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Baseline study of the Vitogo River and associated environment

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PREFACE

Sixteen years ago the United Nations Conference on the Human Environment (Stockholm 5-16 June 1972) adopted the Action Plan for the Human Environment, including the General Principles for Assessment and Control of Marine Pollution. In the light of the results of the Stockholm Conference, the United Nations General Assembly decided to establish the United Nations Environment Programme (UNEP) to "serve as a focal point for environmental action and co-ordination within the United Nations system" [General Assembly resolution 2997(XXVII) of 15 December 1972]. The organizations of the United Nations system were invited "to adopt the measures that may be required to undertake concerted and co-ordinated programmes with regard to international environmental problems", and the "intergovernmental and non-governmental organizations that have an interest in the field of the environment" were also invited "to lend their full support and collaboration to the United Nations with a view to achieving the largest possible degree of co-operation and co-ordination". Subsequently, the Governing Council of UNEP chose "Oceans" as one of the priority areas in which it would focus efforts to fulfill its catalytic and co-ordinating role.

The Regional Seas Programme was initiated by UNEP in 1974. Since then the Governing Council of UNEP has repeatedly endorsed a regional approach to the control of marine pollution and the management of marine and coastal resources and has requested the development of regional action plans.

The Regional Seas Programme at present includes ten regions[1/] and has over 120 coastal States participating in it. It is conceived as an action-oriented programme having concern not only for the consequences but also for the causes of environmental degradation and encompassing a comprehensive approach to combating environmental problems through the management of marine and coastal areas. Each regional action plan is formulated according to the needs of the region as perceived by the Governments concerned. It is designed to link assessment of the quality of the marine environment and the causes of its deterioration with activities for the management and development of the marine and coastal environment. The action plans promote the parallel development of regional legal agreements and of action-oriented programme activities[2/].

The idea for a regional South Pacific Environment Management Programme came from the South Pacific Commission (SPC) in 1974. Consultations between SPC and UNEP led, in 1975, to the suggestion of organizing a South Pacific Conference on the Human Environment. The South Pacific Bureau for Economic Co-operation (SPEC) and the Economic and Social Commission for Asia and the Pacific (ESCAP) soon joined SPC's initiative and UNEP supported the development of what became known as the South Pacific Regional Environment Programme (SPREP) as part of its Regional Seas Programme.

1/ Mediterranean, Kuwait Action Plan Region, West and Central Africa, Wider Caribbean, East Asian Seas, South-East Pacific, South Pacific, Red Sea and Gulf of Aden, Eastern Africa and South Asian Seas.

2/ UNEP: Achievements and planned development of UNEP's Regional Seas Programme and comparable programmes sponsored by other bodies. UNEP Regional Seas Reports and Studies No. 1, UNEP, 1982.

An Action Plan for the South Pacific Regional Environment Programme (SPREP) was adopted at the Conference on Human Environment in the South Pacific at Rarotonga, 8-11 March 1982, and was endorsed seven months later at the South Pacific Conference and South Pacific Forum[3/].

This document has been prepared by Ms. P. Gangaiya and Messrs. J.E. Brodie and R.J. Morrison (Institute of Natural Resources, University of the South Pacific, Suva, Fiji) as a contribution to the South Pacific Regional Environment Programme. The sponsors of the study would like to express their gratitude to the authors and the University of the South Pacific.

3/ SPC/SPEC/ESCAP/UNEP: Action Plan for managing the natural resources and environment in the South Pacific Region. UNEP Regional Seas Reports and Studies No. 29, UNEP, 1983.

CONTENTS

EXECUTIVE SUMMARY

In 1983 the Fiji Pine Commission and British Petroleum South-West Pacific in a joint venture decided to construct a wood processing plant at Drasa, Western Viti Levu, to deal with the substantial pine wood being produced in nearby areas. The major water system in the area is the Vitogo River and it was therefore decided in 1984 to carry out a baseline study of this river and the associated environment to provide data for the assessment of the impact of the construction and operation of the processing plant. The main objective was to establish background levels for those environmental parameters which appeared to be most vulnerable to the effects of the plant operation. These included the general water quality of the river and the associated estuary, the heavy metal status of sediments and shellfish from the area and the extent of bacterial contamination of the water and shellfish (Gafrarium tumidum).

Water samples were collected at two monthly intervals from September 1984 to July 1985 from five sites for general water quality investigations. Sediment samples were collected from two sites and shellfish from one site over the same period. From September 1985 to January 1986 water samples were collected at two monthly intervals from five sites for heavy metal analysis; sediments and shellfish were collected at the same time from two sites. All samples were analyzed using standard techniques.

During the period of the study prior to the construction of the processing plant the environment in the Vitogo area was relatively free from contamination. Water quality was generally good. The values for heavy metals in both sediment and shellfish were low, often below the detection limits available, indicating a virtually pollution-free situation. Coliform contents of shellfish were all within the USEPA standards set for edible material.

This contamination-free situation may change once the processing plant becomes operational because wastes such as storm water run-off and overflows, waste oil, treated domestic sewage, burnt ash and residual wood treatment chemicals containing toxic elements such as copper, chromium and arsenic will pose problems of handling and disposal. However, with careful consideration of the proposals presented in this report the likely effects of the impact of the development on the Vitogo area environment can be kept to a minimum.

1. INTRODUCTION

Development activities in countries such as Fiji depend largely on the exploitation of natural resources which tend to be more vulnerable in tropical regions than elsewhere. Every effort must be made to preserve the natural resources for sustained development. Excessive demands on limited resources will result in significant deterioration of the ecological systems upon which life depends. Indications of such misuse usually show up as soil erosion, lack of water or its quality, deforestation, depletion of ecologically important life forms and other adverse natural phenomena. The implications of such effects on the quality of the environment should cause even more concern if the area to be developed has been relatively free of environmental problems as in the case of the Vitogo River and associated bay area in Western Viti Levu, Fiji, where a sawmill and chipmill is to be constructed to process the pine timber cultivated in the adjacent forests.

The Vitogo River enters the sea near Lautoka, the second largest city in Fiji. Until the last decade all industrial development in this area has been confined to within a few kilometres radius of the city. The area under study, which falls outside the city boundaries, has not been influenced by any major environmental changes arising from industrial development. In the surrounding hills a major pine forest plantation has been developed over the last twenty-five years. While some pine harvesting has occurred, little wood treatment has taken place; the effects of harvesting on the environment have therefore been considered to be minimal. However, the construction of the sawmill and chipmill may significantly affect water quality in the Vitogo River and associated coastal areas. The effects of the mill on the quality of the environment can be evaluated in future only on the basis of comparison with the present state of the environment.

Obviously, this necessitates the completion of a baseline study. The Institute of Natural Resources (INR), with financial support from SPREP, was able to carry out the baseline study, the objectives of the study being:

- to generate baseline data on the quality of the Vitogo River estuary and adjacent coastal bay area; and

- to assess the potential impact of the wood chipmill on the quality of the studied area and provide a proposal for mitigation of effects.

This report is a record of the findings of the baseline study. This introductory section is followed by a description of the physical characteristics of the study area. The section "Method of Investigation" records details on location of sampling sites, samples collected, regularity of sampling and analyses performed. Results and discussion of environmental quality investigations follow. Under "Potential Impact of Sawmill and Chipmill Development" the potential impact of the development on the environment and possible mitigative measures are projected. Some concluding remarks are made in the last section.

2. DESCRIPTION OF AREA

The geographical setting of the area under consideration with respect to Lautoka city is shown in Figure 1. The location of the processing complex, about 14 km north-east of Lautoka, is also indicated. Some physical characteristics of interest are outlined below.

2.1 Topography

The area is of variable terrain, from a coastal plain to gently rolling hill country a few kilometres in the interior to moderately steep dissected land along the foothills of the Mount

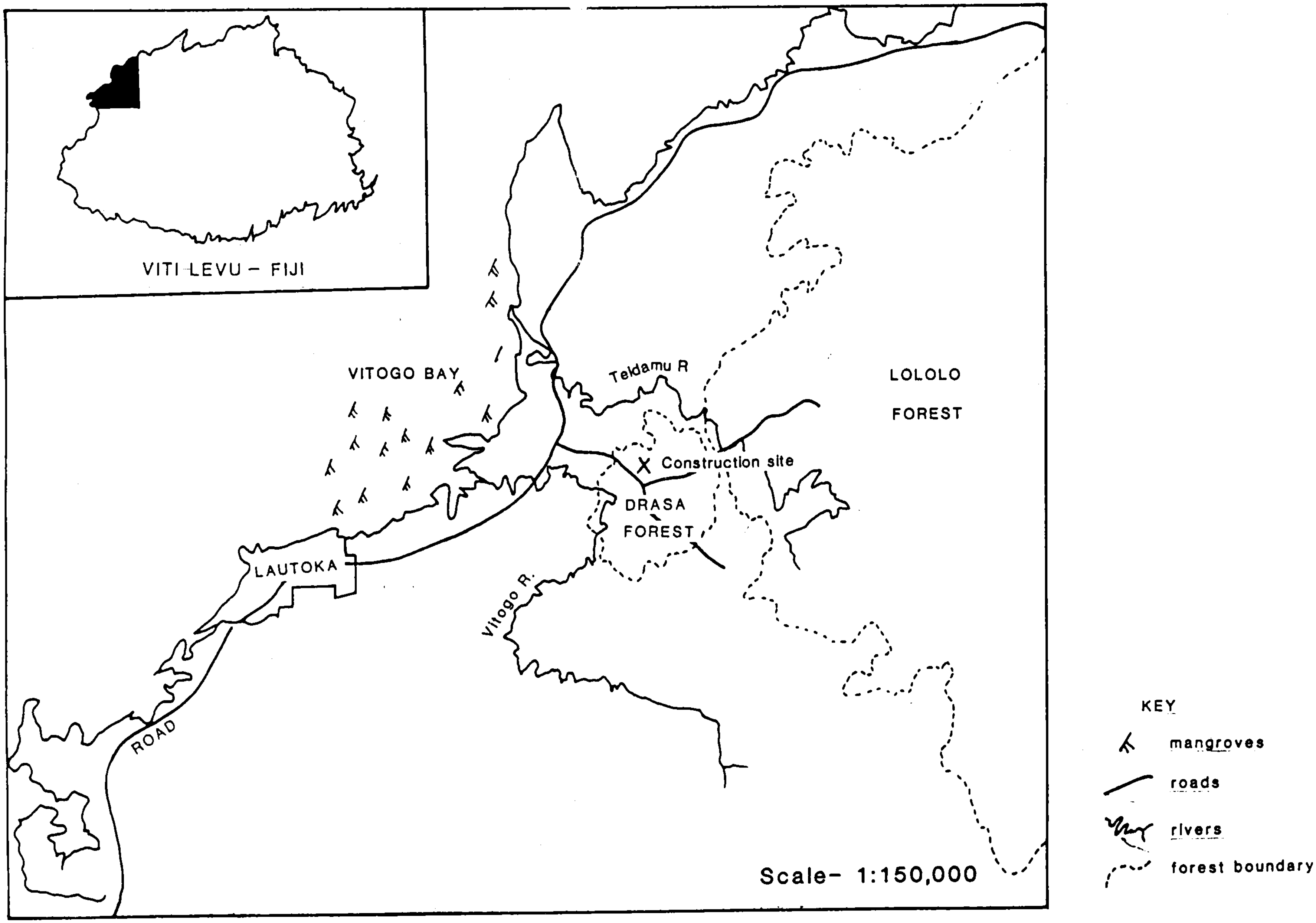

Figure 1. The study area

Evans Range. Elevation ranges from 40 m above sea level (asl) near Drasa to about 540 m asl in the vicinity of the Lololo Forest lookout. The elevation of the mill site is approximately 60 m asl. The site is on the northern side of a gently sloping ridge, falling towards the north-west, on the coastal plain. Between 1 and 4 kilometres west of the site is the coastal plain which extends to the south-west past Lautoka.

2.2 Geology

The geology of the Lautoka area is described in detail by Bartholomew (1959). The rocks underlying the higher elevation areas are mainly of volcanic origin, deriving from basaltic and andesitic volcanic activity during the Plio-Pleistocene period. The rocks include augite-olivine basalt flows, tuffs, volcanic brecias and associated sediments. The sediments of the coastal plain apparently comprise about 10 m of clayey aluvium.

2.3 Soils

The soils in this area form a complex of Oxisols, Ultisols and Inceptisols with minor areas of Entisols, Alfisols and Mollisols (Twyford and Wright, 1965; Leslie *et al.*, 1985).

Oxisols: these are typical soils of the highly weathered and highly degraded dry zone areas of Fiji. They have been formed in materials that have been intensively weathered chemically and frequently have oxidic mineralogy. They generally have red colours, deep profiles, high porosity, weak structures and are erosion prone. They tend to be moderately acidic (pH 5–6) and low in Ca, Mg, K and P.

Ultisols (usually Oxic subgroup): have better structures than Oxisols with clay accumulation in subsoil horizons. The mineralogy tends to be kaolinitic and oxidic. They generally have red or red-brown colours, are moderately to strongly acidic (pH 4.5–6) and are formed from weathering products of basalts and andesites. In a few areas soils having similar morphological features but having high base status (Alfisols) have been identified.

In some highly degraded areas erosion has removed most of the soil profile leaving a thin surface layer on top of *in situ* weathered rock. These soils frequently are strongly acidic (pH 4–5) and are classified as Entisols or Inceptisols.

There are limited areas of shallow, dark, soils found particularly on steeper slopes and formed from uplifted sediments. They are strongly structured due to the presence of montmorillonites which stabilize soil aggregates. These shallow dark soils (known locally as nigrescents) have a high pH (pH 6–7.3) and are relatively rich in phosphate, bases and organic matter. These soils are classified as Inceptisols or Mollisols.

2.4 Climate

The island of Viti Levu is divided climatically into two zones, the north-west (project area) region having a marked dry season from May to November and the south-east region having a humid climate with a more evenly distributed rainfall. Surface wind directions and speed in the region exhibit a marked diurnal variation (Sharma, 1982). During the day, westerly to north-westerly wind flow (sea breeze) usually prevails while south-westerlies usually predominate at night. South-easterlies tend to be augmented by a downhill wind drift from the east, i.e. a night-time land breeze. The average annual temperature of the area under study is 26 ^{o}C and the average annual rainfall is 2.5 m at Lololo which is the closest monitoring station to the study area [Fiji Meteorological Service information supplied to Cawthron Technical Group (1984)].

2.5 Vegetation

Most of the steeper slopes of the region are under pine (*Pinus caribaea* var. *hondurensis*) cultivation as shown in Figure 1. The pines were established on badly degraded "talasiga" grasslands. Talasiga vegetation, consisting of the introduced mission grass (*Pennisetum polystachyon*), Karuka fern (*Pteridium esculentum*), Qato or bracken fern (*Dicranopteris linearis*) and Nokonoko (*Casuarina equisetifolia*), can still be found in places. Remnants of indigenous hardwood forest occur within the pine plantations. The native reed (*Miscanthus floridulus*) and the guava (*Psidium guajava*) are common in such areas. The flat coastal area and the rolling countryside have been utilized for intensive sugarcane cultivation. The lower reaches of the Vitogo River and the Vitogo Bay have rich stands of mangroves.

2.6 Water resources

The major rivers draining the catchments of the study area are the Vitogo and the Teidamu. The catchment areas of these two rivers are marked in Figure 2. The Vitogo River is of particular interest in this study because water requirements of the mill are to be met by drawing water (position marked in Figure 2) at a rate of 0.015 m^3/sec from this source. The catchment area of the Vitogo River extends well into the foothills of Mount Evans Range. The major tributaries are Vilakolewasautoko Creek, Savubasaga Creek and the headwaters of the river itself. The Teidamu River is also of interest because it drains the area around the mill. These two rivers constitute a major proportion of the fresh water input into Vitogo Bay. Other fresh water inputs to Vitogo Bay are shown in Figure 3.

3. METHOD OF INVESTIGATION

The Institute of Natural Resources was involved in studies of the general quality of the water at the proposed intake site even before this comprehensive baseline study was initiated. The data obtained from that study is given in Table 1. As part of the present study a preliminary tour of the project area was made in July 1984 to determine accessibility to potential sampling sites, availability of appropriate sample types that would indicate water quality and the precautionary measures that would need to be taken for sample preservation. Details of the location of the sampling sites, dates of sampling, types of samples collected and the analyses performed are outlined in this section.

3.1 Sample collection

The type of sample that is usually collected in investigations into water quality is the actual water itself. However, when looking at water quality from the point of view of pollution one often needs to measure parameters that, in water, are present in extremely low concentrations, such that detection is sometimes impossible with the facilities available. The higher concentrations that occur in bioaccumulating organisms and sediments with which the water in question is in contact can be used as a partial solution to this problem. Sediments and shellfish can be very appropriate indicators of water quality because polluting agents such as heavy metals tend to concentrate in such samples and are therefore more easily detectable. Besides, studies on heavy metals in shellfish are useful in themselves because they indicate the quality of shellfish which are usually heavily harvested for human consumption. With these considerations in mind it was decided that water, sediment and shellfish samples would be collected from various sites within the study area (Figure 4) for general water quality, heavy metal and coliform status determination. The most common species of shellfish found in the area was *Gafrarium tumidum*, a food source for the local villagers. Water was sampled bimonthly at five sites (marked 1 to 5 in Figure 4) along the Vitogo River from September 1984 to July 1985 for general water quality

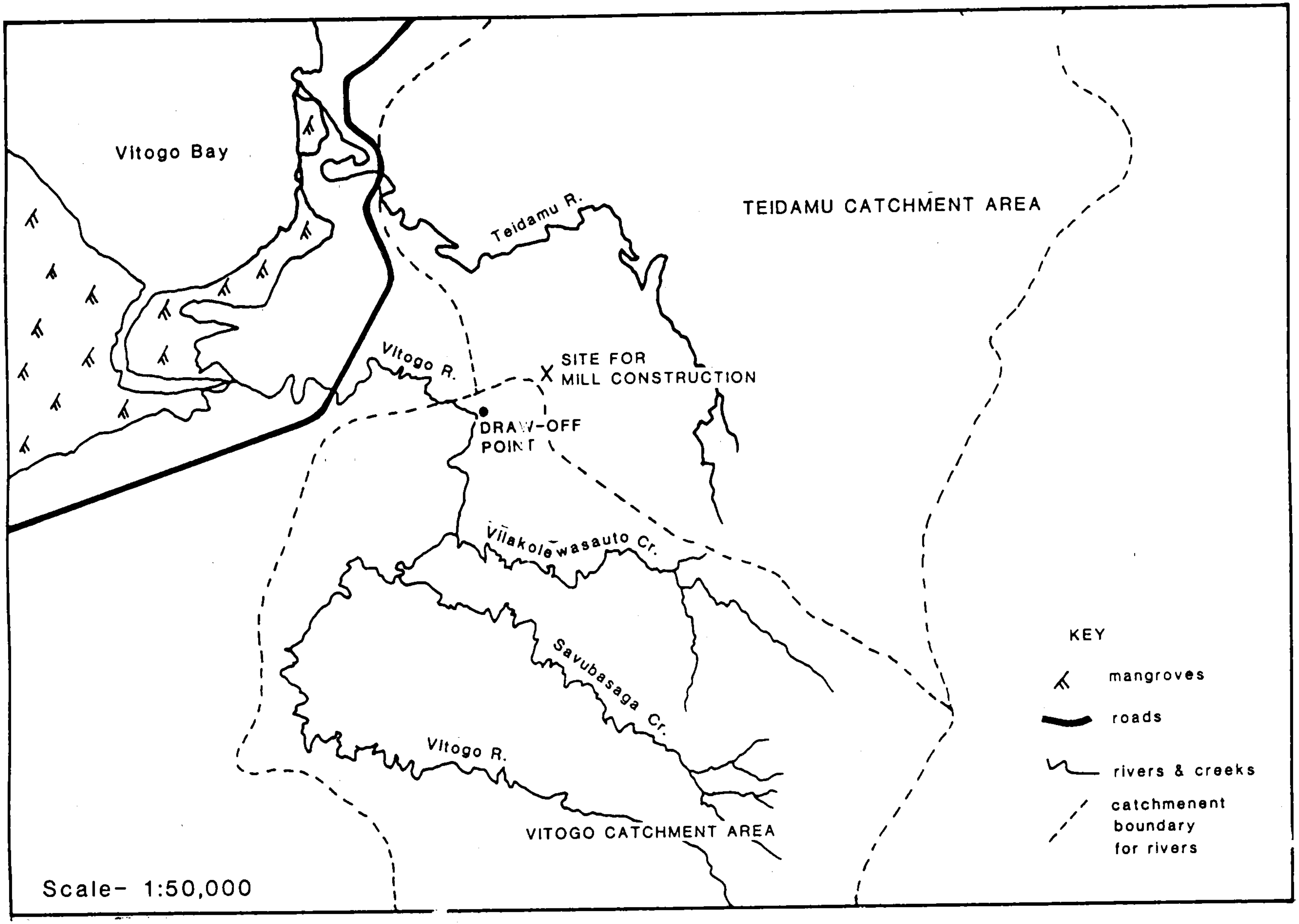

Figure 2. Vitogo and Teidamu catchment areas

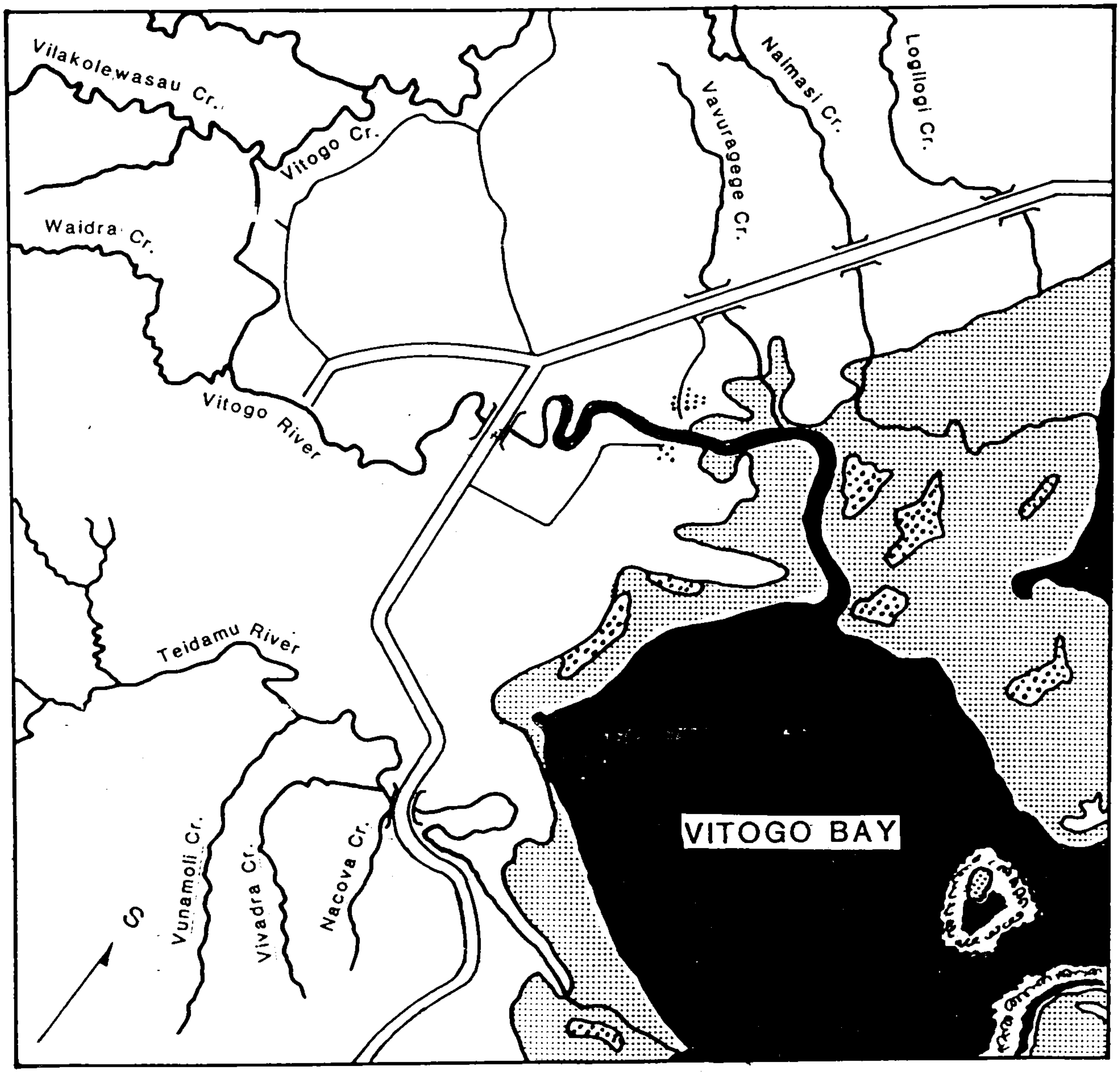

Figure 3. Freshwater inputs into Vitogo Bay

Table 1. General water quality results for water draw-off point on the Vitogo River*

Measurement	1983						1984	
	Feb.	Jul.	Aug.	Oct.	Nov.	Dec.	Mar.	Apr.
pH	6.95	9.20	7.71	9.00	7.00	7.20	6.30	7.10
Turbidity	170	14	30	6	18	32	10	6
Colour	35	25	45	5	15	45	25	15
Alkalinity (mg $CaCO_3$/l)	26	53	37	52	33	23	8	34
Total Fe (mg/l)	<0.2	0.84	0.77	0.22	0.73	2.0	0.32	0.37
Dissolved Fe (mg/l)	<0.2	0.15	0.07	0.5	0.23	0.50	0.14	0.09
Total Mn (mg/l)	<0.1	0.60	0.50	<0.1	<0.1	0.10	<0.1	<0.1
Dissolved Mn (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cl (mg/l)	7.2	12.0	8.0	6.1	6.2	6.0	5.8	6.2
SO_4 (mg/l)	19.5	6.8	3.5	4.0	1.4	1.2	11.0	3.0
Total dissolved solids (mg/l)	80	120	140	70	55	58	46	80
Suspended solids (mg/l)	107	1.6	3.3	3.2	20	26	2.5	0.4
Ca (mg/l)	5.0	13.9	12.0	9.1	5.6	6.0	1.5	1.5
Mg (mg/l)	1.8	3.5	3.4	4.1	4.3	2.4	0.9	0.9
Na (mg/l)	10.8	8.7	7.1	5.0	4.9	3.3	3.8	3.8
K (mg/l)	0.86	0.80	1.0	2.0	1.8	1.2	0.70	0.70

* Water samples were received from the joint venture company such that more than 24 hours elapsed between collection and the initiation of analyses. No special preservation techniques were employed. Hence pH, turbidity, suspended solids, dissolved Fe and Mn data have low confidence limits.

determination. During the same period 5 sediment samples were taken from site 5 (Vitogo River bed), 8 from site 6 (Vitogo shellfish bed), and 3 from site 9 (Teidamu shellfish bed). Water samples were collected from September 1985 to January 1986 for heavy metal analyses only, from sites 1 to 3 along the Vitogo River and sites 7 and 8 along the Teidamu River. Shellfish were collected from sites 6 and 9 from May 1985 to January 1986 for coliform and heavy metal analyses. A summary of this information is given in Table 2.

3.2 Analytical procedures

The samples collected were brought back to the Institute of Natural Resources Analytical Services Laboratory where all analyses were carried out. Analytical procedures are outlined.

Analyses of water samples

Conductivity was measured on a conductivity meter standardized against a standard salt solution.

pH was measured with a glass electrode standardized against buffers of pH 4, 7 and 9.

Salinity was measured using a salinity meter standardized against a salinity standard.

Turbidity was measured in a nephelometer against suspended silica standards and is expressed as nephelometric turbidity units (NTU).

Alkalinity was measured by titrating an aliquot of the sample with standard HCl to the phenolphthalein end point for carbonate alkalinity and the mixed bromocresol green-methyl red end point for bicarbonate alkalinity (APHA-AWWA-WPCF, 1981).

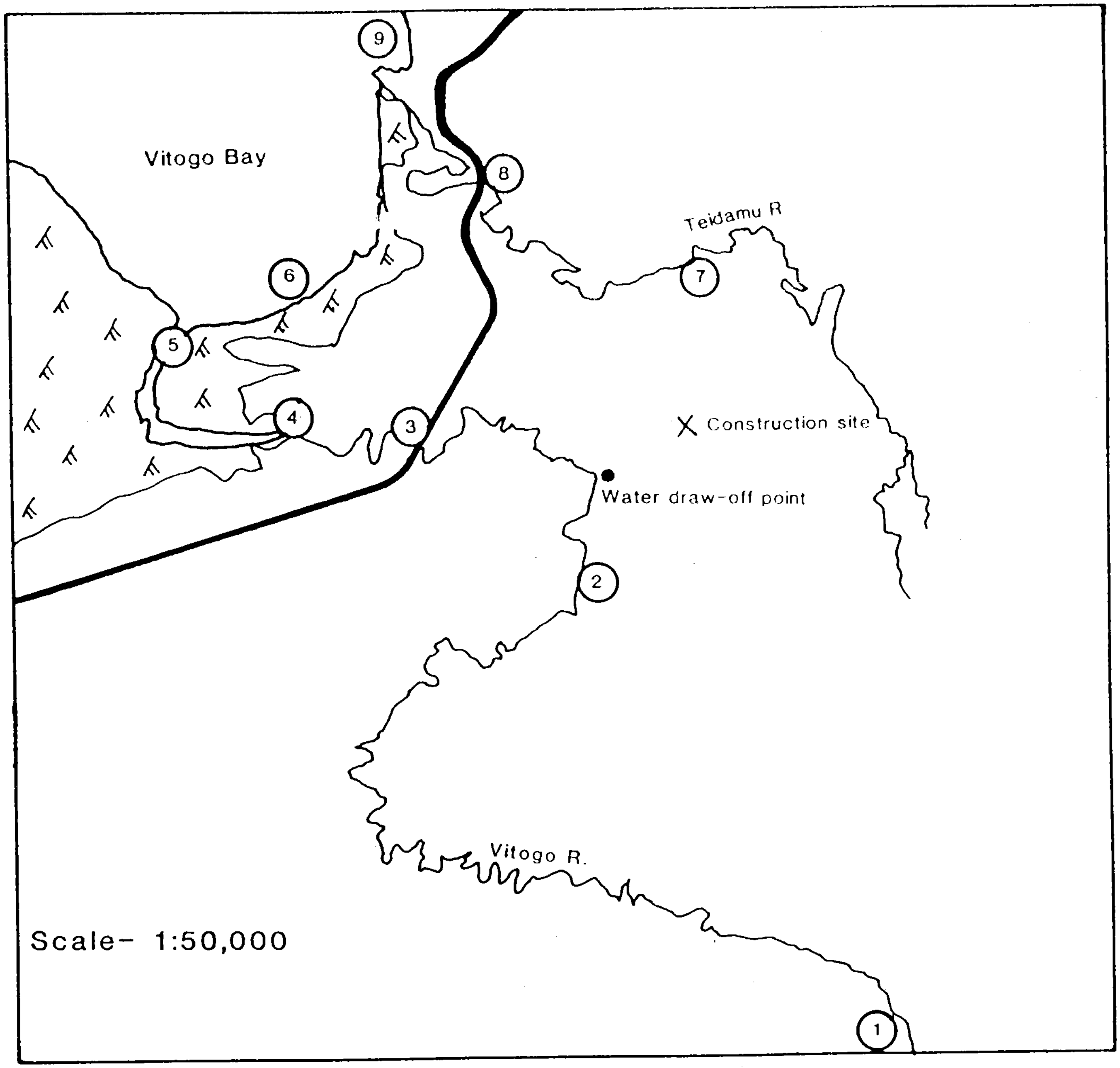

Figure 4. Sampling sites

Table 2. Summary of information on sampling and analysis

Bimonthly sampling	Sample types collected	Collection sites	Analysis performed
July 1984	(Preliminary tour - no sampling)		
September 1984 through July 1985	Water	1 to 5	General water quality - conductivity, pH, turbidity, salinity, alkalinity, Ca, Mg, Na, K, Fe, Mn, Cl, SiO_2, SO_4, NO_3. NH_3, TN, TP, PO_4, faecal and total coliforms*
September 1985 through January 1986	Water	1, 2, 3, 7, 8	Heavy metals (As, Cd, Cr, Cu, Fe, Hg, Mn, Pb, Se, Zn)
November 1984 through January 1986	Sediment	5, 6, 9	Heavy metals
May 1985 through January 1986	Shellfish	6, 9	Heavy metals, coliforms

* Coliforms only on September 1984 through March 1985 samples.

Calcium, magnesium, sodium and potassium were measured after suitable dilution by flame atomic absorption spectrophotometry (FAAS).

Chloride was measured using a chloride ion selective electrode.

Sulphate was measured using a turbidimetric barium sulphate method.

Silica (dissolved) was measured by a colorimetric procedure by formation of the reduced beta silicomolybdate complex.

Dissolved iron and manganese were measured after filtration of a sample which had been acidified immediately upon collection. The filtration, through a 0.47 um membrane, was completed under vacuum and iron and manganese determined by FAAS on the filtrate.

Total iron and manganese were determined on another aliquot of the acidified sample. An aliquot of 3 cm^3 of concentrated perchloric acid was added to 100 cm^3 of the sample and the mixture heated and evaporated until fumes of perchloric acid were evolved. The digest was diluted to 100 cm^3 and iron and manganese determined by FAAS.

Total Kjeldahl nitrogen was measured by Kjeldahl digestion using sulphuric acid, potassium sulphate and a selenium catalyst followed by steam distillation of the ammonia and determination by the indophenol blue colorimetric method (see ammonia method following).

Total phosphorus was measured by the orthophosphate method after digestion of the water sample with perchloric acid to fumes.