Ramu Nickel Joint Venture

Ramu Nickel Project

Environmental Plan

Volume A :

Executive Summary
Sotpela Ripot
English Translation of Sotpela Ripot

January 1999

CR 161/9/v4

Prepared by: NSR Environmental Consultants Pty Ltd
124 Camberwell Road
Hawthorn East, Victoria 3123 Australia

Tel: 61-3-9882 3555 Fax: 61-3-9882 3533
e-mail: nsr@nsrenv.com.au

Contents

Figures

Tables

Plates

Boxes

Executive Summary

1. Introduction

The Ramu Nickel Project is a proposal to mine and refine lateritic ores to produce nickel and cobalt for sale on world markets. The project is located in Madang Province, Papua New Guinea (PNG) (Figure 1).

1.1 Participants and Proponent

The Ramu Nickel Joint Venture (RNJV) is owned in joint venture by Ramu Nickel Limited, a wholly owned subsidiary of Highlands Pacific Limited (HPL) (65%), and Nord Australex Nominees Pty Ltd (35%). It is anticipated that the PNG National Government and project area landowners will acquire a 30% participating interest in the joint venture. Following acquisition of its interest, the State would on sell 25% to Orogen Minerals Limited (Orogen) whilst the landowners would retain 5% for their benefit. Orogen is owned 51% by the PNG Government and 49% by public shareholding. Eastern Pacific Minerals Limited has a right to take a 10% participating interest in the joint venture, which will dilute to 7% following State and landowner participation.

The project proponent is HPL as manager for the joint venture.

1.2 Ramu Nickel Project's Environmental Plan

The Ramu Nickel Project's Environmental Plan (EP) comprises three volumes:

- Volume A: Executive Summary (this volume) which comprises an extended summary in English (first), a shortened summary in Tok Pisin (second) and an English translation of the shortened summary (third).
- Volume B: Main Report.
- Volume C: twenty-five technical appendices.

The EP seeks approval for the project to proceed and, to this end, provides:

- For interested bodies and persons, a basis for understanding the proposal, alternatives and preferred solutions, the existing environment, and the expected changes to that environment should the proposal be implemented.
- For groups or persons with rights or interests in land, an outline of the effects of the proposal on that land, and of benefits and compensation.
- For PNG decision-makers, information for assessing the potential impacts of the proposed project and associated development, having regard to legislative and policy provisions.
- For the proponent, a series of commitments to measures or actions which are to be undertaken to minimise adverse impacts before, during and following the implementation of the proposal.

1.3 Project History and Development Concept

The Ramu lateritic nickel and cobalt resource is located on the Kurumbukari Plateau (Plate 1), part of the southern flank of the valley of the Ramu River. The Kurumbukari deposits have been explored discontinuously since 1962 by a succession of companies. Highlands Gold Properties Pty Limited (HGP) assumed the management of the current joint venture in 1992. An intensive period of geological exploration and engineering culminated in the prefeasibility study in July 1996 (HGP 1996), which indicated technical and commercial viability. Thereafter, RNJV was established to prepare the bankable feasibility study for the project.

RNJV expects the project to produce some 32,800 t/a of high-grade nickel

Plate 1 Kurumbukari exploration camp located on the Kurumbukari Plateau

Figure 1 Locality map

metal and about 3,200 t/a of cobalt (as a cobalt salt). A production life of 20 years has been adopted for feasibility study and environmental approval purposes, but there is significant potential to substantially extend the life of the overall project by further exploration in areas of known mineralisation at Kurumbukari.

The main components of the project (see Figure 1) include:

- A series of shallow open-cut mine pits and a beneficiation plant to produce ore slurry feedstock at Kurumbukari.
- A slurry pipeline approximately 134 km long to transport the ore slurry from the Kurumbukari mine site eastwards to the refinery site at Basamuk on the Rai Coast, east of Madang, and on the northern coast of mainland Papua New Guinea (Plate 2).
- At Basamuk, a refinery to produce nickel and cobalt product using acid pressure leaching technology. An acid plant, a lime plant, a power station, a wharf, a limestone quarry and an accommodation area will be components of the Basamuk refinery site.

The preferred option for tailing disposal is deep sea tailing placement (DSTP) on the ocean floor of the Vitiaz Basin immediately north of the refinery.

Other project infrastructure will include access roads and the pipeline corridor between the mine site and the refinery.

2. Rationale for the Development

2.1 PNG Government Objectives

2.1.1 Policy

The purpose of the proposed development is to mine, extract and process nickel and cobalt from a nickel laterite mine using methods that are environmentally appropriate, technologically achievable and economically viable. As such, the Ramu Nickel Project is consistent with the Fourth National Goal and Directive Principle of the Constitution of Papua New Guinea which states:

> We declare our Fourth Goal to be for Papua New Guinea's natural resources and environment to be conserved and used for the collective benefit of us all, and be replenished for the benefit of future generations.

While the process of mining will unavoidably consume a non-replenishable resource, the taxes, royalties, profits and other economic benefits derived from the project will contribute to the capital wealth of the nation. Therefore, the economic benefits from a mining project can provide a durable economic asset for future generations, even after the specific original resource has been depleted.

2.1.2 Benefits

The Ramu Nickel Project will be Papua New Guinea's first nickel and cobalt mine and will conduct full downstream processing of ore to manufacture metal products which are saleable direct to international markets. This value-added component of the project will make a significant additional contribution to the nation's export earnings and help to re-

Plate 2 Proposed refinery site at Basamuk on the Rai Coast

dress the predicted declines in the export volumes of gold, copper and petroleum. It is estimated that the project will add 15% to the current exports of Papua New Guinea.

The project will benefit the national, provincial and local economies of Papua New Guinea in the form of royalties, direct and indirect taxation, improvements in the nation's balance of trade, infrastructure development, commerce, employment and educational opportunities. By direct shareholding in HPL or in Orogen, or through membership of the National Provident Fund, Public Officers' Superannuation Fund and other financial institutions, the Ramu Nickel Project will also distribute benefits to a more broadly-based cross-section of the Papua New Guinean population.

Apart from the start-up and shut-down years, annual sales revenue is estimated at between US$260 and $270 million. The breakdown of expenditure is given in Figure 2.

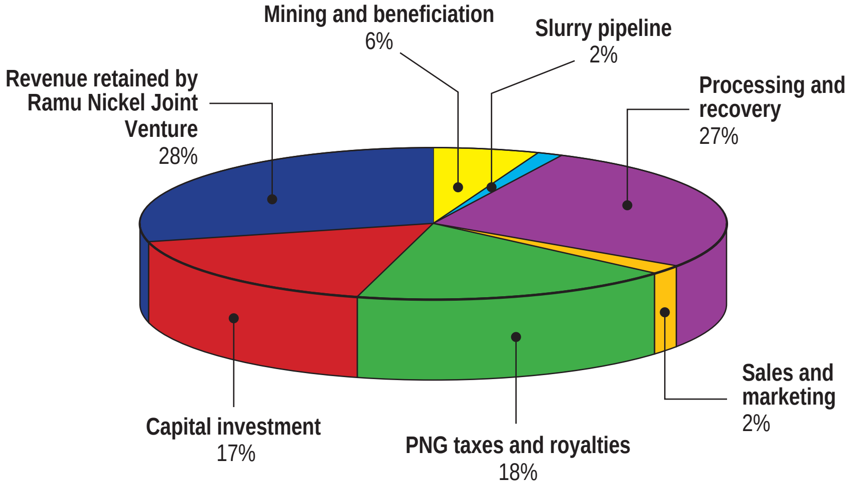


Figure 2 Distribution of total project revenues

Table 1 rests on a number of assumptions about future events, but provides an approximation of possible benefit streams over the life of the project.

2.2 Provincial Government and Landowner Attitudes

The Madang Provincial Government has expressed consistent support for the project.

Sentiment at local level has been summed up by the project's socio-economic impact study (SEIS) as follows:

> In the course of undertaking this study, no vocal opposition to the mine was encountered by the consultants. To the contrary, all those individuals who expressed an opinion were eager to see the development proceed, even if they were as yet unclear about the exact scope and scale of the project's likely impacts. People certainly want the opportunity to make more money and are eager to get improved access to health and education services, which they see the project as being able to provide.

The SEIS report goes on to note, however, that:

> …there is little doubt that community expectations will not be fully met in the short to medium term and that it will not take long for some dissenting voices to be heard. It is then that the effectiveness of coordination and dispute resolution mechanisms will be put to the test.

Table 1 Estimated value of benefit streams*

Benefit	Million Kina/year	No. Years	Total Million Kina (rounded)
Compensation	0.5 to 1	3	1.5 to 3
Royalties	7.4	20	150
Special Support Grant	3.7	20	75
Tax credits, up to	4	16†	65
Approximate total			300

*Values are based on assumptions about future market conditions, projected production rates and matters still to be negotiated. They are indicative only.

†Taxable income is not expected to be significant in Years 1 to 4.

2.3 Opportunity for Nickel Commercialisation

2.3.1 World-class Deposit

The size and quality of the Ramu resource have long been appreciated (see Section 2.3.3), but a mine has not previously been developed because the lateritic nickel and cobalt occur in weathered and chemically stable forms that are difficult to treat.

However, advances in extractive metallurgy have given confidence that economic processing is now technically feasible.

2.3.2 Feasibility

Approximately US$30 million has been spent on exploration, environmental, prefeasibility and feasibility studies up to September 1998 including:

- 11,700 m of diamond drilling.
- An independent audit of the resource.
- Trial mining (Plate 3) and beneficiation.
- Metallurgical testwork.
- Erosion studies and rehabilitation trials (Plate 4).
- Environmental impact investigations.
- Socio-economic surveys.
- Geotechnical investigations and risk assessment.
- Engineering design and costing.

The estimated total capital cost of the project is US$838 million. By virtue of a number of competitive advantages, the project will produce nickel and cobalt inside the lowest 10% of world nickel production costs (Figure 3). This will meet the RNJV commercial target return on investment based on conservative adopted values for the future price of nickel and cobalt on international markets.

2.3.3 Competitive Advantages

Lateritic nickel deposits are found in many parts of the world and are by no means uncommon. However, RNJV's low projected cash cost of production reflects a number of significant competitive advantages:

- A large resource.
- Ease of mining.
- Good leaching properties of the ore, with low acid consumption.
- A coastal refinery site, which will reduce the cost of transporting and handling process consumables and products.
- The low cost and environmental feasibility of the preferred option for tailing management (deep sea tailing placement).
- Abundant supplies of water and high-grade limestone near the refinery site.

2.3.4 Sustainability

It is sometimes thought that inter-generational security of mineral supplies is at risk, because each deposit that is mined-out brings closer the moment of ultimate mineral shortage. For all practical purposes, however, this model is simplistic and incorrect within a time frame of centuries and even millenia.

New discoveries will be made, including the reclassification of inferred resources as commercial reserves, as improvements in mining and processing technology allow the profitable development of increasingly larger deposits at lower and lower grades.

The relationship between technology, quantity and grade is shown in Figure 4: as the economically recoverable grade

Plate 3 Trial mining at Kurumbukari undertaken as part of the project's feasibility assessment

Plate 4 Rehabilitation trials conducted at Kurumbukari

decreases with reduced production costs, the amount of available resources increases.

It is for these reasons that two centuries of predictions of an absolute scarcity, from Malthus (1798) and the Club of Rome (Meadows *et al*. 1972) to the present day, have not been borne out.

In Papua New Guinea, two other factors are far more important to the future production of minerals than the depletion of known deposits:

- The mineral industry's human resource capital—the people to discover, build and operate new mines that can compete internationally.
- A socio-political climate that allows the mining industry to continue to invest and operate.

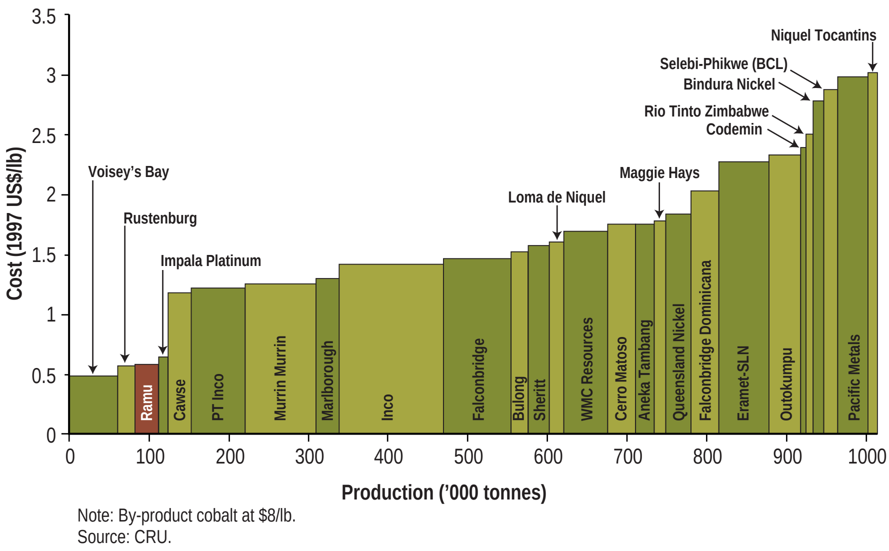
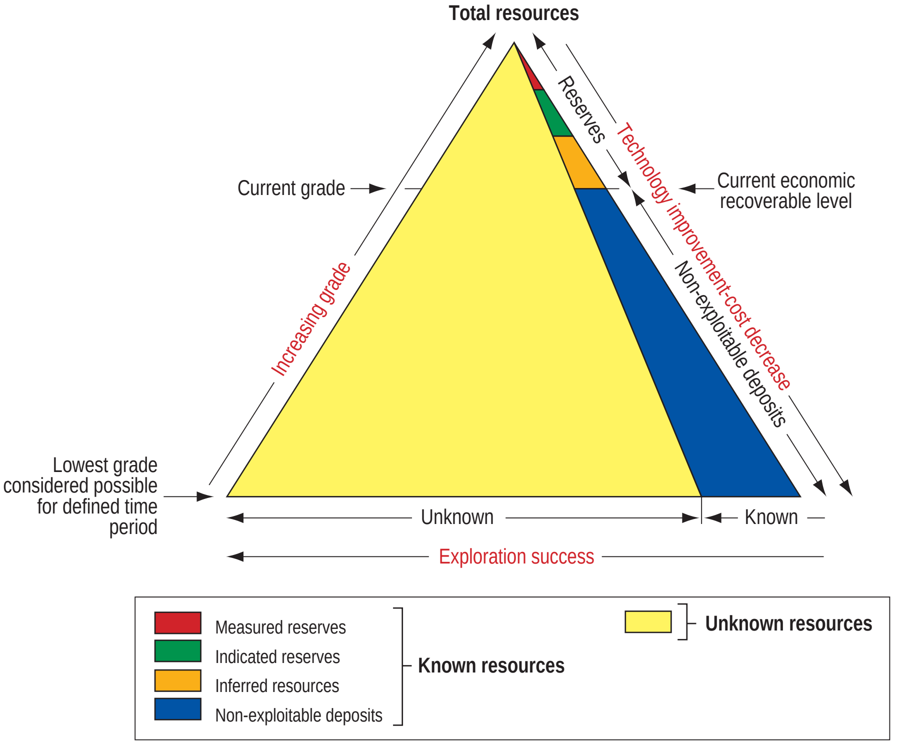


Figure 3 Nickel cash cost and production comparisons

Unlike minerals in the ground, expertise and investment can migrate overnight. The Ramu Nickel Project represents the continuity and diversity of the PNG mining sector in a climate of government and community support. The project will therefore help to sustain the expertise, upon which the future development of the country's rich mineral endowment depends.

2.4 Project Objectives

The economic objective of the project is to mine and process the lateritic nickel and cobalt resource at Kurumbukari on a profitable basis and in a climate of public participation and support.



Source: Govett and Govett (1974).

Figure 4 The relationship between resources and reserves

The environmental objectives are:

- To plan, operate and decommission the project in accordance with good industry practice and in compliance with the conditions and standards prescribed by the PNG Government.
- To site and operate the components of the project so as to minimise the effects on local villagers, their resources and the environment.

3. Environmental Planning and Permitting Process

3.1 Legislative Requirements

3.1.1 Environmental Planning Act

This Ramu Nickel Project EP has been prepared on a voluntary basis, pursuant to Section 4(6) of the PNG *Environmental Planning Act 1978* (Chapter 370). The EP is submitted to the PNG Government for the consideration of and approval by the Minister responsible for Environment and Conservation.

The acceptance of an EP by the Minister for Environment and Conservation is a prerequisite for the granting of a special mining lease (SML).

3.1.2 Special Mining Lease

The capital cost of the project exceeds US$75 million, which is the threshold above which a special mining lease (SML) is required. The required steps in the SML approval process are shown diagrammatically in Figure 5. Boxes in yellow are the primary responsibility of the proponent and its consultants. Boxes in blue require the collaboration of the State and the proponent, with the former taking the lead role. Boxes in pink are the steps at which final government approvals are given.

Figure 5 shows that the EP requires approval by the Minister for Environment and Conservation before the National Executive Council can approve the SML and the mine development contract.

3.1.3 Water Resources Act

The *Water Resources Act 1982* (Chapter 205) requires permits for the taking of water and the discharge of water or waste to the environment. Schedule 4 of the Water Resources Regulations 1981 sets water quality standards for various uses and discharges. Water quality standards for Papua New Guinea are currently under review, and new standards have been proposed (PNG 1998).

3.1.4 International Agreements

Papua New Guinea is also a party to a number of international conventions and treaties (Box 1).

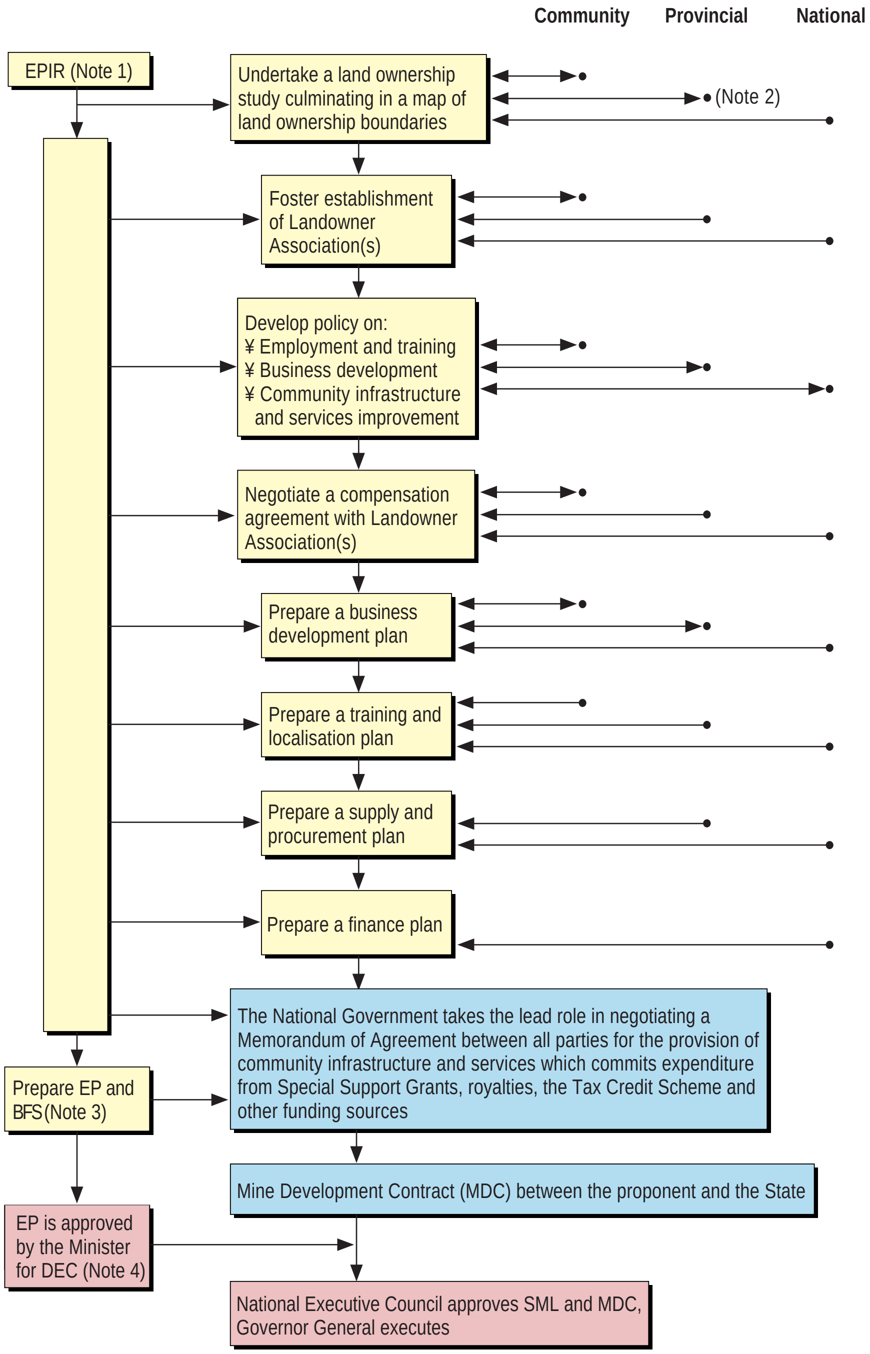
3.2 Consultation

3.2.1 Previous Documentation

The EP follows the presentation of the Environmental Plan Inception Report (EPIR; NSR 1997a) to the PNG Government in July 1997. This report identified the environmental sensitivities of the project and defined the general scope of the investigations required for an assessment of the impacts. Officers of the Department of Environment and Conservation (DEC) reviewed the EPIR and suggested additions to the scope of investigations which have been incorporated into this EP.

3.2.2 Meetings and Presentations

A series of site visits, workshops and meetings have been held since the release of the EPIR. The Ramu Nickel Provincial Project Team (RNPPT) held its inaugural meeting in May 1998 and ministerial inspections have been made. During the course of the SEIS, a range of national-, provincial- and district-level government officers, political representatives and prospective landowner representatives were interviewed.



Note 1: Environmental Plan Inception Report (EPIR).
Note 2: District Officer Lands needs to check boundaries and sign off.
Note 3: Environmental Plan (EP), Bankable Feasibility Study (BFS).
Note 4: Dept of Environment and Conservation (DEC).

Figure 5 Special mining lease (SML) procedure

> *Box 1 Relevant international conventions and treaties*
>
> RAMSAR Convention on Wetlands Especially as Waterfowl Habitat (1971)
>
> International Plant Protection Convention (1951)
>
> Plant Protection Agreement for Southeast Asia and the Pacific Region (1956)
>
> Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) (1993)
>
> Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1992)
>
> Convention on the Conservation of Migratory Species of Wild Animals (1979)
>
> Convention on Biological Diversity (1992)
>
> Convention Concerning the Protection of World Cultural Heritage and Natural Heritage (1972)
>
> UN Framework Convention on Climate Change (1992)

3.3 Schedule

The schedule for project permitting through to construction and first production is given in Figure 6.

4. Project Description

Details of the two main project areas, the Kurumbukari mine site and the Basamuk refinery complex, are shown in Figure 7.

4.1 Kurumbukari Facilities

The proposed Kurumbukari mine site is located on a dissected plateau bounded to the northeast by the extensive floodplain of the Ramu River and to the southwest by the foothills of the Bismarck Range.

4.1.1 Mining

Geology

Basement rocks underlying the Kurumbukari mine site consist of dunite with minor pyroxenites. Uplift has created an elevated plateau that has been exposed to prolonged deep tropical weathering and surface laterisation.

At Ramu, this soil laterisation process has dissolved silica and other ions leaving a deposit which consists mainly of hydrated iron oxides enriched in nickel and cobalt. Chromite occurs as a residual mineral and has become concentrated in some areas by physical processes.

An idealised laterite profile is shown in Figure 8 and consists of:

- Overburden averaging 2.5 m thickness, comprising a humic layer (up to 1 m) overlying red limonite.
- Ore comprising yellow limonite (average thickness 7.5 m) and ore-grade saprolite (average thickness 2 m).
- Rocky saprolite, comprising weathered dunite boulders in a saprolite ore matrix (average thickness 3.5 m) overlying the predominantly dunite bedrock.

Mineral Resource and Ore Reserve

Nickel and cobalt ore occur in the yellow limonite, saprolite and rocky saprolite horizons of the laterite profile. The estimated mineral resource at a 0.5% nickel cutoff grade is 143.2 Mt @ 1.01% nickel and 0.10% cobalt. The estimated ore reserve is 75.7 Mt @ 0.91% nickel and 0.10% cobalt.

Mining is proposed within four separate zones (Figure 9). The Ramu East, Ramu Central and Ramu Central Extended zones are located on the Kurumbukari Plateau and together form the Kurumbukari resource block. The Ramu West resource block is the fourth zone in which mining is proposed.

Mining Sequence

The mining process is shown in Figure 10 and comprises the following phases:

- Land clearance: the land area cleared will be the minimum required for operations, and begins with the salvage of timber one year in advance of clearing the remaining vegetation. Vegetation will either be stockpiled, chipped for mulch, used in brush matting or used to build sediment filters downstream of cleared land.

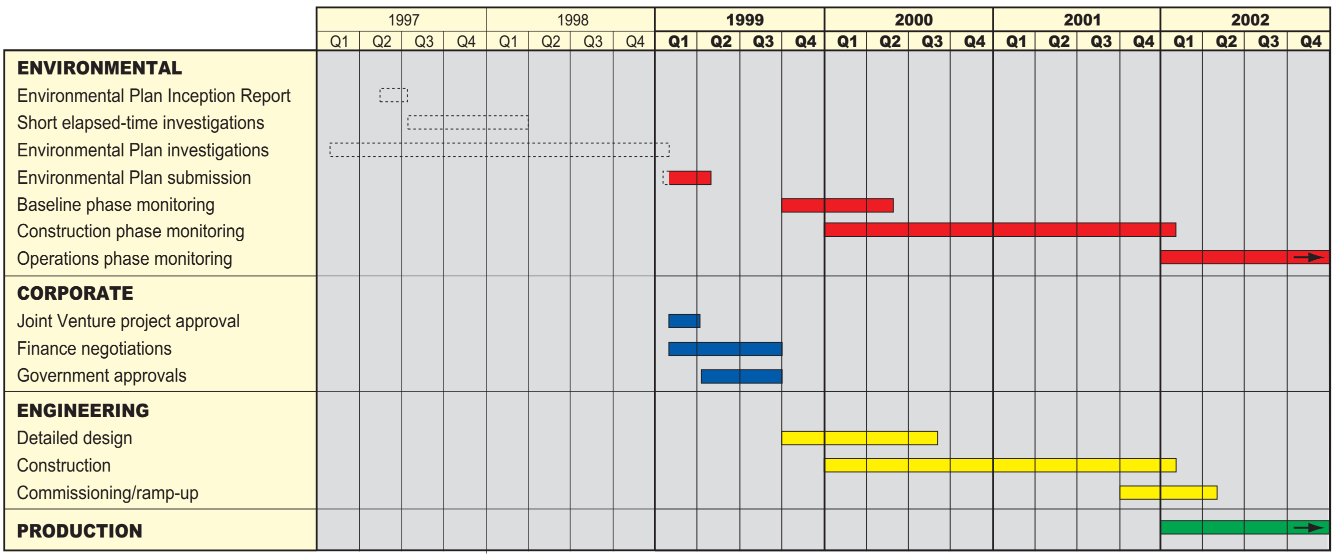


Figure 6 Permitting and development schedule

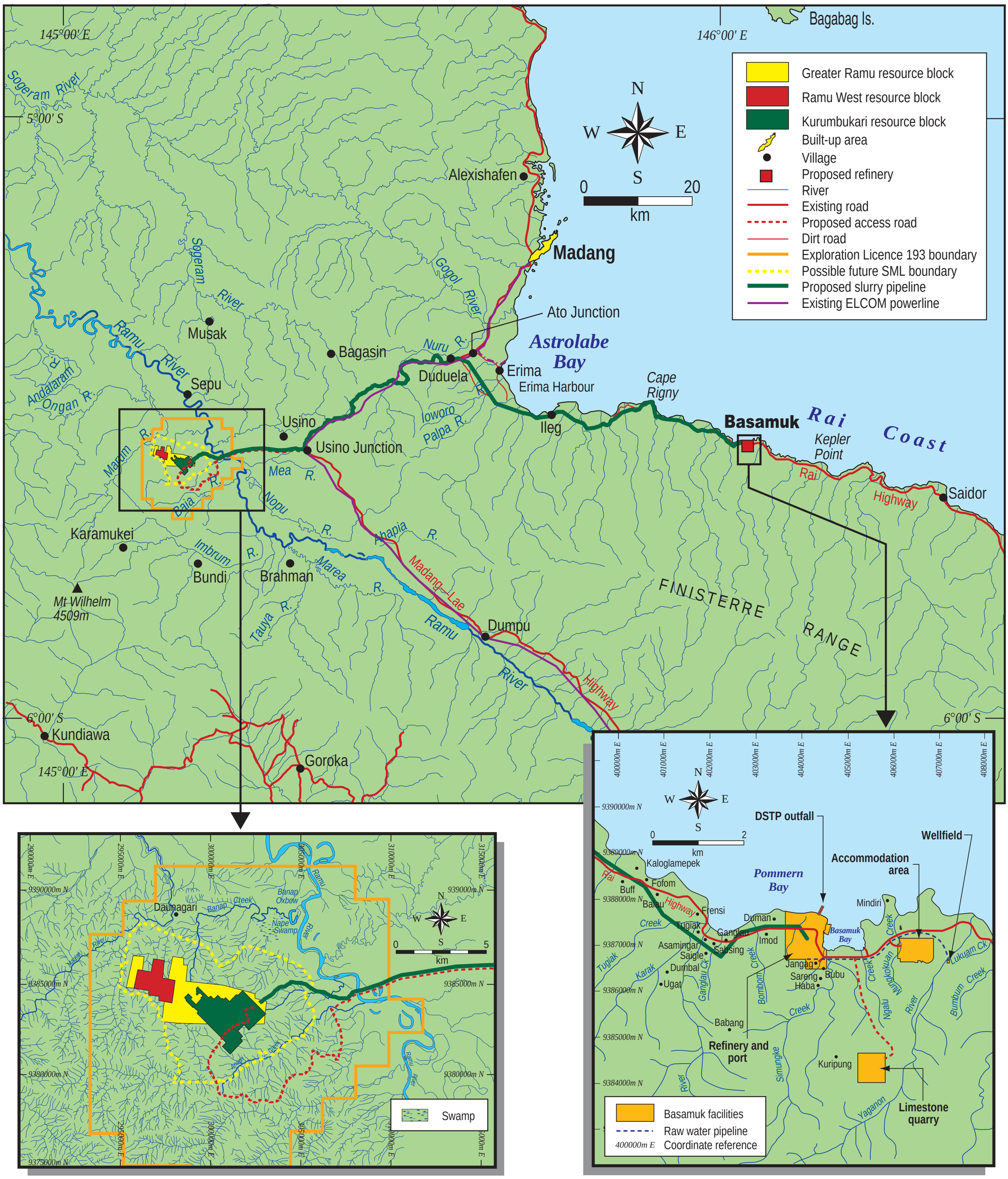


Figure 7 Plan of main project and infrastructure components

Topsoil will be removed just ahead of mining and will be progressively re-used for rehabilitation.

- Overburden removal: overburden thickness averages 2.5 m and varies from almost non-existent to about 20 m. It will be stripped at an annual average rate of 1.1 Mt, generally immediately before the underlying ore is mined. Overburden is non-acid-producing and will be directly placed in mined-out areas, and neither separate disposal nor long-term storage above ground is required.

- Ore mining: ore will be mined in cells of 1 to 4 ha at a rate of about 4.6 Mt/a, which corresponds to an area of about 48 ha/a. Ore thickness varies from 7 to 15 m and will be mined in benches by excavators and loaded into trucks for haulage to the beneficiation plant.
- Progressive rehabilitation: rehabilitation will start as soon as an individual cell has been mined. The general procedure is shown in Figure 10:
  - Boulders exposed during mining will be used to form stable, free-draining batters along the lower slopes of mined-out areas.
  - Overburden will be placed over previously mined surfaces.
  - Freshly stripped topsoil with fertiliser will be applied and a stabilising nursery crop sown (Plate 5).

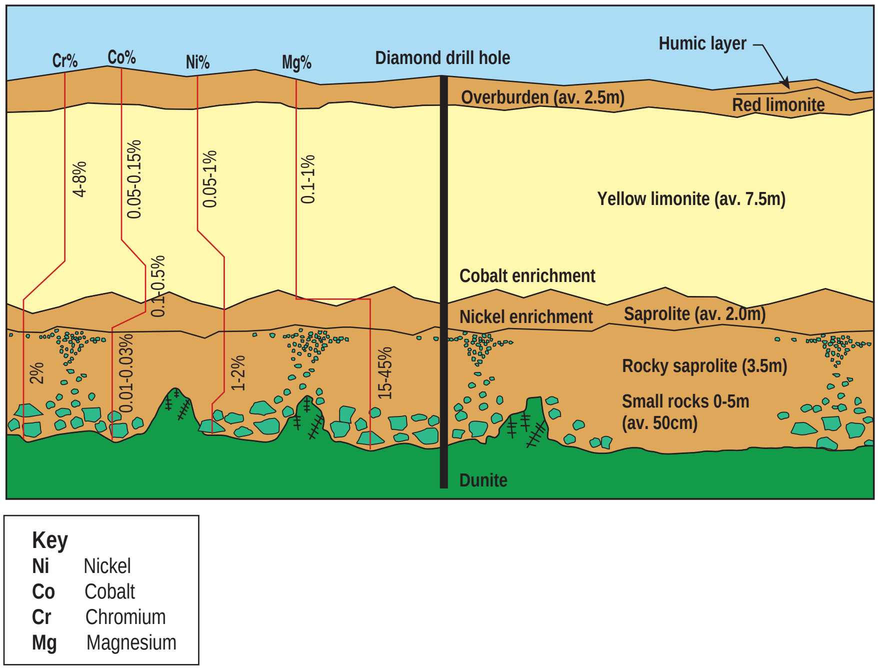


Figure 8 Idealised Ramu laterite profile

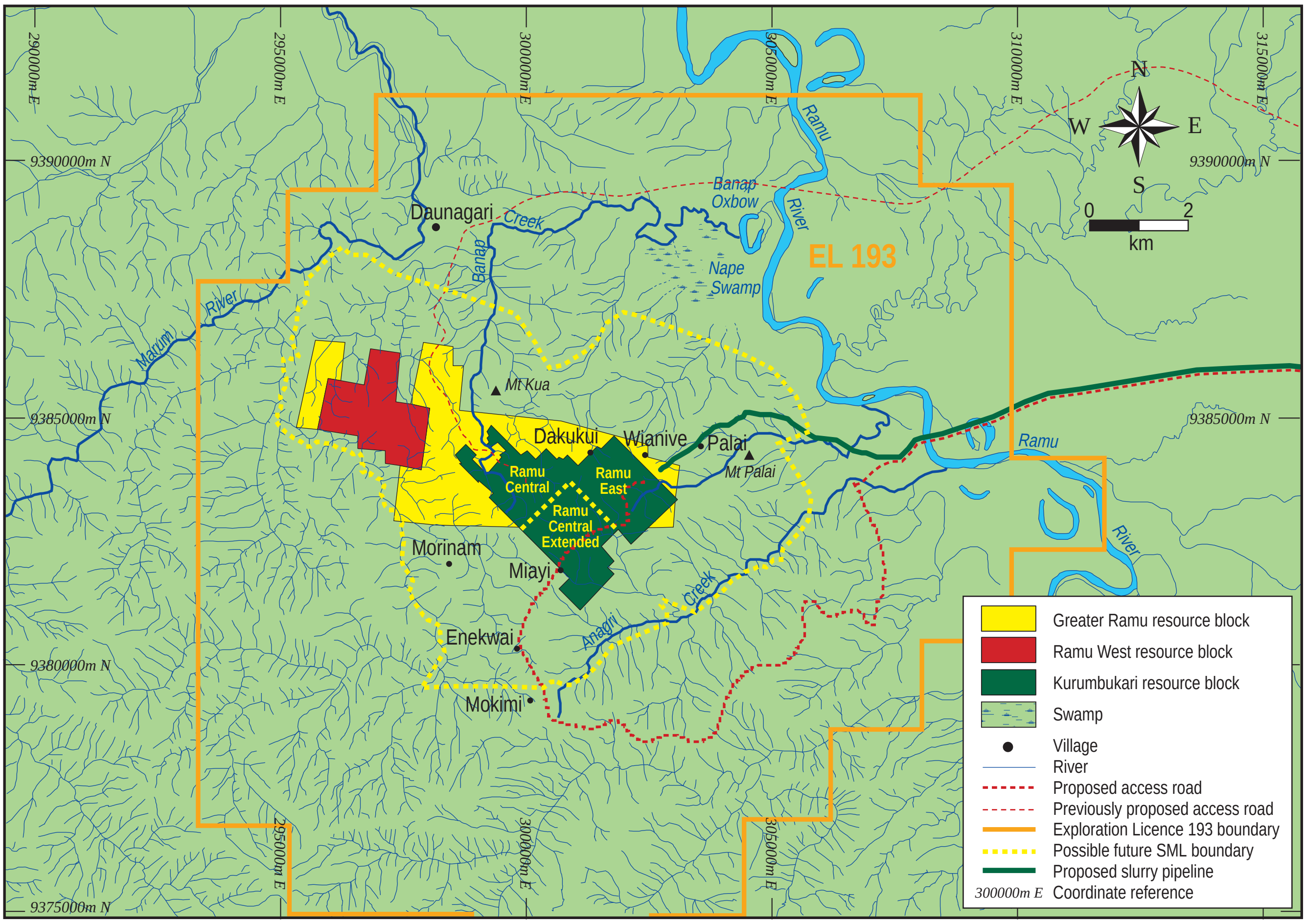


Figure 9 Greater Ramu mineralised zone

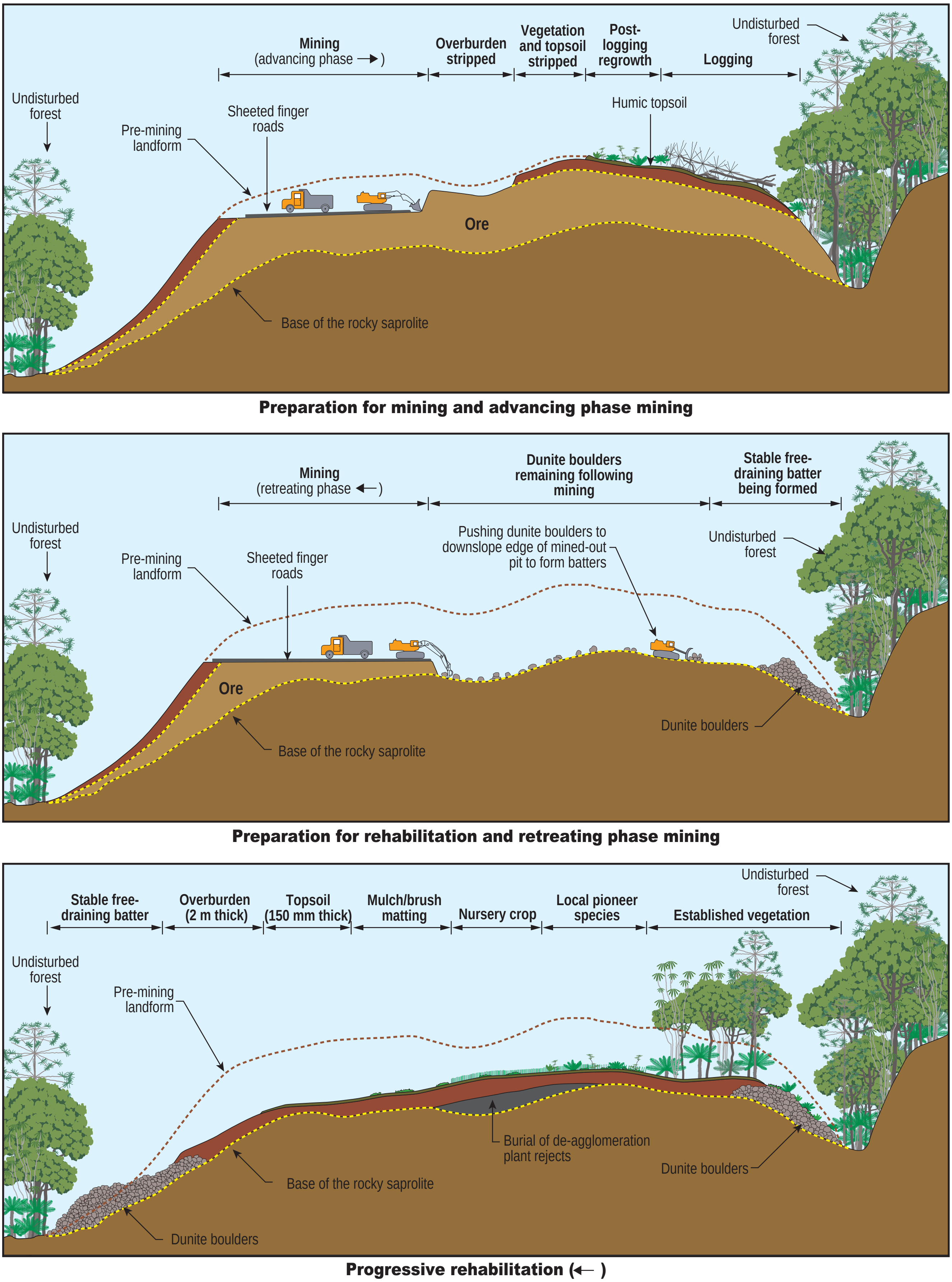


Figure 10 Schematic cross-section of preparation, mining and rehabilitation stages

- Some propagation of local pioneer and nitrogen-fixing species is envisaged, but ultimately, natural recolonisation will be the predominant regrowth mechanism.

- Erosion control: once disturbed, the clay soils of the Kurumbukari Plateau are easily eroded, particularly during intense rainfall. The mine site spans the headwaters of a number of catchments on the Kurumbukari Plateau. RNJV proposes an erosion control plan in each disturbed catchment to minimise fugitive sediment comprising:
  - The retention of eroded material close to the source during small to moderate flood events (micro-scale control): localised slope protection; small check dams; vegetative filter strips; and road drainage.
  - Settling ponds (macro-scale controls): three ponds are envisaged to accommodate the initial 10 years of mining, each pond designed to retain a 24-hour, 10-year rainfall event. Trapped sediment will be periodically excavated and sent to the beneficiation plant for blending with run-of-mine ore. Additional facilities will be required for the later years of mining.

Sequence of Mining Activities

Figure 11 shows the progressive sequence of clearing, mining and rehabilitation, and the location of the three settling ponds up to Year 11.

4.1.2 Beneficiation

Beneficiation is the first stage of ore processing, and can be carried out at Kurumbukari. It involves the physical removal by screening and gravity separation of the larger stones and chromite sand, followed by thickening (Figure 12), so as to produce a consistent slurry feed for overland pipeline transport (see Figure 7). The slurry will average 1.12% nickel and 0.11% cobalt.

The stones will be used for drainage and erosion control structures; the thickener overflow will be recycled; and the chromite sand will be stored in mined-out pits, from which it may be subsequently reclaimed at some future date if it becomes economic to do so.

Plate 5 Millet cover crop trial on red limonite (fertilised)

4.2 Transport Infrastructure

4.2.1 Roads

Madang to Kurumbukari

A permanent, 36-km road will be constructed from Usino Junction on the Madang–Lae Highway across a new bridge over the Ramu River to the mine at Kurumbukari (see Figure 7). This road will allow access from the mine site to Madang (92 km away) and to Lae (208 km away). The Ramu Highway is currently being sealed between Usino and Lae and upgraded between Usino Junction and Madang.

Basamuk Access Tracks

A two-lane gravel-surfaced 3-km-long access road will be constructed between the refinery at Basamuk and the accommodation area, water supply point and limestone quarry (see Section 4.3, to follow).

Dry weather road access along the 95 km from Madang to Basamuk will be via the Ramu Highway to Ato Junction and then along the gravel Rai Highway. The latter fords numerous large rivers of the Finisterre Range and so heavy equipment, construction materials and operations access will be via the new port at Basamuk Bay.

4.2.2 Slurry Pipeline

The ore slurry will be transported by a 134-km pipeline across a range of low hills between the Ramu River valley and Astrolabe Bay, and then east along the coast to the refinery at Basamuk (see Figure 7). The pipeline will be 500 mm in diameter and comprise welded, high-tensile steel generally on above-ground supports. The nominal rate of flow will be 430 t of dry solids/h at a slurry density of 32% solids by weight.

4.3 Basamuk Facilities

4.3.1 Refinery

The location of the Basamuk refinery complex is shown in Figure 7. The refinery will produce nickel and cobalt in two main stages (Figure 13):

- Acid pressure leaching in autoclaves to dissolve nickel and cobalt from the ore and their subsequent precipitation as intermediate hydroxides using lime.
- Re-leaching of the hydroxides by ammonia followed by nickel solvent extraction and electrowinning, and cobalt salt precipitation.

The Ramu ores have good metallurgical properties, with expected nickel and cobalt recoveries of 93% and 88% respectively. Testwork indicated that ores could be blended at 2:1 limonite:saprolite, a sulfuric acid consumption rate of

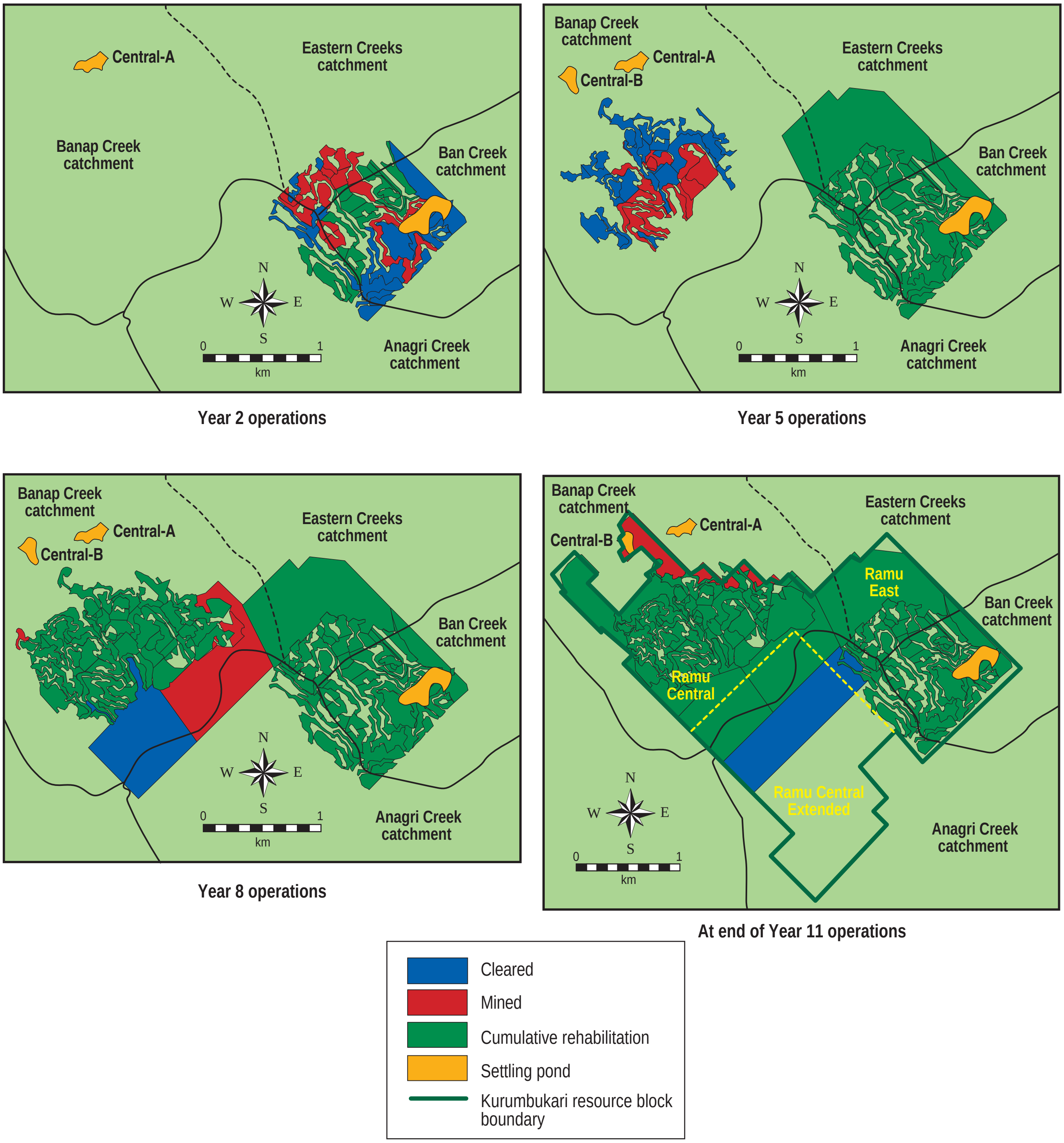


Figure 11 Clearing, mining and rehabilitation sequence to Year 11

250 kg/t and an autoclave retention time of 60 minutes.

4.3.2 Acid Plant

The acid plant will produce approximately 3,350 t/day of sulfuric acid and 120 t/day of sulfur dioxide by combustion of elemental sulfur. Excess heat will be recovered for various plant uses, including melting elemental sulfur, steam, the boiler feedwater deaerator and general plant heating.

4.3.3 Quarry and Lime Plant

The annual refinery requirements for 0.7 Mt of limestone slurry and 0.3 Mt of milk of lime will be met by a proposed 1.2 Mt/a quarry located 3 km from Basamuk feeding a conventional lime plant in the refinery complex (see Figure 7).

4.3.4 Port

Project-dedicated port facilities will be constructed at Basamuk. Consumables including fuel oil and elemental sulfur will be imported and delivered by bulk carriers. Nickel metal and cobalt salt will be exported across the wharf.

A general view of Basamuk Bay and hinterland is given in Plate 6.

4.4 Services

4.4.1 Electrical Power

The provision of electrical power for the mine, the refinery and associated facilities is shown in Table 2. Diesel generator sets will supply power to the Kurumbukari mine site and the Basamuk refinery complex. The two ore slurry pumping stations will draw power from the ELCOM Ramu grid switchyards at Usino Junction and Ato Junction. A new transmission line will be installed from Ato Junction to the nearby pump station.

4.4.2 Raw and Potable Water

Water requirements and sources are shown in Table 3.

4.4.3 Accommodation

Accommodation and messing facilities will be required for both the construction and operations phases. RNJV intends to build the permanent camps early to meet the construction accommodation requirements. For the operations phase, there will be single-status accommodation at Kurumbukari, permanent accommodation in Madang and a township at Basamuk.

The make-up of the accommodation mix is given in Table 4.

4.4.4 Sewage Treatment

Remote sites, sites without power and temporary construction facilities will use septic tanks and absorption trenches to treat and dispose of sewage. Package sewage treatment plants will be provided by RNJV at Kurumbukari and Basamuk. There will be two sewage systems at Basamuk, one for the refinery and the other for the accommodation area. Treatment plant effluent from the refinery will be mixed with tailing and discharged to the ocean at depth with the tailing stream. Treated effluent from the accommodation area package sewage treatment plant will be discharged via a separate ocean outfall to the south of the accommodation area. Effluent from the Kurumbukari package sewage treatment plant will be disposed of via absorption trenches. Sludge from the treatment plants will be pressed and the cake disposed to designated mined-out pits or landfills.

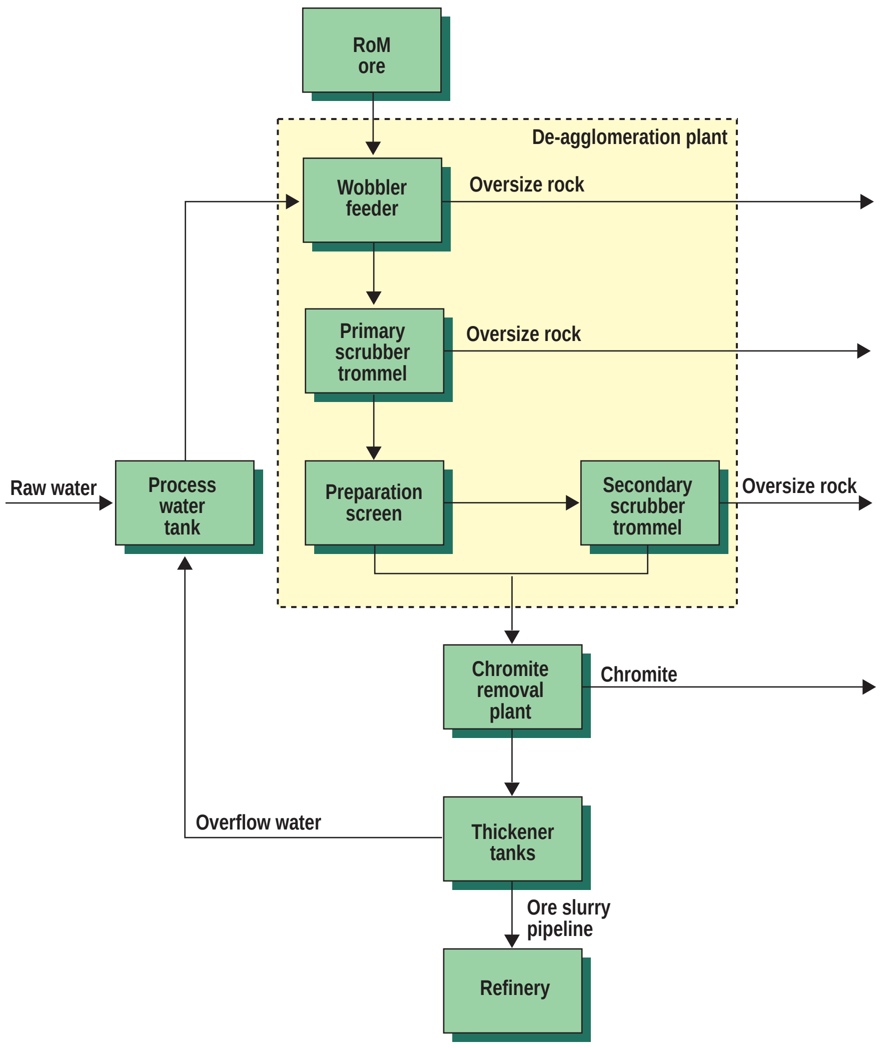


Figure 12 Beneficiation flowsheet

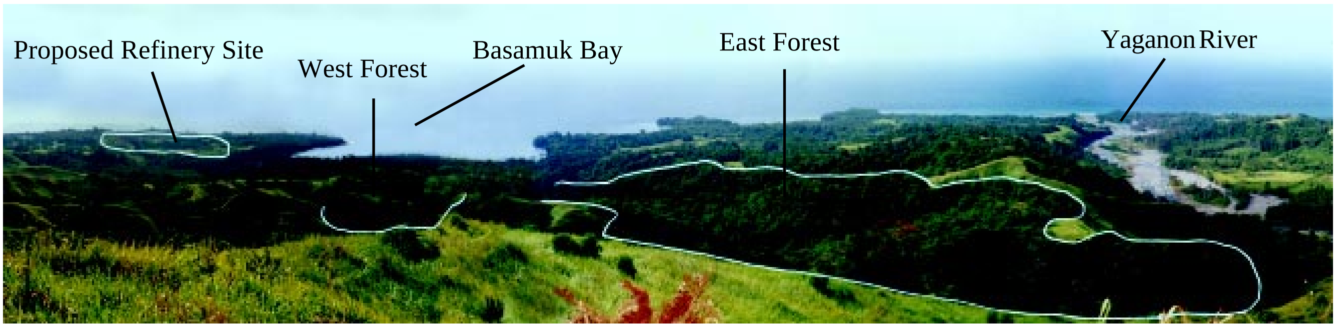


Plate 6 Basamuk Bay and hinterland

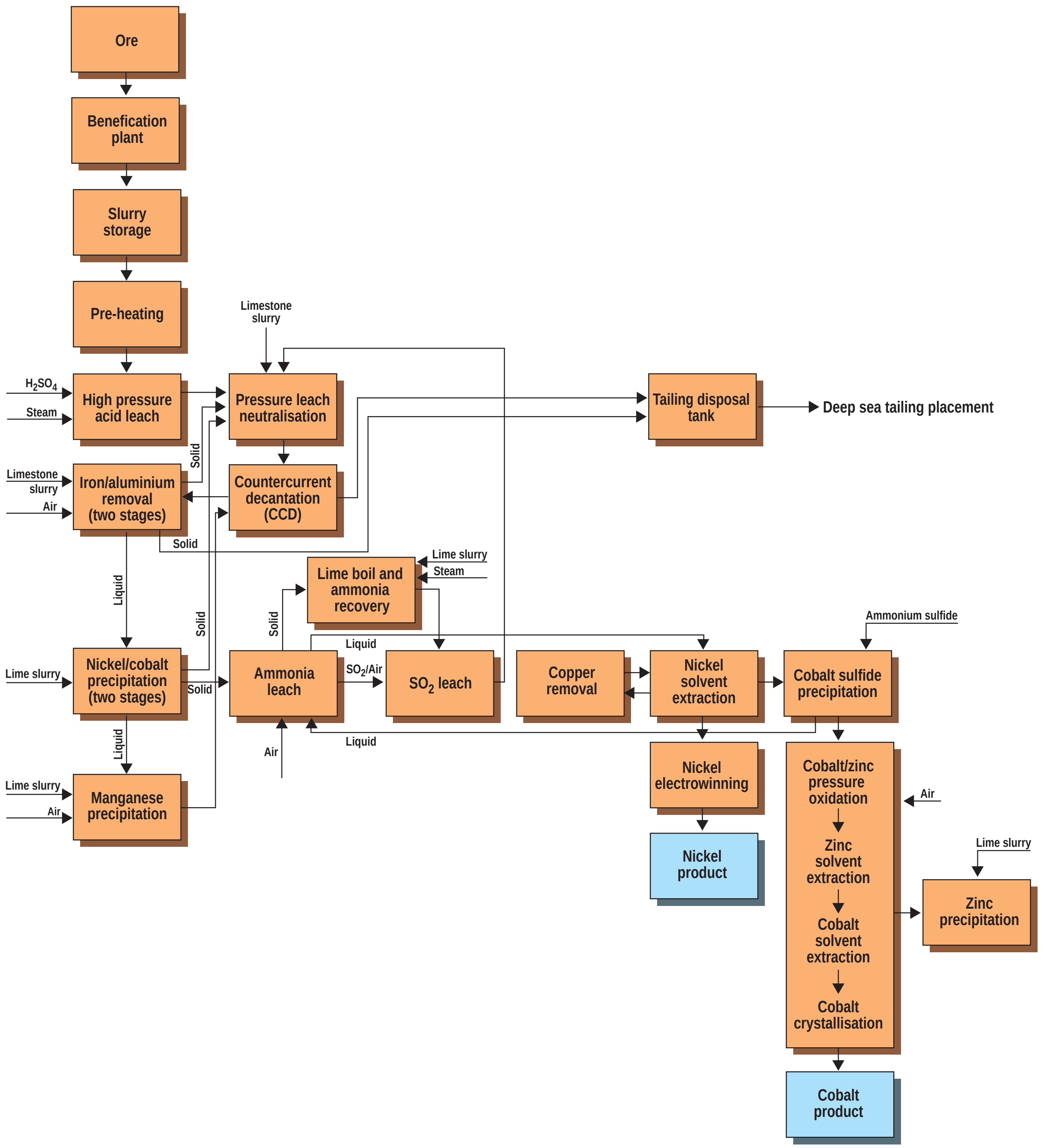


Figure 13 Refinery flowsheet

4.4.5 Refuse Disposal

Wastes generated at Kurumbukari and Basamuk will be sorted and then recycled where possible, otherwise they will be disposed to landfill.

4.4.6 Telecommunications

A telecommunications network will be set up linking project facilities with each other and with national and global systems.

4.5 Tailing Treatment and Disposal

Two options for the management of refinery tailing have been considered, on-land storage and DSTP. The latter is the preferred option for reasons which are set out in Section 6.2.3. Both options involve treatment of the tailing.

4.5.1 Tailing Treatment

Tailing solids from the refinery will be produced at up to 5 Mt/a and a total of about 100 Mt will be generated over the project's nominal, 20-year life.

The tailing will be treated by the addition of limestone and/or lime to neutralise residual acidity and raise the pH to approximately 7.8 so that soluble metals are precipitated prior to disposal.

4.5.2 DSTP System

Configuration

The layout of the proposed DSTP system is shown in Figure 14 and in schematic cross-section in Figure 15.

The principal features are:

- Mixing of tailing with seawater at a ratio of 1:1.5 by volume in a mix/deaeration tank on the shoreline, which removes entrained air prior to discharge.
- Seawater intake pipeline from 60 m depth.
- Tailing outfall pipeline terminus at 150 m depth, which is:
  - 70 m below the deepest measured zone of sunlight (euphotic zone).
  - 50 m below the zone in which upwelling can occur.
  - 30 m below the deepest measured surface mixed layer of the ocean (a layer which is mixed by wind and wave action, and within which water can circulate freely). A typical measured profile showing the mixed layer at 75 m depth is given in Figure 16.
- Location of the outfall terminus in a steep-sided submarine canyon, which will direct the flow of tailing as a density current along the canyon floor and into a deep oceanic basin (Vitiaz Basin).

Operation

The tailing will consist of:

- A treated alkaline slurry, from which the nickel and cobalt have been extracted. Potential contaminants in the

Table 2 Power demand and supply

Location	Power Demand (MW)	Installed Capacity (MW)
Mine	4	4.8
Refinery	53	71.5
Usino Junction	4.35	Grid
Ato Junction	4.35	Grid

Table 3 Water requirements and supply

Requirement or Supply	L/sec	m^3/day
Kurumbukari		
Raw water requirement:		
Mine	2.4	205
Beneficiation plant	88	7,584
Other	2.8	243
Total	93	8,032
% of mean daily flow (Gagaiyo River)	4%	4%
% of 1-in-50-year minimum flow (Gagaiyo River)	67%	67%
Basamuk		
Raw water requirement:		
Process stream	195	16,850
Cooling water	126	10,900
Potable	19	1,650
Other	10	865
Total	350	30,265
% of mean daily flow (Yaganon River)	2%	2%
% of 1-in-50-year minimum flow (Yaganon River)	53%	53%

Table 4 Accommodation for employees during construction and operations

Accommodation Type	Kurumbukari Mine Camp		Basamuk Refinery		Basamuk Permanents	Madang Permanents
	Construction	Operations	Construction	Operations	Operations	Operations
Houses			20	20	11	15
Duplexes					104	50
2-man single-status quarters		16		74		34
4-man dongas (2 per ensuite)	88	56	300	140		
8-man dongas (4 per ensuite)	128	264	480	376		
16-man dongas (8 per ensuite)	272		592			
8-man dongas (spare)				400		
Hostel	50	30				
Hired 1,100-man camp			1,100			
Total beds	538	366	2,492	1,010	115	99
100-man fly camp	This camp is not included in the above figures.					

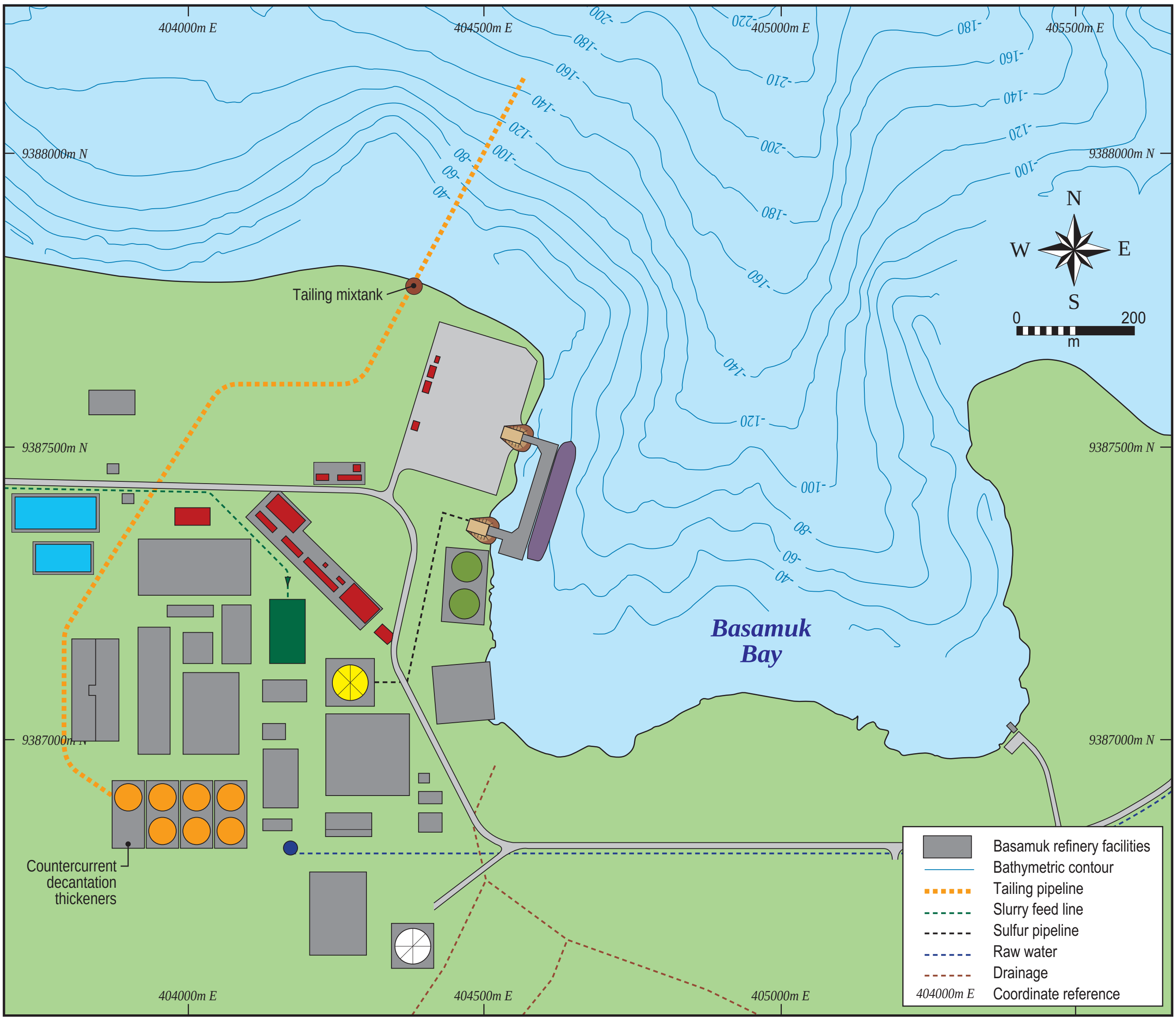


Figure 14 Layout of the DSTP system option

tailing have been identified as the residual nickel and cobalt, and also chromium and manganese.

- Process reagents, with ammonia being the only reagent of potential environmental concern.

Tailing will flow by gravity pipeline from the refinery to the tailing disposal tank, then to the mix/deaeration tank. The density difference between the tailing and seawater will draw seawater into the mix/deaeration tank via the seawater intake pipe. After mixing, the diluted tailing will flow by submarine pipeline to 150 m depth, where it will be discharged as a turbulent jet at an estimated velocity of 4.2 m/s and a density of 1,100 kg/m^3.

Because the tailing seawater mixture is denser than the receiving seawater at 150 m depth (see Figure 16), beyond the outfall the tailing will flow down the sloping seafloor of the Basamuk canyon. The footprint of the tailing solids is predicted to ultimately deposit on the deep ocean floor within the Vitiaz Basin (see Section 6.3.4 'Deposition').

The above model for tailing behaviour is based on the observed behaviour of existing DSTP systems, and closely mimics the behaviour of natural land-derived sediment flows from coastal rivers discharging into deep ocean basins.

4.6 Workforce

The construction workforce peaks at approximately 2,500. The permanent workforce is projected to be 1,045.

4.7 Decommissioning

The project will ultimately close after an operational life which is nominally 20 years. Decommissioning principles include:

- Liaison with the PNG Government's Mine Decommissioning and Rehabilitation Committee concerning closure requirements.
- Liaison with landowners and community groups.
- Compliance with all relevant legislative requirements, SML and other lease conditions, commitments made

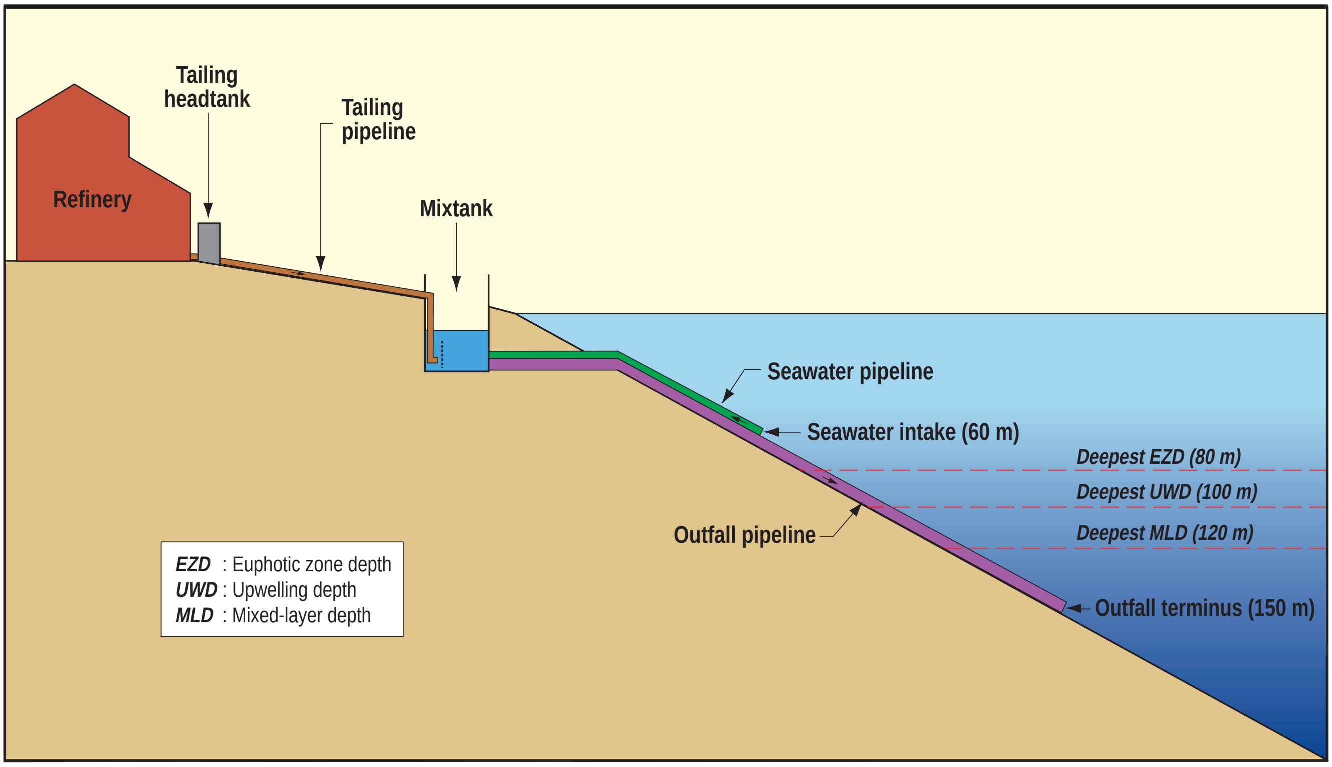


Figure 15 Conceptual DSTP disposal system

by RNJV and the requirements of project financiers and insurers (if any).

- Removal or burial of unwanted equipment and material.
- Completion of rehabilitation.

Final landforms at the mine will comprise steep slopes, grassy terraces and rocky outcrops. At Basamuk, the quarry will present as an open pit, and the plant area as a grassy flat.

All project areas will be reclaimed by forest over time, unless regular burning by villagers maintains fire-adapted grass and shrub communities.

5. Project Setting and Issues

5.1 Description

The undulating terrain of the proposed mine site area is covered with tropical mixed rainforest and some areas of kunai grassland. Population density is low; scattered settlements subsist from shifting cultivation. A number of small hamlets exist within the proposed SML. The closest village to the mine site is Daunagari, located about 5 km to the north of the existing Kurumbukari exploration camp (see Plate 1); Usino, about 20 km to the east of the proposed mine site and with a population of about 2,000, is the closest town.

From the Kurumbukari mine site, the proposed slurry pipeline travels eastwards towards the coast, crossing the Ramu River and the extensive Ramu River floodplain and connecting with the

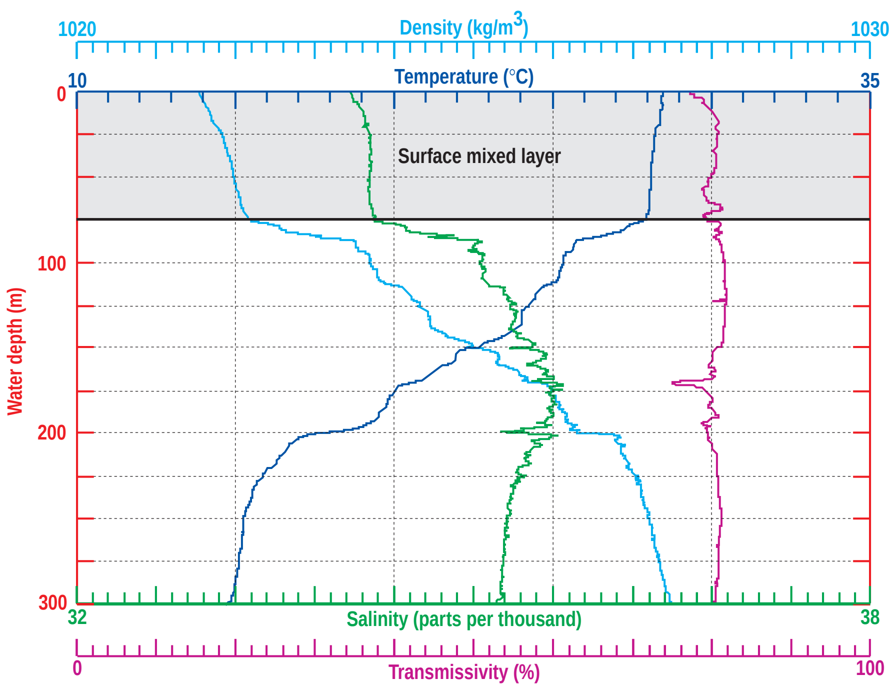


Figure 16 Typical oceanographic profile, August 1995

Madang–Lae Highway which it follows on its descent to the coastline of Astrolabe Bay. Vegetation in the Ramu valley is a complex of low altitude forests on plains and fans, and grassland along the access road alignment.

The pipeline reaches the coastline near the coastal town of Erima and from there the pipeline route runs southeast to the proposed refinery complex at Basamuk. Basamuk Bay on the Rai Coast (Plate 7) is a natural harbour with deep water offshore and a narrow fringing reef on the bordering headlands. The natural vegetation in the surrounding coastal zone has been largely replaced with cash crops of coconut and cocoa, while the foothills are used for subsistence gardening. Native forest in the foothills is mostly secondary regrowth in the valleys, with kunai grass on the ridges and slopes. The Basamuk area has a population of between 1,000 and 1,500 people in approximately 15 villages scattered along the coastal zone and adjacent foothills.

Deep water close to shore to the north of Basamuk Bay leads to the Vitiaz Basin, which is over 2,000 m in depth.

5.2 Issues

The planning and impact issues raised by the Ramu Project within this environment may be summarised as follows:

Planning

- Refinery location.
- Tailing disposal strategy.
- Water quality management.
- Air quality management.
- Rehabilitation of mined land.
- Social and economic development.

Impact Assessment

- Effect of project land requirements on land use and conservation.
- Water quality impacts of construction and downstream of mining.
- Shallow-water marine impacts.
- Deep-water marine impacts.
- Social and economic benefits and impacts.
- Effects on archaeological and cultural sites.

These issues are discussed in Section 6.

6. Environmental Planning

6.1 Investigations

A comprehensive suite of site investigations and testwork has been carried out for environmental planning and impact assessment purposes. These studies are listed in Box 2, grouped according to the section of the appendix volume (Volume C) in which they appear.

6.2 Main Planning and Management Options

Options exist for many aspects of a large project. Of these, four are considered to be of major significance for the Ramu Nickel Project and are discussed below:

- Refinery location.
- Power generation.

Plate 7 Basamuk Bay

Box 2 List of environmental planning and impact assessment studies

Appendices 1 to 8

1 Bathymetry and Physical Oceanography
2 Currents and Water Properties off Northern PNG
3 Marine Biological Communities
4 Freshwater Impacts
5 Marine Impacts
6 Conceptual Study of On-Land Tailings Disposal Options
7 Hydrology and Meteorology
8 Deep Sea Tailing Placement Engineering

Appendices 14 to 19

14 Resource Use Surveys
15 Ocean Floor Sediments
16 Chemical and Toxicological Characterisation of Tailing
17 Terrestrial Vertebrate Fauna
18 Archaeology and Material Culture Study
19 Sediment Study: Management Plan and Downstream Impacts

Appendices 9 to 13

9 Physical Properties of Tailing
10 The Numerical Model of Deep Sea Tailing Placement
11 Vegetation Survey
12 Aquatic Biology
13 Water Quality and Sediment Chemistry

Appendices 20 to 25

20 Assessment of Limitations to Rehabilitation, Kurumbukari Mine Site
21 Air Quality Assessment
22 Socio-economic Impact Study
23 Vegetation and Fauna of the Basamuk Bay Refinery Site
24 Deep-Slope Fisheries Survey, off the Rai Coast
25 Ramu Nickel Project Local Business Development Policy

- Tailing management.
- Air emission control.

6.2.1 Refinery Location

The Ramu nickel deposits were first identified in the 1960s, but it required improved ore processing technology—high pressure acid leach—for the project to become economic. However, the energy and consumables required by the new technology are substantial, and the ability to provide, in particular, sulfur, limestone and electricity at low cost becomes critical to economic feasibility. Of the major consumables, limestone is available locally, but sulfur and fuel for electricity generation need to be imported. At the same time, access to the mine site is hindered by a combination of mountainous and swampy terrain. The optimal arrangement of facilities to meet these requirements is to have the ore treated at the mine to remove coarse particles and chromite, and then send the beneficiated ore as a slurry by pipeline to the refinery located adjacent to the port, where the major consumables by volume, sulfur and fuel oil, can be offloaded from ships. This arrangement is substantially cheaper than other options, such as locating the refinery at the mine and transporting imported consumables from the port to the mine.

Having decided on a coastal location for the refinery, a precise location involved the consideration of many factors, as shown in Table 5.

The coast of Astrolabe Bay (see Figure 7) provided the shortest slurry pipeline distance and prefeasibility desk studies and preliminary field investigations identified a potentially suitable site at Erima. Subsequent detailed geotechnical studies showed unacceptably poor foundation conditions.

A second review of siting and layout options was then undertaken in the Erima and Ato region (between the tributaries of the Palpa River) and then further afield along the Rai Coast. Cape Rigny was identified for more detailed investigations, but the water was too deep at the nominal port site for a conventional wharf. Around this time, Basamuk Bay was identified as a potential site. Detailed investigations showed geotechnical conditions to be suitable and Basamuk was selected as the refinery site.

6.2.2 Power Generation

Kurumbukari

The prefeasibility study supported the

Table 5 Refinery siting factors

Factor	Erima	Cape Rigny	Basamuk
Suitable port bathymetry	Poor	Very poor	Good
Flat topography	Very good	Poor	Poor
A reliable process water supply	Poor	Good	Very good
Suitable geotechnical conditions	Very poor	Moderate	Very good
Potential for deep sea tailing placement	Moderate	Good	Very good
Proximity to a limestone resource	Poor	Poor	Very good
Length of ore slurry pipeline	Very good	Good	Moderate
Land tenure	Good	Poor	Unknown

Suitability ratings: very good, good, moderate, poor, very poor, unknown.

construction of an electricity transmission line from the ELCOM Ramu grid at Usino Junction to the mine site. However, construction costs were later found to be prohibitive and diesel-fired generator sets are now proposed.

Basamuk
During the prefeasibility study and early in the feasibility study, a coal-fired power station, raising steam to power steam turbine/generator sets was considered. This could have enabled the excess steam raised from waste heat in the acid plant (supplemented by boiler steam) to be used for power generation. However, it became apparent that the steam usage by the leach circuit would be higher than previously thought and there would be no steam from the acid plant for power generation. A fuel study also indicated that, although coal provided the cheapest energy in terms of cost per unit of energy as delivered to the wharf, the capital cost of the steam turbine option was very high when compared to diesel engines.

The configuration finally selected was the acid plant, with an auxiliary boiler to be used for start-up, to generate all steam for the leach circuit and other process areas, and a totally independent power station using medium-speed diesel engines running on heavy fuel oil.

6.2.3 Tailing Management

Tailing management by storage on-land and DSTP via a submarine outfall have been examined and compared.

On-land Tailing Storage
On-land tailing storage in impoundment structures is used extensively around the world. The method is best suited where evaporation significantly exceeds rainfall: the water deficit promotes drying and consolidation of the tailing materials and allows the structure to operate without the need to discharge water. On-land options were considered for tailing produced as either a slurry or a filter cake, and five options were identified and assessed against the criteria in Table 6:

Table 6 Site selection criteria for on-land tailing disposal

Factor	Selection Criteria
Foundation materials	Competent, stable, low seepage potential
Fill slope stability for embankment fill materials	Modest horizontal to vertical ratio
Proximity to other project components	Nearby
Geometry	Provision of adequate storage volume and modest requirements for embankments in terms of length and height

Basamuk

- Option 1a: conventional turkey’s nest tailing dam on the coastal plain.
- Option 1b: conventional valley tailing dam in the coastal foothills.
- Option 1c: filtered tailing landfill storage on the coastal plain.

Kurumbukari

- Option 2a: conventional tailing dam.
- Option 2b: filtered tailing landfill storage.

In concept, Option 2a involved creating a storage area in each cell as it was mined-out and using the post-mining topography to create a larger conventional valley tailing dam. In practice, the post-mining topography offered no dam sites of adequate capacity, and this option was not pursued further.

For the other disposal options, potential sites were identified, and the suitability and risks of each were ranked in terms of dam stability, seismic stability, tailing handling and placement, water handling and effluent, land use, groundwater seepage, and capping and closure (Table 7).

Table 7 A comparison of identified conceptual on-land tailing disposal options

Option Description	Total Rank *	Cost (Millions US$)	Potential Fatal Flaws
Option 1a: conventional turkey’s nest tailing dam, coastal plain	20	555	Potential for downstream environmental impacts during operations and closure. Significant land area impacted. Potential requirement for foundation ground improvement to prevent seismic liquefaction.
Option 1b: conventional valley tailing dam, coastal foothills	22	185	Potential for downstream environmental impacts during operations and closure. Significant land area impacted. Potential requirement for foundation ground improvement to prevent seismic liquefaction, valley wall instability.
Option 1c: filtered tailing, landfill storage, coastal plain	18	503	Inability of pressure filters to produce dry cake and to handle/place material. Potential for downstream environmental impacts during operations and closure. Significant land area impacted.
Option 2b: filtered tailing, landfill storage, Kurumbukari	15	640	Significant tailing pipeline and pump back costs. Inability of pressure filters to produce dry cake and to handle/place material. Potential for downstream environmental impacts, complicated by requirement for initial 2 years storage off mine site, during operations and closure.

*Based upon qualitative ranking system out of total 35 points (lower ranking is generally more favourable with lower associated risks).

Table 7 indicates that Option 1b offers the lowest cost option, for the highest risk, but differences in ranking between options are minor and the risk for all options is high.

Deep Sea Tailing Placement
DSTP involves the discharge of tailing to the ocean at depth, with ultimate deposition of the tailing solids on the deep ocean floor. Countries presently or formerly using this method include:

- Papua New Guinea—two operating and one approved.
- Indonesia—one operating, one under construction and one approved.
- Turkey—one operating.
- Chile—one operating.
- France—two operating.
- Canada—two operated successfully, now closed.

The attractions of the method are low capital, operating and decommissioning costs, natural post-closure recolonisation of tailing deposits and long-term safety.

However, specific site criteria need to be met, and these are shown in Table 8. This shows that Basamuk is well suited to the method, with the proviso that RNJV's environmental objectives can also be met (see Section 2.4).

Table 8 Site investigations to assess suitability for DSTP

Site Selection Criteria	Survey/ Investigation Type	Basamuk Option Suitability	Basamuk Option Report Reference
Occurrence of steep nearshore submarine slopes (>12°) that would allow tailing to flow away from the outfall	Ocean floor bathymetry	Very good	Appendix 1
Geotechnically stable nearshore submarine slopes to provide pipeline outfall security	Geotechnical assessment of bathymetric and geological data [1]	Moderate	Feasibility Study
Occurrence of a deep ocean basin to which tailing can flow and then deposit	Deep ocean floor bathymetry	Good	Appendix 1
Occurrence of a permanent density gradient in the ocean profile to trap tailing at depth	Oceanographic profiling	Very good	Appendix 1
Lack of strong deep ocean currents capable of resuspending and transporting tailing solids beyond the receiving basin	Deep water current metering	Good	Appendix 1
Lack of upwelling currents capable of mobilising tailing from depth into the surface waters [2]	Interpretation of satellite imagery for upwelling	Very good	Appendix 2
Preferred, but not essential			
Occurrence of a submarine canyon to confine tailing flow and deposition	Ocean floor bathymetry	Very good	Appendix 1
Lack of current or potential commercial or subsistence utilisation of local deepwater fisheries	Assessment of utilisation of deepwater fisheries	Moderate	Appendix 24
Moderate range of tide levels to allow a conventional shoreline mixtank to be used	Review tide charts	Good	Appendix 8

Suitability ratings: very good, good, moderate, poor, very poor.

[1] This assessment is of a preliminary nature.

[2] Upwelling of ocean water has been identified at Basamuk, but has been shown to occur from depths of 100m: any DSTP system outfall would need to be sited well below this depth.

Comparison of On-land Tailing Storage and Deep Sea Tailing Placement
On-land and DSTP tailing options are compared in Table 9. Constraints and uncertainties exist with each. In the case of the on-land options, these factors are significant, particularly those of long-term erosion, the unavoidable need for regular discharges of water from the impoundment and the inherent uncertainties in safeguarding a permanently saturated structure against seismic liquefaction in perpetuity.

The constraints and uncertainties for DSTP are somewhat less by comparison. Moreover, in the regional context, the Vitiaz Basin receives a very large volume of natural sediment (estimated at 80 Mt/a), mainly from rivers draining the Finisterre Range. The tailing is of inherently low toxicity, and 5 Mt/a of tailing would add a relatively small pro-

Table 9 Tailing disposal option comparison

Issues	On-land				DSTP
	1a	1b	1c	2b	
Land clearance	Mo_p	Mo_p	Mo_p	Mi_p	No
Catastrophic failure	Mo	Mo	Mi	Mi	No
Erosion	O	O	S	S	No
Pipeline rupture	Mi	Mi	Mi	Mi	Mo
Shallow marine impacts	Mo_p	Mo_p	Mi_p	No	No
Deepwater marine impacts	No	No	No	No	Mi
Feasibility of preventing seismic liquefaction	?	?	?	?	No
Feasibility of producing and handling filter cake	No	No	?	?	No

Constraint ratings:

O = Overriding; S = Severe; Mo = Moderate; Mi = Minor; No = None; ? = Unknown;
p = Based on preliminary data.

portion to the natural regional sediment flux.

For these reasons, DSTP is the preferred tailing management option. The primary factors in this choice are:

- Favourable offshore site conditions.
- Large cost saving.
- Low toxicity tailing.
- Negligible loss of land and resources.
- A high probability of full ecological recovery, as deposited tailing will be buried by high rates of natural sedimentation.
- Long-term safety guaranteed.
- High level of predictability and low technical risk.

The on-land options are considered technically feasible. However, they all rank poorly in each of the above respects, and particularly in terms of:

- High to very high cost.
- High technical risk.
- The onerous long-term requirement to protect downstream environments and people in perpetuity against the potential of catastrophic failure, to which a saturated structure in an area of high seismic activity is prone.

The final issue—whether the marine environmental impact of DSTP is sufficiently low and whether the tailing deposits will ultimately be recolonised for the option to be acceptable—is addressed in Section 6.3.4.

6.2.4 Air Emission Control

The proposed refinery at Basamuk will have four types of air emission: particulates; hydrocarbons; sulfur dioxide (SO_2); and oxides of nitrogen (NO_x).

Particulates and hydrocarbons are not expected to be problematic from the standpoint of human health. However, a preliminary investigation found that SO_2 emissions, in particular, could be problematic and recommended that RNJV assess ways to reduce refinery emission levels and thereby bring ground level concentrations into line with air quality goals. The following options were then proposed by RNJV:

In the acid plant

- Option 1: increasing the SO_2 removal efficiency by providing a greater amount of catalyst in several beds and by adding a caesium catalyst in the fourth converter pass.
- Option 2: incorporating a scrubber on the exhaust stack to increase the SO_2 removal efficiency.

In the power station

- Option 3: paying a premium for a low-sulfur heavy fuel oil for diesel generators instead of standard heavy fuel oil in order to reduce SO_2 emissions.
- Option 4: fitting flue gas desulfurisation scrubbers to the engine exhausts.

A second round of air dispersion modelling was then carried out and the results are reported in this EP.

Ground-level concentrations have been derived for SO_2 and nitrogen dioxide (NO_2) (assuming 10% of the total NO_x emissions is present as NO_2 for which the goal is set) under each of the air emission reduction options (Options 1 to 4 as already defined) and under selected combinations of options (1 and 3, 1 and 4, 2 and 3, and 2 and 4).

The modelling shows that a combination of Options 2 and 3 achieves the highest reductions of both SO_2 and NO_x. The assumed annual average air quality goals can thereby be met for NO_2 and come very close to being met for SO_2 (67 $\mu g/m^3$, compared to the assumed goal of 60 $\mu g/m^3$).

Similarly, the assumed 1-hour maximum air quality goals for SO_2 and NO_2 are predicted to be exceeded (albeit less than 1% of the time) during worst-case conditions at some villages on the higher ground to the south of the refinery. This is shown for SO_2 in Figure 17.

These findings indicate that the air quality issues are close to being resolved, but a further round of planning and assessment is required. To this end, RNJV proposes the following course of action:

- Collecting in-situ meteorological data at Basamuk (currently only available from a previously considered refinery site at Erima, some 48 km to the west-northwest of Basamuk, where the terrain is flatter). A meteorological station has been installed at Basamuk and data collection commenced in August 1998.
- Re-running the air dispersion model when data from the representative wind fields have been collected at Basamuk.
- Negotiating a set of air quality criteria with DEC that will be applicable to RNJV.
- Formulating an acceptable air emissions management strategy for the project (such as the adoption of Options 2 and 3) and possibly other mitigation measures, in consultation with DEC.
- Developing a monitoring program for project operations in consultation with DEC.

6.3 Impact Assessment and Safeguards

6.3.1 Land Impacts

The development of the project will require some 1,585 ha of land. A compensation agreement is presently being negotiated with the local people, which is expected to cover the occupation of customary land, unavoidable damages to land, loss of useful resources and increases in freshwater and seawater turbidity.

Within the proposed SML, one or more hamlets will require relocation to accommodate the mine (Figure 18). RNJV will assist affected landowners to resettle to alternative areas with sufficient land to meet subsistence gardening and settlement needs and with access to clean water and adequate bushland resources.

About 1,000 ha of primary forest in the mine area will be cleared. The loss of forest in the mine area, though locally substantial, is not expected to be regionally significant (see cover of this report). This is because mining will disturb less than 10% of the forest which covers the Kurumbukari Plateau, and because the medium-crowned lowland hill forest typical of the locality is common in northern Papua New Guinea, occupying expansive tracts of similar climatic and altitudinal conditions.

The impact to vegetation will be mitigated by progressive clearing, mining and then rehabilitation of disturbed areas (see Figure 11), which will provide a mosaic of undisturbed and disturbed vegetation. The forested slopes of Mt Kua, located in the northern portion of the proposed SML (see Figure 18), will be untouched by the project and will provide refuge for fauna.

The project will have localised effects on subsistence gardens and cash cropping. Where these impacts are unavoidable, local communities will receive compensation.

At the time of writing, no villages required resettlement along the pipeline route, but there may be a need to resettle villages in close proximity to the refinery.

6.3.2 Freshwater Impacts

Mining will be confined within individual zones for periods of about 5 years. Generally over each period, sedimented runoff will be confined to a single catchment. RNJV's erosion control plan (see Section 4.1.1) will mitigate the effects of fugitive sediment from disturbed areas, but residual freshwater impacts will still occur over the life of the mine.

During periods of major catchment disturbance, such as settling ponds construction, locally severe impacts are predicted for the streams draining active mining zones, in the Ban Creek, Eastern Creeks, Anagri Creek and Banap Creek catchments: increases in suspended sediment concentrations during high flows; and increases in bed sedimentation and floodplain deposition. Fish population densities are expected to be severely reduced in the main streams, but increase once the settling ponds start to intercept fugitive coarse sediment. The total length of all creeks thus affected is about 40 km, a tiny fraction of all Ramu River tributaries. Freshwater impacts at the end of the nominal 20-year mine life are shown in Figure 19. Further increases in fish density are expected following mine closure, as the natural sediment regime resumes.

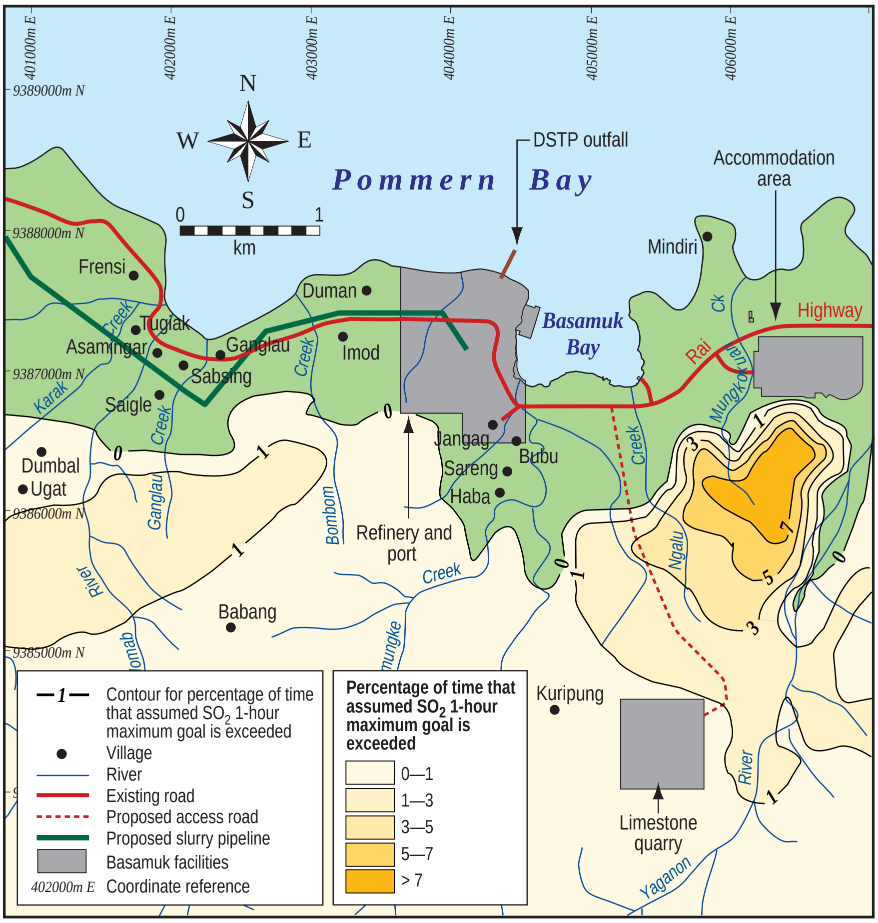


Figure 17 Predicted percentage of time that the assumed SO_2 1-hour maximum goal (350 µg/m³) is exceeded under emission control options 2 and 3

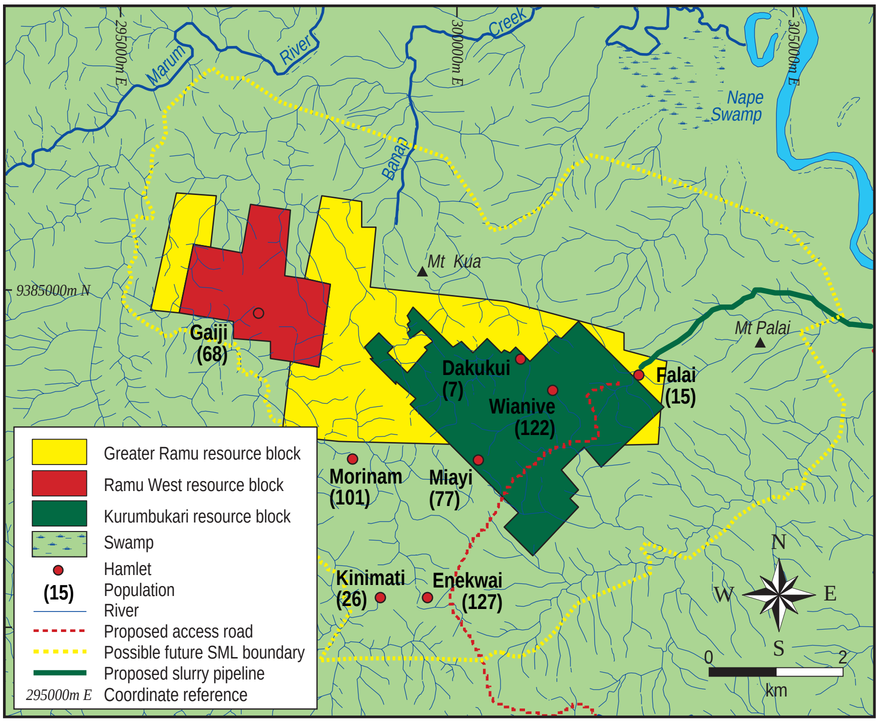
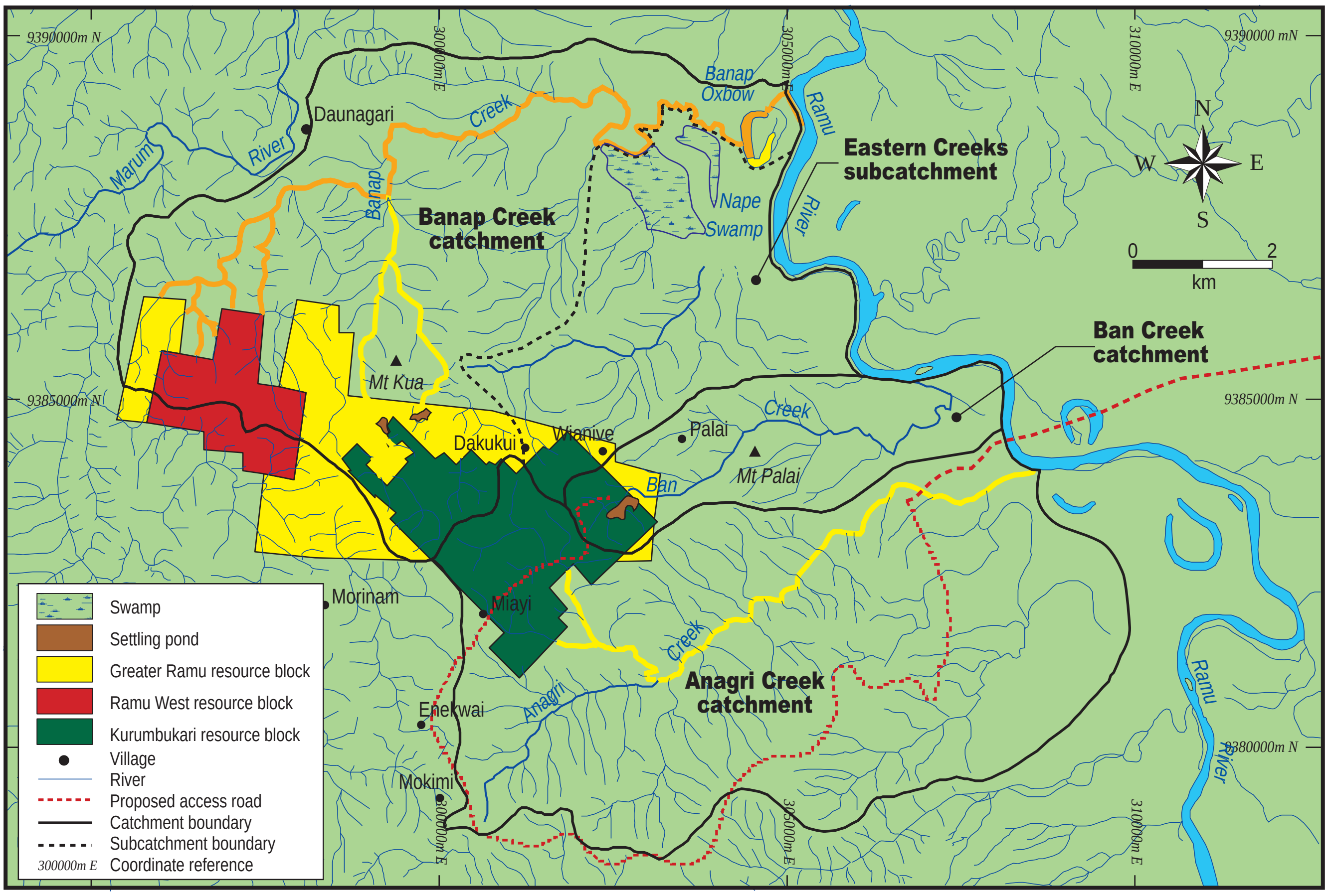


Figure 18 Hamlets and populations at Kurumbukari



MODERATE IMPACTS

Physical:
Moderate aquatic habitat damage from sediment deposition and bed sediment transport. Elevated TSS concentrations during high flows.

Biological:
Moderate reduction of fish population density and biomass. Moderate reduction in supply of fish food organisms.

MINOR IMPACTS

Physical:
Minor aquatic habitat damage from sediment deposition and bed sediment transport. Elevated TSS concentrations during high flows.

Biological:
Minor reduction of fish population density and biomass. Minor reductions in fish food organisms.

Figure 19 Aquatic biological impact zones at the end of mine life, Kurumbukari

Plate 8 Banap Oxbow in the foreground with the Ramu River in the distance

Plate 9 Nape Swamp with Kurumbukari Plateau in the background

The only permanent change predicted is that Banap Oxbow (Plate 8) is expected to infill with sediment over the life of the mine, resulting in the loss and/or reduction of aquatic habitat and the associated subsistence fishery. This effect is unavoidable, and will require compensation to be paid. Impacts on the other subsistence fishery of the mine area, Nape Swamp (Plate 9), are expected to be minor.

Water quality impacts due to trace metals originating from the mine are predicted to be insignificant.

No detectable bed sedimentation or heavy metal impacts on the Ramu River are expected. Highly localised, minor impacts on aquatic habitats at the mouths of the Ban and Banap creeks are expected during construction and early operations. However, no significant impacts are expected on the overall aquatic habitats of the Ramu River, as episodes of elevated, mine-induced TSS fall within the natural range (Figure 20).

6.3.3 Shallow-water Marine Impacts

The main impacts on the shallow-water marine environment will be caused by plumes of turbid water associated with the construction activities near the coast, especially the refinery complex at Basamuk. The sources of turbid water will include sediment-laden floodwaters from creeks draining construction areas, turbid plumes resulting from the shoreline dumping of incompetent waste rock and soil generated during excavation of the refinery site, port construction and associated dredging, and from the construction of the tailing-seawater mixtank and the onshore-offshore section of the tailing and seawater intake pipelines.

RNJV will install and maintain silt curtains, similar to those deployed by the Lihir Gold Mine (Plate 10) at the mouths of the most affected streams, in order to contain and settle the solids in turbid runoff. However, residual shallow-water impacts will still occur during construction, and nearshore biological impact zones are shown in Figure 21.

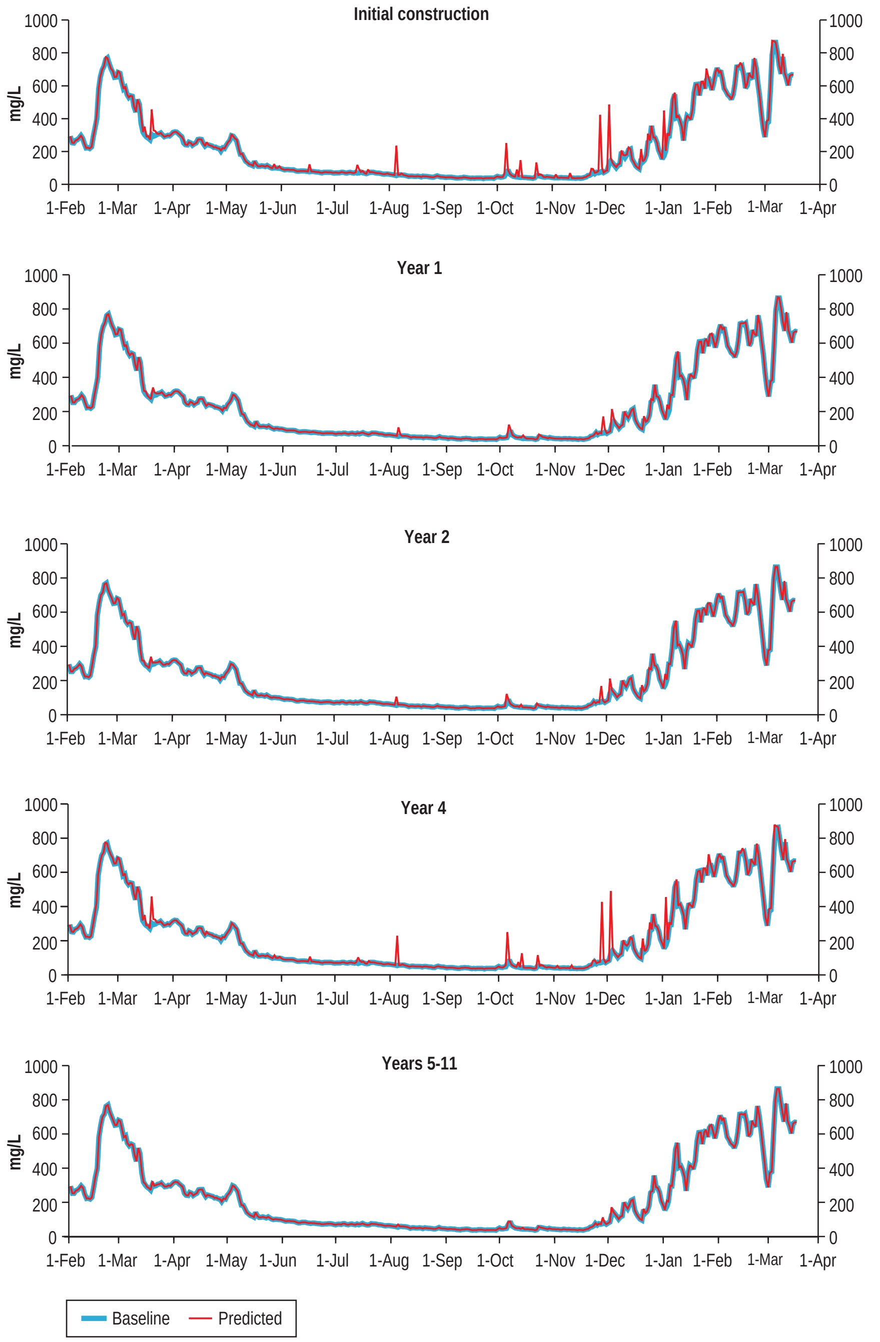


Figure 20 Baseline and predicted mean daily TSS at Ramu River at Sepu

Within and adjacent to the main areas of nearshore construction and creek mouths, impacts on the fringing coral reef (where present) are predicted to be severe but to decrease rapidly with distance from the sources of turbid water plumes generated by construction activity. Within about 500 m either side of the sources of turbid water plumes, impacts on the fringing coral reef are expected to be minor. Small and localised sections of coral reef will be lost, such as a 10-m-wide section needed for the construction of the tailing-seawater pipelines; however, this represents a small area compared to the large unaffected areas of fringing reef within Basamuk Bay and along the adjacent Rai Coast. Within the severe impact zones, most or all of the reef-attached fish species are expected to be displaced, and reef-associated fishes are expected to migrate to less-affected reef areas. Following construction, the settlement and recruitment of juvenile corals in the af-

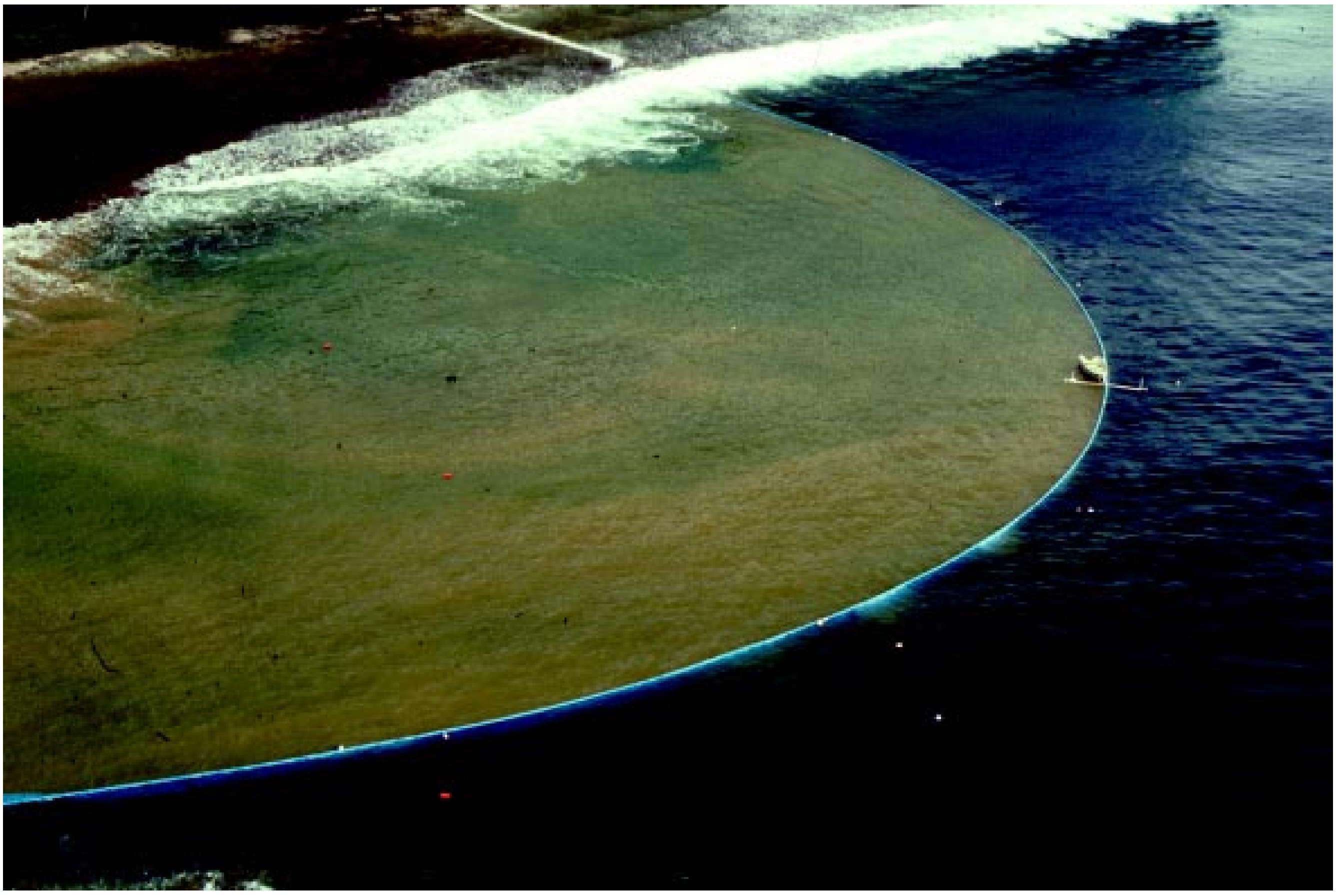


Plate 10 Lihir silt curtain

fected areas of fringing reef is expected to be rapid.

During operations, the sources of construction-derived sediments will have ceased and no long-term impacts on the shallow-water marine environment are predicted.

The effects of treated sewage discharge from the Basamuk accommodation area are expected to be highly localised and restricted to a short distance from the outfall. No observable effects on the fringing coral reef are expected.

6.3.4 Deep-water Marine Impacts

Impacts on the deep-water marine environment will arise mainly during the operations phase from DSTP. However, over a period of several months during construction, the shoreline dumping of incompetent waste from foundation works at the refinery site is expected to have minor impacts on deep-slope habitats, as the waste material descends the submarine slope below the proposed dumping site.

DSTP Impact Mechanisms

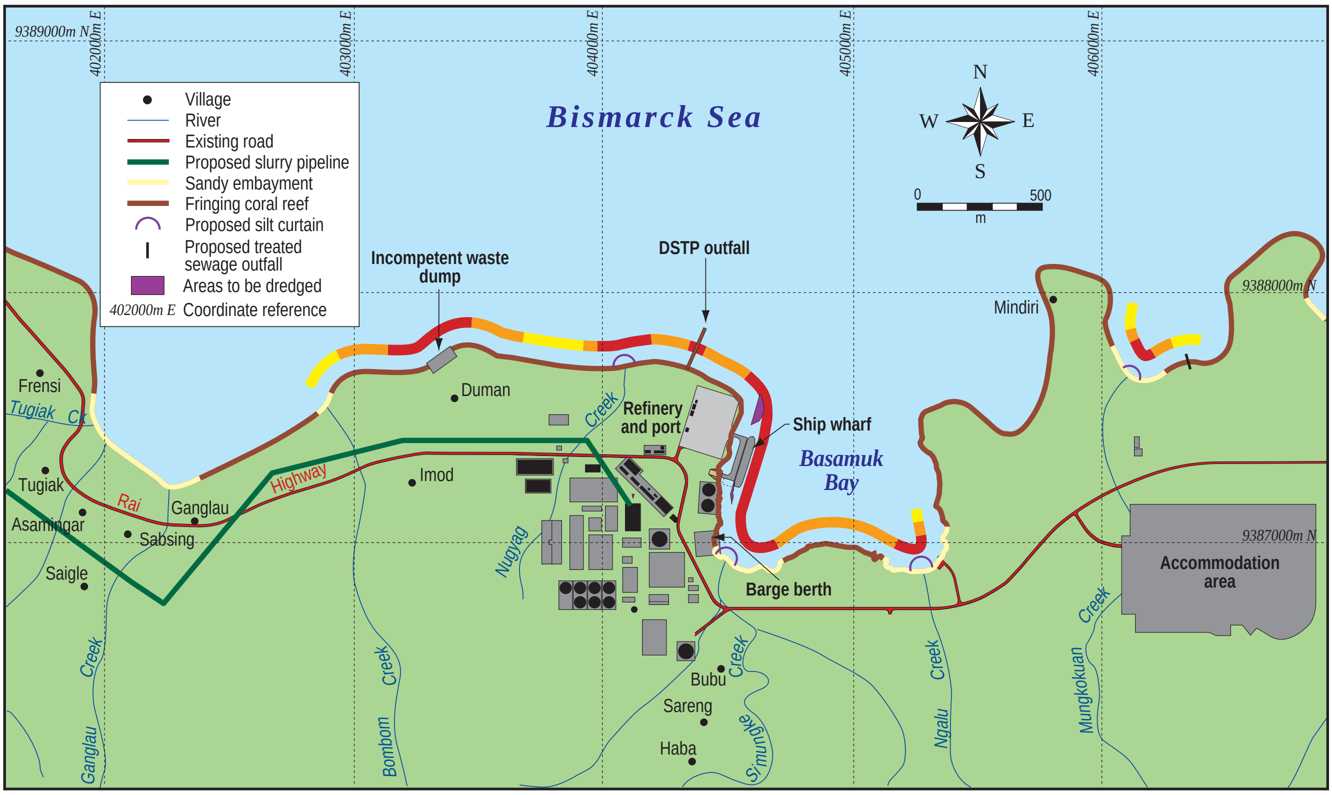
The significant impact mechanisms of the DSTP system are:

- The flow of tailing as a bottom-attached density current.
- Elevated concentrations of suspended fine tailing solids in a series of dilute, subsurface plumes, which shear off the descending density current.
- Tailing deposition on the floor of the Basamuk canyon and on the deep ocean floor of the Vitiaz Basin.

Plume Formation

Case studies of operating DSTP systems indicate the following processes:

- The neutralised and diluted refinery tailing will emerge from the pipe at a depth of 150 m as a high-energy, turbulent jet. It will be denser than seawater and will flow down the sloping floor of the Basamuk canyon.
- Within a short distance, friction and entrainment of seawater will have dissipated much of the tailing's initial energy. Substantial dilution will occur during this initial mixing phase, but the slower-moving mixture will still be denser than the surrounding seawater.
- Gravity will cause the negatively-buoyant mixture of tailing and seawater to continue down the sloping seabed as a density current. This will gradually spread across the bed of the canyon. This larger, slower movement is termed a 'lutite flow'.
- Localised tailing solids deposition will occur along the flow path.
- The peripheries of the density current are expected to eventually reach a density equal to that of the surrounding seawater, at which point part of the liquid fraction, and some of the finest tailing particles, will shear off and form a subsurface plume in the water column. The formation of these plumes will occur at density discontinuities in the water column.



SEVERE IMPACT ZONE	**MODERATE IMPACT ZONE**	**MINOR IMPACT ZONE**
Physical: Severe reef damage from sediment deposition and resuspension. High TSS concentrations. Nearshore water very frequently turbid. Biological: High mortality of corals and associated fauna. Loss and/or reduction of reef-attached fish. Reduction in numbers of reef-associated fish.	Physical: Moderate reef damage from sediment deposition and resuspension. Elevated TSS concentrations. Nearshore water frequently turbid. Biological: Moderate reduction in live coral cover and diversity. Moderate reduction of reef-attached fish diversity and population density. Minor reduction in reef-associated fish population density and biomass.	Physical: Minor effects of increased sedimentation rates. Elevated TSS concentrations. Nearshore water occasionally turbid. Biological: Some reduction in live coral coverage and diversity. Detectable changes in reef-attached fish diversity and population density. No change in diversity of reef-associated fish.

Figure 21 Predicted nearshore biological impact zones (physical and biological effects) during the construction phase

- The remaining solids in the lutite flow, especially the coarser tailing particles, will continue to move down the slope.
- Deep in the basin, in the zone of main deposition, a very dilute, but vertically expansive bottom-attached plume may occur, termed the 'nepheloid layer'.
- Ultimately the sediment, less losses to subsurface plumes, will settle on the ocean floor.

Both density discontinuities and current shearing (horizontal layers of water flowing in opposing directions) have been measured throughout the water column off Basamuk. Both factors are expected to contribute to the variable distribution through the water column of subsurface plumes; however, as in the case for other DSTP systems, these subsurface plumes are expected to be very dilute (<50 mg total suspended solids (TSS)/L) and remain trapped at various depths below the surface mixed layer where they will be advected horizontally by prevailing currents and will not rise to the surface.

The process of density flow and plume formation is consistent with the model of McCave (1972), by which large quantities of fine sediment are transported from their terrigenous origins to beyond continental shelves (Figure 22).

Deposition

Figure 23 shows the area in which the principal deposition of tailing is expected to occur. The area is generally defined by a 1-km margin around the tailing density flow. The footprint of the density flow has been defined by the 10 parts per million (ppm) contour, that is, by the points at which the moving and gradually spreading density current has eventually decreased in suspended sediment concentration to 10 ppm[1], by processes of deposition and dilution. In general, it is expected that settling within the den-

[1] Suspended solids in ocean water typically average 5 ppm. A concentration of 10 ppm in a glass beaker would appear clear to the eye.

sity flow footprint (where the faster, turbulent density currents prevail) will be minor, with major settling occurring in the much slower, laminar, deep-ocean currents at the perimeter of the density flow. In simple terms, the configuration of settling could resemble a halo, in the manner observed at other DSTP operations, mimicking the formation of levees along floodplain rivers and in natural deep-sea turbidite (density) current fans (see Figure 22).

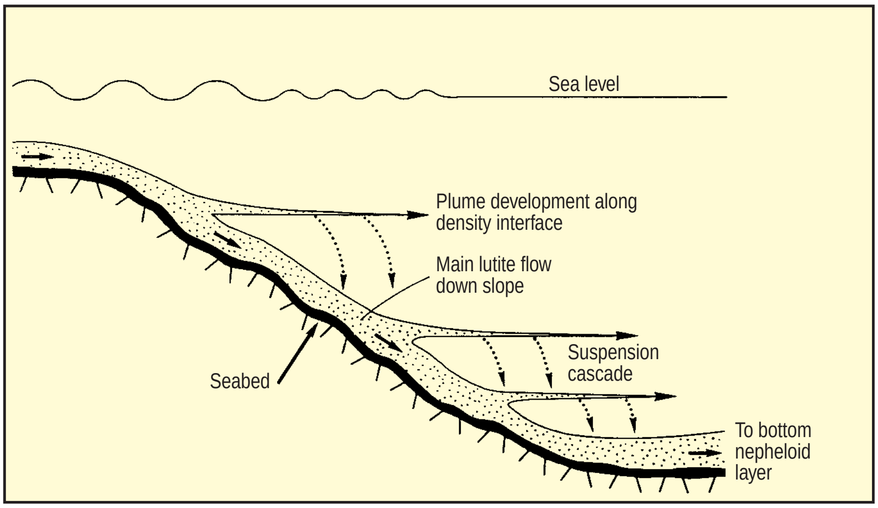
The linear pattern at the start of the density flow reflects the strong confining effect of the Basamuk canyon down to around 800 m depth. Substantial settling is expected to occur between 1,000 m and 1,600 m water depth. Tailing deposits are expected to range from a few cm to tens of metres thickness. By way of context, a 100-km-long seismic profile across the Vitiaz Basin has indicated natural sediment deposits of up to 2 km in thickness (Milliman 1995).

The area of main deposition has been estimated to be of the order of 150 km^2. This is some 1.5 % of the approximately 10,000 km^2 area of the Vitiaz Basin, defined as the area from Teliata Point to Long Island and extending westwards in an arc through smaller islands to Cape Juno north of Madang (see Figure 24).

Figure 23 also shows the inputs of sediment from rivers on either side of the DSTP system. An annual total of 12 Mt has been estimated. This material will comprise:

- The bedload and heavier suspended sediments, which will flow in their own density currents to join, dilute and settle with the tailing flow.
- The lighter suspended sediments, which will float in spreading freshwater plumes from the river mouths, and settle to the ocean floor over a wider expanse of the Vitiaz Basin.

Water Column Effects
Chemistry: all filterable (<0.45 µm) metal concentrations in the tailing are lower than World Bank guidelines (World Bank 1995) applicable to liquid effluents from open pit mining and milling (such as discharge of overflow water from a tailing dam). While the guidelines are not directly applicable to DSTP, they provide a useful point of reference. Filterable concentrations of arsenic, cadmium, copper, iron, mercury, lead and zinc in the proposed tailing slurry are all low, being less than the current PNG standards for marine waters *(Water Resources Act 1992)* and also less than the proposed PNG objectives (as of May 1998) for the protection of marine ecosystems (PNG 1998). All other filterable metal concentrations (nickel, chromium and cobalt) are less than 0.5 mg/L, except manganese which is 29 mg/L.



Source: After McCave (1972).

Figure 22 Schematic of density flows and plumes

Bioassay: chronic and acute sub-lethal toxicity tests on organisms representing three trophic levels were undertaken on the tailing liquor by CSIRO's Centre of Advanced Analytical Chemistry. The results showed the tailing liquor to be non-toxic to even the most sensitive species tested after only 100 dilutions in seawater.

Mixing: mixing tests elucidate the non-conservative physico-chemical processes which occur when a tailing slurry is mixed with seawater, such as hydrolysis, precipitation/dissolution, and adsorption/desorption. Analytical results indicated that some metals in the tailing will be mobilised from the solid phase on mixing with seawater. However, concentrations of filterable metals as a proportion of total metals were still low, generally 5% or less of the total concentration of each metal.

Mixing Zone Requirement: the PNG *Water Resources Act 1982* allows a mixing zone between the discharge point and a boundary where ambient water quality standards must be met. Within the mixing zone, these standards may be exceeded.

Table 10 shows the total dilutions of tailing in seawater required to comply with various water quality standards/guidelines, based on the results of the mixing tests.

Compliance with existing PNG regulatory requirements for all metals is pre-

Table 10 Dilutions of tailing required to comply with ambient water quality standards/guidelines

Parameter	PNG Schedule 4 (1982)	Proposed PNG Objectives	ANZECC (1992)	USEPA
Nickel	0	340	340	460
Cobalt	720	460	-	-
Manganese	<50	550	-	-
Ammonia	-	-	-	865

Note: toxicity testwork showed the tailing to be non-toxic to the most sensitive species tested after 100 dilutions of the tailing liquor (equivalent to 40 dilutions downstream of the mixtank).

dicted to be achieved with 720 dilutions of the tailing. This is based on compliance with the standard for cobalt, which is specified as the 'limit of detection' and therefore depends on the analytical method used. The method detection limit for analytical results reported in the EP, and therefore the PNG standard, was 0.5 µg/L, but this is arbitrary and of no toxicological significance. Compliance with the proposed PNG objectives (PNG 1998) for all metals would be achieved with 550 dilutions of the tailing slurry, based on compliance with the proposed objective for manganese.

When compared to international water quality criteria, all filterable metal concentrations are predicted to comply with Australian guidelines (ANZECC 1992) and United States criteria (USEPA 1986 and 1995) with 460 dilutions of the tailing slurry, apart from ammonia (USEPA 1989), for which 865 dilutions would be required.

The toxicity testwork showed the tailing liquor to be non-toxic after 100 dilutions, based on the no-effect concentration (NOEC) for the most sensitive test species. (This translates to a dilution of some 40-fold after allowance for pre-discharge dilution of 1:1.5 tailing slurry:seawater by volume in the mixtank.)

Numerical modelling was undertaken to provide a guide to the distances required to attain the various water quality objectives. Assuming a conservative set requirement of 1,000 dilutions, this would translate into a mixing zone with a radius of 1 km from the mixtank, (and, say, >100 m below the surface). Ambient water quality standards may possibly be exceeded in the tailing density current and bottom-attached lutite flow outside this zone; however the physical impacts of continuous tailing discharge will eclipse any effects due to deteriorated water quality. In other words, any water chemistry effects are secondary to physical impacts, and this limits the usefulness of applying a mixing zone based on water quality criteria to the density current and lutite flow. (Furthermore, the toxicity testwork showed the tailing to be non-toxic after some 40-fold dilutions (see prior discussion), and this will

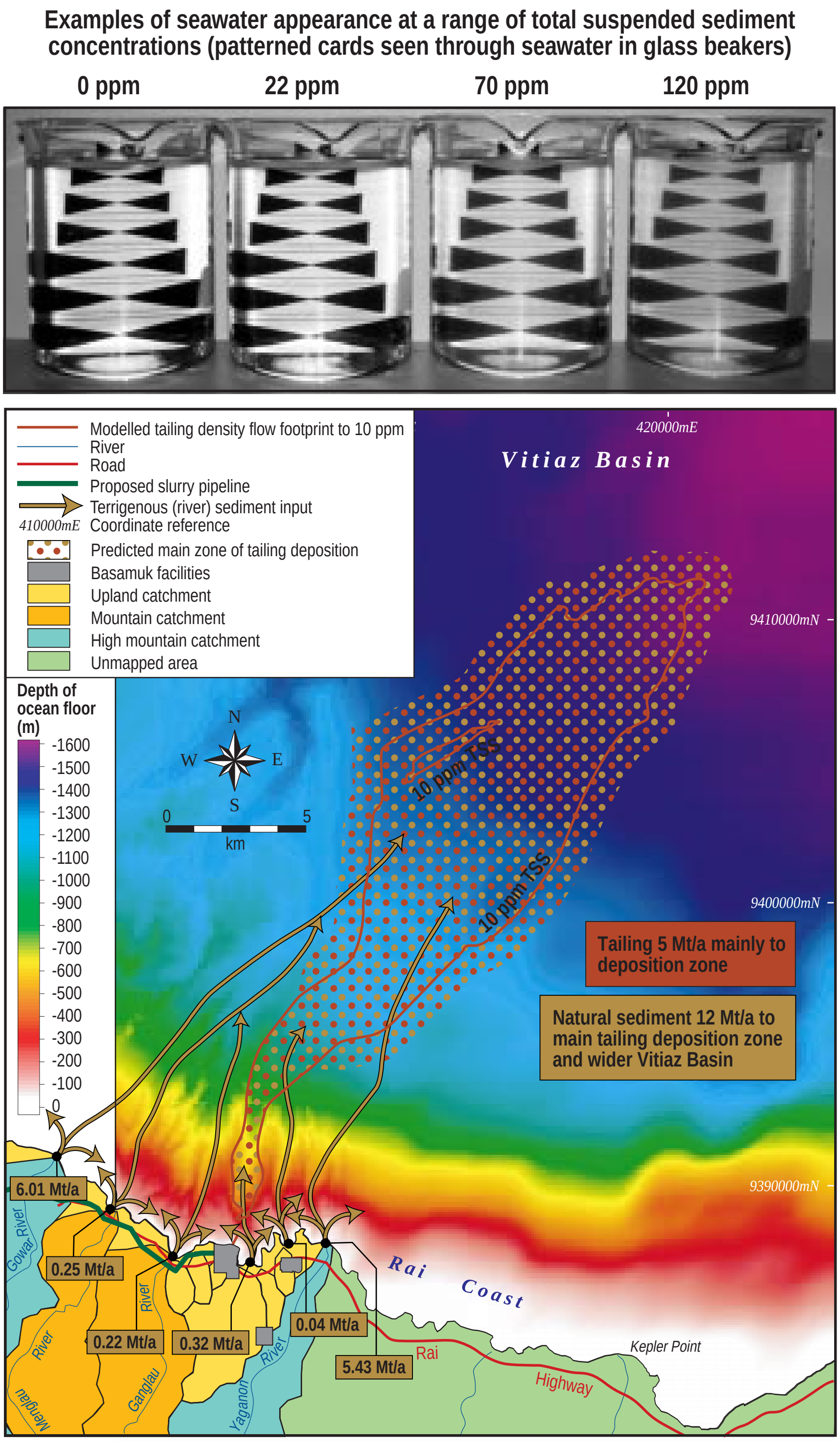


Figure 23 Predicted main tailing deposit footprint

occur within a short distance of the outfall terminus and well inside the suggested mixing zone).

Benthic Effects

Shoreline dumping of incompetent rock and soil generated by refinery site construction activities will result in this material ultimately reporting to the deep-water marine environment. Concentrations of metals in soil from the area to be excavated are similar to, or less than, concentrations in ocean floor sediment samples taken offshore of Basamuk and literature values for mean crustal abundances and deep-sea clay.

The principal benthic impacts arise from the passage of the density current and tailing solids settling on the seabed.

Plate 11 Finisterre Range behind Basamuk Bay

Smothering of the Benthic Habitat on the Ocean Floor: the main physical impact of DSTP will be the physical smothering of benthic habitats within Basamuk canyon and on the deep ocean floor of the Vitiaz Basin.

The predicted zone of major deposition has been given in Figure 23. The peripheral area of much more diffuse sedimentation, expected to be of the order of tens of millimetres, will contribute to the already high regional sediment flux into the Vitiaz Basin. This is a consequence of the numerous, short, steep, sediment-laden rivers draining the steep and very unstable terrain of the Finisterre Range (Plate 11).

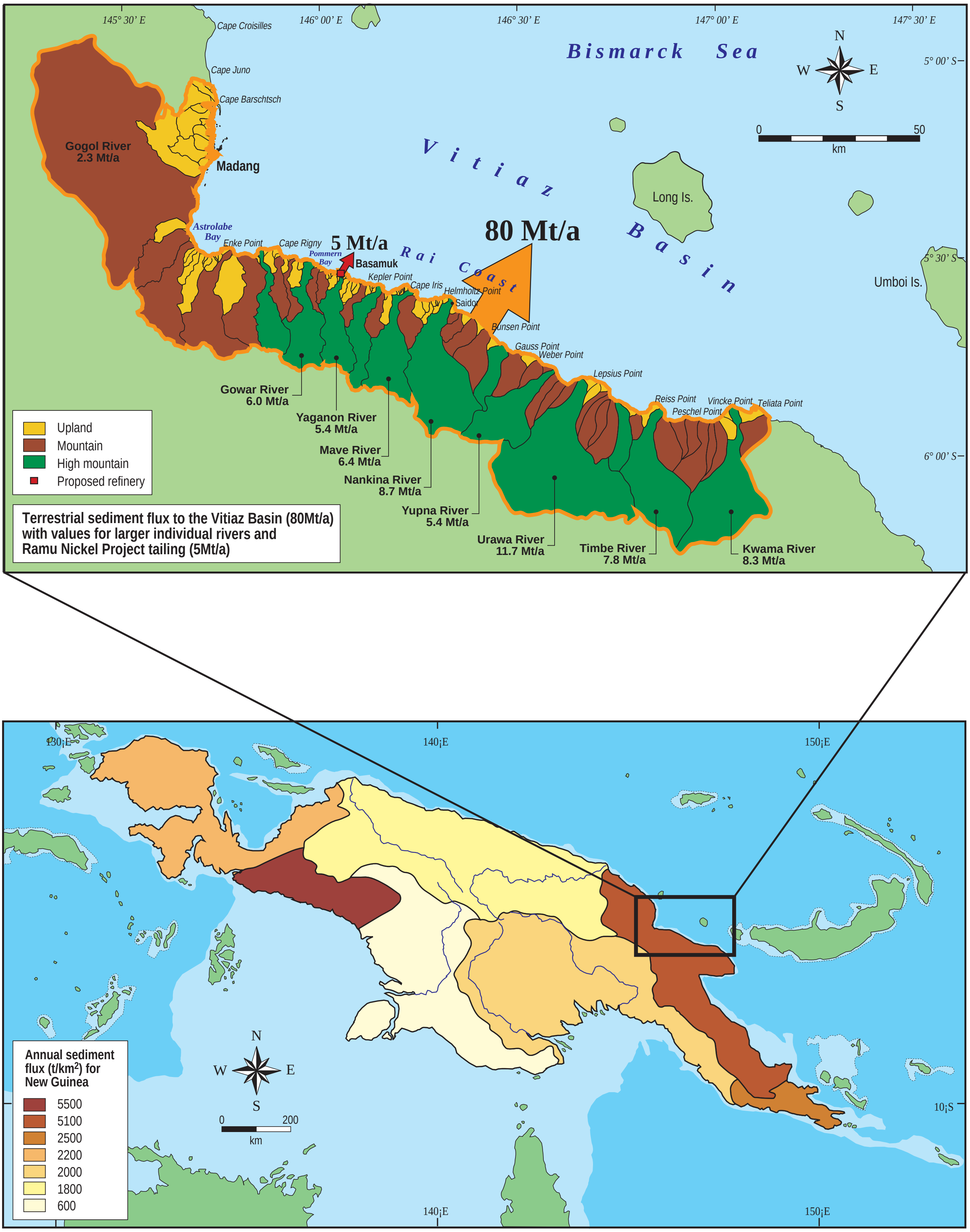
In areas of heavy sedimentation, sedentary and less mobile bottom-dwelling fauna will be smothered: the tailing deposits are also expected to be devoid of bottom-dwelling fauna. A less diverse bottom-dwelling invertebrate fauna is expected to persist in the more lightly sedimented areas.

Figure 24 puts the Rai Coast into perspective. The lower illustration shows that it is part of the second-highest sediment-yielding basin of the island of New Guinea. (New Guinea yields 1,700 Mt/a of sediment to the coastal ocean, which is more than the Amazon Basin.) A typical sediment-laden plume from the Gogol River spreading out across the ocean surface in the Vitiaz Basin is shown in Plate 12.

The upper illustration in Figure 24 shows the annual sediment flux to the Vitiaz Basin, indicating the individual contributions of the larger rivers. In the regional context of the Vitiaz Basin, the Ramu tailing will add approximately 6% to this annual load.

Case studies of overseas DSTP systems, after closure, report rapid rates of recolonisation: Island Copper Mine (Ellis 1989) and Kitsault Molybdenum Mine (NSR 1997b). In each of these Canadian examples, a diverse benthic community became established within 1 to 2 years of DSTP closure. Provided the tailing is not toxic (see as follows), then a similar recovery is expected on the ocean floor offshore of Basamuk.

Plate 12 Sediment-laden plume of the Gogol River



Source: Milliman (1995).

Fi 23 S di fl N G i d Vi i B i

Figure 24 Sediment flux, New Guinea and Vitiaz Basin

Sediment Toxicity: testwork results show that metal content of the tailing will remain almost entirely associated with the particulate matter settling on the ocean floor. This will mostly occur at depths, where anoxic conditions (devoid of oxygen) in the sediments will promote the formation of stable metal sulfide species (e.g. nickel sulfide, cadmium sulfide) and co-precipitation with common iron sulfide minerals. In the long term, the continued settling of natural sediment after closure will dilute, and eventually bury, the tailing deposits.

The possibility of adverse toxicological effects of deposited tailing solids on benthic biota was assessed by a four-tiered chemical and toxicological testwork program.

The first tier of assessment compared metal concentrations in tailing solids with reference values, such as world average values for deep-sea clay and crustal abundances. The second level of assessment compared metal concentrations with sediment quality criteria. Subsequent levels of assessment more closely considered the bioavailable fraction of the potential contaminants. Toxicity testing of the interstitial water by CSIRO provided the final tier of assessment.

The results showed that nickel was the primary possible toxicant: it was enriched in tailing (0.7 mg Ni/g dry weight) relative to reference values and sediment quality criteria, and it was present in tailing interstitial water at concentrations greater than relevant water quality criteria for the overlying water column. However, the bioassays on marine reference species (selected for their known sensitivity to nickel) indicated that the settled tailing was non-toxic.

It follows, therefore, that water transferring from the seabed sediments into the water column would also be non-toxic.

Some confidence attaches to this finding, as the Ramu tailing will be diluted nearly 3-fold by the estimated annual 12-Mt sediment loads of the Gowar, Menglau, Ganglau and Yaganon (Plate 13) rivers, which enter the ocean in a 10-km section of the coast either side of Basamuk. The submarine canyons of these rivers (Figure 25) all converge in the zone of predicted major tailing deposition.

Effect on Fishes and Fisheries

Laboratory toxicity testing, as already reported, has shown negligible residual toxicity of the tailing at the dilutions expected within the deep-sea environment. Therefore, no material effects are expected to fishes encountering the dilute subsurface plumes in the water column.

Investigations confirmed the expected occurrence of an unexploited, deep-slope fishery resource along the Rai Coast, involving predominantly two species: the goldband snapper (*Pristopomoides multidens*) in the depth range 100 to 200 m and the ruby snapper (*Etelis carbunculus*) in the depth range 200 to 400 m.

Plate 13 Mouth of the Yaganon River

The preferred depth range of the goldband snapper (Plate 14) is mostly upslope of the proposed DSTP outfall and initial tailing deposition zone and, as such, is expected to be little affected. In contrast, the depth range of the ruby snapper (200 to 400 m) is downslope of the proposed outfall. This species will therefore be affected. However the habitat area expected to be smothered by tailing flows and deposition off Basamuk is small in area, in comparison to the extensive unaffected areas of submarine slope in the same depth range elsewhere along the Rai Coast and along the north coast of mainland Papua New Guinea. Therefore, the project's effect on bottom-dwelling fishes or potential deep-slope fisheries is expected to be restricted to a highly localised area of ocean floor and is not expected to be regionally significant.

In the long-term, these effects are considered to be reversible: the deposited tailing is expected to be both recolonised directly, and itself buried by natural sediment which will continue to flow into Basamuk canyon in perpetuity. Ultimately, a diverse assemblage of benthic species are expected to become established.

Regulatory Requirements
DSTP discharges are regulated in Papua New Guinea under the *Water Resources Act 1982*, which provides for a non-conforming mixing zone to be set by the Water Resources Board, at whose boundary the ambient water quality criteria must be met.

At the operational mines of Misima and Lihir, the mixing zone for DSTP is an imaginary cylinder jutting out of the submarine slope. The radius of the cylinder is the distance required for ambient water quality criteria to be met.

The results of numerical modelling for the Ramu Nickel Project indicate that 1,000 dilutions would be attained within a distance of 1 km (and, say, greater than 100 m below the water surface of the outfall). If the Misima and Lihir models are followed, then a mixing zone radius of 1 km would provide a conservative basis for regulation of the project's proposed DSTP system.

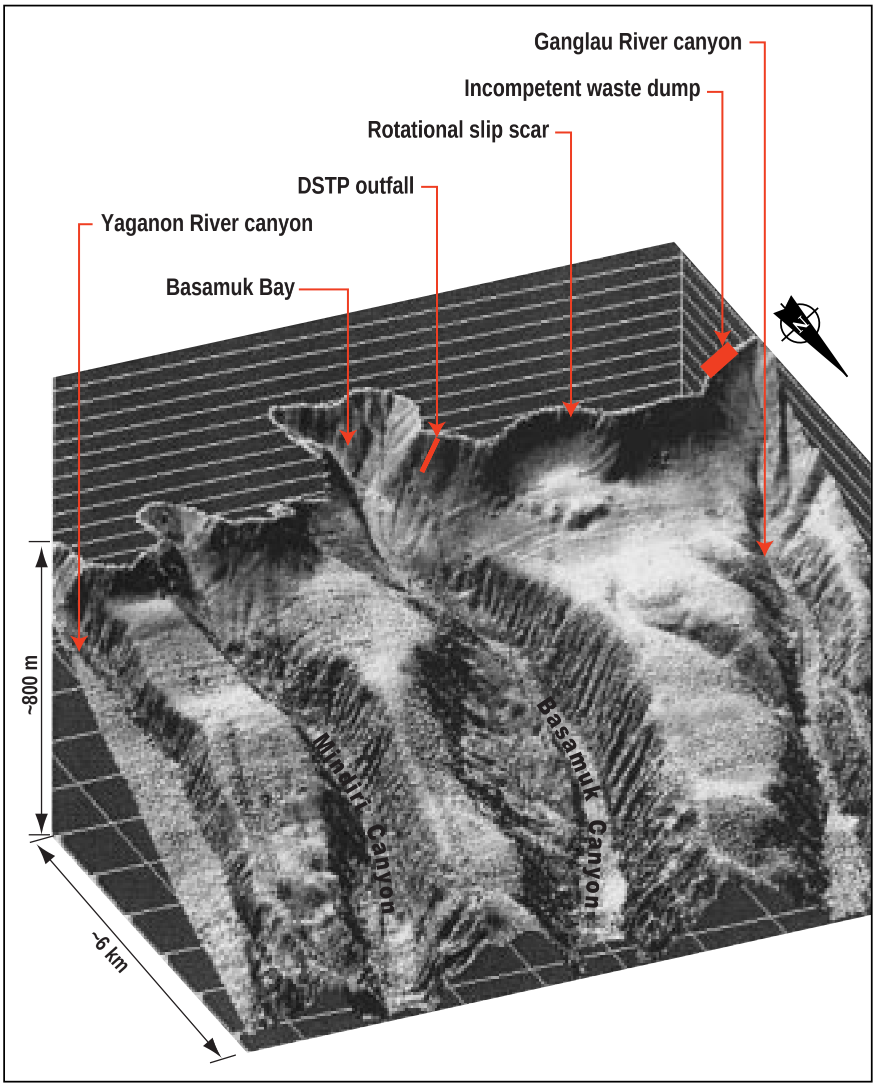


Figure 25 Three-dimensional image of submarine canyons off Basamuk

Assuming this distance horizontally on the seafloor, the diffuse lutite flow would have reached a depth of approximately 350 to 400 m.

Summary
The proposed refinery site at Basamuk is located on the edge of one of the world's most active sedimentary environments, with massive sediment yields in rivers draining north to the Rai Coast from the very steep and unstable Finisterre Range.

In these and other respects, the DSTP system proposed for the Ramu Project is greatly advantaged by both favourable site conditions and the characteristics of the tailing itself:

- The tailing flow is fundamentally non-toxic: after dilution in the mixtank, the liquor requires only 40 additional dilutions to achieve the empirically determined threshold of chronic effect. This is expected to occur within a short distance of the outfall terminus.
- The interstitial (pore) water that will form in the tailing deposits on the ocean floor is also fundamentally non-toxic.
- Vertical movement in the water column in limited by the natural stratification of the ocean and the absence of upwelling except in the shallowest 100 m; lateral movement is limited by the confining effect of the Basamuk canyon.

- Substantial natural dilution and eventual burial by river sediment will occur both around Basamuk and regionally in the Vitiaz Basin.
- The DSTP impacts will be overwhelmingly physical, not chemical. After decommissioning, the operational environmental effects on the marine environment are expected to be substantially or entirely reversible.

Section 2.4 sets out the RNJV environmental objectives for the Ramu Nickel Project:

- To plan, operate and decommission the project in accordance with good industry practice and in compliance with the conditions and standards prescribed by the PNG Government.
- To site and operate the components of the project so as to minimise the effects on local villagers, their resources and the environment.

It is considered that the preferred DSTP option for tailing management achieves these objectives. Moreover, of all the DSTP feasibility and impact factors assessed by this EP, the factors most important to achieving an environmentally satisfactory outcome are also the factors least prone to uncertainty:

- The low toxicity of tailing has been established by comprehensive testwork.
- The ability to confine tailing below the surface mixed layer is well-proven at operating mines.
- Existing fisheries will be entirely unaffected, and the effect on known but undeveloped fisheries in deeper water is expected to be very small.

Furthermore, confidence also seems warranted in the long-term outlook for substantial reversibility of the effects of tailing deposition after closure: the Vitiaz Basin is one of the most heavily sedimented marine environments in the world. Within a decade or less, it would be expected that all sediment of Ramu Nickel Project origin will have been buried by natural input to the basin.

Plate 14 Dissected goldband snapper

6.3.5 *Air Quality Impacts*

Effects on Human Health

Gaseous emissions from fixed and mobile equipment at Kurumbukari and fugitive dust from all project areas are not expected to pose a significant risk to human health. At Basamuk, air dispersion modelling shows that annual average air quality goals are close to being met at nearby villages, while worst-case ground-level concentrations exceed the assumed 1-hour maximum air quality goals at the villages of Kuripung, Babang, Dumbal and Ugat for SO_2 and the villages of Kuripung and Babang for NO_2 (assuming that 10% of NO_x at the receiving location is present as NO_2). In both cases, exceedence reflects an unusual combination of meteorological conditions occurring for less than 1% of the time. SO_2 is the significant contaminant in terms of human health protection, and Figure 17 shows the percentage of time that the assumed 1-hour maximum goal is exceeded for the areas and villages around the Basamuk refinery.

Effects on Vegetation

No effects on vegetation are predicted from gaseous emissions from fixed and mobile equipment at Kurumbukari or from fugitive dust in any project area. At Basamuk, modelling predicts that vegetation on the hills to the south of the refinery will be exposed to elevated levels of SO_2, albeit for very short periods of time. The reaction of plants to SO_2 is complex and it is difficult to predict actual impacts on vegetation with any certainty. However, adverse impacts on vegetation are quite possible. Therefore, as part of the development of an acceptable air emissions management strategy and monitoring program for the project, RNJV will work with DEC on the formulation of an acceptable vegetation monitoring program and response strategy in areas where elevated concentrations are predicted to occur.

Development of an Acceptable Air Emissions Management Strategy

Section 6.2.4 sets out the RNJV commitment to repeating the air dispersion modelling based on site meteorological data from Basamuk, to reviewing predicted air quality impacts, to negotiating air quality criteria with the Department of Environment and Conservation (DEC), and to reaching agreement with DEC on an acceptable air emissions management strategy and monitoring program for the project. The protection of human health will be central to the negotiations on air quality standards.

The findings of this EP are therefore subject to updating in light of these further studies and negotiations. However, initial modelling has indicated that a satisfactory solution to the air quality management issues is within reach.

6.4 Accidental Events and Natural Hazards

6.4.1 General

Accidental and natural events that could lead to environmentally hazardous discharges are fundamentally different from the normal operational discharges of wastes and wastewaters described previously. The probability of accidental events is low, given that the design, operating and control measures adopted by RNJV will have the specific aim of their prevention. Similarly, natural occurrences of sufficient magnitude to cause significant damage have a very low probability of occurrence. Nevertheless, events of this nature cannot be precluded. In such cases, the resources of RNJV will be mobilised in accordance with emergency plans.

6.4.2 Earthquakes

The PNG region is one of the most seismically active zones in the world, regularly experiencing earthquakes of magnitude 7.0 or more on the Richter scale.

The adopted seismicity and tsunami design criteria are given in Table 11.

6.4.3 Tsunamis

Tsunamis are waves caused by undersea earthquakes and/or undersea landslides, the larger of which will inundate low-lying coastal land. In 1970, a magnitude 7 earthquake generated a 3-m-high tsunami along the coastline north of Madang.

The Standards Council of Papua New Guinea recommends that buildings be constructed 2 m to 3 m above the highest tide level (PNGS 1982).

On 17 July 1998, a series of tsunamis hit the north coast of Papua New Guinea near the settlement of Aitape in West Sepik Province. Wave heights of approximately 8 m were estimated. While the return period of such an event is unknown, a tsunami of this magnitude is likely to be a very low probability event, against which it is difficult or impossible to defend most coastal areas.

For the Ramu Nickel Project, all important facilities and all accommodation areas and localities requiring personnel attendance on a frequent basis will be sited at elevations 3.5 m above the highest tide level (see Table 11). Process reagents, chemicals and fuel storage areas will also be similarly sited.

6.4.4 Fuel and Reagent Spills

The primary protection against fuel and reagent spillage is to bund the areas in which these materials are handled, to keep good inventory records, to make routine inspections and to train operators in correct procedures. Nonetheless, accidents can occur.

Prior to plant commissioning at the refinery, RNJV will prepare a spill contingency plan.

6.4.5 Ore Slurry Pipeline Failure

Rupture of the pipeline would create an initial release of slurry under high pressure. The resulting pressure drop in the pipeline would be sensed by the control system and the pumps would be halted.

Since the rupture would almost certainly not be located at a high point in the pipeline, slurry would continue to flow under hydrostatic pressure from the line above the rupture point.

Table 11 Project-adopted seismic and tsunami design criteria

Relevant Criteria for Design	Reference
PNG seismic zone—Ramu and Huon	Ripper and Letz, 1993
PNG design earthquake zone—Zone 2	PNGS Code, 1982
100-year return period event—Magnitude 7.1*	Ripper and Letz, 1993
475-year return period event—Magnitude 7.7*	Ripper and Letz, 1993
Maximum credible earthquake—Magnitude 7.8	Ripper and Letz, 1993
Peak ground acceleration: soil—0.42 g	Beca Gure, 1985
Peak ground acceleration: rock—0.35 g	Beca Gure, 1985
Tsunami design (above high tide)—3.5 m	Fluor Daniel, 1998

*Surface wave magnitude, normalised to 100 km^2 zone as per Ripper and Letz (1993).

The pipeline rupture locations with the highest spill volume potential will be the centre of the Ramu valley and across the foothills of the Finisterre Range. The maximum volume of slurry that could be discharged would be about 4,800 m^3, equivalent to some 2,000 t of solids. Depending on the location of the break, the total volume could enter the local drainage.

However, the impact from such an event would be non-toxic and temporary, given the generally high sediment load in the rivers along the alignment and the fact that the contents of the pipeline will be an ore slurry of weathered soil.

If a spill occurs, it will be attended by an RNJV control and clean-up team. Environmental monitoring will be carried out to determine the extent of damage and the effectiveness of clean-up.

6.4.6 DSTP Pipeline Failure

If a failure in the DSTP pipeline were detected, then the refinery would be shut down until the problem had been rectified. The main failure possibilities of the DSTP pipeline system and the corresponding safeguards are as follows:

- The pipeline floats to the surface due to entrained air in the tailing slurry. For such an event to occur, the deaeration mixtank would have to first experience an abnormal increase in drawdown, which would be detected at the refinery control room, prompting an investigation of the system and instigation of corrective response.
- The check valve in the mixtank fails, causing the outfall/seawater intake system to operate in reverse. Failure of the check valve will be detected in such an event.
- The outfall pipe develops a leak. This would cause an abnormally low mixtank fluid level, which would alert the refinery control room. Minor leakages at depth are more difficult to detect than those in shallower areas and the line can be inspected periodically by remotely operated vehicle.
- The outfall pipe becomes blocked. Even partial blockage of the pipeline will result in unusually high levels in

the mixtank fluid, causing operators to investigate and instigate corrective action.

- A ship's anchor damages the pipe. The location of the outfall and seawater intake pipelines will be shown on navigational charts and warnings to mariners will be issued. An area surrounding the pipelines will be designated 'no anchorage'. Moreover, any ship trying to anchor over the pipelines would be in full view of the refinery, and could be warned off.

7. Social and Economic Development

The considerable benefit streams generated by the project will act as major stimuli for development in the project areas and Madang Province. The benefit streams have the potential both to improve social and economic welfare, particularly in the areas of education, health, employment and business development, but also have the potential to generate negative impacts if they are not effectively managed.

The socio-economic impacts of the proposed mining project have been investigated in the Socio-economic Impact Study (SEIS) conducted by Project Design and Management Pty Ltd.

7.1 Benefit Streams

Table 12 presents a summary of the main benefit streams. The exact scope and scale of some streams will depend on negotiations between the parties, and on future events, such as production volumes and the price of nickel and cobalt on world markets.

Table 12 Types of benefit streams and relevant stakeholder group

Government	Landowners	Local Business	RNJV
Royalties Dividends from equity Special Support Grant Infrastructure (mining) grant Tax credit scheme	Royalties Dividends from equity Compensation and land use payments	Mine-related contracts Other spin-off businesses	Employment and training Education sponsorship Special community grants Technical assistance Tax credit scheme

7.1.1 Royalties

Royalties are currently paid at 2% of the free-on-board (f.o.b.) value of mine products exported from Papua New Guinea, or of the net smelter return from products smelted or refined in Papua New Guinea. Under the Mining Act, 80% of the royalties are distributed to the Provincial Government and 20% to the landowners in the SML, although this is subject to negotiation. The owners of the limestone quarry will also receive royalties. The values for metals production and price adopted by the Ramu Nickel Project Feasibility Study indicate payments of about K5.9 million annually to the Provincial Government and K1.5 million to the landowners.

7.1.2 Compensation

Landowners are entitled to compensation for the use of their land and the loss of resources. RNJV is currently negotiating a formal agreement. Payments might be between K1.5 and 3 million over the first 3 years of project life, and at a lower level thereafter.

7.1.3 Special Support Grant

Special Support Grants (SSGs) are paid by the National Government to provincial governments which host mining and petroleum projects. The grant system is based on 1% of the f.o.b. value of production and could amount to approximately K3.7 million/a.

7.1.4 Infrastructure

Infrastructure grants by the National Government to provinces are not fixed to production. Their value would be a matter for negotiation between the National and provincial governments and local level governments (LLGs) involved in the project.

7.1.5 Dividends

Dividends depend on profit; dividend income to Madang Province or LLGs or landowners will require them to take up share equity in the project.

7.1.6 Tax Credits

The tax credit scheme allows companies to spend up to 2% of gross turnover annually on public infrastructure projects within or near the project area. Once each project is completed, the company receives a tax credit equal to the amount spent. This could represent K64 million over the life of the project.

7.1.7 Benefit Summary

Table 1 (see Chapter 1) has summarised the projected benefit streams to landowners and provincial government for compensation, royalties, SSG and tax credits.

7.2 Sector Impacts

7.2.1 Provincial and Local Governments

Properly managed, the additional revenues to Madang Province will stimulate the development and growth of LLGs in both the project area and throughout the province.

RNJV is aware of the difficulties facing provincial government initiatives in the past, and intends to contribute time as well as money towards improvements in this area. Emphasis will be given to the provision of infrastructure works and services in the project districts and LLG areas, and on the transfer of responsibilities for projects and services from RNJV to the designated agencies.

7.2.2 Social Services

Education

The project will increase demand for educational services. It will also offer a means for meeting this demand, and for remedying existing deficiencies.

The SEIS has identified a number of potential education projects, to which RNJV might contribute. These include new schools in Kurumbukari and Daunagari, support for existing community schools servicing the SML, pipeline and Basamuk communities, support for the Rai Coast High School, a new high school to service the Kurumbukari/ Usino–Walium area and curriculum and facilities enhancements.

Health
As with education, the project will add to the demand for health services. It will also provide the means for meeting new demand and for remedying existing deficiencies, both directly in the form of new facilities, and indirectly, by means of improved diet, sanitation, communications and access.

If no upgrading is carried out, existing facilities will be overloaded by project-induced demand. These facilities include the Daunagari Aid Post, the Walium Health Centre on the highway between Lae and Madang, the aid posts at Usino and Ganglau and the clinic at the Rai Coast High School. The SEIS recommends support for a number of health facilities.

Social health problems of alcoholism and sexually transmitted diseases tend to accompany improvements in material wealth in Papua New Guinea, and are to be expected. However, the evidence of existing large mines in Papua New Guinea is that overall, projects like Ramu can make an enormous positive contribution to community health.

7.2.3 Primary Resources

Subsistence Land
The land requirement for the proposed Ramu Nickel Project is estimated to be 1,585 ha (Table 13).

At Kurumbukari, the mining of approximately 1 ha of land per week may be offset to some extent by the opportunity to revegetate mined areas with commercial plants such as coffee, cocoa, vegetables, trees, and possibly pasture for smallholder cattle.

At Basamuk, roughly 150 ha of land will taken by the refinery complex, accommodation area and quarry.

In all cases, compensation will be paid.

In addition, the project will provide a market for produce, and cash from royalties and compensation will enable capital investment in agricultural production. On the negative side, paid jobs and the purchasing power of cash replace—and hence must to some extent weaken—the subsistence economy. In particular, men become unavailable for their previous tasks, the burden for which falls mostly on the women.

In-migration to project areas is expected to take place in pursuit of employment, business opportunities and inter-marriage. To the extent that these objectives are not met, in-migrants will strain the physical infrastructure and economic base of the project areas, unless they return to their place of origin.

RNJV intends to mitigate these effects to some extent, for example by employment preference for local people (see Section 7.2.4 to follow).

Table 13 Project land requirements

Component	Area	Ha
Kurumbukari mine site	Proposed mine pits and haul roads over 20 years	1,000
	Beneficiation plant site	12
	Mine camp	8
	Mine/camp service/access road	2
Mine access road	Kurumbukari mine camp to Ramu bridge[1]	37
Slurry pipeline	Kurumbukari mine site to Ramu bridge	14
	Ato Junction to refinery	169
Combined road/pipeline	Ramu bridge to Usino Junction	51
	Usino Junction to Ato (existing highway)	132
Basamuk refinery	Refinery/port areas	79
	Accommodation area	48
	Limestone quarry	25
	Refinery/camp access road	4
	Limestone quarry access road	4
Total area		**1,585**

[1] Ramu bridge is the meeting point of the access road and the slurry pipeline, just before the Ramu River.

Forestry
Timber felled from the mainly forested land of the Kurumbukari Plateau will be available for salvage, either via a sawmill for local use or to supply round logs for export or pulping. There will also be opportunities for replanting the mined areas with commercially useful tree species.

Fisheries
The project will increase the demand for fresh fish. It will also generate capital for investment in new boats and gear and improve market access.

7.2.4 Employment

The project will be the largest employer in the province during the construction phase, and the second largest (after Ramu Sugar) during operations.

Construction
The construction workforce will peak at approximately 2,500 (Figure 26).

RNJV and its contractors will employ as many local people as possible during construction, but are constrained by the demands of this phase for short-term skilled labour. Many of the construction jobs will therefore be filled by people from elsewhere in Papua New Guinea and expatriates on a fly-in, fly-out roster.

Operations
The project will provide permanent employment for some 1,045 workers (Table 14). The workforce will be structured to satisfy the operating requirements of the project. Employment will also be available through contractors in fields such as catering, janitorial services, security, transport and road and camp maintenance.

Recruitment preference will be given to local people from project impact areas, followed in order by persons from within Madang Province, PNG citizens from other provinces and non-citizens.

It is planned to reduce the proportion of expatriate workers from about 20% to about 12% over the life of the project. Some employment classifications, generally of an unskilled or semi-skilled na-

Table 14 Composition of operations workforce

Area	Expatriate Staff	Senior National Staff	National Staff	National Tradesmen	National Award Skilled	Local Award Unskilled	Total
Mine							
Mine operations	7	17	3	0	120	12	159
Beneficiation plant	8	9	6	0	20	20	63
Plant maintenance	14	4	2	29	20	4	73
Mine admin. support	2	11	24	0	2	0	39
Total mine	31	41	35	29	162	36	334
Refinery							
Operations	80	14	32	0	85	88	299
Engineering	50	4	8	43	63	8	176
Administration	30	14	21	8	45	4	122
Operations support							
Human resources	6	6	12	0	0	0	24
Environment	3	2	10	0	0	2	17
Marketing	4	0	1	0	6	0	11
Community affairs	8	26	24	0	0	4	62
Total refinery	181	66	108	51	199	106	711
Overall total	212	107	143	80	361	142	1,045

ture, will be reserved exclusively for PNG nationals.

The mining and refining operations will operate continuously, 24 h/d, 365 d/a.

Training and Localisation
A Training and Localisation Plan has been prepared for submission to the Department of Labour for approval before project implementation. The plan identifies all positions to be filled for project operation and nominates positions expected to be filled by expatriates and nationals. The plan will outline training and development programs to progressively localise, wherever possible, the expatriate positions.

Training initiatives during project operations will include secondary school sponsorships, graduate sponsorships, trades apprenticeships, administrative and secretarial training and on-the-job operator, safety and environmental training. In order to maximise local participation in the construction workforce, a training program will be conducted during pre-construction and construction. This program will teach local people safety and the fundamentals of hand tool use.

Trained personnel will be introduced to the construction workforce through contractors. Carpentry, metalwork and computing courses will be available and temporary classrooms and a training workshop will be built.

Business Development
RNJV will support the establishment of new businesses, and assist existing enterprises in the Madang Province, in order for them to participate in the opportunities generated by the project, where:

- The business contributes to the commercial implementation of the project.
- The business will be able to deliver goods and/or services on a competitive basis, including rates and delivery.

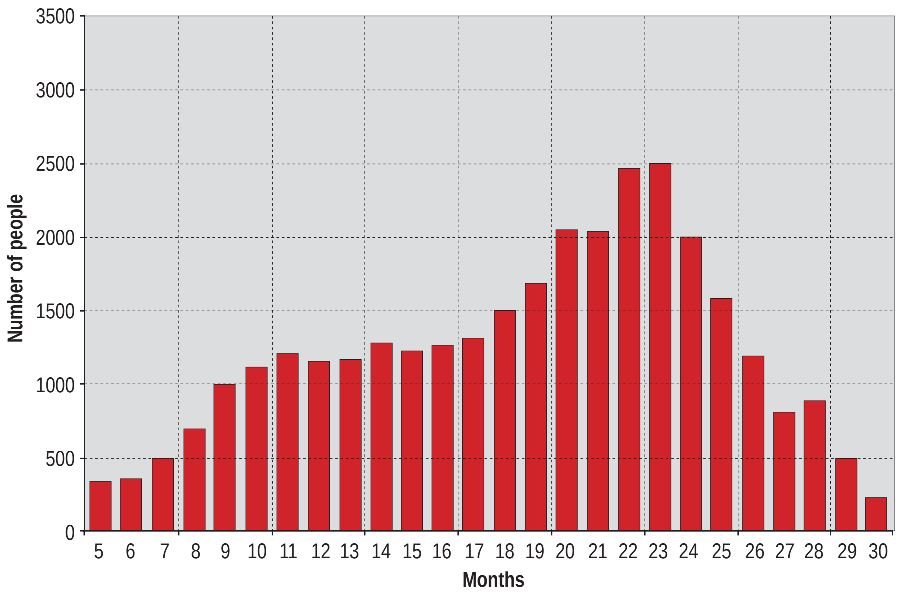


Figure 26 Construction workforce profile

- The business will be sustainable without subsidy and may span the construction phase, the operational phase or both.
- A business seeking assistance from RNJV must be motivated by, and operate under, accepted commercial principles.

RNJV may offer support or assistance to a local business enterprise but it will not offer to subsidise the operations of any business venture.

A business development plan has been prepared (Appendix 25) which provides for the establishment of an RNJV Business Development Office, and clan-based landowner companies under an umbrella management services company. The provisional business development structure is shown in Figure 27.

The project will become the most significant business in Madang Province. It will generate unprecedented opportunities for existing contractors and suppliers, both through project purchasing and an annual salary and wage bill, which is estimated to be some K17 million.

Table 15 Potential contracting opportunities for local businesses according to location

Kurumbukari	Pipeline	Basamuk
Bush clearance	Truck/bus transport	Barging and loading
Security	Bush clearing and security	Boat/bus services for workers
Catering	Road construction and maintenance	Light industrial, to service the processing plant
Janitorial	Sea transport	Security
Road construction and maintenance	Dry hire of equipment	Catering
		Janitorial
		Road construction and maintenance

Many components of the project could be sub-contracted to local companies either operating independently, or in joint venture with established PNG-based companies. Examples of contracting opportunities are summarised by location in Table 15. Other local contracting opportunities could include housing construction, vehicle and equipment maintenance and temporary earthworks.

7.2.5 Madang

Madang can expect strong growth in the retail and wholesale sector, in the residential, commercial and industrial property market, in plant, transport and associated service industries, and in the financial and commercial services market.

An expanded population will significantly increase the demands on the town's facilities and infrastructure. Madang has no reticulated sewerage, roads are poor, traffic is congested and there is

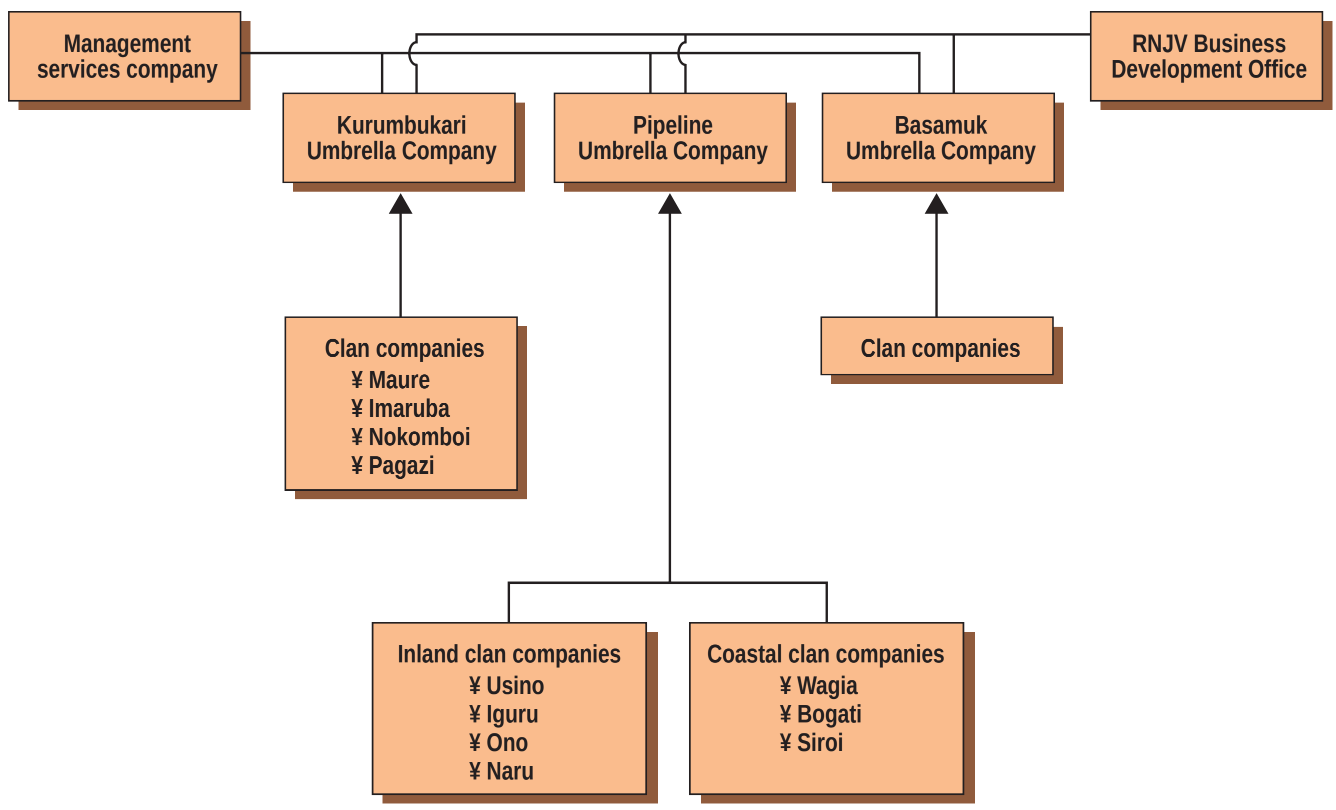


Figure 27 Provisional Ramu Nickel landowner business development structure

no reticulated water supply in many areas. Social problems of crime and prostitution are also increasing.

The increased demands induced by the project will allow the Madang Urban LLG to present a strong case to the National Government for additional financial and technical support. This case could be based on a plan to address the changing future needs of the town, and a method of financing its implementation.

7.3 Impacts on Archaeology and Material Culture

Traditional artefacts and all archaeological and cultural sites, including burial and settlement sites, are protected under PNG law.

Identified sites of cultural and archaeological significance that may be affected by the project are summarised in Table 16. Sites 2, 4, 5, 6 and 8 and possibly others will be unavoidably lost; the remainder can be protected with due care. To this end, RNJV will maintain communication with the local owners and the Trustees of the PNG National Museum and Art Gallery.

Table 16 Archaeological and cultural sites likely to be affected by the project

Site No.	Local Name	Type of Site	Significance
Kurumbukari			
1	Ikrungu	Mythical	Low
2	Kurumbukari (exploration camp)	Archaeological/settlement	Low
3	Miayi	Settlement/burial	High
4	Wianive	Archaeological	High
Basamuk			
5	Basamuk	Archaeological	High
6	Basamuk	Burial	High
7	Soup (Basamuk)	Sacred	High
8	Ganabaing (Basamuk)	Mythical/historical	Medium
9	Guang-Busunou	Archaeological/settlement	High
10	Sarang-Guau	Archaeological/burial	High
11	Ibab-Guang	Archaeological/settlement	High
12	Imod Hill	Sacred	Not known[1]

[1] Site identified by Appendix 14 and no significance rating was provided.

7.4 Implications for Local Communities

The Ramu Nickel Project will greatly improve the standard of living of local communities, particularly in the medium to long term. At Kurumbukari especially, this change will occur from a low base of high infant mortality, low Tok Pisin literacy, and poor access to health and education services.

The main potential negative social and economic impacts of the project are those associated with the development of a large-scale mining project in a remote rural area: a weakened subsistence production base, increased domestic and agricultural workloads for women, new health problems related to diet, alcohol abuse and sexually transmitted diseases, problems associated with in-migration, and an increase in economic inequalities with the attendant potential for conflict.

At the same time, the significant overall improvements in community health that have occurred at other major mines in Papua New Guinea are expected to occur as a result of the Ramu Nickel Project.

Whether or not the economic and social impacts of the project are ultimately positive or negative will depend on how the project's benefit streams are managed. Elsewhere in Papua New Guinea, this process has been problematic, and delivery has often fallen short of expectations.

These issues are being addressed by the Forum process (which is co-ordinated by DMR), to which RNJV is committed.

From the project's perspective, the management focus for social and economic development should be on the basic issues of revenue from compensation and royalty, social services, jobs, training and business development. This focus manifestly reflects the explicit priorities of villagers for material advancement and access to social services, but there are two areas in which, historically in Papua New Guinea, the satisfactory delivery of these benefits has been impeded:

- The tendency for cash benefits to be handled and spent in an inequitable, opaque and non-accountable way.
- Shortcomings in the delivery of government services, and the misperception that it is a straightforward matter for the company to fill the gap: 'kampani mas givim'.

If these recurring, historic problems can be remedied, then the project's revenues to the public sector of more than K200 million over 20 years should bring large and widespread socio-economic benefits throughout Madang Province. However, for this to occur in practice requires a framework that reflects the lessons to be learned from previous projects: in particular, local community, government and company interests and concerns need to be voiced, discussed and effectively acted upon within a set of agreed and enforced principles of equity and accountability.

8. Environmental Management and Monitoring

The proposed environmental management and monitoring program includes the following steps:

- Implementation of management commitments and compensation arrangements.
- Assembling a baseline range of variables to define the pre-mining conditions such as variability in stream water quality (Plates 15 and 16).
- Monitoring of construction effects.
- Following construction, performing an intensive short-term study to validate the predictions of the effects of the project, particularly compliance with water quality criteria at mixing zone boundaries.

Plate 15 Banap Creek at low flow

Plate 16 Banap Creek at high flow

- Monitoring operations for regulatory compliance and to identify any unforeseen effects.
- Reporting to local communities and to government.
- Consultation with local communities routinely and as issues arise.

9. References

9.1 Ramu Environmental Plan Appendices

Appendix 1 (Volume C) 1998. Bathymetry and Physical Oceanography. November. A report prepared by NSR Environmental Consultants Pty Ltd for Highlands Pacific Limited.

Appendix 2 (Volume C) 1998. Currents and water properties off northern PNG as they may relate to development in Astrolabe Bay and off the Rai Coast. July. A report prepared by George Cresswell, CSIRO Marine Research, Hobart, Tasmania for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 3 (Volume C) 1998. Marine Biological Communities. July. A report prepared by NSR Environmental Consultants Pty Ltd for Highlands Pacific Limited.

Appendix 4 (Volume C) 1998. Freshwater Impacts. November. A report prepared by NSR Environmental Consultants Pty Ltd for Highlands Pacific Limited.

Appendix 5 (Volume C) 1998. Marine Impacts. December. A report prepared by NSR Environmental Consultants Pty Ltd for Highlands Pacific Limited.

Appendix 6 (Volume C) 1998. Conceptual Study of On-Land Tailings Disposal. October. A report prepared by Klohn-Crippen Consultants Ltd for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 7 (Volume C) 1998. Hydrology and Meteorology. A report prepared by NSR Environmental Consultants Pty Ltd for Highlands Pacific Limited.

Appendix 8 (Volume C) 1998. Deep Sea Tailing Placement Engineering. A report prepared by Hay and Company Consultants Inc. for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 9 (Volume C) 1998. Physical Properties of Tailing. November. A report prepared by Ocean Science Institute for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 10 (Volume C) 1998. The Numerical Model of Deep Sea Tailings Placement. November. A report prepared by Ocean Science Institute for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 11 (Volume C) 1998. Vegetation Survey. A report prepared by George Vatasan for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 12 (Volume C) 1998. Aquatic Biology. September. A report prepared by Ross Smith and Adrian Flynn, R & D Environmental Pty Ltd for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 13 (Volume C) 1998. Water Quality and Sediment Chemistry. November. A report prepared by NSR Environmental Consultants Pty Ltd for Highlands Pacific Limited.

Appendix 14 (Volume C) 1998. Resource Use Surveys. September. A report prepared by Noki Makap, NOMAK Consultancy Services Ltd for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 15 (Volume C) 1998. Ocean Floor Sediment. October. A report prepared by NSR Environmental Consultants Pty Ltd for Highlands Pacific Limited.

Appendix 16 (Volume C) 1998. Chemical and Toxicological Characterisation of Tailing. November. A report prepared by NSR Environmental Consultants Pty Ltd for Highlands Pacific Limited.

Appendix 17 (Volume C) 1998. Terrestrial Vertebrate Fauna of the Ramu Nickel Project. November. A report prepared by Francis Crome and Stephen Richards, Francis Crome Pty Ltd for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 18 (Volume C) 1998. Archaeology and Material Culture Study of the Ramu Nickel Project. July. A report prepared by Alois Kuaso, Department of Prehistory, Papua New Guinea National Museum and Art Gallery for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 19 (Volume C) 1998. Ramu Nickel Project Feasibility Study. Sediment Study: Management Plan and Downstream Impacts. October. A report prepared by Klohn-Crippen Consultants Ltd for Highlands Pacific Limited.

Appendix 20 (Volume C) 1998. Assessment of Limitations to Rehabilitation, Kurumbukari Mine Site, Papua New Guinea. June. A report prepared by Natural Resource Assessments Pty Ltd for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 21 (Volume C) 1998. Air Quality Assessment. December. A report prepared by Holmes Air Sciences for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 22 (Volume C) 1998. Socio-economic Impact Study (SEIS). May. A report prepared by Jonathon Hampshire, Gary Simpson and Noki Makap, Project Design and Management Pty Ltd for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 23 (Volume C) 1998. Vegetation and fauna of the Basamuk Bay refinery site. July. A report prepared by Francis Crome, Francis Crome Pty Ltd for NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

Appendix 24 (Volume C) 1998. Deep-Slope Fisheries Survey, off the Rai Coast, Papua New Guinea. November. A report prepared by NSR Environmental Consultants Pty Ltd for Highlands Pacific Limited.

Appendix 25 (Volume C) 1998. Ramu Nickel Project Local Business Development Policy. October. A report prepared by Ramu Nickel Joint Venture.

9.2 References Cited

ANZECC 1992. Water Quality Guidelines for Fresh and Marine Waters. November. Australian and New Zealand Environment and Conservation Council.

Beca Gure (PNG) Pty Ltd 1985. Earthquake engineering for bridges in Papua New Guinea. A report prepared for Papua New Guinea Department of Works.

Ellis, D. 1989. *Environments at risk. Case histories of impact assessment.* Chapter 4, Mining - Island Copper (Canada) pp. 70–108. Springer-Verlag, New York.

Fluor Daniel and Simons 1998. Draft Feasibility Study Report (8 vols). July. A report prepared by Fluor Daniel-Simons Joint Venture for Highlands Pacific Group.

Govett, G.J.S. and Govett, M.H. (eds) 1974. *Developments in Economic Geology 3, World Mineral Supplies Assessment and Perspective.* Elsevier Scientific Publishing Company.

HGP 1996. Ramu Prefeasibility Study. July. A report prepared by Highlands Gold Properties Pty Limited on behalf of the Ramu Joint Venture.

Malthus, T. R. 1798. *An Essay on the Principle of Population.*

McCave, I.N. 1972. Transport and escape of fine-grained sediment from shelf areas. *In:* Swift, D.J.P., Duane, D.B. and Pilkey, O.H. (eds) *Shelf sediment transport: process and pattern*, pp. 225–48. Hutchinson and Ross, Stroudsburg, P.A.

Meadows, D. H., Meadows, D. L., Randers, J. and Behrens, W. W. III 1972. *The Limits to Growth: a Report for the Club of Rome's Project on the Predicament of Mankind*. Pan Books, London.

Milliman, J.K. 1995. Sediment discharge to the ocean from small mountainous rivers: The New Guinea example. *Geo-Marine Letters* (1995), 15: 127–33.

NSR 1997a. Ramu Nickel Project Environmental Plan Inception Report. July. A report prepared by NSR Environmental Consultants Pty Ltd for Highlands Pacific Limited.

NSR 1997b. Misima Mine, Papua New Guinea: Review of Submarine Tailing Disposal. Report CR 206/21. NSR Environmental Consultants Pty Ltd, Hawthorn East, Victoria.

PNG 1998. Office of Environment and Conservation. May. Proposed Environment Protection Policy - Waters of PNG.

PNGS 1982. PNG Standard 1001-1982: Part 4 - Earthquake loadings. National Standards Council of Papua New Guinea.

Ripper, I.D. and Letz, H. 1993. Return periods and probabilities of occurrence of large earthquakes in Papua New Guinea. Geological Survey Report 93/1. Department of Mining and Petroleum, Papua New Guinea.

USEPA 1986. Quality criteria for water. EPA 440/5-86-001. United States Environmental Protection Agency, Office of Water, Regulations and Standards, Washington.

USEPA 1989. Ambient water quality criteria for ammonia (saltwater). April. EPA 440/5-88-004. United States Environment Protection Agency, Office of Water, Regulations and Standards, Washington.

USEPA 1995. Interim Final Rule. Water Quality Standards. Establishment of Numeric Criteria for Priority Toxic Pollutants - Revisions of Metals Criteria. Federal Register 40 CFR Part 131.

World Bank 1995. Mining and Milling–Open Pit. World Bank Environment, Health and Safety Guidelines.

Legislation

Environmental Planning Act 1978 (Chapter 370)

Water Resources Act 1982 (Chapter 205)

Water Resources Regulations 1981 (Schedule 4)

Conventions and Treaties

Convention Concerning the Protection of World Cultural Heritage and Natural Heritage 1972

Convention on Biological Diversity 1992

Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) 1993

Convention on the Conservation of Migratory Species of Wild Animals 1979

Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1992

International Plant Protection Convention 1951

Plant Protection Agreement for South-east Asia and the Pacific Region 1956

RAMSAR Convention on Wetlands Especially as Waterfowl Habitat 1971

UN Framework Convention on Climate Change 1992

GIS Database Sources

ADC World Map. Base map information from American Digital Cartography Inc.

AGSO 1998

Standards

PNGS 1982. PNG Standard 1001-1982: Part 4 - Earthquake loadings. National Standards Council of PNG

10. Study Team

Highlands Pacific Limited appointed NSR Environmental Consultants Pty Ltd to prepare this Environmental Plan. NSR engaged a number of specialist subconsultants. Their contributions, and those of Highlands Pacific Limited and Highlands's engineering consultants, are acknowledged.

10.1 Highlands Pacific Limited

E. Anderson

J. Blackley

S. Dalton

E. Hills

P. Mason

S. Mellombo

M. Piamnock

L. Queen

R. Queen

T. Riley

M. Wilkes

10.2 NSR Environmental Consultants Pty Ltd

J. Bant

H. Blaszkiewicz

M. Cleland

M. Cramer

C. Coyne

L. David

R. Dehnert

A. Flynn

K. Friday

T. Halliday

C. Hardy

I. Hargreaves

B. Hughes

M. Jones

S. Jones

M. Leake

N. Leake

S. Mackay

C. Monahan

J. O’Neil

D. Oram

B. Sands

A. Sharp-Paul

P. Towler

M. Wright

10.3 Specialist Consultants

Australian Centre for Tropical Freshwater Research, James Cook University of North Queensland
S. Richards

CSIRO Division of Marine Research
G. Cresswell

David Balloch & Associates
D. Balloch

Department of Prehistory, Papua New Guinea National Museum and Art Gallery
A. Kuaso

P. Swadling

Ecowise
G. Newton

J. Skinner

Francis Crome Pty Ltd
F. Crome

G.S. Vatasan
E. Magulo

J. Simaga

G. Vatasan

Hay & Company Consultants Inc. (HayCo)
R. Gardener

J. Stronach

Holmes Air Sciences
N. Holmes

S. Lakmaker

Museum of Victoria
J. Taylor

R. Wilson

Natural Resource Assessments Pty Ltd (NRA)
M. Evans

NOMAK Consultancy Services
N. Makap

Ocean Science Institute (OSI)
C. Jenkins

Project Design and Management Pty Ltd (PDM)
J. Hampshire

G. Simpson

R&D Environmental Pty Ltd
R. Smith

Textonic Editorial Services
C. Taylor

WA Marine Research Laboratories
S. Newman

10.4 Engineering Consultants

Beca Simons NZ
A. Peacock

J. Pezaro

P. Smythe

R. Steel

P. Wells-Green

Fluor Daniel
J. Boland

J. Eather

J. Kelly

G. Morgan

P. Tyrer

J. Walker

H. A. Simons
A. Kozak

Klohn-Crippen Consultants Limited
E. Buschiazo

A. Markham

M. Thompson

Tennent Isokangas Pty Ltd
T. Isokangas

M. Rose

H. Tennent

B. White

Sotpela Ripot

Toksave Long Projek

Wanpela nupela maining projek bai kamap insait long liklik ples oli kolim long Kurumbukari, insait long Madang Provins long Papua New Guinea (PNG). Dispela ples em i stap arere long wara Ramu, samting olsem 75 kilomita longwe long Madang taun, long hap igo long sautwes (Mep 1[1]). Dispela wok maining bai kamuatim tupela samting long graun em oli kolim long Nikel na Kobolt. Kampani bai kamautim ol ston na graun karim dispela Nikel na Kobolt na behain bai katim dispela igo liklik tru pastaim long Kurumbukari. Behain long dispela, ol bai miksim wantaim wara na pamim igo kamap long Basamuk, long Rai Kos insait long wanpela paiplain (Mep 7). Longpela dispela paiplain bai winim moa long 134 kilomita. Kampani bai mekim ol kainkain wok insait long wanpela bikpela fektori long Basamuk long rausim Nikel na Kobolt stap pas long ol ston na graun ikam long maining eria. Olgeta wanwan yia, kampani bai rausim samting olsem 32, 800 tan Nikel na 3,200 tan Kobolt na salim dispela igo long ol wol maket ausait long PNG.

Long ol fisibiliti stadi kampani i bin wokim bilong painim aut sais bilong maining na kos bilong kamapim projek, i soim olsem dispela projek bai ron inap winim moa long 20 yia olgeta. Tasol, oli ting dispela eria igat inap risosis bilong surikim laif bilong dispela projek igo antap long 35 na 40 yia olgeta.

Tupela kampani bai bung wantaim long kamapim Joint Venture long wokim kamap dispela projek. Wanpela long dispela tupela kampani em Ramu Nickel Ltd husat bai holim 65% sea na narapela kampani em Nord Australex husat bai holim 35% sea insait long dispela projek. Bikpela kampani Highlands Pacific Ltd (HPL) em i mama kampani bilong Ramu Nickel Ltd, na bai go pas long lukautim na menesim olgeta wok bilong dispela Joint Venture namel long dispela tupela kampani em oli kolim long Ramu Nickel Joint Venture (RNJV).

Ol bikpela kain wok maining olsem, save kamapim planti sensis o bagarap insait long envaironmen. Olsem na kampani i wokim olgeta envaironmen stadi na kamapim dispela Envaironmen Plen (EP) ripot igo long Gavman bilong PNG, behainim seksen 4 (6) bilong lo oli kolim *Environmental Planning Act, 1978* (Chapter 370).

Lukluk Insait Long Projek

Wok Maining

Kurumbukari maining eria em stap antap long wanpela plet eria, namel long wara Ramu long not-is sait na ol bikpela maunten bilong Bismak long hap igo long sautwes.

Kampani i wokim plen bilong brukim dispela maining eria igo long fopela hap (Mep 9) bilong wok maining. Dispela fopela eria bai oli kolim long Ramu East, Ramu Central, Ramu Central Extended na Ramu West. Wok maining insait long dispela fopela hap eria bai go olsem:

- Ramu East - Bai kirap insait long yia 1 igo yia 4.
- Ramu Central - Bai kirap insait long yia 5 igo yia 11.
- Ramu Central Extended - Bai kirap long yia 9 igo yia 14.
- Ramu West - Bai kirap insait long yia 15 igo yia 20.

Pasin bilong kirapim wok maining insait long ol dispela fopela eria bai behainim fopela step:

- Kliarim bus antap long graun, dispela mas go pas.
- Digim na rausim graun na ston antap karamapim ol ston karim Nikel na Kobolt.
- Wok maining we ol stat long kamautim ol ston i karim Nikel na Kobolt.
- Stretim gut na planim gras na diwai antap long ol eria kampani i pinis long wok maining long en.

Kliarim Bus

Kampani bai nonap long mekim nating nobaut long rausim ol bus antap long maining eria. Ol bai lukaut gut long katim ol bus inap long mak bilong em, na insait long eria oli laik wok long en long wanwan taim. Pastaim tru, olsem wan yia bifo maining stat, ol bai katim na rausim ol gutpela bikpela diwai bilong wokim timba. Behain long dispela, ol bai rausim olgeta bus na gras bilong rereim graun bilong wok maining. Olgeta bus, lif, diwai han na gras, ol bai rausim na putim arere long wanpela eria, o katim igo liklik bilong putim igo bek long graun o yusim bilong pasim rot wara ron long en bilong stopim ol graun bruk igo insait long ol wara. Ol bai rausim graun antap inogat Nikel na Kobolt long en, na hipim o bungim arere bilong ol ken yusim behain taim bilong stretim na mekim kamap gut ol eria kampani i pinis long wok maining long en.

Graun Na Ston Stap Antap

Ol graun wantaim ston sindaun antap long ol ston i karim Nikel na Kobolt, oli save kolim ovabuden (overburden). Behain long taim oli pinis long rausim ol diwai na bus antap long ol maining eria, kampani bai stat long digim aut

[1] Bilong lukluk long olgeta piksa mep, plis yu mas lukim insait long narapela Sotpela Ripot.

olgeta ovabuden, sindaun antap karamapim ston i karim Nikel na Kobolt. Mak o sais bilong dispela ovabuden i bikpela tumas long sampela eria na inogat tru long sampela hap. Insait long olgeta wanwan yia, sais bilong ovabuden kampani bai kamautim bai winim moa long wan milion tan. Insait long maining plen, kampani bai stat wok maining behain tasol long oli rausim olgeta ovabuden. Oli nonap larim graun stap igo longpela taim long wanem, nogut rein wara i wasim na rausim sampela Nikel na Kobolt na igo wes nating na lus. Olgeta ovabuden bai go stret long eria maining i pinis long en, bilong halivim stretim gut graun bilong planim grass na diwai bilong kamapim gut ples ken.

Wok Maining Long Or

Mak bilong maining long ol ston i karim Nikel na Kobolt oli kolim or (ore), bai stap long 4.6 milion tan long olgeta wanwan yia. Dispela bai min olsem eria maining bai karamapim long olgeta wanwan yia bai winim moa long 48 hekta. Maining bai stat long antap na igo daun, na ol buldosa nabaut bai digim na lodim ol or igo long ol trak bilong karim igo long masin bilong katim na miksim wantaim wara.

Stretim Gut Eria Maining I Pinis Long En

Kampani gat plen bilong stretim na mekim kamap gut olgeta eria wok maining i pinis long en. Dispela wok bai stat quik taim tasol behain long wok maining i pinis insait long wanpela eria. Piksa Mep 10 i soim plen bilong dispela wok, na i karamapim ol dispela samting:

- Ol bai lainim olgeta bikpela ston long tambolo arere long mainten sait bilong larim isi ron bilong wara na givim sapot long beis bilong en long ol eria maining i pinis long en.
- Ol ovabuden i kam long maining eria bai ol i yusim bilong karamapim olgeta eria maining i pinis long en, na levelim gut.
- Antap long dispela ovabuden kampani bai spredim nupela blekpela graun.
- Planim ol grass na diwai bilong halivim strougim gut dispela nupela graun.
- Kamapim strongpela na bikpela bush karamap.

Kontrolim Graun Bruk Long Taim Bilong Rein

Long taim bilong bikpela rein, planti graun bai bruk na igo insait long het bilong ol wara na bagarapim ol dispela wara i save ron igo aut long maining eria. Ol kain graun i save stap long Kurumbukari maining eria ino strong tumas na isi long rein i wasim ol na rein wara karim igo.

RNJV igat plen pinis long traim na kontrolim dispela kain bagarap long graun na wara mas inoken kamap. RNJV igat tupela rot o wei insait long dispela plen bilong kontrolim mak bilong graun bruk long bikpela rein taim. Wanpela wei kampani bai traim long pasim ol graun bruk klostu yet long maining eria na stopim ol long inoken go insait long het bilong ol wara ron igo aut long maining eria na bagarapim ol.

Narapela rot em kampani laik yusim sampela bikpela wei bilong pasim graun bruk insait long maining eria. RNJV bai konstraktim na yusim ol kain banis raun wara we rein wara insait long ol maining eria bai go insait na sindaun. Taim dispela rein wara igo insait na sindaun insait long dispela raun wara, olgeta graun stap miks wantaim rein wara bai pundaun insait long flo bilong banis raun wara. Wara antap tasol bai lusim dispela banis raun wara na igo aut na bungim ol bikpela wara. Dispela wei inap long stopim olgeta graun bruk antap long maining eria, na pasim rot bilong ol wara antap long Kurumbukari eria long kisim bikpela bagarap long en.

Dispela rot bilong kontrolim rein wara na graun bruk RNJV bai yusim long stat bilong wok maining igo inap long tenpela yia. RNJV bai klinim na rausim ol graun igo daun na sindaun long flo bilong banis raun wara olgeta taim, nogut graun bai pulap insait na bagarapim wok bilong en. RNJV bai yusim dispela graun ol rausim insait long ol banis raun wara long putim igo miks wantaim or ken bilong rausim Nikel na Kobolt.

Kampani bai lukluk na stadi gut long hau dispela kain pasin bilong pasim graun bruk insait long banis raun wara bai wok insait long nambawan tenpela yia bilong wok maining. Insait long dispela painim aut, kampani bai stretim gut plen bilong kontrolim rein wara na graun bruk long laif bilong dispela maining projek.

Prosesim Or Bilong Rausim Nikel Na Kobolt

Rot bilong prosesim ol or bilong rausim Nikel na Kobolt bai behainim ol dispela step:

- Ol bai brukim ol bikpela sais ston nabaut igo liklik. Ol wesan i gat wanpela narapela samting ol kolim kromait bai ol rausim na storim antap long maining eria yet.
- Kampani bai miksim wesan i karim Nikel na Kobolt wantaim wara na pamim dispela igo long Basamuk insait long wanpela longpela paiplain, longpela bilong en bai winim moa long 134 kilomita. Samting olsem 430 tan or miks wantaim wara igo long Basamuk faktori insait long dispela paiplain long olgeta wanwan haua. Mak bilong Nikel na Kobolt stap miks wantaim or na wara istap olsem 1.12% Nikel na 0.11% Kobolt.
- Kampani bai yusim sampela kain marasin insait long faktori bilong traim na mekim isi wok long rausim Nikel na Kobolt istap miks wantaim graun na ston insait long or.
- Behain long step 3 antap, kampani bai yusim narapela rot ken bilong rausim Nikel na Kobolt. Dispela kain faktori kampani bai wokim long Basamuk, em i kain faktori husat i gat save long dispela kain wok long prosesim na rausim Nikel na Kobolt stap insait long or.

Ol kain marasin ol i kolim asid kampani bai yusim insait long faktori bilong halivim rausim Nikel na Kobolt, bai oli wokim yet long faktori long Basamuk. Ol bai yusim wanpela kain marasin oli kolim salfa bilong mekim dispela asid ol bai yusim long rausim Nikel na Kobolt.

Ol tu bai yusim wanpela samting ol i kolim laim bilong halivim wok long prosesim or insait long faktori. Kampani bai wokim dispela laim long Basamuk. Ol bai digim na rausim ol ston oli kolim laimston, stap klosta long faktori eria na wokim kamap laim long en. Faktori bai nidim samting olsem 1 - 2 milion tan laim long olgeta wanwan yia long laif bilong projek. Ples we ol bai digim dispela laimston oli kolim kwari, bai stap samting olsem 3 kilomita longwe long faktori long Basamuk.

Pasin Bilong Rausim Teiling

Pipia das na wesan kamaut long faktori behain long oli rausim Nikel na Kobolt, em oli kolim long teiling (tailing). Faktori long Basamuk bai kamapim samting olsem 5 milion tan teiling long olgeta wanwan yia. Insait long laif bilong dispela projek, moa long 100 milion tan teiling bai kamaut long Basamuk faktori. Dispela mak bai go antap sapos laif bilong dispela maining projek i abrusim 20 yia na go antap.

Bifo long kampani i tromoi teiling igo, ol bai pastaim tru miksim dispela teiling wantaim laimston o laim, o tupela wantaim. Dispela em i bilong halivim long daunim pawa bilong ol marasin nogut stap miks wantaim teiling na tu halivim long rausim sampela long ol dispela marasin nogut bifo long ol i ken tromoi dispela teiling igo aut. Dispela pasin emi bilong pasim ol rot we ol marasin nogut stap inait long teiling long bagarapim envaironmen taim kampani tromoi teiling igo.

Kampani bin spendim bikpela taim na moni long lukluk gut long painim aut sapos igutpela long pasim dispela teiling antap long graun o tromoi igo daun long dip solwara insait long wanpela paiplain. Insait long dispela stadi painim aut, oli painim aut olsem gutpela rot tru bilong rausim dispela teiling em long putim dispela igo daun long dip solwara.

Kampani i laik dispela teiling mas lusim faktori long Basamuk insait long wanpela paiplain igo daun long nambis na behain igo aut long dip solwara. Maus bilong dispela paiplain we teiling bai kamaut long en, bai stap samting olsem 150 m lusim antap igo daun long dip solwara. Taim teiling i ron kamaut long maus bilong dispela paiplain, em bai ron spit moa yet igo daun long solwara and sindaun tambolo long floa bilong solwara samting olsem 1,000 m na 1,600 m, lusim antap igo daun. Dispela teiling bai ino nap long kam bek antap long nambis na bagarapim rif, pis na ol komuniti husat istap arere long nambis klostu long Basamuk.

Ol Sapot Wok Bilong Projek

Projek bai nidim planti ol sapot samting bilong kirapim ol wok. Ol bikpela samting projek i nidim i stap olsem:

- Bai gat bikpela nid bilong wanpela wof o bris na ol sapot samting klostu long Basamuk bilong bringim ikam ol samting olsem disel, bensin na ol arapela ikwipmen. Na tu, Nikel na Kobolt ol i wokim kamap long faktori bai lusim Basamuk long sip.
- Planti ol rot nau stap insait long maining eria na long faktori eria ino gutpela tumas. Kampani mas wokim kamap gut ol dispela rot na bris na tu wokim sampela nupela bilong halivim gut ron bilong dispela projek.
- Bai gat bikpela nid long kol wara na dispela mas i kam long ol wara ron klostu long maining eria na long Basamuk faktori eria.
- Bilong wokim kamap olgeta dispela wok, nid bilong pawa em i wanpela bikpela samting.
- Narapela bikpela samting projek bai nidim long en em telefon na redio bilong salim toktok igo kam. Ol dispela samting mas stap sambai na redi long maining projek ken yusim, na ronim ol wok.
- Kampani bai wokim wanpela singel kota long Kurumbukari bilong olgeta singel wokman. Ol marit lain bai kisim akomodesin long Madang taun na long Basamuk.
- Mas i gat plen bilong kolektim, tritim na tromoi ol pipia wes long toilet na ol haus. Dispela tu em bikpela samting bilong lukaut gut long en.

Lain Wokman Na Meri

Long taim wok maining i stat long ron, samting olsem 1,045 wokman na meri bai stap insait long ol wok. Kampani bai givim nambawan sans igo long ol aspeles man meri bilong Kurumbukari na Basamuk long kisim wok insait long projek.

Nambatu sans long en bai go long ol lain insait long Madang Provins na namba tri sans bai go long ol arapela man meri long PNG. Sapos kain wokman projek i gat nid long en ino stap long PNG, last sans long en kampani bai lukluk ausait long PNG long ol arapela kantri bilong painim ol dispela wokman.

Long stat long wok maining, namba bilong ol wokman i kam long arapela kantri bai stap samting olsem 20% long ol lain wokman. Dispela mak bai igo daun inap long 12% insait long laif bilong projek.

Ol Bagarap Na Rot Bilong Pasim Ol

Bagarap Long Graun

Dispela maining projek bai nidim samting olsem 1,585 hekta graun bilong kamapim olgeta wok. Long dispela nid long graun, toktok long kompensesin long graun i wok long go het namel long ol papa graun na kampani. Dispela kompensesin agrimen bai karamapim ol toktok long yusim kastomari graun, ol kain bagarap bai kamap long dispela graun, risosis bilong ol pipal, wara na solwara.

Sampela long ol liklik ples we ol papa graun i stap long en long Kurumbukari bai stap insait stret long maining eria oli kolim SML. Kampani bai halivim ol dispela lain man meri long muv igo long narapela hap bilong mekim rot bilong maining igo het. Dispela nupela eria ol dispela lain igo stap long en mas gat inap graun bilong mekim haus, gaten na tu mas gat planti gutpela wara klostu na ol bikpela bus bilong painim ol wail apus na diwai.

Taim kampani kliarim ol bikpela bus insait long maining eria, planti wail laif bai kisim taim long painim ples bilong sindaun, painim kai na slip. Na tu planti long ol risosis bilong bus bai kisim bagarap. Mak bilong bikpela bus wantaim diwai kampani bai rausim i stap olsem 1,000 hekta. Insait long maining eria stret, dispela em bikpela hevi tru, tasol insait long bikples Kurumbukari, bikpela bus stap ausait long wok maining eria i karamapim bikpela eria tru.

Eria bai kisim bagarap long wok maining bai karamapim samting olsem 10% long olgeta eria stap insait long bikples Kurumbukari. Dispela mak em i liklik tru, olsem na dispela bagarap ino bikpela samting tru. Insait long PNG, sais bilong ol eria stap ananit long dispela kain bus em i bikpela tru. Olsem na dispela em ino bikpela wari tumas long bagarap kamap long hap liklik seksen long dispela kain bus, insait long PNG.

Bilong kontrolim gut ol bagarap i kamap, kampani bai makim wan wan blok long maining eria na taim em pinis maining long wanpela blok, em bai stratim gut dispela blok, na planim grass na diwai bilong mekim kamap gut ples ken. Kampani bai givim bikpela tingting long dispela wok, long wanem kampani laikim tru long sapotim ol wail laif na bus long Kurumbukari mas kambek ken olsem bifo. Insait long laif bilong maining, Mt Kua eria bai stap na maining bai nonap bagarapim dispela eria. Dispela bai givim sans long ol wail laif long muv igo long dispela hap na sindaun long en taim maining igo het. Maining bai inonap long igo insait long Mt Kua eria bilong larim ol wail laif ken stap na bikpela bus tu bai stap bilong ol papa graun ken yusim.

Long dispela taim long raitim kamap dispela ripot, i luk olsem, ron bilong paiplain lusim maining eria antap long Kurumbukari igo long fektori eria long Basamuk, bai abrusim ol viles na inonap long mekim wanpela viles muv igo aut long narapela hap. Tasol, i luk olsem, sampela ol viles klostu long ples we kampani bai wokim kamap fektori long en, bai mas muv igo aut long narapela hap. Sampela hap liklik bagarap bai kamap long sampela gaten kaikai, kokonas na koko plantesin o ol arapela wok husat i stap arere long paiplain rot o faktori eria.

Kampani bai traim bes long daunim mak na pasim ol rot bilong dispela kain bagarap long kamap. We em i hat tru long pasim dispela bagarap, kampani bai peim kompensesin long ol man na meri husat i papa long ol dispela risosis.

Bagarap Kamap Long Ol Wara

Insait long olgeta wan wan 5 yia, wok maining bai stap insait long wanpela blok. Dispela bai mekim isi long kontrolim bagarap kamap long ol wanwan wara ron igo aut lusim Kurumbukari maining eria. Ol plen bilong kampani long kontrolim graun bruk igo insait long wara bai halivim long pasim rot bilong ol graun na pipia wes long inoken igo insait long het bilong ol wara na bagarapim ol.

Tasol, sampela liklik bagarap bai kamap yet long ol wara long maining projek, long wanem em ino isi samting long painim rot bilong pasim olgeta bagarap long noken kamap.

Long taim ol bikpela wok i kirap, planti long ol wara ron igo aut long Kurumbukari maining eria bai karim planti graun na bai doti tru. Long taim bilong bikpela rein, dispela ol wara bai doti tru na kisim bikpela bagarap long planti graun bruk igo daun long wara. Planti long ol fis istap insait long wara nau bai kisim bagarap na namba bilong ol bai igo daun tru.

Dispela ol wara bai stat long kamap klin ken taim kampani i wokim kamap pinis ol banis raun wara na pasim ol graun bruk insait long maining eria. Piksa Mep 19 i soim mak bilong ol bagarap kamap long ol wara insait long 20 yia main laif. Behain long main laif i pinis, olgeta wara bai stat long kamap klin ken na ol fis bai kam bek ken.

Wanpela bikpela bagarap tasol kampani i save long en bai kamap long dispela maining projek, em bai kamap long wara Banap Oxbow, we graun miks wantaim ston na wesan bai igo insait na pulamapin dispela wara na planti ol samting nau istap insait long en olsem fis, bai kisim bagarap olgeta. Nape Tais bai nonap kisim bikpela bagarap na ol fis nabaut bai stap olsem yet.

Olgeta wara ron i go aut long maining eria bai nonap karim sampela poisen o marasin nogut insait long ol. Olsem na wara bai nonap kamap poisen na mekim ol man pret.

Wara Ramu tu bai nonap long kisim bikpela bagarap long dispela maining projek ikam long ol pipia ston, graun o poisen marasin. Sampela liklik senis o bagarap bai kamap klostu long maus bilong tupela wara Ban na Banap we tupela i bungim wara Ramu. Dispela eria bai kisim bagarap long taim bilong konstraksen tasol na stat bilong maining. Tasol nogat wanpela bikpela bagarap bai kamap long wara Ramu na em bai stap yet olsem nau, long laif bilong wok maining.

Bagarap Kamap Long Solwara Klostu Long Nambis Long Basamuk

Ples bilong wokim kamap faktori long Basamuk em i stap klostu tasol long nambis. Olsem na planti wok bai kamap long taim bilong konstraksen na dispela taim solwara arere long nambis long Basamuk bai kamap doti. Ol graun bruk, wesan na ston igo insait long ol wara ron ikam daun bai karim ol igo na tromoi igo insait long solwara. Dispela solwara bai doti long taim oli konstraktim bris bilong sip na wokim paiplain bilong karim teiling igo daun long dip solwara. Na tu kampani bai tromoi ol pipia ston na graun ol kamautim long ples bilong sanapim faktori bai go insait long solwara.

Wanpela rot bilong pasim ol doti wara long noken ron igo aut tumas, em long yusim wanpela samting ol kolim “Silt curtain”. Dispela em i wanpela kain strongpela sel banis kampani bai yusim bilong banisim maus bilong ol wara na tu eria we ol tromoi ol pipia ston na graun long en. Dispela rot bai pasim ol doti wara insait long liklik eria bilong solwara na inonap bagarapim bikpela solwara klostu long nambis long Basamuk. Piksa Mep 21 i soim mak bilong ol bagarap bai kamap long solwara na ol rif na pis stap insait long en.

Ol rif stap klostu long maus bilong ol wara na arere long ples ol bikpela wok i kamap long en, bai kisim bagarap. Longwe long dispela, ol rif bai nonap kisim bagarap. Samting olsem 500 m lusim eria we konstraksen wok i kamap long en, bagarap kamap long ol rif bai ino bikpela tumas.

Rif stap insait long ples teiling paiplain bai ron long en bai kisim bagarap olgeta. Tasol sais bilong rif eria kisim bagarap long wok bilong putim teiling paiplain bai liklik tru. Bikpela rif eria bilong Basamuk na Rai Kos bai nonap long kisim bagarap. Insait long eria long solwara na rif kisim bikpela bagarap long en, ol rif fis bai lusim dispela eria na ronowe igo long narapela hap we bagarap ino kamap long en. Behain long ol wok konstraksen i pinis, wara na solwara bai stat long kamap klin ken na ol fis bai kam bek long olpela ples bilong ol. Taim konstraksen wok i pinis na faktori i stat long wok, bai nogat moa rot bilong ol wara na solwara long kamap doti ken.

Olsem na bai nogat moa rot bilong rif na fis i kisim bagarap bihain long dispela taim.

Bagarap Kamap Long Dip Solwara
Bagarap insait long dip solwara bai kamap long wanpela mein rot tasol long taim faktori i stat long wok. Dispela mein rot em long ol pipia wes i kamaut long fektori em oli save kolim long teiling bai kamap taim kampani i tromoi dispela teiling i go daun long solwara klostu long Basamuk insait long wanpela paiplain.

Sampela bagarap tu bai kamap long ol rif long dip solwara taim kampani tromoi igo daun ol pipa ston na graun i kam long eria oli kamautim bilong sanapim faktori insait long sampela mun long konstraksen taim.

Bagarap long dip solwara bai kamap long teiling taim dispela teiling i kamaut long maus bilong paip na ron igo daun long dip solwara na sindaun tambolo long flo bilong solwara. Tasol wanpela samting, em mak bilong ol wesan na graun ol wara i save karim i kam daun long Finisterre Range or maunten nau, i winim mak bilong dispela teiling inap planti taim antap. Olsem na mak bilong teiling bai ino bikpela tumas. Taim teiling i kamaut long maus bilong paiplain samting olsem 150 m lusim antap igo daun ananit long dip solwara, em bai ron spit behainim sait long graun na rol i go daun long dip solwara na sindaun long flo bilong dip solwara. Piksa Mep 21 i soim ron bilong teiling ananit long dip solwara, na we em bai go sindaun long en. Dip wara klostu long Basamuk bai holim pas olgeta teiling long dispela eria. Dispela em i gutpela long wanem teiling bai nonap muv igo kam ananit long solwara na bagarapim bikpela eria long flo bilong solwara.

Bilong kontrolim ol bagarap kamap long teiling insait long solwara, PNG Gavman bai putim tambu baundri mak ananit long lo bilong kantri we mak bilong bagarap mas noken abrusim. Ananit long ol envaironmen lo, Kampani mas sek ap gut long dispela baundri mak na ol tambu lo Gavman i putim long em, olgeta taim insait long laif bilong projek, long daunim mak bilong bagarap long envaironmen.

Insait long baundri eria, solwara bai kisim bikpela bagarap, tasol dispela bai nonap long bagarapim o kilim dai ol kind fis ol i save stap long dip na namel solwara. Taim ol fis i painim aut olsem dispela hap eria long solwara we teiling igo daun long en i senis, ol bai lusim dispela eria na ronowe igo long ol narapela hap long solwara we nogat bagarap i kamap long en.

Solwara ino nap long kisim bagarap long ol poisen marasin long wanem kampani bai daunim tru strong bilong ol bifo em i go daun long paip. Dispela teiling bai go kol olgeta taim em igo miks wantaim bikpela wara. Ol stadi kampani i wokim kamap i soim olsem, nogat bikpela bagarap bai kamap insait long solwara i kam long ol marasin nogut.

Wanpela rot we ol bikpela bagarap o senis bai kamap insait long dip solwara bai kamap long ol teiling taim ol i ron i go daun lusim maus bilong paip na go sindaun tambolo long flo bilong solwara, klostu long Basamuk. Dispela teiling bai karamapim olgeta samting olsem ol binatang na long ol kain kain animol ol save stap na painim kaikai raum long flo bilong solwara, insait long bikpela eria ananit long solwara em oli kolim long Vitiaz Bay.

Long ol hap eria long dip solwara we planti teiling tru igo pundaun long en, nogat wanpela samting bai stap laif, olgeta samting olsem ol binatang na ol animol husat i save slo tumas long muv igo kam, bai olgeta kisim bagarap long dispela teiling. Ol bikpela fis nabaut husat i save stap long dip solwara bai lusim tasol dispela eria na muv i go aut long ol arere solwara ino kisim bagarap long en.

Antap long ol teiling, nogat wanpela laif bai stap long en. Long ol hapsait long dip solwara we ino planti tumas teiling igo pundaun long en, planti long ol binatang na ol animol husat i save stap long en, bai stap olsem yet na nonap senis tumas o kisim bikpela bagarap long en.

Insait long Basamuk Bay na tu long Rai Kos, bikpela dip solwara fis risos il stap. Tasol wanpela samting em ino planti man o kampani i save yusim dispela risos, bilong kaikai long ples o bilong salim na kisim moni long en. Eria long solwara stap autsait long nambis bilong Rai Kos em i traipela tumas na eria insait long Basamuk Bay we teiling bai go daun na karamapim em bai liklik hap tasol. Olsem na ol bagarap teiling bai mekim kamap long sait na flo bilong solwara long Basamuk em bai liklik tru, na ol dip solwara fis tu bai inonap kisim bikpela bagarap long en.

Taim laif bilong dispela wok maining i pinis, olgeta wok long faktori tu bai pinis na long dispela taim, no moa teiling bai go daun long dispela eria. Long dispela taim igo, ples teiling i go pundaun long en tambolo long flo bilong solwara bai i go strong na ol wanwan binatang na fis nabaut bai isi isi long stat long kam bek ken. Dispela em bai tekim sampela years moa yet behain long wok maining i pinis.

Bagarap Kamap Long Man Na Sindaun Bilong Ol Long Ples
Dispela maining projek bai kamapim planti gutpela rot bilong bringim halivim long wok developmen insait long projek eria na tu long bikples Madang Provins. Ol gutpela halivim ikam long projek bai givim sans long kamapim gutpela sindaun long ples na opim rot bilong wok developmen na ol komuniti sevis olsem edukesin, helt, painim wok moni, na wok bisnis. Sapos ol pipal na Gavman ino klia gut na mekim nating nobaut long ol dispela gutpela halivim, planti bagarap na heve tu ken kamap. Olsem na olgeta mas bung wantaim long lukluk gut, plen gut na mekim gutpela wanbel disisen long kamapim ol dispela wok i ken ron gut.

Wanpela impoten samting tru long lukluk long en, em long ol rot we moni bai kam long ol pipal na Gavman olsem long royalti moni, sosel sevis, wok, trening na bisnis develpmen. Long ai bilong ol pipal dispela ol samting i min olsem ples na laif bilong ol bai senis na kamap gutpela na ol senis long helt, edukesin na bisnis developmen bai go gutpela and bikpela insait long eria bilong ol. Tasol, planti taim yumi lukim pinis long PNG, tupela pasin i save bagarapim ol dispela tingting.

- Ol disisen long spendim ol moni i kam long kain projek olsem, is save go long ol wrong samting, na moni i save wes nating na lus, na nogat wanpela gutpela wok o sevis save kamap long ol ples na Provins.

- Planti taim Gavman yet i save feil long givim sevis bilong ol yet igo long ol pipal, na behain ken tanim na tok, "Kampani mas givim" long stretim hap wok o sevis em yet i feil long givim long ol pipal.

Insait long 20 yia main laif, mak bilong moni dispela projek bai peim igo aut long ol pipal bai go antap winim K200 milion. Dispela em traipela moni na em inap long kamapim planti wok developmen insait long Madang Provins. Tasol, sapos yumi laik lukim tru tru samting kamap long yusim dispela kain moni, yumi mas sanap bung wantaim long luk luk gut long ol rot asua bin kamap pinis long ol arapela projek long PNG. Dispela i min olsem olgeta tingting na nid bilong ol lokal komuniti, Gavman na kampani mas bung wantaim na toktok long en, na wanem samting mas kamap ol mas wanbel na agri long en. Behainim dispela pasin bai karim gutpela kaikai na olgeta bai hamas long en.

Envaironmen Menesmen Na Monitoring Progrem

Ol wok bilong painim aut ol bagarap kamap long envaironmen na stretim ol heve projek i kamapim insait long envaironmen ino pinis long dispela ripot. Neks step save kamap behain long dispela ripot em oli kolim long Envaironmen Menesmen Na Monitoring, we kampani mas lukaut gut long olgeta wok bilong en long noken kamapim bikpela bagarap long envaironmen na long sindaun bilong ol pipal.

Kampani bai wokim ol menesmen na monitoing progrem behainim ol dispela step:

- Behainin gut olgeta agrimen kampani yet i agri long en na long peim kompensesin.
- Wokim kamap ol stadi bilong painim aut mak bilong ol samting stap nau long envaironmen bilong halivim ol sekim ol senis i kamap behain long taim wok maining i kirap na ron.
- Lukaut gut na sekim ol wok kamap long taim bilong konstraksen na lukluk gut long ol senis i kamap long envaironmen.
- Behain tasol long stat bilong wok maining, sekim ol wara sapos bagarap i kamap o nogat na tu long solwara long "Miksing Zon Baundri" long Basamuk.
- Lukaut gut long olgeta wok i kamap long taim bilong maining long laif bilong projek, na sekim sapos sampela bikpela senis o bagarap i kamap long envaironmen o nogat.
- Olgeta samting ol painim aut long ol dispela mesemen na monitoring wok, kampani bai toksave long ol pipal na Gavman long ol ripot em bai raitim kamap long en.
- Olgeta taim kampani bai traim long kamapim gutpela sindaun wantaim ol pipal na toktok wantaim ol long olgeta wok na senis i kamap long laif bilong projek.

English Translation of Sotpela Ripot

Introduction

The Ramu Nickel Project is based on the mining of a lateritic nickel and cobalt resource at Kurumbukari, some 75 km west-southwest of Madang, in Madang Province, Papua New Guinea (Figure 1[1]). Slurried ore from the Kurumbukari mine site will be transported by pipeline some 134 km to a refinery at Basamuk on the Rai Coast (Figure 7). The refinery will produce some 32,800 t/a of nickel metal and 3,200 t/a of cobalt salt for export to world markets.

The Feasibility Study has identified ore reserves for a 20-year mine life. However, the geological resource base suggests that a mine life of between 35 and 40 years is probable.

The proponent of the project is a joint venture between Ramu Nickel Limited (65%) and Nord Australex (35%). Ramu Nickel is wholly owned by Highlands Pacific Limited (HPL), acting as manager for the Ramu Nickel Joint Venture (RNJV).

The project's environmental planning proposals and impacts are addressed in this voluntary Environmental Plan (EP), which is submitted in compliance with Section 4(6) of the *PNG Environmental Planning Act 1978* (Chapter 370).

Project Outline

Mining

The proposed Kurumbukari mine site is located on a dissected plateau bounded to the northeast by the extensive floodplain of the Ramu River and to the southwest by the foothills of the Bismarck Range.

Mining is proposed within four separate zones (Figure 9). The Ramu East, Ramu Central and Ramu Central Extended zones are located around the drainage divides of the Kurumbukari Plateau and together form the Kurumbukari Resource Block. The Ramu West zone is situated in the southwestern headwaters of Banap Creek.

The proposed mining sequence will be:

- Ramu East (Years 1 to 4).
- Ramu Central (Years 5 to 11).
- Ramu Central Extended (Years 9 to 14).
- Ramu West (Years 15 to 20).

The mining process comprises the following four phases:

- Land clearance.
- Overburden removal.
- Ore mining.
- Progressive rehabilitation.

Land Clearance

Land clearance will be kept to the minimum required for operations, and commences with the salvage of timber one year in advance of clearing the remaining vegetation. Vegetation will either be stockpiled, chipped for mulch, used in brush matting or used to build sediment filters downstream of cleared land. Topsoil will be removed just ahead of mining and be re-used as soon as possible as part of the progressive rehabilitation program.

Overburden Removal

The thickness of overburden across the proposed mine site varies from almost non-existent to about 20 m, with an average thickness of 2.5 m. On average, 1.1 Mt of overburden will be mined annually. In general, it is planned to strip overburden immediately before mining so as to limit the potential for erosion of the underlying nickel bearing ore. Overburden will be transported directly to mined-out areas for immediate use in rehabilitation. Disposal or long-term storage of overburden is not required for the Ramu Nickel Project.

Ore Mining

Mining will be at a rate of about 4.6 Mt/a, which corresponds to a mined area of about 48 ha/a. Mining within individual zones will occur in a cellular fashion, with open cut cells typically 1 to 4 ha in area. Ore thickness varies around an average of about 12.5 m. Ore will be mined in benches by excavators and loaded into trucks for haulage to the beneficiation plant.

Progressive Rehabilitation

Rehabilitation will commence as soon as mining of an individual cell is complete. The general procedure is shown in Figure 10 and includes:

- Using boulders exposed during mining, wherever possible, to form stable, free-draining batters along the lower slopes of mined-out areas.
- Replacement of overburden over mined surfaces.
- Application of freshly stripped topsoil.
- Sowing 'nursery' crops to assist in stabilising the soil surface.
- Establishment of permanent vegetation cover.

Erosion Control

The clayey soils of the Kurumbukari Plateau, once disturbed, have high potential for erosion, particularly during intense rainfall. The mine site spans the head-

[1] For figure references, see the extended summary report.

waters of a number of catchments on the Kurumbukari Plateau. RNJV proposes to implement an erosion control plan in each disturbed catchment to minimise the delivery of fugitive sediment to the streams. The erosion control plan comprises a combination of micro- and macro- controls. Micro-controls include a variety of techniques to retain eroded material close to the source during small to moderate flood events.

Macro-controls comprise the construction, operation and ongoing maintenance of settling ponds. The Ramu Nickel Project will be the first mining project in Papua New Guinea which will attempt to utilise settling ponds as a pre-emptive measure to assist in the containment of fugitive sediment in runoff from disturbed areas. Three settling pond sites have been identified for the initial 10 years of mining. Each pond has been designed to retain a 24-hour 10-year rainfall event. The ponds will require periodic excavation of the trapped sediment, which will be routed to the beneficiation plant for blending with run-of-mine ore. Based on the operation and performance of these ponds over the initial 10 years of mining, erosion control structures and procedures will be implemented and optimised for the later years of mining.

Ore Processing

Processing of the ore consists of the following four stages:

- Ore preparation at the mine site, which includes the removal of oversize material and chromite sand, to produce a consistent slurry feed for overland pipeline transport. Chromite sand will be stored in mined-out pits at the mine site.
- Slurry transportation over 134 km by pipeline to the refinery at Basamuk. The slurry pipeline will carry about 430 t/h of feed for the refinery. On average the slurry will have a metal content of 1.12% nickel and 0.11% cobalt.
- Acid pressure leaching at the refinery to extract nickel and cobalt from the ore into soluble constituents, and their subsequent precipitation as intermediate hydroxides using lime.
- Releaching of the hydroxides followed by nickel solvent extraction and electrowinning, and cobalt salt precipitation.

Acid used in the refinery will be produced on-site. Elemental sulfur will be used as feed stock for the acid plant.

Lime and limestone slurry used in the process will be produced on-site. The 1.2 Mt/a of limestone required for the lime plant will be extracted from a limestone quarry located 3 km from Basamuk.

Tailing Treatment and Disposal

Tailing solids from the refinery will be produced at up to 5 Mt/a and a total of about 100 Mt will be generated over the life of the project. However, greater quantities could be produced if the mine life were extended beyond 20 years.

The tailing will be treated by the addition of limestone and/or lime (as necessary) to neutralise residual acidity and raise the pH so that soluble metals are precipitated prior to disposal. Both on-land and deep sea tailing placement (DSTP) options have been considered and DSTP is the preferred option for tailing disposal.

Tailing will flow by gravity from the refinery to the coast and through an outfall pipeline on the seafloor with a terminus at a water depth of 150 m. Beyond the outfall the tailing will flow as a negatively-buoyant density current along the sloping seafloor and down a submarine canyon before ultimately depositing on the deep ocean floor within the Vitiaz Basin, at depths generally between 1,000 m and 1,600 m.

Project Infrastructure

Project infrastructure will include:

- Project-dedicated port facilities at Basamuk. Consumables including fuel oil and elemental sulfur will be imported and delivered by bulk carriers. Nickel metal and cobalt salt will be exported across the wharf.
- Construction and upgrade of roads and bridges to access the mine site, refinery and limestone quarry.
- Water supplies sourced from rivers close to the mine site and the refinery.
- Power supplies at the Kurumbukari and Basamuk facilities.
- A telecommunications network.
- Single-status accommodation at Kurumbukari, permanent accommodation in Madang and a township at Basamuk.
- Treatment of sewage and treated effluent disposal.

Workforce

During operations, the project will provide permanent employment for some 1,045 workers. Recruitment preference will be given to local people from project impact areas followed, in order, by persons from within Madang Province, Papua New Guinean citizens from other provinces then non-citizens.

Initially, the proportion of expatriates will be about 20% of the workforce. However, it is planned to progressively reduce this proportion to about 12% over the life of the project. Additional indirect employment will be provided by contractors who provide services to the operation.

Impacts and Safeguards

Land Impacts

The development of the project will require some 1,585 ha of land. A compensation agreement is presently being negotiated with the local people, which is expected to cover the occupation of customary land, unavoidable damages to land, loss of useful resources and freshwater and seawater turbidity.

Within the proposed special mining lease (SML) one or more hamlets will require relocation to accommodate the mine. RNJV will assist affected landowners to resettle to alternative areas with sufficient land to meet subsistence gardening and settlement needs and with access to clean water and adequate bushland resources.

The clearance of primary forest in the mine area and along the access road will result in the clearance of about 1,000 ha of forest habitat and will impact the fauna, flora and bushland resources of the region. The loss of forest in the mine area, though locally significant, is not expected to be regionally significant.

This is because mining will disturb less than 10% of the forest which covers the Kurumbukari Plateau, and because the medium-crowned lowland hill forest typical of the locality is common in northern Papua New Guinea, occupying expansive tracts of similar climatic and altitudinal conditions.

The impact to vegetation will be mitigated by progressive clearing, mining and then rehabilitation of disturbed areas, which will provide a mosaic of undisturbed and disturbed vegetation. The success of revegetation will be important in determining the ultimate impacts to fauna and flora of the Kurumbukari region. The forested slopes of Mt Kua, located in the northern portion of the proposed SML, will be left untouched by the project to provide refuge for fauna and to ensure a large tract of original forest is left intact.

At the time of writing, no villages required resettlement along the pipeline route, but there may be a need to resettle villages in close proximity to the refinery. The project will have localised effects on subsistence gardens and cash cropping. Specific mitigation measures and safeguards are proposed to minimise these effects and where these impacts are unavoidable, local communities will receive compensation.

Freshwater Impacts

Mining will be confined within individual zones for periods of about 5 years. Generally over this period, sedimented runoff will be confined to a single catchment. RNJV's erosion control plan will mitigate the effects of fugitive sediment from disturbed areas. However, residual freshwater impacts will still occur over the life of the mine.

During periods of major catchment disturbance, such as during construction of settling ponds, locally severe impacts are predicted for the streams draining the mining zones. These severe impacts include increases in suspended sediment concentrations during high flows, and increases in bed sedimentation and floodplain deposition, and are expected to result in major reductions of fish population densities in the main streams. Recovery of the streams will commence once the settling ponds are operational and fugitive coarse sediment is intercepted and retained. Freshwater impacts at the end of the 20-year mine life are shown in Figure 19. Recovery of impacts will continue in the streams following mine closure.

The only permanent change predicted is that the Banap Oxbow will infill with sediment over the life of the mine, resulting in the loss and/or reduction of aquatic habitat and the associated subsistence fishery. Impacts on the other important subsistence fishery of the mine area, Nape Swamp, are expected to be minor.

Water quality impacts due to trace metals originating from the mine are predicted to be insignificant.

No detectable impacts on the Ramu River are expected with respect to bed sedimentation and trace metals. Highly localised, minor impacts on aquatic habitats at the mouths of the Ban and Banap creeks are expected during construction and early operations. However, no significant impacts are expected on the overall aquatic habitats of the Ramu River.

Shallow-water Marine Impacts

The main impacts on the shallow-water marine environment will be caused by plumes of turbid water associated with the construction of the refinery complex at Basamuk. The sources of turbid water include sediment-laden floodwaters from creeks draining construction areas, turbid plumes resulting from the coastal dumping of incompetent waste rock and soil generated during excavation of the refinery site, port construction and associated dredging, and from the construction of the tailing-seawater mixtank and the onshore-offshore section of the tailing and seawater intake pipelines.

Silt curtains, installed at the mouths of the most-affected streams, will assist in mitigating the effects of turbid runoff. However, residual shallow-water impacts will still occur during construction, and nearshore biological impact zones are shown in Figure 21.

Within and adjacent to the main areas of nearshore construction and creek mouths, impacts on the fringing coral reef (where present) are predicted to be severe but decrease rapidly with distance from the sources of turbid water plumes generated by construction activity. Within about 500 m either side of the sources of turbid water plumes, impacts on the fringing coral reef are expected to be minor. Some sections of coral reef will be lost, such as a 10-m wide section alienated by construction of the tailing-seawater pipelines; however, this represents a small area compared to the large unaffected areas of fringing reef within Basamuk Bay and along the adjacent Rai Coast. Within the severe impact zones, most or all of the reef-attached fish species will be displaced, and reef-associated fishes will migrate to less-affected reef areas. Following construction, recovery in the hard coral fauna of the impacted fringing reef is expected to be rapid, within about 5 to 10 years, owing to the predominance in the coral reef community of the staghorn coral which is a pioneering and fast-growing species.

During operations, the sources of construction-derived sediments will have ceased and no long-term impacts on the shallow-water marine environment are predicted.

Deep-water Marine Impacts

Impacts on the deep-water marine environment will arise mainly during the operations phase from DSTP. However, over several months during construction, the coastal dumping of incompetent waste from the excavation of the refinery site is expected to result in minor impacts to deep-slope habitats as the waste material descends down the submarine slope.

During operation of the DSTP system, the discharge at depth of the tailing-seawater mixture will result in mid-water and deep-water, water quality impacts as well as tailing deposition on the floor of the Vitiaz Basin. However, the introduction of tailing should be considered in the light of the much larger inputs of natural terrestrial sediments from rivers and creeks draining the Finisterre Range.

The refinery tailing, when diluted with seawater and discharged at 150 m, will move down the steep submarine slope as a density current. Tailing solids deposition will occur along the path of the density current and accumulate on the seafloor. Development of a numerical model simulating DSTP to the Basamuk canyon has indicated that separation of material from the periphery of the descending density current will result in an expansive lutite flow across the bed of the canyon. A number of dilute subsurface plumes will separate from the upper surface of the lutite flow and become trapped by the natural density stratification of the ocean. The plumes will then disperse under the influence of the prevailing currents, ultimately depositing on the seabed.

The physical setting for DSTP in the Basamuk canyon is advantageous as it constrains the alongshore spread of tailing plumes while at the same time directing the density current to the actively depositing Vitiaz Basin.

The PNG Government will specify a mixing zone around the tailing discharge point. At the boundary of the mixing zone, there will be a requirement for compliance of the subsurface plumes in the water column with marine ambient water quality criteria.

Although a deterioration of water quality may be expected within the mixing zone, adverse impacts on mid-water fisheries, such as deep-slope snapper, are not expected. Fishes are either expected to be attracted to or to avoid these deep-water subsurface plumes. Chemical impacts of DSTP are expected to be insignificant, as tailing chemicals will be diluted many times within the subsurface turbidity plumes and by the flux of ocean water passing over the tailing deposits on the seafloor. Laboratory toxicity testing of tailing-seawater dilutions has shown that there is negligible residual toxicity at the dilutions expected within the deep-sea environment.

The main physical impact of DSTP will be the deposition of tailing solids on the seafloor, and consequent smothering of bottom habitats of Basamuk canyon and the Vitiaz Basin. In areas of heavy sedimentation, sedentary and less mobile bottom-dwelling fauna will be smothered and the surface of the tailing deposits is expected to be devoid of bottom-dwelling fauna. In areas of light sedimentation, a less diverse bottom-dwelling invertebrate fauna is expected to persist.

A deep-slope fishery resource is present adjacent to Basamuk Bay and along the Rai Coast. At present, the deep-slope fisheries are not exploited commercially or for subsistence. The deep-slope bottom habitat likely to be impacted by operation of the DSTP will be small in area in comparison to the large and unaffected areas of submarine slope adjacent to the DSTP and beyond. Therefore, significant impacts on bottom-dwelling fishes or potential deep-sea fisheries are not expected at the local or regional level.

Upon cessation of mining and decommissioning of the DSTP system, the deep-slope and seafloor tailing deposits will stabilise and consolidate with time. Recovery of the deposit site may take from months to years and benthic species more opportunistic than the original occupants of the deposition site may recolonise the area.

Socio-economic Impacts

The considerable benefit streams generated by the project will act as major stimuli for development in the project areas, as well as for Madang Province. The benefit streams have the potential both to improve social and economic welfare, particularly in the areas of education, health, employment and business development, but also have the potential to generate negative impacts if they are not effectively managed.

From the project's perspective, the management focus should be on the basic issues of revenue from compensation and royalty, social services, jobs, training and business development. While this focus manifestly reflects the explicit priorities of villagers for material advancement and access to social services there are, historically, two means by which the satisfactory delivery of these benefits can be impeded in Papua New Guinea:

- The tendency for cash benefits to be handled and spent in an inequitable, opaque and non-accountable way.
- Shortcomings in the delivery of government services, and the misperception that it is a straightforward matter for the project to fill the gap: 'kampani mas givim'.

The Ramu Nickel Project's revenues to the public sector will exceed K200 million over 20 years. This is sufficient to produce large and widespread socio-economic benefits throughout Madang Province. However, for this to occur in practice requires a framework that reflects the lessons of previous projects: in particular, local community, government and company interests and concerns need to be voiced, discussed and effectively acted upon within a set of agreed parameters of equity and accountability.

Environmental Management and Monitoring Program

The proposed environmental management and monitoring program includes the following steps:

- Implementation of management commitments and compensation arrangements.
- Assembling a baseline range of variables to define the pre-mining conditions.
- Monitoring of construction effects.
- Following construction, performing an intensive short-term study to validate the predictions of the effects of the project, particularly compliance with water quality criteria at the mixing zone boundary.
- Monitoring operations for regulatory compliance and to identify any unforeseen effects.
- Reporting to local communities and to government.
- Consultation with local communities routinely and as issues arise.