem.

Stormdrain effluent in dry and wet conditions and surface runoff during rainfall are the main vectors transporting pollutants from residential areas, road surfaces, stables and pastures to the Hout Bay River. Although pollution concentrations are high during dry conditions the greatest pollution discharge to the surf zone of Hout Bay occurs during wet conditions, particularly during storm events. The potential impact of microbiological and chemical pollution of the marine environment is more severe during storm events when extreme pollution peaks occur as opposed to the gradual accumulative impact associated with dry conditions and low intensity, light rainfall.

It is necessary that development proceeds but not to the detriment of the marine environment or public health. In view of the recreational and aesthetic value of Hout Bay it is recommended that monitoring of the water quality of the Hout Bay River and surf zone be continued and where possible control measures undertaken to prevent further pollution of the marine environment.

9.2 Recommendations for future research

Given the time and financial constraints on the study much insight has been gained into the functioning of the hydrodynamic system in Hout Bay. However, it is recommended that further research be undertaken in the following areas:

1. Extension of the beach zone study area by installation of additional well points and continued monitoring of the chemical and microbiological quality of ground water in the beach zone.

2. Artificial tracer studies inland and in the beach zone to determine subsurface flow paths and flow rates in both the alluvial and weathered granite aquifers.

3. A detailed study into the spatial and temporal variation in microbiological quality of Hout Bay River sediments, comparing in particular the pre- and post-storm event samples.

4. Investigation into die-off rates of bacteria entering the marine environment along the Hout Bay coastline.

5. Greater emphasis on the presence of viruses, with a broader spectrum of viruses being enumerated in both surface and ground water.

6. Investigation into the gradual accumulation effect versus shockloading impact of chemical and microbiological pollutants on the marine biology.

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APPENDIX A

CHEMICAL AND MICROBIOLOGICAL DATA FOR SURFACE AND GROUND WATER SAMPLES

TABLES A-1 TO A-6

show the microbiological results

of surface water analysis in Hout Bay

fc = faecal coliforms / 100ml

fs = faecal Streptococci / 100ml

coli = coliphage / 10ml

o.o = no result available

Table A-1: Microbiological data for the Hout Bay River (routine sampling) during dry conditions

site	mt	dy	fc	fs	coli
1	1	19	1100	100	10
1	2	29	700	260	0
1	3	9	300	160	8
1	3	29	400	32	0
1	4	18	1050	188	51
1	5	9	2700	376	14
2-3	7	4	2000	3430	23
2-3	8	22	500	245	4
4	1	19	4600	300	0
4	2	29	3200	130	32
4	3	7	2400	1	0
4	3	29	2500	100	4
4	4	19	5200	260	2040
4	5	9	3150	620	3140
4	7	4	880	336	13
4	8	22	1000	100	2
5-5	7	4	690	160	10
6-5	7	4	490	160	7
6-5	8	22	60	76	0
7	1	19	3800	200	0
7	2	29	400	156	0
7	3	29	4400	148	4
7	4	18	1600	140	6
7	5	9	320	60	0
7	7	4	317	100	13
7	8	22	65	40	4
7-1	7	4	330	137	3
7-1	8	22	68	40	4
9-5	7	4	205	83	23
9-5	8	22	350	20	0
10	1	19	60000	750	4
10	2	29	630	24	0
10	3	7	27500	24	64
10	3	29	3800	48	0
10	4	19	1800	160	2
10	5	9	70	16	0
10	7	4	290	12	0
10	8	22	24	49	0
11-5	7	4	240	0	0
11-5	8	22	210	16	2
12	1	19	240	56	0
12	2	29	40	40	0
12	3	29	100	90	0
12	4	19	300	60	66
12	5	9	130	20	0
12	7	4	28	4	0
12	8	22	38	4	0
13	1	19	1020	108	94
13	2	29	3300	190	0

Table A-1: Continued

site	mt	dy	fc	fs	coli
13	3	9	2300	2820	0
13	3	29	1600	200	0
13	4	19	2700	590	560
13	5	9	2935	740	3020
13	7	4	1000	250	3
13	8	22	1010	200	4
15	1	19	8800	740	56
15	2	29	3300	660	0
15	3	7	5800	1020	0
15	3	29	2200	200	0
15	4	19	5200	540	1960
15	5	9	12200	2280	24200
15	7	4	1230	280	40
15	8	22	1090	330	2
15-1	7	4	1800	1290	16
15-1	8	22	1010	300	10
15-2	1	19	8400	692	26
15-2	7	4	8625	175	17
15-2	8	22	750	285	10
17	1	19	7300	752	22
17	2	23	500	560	0
17	3	7	470	400	0
17	3	29	380	820	0
17	4	18	1800	190	67
17	5	9	4200	640	1460
17	7	4	645	180	20
17	8	22	750	435	6
17-1	7	4	840	160	23
17-1	8	22	1080	435	54
17-2	7	4	810	159	13
17-2	8	22	60	8	0
20	1	19	490	284	16
20	3	29	1680	430	4
20	4	19	4900	630	280
20	5	9	8200	390	6600
20	7	4	790	168	30
20	8	3	660	90	4
20	8	15	430	364	10
20	8	22	720	370	30
21-5	7	4	395	190	3
24	5	11	1280	200	0
24	7	4	710	230	13
24	8	22	740	370	0
29	7	4	540	146	30
29	8	22	1000	185	2
30	7	4	555	800	33
30	8	22	640	330	0
34-5	7	4	575	150	17
34-5	8	22	775	380	4

Table A-1: Continued

site	mt	dy	fc	fs	coli
DRR	7	4	1550	195	13
DRR	8	3	670	110	4
DDR	8	16	3035	124	77
DDR	8	22	3820	56	14
RB2	8	3	550	80	6
RB2	8	15	490	96	0
RB3	8	3	670	70	4
RB3	8	15	390	176	0

Table A-2: Microbiological data for the Hout Bay River (routine sampling) during wet conditions

site	mt	dy	fc	fs	coli
1	5	23	209000	17000	16
1	6	6	107500	19600	16
1	6	20	20800	28	0
2-3	7	18	500	264	0
2-3	8	8	3300	1430	40
2-3	9	12	385	145	0
4	5	23	780	650	2
4	6	6	340	90	0
4	6	20	220	119	2
4	7	18	310	136	0
4	8	8	230	272	4
4	9	12	210	105	0
5-5	7	18	160	68	0
6-5	8	8	280	156	0
7	5	23	2900	1400	12
7	6	6	700	60	0
7	6	20	100	44	0
7	7	18	130	16	0
7	8	8	160	80	10
7	9	12	96	20	0
7-1	8	8	4	72	0
9-5	7	18	40	12	0
9-5	8	8	4	52	0
10	5	23	440	120	0
10	6	6	189	18	0
10	6	20	190	6	0
10	7	18	10	8	0
10	8	8	92	60	2
10	9	12	88	0	0
12	5	23	160	20	0
12	6	6	47	16	0
12	6	20	31	6	0
12	7	18	4	0	0
12	8	8	64	16	0
12	9	12	18	0	2
13	5	23	9300	6800	32
13	6	6	11600	7800	280
13	6	20	46000	250	8
13	7	18	370	96	0
13	8	8	1260	940	4
13	9	12	370	228	4
15	5	23	2400	1590	74
15	6	6	240	136	0
15	6	20	1160	1010	2
15	7	18	110	216	0
15	8	8	1800	1290	16
15	9	12	490	250	2
15-1	7	18	490	160	0

Table A-2: Continued

site	mt	dy	fc	fs	coli
15-1	8	8	2800	910	16
15-2	7	18	300	240	2
15-2	8	8	1600	870	28
15-2	9	12	730	410	6
17	5	23	3100	1620	4
17	6	6	400	152	0
17	6	20	2700	1310	8
17	7	18	1180	292	2
17	8	8	4600	1440	28
17	9	12	700	350	10
17-1	7	18	320	248	12
17-1	8	8	3200	1520	26
17-2	8	8	520	1024	8
20	5	23	3400	19200	22
20	6	6	400	152	0
20	6	20	1980	110	24
20	7	18	1600	68	16
20	8	3	660	90	4
20	8	8	1900	1010	54
20	8	15	430	364	10
20	9	12	570	440	8
24	5	11	1280	200	0
24	5	23	14400	5100	128
24	6	6	11800	11700	226
24	6	20	700	1000	4
24	7	18	1050	390	4
24	8	8	3000	1440	10
24	9	12	700	240	14
29	6	6	260	147	2
29	6	20	460	524	3
29	7	4	540	146	30
29	7	18	820	170	4
29	8	8	2000	1030	16
29	9	12	605	171	12
30	6	6	100	280	2
30	6	20	310	139	0
30	7	18	170	48	0
30	8	8	950	260	2
30	9	12	305	86	0
34-5	7	18	1650	280	14
34-5	8	8	4300	1140	22
34-5	9	12	554	270	14
DRR	7	18	110	32	0
DDR	8	8	260	224	2
DDR	9	12	56	31	2

Table A-3: Microbiological data for tributaries of the Hout Bay River during dry conditions

site	mt	dy	fc	fs	coli
3	1	19	230	144	0
3	2	29	510	320	0
3	3	7	510	980	0
3	3	29	30	90	0
3	4	19	2100	200	0
3	5	9	100	570	0
3	5	23	220	220	2
3	6	6	1100	420	2
3	8	22	320	310	2
5	2	29	20	4	0
5	3	7	0	20	0
5	3	29	8	728	0
5	4	19	388	70	0
5	6	6	300	321	2
5	6	20	230	90	0
5	8	22	0	70	0
9	1	19	630	136	0
9	2	29	590	100	0
9	3	7	250	40	0
9	3	29	340	40	0
9	4	19	2870	180	0
9	5	9	110	12	2
9	8	22	75	16	0
11	2	29	3200	160	0
11	3	9	98000	960	356
11	3	29	6000	390	0
11	4	19	7800	392	32
11	5	9	400	24	0
11	8	22	965	145	6
11-1	8	22	330	260	2
11-2	8	22	4	0	0
17-1	7	4	840	160	23
17-1	8	22	1080	435	54
18	1	19	204000	390	154
18	2	29	9100000	550	4
18	3	9	1200	672	0
18	3	29	22400	1032	8
18	4	19	74000	1228	6
18	5	9	13400	450	0
18	8	22	182	122	0
21	5	9	3300	210	0
21	8	22	40	28	0
27	5	9	111	64	0
27	8	22	12	4	0
31	8	22	16	4	0
34	8	22	16300	1890	4

Table A-4: Microbiological data for tributaries of the Hout Bay River during wet conditions

site	mt	dy	fc	fs	coli
3	5	23	220	220	2
3	6	6	1100	420	2
3	6	20	230	140	0
3	7	18	1060	568	30
5	5	23	3200	1350	0
5	6	6	300	321	2
5	6	20	230	90	0
5	7	18	280	160	0
5	8	8	36	130	2
9	5	23	31000	9500	18
9	6	6	200	340	0
9	8	8	340	140	0
11	5	23	1600	480	2
11	6	6	61	25	0
11	6	20	2000	55	12
11	7	18	1610	16	0
11	8	8	2500	60	2
11-1	8	8	380	276	0
11-2	8	8	70	8	0
17-1	7	18	320	248	12
17-1	8	8	3200	1520	26
18	5	23	2140	940	2
18	6	6	11000	6400	20
18	6	20	1290	570	0
18	8	8	5800	1630	0
21	5	23	27300	910	60
21	6	6	900	385	0
21	6	20	270	310	0
21	8	8	240	210	0
27	5	23	750	280	0
27	6	6	96	18	0
27	6	20	42	10	0
27	8	8	204	0	0
31	6	20	57	7	0
31	7	18	30	8	4
31	8	8	56	60	0
34	6	20	16000	360	115
34	7	18	13500	810	4
34	8	8	13000	1600	0

Table A-5: Microbiological data for stormdrain effluent during dry conditions

site	mt	dy	fc	fs	coli
2	2	29	83000000	860000	9000
2	3	7	15000000	420000	15600
2	3	29	14200	300	12
2	4	19	210000	40000	640
2	5	9	110000	26000	10400
6	2	29	750	2550	0
6	3	7	480	600	0
6	3	29	160	60	0
6	5	9	2060	24	0
6	8	22	850	40	0
8	2	29	5200	390	0
8	3	29	700	3800	0
8	4	19	9200	100	0
8	5	9	3750	157	2
8	8	22	3800	3600	0
14	1	19	54000	2300	96
14	2	29	670000	2470	0
14	3	9	70000	5000	0
14	3	29	6600	630	0
14	4	19	17900	7900	0
14	5	9	5200	1300	0
14	8	22	26000	1285	34
16	1	19	3800	920	4
16	2	29	7600	920	0
16	3	7	11600	420	0
16	3	29	1100	470	0
16	4	19	39000	6200	20
16	5	9	0.0	800	0
16	8	22	26000	2710	0
19	2	29	720000000	90000	44000
19	3	29	2280000000	30000	88000
22	5	9	25000	45000	0
22	8	22	10400	2650	0
23	8	22	190000	160000	275
33	8	22	1250	12600	60
WBC	7	13	70	104	0
CPH	1	22	3600000000	220000000	370000

Table A-6: Microbiological data for stormdrain effluent during wet conditions

site	mt	dy	fc	fs	coli
2	5	23	390000	96000	9240
2	6	6	58000	30000	524
2	6	20	43000	25000	17500
6	5	23	34000	28000	474
6	6	6	1800	1190	0
6	6	20	430	540	8
6	8	8	580	364	0
8	5	23	450000	450000	1460
8	6	6	166000	170000	690
8	6	20	2200	1285	0
8	8	8	64000	47000	142
14	5	23	74000	23600	660
14	6	6	4500	880	4
14	6	20	2300	1700	2
14	7	17	74000	173000	133
14	7	18	10700	2290	8
14	8	8	2400	3100	0
16	5	23	84000	22700	52
16	6	6	1880	410	10
16	6	20	3700	1600	6
16	7	17	245000	184000	97
16	7	17	179000	58000	15000
16	7	17	18500	27000	260
16	7	18	9200	2500	0.0
16	8	7	650000	48000	2
16	8	7	93000	92000	302
16	8	7	115000	2900	962
16	8	8	26000	1000	110
19-c	6	20	11500000	150000	21000
22	5	23	593000	302000	5980
22	6	6	130000	116000	512
22	6	20	7750	1635	1236
22	7	18	71000	14300	232
22	8	8	10500	7500	0
23	5	23	44000	45000	28
23	6	6	200000	77000	86
23	6	20	78000000	2330	88
23	7	18	1100	348	2
23	8	8	3700000	10400	0
28	5	23	1170000	3000	0
28	6	6	1000000	60000	414
28	6	20	900000	47000	3
32	6	20	34000000	76000	37200
33	6	20	7000	4700	77
WBC	7	7	2300	2800	0
MW	7	17	19000	3000	0
CPH	7	17	780000	3600	70

TABLES A-7 TO A-12

show the chemical results

of surface water analysis in Hout Bay

K	=	potassium (mg/l)
Na	=	sodium (mg/l)
Ca	=	calcium (mg/l)
Mg	=	magnesium (mg/l)
NH-4	=	ammonia as nitrogen (mg/l)
SO	=	sulphate (mg/l)
Cl	=	chloride (mg/l)
CaCO	=	total alkalinity as $CaCO_3$ (mg/l)
NO	=	nitrate and nitrite as nitrogen (mg/l)
P	=	phosphate as phosphorus (mg/l)
nm 545	)	
nm 275	)	UV absorbance at the respective wavelengths (nm)
nm 254	)	
DOC	=	dissolved organic carbon (mg/l)
EC	=	electrical conductivity (mS/m)
pH	=	pH (pH units)

o.o	)	
o.oo	)	no result available
o.ooo	)	

Table A-7: Chemical data for the Hout Bay River (routine sampling) during dry conditions

sit	mt	dy	K	Na	Ca	Mg	NH-4	SO-4	Cl	CaCO	NO
1	1	19	3.3	44.0	33.1	7.7	0.09	26.0	72.0	91.0	0.32
1	2	29	10.9	258.0	44.4	32.0	0.05	0.0	470.0	109.0	0.10
1	3	9	5.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.05
1	3	29	5.0	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
1	4	18	4.0	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
2-3	7	4	1.9	31.0	9.7	4.5	0.05	20.0	55.0	18.0	0.10
2-3	8	22	1.8	30.0	10.4	4.5	0.05	23.0	51.0	20.0	0.10
4	1	19	2.2	30.0	10.9	4.2	0.05	19.0	53.0	23.0	0.10
4	2	29	2.3	30.0	10.5	4.2	0.05	0.0	53.0	25.0	0.10
4	3	29	2.1	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
4	4	19	2.1	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
4	7	4	1.6	27.0	8.8	3.9	0.05	17.0	48.0	17.0	0.10
4	8	22	1.7	29.0	9.7	4.3	0.05	17.0	52.0	19.0	0.10
5	2	29	1.2	45.0	7.9	4.2	0.05	0.0	84.0	11.0	0.10
5	3	7	1.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.05
5	3	29	1.1	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
5	4	19	1.1	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
5	8	22	0.9	45.0	4.2	5.3	0.05	13.0	83.0	3.0	0.10
5-5	7	4	1.4	25.0	7.5	3.5	0.05	15.0	44.0	15.0	0.10
5-5	7	18	0.9	16.0	3.4	2.1	0.05	6.0	29.0	5.0	0.10
6	2	29	1.8	24.0	22.1	3.3	0.05	0.0	38.0	50.0	0.10
6	3	7	3.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.05
6-5	7	4	1.3	23.0	7.2	3.1	0.05	13.0	40.0	15.0	0.10
6-5	8	22	1.3	23.0	7.9	2.9	0.05	14.0	39.0	18.0	0.10
7	1	19	1.5	24.0	7.4	2.7	0.05	14.0	40.0	16.0	0.10
7	2	29	1.6	23.0	7.0	2.8	0.05	0.0	41.0	18.0	0.10
7	3	29	1.5	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
7	4	18	1.5	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
7	7	4	1.1	21.0	5.1	2.7	0.05	9.0	38.0	10.0	0.10
7	8	22	1.1	20.0	5.5	2.6	0.05	10.0	35.0	12.0	0.10
7-1	7	4	1.0	21.0	4.5	2.7	0.05	9.0	38.0	9.0	0.10
7-1	8	22	1.1	21.0	5.3	2.7	0.05	10.0	37.0	12.0	0.10
9-5	7	4	1.1	21.0	4.5	2.6	0.05	10.0	37.0	9.0	0.10
9-5	8	22	1.3	24.0	9.7	3.3	0.05	11.0	44.0	22.0	0.10
10	1	19	1.4	23.0	7.9	2.6	0.07	23.0	30.0	20.0	0.10
10	2	29	1.4	21.0	2.7	2.2	0.05	0.0	37.0	7.0	0.10
10	3	7	1.8	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.05
10	3	29	1.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
10	4	19	1.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
10	7	4	1.0	19.0	2.7	2.4	0.05	10.0	33.0	4.0	0.10
10	8	22	0.8	18.0	2.2	2.2	0.05	8.0	32.0	4.0	0.10
10	9	12	0.8	16.0	2.0	2.0	0.05	6.0	28.0	4.0	0.10
11	2	29	1.7	21.0	5.3	2.2	0.05	0.0	36.0	12.0	0.13
11	3	9	1.8	0.0	0.0	0.0	0.16	0.0	0.0	0.0	0.12
11	3	29	1.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
11	4	19	1.5	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
11	8	22	1.4	22.0	20.9	3.2	0.07	20.0	39.0	42.0	0.50
11-5	7	4	0.9	18.0	2.4	2.2	0.05	7.0	33.0	4.0	0.10
11-5	8	22	0.7	17.0	4.1	2.1	0.05	8.0	30.0	9.0	0.10

Table A-7: Continued

sit	mt	dy	K	Na	Ca	Mg	NH-4	SO-4	Cl	CaCO	NO
12	1	19	1.2	19.0	1.7	2.0	0.05	13.0	28.0	5.0	0.10
12	2	29	1.1	19.0	1.3	1.8	0.05	0.0	32.0	5.0	0.10
12	3	9	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.10
12	4	19	1.1	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.01
12	7	4	0.8	17.0	1.5	2.1	0.05	7.0	31.0	1.0	0.10
12	8	22	0.6	17.0	1.1	1.9	0.05	7.0	28.0	2.0	0.10
13	1	19	2.1	31.0	10.0	4.4	0.05	23.0	52.0	21.0	0.10
13	2	29	2.5	32.0	11.7	4.5	0.05	0.0	56.0	26.0	0.10
13	3	9	2.7	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.05
13	3	29	2.4	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
13	4	19	2.4	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
13	7	4	1.7	29.0	9.1	4.3	0.05	18.0	52.0	16.8	0.10
13	8	22	1.8	30.0	10.5	4.6	0.05	24.0	52.0	19.0	0.10
15	1	19	2.5	36.0	11.9	6.0	0.05	27.0	62.0	27.0	0.10
15	2	29	2.9	38.0	12.5	5.9	0.05	0.0	68.0	29.0	0.10
15	3	7	3.4	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.05
15	3	29	2.6	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
15	4	19	2.8	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
15	7	4	2.0	33.0	11.9	5.5	0.05	20.0	61.0	24.0	0.10
15	8	22	2.3	36.0	14.0	6.0	0.06	25.0	64.0	31.0	0.30
15-1	7	4	2.1	34.0	13.6	5.7	0.05	23.0	62.0	27.0	0.10
15-1	8	22	2.1	35.0	14.6	5.9	0.05	26.0	60.0	23.0	0.10
15-2	1	19	10.0	35.0	11.9	5.7	0.05	28.0	62.0	27.0	0.10
15-2	7	4	1.9	32.0	11.1	5.2	0.05	23.0	57.0	21.0	0.10
15-2	8	22	2.0	34.0	11.9	5.7	0.05	26.0	59.0	25.0	0.10
17	1	19	2.8	41.0	23.4	7.4	0.07	26.0	70.0	63.0	0.10
17	2	23	3.4	49.0	27.4	7.7	0.05	0.0	84.0	73.0	0.10
17	3	7	3.5	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.05
17	3	29	3.2	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.56
17	4	18	4.6	0.0	0.0	0.0	0.30	0.0	0.0	0.0	0.10
17	7	4	2.6	40.0	29.6	7.3	0.10	24.0	65.0	74.0	0.10
17	8	22	2.5	40.0	22.1	7.1	0.11	26.0	72.0	53.0	0.10
17-2	7	4	2.3	38.0	19.8	6.6	0.10	24.0	65.0	48.0	0.10
20	1	19	2.6	38.0	17.9	6.2	0.07	24.0	65.0	47.0	0.10
20	3	29	2.6	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
20	4	19	2.7	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
20	7	4	2.2	35.0	15.3	5.9	0.06	26.0	60.0	33.0	0.10
20	8	3	2.1	34.0	15.2	5.6	0.05	18.0	59.0	31.0	0.10
20	8	15	2.1	36.0	16.4	6.0	0.06	26.0	61.0	35.0	0.21
20	8	22	2.2	36.0	15.4	6.0	0.08	26.0	61.0	33.0	0.20
21-5	7	4	1.3	23.0	6.4	3.1	0.05	12.0	41.0	13.0	0.10
24	5	11	3.9	59.0	43.3	11.0	0.05	23.0	102.0	127.0	0.10
24	7	4	3.0	52.0	27.0	8.9	0.10	26.0	90.0	69.0	0.10
24	8	22	2.9	50.0	23.7	8.0	0.17	30.0	87.0	58.0	0.10
29	7	4	1.7	30.0	9.8	4.7	0.05	20.0	52.0	19.0	0.10
29	8	22	2.0	33.0	10.9	5.1	0.05	23.0	57.0	22.0	0.10
30	7	4	1.4	24.0	7.3	3.4	0.05	10.0	44.0	15.0	0.10
30	8	22	1.7	25.0	8.7	3.5	0.05	15.0	43.0	18.0	0.10
34-5	7	4	2.9	50.0	26.4	8.7	0.10	27.0	84.0	67.0	0.10

Table A-7: Continued

sit	mt	dy	K	Na	Ca	Mg	NH-4	SO-4	Cl	CaCO	NO
34-5	7	18	1.7	24.0	9.9	3.7	0.05	10.0	40.0	24.0	0.10
34-5	8	22	2.7	45.0	23.1	7.4	0.05	28.0	77.0	56.0	0.10
DRR	7	4	1.3	23.0	7.0	3.2	0.05	12.0	42.0	14.0	0.10
DRR	8	3	1.4	22.0	8.4	3.2	0.05	12.0	39.0	17.0	0.10
DDR	8	16	1.4	24.0	8.3	3.2	0.05	16.0	41.0	16.0	0.10
DDR	8	22	1.4	24.0	7.8	3.1	0.05	15.0	40.0	17.0	0.10
RB2	8	3	1.7	28.0	11.6	4.2	0.05	15.0	50.0	22.0	0.10
RB2	8	15	1.8	28.0	10.5	4.3	0.05	17.0	51.0	21.0	0.16
RB3	8	3	1.8	29.0	11.1	4.5	0.05	15.0	52.0	22.0	0.10
RB3	8	15	2.0	32.0	11.2	4.8	0.05	25.0	53.0	21.0	0.19

Table A-7: Continued

sit	mt	dy	P	nm545	nm275	nm245	DOC	EC	pH
1	1	19	0.05	0.022	0.758	0.940	0.0	46.0	8.30
1	2	29	0.05	0.000	0.000	0.000	4.4	175.0	8.00
1	3	9	0.05	0.000	0.000	0.000	8.0	64.0	0.00
1	3	29	0.05	0.000	0.000	0.000	7.0	76.0	0.00
1	4	18	0.05	0.000	0.000	0.000	7.3	63.0	7.65
2-3	7	4	0.05	0.017	0.757	0.935	4.8	26.0	6.90
2-3	8	22	0.05	0.018	0.726	0.897	4.5	26.0	7.00
4	1	19	0.05	0.020	0.737	0.908	0.0	24.5	7.50
4	2	29	0.05	0.000	0.000	0.000	4.1	26.0	7.50
4	3	29	0.05	0.000	0.000	0.000	4.7	25.0	7.60
4	4	19	0.05	0.000	0.000	0.000	3.7	25.0	7.30
4	7	4	0.05	0.017	0.759	0.938	4.9	23.0	6.90
4	8	22	0.05	0.016	0.688	0.851	4.7	25.0	6.90
5	2	29	0.05	0.000	0.000	0.000	1.2	33.0	6.70
5	3	7	0.05	0.000	0.000	0.000	1.7	33.0	0.00
5	3	29	0.05	0.000	0.000	0.000	1.3	33.0	7.40
5	4	19	0.05	0.000	0.000	0.000	1.9	31.5	7.30
5	8	22	0.05	0.005	0.313	0.387	1.8	33.0	5.60
5-5	7	4	0.05	0.021	0.843	1.034	4.9	21.0	6.90
5-5	7	18	0.05	0.070	2.037	2.443	9.1	13.0	6.20
6	2	29	0.05	0.000	0.000	0.000	2.7	27.0	7.80
6	3	7	0.05	0.000	0.000	0.000	5.0	37.0	0.00
6-5	7	4	0.05	0.022	0.840	1.028	4.9	19.0	6.70
6-5	8	22	0.05	0.021	0.723	0.882	4.8	20.0	6.80
7	1	19	0.05	0.021	0.685	0.828	0.0	18.5	7.25
7	2	29	0.05	0.000	0.000	0.000	3.1	19.0	7.40
7	3	29	0.05	0.000	0.000	0.000	3.6	20.0	0.00
7	4	18	0.05	0.000	0.000	0.000	3.1	19.5	7.20
7	7	4	0.05	0.022	0.828	1.011	4.7	17.0	6.70
7	8	22	0.05	0.022	0.764	0.928	4.5	17.0	6.70
7-1	7	4	0.05	0.024	0.888	1.084	4.9	16.0	6.50
7-1	8	22	0.05	0.023	0.763	0.925	4.2	17.0	6.80
9-5	7	4	0.05	0.024	0.855	1.089	4.7	16.0	6.50
9-5	8	22	0.05	0.018	0.578	0.701	3.2	22.0	6.90
10	1	19	0.05	0.048	1.246	1.483	0.0	23.5	7.55
10	2	29	0.05	0.000	0.000	0.000	2.9	15.0	6.80
10	3	7	0.05	0.000	0.000	0.000	4.9	15.0	0.00
10	3	29	0.05	0.000	0.000	0.000	3.4	16.0	0.00
10	4	19	0.05	0.000	0.000	0.000	2.2	15.0	6.60
10	7	4	0.05	0.026	0.920	1.117	4.9	14.0	6.20
10	8	22	0.05	0.024	0.797	0.964	4.3	14.0	6.10
10	9	12	0.05	0.063	1.457	1.745	6.3	12.0	6.00
11	2	29	0.05	0.000	0.000	0.000	2.6	17.0	7.10
11	3	9	0.13	0.000	0.000	0.000	9.5	18.5	0.00
11	3	29	0.05	0.000	0.000	0.000	3.6	20.0	0.00
11	4	19	0.05	0.000	0.000	0.000	3.3	17.5	7.15
11	8	22	0.05	0.013	0.874	1.080	7.7	26.0	7.20
11-5	7	4	0.05	0.027	0.974	1.180	5.2	13.0	6.10
11-5	8	22	0.05	0.024	0.834	1.007	4.4	14.0	6.70
12	1	19	0.05	0.031	0.681	0.812	0.0	12.5	6.50

Table A-7: Continued

sit	mt	dy	P	nm545	nm275	nm245	DOC	EC	pH
12	2	29	0.05	0.000	0.000	0.000	3.3	13.0	6.50
12	3	9	0.05	0.000	0.000	0.000	2.3	13.0	0.00
12	4	19	0.05	0.000	0.000	0.000	2.6	13.5	6.65
12	7	4	0.05	0.027	0.970	1.179	5.3	12.0	5.30
12	8	22	0.05	0.027	0.869	1.048	3.6	12.0	5.60
13	1	19	0.05	0.027	0.827	1.014	0.0	26.0	7.50
13	2	29	0.05	0.000	00000	0.000	4.2	27.0	7.70
13	3	9	0.05	0.000	0.000	0.000	5.7	27.0	0.00
13	3	29	0.05	0.000	0.000	0.000	4.7	27.0	0.00
13	4	19	0.05	0.000	0.000	0.000	4.3	26.5	7.40
13	7	4	0.05	0.020	0.788	0.975	5.2	24.0	7.00
13	8	22	0.05	0.016	0.701	0.869	4.1	26.0	6.80
15	1	19	0.05	0.021	0.741	0.914	0.0	31.5	7.50
15	2	29	0.05	0.000	0.000	0.000	5.0	33.0	7.65
15	3	7	0.05	0.000	0.000	0.000	5.5	32.0	0.00
15	3	29	0.05	0.000	0.000	0.000	4.8	33.0	0.00
15	4	19	0.05	0.000	0.000	0.000	4.3	34.0	7.10
15	7	4	0.05	0.016	0.716	0.888	5.1	29.0	7.00
15	8	22	0.05	0.013	0.652	0.814	3.9	32.0	7.10
15-1	7	4	0.05	0.032	0.840	1.029	5.2	30.0	6.90
15-1	8	22	0.05	0.012	0.614	0.768	4.0	31.0	6.70
15-2	1	19	0.05	0.021	0.781	0.962	0.0	30.5	7.50
15-2	7	4	0.05	0.031	0.826	1.013	5.2	27.0	6.90
15-2	8	22	0.05	0.013	0.652	0.811	5.4	30.0	6.70
17	1	19	0.05	0.015	0.733	0.910	0.0	40.0	7.80
17	2	23	0.05	0.000	0.000	0.000	6.3	46.0	8.00
17	3	7	0.05	0.000	0.000	0.000	6.3	39.0	0.00
17	3	29	0.05	0.000	0.000	0.000	5.9	75.0	0.00
17	4	18	0.05	0.000	0.000	0.000	9.5	27.5	7.60
17	7	4	0.05	0.019	0.764	0.948	5.0	41.0	7.30
17	8	22	0.05	0.014	0.690	0.861	5.1	39.0	7.10
17-2	7	4	0.05	0.013	0.704	0.878	4.8	35.0	7.10
20	1	19	0.05	0.021	0.729	0.903	0.0	35.0	7.80
20	3	29	0.05	0.000	0.000	0.000	5.2	38.0	0.00
20	4	19	0.05	0.000	0.000	0.000	5.3	38.0	7.65
20	7	4	0.05	0.017	0.744	0.922	4.4	31.0	6.90
20	8	3	0.05	0.026	0.840	1.040	5.6	32.0	7.00
20	8	15	0.05	0.017	0.716	0.887	5.2	33.0	7.20
20	8	22	0.05	0.016	0.699	0.868	4.4	33.0	7.10
21-5	7	4	0.05	0.024	0.893	1.095	4.5	19.0	6.60
24	5	11	0.05	0.007	0.540	0.686	7.0	58.0	7.80
24	7	4	0.05	0.016	0.713	0.891	4.9	48.0	7.40
24	8	22	0.05	0.020	0.814	1.005	5.3	45.0	7.40
29	7	4	0.05	0.019	0.733	0.907	4.4	26.0	6.90
29	8	22	0.05	0.018	0.684	0.847	4.7	28.0	6.70
30	7	4	0.05	0.019	0.788	0.959	4.2	20.0	6.80
30	8	22	0.05	0.019	0.751	0.921	5.3	21.0	6.80
34-5	7	4	0.05	0.016	0.756	0.941	5.2	46.0	7.30
34-5	7	18	0.05	0.070	1.864	2.245	10.3	21.0	6.90

Table A-7: Continued

sit	mt	dy	P	nm545	nm275	nm245	DOC	EC	pH
34-5	8	22	0.05	0.021	0.754	0.934	6.1	42.0	7.30
DRR	7	4	0.05	0.021	0.766	0.942	4.5	20.0	6.70
DRR	8	3	0.05	0.024	0.899	1.097	5.5	20.0	6.80
DDR	8	16	0.05	0.025	0.771	1.026	4.5	21.0	6.00
DDR	8	22	0.05	0.023	0.778	0.950	3.8	20.0	7.10
RB2	8	3	0.05	0.025	0.875	1.079	5.3	27.0	6.80
RB2	8	15	0.05	0.015	0.746	0.923	5.2	25.0	7.20
RB3	8	3	0.05	0.027	0.909	1.120	5.5	27.0	6.70
RB3	8	15	0.05	0.018	0.753	0.933	4.5	85.0	6.90

Table A-8: Chemical data for the Hout Bay River (routine sampling) during wet conditions

site	mt	dy	K	Na	Ca	Mg	NH-4	SO	Cl	CaCO	NO
1	5	23	11.2	26.0	48.9	3.7	0.10	24	35	128.0	1.10
1	6	20	5.7	40.0	68.4	6.7	1.30	25	58	169.0	2.55
2-3	7	18	1.0	19.0	3.8	2.4	0.05	7	32	7.0	0.10
2-3	9	12	1.3	24.0	6.8	3.5	0.05	12	42	14.0	0.10
4	5	23	0.9	21.0	8.8	3.0	0.05	23	39	4.7	0.10
4	6	20	1.3	24.0	6.5	3.5	0.05	10	43	11.0	0.10
4	7	18	1.0	18.0	3.9	2.4	0.05	5	33	7.0	0.10
4	9	12	1.3	23.0	6.6	3.3	0.05	12	41	14.0	0.10
5-5	7	18	0.9	16.0	3.4	2.1	0.05	6	29	5.0	0.10
6-5	7	17	0.9	17.0	3.7	2.1	0.05	6	29	7.0	0.10
7	5	23	0.8	19.0	7.5	2.8	0.05	21	36	2.5	0.10
7	6	20	1.0	20.0	4.6	2.7	0.05	5	37	10.0	0.10
7	7	18	0.7	15.0	2.1	1.8	0.05	5	25	3.0	0.10
7	8	8	0.9	17.0	3.7	2.2	0.06	7	30	6.0	0.10
7	9	12	0.9	18.0	3.4	2.3	0.05	7	31	8.0	0.10
7-1	7	17	0.8	15.0	2.1	1.8	0.05	5	26	3.0	0.10
7-1	8	22	1.1	21.0	5.3	2.7	0.05	10	37	12.0	0.10
9-5	7	18	0.7	14.0	2.1	1.7	0.05	6	24	2.0	0.10
10	5	23	0.7	18.0	5.0	2.7	0.05	14	36	1.0	0.10
10	6	20	0.9	19.0	1.9	2.3	0.05	5	33	3.0	0.10
10	7	18	0.7	14.0	1.4	1.6	0.05	5	23	2.0	0.10
10	9	12	0.8	16.0	2.0	2.0	0.05	6	28	4.0	0.10
11-5	7	17	0.7	14.0	1.4	1.6	0.05	5	23	2.0	0.10
12	5	23	0.6	18.0	5.0	2.7	0.05	15	36	0.0	0.10
12	6	20	0.9	17.0	3.4	2.3	0.07	5	32	7.3	0.10
12	7	18	0.6	12.0	1.2	1.6	0.05	4	23	1.0	0.10
12	9	12	0.7	14.0	1.2	1.8	0.05	6	28	2.0	0.10
13	5	23	1.0	20.0	11.3	3.0	0.05	26	37	7.3	0.10
13	6	20	1.5	25.0	7.1	3.6	0.09	9	45	13.0	0.10
13	7	18	1.0	18.0	4.2	2.4	0.05	6	33	7.0	0.10
13	9	12	1.4	25.0	7.0	3.6	0.05	13	41	14.0	0.10
15	5	23	7.3	22.0	12.5	3.3	0.05	26	46	8.8	0.10
15	6	20	1.7	29.0	10.1	4.4	0.05	13	51	19.0	0.13
15	7	18	1.2	21.0	7.3	3.0	0.05	7	37	18.0	0.10
15	8	8	1.6	25.0	8.8	4.0	0.05	15	45	16.0	0.20
15	9	12	1.6	28.0	9.4	4.5	0.05	14	49	19.0	0.10
15-1	7	18	1.1	19.0	5.6	2.7	0.05	7	33	10.0	0.10
15-2	7	18	1.2	19.0	6.4	2.9	0.05	7	35	13.0	0.21
17	5	23	1.3	24.0	13.8	3.9	0.05	24	44	20.5	0.10
17	6	20	2.5	36.0	21.0	6.1	0.13	13	62	51.0	0.20
17	7	18	1.5	21.0	10.2	3.4	0.05	12	37	26.0	0.10
17	8	8	1.8	27.0	12.9	4.5	0.05	17	49	28.0	0.10
17	9	12	1.9	33.0	16.6	5.6	0.08	20	56	41.0	0.10
20	5	23	1.1	23.0	14.8	3.6	0.05	32	43	11.5	0.10
20	6	20	1.8	29.0	12.5	4.7	0.05	12	51	26.0	0.13
20	7	18	1.1	19.0	5.7	2.8	0.05	8	34	11.0	0.10
20	9	12	1.7	30.0	11.5	4.8	0.05	20	50	26.0	0.10
24	5	23	1.5	29.0	13.3	4.4	0.05	22	52	23.0	0.10
24	6	20	2.5	40.0	20.7	6.5	0.11	14	69	51.0	0.10

Table A-8: Continued

site	mt	dy	K	Na	Ca	Mg	NH-4	SO	Cl	CaCO	NO
24	7	18	1.6	24.0	9.2	3.5	0.05	10	39	23.0	0.10
24	9	12	2.3	40.0	19.2	6.6	0.10	24	70	46.0	0.10
29	6	20	1.8	28.0	10.1	4.3	0.05	12	48	22.0	0.18
29	7	18	1.0	18.0	4.4	2.8	0.05	7	34	7.0	0.10
29	9	12	1.5	27.0	8.2	4.2	0.05	16	47	17.0	0.10
30	6	20	1.3	22.0	6.0	3.1	0.05	7	39	13.0	0.10
30	7	18	0.8	15.0	3.2	2.0	0.05	5	28	5.0	0.10
30	9	12	1.2	20.0	5.5	2.8	0.05	9	34	12.0	0.10
34-5	7	18	1.7	24.0	9.9	3.7	0.05	10	40	24.0	0.10
34-5	9	12	2.1	37.0	18.8	6.2	0.09	22	63	45.0	0.10
RB2	8	3	1.7	28.0	11.6	4.2	0.05	15	50	22.0	0.10
RB2	8	15	1.8	28.0	10.5	4.3	0.05	17	51	21.0	0.16
RB3	8	3	1.8	29.0	11.1	4.5	0.05	15	52	22.0	0.10
RB3	8	15	2.0	32.0	11.2	4.8	0.05	25	53	21.0	0.19

Table A-8: Continued

site	mt	dy	P	nm545	nm275	nm254	DOC	EC	pH
1	5	23	0.05	0.010	0.413	0.541	6.6	42.0	7.60
1	6	20	0.05	0.006	0.403	0.513	5.7	57.0	7.60
2-3	7	18	0.05	0.068	1.941	2.332	9.5	14.0	6.30
2-3	9	12	0.05	0.053	1.211	1.467	5.6	20.0	6.90
4	5	23	0.05	0.045	1.587	1.922	9.4	16.0	6.30
4	6	20	0.05	0.029	1.095	1.337	6.3	20.0	6.40
4	7	18	0.05	0.068	1.939	2.330	8.5	14.0	6.40
4	9	12	0.05	0.053	1.222	1.480	5.8	20.0	6.80
5-5	7	18	0.05	0.070	2.037	2.443	9.1	13.0	6.20
6-5	7	17	0.05	0.071	1.947	2.337	9.4	13.0	6.30
7	5	23	0.05	0.050	1.715	2.080	9.9	15.0	5.60
7	6	20	0.05	0.034	1.224	1.487	6.6	15.0	6.80
7	7	18	0.05	0.070	2.158	2.586	10.5	10.0	5.70
7	8	8	0.05	0.050	1.045	1.746	7.8	14.0	6.30
7	9	12	0.05	0.055	1.306	1.572	5.8	14.0	6.50
7-1	7	17	0.05	0.072	2.213	2.655	10.9	10.0	5.50
7-1	8	22	0.05	0.023	0.763	0.925	4.2	17.0	6.80
9-5	7	18	0.05	0.072	2.261	2.713	11.0	10.0	5.30
10	5	23	0.05	0.048	1.775	2.160	10.3	14.5	4.80
10	6	20	0.05	0.034	1.293	1.572	6.0	13.0	5.90
10	7	18	0.05	0.071	2.305	2.764	1.0	10.0	5.00
10	9	12	0.05	0.063	1.457	1.745	6.3	12.0	6.00
11-5	7	17	0.05	0.072	2.350	2.817	12.0	10.0	5.10
12	5	23	0.05	0.060	1.884	2.287	11.1	15.0	4.50
12	6	20	0.05	0.037	1.361	1.651	6.6	13.0	6.40
12	7	18	0.05	0.066	2.315	2.778	9.7	9.0	4.70
12	9	12	0.05	0.051	1.431	1.725	6.4	11.0	5.20
13	5	23	0.05	0.054	1.480	1.790	9.3	16.5	6.50
13	6	20	0.05	0.031	1.120	1.369	5.6	20.0	6.90
13	7	18	0.05	0.072	2.012	2.413	10.3	14.0	6.40
13	9	12	0.05	0.048	1.188	1.442	5.8	21.0	6.80
15	5	23	0.05	0.043	1.537	1.864	9.9	18.5	7.70
15	6	20	0.05	0.027	1.037	1.268	5.5	24.0	6.90
15	7	18	0.05	0.067	1.887	2.267	9.7	18.0	6.80
15	8	8	0.05	0.044	1.318	1.595	7.9	22.0	6.90
15	9	12	0.05	0.047	1.160	1.408	6.1	25.0	6.80
15-1	7	18	0.05	0.068	1.968	2.363	9.2	15.0	6.30
15-2	7	18	0.05	0.074	1.993	2.391	9.0	16.0	6.80
17	5	23	0.05	0.042	1.533	1.862	9.8	21.5	6.80
17	6	20	0.05	0.025	0.990	1.219	6.2	34.0	7.20
17	7	18	0.05	0.070	1.919	2.304	9.2	20.0	6.90
17	8	8	0.05	0.043	1.279	1.550	7.8	25.0	7.10
17	9	12	0.05	0.029	1.108	1.352	7.2	31.0	7.20
20	5	23	0.05	0.040	1.532	1.863	9.5	20.0	6.70
20	6	20	0.05	0.023	0.981	1.206	5.7	26.0	7.15
20	7	18	0.05	0.070	1.941	2.332	9.0	16.0	6.60
20	9	12	0.05	0.034	1.167	1.420	6.2	26.0	7.00
24	5	23	0.05	0.042	1.422	1.729	9.1	25.0	6.90

Table A-8: Continued

site	mt	dy	P	nm545	nm275	nm254	DOC	EC	pH
24	6	20	0.05	0.027	1.004	1.234	6.0	36.0	7.30
24	7	18	0.05	0.069	1.872	2.255	9.7	20.0	6.80
24	9	12	0.05	0.030	1.095	0.339	7.1	37.0	7.30
29	6	20	0.05	0.025	1.023	1.256	6.2	24.0	7.10
29	7	18	0.05	0.074	1.996	2.395	9.1	15.0	6.50
29	9	12	0.05	0.034	1.176	1.430	6.4	23.0	6.90
30	6	20	0.05	0.033	1.205	1.468	7.3	18.0	6.90
30	7	18	0.05	0.071	2.095	2.512	9.2	12.0	6.70
30	9	12	0.05	0.040	1.299	1.575	6.5	17.0	6.80
34-5	7	18	0.05	0.070	1.864	2.245	10.3	21.0	6.90
34-5	9	12	0.05	0.031	1.110	1.365	6.6	34.0	7.20
RB2	8	3	0.05	0.025	0.875	1.079	5.3	27.0	6.80
RB2	8	15	0.05	0.015	0.746	0.923	5.2	25.0	7.20
RB3	8	3	0.05	0.027	0.909	1.120	5.5	27.0	6.70
RB3	8	15	0.05	0.018	0.753	0.933	4.5	85.0	6.90

Table A-9: Chemical data for tributaries of the Hout Bay River during dry conditions

site	mt	dy	K	Na	Ca	Mg	NH-4	SO	Cl	CaCO	NO
3	1	19	5.1	59.0	13.5	6.8	0.29	20.0	112.0	28.0	0.10
3	2	29	5.9	64.0	16.7	6.8	0.36	0.0	117.0	40.0	0.10
3	3	29	5.4	0.0	0.0	0.0	0.48	0.0	0.0	0.0	0.10
3	4	19	5.1	0.0	0.0	0.0	0.37	0.0	0.0	0.0	0.10
3	8	22	2.5	46.0	4.1	5.4	0.06	12.0	84.0	9.0	0.10
5	2	29	1.2	45.0	7.9	4.2	0.05	0.0	84.0	11.0	0.10
5	3	7	1.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.05
5	3	29	1.1	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
5	4	19	1.1	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
5	8	22	0.9	45.0	4.2	5.3	0.05	13.0	83.0	3.0	0.10
9	1	19	2.3	36.0	20.8	5.0	0.05	7.0	66.0	54.0	0.26
9	2	29	2.6	37.0	24.8	5.1	0.05	0.0	69.0	67.0	0.16
9	3	7	2.9	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.14
9	3	29	2.1	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.13
9	4	19	2.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.12
9	8	22	1.9	34.0	19.9	4.7	0.05	9.0	60.0	48.0	0.40
11	2	29	1.7	21.0	5.3	2.2	0.05	0.0	36.0	12.0	0.13
11	3	9	1.8	0.0	0.0	0.0	0.16	0.0	0.0	0.0	0.12
11	3	29	1.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
11	4	19	1.5	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
11	8	22	1.4	22.0	20.9	3.2	0.07	20.0	39.0	42.0	0.50
11-1	8	22	0.6	15.0	44.3	2.4	0.05	47.0	23.0	79.0	0.10
11-2	8	22	0.8	22.0	1.3	2.5	0.05	8.0	38.0	2.0	0.10
17-1	7	4	2.6	40.0	29.6	7.3	0.10	24.0	65.0	74.0	0.10
17-1	8	22	2.4	38.0	19.4	6.7	0.11	27.0	66.0	44.0	0.20
18	1	19	2.6	37.0	18.5	4.9	2.11	21.0	64.0	49.0	0.17
18	2	29	3.1	45.0	20.9	6.3	0.05	0.0	81.0	41.0	0.10
18	3	9	3.4	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.08
18	3	29	3.2	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
18	4	19	3.2	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
18	8	22	1.0	30.0	7.7	4.0	0.06	15.0	52.0	16.0	0.20
21	5	9	1.3	29.0	9.2	3.6	0.05	8.0	53.0	22.0	0.10
21	5	5	1.6	25.0	8.2	3.2	0.05	10.0	45.0	20.0	0.11
21	8	22	0.9	22.0	3.5	2.8	0.05	10.0	41.0	5.0	0.10
27	5	9	0.2	30.0	3.5	3.7	0.05	4.0	56.0	6.0	0.10
27	5	23	0.5	25.0	3.8	3.4	0.05	7.0	47.0	6.0	0.10
27	8	22	0.4	24.0	1.6	3.1	0.05	9.0	43.0	2.0	0.10
31	8	22	0.5	19.0	1.8	2.4	0.05	7.0	34.0	3.0	0.10
34	8	22	1.4	31.0	10.6	4.2	0.08	13.0	52.0	25.0	0.30

Table A-9: Continued

site	mt	dy	P	nm545	nm275	nm254	DOC	EC	pH
3	1	19	0.05	0.026	1.057	1.302	0.0	45.0	7.15
3	2	29	0.05	0.000	0.000	0.000	6.0	49.0	7.15
3	3	29	0.05	0.000	0.000	0.000	6.0	52.0	0.00
3	4	19	0.05	0.000	0.000	0.000	5.4	53.0	7.00
3	8	22	0.05	0.008	0.423	0.521	2.6	33.0	6.40
5	2	29	0.05	0.000	0.000	0.000	1.2	33.0	6.70
5	3	7	0.05	0.000	0.000	0.000	1.7	33.0	0.00
5	3	29	0.05	0.000	0.000	0.000	1.3	33.0	7.45
5	4	19	0.05	0.000	0.000	0.000	1.9	31.5	7.32
5	8	22	0.05	0.005	0.313	0.387	1.8	33.0	5.60
9	1	19	0.05	0.006	0.290	0.356	0.0	34.5	7.75
9	2	29	0.05	0.000	0.000	0.000	2.7	37.0	7.80
9	3	7	0.05	0.000	0.000	0.000	3.2	36.0	0.00
9	3	29	0.05	0.000	0.000	0.000	2.9	34.0	0.00
9	4	19	0.05	0.000	0.000	0.000	2.5	35.0	7.55
9	8	22	0.05	0.005	0.274	0.337	2.0	33.0	7.40
11	2	29	0.05	0.000	0.000	0.000	2.6	17.0	7.10
11	3	9	0.13	0.000	0.000	0.000	9.5	18.5	0.00
11	3	29	0.05	0.000	0.000	0.000	3.6	20.0	0.00
11	4	19	0.05	0.000	0.000	0.000	3.3	17.5	7.15
11	8	22	0.05	0.013	0.874	1.080	7.7	26.0	7.20
11-1	8	22	0.05	0.023	1.347	1.674	12.3	31.0	8.70
11-2	8	22	0.05	0.020	0.782	0.968	3.5	16.0	5.50
17-1	7	4	0.05	0.019	0.764	0.948	5.0	41.0	7.30
17-1	8	22	0.05	0.014	0.684	0.851	5.7	37.0	7.10
18	1	19	0.24	0.010	0.449	0.566	0.0	36.0	7.50
18	2	29	0.10	0.000	0.000	0.000	5.0	41.0	7.60
18	3	9	0.05	0.000	0.000	0.000	5.7	14.0	0.00
18	3	29	0.16	0.000	0.000	0.000	4.4	48.0	0.00
18	4	19	0.17	0.000	0.000	0.000	5.1	49.0	6.95
18	8	22	0.05	0.011	0.545	0.679	2.9	24.0	6.90
21	5	9	0.05	0.007	0.329	0.405	3.4	24.0	7.40
21	5	5	0.05	0.037	0.495	0.605	4.1	20.5	7.20
21	8	22	0.05	0.037	1.229	1.483	6.4	17.0	6.30
27	5	9	0.05	0.000	0.164	0.209	2.2	68.0	6.50
27	5	23	0.06	0.009	0.434	0.547	3.3	19.0	6.50
27	8	22	0.05	0.012	0.607	0.759	3.7	18.0	5.50
31	8	22	0.05	0.031	1.107	1.351	6.7	14.0	5.70
34	8	22	0.05	0.011	0.540	0.674	2.8	27.0	7.00

Table A-10: Chemical data for tributaries of the Hout Bay River during wet conditions

site	mt	dy	K	Na	Ca	Mg	NH-4	SO	Cl	CaCO	NO
3	5	23	7.2	114.0	28.2	19.5	0.10	63	220	29.0	0.10
3	6	20	3.5	59.0	8.1	7.9	0.06	20	108	10.6	0.45
3	7	18	2.2	42.0	3.7	5.0	0.08	11	75	7.0	0.18
5	5	23	1.6	34.0	10.0	4.1	0.05	19	63	5.0	0.10
5	6	20	1.4	48.0	5.4	5.9	0.05	15	86	10.6	0.10
5	7	17	1.2	36.0	4.0	4.2	0.05	11	65	5.0	0.06
5	7	18	0.9	26.0	2.5	3.1	0.05	7	45	4.0	0.10
5	8	8	1.2	38.0	4.4	4.5	0.05	11	71	6.0	0.10
9	5	23	3.5	28.0	23.3	4.4	0.05	9	53	57.0	0.70
9	6	20	1.9	31.0	17.4	4.3	0.05	5	56	42.0	0.50
11	5	23	2.3	22.0	11.3	27.0	0.05	16	46	9.8	0.20
11	6	20	1.7	23.0	6.0	2.9	0.05	8	40	10.0	0.53
11	7	18	1.5	22.0	8.1	3.0	0.05	9	37	18.0	0.19
11-1	8	8	0.9	15.0	18.9	3.1	0.10	43	21	23.0	0.10
17-1	7	18	7.2	49.0	79.7	10.2	0.05	13	78	224.0	0.10
18	5	23	0.7	28.0	5.7	3.7	0.05	11	50	10.0	0.10
18	6	20	0.8	29.0	4.1	4.0	0.05	5	54	7.0	0.10
21	5	23	1.0	21.0	7.5	3.0	0.05	16	40	4.0	0.10
21	6	20	0.9	23.0	2.4	3.1	0.05	5	41	6.0	0.10
27	5	23	0.5	25.0	3.8	3.4	0.05	7	47	6.0	0.10
27	6	20	0.6	25.0	1.7	3.6	0.05	5	48	12.0	0.10
27	8	8	0.6	21.0	1.3	2.6	0.05	8	37	1.0	0.10
31	6	20	0.8	20.0	3.0	2.7	0.05	5	36	5.0	0.10
31	7	18	0.6	15.0	1.4	1.8	0.05	6	26	2.0	0.10
34	6	20	0.9	29.0	6.0	4.0	0.12	11	54	10.0	0.10
34	7	18	0.9	24.0	4.9	2.9	0.05	7	41	10.0	0.10
34	8	8	0.9	25.0	7.3	3.4	0.05	11	46	13.0	0.10

Table A-10: Continued

site	mt	dy	P	nm545	nm275	nm254	DOC	EC	pH
3	5	23	0.05	0.012	0.540	0.671	5.3	91.0	6.40
3	6	20	0.05	0.011	0.492	0.609	4.1	44.0	7.40
3	7	18	0.05	0.012	0.460	0.568	3.5	29.0	6.30
5	5	23	0.05	0.021	0.881	1.081	6.0	25.0	6.20
5	6	20	0.05	0.010	0.446	0.554	3.3	0.0	0.00
5	7	17	0.05	0.026	0.556	0.686	4.4	25.0	6.10
5	7	18	0.05	0.074	1.178	1.435	6.2	18.0	5.80
5	8	8	0.05	0.017	0.479	0.591	3.2	28.0	6.10
9	5	23	0.05	0.023	0.492	0.611	5.0	31.0	7.30
9	6	20	0.05	0.009	0.321	0.397	2.3	29.0	7.40
11	5	23	0.05	0.014	0.688	0.840	6.0	18.0	6.40
11	6	20	0.05	0.007	0.354	0.443	2.7	19.0	6.50
11	7	18	0.05	0.031	0.693	0.841	5.4	19.0	6.60
11-1	8	8	0.05	0.022	0.841	1.030	7.3	22.0	7.20
17-1	7	18	0.05	0.021	0.954	1.176	11.3	68.0	7.50
18	5	23	0.05	0.012	0.484	0.607	4.2	22.0	6.90
18	6	20	0.05	0.013	0.672	0.838	4.1	21.0	6.70
21	5	23	0.05	0.047	1.658	2.006	10.5	16.5	6.20
21	6	20	0.05	0.039	0.501	1.828	7.9	17.0	5.90
27	5	23	0.06	0.009	0.434	0.547	3.3	19.0	6.50
27	6	20	0.05	0.011	0.671	0.848	4.1	19.0	4.80
27	8	8	0.05	0.020	0.849	1.054	5.5	16.0	5.00
31	6	20	0.05	0.032	1.323	1.618	6.6	15.0	6.00
31	7	18	0.05	0.068	2.008	2.417	9.5	11.0	5.30
34	6	20	0.05	0.014	0.674	0.840	4.4	22.0	6.80
34	7	18	0.05	0.033	1.104	1.354	6.6	18.0	6.80
34	8	8	0.05	0.024	0.804	0.989	5.2	21.0	6.70

Table A-11: Chemical data for stormdrain effluent during dry conditions

site	mt	dy	K	Na	Ca	Mg	NH-4	SO-4	Cl	CaCO3	NO
2	2	29	11.4	54.0	55.7	11.3	0.05	0.0	82.0	135.0	0.10
2	3	7	14.5	0.0	0.0	0.0	11.10	0.0	0.0	0.0	0.22
2	3	29	7.3	0.0	0.0	0.0	7.76	0.0	0.0	0.0	0.33
2	4	19	9.2	0.0	0.0	0.0	14.89	0.0	0.0	0.0	0.59
6	2	29	1.8	24.0	22.1	3.3	0.05	0.0	38.0	50.0	0.10
6	3	7	3.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.05
6	3	29	2.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.10
6	8	22	2.0	35.0	15.1	4.7	0.05	12.0	62.0	35.0	0.20
8	2	29	4.8	52.0	59.6	5.3	0.05	0.0	79.0	154.0	1.13
8	3	29	4.7	0.0	0.0	0.0	0.05	0.0	0.0	0.0	1.50
8	4	19	4.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	1.63
8	8	22	3.0	38.0	28.1	4.6	0.16	22.0	66.0	62.0	1.00
14	1	19	11.0	74.0	43.0	12.2	0.05	14.0	98.0	190.0	1.50
14	2	29	18.5	107.0	90.8	13.3	0.05	0.0	111.0	309.0	0.29
14	3	29	8.5	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.48
14	4	19	19.7	0.0	0.0	0.0	0.07	0.0	0.0	0.0	1.59
14	8	22	10.9	102.0	100.6	18.8	0.13	60.0	150.0	241.0	8.80
16	1	19	2.4	47.0	84.8	11.6	0.05	21.0	69.0	238.0	0.50
16	2	29	2.7	48.0	90.9	12.0	0.05	0.0	70.0	247.0	0.46
16	3	7	3.5	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.51
16	3	29	2.8	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.56
16	4	19	5.3	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.64
16	8	22	4.8	68.0	112.2	16.9	0.07	44.0	98.0	300.0	2.30
19	2	29	11.4	4.1	21.5	2.7	32.60	0.0	48.0	190.0	0.10
19	3	29	13.7	0.0	0.0	0.0	49.24	0.0	0.0	0.0	0.10
22	5	5	4.0	34.0	38.4	5.1	0.05	36.0	48.0	89.0	1.04
22	5	9	1.3	18.0	14.8	2.6	0.25	20.0	22.0	36.0	0.24
22	8	22	11.7	87.0	85.6	12.1	0.07	67.0	139.0	209.0	3.30
23	8	22	10.4	45.0	55.4	4.2	10.80	40.0	48.0	188.0	0.30
33	8	22	33.0	114.0	136.0	26.7	0.23	79.0	157.0	428.0	2.10
WBC	7	13	0.8	33.0	40.1	4.1	0.05	22.0	62.0	84.0	0.10
CPH	1	22	0.0	0.0	0.0	0.0	25.20	0.0	8520.0	0.0	0.10

Table A-11: Continued

site	mt	dy	P	nm545	nm275	nm254	DOC	EC	pH
2	2	29	2.96	0.000	0.000	0.000	48.4	68	6.80
2	3	7	4.00	0.000	0.000	0.000	17.1	0.0	0.00
2	3	29	1.66	0.000	0.000	0.000	8.3	64	0.00
2	4	19	2.08	0.000	0.000	0.000	9.1	70	7.50
6	2	29	0.05	0.000	0.000	0.000	2.7	27	7.80
6	3	7	0.05	0.000	0.000	0.000	5.0	37	0.00
6	3	29	0.05	0.000	0.000	0.000	4.1	36	9.25
6	8	22	0.05	0.003	0.225	0.281	2.5	31	7.50
8	2	29	0.05	0.000	0.000	0.000	12.8	58	8.30
8	3	29	0.05	0.000	0.000	0.000	12.2	62	0.00
8	4	19	0.05	0.000	0.000	0.000	13.6	62	8.20
8	8	22	0.05	0.019	1.204	1.506	11.1	37	7.10
14	1	19	0.11	0.015	1.233	1.540	0.0	79	8.70
14	2	29	2.19	0.000	0.000	0.000	17.0	102	8.20
14	3	29	0.33	0.000	0.000	0.000	6.4	60	0.00
14	4	19	0.41	0.000	0.000	0.000	14.1	110	8.20
14	8	22	0.05	0.006	0.772	0.985	15.0	110	7.80
16	1	19	0.05	0.006	0.213	0.264	0.0	71	8.50
16	2	29	0.05	0.000	0.000	0.000	3.3	70	8.40
16	3	7	0.05	0.000	0.000	0.000	6.1	80	0.00
16	3	29	0.05	0.000	0.000	0.000	5.9	75	0.00
16	4	19	0.05	0.000	0.000	0.000	5.9	24	8.25
16	8	22	0.06	0.003	0.305	0.387	9.4	96	8.10
19	2	29	4.74	0.000	0.000	0.000	39.6	64	7.40
19	3	29	4.51	0.000	0.000	0.000	22.0	74	0.00
22	5	5	0.07	0.007	0.371	0.468	5.7	40	8.50
22	5	9	0.05	0.008	0.576	0.665	8.9	19	7.65
22	8	22	0.05	0.009	0.675	0.860	11.8	98	8.30
23	8	22	2.22	0.041	1.225	1.610	19.4	60	8.30
33	8	22	0.05	0.011	1.099	1.409	18.4	124	8.10
WBC	7	13	0.05	0.071	2.391	2.917	15.0	39	7.80
CPH	1	22	12.50	0.000	0.000	0.000	0.0	0.0	0.00

Table A-12: Chemical data for stormdrain effluent during wet conditions

site	mt	dy	K	Na	Ca	Mg	NH-4	SO	Cl	CaCO	NO
2	5	23	8.6	68.0	76.4	20.8	3.30	41	116	74.0	42.00
2	6	20	9.2	61.0	35.2	14.0	6.92	47	96	106.0	4.70
6	5	23	3.7	18.0	17.0	2.7	0.05	11	33	42.5	0.10
6	6	20	2.2	37.0	18.2	5.0	0.05	14	68	40.0	0.33
8	5	23	1.5	14.0	13.3	1.6	0.05	8	22	29.0	0.20
8	6	20	4.9	46.0	46.6	6.1	0.29	32	71	97.0	3.33
8	8	22	3.0	38.0	28.1	4.6	0.16	22	66	62.0	1.00
14	5	23	9.2	57.0	53.0	8.5	0.05	35	94	111.0	2.80
14	6	20	3.6	37.0	44.3	6.2	0.05	35	59	81.0	2.47
14	7	18	10.6	92.0	102.7	19.3	0.05	60	144	233.0	9.67
14	8	8	11.3	95.0	105.3	19.3	0.11	67	146	241.0	10.20
16	5	23	4.9	50.0	77.0	11.0	0.05	32	77	195.0	1.10
16	6	20	5.6	70.0	117.6	16.8	0.08	46	105	301.0	2.57
16	7	18	6.6	77.0	122.9	17.8	0.14	48	113	315.0	3.20
16	8	8	5.5	69.0	124.1	17.2	0.11	49	109	309.0	2.70
19-c	6	20	13.8	41.0	25.0	3.0	44.14	12	54	229.0	0.10
22	5	5	4.0	34.0	38.4	5.1	0.05	36	48	89.0	1.04
22	5	23	4.9	30.0	26.1	4.3	0.05	30	55	50.0	0.60
22	6	20	12.2	75.0	83.5	15.8	0.05	69	114	196.0	3.83
22	7	18	11.7	93.0	58.3	12.6	0.05	32	167	112.0	4.89
23	5	23	5.9	16.0	24.4	3.1	0.05	28	24	53.0	0.50
23	6	20	14.0	51.0	30.3	4.3	34.38	20	51	219.0	0.10
23	7	18	8.4	41.0	68.7	10.4	0.40	49	67	167.0	1.25
28	5	23	18.5	87.0	65.5	10.9	32.50	33	72	363.0	0.10
28	6	20	18.5	86.0	98.8	16.7	22.45	40	73	426.0	0.10
32	6	20	11.4	61.0	39.9	4.0	20.37	39	59	180.0	2.12
33	6	20	49.3	137.0	146.7	28.1	0.69	103	193	427.0	2.44
33	8	22	33.0	114.0	136.0	26.7	0.23	79	157	428.0	2.10
WBC	7	6	1.1	31.0	37.5	3.9	0.50	10	65	70.0	0.10
WBC	7	7	0.9	34.0	40.8	4.2	0.05	20	62	88.0	0.10
MW	7	6	1.1	11.0	9.9	1.8	0.25	2	18	28.0	0.10
MW	7	17	1.9	26.0	13.3	2.9	0.05	9	46	32.0	0.11
CPH	7	6	8.6	208.0	15.0	23.1	0.06	50	360	22.0	0.10
CPH	7	17	2.3	16.0	10.5	1.8	0.05	14	24	22.0	0.17

Table A-12: Continued

site	mt	dy	P	nm545	nm275	nm254	DOC	EC	pH
2	5	23	0.10	0.034	0.723	0.934	10.2	96.0	7.60
2	6	20	0.66	0.018	0.847	1.053	9.0	66.0	7.45
6	5	23	0.05	0.037	0.788	0.939	5.5	21.5	7.30
6	6	20	0.05	0.007	0.345	0.430	2.8	33.0	7.60
8	5	23	0.05	0.026	0.434	0.529	4.3	14.0	6.90
8	6	20	0.05	0.021	1.253	1.581	10.8	52.0	7.10
8	8	22	0.05	0.019	1.204	1.506	11.1	37.0	7.10
14	5	23	0.06	0.015	0.967	1.324	13.9	64.0	7.50
14	6	20	0.11	0.004	0.359	0.459	4.5	45.0	7.70
14	7	18	0.05	0.014	1.126	1.426	15.2	107.0	7.80
14	8	8	0.05	0.015	0.863	1.101	7.0	113.0	7.80
16	5	23	0.08	0.012	0.585	0.777	10.1	68.0	7.80
16	6	20	0.09	0.002	0.370	0.476	8.4	97.0	7.90
16	7	18	0.05	0.018	0.532	0.671	12.0	103.0	7.80
16	8	8	0.08	0.008	0.391	0.496	11.7	100.0	8.20
19-c	6	20	5.52	0.038	0.851	1.000	16.3	71.0	7.60
22	5	5	0.07	0.007	0.371	0.468	5.7	40.0	8.50
22	5	23	0.06	0.084	1.242	1.582	11.7	33.5	7.00
22	6	20	0.07	0.005	0.667	0.866	10.5	87.0	8.30
22	7	18	0.05	0.024	1.131	1.438	13.9	75.0	7.90
23	5	23	0.05	0.022	0.769	0.981	9.1	24.5	7.30
23	6	20	6.61	0.053	1.099	1.303	33.4	72.0	7.70
23	7	18	0.05	0.018	0.711	0.905	10.9	60.0	8.20
28	5	23	12.50	0.094	1.565	1.889	27.6	102.0	7.60
28	6	20	7.23	0.024	1.211	1.508	21.0	111.0	7.60
32	6	20	4.82	0.032	1.043	1.289	20.0	67.0	8.00
33	6	20	0.17	0.015	1.302	1.664	20.0	155.0	8.10
33	8	22	0.05	0.011	1.099	1.409	18.4	124.0	8.10
WBC	7	6	1.04	0.056	2.325	2.832	18.0	38.0	7.60
WBC	7	7	0.05	0.044	2.068	2.545	14.3	39.0	7.90
MW	7	6	0.55	0.024	0.217	0.264	3.3	13.0	7.80
MW	7	17	0.05	0.021	0.449	0.602	3.9	24.0	7.80
CPH	7	6	0.07	0.012	0.229	0.279	2.7	132.0	7.10
CPH	7	17	0.05	0.015	0.435	0.587	5.0	16.0	7.00

TABLES A-13 TO A-14

show the microbiological and chemical
results of storm event sampling in Hout Bay

Time is given as a ratio where the onset of rainfall is taken as oo.oo

Table A-13: Microbiological data for storm event sampling

site	mt	dy	time	fc	fs	coli
5	5	19	0.83	86000	19300	162
5	5	19	5.25	12000	8300	478
5	5	19	25.33	1900	2400	30
5	7	17	1.03	3600	12900	0
5	7	17	25.21	280	160	0
5	8	7	1.33	200	3200	0
5	8	7	4.33	2000	1000	8
5	8	7	7.53	360	256	0
5	8	7	22.47	36	130	2
7	3	7	0.67	8400	200	0
7	3	7	3.33	43000	420	0
7	3	7	17.67	82000	980	0
7	5	19	1.00	10000	2200	30
7	5	19	5.42	35000	14300	82
7	5	19	25.50	870	100	0
7	7	17	1.15	310	50	10
7	7	17	4.08	27000	15000	23
7	7	17	8.75	160	100	0
7	7	17	25.36	130	16	0
7	8	7	1.25	320	140	2
7	8	7	4.42	48000	9000	22
7	8	7	7.63	2300	1700	4
7	8	7	10.92	160	80	10
14	5	19	1.33	201000	55000	50
14	5	19	5.12	154000	26300	206
14	5	19	25.25	14100	7600	16
14	7	17	0.87	74000	173000	133
14	7	17	24.87	10700	2290	8
14	8	7	3.88	2000000	1660000	218
14	8	7	7.25	25000	8600	20
14	8	7	22.16	2400	3100	0
15	3	7	0.00	5800	1020	0
15	3	7	0.75	1150000	70000	8
15	3	7	1.50	163000	70000	8
15	3	7	3.08	178000	21000	0
15	3	7	17.50	1940	1700	0
15	5	19	0.33	158000	64000	140
15	5	19	2.02	428000	133000	760
15	5	19	5.08	222000	127000	1012
15	5	19	25.17	1400	1300	26
15	7	17	0.80	44000	89000	43
15	7	17	3.83	209000	89000	40900
15	7	17	9.02	2200	800	10
15	7	17	24.75	110	216	0
15	8	7	0.92	1100	230	18
15	8	7	2.92	63000	60000	106
15	8	7	3.83	550000	166000	280
15	8	7	5.25	29000	21000	90
16	3	7	0.00	11600	420	0
16	3	7	0.60	1070000	120000	220

Table A-13: Continued

site	mt	dy	time	fc	fs	coli
16	3	7	3.13	121000	35000	80
16	5	19	0.36	130000	131000	28
16	5	19	2.00	68000	55000	274
16	5	19	2.75	126000	69000	130
16	5	19	5.12	120000	93000	860
16	5	19	25.20	4100	5300	18
16	7	17	0.82	245000	184000	97
16	7	17	3.85	179000	58000	15000
16	7	17	9.00	18500	27000	260
16	7	17	24.83	9200	2500	0.0
16	8	7	1.00	650000	48000	2
16	8	7	3.83	93000	92000	302
16	8	7	7.33	115000	2900	962
16	8	7	22.08	26000	1000	110
17	3	7	0.83	470	400	0
17	3	7	1.33	400	530	0
17	3	7	1.83	780	260	0
17	3	7	3.00	5600000	700000	60
17	3	7	6.25	84000	41000	56
17	3	7	9.00	22000	4000	64
17	3	7	17.00	2200	1290	12
17	5	19	0.50	380000	120000	100
17	5	19	1.08	280000	87000	58
17	5	19	1.58	71000	77000	664
17	5	19	2.42	183000	70000	2160
17	5	19	2.83	222000	86000	820
17	5	19	3.50	287000	68000	560
17	5	19	4.50	183000	121000	960
17	5	19	4.83	196000	149000	900
17	5	19	6.66	103000	89000	322
17	5	19	7.50	63000	32000	236
17	5	19	25.00	1740	2200	24
17	7	17	0.75	1340	220	7
17	7	17	2.33	7600	9500	0
17	7	17	2.75	16800	6000	27
17	7	17	3.58	117000	65000	43
17	7	17	4.25	140000	70000	267
17	7	17	6.58	68000	18000	133
17	7	17	8.58	500	140	7
17	7	17	11.25	1200	100	0
17	7	17	24.33	1180	292	2
17	8	7	0.83	1240	330	10
17	8	7	2.75	2220000	640000	390
17	8	7	3.08	51500	3500	24
17	8	7	3.33	180000	59000	134
17	8	7	3.58	151000	77000	372
17	8	7	4.08	312000	104000	742
17	8	7	4.50	176000	92000	282
17	8	7	6.00	210000	55000	1780

Table A-13: Continued

site	mt	dy	time	fc	fs	coli
17	8	7	7.00	61100	31000	156
17	8	7	8.00	39000	3000	70
17	8	7	10.00	21600	8700	102
17	8	7	12.00	7700	4400	24
17	8	7	21.16	4600	1440	28
WBC	7	7	0.00	2300	2800	0
MW	7	17	0.00	19000	3000	0
CPH	7	17	0.00	780000	3600	70

Table A-14: Chemical data for storm event sampling

site	dy	time	K	Na	Ca	Mg	NH-4	SO-4	Cl	CaCO
5	7 17	1.03	1.2	36.0	4.0	4.2	0.05	11.0	65.0	5.0
5	7 17	25.27	0.9	26.0	2.5	3.1	0.05	7.0	45.0	4.0
5	8 7	1.33	1.2	40.0	4.5	5.0	0.05	15.0	74.0	5.0
5	8 7	4.33	1.8	41.0	5.1	5.0	0.07	17.0	74.0	7.0
5	8 7	7.53	1.6	45.0	6.1	5.3	0.09	18.0	82.0	8.0
5	8 7	22.47	1.2	38.0	4.4	4.5	0.05	11.0	71.0	6.0
7	3 7	0.00	1.7	0.0	0.0	0.0	0.05	0.0	0.0	0.0
7	3 7	0.67	1.7	0.0	0.0	0.0	0.05	0.0	0.0	0.0
7	3 7	3.33	2.1	0.0	0.0	0.0	0.05	0.0	0.0	0.0
7	3 7	17.67	2.0	0.0	0.0	0.0	0.05	0.0	0.0	0.0
7	5 19	1.00	2.2	22.0	8.1	3.0	0.05	11.0	37.0	18.0
7	5 19	5.42	2.8	19.0	5.6	2.5	0.05	13.0	33.0	10.0
7	5 19	25.50	1.0	19.0	3.1	3.0	0.05	10.0	36.0	3.0
7	7 17	1.15	1.0	18.0	4.0	2.4	0.05	7.0	33.0	8.0
7	7 17	4.08	2.8	14.0	9.4	2.1	0.10	8.0	25.0	24.0
7	7 17	8.75	0.8	13.0	2.6	2.1	0.05	5.0	20.0	12.0
7	7 17	25.36	0.7	15.0	2.1	1.8	0.05	5.0	25.0	3.0
7	8 7	1.25	1.1	20.0	4.9	2.5	0.05	8.0	35.0	11.0
7	8 7	4.42	1.9	17.0	6.5	2.2	0.09	11.0	29.0	14.0
7	8 7	7.63	1.1	18.0	3.8	2.2	0.13	8.0	33.0	7.0
7	8 7	10.92	0.9	17.0	3.7	2.2	0.06	7.0	30.0	6.0
14	5 19	1.33	1.8	5.0	7.8	0.9	0.05	5.0	6.0	23.0
14	5 19	5.17	7.1	30.0	23.6	4.1	0.07	32.0	48.0	50.0
14	5 19	25.25	15.8	117.0	131.6	22.1	0.16	92.0	214.0	258.0
14	7 17	0.87	3.3	15.0	12.4	2.2	0.06	12.0	23.0	31.0
14	7 17	24.87	10.6	92.0	102.7	19.3	0.05	60.0	144.0	233.0
14	8 7	3.88	1.9	12.0	13.1	2.0	0.05	11.0	15.0	35.0
14	8 7	7.25	10.2	8.6	90.5	17.1	0.08	60.0	137.0	204.0
14	8 7	22.16	11.3	95.0	105.3	19.3	0.11	67.0	146.0	241.0
15	3 7	0.00	3.4	0.0	0.0	0.0	0.05	0.0	0.0	0.0
15	3 7	0.75	4.5	0.0	0.0	0.0	0.11	0.0	0.0	0.0
15	3 7	1.50	4.5	0.0	0.0	0.0	0.09	0.0	0.0	0.0
15	3 7	3.08	3.8	0.0	0.0	0.0	0.05	0.0	0.0	0.0
15	3 7	17.50	3.7	0.0	0.0	0.0	0.05	0.0	0.0	0.0
15	5 19	0.33	2.7	14.0	11.7	2.2	0.05	9.0	23.0	30.0
15	5 19	2.07	2.8	16.0	11.1	2.9	0.05	14.0	26.0	29.0
15	5 19	5.08	3.7	15.0	9.7	2.6	0.07	14.0	25.0	24.0
15	5 19	25.17	1.4	21.0	5.0	3.3	0.05	11.0	38.0	7.0
15	7 17	0.80	2.3	29.0	11.0	4.6	0.05	19.0	51.0	24.0
15	7 17	3.83	2.8	16.0	11.6	2.6	0.11	8.0	26.0	33.0
15	7 17	9.07	1.0	13.0	3.3	1.8	0.05	8.0	24.0	5.0
15	7 17	24.75	1.2	21.0	7.3	3.0	0.05	7.0	37.0	18.0
15	8 7	0.97	3.0	41.0	17.1	7.3	0.05	30.0	72.0	38.0
15	8 7	2.92	2.6	30.0	14.0	5.2	0.05	21.0	54.0	29.0
15	8 7	3.83	3.4	20.0	14.6	3.7	0.12	12.0	35.0	34.0
15	8 7	5.25	2.4	28.0	12.7	3.8	0.10	20.0	45.0	30.0
15	8 7	22.00	1.6	25.0	8.8	4.0	0.05	15.0	45.0	16.0
16	3 7	0.00	3.5	0.0	0.0	0.0	0.05	0.0	0.0	0.0
16	3 7	0.60	7.1	0.0	0.0	0.0	0.16	0.0	0.0	0.0
16	3 7	3.13	13.0	0.0	0.0	0.0	0.05	0.0	0.0	0.0

Table A-14: Continued

site	dy	time	K	Na	Ca	Mg	NH-4	SO-4	Cl	CaCO
16	3 7	17.58	3.1	0.0	0.0	0.0	0.05	0.0	0.0	0.0
16	5 19	0.36	3.0	7.0	12.8	1.5	0.05	8.0	11.0	34.0
16	5 19	2.00	4.8	24.0	41.0	5.9	0.05	15.0	37.0	113.0
16	5 19	2.75	1.9	5.0	9.4	0.9	0.05	7.0	5.0	27.0
16	5 19	5.12	16.3	38.0	48.2	7.3	0.46	43.0	66.0	109.0
16	5 19	25.20	58.0	64.0	107.7	15.5	0.16	44.0	100.0	280.0
16	7 17	0.82	2.6	18.0	19.9	4.5	0.05	15.0	30.0	48.0
16	7 17	3.85	5.5	10.0	15.9	2.3	0.15	6.0	16.0	47.0
16	7 17	9.00	7.7	69.0	117.3	15.7	0.17	51.0	114.0	286.0
16	7 17	24.83	6.6	77.0	122.9	17.8	0.14	48.0	113.0	315.0
16	8 7	1.00	4.6	35.0	44.3	7.3	0.12	27.0	55.0	104.0
16	8 7	3.83	2.4	16.0	23.8	3.3	0.03	15.0	23.0	65.0
16	8 7	7.33	5.9	70.0	117.3	16.6	0.23	47.0	105.0	299.0
16	8 7	22.08	5.5	60.0	124.1	17.2	0.11	0.0	109.0	309.0
17	3 7	0.83	3.5	0.0	0.0	0.0	0.05	0.0	0.0	0.0
17	3 7	1.33	3.3	0.0	0.0	0.0	0.10	0.0	0.0	0.0
17	3 7	1.83	3.6	0.0	0.0	0.0	0.07	0.0	0.0	0.0
17	3 7	3.00	5.7	0.0	0.0	0.0	0.13	0.0	0.0	0.0
17	3 7	6.25	4.1	0.0	0.0	0.0	0.05	0.0	0.0	0.0
17	3 7	9.00	5.4	0.0	0.0	0.0	0.06	0.0	0.0	0.0
17	3 7	17.00	3.8	0.0	0.0	0.0	0.05	0.0	0.0	0.0
17	5 19	0.50	2.2	15.0	19.6	2.9	0.05	8.0	23.0	53.0
17	5 19	1.08	1.9	14.0	17.9	2.7	0.05	6.0	21.0	50.0
17	5 19	1.58	3.6	25.0	21.0	4.7	0.05	15.0	40.0	57.0
17	5 19	2.42	3.4	20.0	15.1	3.5	0.05	14.0	33.0	40.0
17	5 19	2.83	2.4	13.0	15.1	2.3	0.05	7.0	20.0	41.0
17	5 19	3.17	2.5	12.0	14.8	2.3	0.05	7.0	20.0	41.0
17	5 19	3.50	2.6	11.0	14.8	2.2	0.05	12.0	17.0	39.0
17	5 19	4.50	2.9	7.0	10.6	1.7	0.05	9.0	11.0	29.0
17	5 19	4.83	3.6	10.0	12.2	2.1	0.07	7.0	18.0	34.0
17	5 19	6.66	4.0	19.0	21.9	3.3	0.05	15.0	32.0	53.0
17	5 19	7.50	3.7	21.0	13.9	3.2	0.05	13.0	36.0	31.0
17	5 19	25.00	2.1	23.0	10.6	3.7	0.05	12.0	41.0	22.0
17	7 17	0.75	2.1	34.0	17.1	5.7	0.07	20.0	58.0	40.0
17	7 17	2.33	2.2	31.0	18.0	5.1	0.09	22.0	52.0	43.0
17	7 17	2.75	2.28	32.3	18.37	5.4	0.08	22.0	56.0	44.0
17	7 17	3.58	1.4	11.0	10.7	1.8	0.06	4.0	18.0	31.0
17	7 17	4.25	2.1	11.0	11.1	1.9	0.25	8.0	17.0	31.0
17	7 17	6.58	3.0	18.0	11.6	2.9	0.11	9.0	31.0	30.0
17	7 17	8.58	1.2	14.0	5.0	1.9	0.05	8.0	26.0	10.0
17	7 17	11.25	1.1	15.0	5.9	2.0	0.05	6.0	26.0	12.0
17	7 17	24.33	1.5	21.0	10.2	3.4	0.05	12.0	37.0	26.0
17	8 7	0.83	2.4	38.0	20.5	6.9	0.10	25.0	66.0	49.0
17	8 7	2.75	3.9	37.0	28.3	5.8	0.22	27.0	61.0	64.0
17	8 7	3.08	2.9	39.0	20.2	7.0	0.09	29.0	67.0	48.0
17	8 7	3.33	3.0	29.0	21.1	5.4	0.08	22.0	51.0	52.0
17	8 7	3.58	2.7	27.0	17.6	4.7	0.08	21.0	46.0	42.0
17	8 7	4.08	3.0	22.0	17.4	3.9	0.10	19.0	37.0	42.0
17	8 7	4.50	3.0	26.0	16.7	4.4	0.12	23.0	43.0	39.0
17	8 7	6.00	2.7	26.0	17.0	4.5	0.13	20.0	44.0	41.0

Table A-14: Continued

site	dy	time	K	Na	Ca	Mg	NH-4	SO-4	Cl	CaCO
17	8 7	7.00	2.4	29.0	15.0	4.3	0.12	20.0	48.0	36.0
17	8 7	8.00	2.6	29.0	15.9	4.4	0.12	20.0	48.0	38.0
17	8 7	10.00	2.0	29.0	13.2	4.1	0.13	16.0	49.0	32.0
17	8 7	12.00	1.8	29.0	12.3	4.1	0.10	15.0	49.0	29.0
17	8 7	21.17	1.8	27.0	12.9	4.5	0.05	17.0	49.0	28.0
WBC	7 6	0.00	1.1	31.0	37.5	3.9	0.50	10.0	65.0	70.0
WBC	7 17	0.00	0.9	34.0	40.8	4.2	0.05	20.0	62.0	88.0
MW	7 6	0.00	1.1	11.0	9.9	1.8	0.25	2.0	18.0	28.0
MW	7 17	0.00	1.9	26.0	13.3	2.9	0.05	9.0	46.0	32.0
CPH	7 6	0.00	8.6	208.0	15.0	23.1	0.06	50.0	360.0	22.0
CPH	7 17	0.00	2.3	16.0	10.5	1.8	0.05	14.0	24.0	22.0

Table A-14: Continued

site	dy	NO	P	nm545	nm275	nm254	DOC	EC
5	7 17	0.06	0.05	0.026	0.556	0.686	4.4	25.0
5	7 17	0.10	0.05	0.074	1.178	1.435	6.2	18.0
5	8 7	0.10	0.05	0.009	0.381	0.474	3.0	30.0
5	8 7	0.10	0.05	0.017	0.558	0.678	4.3	31.0
5	8 7	0.30	0.05	0.015	0.485	0.596	3.9	34.0
5	8 7	0.10	0.05	0.017	0.479	0.591	3.2	28.0
7	3 7	0.05	0.05	0.000	0.000	0.000	4.2	18.0
7	3 7	0.05	0.05	0.000	0.000	0.000	4.1	19.0
7	3 7	0.05	0.05	0.000	0.000	0.000	4.8	19.0
7	3 7	0.05	0.05	0.000	0.000	0.000	4.3	17.0
7	5 19	0.14	0.05	0.023	0.506	0.618	3.6	19.0
7	5 19	0.40	0.05	0.051	1.470	1.753	8.8	15.8
7	5 19	0.10	0.05	0.041	1.690	2.061	9.6	15.2
7	7 17	0.09	0.05	0.042	1.271	1.534	6.4	14.0
7	7 17	0.29	0.05	0.082	1.254	1.471	9.8	15.0
7	7 17	0.10	0.05	0.081	2.475	2.952	13.4	11.0
7	7 17	0.10	0.05	0.070	2.158	2.586	10.5	10.0
7	8 7	0.10	0.05	0.028	0.813	0.995	4.0	16.0
7	8 7	0.30	0.05	0.038	1.023	1.229	8.3	16.0
7	8 7	0.10	0.05	0.040	1.225	1.475	7.3	15.0
7	8 7	0.10	0.05	0.050	1.045	1.746	7.8	14.0
14	5 19	0.18	0.05	0.013	0.263	0.329	2.3	7.8
14	5 19	1.30	0.11	0.073	2.107	2.503	15.6	31.5
14	5 19	9.22	0.05	0.014	1.447	1.848	20.0	137.0
14	7 17	0.86	0.05	0.024	0.356	0.462	4.4	18.0
14	7 17	9.67	0.05	0.014	1.126	1.426	15.2	107.0
14	8 7	0.80	0.05	0.028	0.412	0.508	3.6	16.0
14	8 7	9.40	0.05	0.016	0.907	1.158	15.1	102.0
14	8 7	10.20	0.05	0.015	0.863	1.101	7.0	113.0
15	3 7	0.05	0.05	0.000	0.000	0.000	5.5	32.0
15	3 7	0.21	0.07	0.000	0.000	0.000	12.4	32.0
15	3 7	0.09	0.01	0.000	0.000	0.000	10.6	28.0
15	3 7	0.05	0.05	0.000	0.000	0.000	9.6	28.0
15	3 7	0.05	0.05	0.000	0.000	0.000	6.3	29.0
15	5 19	0.15	0.05	0.019	0.366	0.456	3.2	16.0
15	5 19	0.20	0.05	0.033	0.507	0.620	3.8	17.0
15	5 19	0.36	0.05	0.052	0.972	1.133	4.4	16.5
15	5 19	0.10	0.05	0.041	1.591	1.933	9.3	17.0
15	7 17	0.20	0.05	0.033	0.997	1.223	6.2	26.0
15	7 17	0.18	0.05	0.107	1.236	1.454	8.6	17.0
15	7 17	0.10	0.05	0.081	2.374	2.840	14.1	11.0
15	7 17	0.10	0.05	0.067	1.887	2.267	9.7	18.0
15	8 7	0.30	0.05	0.019	0.818	1.019	5.9	38.0
15	8 7	0.30	0.05	0.027	0.699	0.877	5.2	29.0
15	8 7	0.30	0.06	0.055	0.684	0.835	6.0	23.0
15	8 7	0.40	0.05	0.031	0.896	1.093	8.5	26.0
15	8 7	0.20	0.05	0.044	1.318	1.595	7.9	22.0
16	3 7	0.51	0.05	0.000	0.000	0.000	6.1	80.0
16	3 7	0.21	0.29	0.000	0.000	0.000	10.6	25.0
16	3 7	0.55	0.11	0.000	0.000	0.000	10.8	64.0

Table A-14: Continued

site	dy		NO	P	nm545	nm275	nm254	DOC	EC
16	3	7	0.66	0.05	0.000	0.000	0.000	5.3	73.0
16	5	19	0.18	0.08	0.018	0.420	0.511	3.6	11.5
16	5	19	0.54	0.06	0.021	0.497	0.618	5.2	37.0
16	5	19	0.11	0.09	0.023	0.338	0.399	2.2	8.0
16	5	19	2.28	0.09	0.047	1.411	1.698	10.8	52.0
16	5	19	1.80	0.05	0.005	0.398	0.504	7.7	90.0
16	7	17	0.35	0.05	0.030	0.413	0.536	4.5	23.0
16	7	17	0.29	0.05	0.099	1.143	1.328	9.1	17.0
16	7	17	2.71	0.05	0.023	0.736	0.918	15.0	97.0
16	7	17	3.20	0.05	0.018	0.532	0.671	12.0	103.0
16	8	7	1.30	0.08	0.017	1.109	1.574	16.0	46.0
16	8	7	0.60	0.05	0.042	0.488	0.592	4.7	24.0
16	8	7	2.60	0.12	0.014	0.462	0.536	12.3	98.0
16	8	7	2.70	0.08	0.008	0.391	0.496	11.7	100.0
17	3	7	0.05	0.05	0.000	0.000	0.000	6.3	39.0
17	3	7	0.05	0.05	0.000	0.000	0.000	6.3	39.0
17	3	7	0.05	0.09	0.000	0.000	0.000	7.1	40.0
17	3	7	0.50	0.30	0.000	0.000	0.000	13.8	30.0
17	3	7	0.07	0.05	0.000	0.000	0.000	8.6	38.0
17	3	7	0.06	0.06	0.000	0.000	0.000	10.7	34.0
17	3	7	0.05	0.05	0.000	0.000	0.000	7.1	38.0
17	5	19	0.10	0.06	0.015	0.314	0.387	3.1	19.5
17	5	19	0.10	0.05	0.015	0.290	0.356	3.0	18.5
17	5	19	0.12	0.05	0.023	0.478	0.597	4.1	27.5
17	5	19	0.15	0.05	0.024	0.434	0.542	4.0	22.0
17	5	19	0.11	0.05	0.024	0.408	0.496	3.3	16.5
17	5	19	0.12	0.05	0.038	0.605	0.716	3.3	16.0
17	5	19	0.15	0.05	0.043	0.589	0.702	3.3	15.0
17	5	19	0.24	0.05	0.048	0.710	0.834	3.3	11.0
17	5	19	0.32	0.05	0.055	0.925	1.081	4.1	14.2
17	5	19	0.51	0.05	0.030	0.800	0.969	6.6	24.0
17	5	19	0.51	0.05	0.046	1.109	1.327	7.6	22.0
17	5	19	0.10	0.05	0.044	1.566	1.398	9.1	21.0
17	7	17	0.15	0.05	0.031	1.052	1.286	6.9	31.0
17	7	17	0.14	0.05	0.031	0.948	1.168	6.4	30.0
17	7	17	0.18	0.05	0.035	0.965	1.188	7.5	31.0
17	7	17	0.06	0.05	0.038	0.406	0.487	4.0	14.0
17	7	17	0.10	0.05	0.061	0.866	1.006	6.8	14.0
17	7	17	0.26	0.05	0.050	0.995	1.193	11.0	20.0
17	7	17	0.10	0.05	0.081	2.262	2.709	13.4	13.0
17	7	17	0.10	0.05	0.085	2.353	2.809	13.5	13.0
17	7	17	0.10	0.05	0.070	1.919	2.304	9.2	20.0
17	8	7	0.30	0.05	0.016	0.767	0.955	5.9	38.0
17	8	7	0.40	0.21	0.020	0.953	1.272	11.5	39.0
17	8	7	0.30	0.05	0.023	0.769	0.961	5.9	38.0
17	8	7	0.30	0.05	0.032	0.643	0.811	6.4	32.0
17	8	7	0.30	0.05	0.027	0.608	0.767	5.9	29.0
17	8	7	0.30	0.05	0.028	0.611	0.761	5.9	25.0
17	8	7	0.40	0.05	0.033	0.771	0.950	6.9	27.0
17	8	7	0.30	0.05	0.026	0.734	0.896	7.2	28.0

Table A-14: Continued

site		dy	NO	P	nm545	nm275	nm254	DOC	EC
17	8	7	0.30	0.05	0.036	0.832	1.013	6.9	28.0
17	8	7	0.40	0.05	0.034	0.916	1.109	8.6	30.0
17	8	7	0.20	0.05	0.035	1.078	1.305	8.6	27.0
17	8	7	0.20	0.05	0.036	1.150	1.399	8.4	26.0
17	8	7	0.10	0.05	0.043	1.279	1.550	7.8	25.0
WBC	7	6	0.10	1.04	0.056	2.325	2.832	18.0	38.0
WBC	7	17	0.10	0.05	0.044	2.068	2.545	14.3	39.0
MW	7	6	0.10	0.55	0.024	0.217	0.264	3.3	13.0
MW	7	17	0.11	0.05	0.021	0.449	0.602	3.9	24.0
CPH	7	6	0.10	0.07	0.012	0.229	0.279	2.7	132.0
CPH	7	17	0.17	0.05	0.015	0.435	0.587	5.0	16.0

TABLES A-15 AND A-16

show the microbiological and chemical results of ground water from the inland well points in Hout Bay

Rest water levels are given in Appendix D

Table A-15: Microbiological data for ground water in Hout Bay

site	mt	dy	fc	fs	coli
1A	8	3	190	0	0
1C	8	3	780	0	0
1C	8	16	20	0	0
1E	8	3	2400	10	0
1E	8	16	4	0	0
2A	5	5	800	12	0
2A	5	21	140	0	0.0
2A	5	24	70	0.0	4
2A	6	8	1600	3100	0
2A	8	3	20	40	0
2A	8	15	0	4	0
2B	5	5	0	0	0
2B	5	20	0	0	4
2B	5	21	0	0	0.0
2B	5	24	0	0.0	8
2B	6	8	0	0	0
2B	8	3	0	0	0
2B	8	15	0	0	0
2C	5	5	0	0	0
2C	5	20	4	0	32
2C	5	21	0	0	0.0
2C	5	24	0	0.0	6
2C	6	8	0	16	0
2C	8	3	24	0	0
2C	8	15	0	0	0
2D	5	5	2200	0	0
2D	5	20	1500	0	2
2D	5	21	1130	0	0.0
2D	5	24	440	0.0	16
2D	6	8	284	4	0
2D	8	3	470	0	0
2D	8	15	0	8	0
2E	5	5	12	0	0
2E	5	20	210	0	12
2E	5	21	0	0	0.0
2E	5	24	0	0.0	2
2E	6	8	0	0	0
2E	8	3	4	0	0
2E	8	15	0	0	0
2F	5	5	170	44	0
2F	5	20	30	16	6
2F	5	21	0	0	0.0
2F	5	24	0	0.0	0
2F	6	8	0	0	0
2F	8	3	0	0	0
2F	8	15	0	0	0
3A	5	5	1400	101	
3A	5	20	140	80	8
3A	5	21	32	12	0

Table A-15: Continued

site	mt	dy	fc	fs	coli
3A	5	24	56	0	4
3A	6	8	12	24	0
3A	8	3	0	0	0
3A	8	15	0	0	0
3B	5	5	2000	77	0
3B	5	20	60	4	0
3B	5	21	0	4	0.0
3B	5	24	0	0.0	0
3B	6	8	4	0	0
3B	8	3	7	0	0
3B	8	15	0	8	0
3C	5	5	590	250	0
3C	5	20	1900	2800	14
3C	5	21	140	160	0.0
3C	5	24	320	0.0	0
3C	6	8	20	0	0
3C	8	3	8	4	0
3C	8	15	8	8	0
3D	5	5	430	0	0
3D	5	20	8	0	16
3D	5	21	12	0	0.0
3D	5	24	12	0.0	12
3D	6	8	0	0	0
3D	8	3	0	0	0
3D	8	15	0	0	0
3E	5	5	110	7	0
3E	5	20	90	4	44
3E	5	21	0	0	0.0
3E	5	24	4	0.0	28
3E	6	8	0	4	0
3E	8	3	0	0	0
3E	8	15	0	0	0
4A	5	5	130	0	0
4A	5	20	350	4	20
4A	5	21	0	0	0.0
4A	5	24	120	0.0	0
4A	6	8	250	192	0
4A	8	3	0	0	0
4A	8	15	4	0	0
4B	5	5	5	0	0
4B	5	20	0	0	2
4B	5	21	0	0	0.0
4B	5	24	4	0.0	0
4B	6	8	0	0	0
4B	8	3	0	0	0
4B	8	15	0	0	0
4C	5	5	8	0	0
4C	5	20	0	0	70
4C	5	21	0	0	0.0
4C	5	24	0	0.0	0

Table A-15: Continued

site	mt	dy	fc	fs	coli
4C	6	8	0	0	0
4C	8	3	0	0	0
4C	8	15	0	0	0
4D	5	5	1	0	0
4D	5	20	0	0	8
4D	5	21	0	0	0.0
4D	5	24	0	0.0	0
4D	6	8	4	0	0
4D	8	3	0	0	0
4D	8	15	0	0	0
4E	5	5	0	0	0
4E	5	20	0	0	6
4E	5	21	0	0	0.0
4E	5	24	0	0.0	6
4E	6	8	4	0	0
4E	8	3	0	0	0
4E	8	15	0	8	0
4F	5	5	0	0	0
4F	5	20	0	0	14
4F	5	21	4	0	0.0
4F	5	24	0	0.0	6
4F	6	8	0	0	0
4F	8	3	0	0	0
4F	8	15	0	0	0
5A	5	5	6	0	0
5A	5	20	56	0	34
5A	5	21	12	0	0.0
5A	5	24	4	0.0	18
5A	6	8	0	0	0
5A	8	3	0	0	0
5A	8	15	0	0	0
5B	5	5	26	0	0
5B	5	20	8	8	42
5B	5	21	0	0	0.0
5B	5	24	0	0.0	0
5B	6	8	28	0	0
5B	8	3	0	0	0
5B	8	15	0	0	0
5C	5	5	250	10	0
5C	5	20	100	0	2
5C	5	21	0	0	0.0
5C	5	24	12	0.0	12
5C	6	8	260	150	0
5C	8	3	33	0	0
5C	8	15	0	0	0
5D	5	5	1	0	0
5D	5	20	0	0	28
5D	5	21	0	0	0.0
5D	5	24	0	0.0	0

Table A-15: Continued

site	mt	dy	fc	fs	coli
5D	6	8	0	0	0
5E	5	5	3	0	0
5E	5	20	0	0	6
5E	5	21	0	0	0.0
5E	5	24	0	0.0	6
5E	6	8	0	0	0
5F	5	5	30	0	0
5F	5	20	0	0	6
5F	5	21	0	0	0.0
5F	5	24	0	0.0	0
5F	6	8	0	0	0
5F	8	3	0	0	0
5F	8	15	0	0	0
5G	5	5	0	0	0
5G	5	20	0	0	16
5G	5	21	0	0	0.0
5G	5	24	0	0.0	0
5G	6	8	8	0	0
5G	8	3	0	0	0
5G	8	15	0	0	0
AB	5	24	0	0	0

Table A-16: Chemical data for ground water in Hout Bay

site	mt	dy	K	Na	Ca	Mg	NH-4	SO	Cl	CaCO
1A	8	3	1.5	21.0	31.4	3.7	1.43	22	40	67.0
1C	8	3	1.9	36.0	13.7	7.9	0.05	35	56	10.0
1C	8	16	2.1	39.0	13.0	6.7	0.06	35	55	14.0
1E	8	3	2.1	29.0	40.3	7.4	0.51	69	42	64.0
1E	8	16	1.8	35.0	19.6	9.9	0.05	79	47	26.0
2A	5	5	5.7	84.0	22.2	29.4	0.16	200	106	23.0
2A	5	20	4.8	76.0	15.5	25.8	0.05	171	87	20.0
2A	5	21	4.9	82.0	16.1	27.5	0.05	186	98	19.0
2A	5	24	5.5	87.0	17.4	30.5	0.05	192	103	23.0
2A	6	8	4.9	0.0	0.0	0.0	0.24	174	89	0.0
2A	8	3	5.2	52.0	33.6	10.1	0.11	18	91	41.0
2A	8	15	4.8	50.0	30.4	8.1	0.08	22	71	43.0
2B	5	5	5.3	81.0	15.7	29.6	0.18	169	117	11.0
2B	5	20	4.7	81.0	14.8	28.9	0.05	175	113	6.0
2B	5	21	4.7	84.0	14.8	29.3	0.11	178	118	6.0
2B	5	24	4.6	83.0	17.5	29.5	0.05	186	118	8.0
2B	6	8	4.5	0.0	0.0	0.0	0.08	160	113	0.0
2B	8	3	4.9	80.0	25.8	50.6	0.07	161	139	4.0
2B	8	15	6.3	77.0	28.0	49.9	0.25	171	134	5.0
2C	5	5	5.9	75.0	15.7	25.6	0.05	135	113	14.0
2C	5	20	5.9	76.0	14.5	26.9	0.05	144	111	12.0
2C	5	21	5.9	78.0	14.8	26.7	0.05	144	116	11.0
2C	5	24	5.9	77.0	17.5	27.0	0.05	147	116	10.7
2C	6	8	6.0	0.0	0.0	0.0	0.05	142	113	0.0
2C	8	3	6.4	83.0	17.0	31.0	0.05	169	126	11.0
2C	8	15	6.7	85.0	17.0	31.4	0.05	165	128	11.0
2D	5	5	2.9	64.0	17.2	4.0	0.05	13	113	34.0
2D	5	20	2.6	64.0	17.5	3.0	0.05	13	108	33.0
2D	5	21	2.6	65.0	16.7	3.5	0.05	12	115	29.0
2D	5	24	2.9	66.0	25.6	4.6	0.05	34	113	40.0
2D	6	8	2.9	0.0	0.0	0.0	0.05	5	113	0.0
2D	8	3	2.8	60.0	16.1	3.7	0.07	11	104	28.0
2D	8	15	3.1	66.0	17.5	3.5	0.05	14	116	31.0
2E	5	5	5.0	69.0	18.6	24.9	0.17	113	82	22.0
2E	5	20	4.7	60.0	16.0	21.2	0.05	83	62	15.0
2E	5	21	5.1	70.0	17.1	24.1	0.07	120	84	18.0
2E	5	24	5.3	73.0	18.2	24.4	0.05	142	91	22.0
2E	6	8	5.7	0.0	0.0	0.0	0.09	170	102	0.0
2E	8	3	5.0	66.0	15.6	24.7	0.05	100	82	7.0
2E	8	15	5.1	66.0	15.0	24.6	0.05	89	76	5.0
2F	5	5	5.9	88.0	17.7	32.0	0.05	178	119	19.0
2F	5	20	5.8	87.0	16.1	32.4	0.05	181	113	17.0
2F	5	21	5.5	81.0	16.7	29.4	0.05	168	111	19.0
2F	5	24	5.9	84.0	17.5	30.0	0.05	167	118	16.5
2F	6	8	6.0	0.0	0.0	0.0	0.05	156	116	0.0
2F	8	3	6.0	83.0	15.7	29.8	0.05	153	122	14.0
2F	8	15	6.1	84.0	15.2	29.8	0.05	154	125	13.0
3A	5	5	8.4	116.0	29.0	23.8	0.10	91	163	39.0
3A	5	20	7.7	82.0	28.0	20.0	0.18	73	104	27.0

Table A-16: Continued

site	mt	dy	K	Na	Ca	Mg	NH-4	SO	Cl	CaCO
3A	5	21	8.2	96.0	27.2	20.4	0.07	90	132	32.0
3A	5	24	8.3	101.0	27.3	21.0	0.1	90	134	37.0
3A	6	8	7.9	0.0	0.0	0.0	0.05	78	185	0.0
3A	8	3	8.6	115.0	36.1	29.0	0.06	90	172	38.0
3A	8	15	9.5	122.0	39.6	30.6	0.05	92	204	35.0
3B	5	5	8.0	205.0	27.4	38.4	0.26	141	303	92.0
3B	5	20	8.5	210.0	27.2	36.6	0.40	181	290	89.0
3B	5	21	7.4	222.0	77.2	42.7	0.13	141	344	109.0
3B	5	24	7.2	221.0	36.7	42.0	0.07	154	340	98.0
3B	6	8	7.4	0.0	0.0	0.0	0.07	127	338	0.0
3B	8	3	10.9	166.0	28.9	33.6	0.10	113	251	71.0
3B	8	15	11.7	173.0	35.6	35.6	0.25	147	270	58.0
3C	5	5	5.7	137.0	16.5	21.9	0.05	53	227	50.0
3C	5	20	5.5	136.0	14.8	22.2	0.05	48	221	49.0
3C	5	21	5.3	138.0	15.6	22.2	0.05	45	238	49.0
3C	5	24	5.4	135.0	22.3	22.0	0.05	50	239	48.0
3C	6	8	5.7	0.0	0.0	0.0	0.05	42	233	0.0
3C	8	3	12.7	95.0	26.6	29.2	0.11	83	151	116.0
3C	8	15	12.9	93.0	28.5	30.7	0.23	82	143	138.0
3D	5	5	4.9	126.0	14.4	21.3	0.06	55	216	46.0
3D	5	20	4.8	126.0	13.3	21.7	0.05	49	205	47.0
3D	5	21	4.8	129.0	13.3	21.4	0.05	50	221	46.0
3D	5	24	4.7	126.0	22.7	22.0	0.05	50	224	46.0
3D	6	8	5.0	0.0	0.0	0.0	0.05	46	219	0.0
3D	8	3	5.0	126.0	13.5	21.3	0.05	47	218	49.0
3D	8	15	5.1	127.0	13.6	21.6	0.08	49	219	49.0
3E	5	5	5.8	134.0	15.7	22.1	0.06	55	232	44.0
3E	5	20	5.5	131.0	14.1	22.0	0.05	55	215	43.0
3E	5	21	5.7	135.0	14.1	21.7	0.09	52	228	44.0
3E	5	24	5.6	132.0	22.3	22.0	0.05	58	236	43.0
3E	6	8	5.7	0.0	0.0	0.0	0.05	54	231	0.0
3E	8	3	5.4	134.0	15.0	22.4	0.05	52	237	42.0
3E	8	15	5.5	136.0	14.8	22.3	0.07	56	243	42.0
4A	5	5	4.0	71.0	48.6	18.8	0.10	91	114	102.0
4A	5	20	2.0	61.0	83.7	9.2	0.05	13	115	193.0
4A	5	21	2.2	58.0	83.7	8.4	0.05	19	96	191.0
4A	5	24	2.0	61.0	82.1	9.3	0.05	13	120	186.0
4A	6	8	2.5	0.0	0.0	0.0	0.05	29	114	0.0
4A	8	15	2.0	61.0	75.3	8.2	0.06	20	108	185.0
4B	5	5	4.5	56.0	88.4	7.7	0.05	24	81	212.0
4B	5	20	4.6	54.0	88.9	7.8	0.05	22	82	214.0
4B	5	21	4.7	53.0	89.2	7.8	0.05	24	80	211.0
4B	5	24	4.7	52.0	84.6	7.5	0.05	25	78	205.0
4B	6	8	4.9	0.0	0.0	0.0	0.05	21	76	0.0
4B	8	3	5.4	49.0	83.0	7.4	0.05	20	78	205.0
4B	8	15	5.6	49.0	81.6	7.5	0.05	21	75	195.0
4C	5	5	2.5	55.0	75.6	8.1	0.05	19	83	188.0
4C	5	20	2.2	54.0	78.6	8.5	0.05	17	85	192.0
4C	5	21	2.1	54.0	80.8	8.5	0.05	21	83	191.0

Table A-16: Continued

site	mt	dy	K	Na	Ca	Mg	NH-4	SO	Cl	CaCO
4C	5	24	2.1	54.0	79.5	8.4	0.05	21	84	194.0
4C	6	8	2.5	0.0	0.0	0.0	0.05	21	79	0.0
4C	8	3	2.5	55.0	84.0	9.8	0.05	20	85	211.0
4C	8	15	2.4	53.0	82.7	9.4	0.05	21	83	206.0
4D	5	5	1.5	65.0	88.4	11.4	0.05	20	108	216.0
4D	5	20	1.0	64.0	90.7	11.3	0.05	19	105	219.0
4D	5	21	1.4	64.0	90.7	11.1	0.05	19	108	217.0
4D	5	24	1.4	64.0	90.0	11.1	0.05	22	109	218.0
4D	6	8	1.6	0.0	0.0	0.0	0.05	21	105	0.0
4D	8	3	1.5	66.0	87.2	10.9	0.05	18	112	216.0
4D	8	15	1.6	67.0	82.7	10.8	0.05	18	113	209.0
4E	5	5	3.1	65.0	93.0	10.4	0.05	23	104	224.0
4E	5	20	2.4	64.0	93.0	10.4	0.05	20	103	224.0
4E	5	21	2.5	64.0	91.5	10.2	0.05	21	106	223.0
4E	5	24	2.7	63.0	92.0	10.4	0.05	24	105	224.0
4E	6	8	2.9	0.0	0.0	0.0	0.05	21	104	0.0
4E	8	3	2.7	64.0	88.5	10.0	0.05	18	107	213.0
4E	8	15	2.7	67.0	85.3	10.2	0.05	20	112	218.0
4F	5	5	2.7	58.0	80.6	8.1	0.05	20	91	195.0
4F	5	20	2.3	58.0	82.2	8.2	0.05	19	84	196.0
4F	5	21	2.3	57.0	83.0	8.0	0.05	19	89	193.0
4F	5	24	2.3	57.0	82.0	8.2	0.01	22	88	193.0
4F	6	8	2.7	0.0	0.0	0.0	0.05	21	88	0.0
4F	8	3	2.8	57.0	84.4	8.9	0.05	19	91	192.0
4F	8	15	2.9	59.0	83.5	9.4	0.05	20	93	199.0
5A	5	5	9.4	107.0	61.7	20.9	0.05	105	169	129.0
5A	5	20	9.6	118.0	71.7	25.1	0.05	111	196	129.0
5A	5	21	9.5	111.0	71.7	23.5	0.05	100	179	145.0
5A	5	24	9.3	109.0	72.0	22.7	0.05	101	175	153.0
5A	6	8	8.7	0.0	0.0	0.0	0.05	100	143	0.0
5A	8	3	8.6	105.0	76.9	24.7	0.05	115	156	144.0
5A	8	15	8.6	101.0	74.8	24.1	0.05	108	167	150.0
5B	5	5	14.6	124.0	77.5	15.1	0.05	75	183	153.0
5B	5	20	12.0	123.0	65.8	15.5	0.05	80	183	132.0
5B	5	21	11.2	133.0	59.2	16.1	0.05	84	205	110.0
5B	5	24	11.0	134.0	61.0	17.0	0.05	89	206	111.0
5B	6	8	9.6	0.0	0.0	0.0	0.05	100	222	0.0
5B	8	3	11.6	133.0	78.9	20.9	0.05	123	231	125.0
5B	8	15	8.0	127.0	60.0	23.2	0.06	134	213	81.0
5C	5	5	7.3	78.0	55.6	19.2	0.05	69	87	169.0
5C	5	20	9.3	79.0	77.5	19.4	0.05	72	77	231.0
5C	5	21	12.1	74.0	119.5	14.6	0.05	73	79	297.0
5C	5	24	12.4	80.0	107.0	16.8	0.05	88	91	270.0
5C	6	8	12.1	0.0	0.0	0.0	0.05	60	81	0.0
5C	8	3	11.9	86.0	138.9	17.6	0.05	84	136	277.0
5C	8	15	11.3	90.0	125.3	16.7	0.08	82	125	270.0
5D	5	5	14.3	167.0	148.8	26.3	1.98	83	257	435.0
5D	5	20	14.0	171.0	150.4	26.0	1.92	67	254	433.0
5D	5	21	13.4	163.0	145.7	25.5	1.96	87	262	414.0

Table A-16: Continued

site	mt	dy	K	Na	Ca	Mg	NH-4	SO	Cl	CaCO
5D	5	24	13.4	163.0	147.0	26.0	2.20	71	251	420.0
5D	6	8	13.9	0.0	0.0	0.0	1.88	55	258	0.0
5E	5	5	5.4	138.0	59.4	18.5	0.37	71	241	140.0
5E	5	20	5.4	143.0	58.0	18.5	0.35	68	246	123.0
5E	5	21	5.1	139.0	60.4	18.2	0.35	71	244	135.0
5E	5	24	4.9	137.0	56.0	18.0	0.15	63	237	130.0
5E	6	8	5.1	0.0	0.0	0.0	0.41	36	236	0.0
5F	5	5	4.4	75.0	89.0	14.7	3.95	8	124	279.0
5F	5	20	4.0	77.0	87.4	14.6	3.83	6	124	276.0
5F	5	21	4.3	75.0	89.9	14.5	3.95	7	124	276.0
5F	5	24	4.6	74.0	89.0	14.7	4.39	8	121	277.0
5F	6	8	4.4	0.0	0.0	0.0	3.90	5	125	0.0
5F	8	3	4.2	75.0	87.7	14.2	1.93	9	123	264.0
5F	8	15	4.3	74.0	85.3	13.3	3.96	8	123	278.0
5G	5	5	3.8	65.0	120.0	14.8	0.98	68	108	279.0
5G	5	20	3.3	66.0	120.0	14.3	0.91	67	111	277.0
5G	5	21	3.3	64.0	122.1	14.0	0.99	60	111	281.0
5G	5	24	3.1	65.0	120.0	14.4	0.84	67	109	277.0
5G	6	8	3.7	0.0	0.0	0.0	1.15	49	113	0.0
5G	8	3	3.5	61.0	112.6	12.8	0.59	52	107	260.0
5G	8	15	3.6	63.0	110.7	13.4	1.04	63	108	267.0
AB	5	24	4.4	51.0	70.0	7.5	0.20	24	68	201.0

Table A-16: Continued

site	mt	dy	NO	P	nm545	nm275	nm254	DOC	EC	pH
1A	8	3	1.00	0.05	0.028	0.431	0.534	7.3	33.0	6.90
1C	8	3	7.30	0.05	0.010	0.817	1.082	8.5	35.0	5.20
1C	8	16	5.60	0.05	0.010	0.894	1.327	9.2	34.0	5.30
1E	8	3	0.10	0.05	0.026	0.476	0.602	7.9	42.0	6.70
1E	8	16	0.10	0.05	0.014	0.417	0.613	5.7	40.0	5.60
2A	5	5	0.10	0.05	0.014	0.745	0.862	8.5	78.0	6.20
2A	5	20	0.10	0.05	0.035	0.423	0.515	13.4	67.0	5.90
2A	5	21	0.13	0.05	0.025	0.367	0.450	6.4	74.0	6.15
2A	5	24	0.45	0.05	0.019	0.307	0.388	5.8	78.0	6.30
2A	6	8	0.11	0.05	0.020	0.317	0.395	6.7	68.0	5.80
2A	8	3	13.40	0.05	0.009	0.581	0.723	8.2	54.0	6.40
2A	8	15	14.82	0.05	0.059	0.763	0.936	8.8	50.0	6.10
2B	5	5	0.10	0.05	0.014	0.504	0.652	3.6	76.0	5.40
2B	5	20	0.10	0.05	0.013	0.508	0.645	4.8	75.0	5.10
2B	5	21	0.10	0.05	0.010	0.485	0.628	4.1	76.0	5.10
2B	5	24	0.10	0.05	0.012	0.442	0.568	5.0	77.0	4.90
2B	6	8	0.10	0.05	0.015	0.531	0.688	4.8	74.0	5.30
2B	8	3	21.80	0.05	0.008	0.595	0.779	6.5	100.0	4.80
2B	8	15	22.11	0.05	0.006	0.542	0.704	6.5	98.0	4.90
2C	5	5	0.10	0.05	0.006	0.181	0.233	3.1	68.0	5.55
2C	5	20	0.10	0.05	0.012	0.168	0.212	3.3	70.0	5.70
2C	5	21	0.10	0.05	0.005	0.158	0.203	2.7	70.0	5.50
2C	5	24	0.10	0.05	0.009	0.171	0.218	3.6	71.0	5.30
2C	6	8	0.10	0.05	0.004	0.143	0.184	3.2	70.0	5.40
2C	8	3	0.10	0.05	0.009	0.142	0.184	3.0	79.0	5.40
2C	8	15	0.19	0.05	0.001	0.144	0.186	3.1	79.0	5.30
2D	5	5	0.13	0.05	0.018	0.170	0.203	2.3	47.0	6.40
2D	5	20	0.10	0.05	0.034	0.105	0.116	1.4	47.0	6.60
2D	5	21	0.10	0.05	0.026	0.149	0.174	1.6	46.0	6.40
2D	5	24	0.10	0.05	0.020	0.287	0.366	3.6	52.0	6.35
2D	6	8	0.10	0.05	0.042	1.127	1.302	5.2	50.0	6.40
2D	8	3	0.10	0.05	0.016	0.132	0.156	2.2	44.0	6.30
2D	8	15	0.16	0.05	0.021	0.101	0.113	1.8	47.0	6.20
2E	5	5	11.04	0.05	0.010	0.276	0.349	3.6	66.0	5.80
2E	5	20	18.62	0.05	0.059	0.462	0.550	3.8	58.0	5.60
2E	5	21	8.67	0.05	0.014	0.248	0.311	3.3	65.0	5.90
2E	5	24	3.60	0.05	0.012	0.255	0.324	4.2	68.0	5.85
2E	6	8	2.92	0.05	0.014	0.225	0.282	3.6	75.0	5.60
2E	8	3	15.20	0.05	0.015	0.243	0.306	3.5	65.0	5.10
2E	8	15	20.26	0.05	0.006	0.208	0.262	3.5	64.0	5.0
2F	5	5	0.74	0.05	0.022	0.296	0.372	4.1	80.0	5.85
2F	5	20	0.75	0.05	0.027	0.295	0.369	4.1	79.0	5.70
2F	5	21	0.80	0.05	0.004	0.224	0.282	3.9	78.0	5.75
2F	5	24	0.90	0.05	0.030	0.281	0.349	4.2	76.0	5.80
2F	6	8	0.97	0.05	0.006	0.212	0.272	3.8	76.0	5.45
2F	8	3	1.00	0.05	0.003	0.157	0.204	3.3	76.0	5.60
2F	8	15	1.18	0.05	0.001	0.165	0.214	3.9	76.0	5.40
3A	5	5	18.84	0.05	0.084	1.664	2.072	11.0	94.0	6.20
3A	5	20	21.66	0.05	0.040	1.489	1.878	14.6	74.0	6.60

Table A-16: Continued

site	mt	dy	NO	P	nm545	nm275	nm254	DOC	EC	pH
3A	5	21	18.62	0.05	0.096	1.867	2.328	13.0	82.0	6.10
3A	5	24	18.80	0.10	0.073	1.719	2.165	15.0	83.0	6.85
3A	6	8	12.95	0.05	0.013	0.967	1.240	11.4	98.0	6.00
3A	8	3	23.30	0.05	0.057	1.193	1.493	11.0	103.0	5.80
3A	8	15	25.00	0.05	0.041	1.033	0.130	10.1	110.0	5.80
3B	5	5	1.21	0.05	0.035	0.878	1.134	8.0	146.0	6.40
3B	5	20	0.10	0.12	0.081	2.374	2.960	15.0	146.0	6.10
3B	5	21	0.71	0.05	0.031	0.799	0.991	6.7	152.0	6.50
3B	5	24	0.40	0.05	0.025	0.788	1.030	9.0	152.0	6.50
3B	6	8	0.74	0.05	0.027	0.603	0.763	9.1	152.0	6.10
3B	8	3	8.50	0.05	0.021	0.645	0.836	9.1	126.0	6.0
3B	8	15	6.14	0.05	0.009	0.762	1.003	11.5	134.0	5.80
3C	5	5	0.47	0.05	0.018	0.325	0.408	3.0	98.0	6.25
3C	5	20	0.56	0.05	0.019	0.286	0.360	3.8	96.0	6.20
3C	5	21	1.08	0.05	0.004	0.187	0.238	2.6	96.0	6.20
3C	5	24	0.40	0.05	0.010	0.237	0.304	3.8	95.0	6.10
3C	6	8	0.24	0.05	0.011	0.415	0.526	3.9	94.0	6.15
3C	8	3	0.10	0.05	0.032	1.850	2.350	17.5	88.0	6.00
3C	8	15	0.10	0.05	0.024	1.643	2.115	16.9	86.0	6.10
3D	5	5	0.10	0.05	0.072	0.635	0.782	3.9	90.0	6.25
3D	5	20	0.10	0.05	0.030	0.465	0.580	3.2	90.0	6.20
3D	5	21	0.10	0.05	0.029	0.440	0.557	4.7	90.0	6.10
3D	5	24	0.10	0.05	0.023	0.373	0.477	5.0	90.0	6.0
3D	6	8	0.10	0.05	0.011	0.368	0.478	5.5	89.0	5.90
3D	8	3	0.10	0.05	0.008	0.383	0.502	4.6	91.0	5.90
3D	8	15	0.10	0.05	0.005	0.393	0.513	4.4	90.0	5.90
3E	5	5	0.25	0.05	0.014	0.254	0.321	2.5	96.0	5.90
3E	5	20	0.24	0.05	0.029	0.342	0.419	3.1	94.0	6.05
3E	5	21	0.23	0.05	0.010	0.276	0.341	3.1	93.0	6.20
3E	5	24	0.20	0.05	0.018	0.286	0.355	3.5	94.0	6.00
3E	6	8	0.26	0.05	0.009	0.228	0.289	3.6	95.0	5.95
3E	8	3	0.10	0.05	0.016	0.220	0.276	3.1	97.0	6.00
3E	8	15	0.17	0.05	0.006	0.204	0.261	3.6	96.0	5.90
4A	5	5	0.19	0.05	0.010	0.322	0.403	3.9	74.0	6.90
4A	5	20	0.32	0.05	0.007	0.145	0.185	4.8	76.0	7.80
4A	5	21	4.20	0.11	0.013	0.114	0.139	3.9	73.0	7.70
4A	5	24	0.50	0.05	0.009	0.139	0.179	5.0	76.0	7.85
4A	6	8	0.63	0.05	0.015	0.182	0.229	5.9	75.0	7.50
4A	8	15	1.60	0.05	0.015	0.203	0.248	4.7	72.0	7.80
4B	5	5	5.35	0.13	0.001	0.119	0.152	3.8	72.0	7.40
4B	5	20	3.83	0.11	0.002	0.107	0.139	4.6	72.0	7.60
4B	5	21	3.91	0.05	0.004	0.115	0.147	4.6	72.0	7.60
4B	5	24	3.70	0.10	0.008	0.139	0.177	5.0	71.0	7.40
4B	6	8	5.78	0.12	0.002	0.104	0.135	5.7	72.0	7.40
4B	8	3	4.10	0.05	0.004	0.107	0.140	4.8	69.0	7.40
4B	8	15	4.57	0.07	0.001	0.091	0.116	4.1	69.0	7.60
4C	5	5	3.81	0.05	0.001	0.054	0.070	3.1	67.0	7.45
4C	5	20	4.06	0.05	0.000	0.046	0.060	3.8	69.0	7.70
4C	5	21	3.90	0.05	0.000	0.051	0.065	3.5	68.0	7.60

Table A-16: Continued

site	mt	dy	NO	P	nm545	nm275	nm254	DOC	EC	pH
4C	5	24	4.10	0.05	0.002	0.058	0.075	4.3	70.0	7.60
4C	6	8	4.49	0.05	0.001	0.048	0.062	5.5	70.0	7.40
4C	8	3	4.70	0.05	0.002	0.065	0.083	5.3	74.0	7.40
4C	8	15	4.62	0.05	0.002	0.050	0.060	4.1	72.0	7.50
4D	5	5	3.16	0.05	0.002	0.070	0.091	3.3	80.0	7.50
4D	5	20	3.10	0.05	0.000	0.060	0.079	4.5	80.0	7.65
4D	5	21	2.94	0.05	0.000	0.063	0.083	4.3	80.0	7.60
4D	5	24	3.00	0.05	0.008	0.085	0.110	4.8	80.0	7.70
4D	6	8	3.41	0.05	0.000	0.067	0.087	6.1	80.0	7.50
4D	8	3	2.40	0.05	0.003	0.065	0.085	5.3	80.0	7.50
4D	8	15	2.40	0.05	0.001	0.062	0.079	4.3	79.0	7.50
4E	5	5	2.79	0.05	0.009	0.126	0.158	3.6	80.0	7.60
4E	5	20	2.38	0.05	0.001	0.099	0.127	4.6	80.0	7.60
4E	5	21	2.17	0.05	0.004	0.111	0.141	4.6	80.0	7.70
4E	5	24	2.10	0.05	0.005	0.115	0.146	5.6	79.0	7.60
4E	6	8	2.12	0.05	0.001	0.107	0.136	6.4	80.0	7.45
4E	8	3	2.60	0.05	0.005	0.109	0.140	5.9	80.0	7.60
4E	8	15	2.67	0.05	0.002	0.106	0.132	5.0	80.0	7.50
4F	5	5	5.40	0.05	0.003	0.063	0.079	3.0	72.0	7.42
4F	5	20	5.70	0.05	0.000	0.057	0.072	3.9	72.0	7.70
4F	5	21	5.75	0.05	0.000	0.054	0.069	4.0	72.0	7.60
4F	5	24	5.50	0.05	0.145	0.242	0.269	4.5	72.0	7.50
4F	6	8	5.90	0.05	0.001	0.062	0.077	5.0	74.0	7.40
4F	8	3	6.40	0.05	0.003	0.057	0.073	4.4	76.0	6.70
4F	8	15	6.23	0.05	0.001	0.054	0.066	4.0	75.0	7.70
5A	5	5	3.58	0.05	0.014	0.530	0.860	6.5	97.0	6.70
5A	5	20	4.24	0.05	0.011	0.489	0.635	8.4	113.0	6.85
5A	5	21	2.99	0.05	0.005	0.454	0.598	7.9	106.0	6.70
5A	5	24	2.50	0.05	0.150	0.602	0.747	9.3	106.0	6.60
5A	6	8	1.11	0.05	0.007	0.488	0.642	10.4	96.0	6.50
5A	8	3	9.80	0.05	0.012	0.513	0.671	9.6	109.0	6.40
5A	8	15	5.56	0.05	0.005	0.479	0.633	9.2	106.0	6.80
5B	5	5	8.57	0.05	0.006	0.603	0.790	8.6	110.0	6.70
5B	5	20	7.37	0.05	0.008	0.532	0.695	8.9	106.0	6.60
5B	5	21	4.00	0.05	0.005	0.456	0.600	7.2	108.0	6.50
5B	5	24	5.50	0.05	0.008	0.469	0.617	8.4	111.0	6.30
5B	6	8	4.76	0.05	0.008	0.464	0.604	8.9	112.0	6.20
5B	8	3	1.80	0.05	0.009	0.546	0.727	10.7	123.0	6.80
5B	8	15	3.50	0.05	0.007	0.411	0.539	7.60	112.0	6.10
5C	5	5	5.97	0.05	0.025	0.726	0.972	10.2	78.0	6.60
5C	5	20	6.64	0.05	0.009	0.295	0.380	9.7	86.0	6.90
5C	5	21	8.50	0.05	0.013	0.571	0.748	12.6	98.0	7.00
5C	5	24	7.86	0.05	0.033	0.573	0.735	12.9	100.0	7.10
5C	6	8	7.25	0.05	0.011	0.480	0.614	13.7	96.0	6.95
5C	8	3	15.30	0.05	0.022	0.521	0.675	13.2	121.0	7.60
5C	8	15	11.97	0.05	0.006	0.525	0.689	11.7	112.0	6.90
5D	5	5	0.10	0.05	0.099	0.867	1.012	14.8	165.0	7.08
5D	5	20	0.10	0.05	0.004	0.704	0.948	18.4	165.0	7.15
5D	5	21	0.10	0.05	0.008	0.681	0.916	17.1	165.0	7.00

Table A-16: Continued

site	mt	dy	NO	P	nm545	nm275	nm254	DOC	EC	pH
5D	5	24	0.20	0.05	0.050	0.759	1.004	19.6	165.0	7.00
5D	6	8	0.21	0.05	0.004	0.695	0.934	21.0	165.0	6.90
5E	5	5	0.10	0.05	0.017	0.212	0.225	2.6	116.0	7.00
5E	5	20	0.10	0.05	0.011	0.059	0.067	2.6	112.0	6.90
5E	5	21	0.10	0.05	0.004	0.059	0.077	3.5	114.0	6.95
5E	5	24	0.10	0.05	0.033	0.162	0.181	3.8	114.0	6.90
5E	6	8	0.10	0.05	0.005	0.108	0.133	3.5	106.0	6.80
5F	5	5	0.10	0.28	0.015	0.665	0.806	7.3	90.0	7.65
5F	5	20	0.10	0.27	0.027	0.693	0.831	8.9	90.0	7.80
5F	5	21	0.10	0.25	0.013	0.668	0.805	9.2	89.0	7.60
5F	5	24	0.10	0.35	0.020	0.704	0.846	9.7	90.0	7.60
5F	6	8	0.10	0.32	0.009	0.584	0.710	10.0	88.0	7.50
5F	8	3	0.10	0.16	0.015	0.646	0.785	11.0	90.0	7.70
5F	8	15	0.10	0.28	0.021	0.673	0.816	8.7	88.0	7.50
5G	5	5	0.10	0.24	0.082	0.620	0.755	5.7	98.0	7.50
5G	5	20	0.10	0.20	0.014	0.507	0.636	7.8	94.0	7.60
5G	5	21	0.10	0.23	0.026	0.550	0.685	7.6	95.0	7.60
5G	5	24	0.10	0.18	0.019	0.515	0.644	8.3	95.0	7.40
5G	6	8	0.10	0.27	0.014	0.531	0.674	10.0	96.0	7.50
5G	8	3	0.10	0.12	0.073	0.573	0.720	8.6	90.0	7.20
5G	8	15	0.10	0.19	0.011	0.488	0.661	7.1	91.0	7.50
AB	5	24	0.10	0.05	0.029	0.360	0.454	8.1	63.0	7.10

TABLES A-17 AND A-18

show the microbiological and chemical
results of analysis of ground water from the well points
in the Hout Bay beach zone

Rest water levels are given in Appendix D

Table A-17: Microbiological data for ground water in the beach zone of Hout Bay

site	mt	dy	fc	fs	coli
BBH1	6	16	1045	0	0
BBH1	6	28	255	0	0
BBH1	7	10	165	0	0
BBH1	7	26	30	0	0
BBH1	8	16	0	0	0
BBH1	8	29	34	0	0
BBH1	11	08	6	0	0
BBH2	6	16	3700	8	0
BBH2	6	28	750	8	4
BBH2	7	10	440	0	0
BBH2	7	26	155	0	0
BBH2	8	16	175	0	0
BBH2	8	29	52	0	0
BBH2	11	08	4	0	0
BBH3	6	16	850	4	0
BBH3	6	28	473	4	0
BBH3	7	10	240	0	0
BBH3	7	26	115	0	0
BBH3	8	16	85	0	0
BBH3	8	29	44	0	0
BBH3	11	08	0	2	0
BBH4	6	16	412	0	0
BBH4	6	28	23	0	0
BBH4	7	10	26	0	0
BBH4	7	26	4	0	0
BBH4	8	16	0	0	0
BBH4	8	29	0	0	0
BBH4	11	08	0	0	0
BBH5	6	16	148	4	0
BBH5	6	28	8	0	0
BBH5	7	10	134	0	0
BBH5	7	26	4	0	0
BBH5	8	16	0	0	3
BBH5	11	08	0	0	0
BBH6	6	16	37000	104	13
BBH6	6	28	21000	27	32
BBH6	7	10	15500	4	0
BBH6	7	26	6800	4	0
BBH6	8	16	3900	0	3
BBH6	8	29	1070	4	0
BBH6	11	08	270	0	0
BBH7	6	16	36000	92	2
BBH7	6	28	20000	50	2
BBH7	7	10	19950	12	24
BBH7	7	26	4300	0	0
BBH7	8	16	900	0	0
BBH7	8	29	601	0	0
BBH7	11	08	226	0	0

Table A-17: Continued

site	mt	dy	fc	fs	coli
BBH8	6	16	5900	20	0
BBH8	6	28	4200	0	0
BBH8	7	10	3750	0	0
BBH8	7	26	400	0	0
BBH8	8	16	210	0	0
BBH8	8	29	76	0	0
BBH8	11	08	14	0	0

Table A-18: Chemical data for ground water in the beach zone of Hout Bay

site	mt	dy	K	Na	Ca	Mg	NH-4	SO	Cl	CaCO
BBH1	6	16	8.0	106.0	145.2	22.7	0.06	107	158	317.0
BBH1	6	28	7.9	104.0	145.1	22.2	0.04	100	164	323.0
BBH1	7	10	7.7	105.0	145.2	22.5	0.05	103	160	320.0
BBH1	7	26	8.0	106.0	150.0	21.3	0.05	98	166	320.0
BBH1	8	16	8.1	110.0	149.1	22.1	0.05	102	172	319.0
BBH1	8	29	8.3	110.0	146.0	21.8	0.05	103	178	319.0
BBH2	6	16	6.2	72.0	122.2	9.1	0.47	59	114	276.0
BBH2	6	28	5.4	64.0	115.0	9.5	0.42	53	100	273.0
BBH2	7	10	5.6	68.0	121.0	8.9	0.30	58	106	282.0
BBH2	7	26	5.7	66.0	122.1	8.6	0.52	57	100	282.0
BBH2	8	16	5.0	63.0	113.7	9.3	0.55	51	95	278.0
BBH2	8	29	4.9	62.0	113.4	9.4	0.49	52	97	278.0
BBH3	6	16	4.9	68.0	117.11	8.9	0.51	52	103	272.0
BBH3	6	28	4.4	60.0	108.0	9.3	0.46	46	93	265.0
BBH3	7	10	4.6	65.0	117.1	8.9	0.41	50	98	280.0
BBH3	7	26	4.7	65.0	117.1	8.8	0.72	52	97	283.0
BBH3	8	16	4.1	60.0	109.8	9.5	0.41	47	92	269.0
BBH3	8	29	4.0	57.0	105.2	9.7	0.30	46	89	262.0
BBH4	6	16	13.9	286.0	146.3	25.8	1.32	112	488	291.0
BBH4	6	28	11.5	209.0	121.7	27.9	1.34	91	365	262.0
BBH4	7	10	13.5	253.0	128.9	34.3	1.15	103	450	292.0
BBH4	7	26	15.3	326.0	142.6	34.9	1.52	123	560	295.0
BBH4	8	16	10.0	158.0	124.2	19.8	1.40	81	265	291.0
BBH4	8	29	10.2	158.0	128.3	19.8	1.53	84	274	298.0
BBH5	6	16	13.7	245.0	139.0	22.0	1.53	108	395	300.0
BBH5	6	28	10.6	146.0	123.2	20.6	1.54	79	249	293.0
BBH5	7	10	10.9	175.0	124.4	24.6	1.24	85	300	296.0
BBH5	7	26	11.8	179.0	131.2	23.3	1.87	87	313	301.0
BBH5	8	16	9.6	122.0	130.3	13.9	1.79	78	195	305.0
BBH6	6	16	14.7	97.0	134.5	32.2	0.45	130	131	364.0
BBH6	6	28	14.7	94.0	136.6	33.8	0.40	133	127	370.0
BBH6	7	10	14.3	91.0	131.0	32.9	0.35	120	125	371.0
BBH6	7	26	13.9	88.0	132.0	33.0	0.37	123	122	359.0
BBH6	8	16	15.2	115.0	143.9	35.2	0.32	131	200	348.0
BBH6	8	29	15.4	110.0	144.8	33.2	0.33	144	189	354.0
BBH7	6	16	12.5	91.0	144.0	28.3	0.42	142	125	354.0
BBH7	6	28	12.5	97.0	145.1	27.4	0.37	150	116	368.0
BBH7	7	10	11.5	89.0	126.2	27.1	0.3	119	106	354.0
BBH7	7	26	12.3	90.0	143.9	28.0	0.34	133	122	360.0
BBH7	8	16	13.1	86.0	147.4	26.7	0.34	153	111	363.0
BBH7	8	29	13.3	83.0	149.4	26.3	0.32	164	114	356.0
BBH8	6	16	12.0	109.0	165.1	27.1	0.42	163	165	352.0
BBH8	6	28	12.5	118.0	160.2	27.0	0.37	164	168	366.0
BBH8	7	10	12.1	96.0	160.3	24.8	0.28	165	141	361.0
BBH8	7	26	12.2	105.0	160.4	25.1	0.54	161	151	367.0
BBH8	8	16	12.5	110.0	156.1	26.0	0.35	168	147	366.0
BBH8	8	29	12.6	107.0	157.3	25.7	0.38	173	147	362.0

Table A-18: Continued

site	mt	dy	NO	P	nm545	nm275	nm254	DOC	EC	pH
BBH1	6	16	5.68	0.09	0.001	0.165	0.212	8.0	128.0	7.35
BBH1	6	28	6.04	0.07	0.002	0.160	0.280	8.5	132.0	7.30
BBH1	7	10	6.40	0.07	0.001	0.170	0.219	10.3	130.0	7.40
BBH1	7	26	6.40	0.05	0.001	0.165	0.214	9.3	133.0	7.50
BBH1	8	16	6.90	0.06	0.001	0.173	0.295	7.6	136.0	7.30
BBH1	8	29	6.30	0.08	0.001	0.184	0.237	7.3	135.0	7.40
BBH2	6	16	0.14	0.08	0.001	0.222	0.289	7.5	96.0	7.40
BBH2	6	28	0.05	0.07	0.003	0.224	0.292	7.5	90.0	7.40
BBH2	7	10	0.10	0.07	0.005	0.246	0.313	10.2	95.0	7.40
BBH2	7	26	0.10	0.05	0.001	0.223	0.290	9.2	93.0	7.60
BBH2	8	16	0.10	0.06	0.003	0.236	0.344	7.2	82.0	7.40
BBH2	8	29	0.10	0.07	0.003	0.234	0.302	7.3	90.0	7.50
BBH3	6	16	0.10	0.09	0.003	0.220	0.286	7.0	90.0	7.45
BBH3	6	28	0.05	0.08	0.004	0.224	0.290	7.3	85.0	7.60
BBH3	7	10	0.10	0.07	0.004	0.227	0.291	9.8	92.0	7.50
BBH3	7	26	0.10	0.05	0.001	0.220	0.287	8.7	90.0	7.50
BBH3	8	16	0.10	0.07	0.003	0.228	0.329	6.9	88.0	7.40
BBH3	8	29	0.10	0.08	0.005	0.219	0.282	6.4	84.0	7.50
BBH4	6	16	0.10	0.09	0.003	0.297	0.383	7.9	215.0	7.50
BBH4	6	28	0.05	0.10	0.005	0.282	0.665	7.5	180.0	8.50
BBH4	7	10	0.10	0.08	0.005	0.303	0.387	10.2	205.0	7.70
BBH4	7	26	0.10	0.05	0.002	0.285	0.370	9.8	250.0	7.70
BBH4	8	16	0.10	0.05	0.004	0.275	0.390	8.0	152.0	7.40
BBH4	8	29	0.10	0.05	0.002	0.258	0.332	7.3	152.0	7.50
BBH5	6	16	0.10	0.06	0.002	0.303	0.391	8.3	190.0	7.50
BBH5	6	28	0.05	0.06	0.007	0.272	0.351	7.8	145.0	7.40
BBH5	7	10	0.10	0.07	0.008	0.307	0.389	10.0	160.0	7.60
BBH5	7	26	0.10	0.05	0.002	0.263	0.341	10.9	165.0	7.60
BBH5	8	16	0.10	0.06	0.005	0.276	0.392	8.2	132.0	7.40
BBH6	6	16	1.16	0.05	0.005	0.328	0.412	9.3	125.0	7.45
BBH6	6	28	0.75	0.04	0.010	0.319	0.405	9.7	127.0	7.40
BBH6	7	10	1.05	0.05	0.023	0.404	0.489	11.7	126.0	7.60
BBH6	7	26	1.21	0.05	0.004	0.300	0.380	12.2	122.0	7.70
BBH6	8	16	1.10	0.07	0.007	0.316	0.444	8.7	148.0	7.40
BBH6	8	29	0.40	0.05	0.004	0.279	0.354	8.7	144.0	7.50
BBH7	6	16	0.74	0.05	0.004	0.289	0.368	9.2	124.0	7.40
BBH7	6	28	0.42	0.04	0.007	0.294	0.376	9.3	127.0	7.40
BBH7	7	10	1.72	0.07	0.023	0.396	0.477	11.4	118.0	7.40
BBH7	7	26	1.24	0.05	0.004	0.291	0.370	12.2	122.0	7.50
BBH7	8	16	0.60	0.08	0.006	0.336	0.466	8.9	127.0	7.30
BBH7	8	29	0.10	0.05	0.005	0.287	0.362	8.7	125.0	7.40
BBH8	6	16	0.10	0.21	0.005	0.240	0.307	9.1	138.0	7.45
BBH8	6	28	0.05	0.19	0.006	0.246	0.316	9.3	144.0	7.40
BBH8	7	10	0.10	0.17	0.013	0.268	0.336	10.8	135.0	7.40
BBH8	7	26	0.10	0.15	0.003	0.237	0.304	11.0	135.0	7.60
BBH8	8	16	0.10	0.16	0.004	0.263	0.370	9.2	142.0	7.30
BBH8	8	29	0.10	0.16	0.003	0.252	0.319	8.9	136.0	7.40

APPENDIX B

FLOW DATA

Table B-1: Flow data for the Hout Bay River, tributaries and stormdrains (26/04 to 27/06)

Place of measurement	FLOW RATES (litres per second) Date of measurement					
	26/04	11/05	03/06	06/06	20/06	27/06
Tributary 5	0,17	0,069	11,90	5,20	1,28	
Stormdrain 6	0,02	*		2,70	3,0	
Longkloof weir (7)			330	330		103,2
Victoria bridge (15)						248,0
Stormdrain 16 at Victoria bridge	0,95	0,61	1,20	1,20	1,80	
Princess Street bridge (17)						206,0
Tributary 21	0,16	**	17,60	5,0		
Stormdrain 22	*	*		0,016	**	218
Stormdrain 23	*	*	**	**	**	
Hout Bay River mouth (24)						200,8

* Dry

** Very low flow

Table B-2: Flow data for the Hout Bay River, tributaries and stormdrains (04/07 to 21/07)

Place of measurement	FLOW RATES (litres per second) Date of measurement 04/07	09/07	13/07	18/07	21/07
World of birds (2)		7,0			
Tributary 3-1		35,0			82,4
Tributary 5	1,28			75	
Stormdrain 6				6,0	
Longkloof weir (7)		2 593	331,6	1 006	
Tributary (9)		323	46,7		259,9
Orangekloof weir (12)	28,0	660,8	126,1		
Victoria bridge (15)			563,5	1 372	2582,3
Public open space (15-2)		2 871	462,4		2582,3
Stormdrain 16 at Victoria bridge	4,0		1,98	3,0	
Princess Street bridge (17)		2 387	700	2367,7	2873,6
Tributary 21	5,0	508			
Stormdrain 22	0,024		0,11	1,63	
Stormdrain 23		2,0	0,1	0,108	
Hout Bay River Mouth (24)			***		3107,6
Tributary 31		369			293,6
Baviaanskloof trib. (34)		539	247,8		563,1
Hout Bay River at well point site 2		2320	694,3		3081,9

*** High tide prevented measurement of flow

Table B-3: Flow data for the Hout Bay River, tributaries and stormdrains (08/08 to 08/11)

FLOW RATES (litres per second)					
Place of measurement	Date of measurement				
	08/08	12/08	22/08	26/08	08/11
World of Birds (2)		4,0	0,8		4,2
Tributary 3-1		13,8	6,6		8,1
Tributary 5			2,7		
Stormdrain 6	10,0				
Longkloof weir		120,0	100,6	133,1	110,9
Tributary 9		20,0		17,9	17,0
Orangekloof weir (12)	123,4		82,3		
Victoria bridge (15)	359,5	303,9	204,9	198,6	138,3
Public open space (15-2)		236		189,9	147,0
Stormdrain 16 at Victoria bridge			1,8		
Princess Street bridge (17)	4286	254,9	355,4	196,4	166,93
Tributary 21	145,2				
Stormdrain 22	0,23		0,04		
Stormdrain 23	0,012		0,02		
Hout Bay River mouth (24)		325,7		***	
Tributary 31		19,4		18,7	
Baviaanskloof trib. (34)		52,3		21,9	
Hout Bay River at well point site 2		190,6		165,9	147,8

*** High tide prevented measurement of flow

Table B-4: Additional flow data for Victoria bridge

Date of measurement	Flow (litres per second)
28/07	460,2
05/08	257,0
12/09	396,6
13/09	350,3
28/09	364,5
26/10	276,4

Table B-5: Flow during storm events

STORM EVENT 19 MAY							
Flow (litres per second) and time after onset of rain*							
Victoria bridge	Time	Princess Street bridge	Time	Tributary 5	Time	Stormdrain 16	Time
2630,6	0,33			6,4	0,83	55,2	0,33
2742,5	1,25					23,3	1,25
						12,4	1,92
2560,0	2,75	2133,1	2,75				
4365,7	4,45					613,7	4,45
4085,8	4,50					37,3	4,50
3917,9	5,08			6,4	5,25	23,3	5,12
3750,0	6,45					5,4	6,45
3162,3	25,17			19,1	25,33	5,4	25,17

*where the onset of rainfall is taken as o and subsequent times given as ratios

Table B-5: Continued

STORM EVENT 17 JULY							
Victoria bridge	Time	Princess Street bridge	Time	Tributary 5	Time	Stormdrain 16	Time
Flow (litres per second) and time after onset of rain							
463	0,80	796,0	0,75				
463	2,25	796,0	2,33	19,0	1,03	37,3	0,82
		1193,5	2,75				
948	3,83	1721	3,58			101,0	3,85
		2033	4,25			37,3	4,75
		2102	6,58				
1072	9,02	4159	8,58			5,0	9,00
1372	24,75	1006	24,33	75,0	25,21	3,0	24,83

Table B-5: Continued

STORM EVENT 7 AUGUST							
Victoria bridge	Time	Princess Street bridge	Time	Tributary 5	Time	Stormdrain 16	Time
Flow (litres per second) and time after onset of rain							
99,6	0,92	111,9	0,83			8,5	1,00
698,4	2,92	497,3	2,75			55,2	1,33
		592,4	3,08				
		926,0	3,33				
612,4	3,83	1157,5	3,58			23,3	3,83
		783,8	4,08				
		771,7	4,50	39,0	4,33		
		671,4	6,00				
385,4	7,25	613,2	7,00	19,0	7,53	2,4	7,33
249,7	22,00	344,2	21,16	19,0	22,47	2,4	22,08

APPENDIX C

WELL POINT SPECIFICATIONS

Table C-1: Inland well point specifications

Well point	Ht (above MSL (m) to top of casing	Depth below ground surface (m)	Length of plain casing (m)	Length of screen (m)	Material at depth
1A	53,628	4,45	3,00	1,45	coarse
1B	53,112	4,14	2,65	1,49	gravel
1C	52,087	4,00	2,79	1,21	and rock
1D	53,598	3,50	2,30	1,20	↓
1E	52,814	5,07	3,94	1,13	
2A	18,195	5,80	4,60	1,20	very coarse alluvial
2B	17,074	3,50	2,30	1,20	gravel
2C	16,443	3,50	2,30	1,20	↓
2D	16,615	6,00	4,80	1,20	gravel, sand fine white clay
2E	18,402	5,19	2,79	2,40	coarse gravel and alluvial
2F	18,950	5,25	4,05	1,20	sands
3A	11,861	5,50	4,25	1,25	sand
3B	11,255	5,75	4,48	1,27	↑
3C	11,046	4,00	2,80	1,20	rock
3D	10,731	4,85	3,65	1,20	↓
3E	10,221	4,50	3,30	1,20	
4A	8,199	5,85	3,45	2,40	↑
4B	8,832	5,80	3,40	2,40	
4C	7,452	6,00	4,80	1,20	fine sand
4D	6,879	6,20	5,03	1,17	↓
4E	5,298	5,40	4,20	1,20	

Table C-1: Continued

Well point	Ht (above MSL (m) to top of casing	Depth below ground surface (m)	Length of plain casing (m)	Length of screen (m)	Material at depth
4F	5,762	6,40	5,10	1,30	fine sand
5A	3,922	4,50	3,30	1,20	coarse gravel
5B	4,440	5,50	4,05	1,45	sand, gravel & white clay
5C	4,179	5,80	4,35	1,45	coarse gravel
5D	3,609	6,50	5,30	1,20	medium sand
5E	3,327	6,60	5,45	1,15	fine sand (grey)
5F	3,413	6,60	5,40	1,20	fine sand
5G	3,517	6,50	5,25	1,25	sand & gravel

Table C-2: Beach well point specifications

Well point	Ht (above MSL (m) to top of metal casing	Depth below ground surface (m)	Length of plain casing (m)	Length of screen (m)	Material at depth
1	2,173	8,00	3,10	4,90	very compact layer
2	1,970	8,00	3,10	4,90	of broken shells
3	2,603	8,70	3,88	4,82	
4	2,002	6,54	2,51	4,03	
5	1,903	4,61	2,11	2,50	beach sand
6	3,156	6,07	2,07	4,00	beach sand
7	3,180	6,45	1,62	4,83	coarse sand, broken shells
8	2,243	6,49	3,26	3,23	coarse sand

APPENDIX D

REST WATER LEVELS IN WELL POINTS

Table D-1: Depth to rest water level (from ground surface, in inland well points (02/05 to 03/06))

Well point	Date of measurement (1988) 02/05	04/05	20/05	21/05	24/05	03/06
Site 1A	Dry					
B	Dry					
C	Dry					
D	Dry					
E	Dry					
Site 2A	14,115	14,07	14,105	14,135	14,12	14,2
B	12,859	12,789	12,869	12,914	12,911	12,914
C	13,103	13,068	13,218	13,243	13,218	13,223
D	12,145	12,115	12,2	12,215	12,265	12,215
E	14,732	14,662	14,642	14,707	14,707	14,822
F	14,73	14,695	14,695	14,75	14,74	14,77
Site 3A	7,641	7,606	7,621	7,616	7,651	7,686
B	7,525	7,465	7,555	7,58	7,595	7,645
C	7,456	7,376	7,466	7,456	7,536	7,636
D	7,511	7,436	7,566	7,586	7,611	7,666
E	7,626	7,571	7,696	7,706	7,721	7,776
Site 4A	5,369	5,319	5,459	5,459	5,194	5,304
B	5,747	5,682	5,807	5,787	5,747	5,657
C	5,202	5,147	5,297	5,287	5,207	5,142
D	4,799	4,744	4,904	4,879	4,829	4,749
E	4,483	4,428	4,523	4,513	4,458	4,433
F	4,812	4,762	4,887	4,882	4,802	4,757

Table D-1: Continued

Well point	Date of measurement (1988) 02/05	04/05	20/05	21/05	24/05	03/06
Site 5A	1,892	1,852	2,722	2,187	2,312	2,282
B	1,91	1,88	2,22	2,225	2,29	2,305
C	2,576	2,591	2,946	2,986	2,931	3,026
D	1,779	1,724	2,039	2,039	2,054	2,054
E	1,687	1,622	1,957	1,962	1,947	1,957
F	1,863	1,783	2,133	2,148	2,153	2,138
G	1,992	1,947	2,192	2,167	2,167	2,157

Table D-1: Depth to rest water level (from ground surface, in inland well points (08/06 to 15/08))

Well point	Date of measurement (1988) 08/06	18/06	11/07	03/08	15/08
Site 1A	Dry	Dry	Dry	48,368	48,403
B	Dry	Dry	Dry	48,702	48,727
C	Dry	Dry	Dry	48,572	48,692
D	Dry	Dry	Dry	Dry	Dry
E	Dry	Dry	Dry	47,754	47,789
Site 2A	14,185	14,195	14,495	14,635	14,635
B	12,959	12,899	13,154	13,104	13,119
C	13,283	13,218	13,478	13,453	13,453
D	12,305	12,255	12,395	12,395	12,37
E	14,757	14,752	15,037	15,287	15,202
F	14,785	14,75	15,02	15,25	15,28
River level	-	-	12,634	12,544	12,544
Site 3A	7,756	7,831	8,166	8,361	8,321
B	7,69	7,775	8,12	8,23	8,19
C	7,681	7,806	8,211	8,361	8,341
D	7,701	7,786	8,126	8,146	8,131
E	7,806	7,871	8,186	8,251	8,236
River level	-	-	7,720	7,498	7,570
Site 4A	5,334	5,244	5,429	5,319	5,249
B	5,677	5,607	5,782	5,677	5,582
C	5,167	5,047	5,277	5,167	5,082

Table D-1: Continued

Well point	Date of measurement (1988) 08/06	18/06	11/07	03/08	15/08
Site 4D	4,804	4,689	4,889	4,769	4,724
E	4,478	4,368	4,563	4,458	4,428
F	4,812	4,702	4,907	4,782	4,707
River level	-	-	2,908	2,708	2,698
Site 5A	2,432	2,272	2,542	2,492	2,402
B	2,425	2,35	2,580	2,500	2,425
C	3,186	3,201	3,501	3,496	3,381
D	2,149	-	2,249	-	-
E	2,067	-	2,172	-	-
F	2,233	2,113	2,318	2,133	2,083
G	2,212	2,012	2,237	2,047	1,997

Table D-2: Rest water levels in beach well points

Measurement Date	Time (start)	High Tide	* Beach well point number							
			1	2	3	4	5	6	7	8
29/04	10:30	14:08	0,653	0,880	0,843	-	-	-	-	-
30/04	13:30	14:39	0,743	0,895	0,878	-	-	-	-	
01/05	13:30	15:09	0,773	0,910	0,883	-	-	-	-	-
02/05	15:30	15:41	0.981	0,935	0,898	-	-	-	-	-
03/05	15:00	16:15	0,788	0,925	0,893	-	-	-	-	-
07/05	13:30	19:31	0,673	0,825	0,798	-	-	-	-	-
11/05	09:00	12:01	0,663	0,815	0,788	-	-	-	-	-
14/05	10:15	14:24	0,763	0,865	0,853	-	-	-	-	-
16/05	11:00	15:43	0,838	0,940	0,928	-	-	-	-	-
18/05	10:30	16:58	0,793	0,945	0,918	-	-	-	-	-
26/05	11:00	12:11	0,823	0,970	0,928	0,932	0,893	0,931	0,955	0,923
31/05	10:00	15:24	0,738	0,910	0,893	0,837	0,838	0,886	0,865	0,843
04/06	09:30	05:51	1,063	1,130	1,103	1,132	1,143	0,966	0,990	0,993
07/06	13:30	09:05	0,943	1,200	1,183	1,172	1,143	1,036	1,080	1,073
09/06	14:30	11:31	0,778	1,020	1,003	0,982	0,973	0,921	0,960	0,913
11/06	09:00	13:24	0,718	0,970	0,933	0,897	0,893	0,856	0,905	0,848
15/06	08:00	03:42	0,823	1,035	0,998	0,997	0,993	0,916	0,950	0,878
17/06	13:00	17:22	0,693	0,900	0,868	0,832	0,823	-	-	-
18/06	09:00	17:58	-	-	-	-	-	0,846	0,870	0,553
28/07	08:00	14:30	0,713	0,900	0,853	0,837	0,843	0,846	0,830	0,838
10/07	13:30	13:17	1,043	1,305	1,273	1,282	1,263	1,096	1,115	1,093
22/07	10:30	08:34	1,063	1,270	1,218	1,182	1,168	1,086	1,120	1,093
26/07	08:00	13:31	0,858	1,070	1,023	0,982	0,968	0,991	1,010	0,973

Table D-2: Continued

Measurement Date	Time (start)	High Tide	* Beach well point number							
			1	2	3	4	5	6	7	8
05/08	10:20	09:00	0,863	0,990	0,953	0,927	0,903	0,946	0,955	0,938
16/08	08:00	05:10	0,958	1,050	1,033	1,002	0,983	0,946	0,960	0,943
29/08	08:30	04:23	1,043	1,215	1,203	1,232	-	1,041	1,060	1,038

* Table Bay

APPENDIX E

RESULTS OF THE GEOPHYSICAL SURVEY IN HOUT BAY

(RESISTIVITY METHOD)

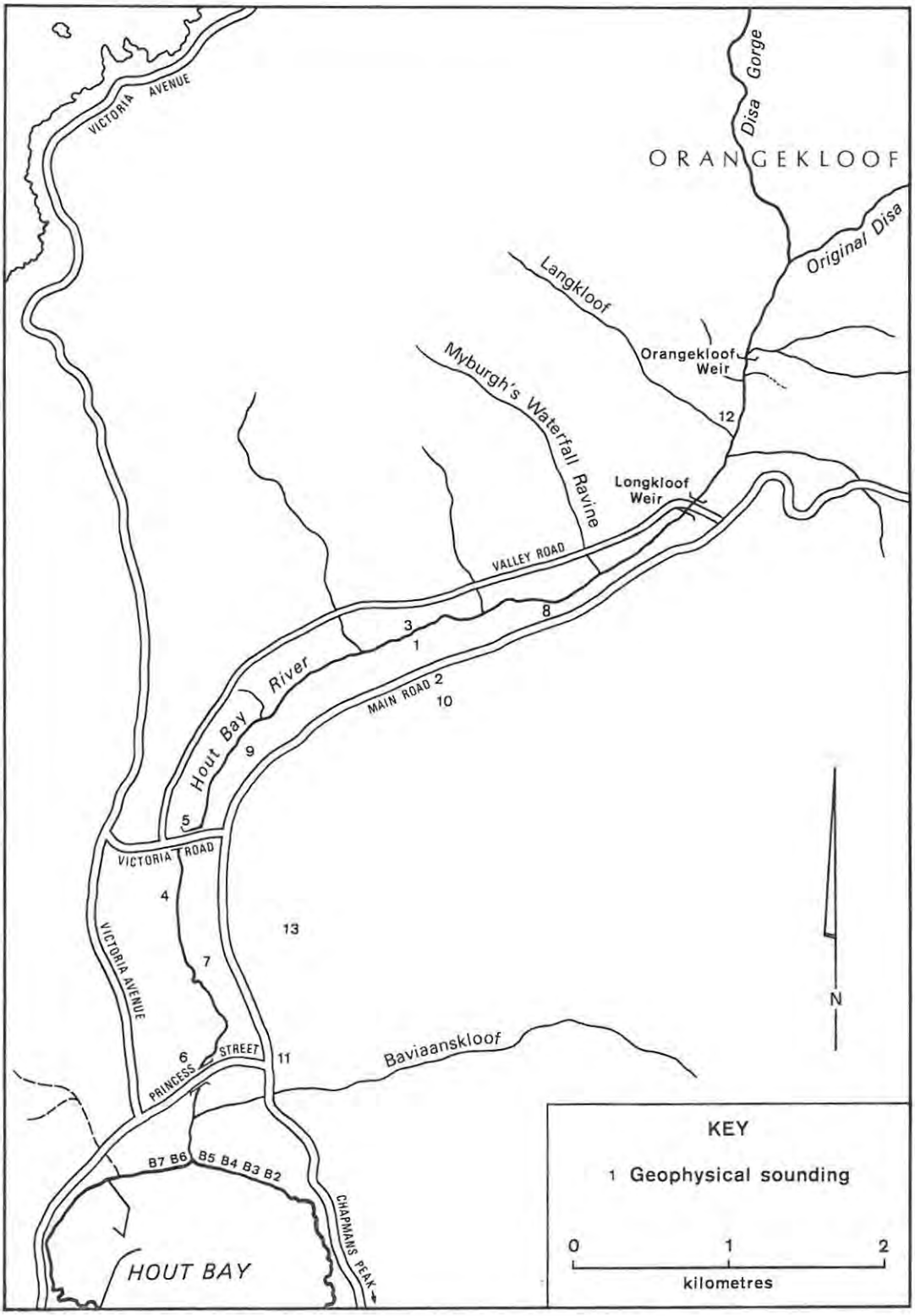

Figure E-1: Location of vertical electrical-sounding sites in Hout Bay

Table E-1: Thickness and resistivity of substrata in Hout Bay as obtained from the geophysical survey

SOUNDING	EARTH MODEL LAYER	THICKNESS (m)	RESISTIVITY (ohm.m)	MATERIAL
1		1,2	1200)	alluvium
		3	250)	
		41	95	weathered granite
			5000	solid bedrock
2		3,2	1100)	alluvium
		15	60)	
		45	115	weathered granite
			550	bedrock
3		3,1	1700)	alluvium
		9	650)	
		40	72	highly weathered granite
			1000	bedrock
4		0,65	410	
		20	65	alluvium
			130	fractured/cracked granite
5		0,6	850)	alluvium and silt
		8,5	32)	
		7	130	weathered granite
			40	

Table E-1 Continued

SOUNDING	EARTH MODEL LAYER THICKNESS (m)	RESISTIVITY (ohm.m)	MATERIAL
6	2	35)	alluvium and silt
	10	40)	
	60	43	highly weathered granite
		25	clay
7	1,1	20)	alluvium
	45	50)	
	15	10	clay
		200	
8	0,2	150)	dry) alluvium
	1,6	2500)	
	4	600	
	23	80	weathered granite
		450	
9	1,3	1200)	alluvium
	5	60)	
	150	130	weathered granite
		1000	bedrock
10	1,1	600	
	23	46	highly weathered granite/alluvium and silt
		400	

Table E-1 Continued

SOUNDING	EARTH MODEL LAYER	THICKNESS (m)	RESISTIVITY (ohm.m)	MATERIAL
11		0,8	1700	
		15	360	fractured granite
			180	
12		5,5	500)	
			)	alluvium
		8,5	230)	
		40	100	weathered granite
			2000	bedrock
13		1,2	750)	
			)	alluvium
		3	30)	
		6	12	clay
		85	40	highly weathered granite/clay
			1000	bedrock

Table E-2: Thickness and resistivity of substrata in the Hout Bay beach zone

SOUNDING	EARTH MODEL LAYER THICKNESS (m)	RESISTIVITY (ohm.m)
B2	17	3,2
		25
B3	1,1	14
	0,7	2
	5	10
	14	4
	50	8
		60
B4		5
		15
		3,5
		100
B5		3,9
		10
		100
B6		1,3
		2
		4,8
		100

Table E-2 Continued

SOUNDING	EARTH MODEL LAYER THICKNESS (m)	RESISTIVITY (ohm.m)
B7		11,5
		1,8
		6,7
		20