STUDY REPORT

No. 113 (2002)

Environmental Impacts Associated with New Zealand Structural Steel Manufacture – Preliminary Study

Roman Jaques

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Preface

This report details the environmental impacts associated with the extraction/acquisition, transportation and manufacture of engineering steel plate in New Zealand. The methodology used in this report is based upon a previous Canadian study. However, this report relies very much on the information provided by the manufacturers, and is therefore not as broad or detailed. It is part of a series of BRANZ reports examining the environmental profiles of a variety of basic building materials, based on the life cycle analysis approach.

Acknowledgments

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Readership

This report is intended for environmental engineers, building technologists and environmental researchers.

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Engineering Steel, Environmental Impacts, Steel Manufacture, Life Cycle Inventory, Life Cycle Analysis.

Abstract

An energy, emissions and material inventory from the manufacture of steel in New Zealand was investigated, using methodologies from a Canadian study. New Zealand has two steel manufacturing plants – BHP New Zealand Steel at Glenbrook and Pacific Steel at Otahuhu. This report is based on data obtained from these two sites for the year ending 1998. The environmental inventory for the first three stages of steel manufacture - raw material extraction (or steel scrap collection), transport to the plant, and the complete primary processing to slab production – were investigated for both plants. The secondary manufacture of engineering products – heavy/light plate – were further examined for the BHP New Zealand steel plant.

Up-to-date environmental data from known sources has been difficult to obtain, particularly from heavy industry. Unlike some other countries, New Zealand's national or regional regulatory requirements for the collection of environmental data are very limited. Consequently, only a limited amount of environmental information is available for studies such as this one.

Environmental profiling studies often use between-company and between-country comparisons to permit relative up-to-date performance measurement. Comparative studies could not be conducted in this study, because of the very different manufacturing methods of the two steel plants and their complementary product range. Also, for some critical environmental data, New Zealand-specific information was unobtainable. An inter-nation comparison could not be made with the Canadian study, due to their differing approach to plant examination, which was based on the development of an artificial industry average.

It is concluded that in the New Zealand manufacture of steel plate, of the four production stages, primary production is the most environmentally significant. In terms of energy use, primary production accounted for some 92%. In terms of emissions to air, primary production accounted for some 97% of the carbon dioxide produced, and the bulk of the methane, sulphur oxides, nitrogen oxides and carbon monoxide. In terms of solid wastes, primary production accounted for the top two. For discharges to water, primary production was responsible for the top three effluents - suspended solids (at 99%), iron and zinc.

Abbreviations and Terms

Baghouse – Filter equipment where dust is collected (and removed) from the steel-making process.

Char – Partially burned, devolatised coal.

Dioxins – Toxic halogenated organic compounds which are resistant to degradation.

EAF – Electric arc furnace.

EMS – Environmental Management System.

Fluxes – Compounds used to remove unwanted impurities.

Heavy metals – Elements with relatively high atomic mass, such as lead, cadmium, arsenic and mercury.

KOBM – Oxygen steel making furnace.

LCI – Life cycling inventory, an environmental profiling method.

LCA – Life cycle analysis, the examination of a product from its extraction to disposal.

MHF – Multi-hearth furnace, the furnaces which produce a mixture of hot, dry primary concentrate and char. The first stage in the iron-making process.

Microns – An SI unit of measure = 1×10^{-6} metres.

NZAAQ - New Zealand Ambient Air Guidelines.

Particulates – Very small pieces of solid matter, such as soot, dust or mist.

PCC – Primary concentrate and char.

PM_{10} – Particulate matter less than 10 microns in diameter.

ppm – Parts per million.

RPCC – Reduced primary concentrate and char.

Slag – Residue from various processes in the iron and steel making, which contains minerals such as silica, alumina, titanium, calcium etc.

SRNZ – Slag Reduction Company of New Zealand.

TSP – Total suspended particulate.

Tundish – Reservoir for molten steel.

USA EPA - United States Environmental Protection Agency.

VRU – Vanadium recovery unit.

1. INTRODUCTION

This work was funded by the Foundation for Research, Science and Technology Public Good Science Fund, under contract BRA 804, as well as funding from the Building Research Levy.

This research provides environmental data on atmospheric emissions, liquid effluents and solid wastes associated with a major building material, steel. Specifically, the object of this research was to *"quantify the major life cycle inventory impacts associated with the raw material extraction, processing and manufacturing of structural steel"*. The structural steel products investigated are light and heavy plate.

This report covers a simplified life cycle inventory (LCI) for structural steel - from raw material extraction/scrap collection, transportation to the mill, primary production through to secondary manufacture. Worldwide, LCI and life cycle analysis (LCA) environmental profile tools are still at the developmental stages. The recognised ideal approach for this type of environmental profiling is LCA, which considers a product from its inception through to its termination. The current implementation of LCA has proved too complex and possibly too costly for many applications, with its methodology being some way from final resolution. However, there is a need now to collect and compile data for those stages of LCA for which New Zealand data is available. The goal of this preliminary work is to permit the identification of areas still requiring research and/or data collection.

This project supports a long-term goal of assisting in the development of a scientifically sound basis for determining the environmental impact of building materials. Details from this type of study can be developed to allow both the building industry and the consumer to select building materials which result in the least environmental impact.

This research report is part of a series of BRANZ studies constructing environmental profiles of common building materials – which includes cement[1] and sawn timber[2].

2. BACKGROUND

2.1 Life Cycle Analysis

The methodology used for this research report is based on LCA, and is a means of identifying the complete environmental impacts caused by a product. The overall goal of using LCA is to reduce the environmental impact of a product or component. LCA usually comprises four inter-related components[3]: 'scoping'; 'inventory'; 'impact assessment'; and 'improvement analysis'. This study of New Zealand steel plate manufacture focuses on the inventory stage.

LCI is sub-process of LCA which quantifies the inputs and outputs that occur over the life cycle of a product. The inputs and outputs quantified include raw materials, solid wastes, emissions to the atmosphere, and liquid effluents. In this study the inventory will target the first three stages of the life cycle:

1. Raw material extraction/collection.
2. Raw material transportation.
3. Manufacturing (both primary and secondary).

2.2 The Forintek Study

The Forintek Canada Corporation project entitled *Building Materials in the Context of Sustainable Development*[4,5] has been used as a base document for this research. Forintek is approximately the Canadian equivalent of New Zealand's Forest Research Institute. In 1991, eight Canadian research organisations formed an alliance to make available environmental data on common construction materials. Their project was prompted by unsubstantiated claims promoting the environmental benefits of using timber alternatives in construction. This situation was exacerbated by the increase in timber prices that made steel and concrete more competitive than in the past. Forintek recognised the need to carry out objective, scientifically based analysis on timber and its competitors, to achieve a fair comparison based on the life cycle approach.

The Forintek study[4] includes estimates for raw material requirements, embodied energy, demand for water, solid wastes and a select number of atmospheric emissions. The investigation can be grouped into four stages: extraction of raw materials; transport of raw materials; primary; and secondary processing and transportation of the finished product.

The Forintek approach is recognised as one of the definitive works in LCA, and was chosen as a model because of its transparency and objectivity. The conventions set down in the Forintek document were applied in this research.

2.3 Research Approach

As previously noted, this is one of a series of life cycle studies performed on common building materials, as part of BRANZ investigations, and is part of an ongoing research effort to produce environmental profiles of common New Zealand construction materials. The conventions for data collection used in this study are the same as used previously[1,2]. The conventions used in this work for such areas as system boundary limits, data categories and quality, and standard concepts are described in APPENDIX A: CONVENTIONS USED.

In late September 1998, contact was made with the environmental officers of the two New Zealand steel plants, explaining the objectives of the BRANZ LCI study on steel. Specific data on the material and energy inputs and outputs for the most recent year for each mill were requested. Also requested was information on the total steel production, emissions, effluents and waste products, as well as the energy and raw material inputs. It was stressed that information gained would be used in a fashion which was non-judgemental and non-comparative, and that no attempt would be made to rate or rank one building material over another. Further information on the operations was also gained through various resource consent documents required by the Auckland Regional Council, a visit to the BHP New Zealand Steel (BHP NZS) mill in 1998, and industry environmental monitoring data.

Due to constraints on time and the complexity of the mills' operations, the only structural engineering product that has been environmentally profiled was steel plate. The secondary processing of this material is more traceable than most steel products, because of its short secondary processing requirements.

As is typical in industry, legislation, technology and competition requires continual change and steel manufacturing is not immune. By convention, the most recent data should be used for unit factors calculations in an LCA study. For this study, the most recent year was 1998. Targeting a single year, however, may not be a good reflection of standard practice. For example, in the 1997/1998 financial year, one of BHP NZS's melting furnaces was offline for two months, which was an unusual event. This anomaly had significant implications for coal and energy usage. This resulted in an environmental profile which differed (in energy and raw material use) from that of a more 'standard' year. However this study does provide a snap-shot of one particular year, and can be used as a basis for future environmental profiles on steel.

2.4 Accounting for Steel Recycling

Steel is said to be the world's most recycled material, with more than half the steel today being sourced from recycled scrap[6]. Some consider this statement to be misleading and exaggerated[7] (with some plants accounting for in-house recycling). It all depends on how the term 'recycle' is defined and what it includes. There is no disputing, however, that the steel-making industry uses much recycled steel, in one form or another. The type of recycled steel used in the industry can be divided into two categories:

- post-consumer waste that is recycled, such as car bodies, machinery etc (by far the most significant).
- wastes produced and recycled within the industry (industry wastes). These typically result from sporadic process inefficiencies etc (of much lesser significance).

Constructing an inventory that accounts for a material with a high-recycled content is no trivial matter. If the material is part of a closed system – that is it may be recycled many times without any significant loss in its properties – then inventory accounting becomes even more problematic. Steel is such a material. Such issues as appropriateness, traceability of successive products, typical values, relevance and sources, all have to be considered[5]. The over-riding goal – which is to end up with a fair and reasonable solution - must be always kept in sight.

According to Forintek's methodology[5], internal recycling is just considered 'good housekeeping' and appears as improved conversion efficiency (i.e. the ratio of inputs to 'useful product') and reduced waste (refer to APPENDIX A: CONVENTIONS USED). This means that '*the energy use and other environmental effects associated with the production of internal scrap in the first instance are attributed to the final products made using that scrap as one of the materials*'[5].

Also, Forintek[5] states that for the example of post consumer waste, "*…tracing the product origins….and making the environmental cost allocations to successive generations of products can be a complex process and has to be done on a case-by-case basis*". This is impractical in the case of steel, because of many factors (e.g. unknown recycling history, traceability problems etc). As a result, Forintek decided to include only transportation energy and the environmental impacts of its use when compiling its environmental profile. This means though, that "*some of the atmospheric emissions and other environmental effects associated with the production of steel from virgin materials are avoided when the raw material is scrap steel*" and results in an underestimation of the environmental effects.

In summary, Forintek accounts for the two types of scrap (industrial and post consumer) by:

- making a full allocation of original manufacturing impacts to all industrial wastes, and
- including only transportation energy (and the associated air emissions) for all post consumer scrap.

The resulting errors of this approximation are seen by Forintek to be somewhat arbitrary, but also to some degree compensating. This methodology is applied to this BRANZ steel LCI study.

The Forintek method outlined above is only one method of dealing with the recycling issue. There are many other ways in which recycling impacts can be accounted for. A Swedish study[8] overviews several accepted allocation procedures used world wide, making a case against their use due to their favouritism towards recycling (the Forintek methodology comes under this category). It then proposes a more 'equitable' method for highly recycled materials (such as aluminium, steel and glass), making use of a calculation-based procedure which accounts for each new life cycle. The disadvantage of the proposed Swedish model though, is that a high level of knowledge is required for the previous and succeeding cycles for it to be accurate. This kind of knowledge is typically difficult to obtain in the case of a material like steel.

3. THE NEW ZEALAND STEEL INDUSTRY

3.1 General Overview

The New Zealand steel industry consists of two manufacturing plants, BHP NZS – located at Glenbrook (approximately 60km south of Auckland), and Fletcher Challenge's Pacific Steel – located at Otahuhu (Auckland). The total capacity of the New Zealand industry is about one million tonnes of finished steel per year (1998 figures).

The two plants provide a variety of steel products - from roll-formed roofing and metal joinery to reinforcing bars and wire rods. The plants are however fundamentally different, in that one produces entirely from scrap steel (Pacific Steel), while the other (BHP NZS) produces mainly from raw material in the form of titanomagnetite sand. The plants are also complementary, producing different and non-competing end products. Because the two plants are fundamentally different and complementary, each will be studied separately, rather than amalgamating and averaging their environmental profiles, as has been performed in other BRANZ life cycle inventory studies[1,2].

3.1.1 Overview of BHP New Zealand Steel Ltd

BHP NZS is a fully integrated steel plant - that is, the vast majority of the steel it produces is derived from raw materials, rather than scrap - using the direct reduction process with locally sourced iron-rich sands. An electric arc furnace (EAF) has been used to melt steel scrap uprisings from the site processes and a small amount of scrap sourced offsite. However, the amounts of scrap processed in the oxygen steel-making furnace have continued to increase with the EAF being closed in late 1998.

Producing steel from iron-rich sands (titanomagnetite) is unique in the world[9]. The operations consist of: an iron-making plant (which converts iron sand and coal products to iron); the slab making plant (which converts the iron to steel slab); rolling mills (where the cast slab is rolled to its finished size); and finishing operations (where a range of finished products are produced). Titanomagnetite (59% Fe) is separated from beaches and deposits. After reduction to iron using coal, the product is melted to pig iron and finally refined to steel as shown in Figure 1.

Iron sand is sourced from the Waikato North Head. This sand was formed through the breakdown of rocks originating from volcanic activity in the Taranaki region 2.5 million years ago[9]. It is found as either iron-rich clay or beach sand and has an average iron concentration of 59%, which is probably the lowest iron concentration for a steel-making raw material in the world[10]. Waikato North Head contains a reserve of more than 150 million tonnes of titanomagnetite.

The other main raw materials used are: coal from Huntly (70 km away); lime (stone) from Otorohanga-Waitomo region (155 km away); water from the Waikato river (15 km away);

natural gas (from Taranaki). Note that the EAF uses ferrous scrap mainly from the North Island. Electricity is sourced mostly from the national grid, but some is also produced via the on-site co-generation plant, which produces electricity from waste heat.

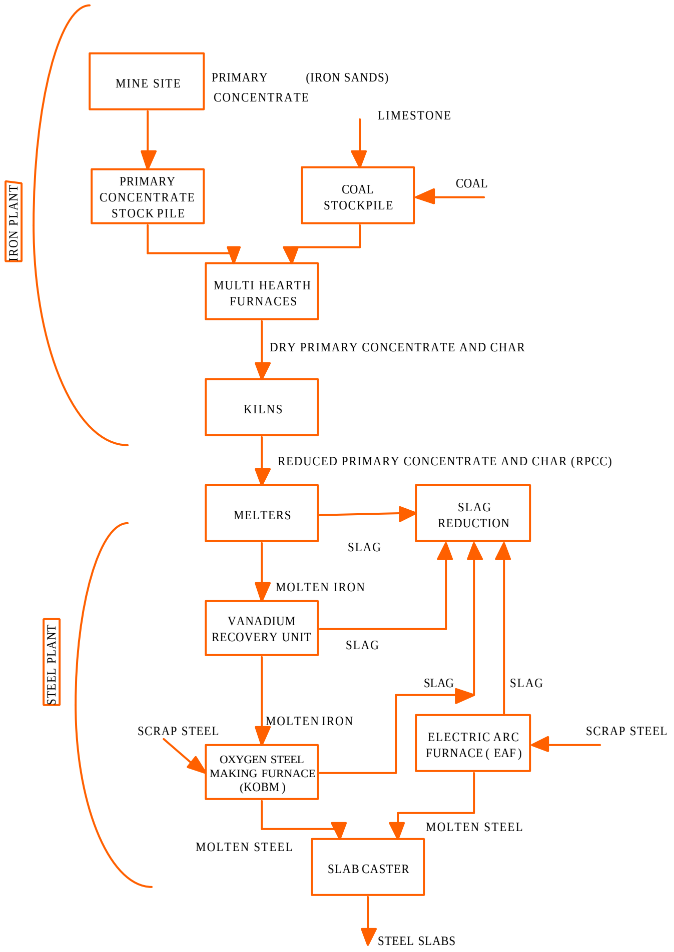

Figure 1: BHP NZS – iron and steel-making process flow[10].

BHP NZS produces a variety of products, including coil, plate, tube, pipe and painted sheet, as noted in Table 1. Of its approximately 600,000 tonne annual production, BHP NZS exports about 60%[9].

Table 1: BHP NZS production for the year ended June 1998.

BHP NZS Year Ended 1998[11]		
Raw Product	**Finished Product**	**Tonnes**
Pig iron		570,600
Steel (KOBM) + (EAF)		628,400
	Painted galvanised	6,500
	Painted zincalume	42,000
	Hot rolled	160,000
	Cold rolled	145,000
	Hollow sections	22,500
	Coated sheet	145,000
	Plate	29,000

The Slag Reduction NZ Ltd Company (SRNZ) also operates on the Glenbrook site. It handles all the slag by-products and specialises in the development and marketing of slag products. All slag from the BHP NZS site is recycled or reused for road surfacing, soil conditioning, drainage material, sand blasting and filtering material for waste water treatment. In all, about 367,000 tonnes of slag was produced at BHP NZS in the 1996 year[12].

3.1.2 Overview of Pacific Steel

Pacific Steel is a division of Fletcher Challenge Steel and Wire[13]. Pacific Steel acquires its scrap as post-consumer material, gathered by Sims Pacific Metals (a joint venture company). The scrap consists of a wide variety of products - including car bodies (about 60,000 units per year), washing machines, fridges, and obsolete industrial material.

Pacific Steel's steel-making process involves the collection of scrap material (sourced both internally and nationally), shredding, reducing in size, some baling, and transportation to the EAF. The scrap is then melted (using high currents) with burnt lime, and the molten metal refined using oxygen. The low alloy molten steel is ladle refined to the required composition. Finally, the steel is cast as billets and then reheated before rolling to the required profile, as shown in Figure 2.

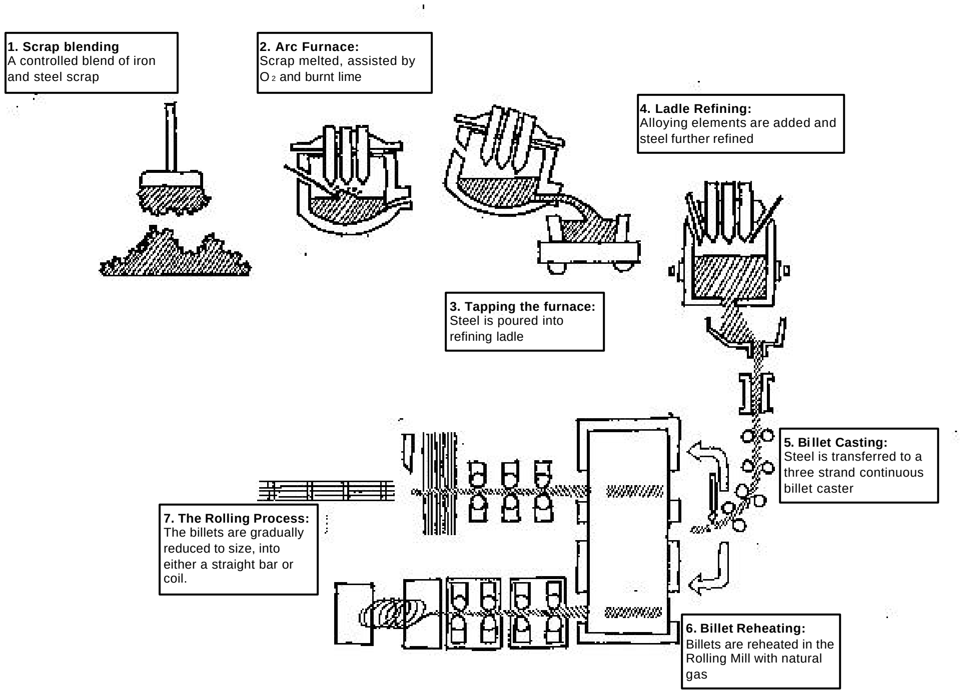

Figure 2: Pacific Steel process flow diagram[13].

Pacific Steel provides around 160,000 tonnes of finished steel yearly, producing a variety of steel products including reinforcing bar, rebar coil, rounds, reid bar, angles, un-equal angles, flats, channels, wire rods and billets, as noted in Table 2. Sims Pacific Metals provides 100% of Pacific Steel scrap metal requirements, which is equivalent to about 200,000 tonnes per annum[13]. The two companies share the same industrial site in Otahuhu.

Table 2: Pacific Steel production for the year ended June 1998.

Pacific Steel: Year End 1998[14]		
Raw Product	**Finished Product**	**Tonnes**
Billet		165,000
	Bar	84,000
	Rod	44,000
	Wire products	30,000
	Mechanising	86,000
	Roofing	7,000

Post consumer scrap is sourced from around New Zealand and is transported to Otahuhu (Auckland), by road, rail and barge. Scrap material is also sourced internally, from the rod and bar mills where off-cuts and seconds are produced (some of which will not go back into the cycle) as part of normal operations. The EAF addition of lime is sourced from Te Kuiti (175 km away), and the liquid oxygen is sourced from an adjacent site.

3.2 National Production Statistics

Steel production in New Zealand over the 1990-1996 period has been steadily rising, with an overall increase of about 13% (Figure 3). This equates to approximately a 2% increase per annum, with peak production in 1995.

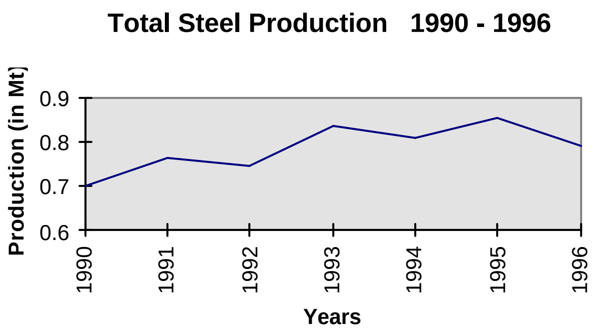

Figure 3: Total steel production in New Zealand (1990 –1996)[16].

3.3 Energy Conservation Measures

In a highly competitive industry such as steel manufacture, energy conservation and efficiency is critical. In New Zealand there have been additional reasons for energy-based efficiencies, both in national (such as possible carbon taxes/emission trading) and global terms (such as climate influences from CO_2 , SO_X and NO_2 emissions). In terms of CO_2 emissions alone, the impact of legislation on steel-making in New Zealand would have a significant effect on the national GDP. Ministry of Commerce[16] data suggest that in 1996 steel-making in New Zealand contributed to 55% of the total CO_2 emissions for industrial process sector. This sector comprises specifically only those major industries in New Zealand such as aluminium, steel and cement production whose CO_2 emissions are more related to the chemical process rather than energy. 'Section 4. Emissions to Air' discusses this in some detail.

It should be noted that producing steel from raw materials requires substantial energy and raw material input. Producing steel from industrial or post consumer scrap is considerably less complex, as illustrated in Figure 1 and **Error! Reference source not found.**. This complexity is reflected in terms of energy requirements, where recycled steel has only approximately 32% of the energy requirement to that of virgin steel[17].

The following is a brief overview of the energy-related improvements carried out on the two steel plants. The examples listed are current for the year surveyed (1998), with the steel industry being in a continual state of improvement.

3.3.1 Energy efficiencies at BHP NZS

A major recent energy improvement was the commissioning of a co-generation plant, which began operating in June 1996. Co-generation is the conversion of otherwise waste heat into useable energy, usually in the form of electricity. This operation is usually performed on site as part of normal industry operations. On the BHP NZS site, co-generation uses waste heat produced in the four direct reduction rotary kilns and the multi-hearth furnaces. The kilns' and multi-hearth furnaces' waste heat can yield up to about 70 MW of electricity, which is equivalent to about 55% of the mill's electricity requirements. In 1998, co-generation supplied 25% of the electricity used on the total site. BHP NZS has a target of reducing purchased energy consumption to 27.5 GJ/t of steel slab by the year 2000[18] from the current of 29 GJ/t. Closure of the EAF in late 1998 changes these targets numerically but nevertheless, as the kilns co-generation plant reaches full output, production of electricity from waste heat will supply 50-55% of site electricity by the year 2000.

Other measures to improve energy efficiency that were undertaken during the 1998 year include:

- *Iron plating* – reducing these levels to as low as practical.
- *Reduced primary concentrate and char* – reducing the amount of dumped product. Its recovery and recycling is also being investigated.
- *Use of melter gas* – melter gas is now burned in the kilns' co-generation plant, increasing the amount of electricity generation.
- *Variable speed drives and impeller changes* – higher efficiency waste gas fan impellers were installed on the kilns, which reduced their motor loads significantly.
- *Roll cooling and descaling optimisation* – optimisation of the descaling and roll coolant, combined with better communication between hot mill and utilities operators.
- *Integration of the rolling mills and primary plants compressed air supply networks* – the joining of separate compressed air supply systems and a control system to allow rotary compressors to run continuously as base load machines, increasing overall efficiency.

3.3.2 Energy efficiencies at Pacific Steel

There is an ongoing strategy to reduce electricity usage at Pacific Steel, but efficiencies are dependent on the through-put where economies of scale operate. Proper control and maintenance of the burners and systems to ensure good efficiencies is important[19]. Other recent energy efficiency-related measures include:

- better control of the type of scrap, leading to less energy usage.
- introduction of a standard power usage model for the EAF.

- reducing the average amount of lime from 1,500 kg to 1,200 kg per heat.
- general production focus on yields.

3.4 Environmental Control in the Steel Industry

Like many other Western nations, the New Zealand steel industry has directed a significant amount of resource to achieving compliance with government-mandated environmental controls, primarily the Resource Management Act, 1991[20] (RMA). In terms of steel production, the RMA replaced the Clean Air Act, 1972[21], Water and Soil Conservation Act, 1967[22], and the Town and Country Planning Act, 1978[23].

For all steel manufacturing-related activities which are not permitted by regional or district plans, consents from Territorial and Regional Authorities are required. They include[24]:

- discharges to air (particulate, gas chemistry, concentration and volume).
- noise levels.
- waste disposal and storage of hazardous substances.
- extracting fresh water.
- discharges to trade waste effluent and stormwater into water.
- discharging water containing wastes onto land.

Air quality regulations and emission control efforts in the industry have focused on particulate (dust) and gaseous (fume) emissions. This focus is reflected in terms of capital investment which for both companies has resulted in the installation of control systems which reduce deleterious atmospheric emissions[25]. The RMA requires companies to ensure that there are "*no adverse effects on the environment*"[20] for all emissions outside the boundary of the site where the process takes place. It is interesting to note that these adverse effects could be either health- or visual-related[26]. This provision is in contrast to the Clean Air Act[21] (the earlier legislation), where the emphasis was on best fume control practice at source of emissions.

At BHP NZS, an Environmental Management System (based on the BS 7750[27] system which is a forerunner to the ISO 14000 series of standards) was introduced in 1990. This provided a foundation for their environmental policy, and provides the company with guidance on how to improve its environmental performance. This includes the provision of specific records in respect of sampling procedures, calibration methods and the validity of data[18]. BHP NZS has also set up a community Environmental Committee, which meets to review and discuss the company's environmental performance. Representatives are from a wide cross-section of the community, including local grower organisations, territorial authorities, general public and senior company managers. BHP NZS has consent conditions from authorities for discharges to air, extracting fresh water, discharging treated waste water and storm-water into water, discharging water containing wastes into land and operating a landfill for non-hazardous wastes.

Pacific Steel also holds public consultation meetings and consults with Regulatory Authorities, industries close to the site, and local indigenous people (iwi). Pacific Steel has put in place measures to address environmental responsibility, including: consulting with their neighbours; environmental policy and procedures (includes contingency plans for emergencies); and an induction process for all employees on environment awareness. Pacific Steel has consent conditions from authorities for discharges to air, trade waste and storm water discharges.

3.5 Details of Steel Mills

A detailed description of the steel mills, expanding on Figure 1 and **Error! Reference source not found.** follows.

3.5.1 Details of BHP NZS steel production

The following information has been sourced predominantly from two publications[10,12].

Raw Materials Handling
Iron sand is mined at Waikato North Head, where water is added to form a slurry. It is then concentrated using both magnetic and gravity cone separators. The concentrated sand (titanomagnetite) is pumped to the mill site in a slurry form, via an underground pipeline, where it is dewatered and stockpiled. The slurry water is flocculated with chemical agents that settle out any residual clay minerals.

PRIMARY PRODUCTION

Multi-Hearth Furnaces (MHF)
The furnaces dry and heat the titanomagnetite sand. Coal and limestone is added to the concentrate and heated, which results in preheating of the raw materials and release of volatile gases from the coal. Waste gas passes through a boiler to raise steam before passing through a wet scrubber for cleaning and discharge to the atmosphere.

Direct Reduction Rotary Kilns
The kilns convert the iron oxide to form reduced primary concentrate (also called sponge iron) and char (RPCC), which is nearly 70% metallic iron. The material is heated up to 900°C. Waste gas passes through a boiler to raise steam before passing through a wet scrubber for cleaning and discharge to the atmosphere.

Electric Resistance Melters
The melters convert metallic iron in the RPCC to liquid pig iron. Surplus carbon from the char dissolves in the molten iron. Slag and pig iron are periodically tapped off into ladles.

Vanadium Recovery Unit (VRU)
This is an iron pre-treatment process, performed immediately prior to the delivery of the molten iron to the oxygen steel making furnace. Nitrogen is injected with a lance into the molten metal, acting as a mixer. Oxygen is blown over the surface to assist the formation of a vanadium rich slag, which is removed for later processing.

Oxygen Steel Making Furnace (KOBM)
This process converts molten iron into steel. Oxygen is blown through the molten metal which is sourced from the vanadium recovery unit or directly from the electric resistance melters. Also, ferrous scrap and fluxes may be added to control the chemical composition. The liquid steel is tapped into a casting ladle, while the resulting slag is tapped off.

Electric Arc Furnace (EAF)
This converts 100% scrap steel (both industrial and post consumer) into molten steel. Lime is used as a fluxing agent, with oxygen increasing energy values. When the steel's composition is correct, the slag is flushed off and the steel tapped off into a casting pot.

SECONDARY PRODUCTION (BHP NZS only)

For the production of heavy and light plate (and all other steel products), steel is further processed from a reheated slab as noted in Figure 4.

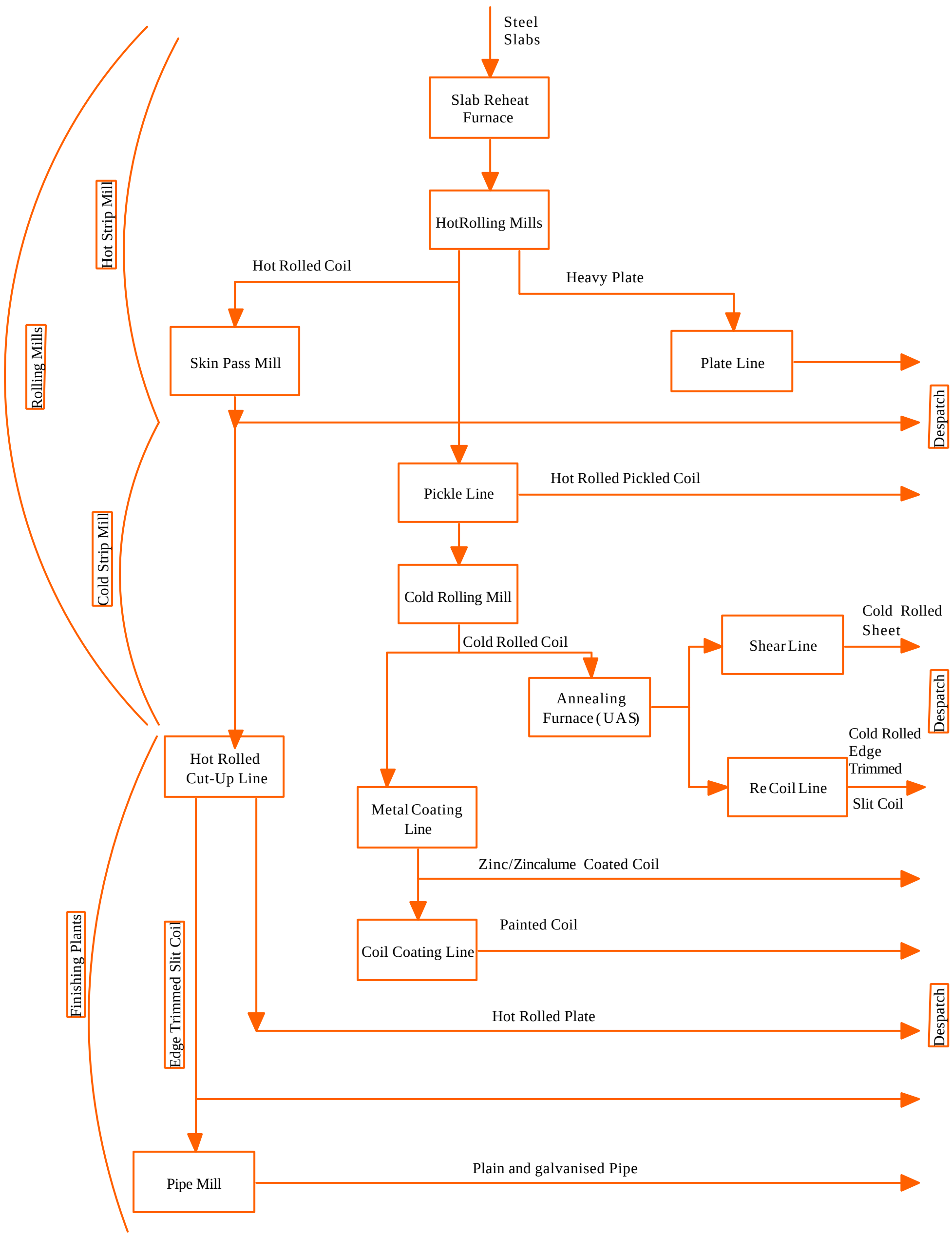

Figure 4: BHP NZS secondary production flow diagram[10].

3.5.2 Details of Pacific Steel plant production

The following information has been mainly sourced from a Pacific Steel publication[13] and with reference to **Error! Reference source not found.**.

Raw Materials Handling

Scrap material (both iron and steel, post consumer and industrial) is sorted, shredded (or reduced to size), and blended, ready for melting.

Electric Arc Furnace (EAF)
Scrap steel is melted with burnt lime and other fluxing agents, with oxygen being used to refine the composition. Careful control of the molten melt is performed, so that the broad specifications can be met. The corrected composition is poured into a refiner ladle when the required temperature is obtained.

Ladle Refining
Here, further refining is performed, where alloying elements are added to the steel. Argon gas is pumped into the liquid steel, stirring and homogenising the temperature and chemical elements. The ladle full of liquid steel is then sent to the billet caster.

Billet Casting
The steel is continuously poured into a tundish, which divides the steel into three strands, then finally into an oscillating mould of the desired billet dimensions. The billet is then cooled and cut to length for the rolling operation.

3.6 Environmental Impact Analysis

3.6.1 Introduction to analysis

As previously mentioned, the fundamental environmental impacts identified by the previous BRANZ report[1] are emissions to air, discharges to water, and solid wastes generated. For BHP NZS, the environmental profiling process starts with the raw material extraction of titanomagnetite sand, transport to mill, primary and secondary production. For Pacific Steel, the process starts with the collection of the post-industrial scrap steel and finishes at the end of primary production.

3.6.2 Emissions to air

A. Fuel emission factors for the mining, transportation and energy generation were obtained from Forintek research guidelines[5]. For the fuel types and their associated emissions, refer to Appendix B.

B. The following assumptions were made:

- All energy used in quarrying was in the form of diesel fuel for Pacific Steel, and electricity for BHP NZS.
- For BHP NZS, titanomagnetite sands are sourced from beaches, which require an estimated 17 MJ per tonne extracted[28]. For the mining of all the other raw materials, a flat 27 MJ/tonne is applied, as for the other reports[1,2].
- For BHP NZS, the amount of transportation energy used for the slurry is minor and factored into the mill's overall operations.

C. For BHP NZS's secondary steel (plate) production, the only significant input was the energy used (natural gas and electricity) for the reheating and rolling processes. For a breakdown of energy use by stage, refer to Appendix H.

3.6.3 Discharges to water

A. It is impossible for water to be traced through the mills' operations, due to the way the water is re-circulated and partially treated in many different processes. Thus, water effluent levels for each site are derived as a single figure, with no differentiation between the primary and secondary processing. The resulting amalgamated figure is proportioned according to weight output for the finished product (in this case steel plate). Thus, for a simple product such as steel plate (i.e. one that has only a minimum amount of surface treatments) it is likely that an overestimation of the pollutants will result. However, this is an indicative figure, and is the best currently available.

B. Water quality figures for the extraction of the titanomagnetite were not available.

4. EMISSIONS TO AIR

4.1 General

Most of the emissions to the atmosphere listed within this section are documented as part of resource consent requirements for air discharge permits under the Resource Management Act. Additional information was sourced mainly from the mills' site environmental officers. Emissions data is derived, estimated or calculated from a wide variety of sources: in-situ sampling, stack monitoring, historical data collection, process analysis, statistical methods, ambient air monitoring, computer-based dispersion modelling, design criteria and overseas parallel studies.

At the time of the data collection (1998), the mills' conducted a limited number of air quality tests on a regular basis. At BHP NZS the only tests performed on a regular basis are for particulates (a solid waste, rather than an emission to air as defined by Forintek[5]) and HCl[11]. At Pacific Steel, the only air quality monitoring that is performed is for particulates (a solid waste), dioxins[19] and PCB's. Ambient air is monitored using regular elemental analysis.

The major pollutants dealt with in this section are:

- *Sulphur oxides:* (both sulphur dioxide and sulphur trioxide). Sulphur dioxide is a colourless gas that, when inhaled, affects the mucous membrane and is a bronchial irritant. Sulphur trioxide is a major contributor to acid rain, and also has adverse health effects when exposures are high.

- *Oxides of nitrogen:* stimulate ozone production and are an important contributor to acid rain and photochemical smog.

- *Carbon dioxide:* the major international greenhouse gas, responsible for about half of the enhanced greenhouse effect. In 1990, BHP NZS emissions accounted for about 6% of the nation's total CO_2 emissions, while Pacific Steel contributed about 0.6%.

- *Carbon monoxide:* is toxic at high concentrations (by reducing the oxygen carrying capacity of blood) and is linked to ozone depletion.

- *Methane*: an important greenhouse gas, responsible for about 25% of its effect. Coal mining is one of its major sources.

For each pollutant, its major source(s) and the measured or estimated concentration levels are listed for each of the three stages; raw material extraction; transport to mill; primary production. In the case of BHP NZS, secondary production is included also. For some pollutants, relevant guidelines or standards are quoted. For the emission values for the various fuel types, refer to APPENDIX B. A more comprehensive breakdown of the sources of the pollutants can be found in APPENDIX C.

4.2 BHP NZS Emissions to Air

For a summary of BHP NZS's emissions to air, refer to Table 3. For a background on how the figures were developed, refer to Table 20 and Table 21 in Appendix C.

4.2.1 BHP NZS emissions due to raw material extraction

Negligible air emissions result from the electrical earth moving machinery (i.e. bucketwheel excavators and shiftable conveyors) in the quarrying and moving of iron-sand. It has been estimated that it takes 17MJ to extract one tonne of titanomagnetite[28]. A flat energy intensity figure of 27MJ/t was applied for the extraction of coal and limestone, as for the other studies[1,2].

4.2.2 BHP NZS emissions due to raw material transportation

The air emissions derive from the collection of scrap steel, coal and limestone, and result from their transportation. As can be seen in Table 21, the main source of emissions for transportation was due to the haulage of Huntly coal.

4.2.3 BHP NZS emissions due to primary production

Primary production is by far the most energy intensive of all the steel making stages, accounting from over 95% of all the energy use. Due to its significance in terms of both energy and emissions, a more detailed breakdown of this stage will be performed.

CO_2 EMISSIONS

About 90% of the carbon dioxide emitted is from the use of coal to reduce iron sand to metallic iron. There are several similar coals used for BHP NZS's steel making process: Huntly East, Huntly West, Rotowaro and Weavers Mines, having an average calorific value of around 21.5 MJ/kg[10]. (Calorific values are subject to an area being mined at any one time, so this figure is always an approximation).

In September 1995 BHP NZS signed a voluntary agreement with the Ministry of Energy for the reduction of CO_2. The voluntary agreement BHP NZS made was to reduce carbon dioxide emissions from 2.705 t CO_2/t slab in 1990 to 2.488 t CO_2/t slab in the year 1999/2000. The voluntary agreement was met in the 1997/1998 business year with a carbon dioxide emission factor of 2.38 t/CO_2 per slab, due to the commissioning of the kilns co-generation plant and a reduction in coal use.

The sources of BHP NZS's CO_2 emissions, include:

1. Natural gas, which as well as the products of combustion is 4.5% by weight CO_2.
2. Electrodes, used in the melters and the EAFs, which are almost all (93.5%) carbon.
3. Coke, which is fed into the KOBM to aid the conversion process, and is 88% carbon by weight.

4. Limestone, used for purification purposes.
5. Diesel, mainly for the many vehicles that operate on site.

The predicted change in emissions on a per tonne of cast slab basis between 1990 and 2000 is shown in Table 3.

Table 3: Summary of BHP NZS's actual and predicted CO_2 emissions [6].

Source of CO_2	1998 (actual) (t CO_2/t slab)	2000 (estimated) (t CO_2/t slab)
Imported electricity	0.003	-0.098
Coal	2.097	2.358
Natural gas	0.202	0.162
Electrodes	0.010	0.012
Coke	0.047	0.014
Limestone	0.024	0.033
Diesel	0.006	0.007
Total	**2.389**	**2.488**

SO_X EMISSIONS

Sulphur oxide discharges can be approximated from a knowledge of the coal consumption rate and a mass balance. BHP NZS's MHF stacks are the main source of sulphur oxide emissions, each one emitting approximately 23.5 kg per hour. This equates to giving a maximum off-site predicted value of 100 micrograms per cubic metre over a one hour average.

It was estimated that the on-site annual SO_x emission is 722[29] tonnes (1.15 kg/tonnes of slab produced[30]), with the geothermal portion of the off-site electricity production adding another seven tonnes, giving a total of 729 tonnes for the 1998 year (or **1,149 g/t slab** produced).

NO_x EMISSIONS

The MHF stacks are the main source of nitrogen oxide emissions - each emit approximately 2.4 kg per hour of nitrogen dioxide and 27 kg per hour of nitric oxide respectively, with the kilns, the slab reheat furnace and the KOBM and VRU2 stacks also emitting some nitrogen oxide.

It was estimated that the annual on-site NOx emission is 940 tonnes (1.5 kg/tonnes of slab produced[30]), with electricity generation contributing an extra 77 tonnes, giving a total of approximately 1017 tonnes over the 1998 year (or **1,618 g/t slab produced**).

CO EMISSIONS

The main sources of carbon monoxide are from the kilns and MHFs. Carbon monoxide emission monitoring has been performed on one MHF and two of the kilns, using a continuous gas analyser.

It was estimated that the annual on-site CO emission is 235 tonnes[30], with electricity generation contributing an extra 10.6 tonnes, giving a total of approximately 245.6 tonnes over the 1998 year (or **391 g/t slab** produced).

CH_4 and VOC's EMISSIONS

The main source of methane and volatile organic compound emissions during primary production arise from the importation of electricity, however, other sources include the burning of coal, coke, natural gas, diesel and petrol. Imported electricity (that is, generated off-site) equated to 475,679 MWh or 1.71 PJ in 1998. It was generated using the following fuel proportions: black coal 1%; gas 19%; hydro 70%; and geothermal 5%[30]. Refer APPENDIX B for fuel type emission rates.

It was estimated that the 'on-site' emissions of CH_4 equalled 13.9 kg/tonnes per year with electricity production contributing another 22.7 t/year, giving a total of 36.6 t/year (or **58g/t slab** produced). The only volatile organic compound emissions that could be derived were those from electricity generation (at 1.7 t per year), as no site (or point) monitoring is performed[30]. Thus, VOC emissions are estimated to be approximately **3 g/tonne of slab**.

TRACE METAL EMISSIONS

Trace metal analysis has been performed on the main emitters: the MHF stack, the kiln stacks and the EAF and KOBM baghouses. Dispersion modelling was carried out, as well as analysis of roof supply drinking water in the area. These figures are accounted for in Section 6 so are not included in the emissions to air summary table, below.

Table 4: BHP NZS air-borne trace metal emissions.

TRACE METAL EMISSIONS TO AIR (source: site environmental data[30]) **(tonnes/year)**			
Zinc[A]	**Copper[B]**	**Lead[C]**	**Manganese[D]**
28.1	1.09	2.24	1.55

Key to Table 4
A = refer Section 2.12 in the site report
B = refer Section 2.11 in the site report
C = refer Section 2.13 in the site report
D = refer Section 2.14 in the site report

OTHER EMISSIONS

Other emissions from the mills include traces of boron, cobalt, chromium, as well as water vapour and odour emissions. They are not expected to have significant effects on air quality beyond the site boundary. Vehicular exhaust emissions are included in the estimations for CO_2 as part of the voluntary agreement between BHP NZS and the New Zealand Government.

4.2.4 BHP NZS emissions due to secondary production

Secondary production for heavy and light plates consist of two major processes - the re-heat furnace – which is gas fuelled, and the hot strip mill – which is electricity powered (refer to Table 22, Appendix C). The hot strip mill may be divided up into three separate sub-processes - the roughing mill, the finishing mill and the plate line. A simple proportioning system for energy (and its related atmospheric emissions) was applied on a weight-basis for steel plate. This was necessary due to the lack of relevant (disaggregated) data being collected on each of the various types of secondary product, making it impossible to derive a more accurate representation.

4.3 PACIFIC STEEL Emissions to Air

For a summary of Pacific Steel's emissions to air, refer to Table 6. For the background on how the figures were developed, refer to Table 23 - Table 25, Appendix C.

4.3.1 Pacific Steel emissions due to raw material extraction

The major emissions for raw material extraction are from the consumption of diesel in the quarrying and handling of the raw materials, as seen in Table 24, Appendix C (background). The mining of the other materials which make up the steel - calcined magnesite (MgO), ferosilicon (FeSi) and fero-vanadium (FeV) were not included in the emissions table because they are consumed in small quantities, and are therefore believed to be relatively insignificant.

4.3.2 Pacific Steel emissions due to raw material transportation

The emissions to air are mainly from the road, rail and marine transport in the collection of scrap steel, as derived by Alcorn[17]. Also, there are dust emissions from the unsealed roads. Secondary emissions are for sourcing raw materials such as coke (from China), silico-manganese (from Australia and China) and burnt limestone (from Waikato), as can be seen in Table 24, Appendix C (background).

4.3.3 Pacific Steel emissions due to billet production

The major emissions resulting for Pacific Steel are from the natural gas usage and the electricity usage. Electricity is used in the EAF and the ladle furnace. A small amount of gas is used for pre-heating the ladles. It should be noted that the electricity generation fuel-mix for off-site generation is assumed to be similar to that for BHP NZS – that is, mainly hydro-power sourced. The emission rates for the various gases were based on those of the Ministry of Commerce[16].

4.4 Summary of Emissions to Air

4.4.1 BHP NZS emission summary

Note: Figures may not add due to rounding errors.

Table 5: BHP NZS emissions to air to secondary production.

Summary of major BHP NZS emissions to air (1998) (g/tonne of finished plate)						
Stage/Pollutant	**CO_2**	**VOC's**	**CH_4**	**SO_x**	**NO_x**	**CO**
Raw Material Extraction	3237	3	1	0	1	0
Transportation	6,794	7	1	0	135	5
Primary Production	2,389,000	3	58	1,149	1,618	391
Secondary Production	47,511	4	4	1	188	14
TOTALS (for finished plate)	**2,446,542**	**16**	**64**	**1,150**	**1,943**	**410**

4.4.2 Pacific Steel emission summary up to primary production

Table 6: Pacific Steel's emissions to air to primary production.

Summary of major Pacific Steel emissions to air (1998) (g/tonne of billet)						
Stage/Pollutant	**CO_2**	**VOC's**	**CH_4**	**SO_x**	**NO_x**	**CO**
Raw Material Extraction	158	0	0	0	0	0
Transportation	48,444	86	13	0	656	170
Primary Production	204,965	11	26	126	342	24
TOTALS (for billet)	**253,567**	**97**	**39**	**126**	**998**	**194**

5. DISCHARGES TO WATER

5.1 General

Water is an essential resource to iron-making, steel-making, and finish processing. It is used for a large variety of cooling, transporting, and processing operations. Although large quantities of water are utilised during the manufacture of steel products, much of it is reused after some processing.

Of the four processes examined as part of this life cycle inventory (raw material extraction, transportation to plant, primary and finally secondary manufacture), the most significant discharges to water occur during the primary manufacturing stage. The BHP NZS operations are dealt with in more detail as their secondary stage was also examined, and more relevant information was available.

5.2 Operations at BHP NZS

Around one million cubic metres of water is in circulation at the BHP NZS mill in Glenbrook at any one time[31]. Most of the water on site is sourced from the Waikato river, with the rest being made up from stormwater collected on site.

Water used as part of the BHP NZS steel-making operations can be divided into two operations - slurry water and process water[31]. Slurry water is used for the transportation of the iron sand to the steel mill, while process water is required for plant cooling, waste gas cleaning, product rinsing, descaling, steam rinsing, chemical processes and general plant cleaning. The majority of the water intake – about 800 m^3 per hour – is used for the iron and steel-making process, while only about 300 m^3 per hour of slurry water is necessary. For the purposes of this study, the *gross process water requirements* for the manufacture of steel (at 800 m^3/hr or **11,153 l/t slab**, is used. Refer to Figure 5 for the process water balance.

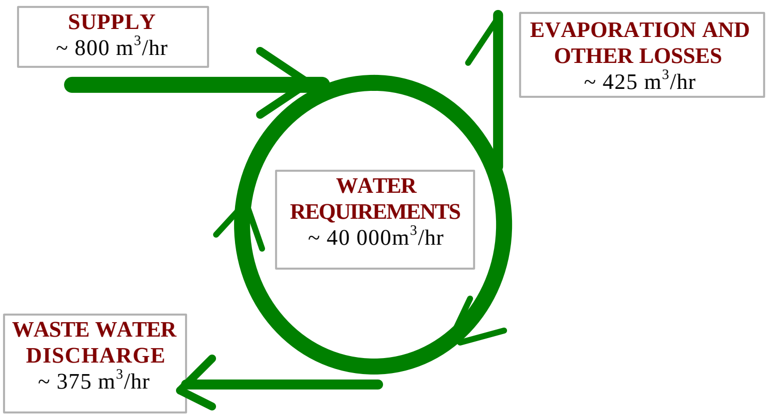

Figure 5: BHP NZS's steel mill water balance (excluding slurry water balance).

Over the last few years, with the steel mill at or near full production, about 22,000m^3 per day of river water[31] was extracted. This equates to approximately 0.09% of the mean Waikato river flow, which is such a low intake that it is seen as having a negligible impact on the river. For a schematic diagram of the location of the water uptakes and discharges, refer to Figure 6, Appendix F.

Spent slurry water is discharged into the Northside Stream. Spent water from the production processes on the Glenbrook site is discharged into the Northside or Southside Outfalls.

5.2.1 Process water

The pipeline that supplies the steel mill with process water is 15 km in length and buried in a trench about 1.7 m deep[31] (refer also to Figure 6). The process water passes through a variety of treatment stages, before usage at the mill[31]. These treatment stages produce three grades of water, according to its application:

- ***secondary*** water for direct cooling and gas cleaning,
- ***filtered*** water for rolling solution make-up and for supply to the softeners and demineralised units, and
- ***demineralised*** water for steam generation.

Various additives are used in the three grades of processing water[31]. Additives include polyaluminium chloride and polyelectric coagulant for speedy settling of clay material, and caustic soda for pH adjustment.

Around 99% of all the spent processing water used on site is recycled. (Because of this, it is impossible to apportion the effluent pollutants to the different iron, steel or finishing processes). Recycling is achieved through cleaning, cooling and recirculation operations. Waste water produced by the mill contains either large quantities of solids (mainly iron oxides, coal dusts, and ash), or chemicals. The remaining one percent of spent water is 'lost', due to leakage, contaminated water and evaporation. Evaporative losses are the largest of the three losses - accounting for 50-60% of the make-up requirement.

There are various types of waste water produced on site:

1. ***Cooling water****:* used to dissipate surplus heat, mostly by indirect methods where the water does not come into direct contact with the product or plant. It typically contains oxide scale, dusts, traces of biocides[§] and salts.
2. ***Process water***: produced as a result of the various chemical processes in the steel mill during rolling and coating. It typically contains dissolved solids, suspended solids and oil.
3. ***Scrubber water***: used to cool and clean waste gases, which contain significant quantities of solids washed out of the gases. It typically contains dusts, iron oxides, coal dusts, lime, ash and zinc.
4. ***Wash down water***: water used for general maintenance - housekeeping, cleaning vehicles and external cooling etc. In almost all cases this water enters the stormwater drainage system laden with suspended material.

Storm water is a special type of waste water being entirely externally generated, and is sourced from roofs, ground surface run-off, and ground water seepage. The total storm water catchment area for the industrial site is 64 hectares, and typically contains dusts. All storm water passes through large settling ponds.

Waste water and storm water are discharged from the mill at the Northside and Southside Outfalls (see Figure 6), with the Southside Outfall only receiving storm water during extremely high intensity rainfall. Storm water from the southern works catchment is recycled to the works water supply reservoir. The Northside Outfall receives the treated waste water discharges

[§] Used to reduce Legionella bacteria in the water.

from the iron-making, steel-making and some finishing processes. Storm water is collected from the entire northern catchment site, and is discharged to the Northside Outfall following treatment in large settling ponds. Some storm water is recycled to the site for washdown and other uses where fully treated water is not essential.

Discharges from both the Northside and Southside Outfalls go into the coastal marine area (called the mixing zone) in the Waiuku Estuary. The discharges are low in suspended solids, low in oil and grease, high in dissolved oxygen and contain moderate levels of dissolved solids (chlorides and sulphates) and extremely low levels of heavy metals. Table 26, Appendix D lists the water quality standards and mandatory requirements, specified under the existing water rights for the Northside and Southside Outfalls, required by the Territorial Authority.

5.2.2 Slurry water

Iron-sand is mined next to the Waiuku State Forest in the Maioro, and transported via an 18 km pipeline to the mill (refer to Figure 6 for a schematic representation). Water is taken from the Waikato river, mixed with the iron-sand into a slurry, and pumped under high pressure to the mill. No chemicals are used in the mining or slurry processing[31]. Up to 7,200 cubic metres of slurry water per day are required.

At the mill, the iron-sand and water are separated and clarified, extracting out the clay. The clarified water is discharged into the Northside Stream, with the clay sludge being landfilled. A small amount of waste water from the clay slurry does in fact discharge at the Northside Outfall. Slurry water cannot be reused in the steel-making process because of its periodically high chloride levels.

Slurry water extraction is on average 19 hours per day for four or five days. Average daily water extraction for the 1997/1998 year is 4,149 m^3/day. Additional water is taken from the river and used at the mine for washing the sand, which discharges to land and soaks away. For the purposes of this study, the *slurry* water requirements for the manufacture of steel equates to 970,866 m^3/yr or **1,545 l/t slab**.

5.2.3 Monitoring

BHP NZS performs a variety of water discharge examinations, in accordance with water rights conditions.

PROCESS WATER

Grab samples are taken off both the Northside and Southside Outfalls each morning, and tested for pH, suspended solids, dissolved oxygen and chemical composition. Flow proportionate composite samples are taken over the previous 24-hour period. Additional information gathered includes secondary water intake, landfill leachate and waste water streams upstream of the outfalls. Critical data - outfall flow rates, zinc levels, pH, suspended solids, discharge temperature, sea temperature, rainfall - is collated daily.

SLURRY WATER

The concentration and chemical composition of the clays in the slurry water are automatically monitored, to ensure proper dosing at the dewatering plant. The clarity of the water overflowing from the clarifier is continuously monitored with a turbidity meter, to check the concentration of suspended solids. The permit conditions for the discharge of slurry transport water dictate that not more than 30 grams per cubic metre of non-filterable residue (i.e. suspended solids) is allowed. This is monitored daily, using a grab sample. Dissolved oxygen is also monitored daily.

For a comparison of the slurry water composition before and after use, refer to Table 27, Appendix E. The only significant effect on the slurry water is an increased concentration of iron and a reduction in zinc levels. Otherwise, there is very little change in the dissolved metals contained in the original river water.

5.2.4 Concentrations of pollutants

A summary of the various concentrations of pollutants - heavy metals, solids and others - are examined at each source (i.e. the Northside Outfall and the Southside Outfall) separately.

PROCESS WATER

Spent process water enters the Northside and the Southside Outfalls and is discharged into the Waiuku Estuary. Water quality parameters monitored for the Outfall discharges include the concentration of copper, chromium, iron, and nickel, the temperature and dissolved oxygen. Compliance with these parameters has been close to 100%. Stormwater is collected in large settling ponds where the solids are removed. The cleaned water is then discharged into the Waiuku Estuary or recycled back into the site water circuits. The daily average concentrations for the two outfalls are shown in Table 28 and Table 29, Appendix G.

SLURRY WATER

Most slurry waste water is discharged to the Northside Stream, after having been clarified and settled. The rest of the water remains as moisture in the stacked iron sand concentrate. Although not measured, it is estimated that about 260-280 cubic metres per hour of water is discharged into the Northside Stream.

Statistical analysis shows that, from 938 grab samples during the 1993-1998 period, the average concentration is 23.7 g/m^3 of suspended solids in slurry water. It has been suggested that this type of sampling method may not provide a representative picture, so a portable composite sampler was used to further the investigation[31]. Ninety samples were taken, with the average of all the daily composite results at 112 g/m^3. However, this composite average is suspect due to an assumption made about the operating hours. Also, the results can not be compared due to the different data sets. It was assumed that the true average lies somewhere between the two averages, i.e. 23.7 - 112 g/m^3. For this LCI study, the 23.7 g/m^3 figure was used for suspended solid concentration.

5.2.5 Summary of discharges to water

The following information for the discharge of pollutants to the Northside Outfall, Southside Outfall and the Northside Stream is mainly sourced from the resource consent application document[31] and the annual site environmental estimate data[30]. The figures are based on discharges to drains, natural water courses and marine areas. This includes mine dewatering, surface run-off and tailings dam overflow. Figures do not include discharges to ponds or dams contained wholly on site.

The figures summarised in Table 7 are for the entire site, which includes rolling and finishing plants, in addition to the iron and steel-making facilities. This will result in an overestimation in the results for just the iron and steel-making facilities. Due to the nature of the water processing/recycling in the steel-making process, this overestimation is unavoidable. The daily concentration ranges for particular pollutants are averaged.

Table 7: BHP NZS discharges to water.

SUMMARY TABLE for Northside and Southside Outfalls (for the 1997/1998 Year)			
Pollutant	**kg of pollutant**	**Gram per tonne of slab**	**Data source**
Zinc	700	1.11	Site Environmental Data[30]
Suspended Solids	40,800	64.9	Measured
Iron	1,862	3.0	Site Environmental Data[30]
Chromium	23	0.037	Site Environmental Data[30]

The *Total Discharge for the Outfalls* is calculated using the following flow rates:

- For the Northside Outfall, waste-water discharge is about 7,400 m^3/day, while the storm water discharge is about 1,900 m^3/day.
- For the Southside Outfall, waste water discharge is about 900 m^3/day.

Thus, the combined discharge is about 10,200 m^3/day.

Although mercury, silver, lead antimony, cadmium, and cyanide analysis were included as part of the 1984 consent conditions, they have rarely been found to be above the detection limits of the laboratory equipment. As a result, that data has not been compiled for the 1998 consent information. Figures for these heavy metals are not included in this study.

For *slurry discharge water*, using an average of 23.7 g/m^3 of suspended solids multiplied by 270 cubic meters per hour, and operating for 95 hours per week[31], the yearly discharge equates to 31.6 tonnes to the Northside Ponds and Stream. This figure is an approximation, as sampling results vary considerably.

5.3 Operations at Pacific Steel

The water usage for Pacific Steel is about 180 m^3 per day, with around 460 m^3 being supplied daily, of which around 200 m^3 is used in the steel plant alone (with the rest going to the rod and bar mill)[32]. Details of the amount and type of pollutants resulting from the production of steel were not available for this report.

In 1992 a comprehensive stormwater treatment system was commissioned[33]. The stormwater from the Pacific Steel Plant is treated in a settling pond, where heavy metals, oil and large particles are removed though an artificial wetland. The discharge outlet is to a tidal inlet which connects to Manukau harbour. The stormwater treatment plant's system effectiveness can be gauged by comparing inlet pollutant concentrations with outlet pollutant concentrations. During the 1992-1997 period of operation, the reduction in suspended solids was 75% or better (the non-filterable residues were about 15g/m^3, with the total zinc concentration being about 0.1 g/m^3 at discharge).

6. DISCHARGES TO LAND

6.1 General

What are the solid wastes from the steel-making process, and how are they defined? The Forintek research guidelines define solid waste as "*any by-product of any manufacturing stage which has no purpose in the process and which must be stored or landfilled*"[5]. Thus, if a by-product is sold for further reprocessing in another industry (for example, slag, the fusible residue of the steel making process), it is not counted as being a solid waste material.

In the iron- and steel-making process, there are several types of solid wastes. Solid wastes arise in the steel-making process as a result of[12]:

- dust from waste gas cleaning.
- production of off-specification product.
- poor synchronisation between processes.
- equipment failure and process delays resulting in dumping of intermediate products.
- packaging.
- clean up of spills and leaks.
- clean up of fugitive emissions from processes and material transfer systems.

Another major type of solid waste is airborne particulates. Airborne particulates are very diverse in their chemical composition and physical properties[34]. They are emitted from mining, raw material transportation and processing activities, from both point and fugitive sources.

Particulates encompass a wide range of substances with particle sizes ranging from a few molecules to those with a diameter of over 100 microns. They are divided into four categories – smoke, deposited, suspended and visibility reducing. Two of these - *suspended* and *deposited* - are used as indicators for assessing the effects of emissions on air quality.

Suspended particulates are dusts or aerosols that stay suspended in the air for long periods. Generally, total suspended particulates have a diameter of up to 50 microns. Particulate matter which is less than 10 microns is known as PM_{10}. PM_{10} is a known respiratory irritant, penetrating the lungs and airways.

Deposited particulates are those which quickly settle on the ground or horizontal surfaces. They are monitored due to their nuisance effects, as they lead to dust settling on surrounding cars, windows etc.

The source of emissions from steel mills can be from either *point sources* (e.g. from chimneys and vents) or *fugitive sources* (e.g. from coal handling, and slag processing). *Point sources* can be relatively easily tested using sampling equipment at the vents. *Fugitive emissions* refer to those that enter the atmosphere without first passing through a system designed to control air flow. Fugitive emissions can be estimated from process associate tests, literature searches, and computer modelling. They are more random and intermittent in nature than point sources, and because of this, they are difficult to quantify.

In addition to those dusts generated at the mill site, quarrying activities generate large dust emissions. The estimate for the total particulate matter generated as part of quarrying and mining the raw materials was estimated to be in the region of 20g per tonne, for open cast mining[34]. Particulate emission is known to vary between sites, and is dependent on the rock type, location of the crushing facilities, extraction areas, topography, extraction rate, weather and prevailing wind[34]. Consultation with BHP NZS suggests that due to the coarse nature of the sand, it would be unlikely to stay in the atmosphere for any length of time, so would not be a pollutant out of the site[28].

The quantities and sources of solid wastes for each of the two steel mills were investigated. For the BHP NZS figures, the 1995/1996 year was investigated, as figures were unavailable for the 1998 year and it is believed that the differences between the two years are small[36].

6.2 Solid Wastes Due to Raw Material Extraction

6.2.1 BHP NZS

It is necessary to mine between 5-6 million tonnes of sand[28] yearly at the Waikato North Head site, to produce about 1.2 to 1.4 million tonnes of iron sand[37]. Bucket wheel excavators and shiftable conveyors are used to mine the sand, and transport it to a stockpile. Oversized material and debris (e.g. roots, stones, clay lumps etc) are removed or re-sized, with the titanomagnetite-rich sand being separated by magnetic or gravity separators. Rejected material is then returned to the mined areas and landscaped. The deposits are stabilised with marram grass and radiata pine trees.

Technically, rejected material is not really a waste product (not being stored or land filled), as it is very similar in composition to its original form. As far as 'waste' materials go, this is one which doesn't fall into any neat category. For the purposes of this research paper, it will not be classified as a waste material. This is in line with the way other raw material over-burden as a result of exploration, mining and processing is treated (for example, limestone and coal) in the Forintek study[5].

Table 8: BHP NZS waste from major raw material extraction.

Raw material	Tonnages (t)	Dust emissions (t)
Limestone	70,600	36
Coal	657,200	335
TOTAL		**371**

6.2.2 Pacific Steel

The major solid wastes resulting from raw material 'extraction'; (i.e. scrap acquisition and processing) for Pacific Steel are given in Table 9.

Table 9: Pacific Steel atmospheric emissions from major raw material extraction.

Raw material	Tonnages (t)	Dust emissions (t)
Burnt Limestone	8,000	4
Silico Manganese	1,900	1
Coke	1,900	1
TOTAL		**6**

6.3 Solid Wastes Due to Transportation

6.3.1 BHP NZS

There are negligible solid wastes due to the transportation of the raw materials. Iron sand is transported in a slurry form, to the Glenbrook site, by means of an 18km underground pipeline. This method has minimal effect on the environment – it is unobtrusive and efficient. The other major raw materials – coal, scrap steel and limestone – are all transported by rail.

6.3.2 Pacific Steel

There are negligible solid wastes due to the transportation of the scrap steel and other raw materials.

6.4 Solid Wastes Due to Manufacture

The main by-product of steel-making is slag. It is produced from four processes – the electric resistance melters, the EAF, the KOBM, and the VRU. Slag contains minerals such as silica, alumina, and titanium, and calcium and magnesium oxides[12]. Slag is a special waste material as it has a high inherent value (i.e. re-usability).

The other waste major material resulting from the manufacture of steel is particulates - both coarse and fine. There is also waste generated from the spent lime/refractories. This is dealt with elsewhere in the report.

6.4.1 BHP NZS slag

About 367,000 tonnes of slag (i.e. 0.58 tonnes slag of per tonne of steel) was produced by BHP NZS in the 1996 year. For more detail on slag and its uses, refer pg 4.

6.4.2 Pacific Steel slag

It was estimated that 35,000 tonnes of slag (i.e. 0.21 tonnes of slag per tonne of billet) was produced in 1998.

6.4.3 BHP NZS particulates

Natural background levels of suspended particulates range between 15 and 20 micro grams per cubic metre, mostly coming from pollen and wind blown dust. Over the past two decades, total suspended particulate levels at the site boundary have been measured to be in concentrations in the range of 10-40 micro-grams per cubic metre.

During the winter time, outside the BHP NZS site, deposited particulate levels are around 2 grams/m^2/30 days. Higher deposition rates may occur during windier, drier months. This data includes background dust levels and the effects of fugitive emission sources as well as point sources, so it is an overestimation of particulates due to the process.

Total particulate emissions from point sources on the BHP NZS site are about 103 kg/hour, or around 900 tonnes per year. It should be noted that not all point sources emit continuously, with the highest single source being the KOBM secondary fume baghouse[28].

Table 10 shows the estimated fugitive emissions from the BHP NZS site, and their sources.

Table 10: BHP NZS particulate emissions from *fugitive* sources only[12].

BHP NZS: FUGITIVE EMISSIONS FOR PRIMARY PLANT	
Emission Source	**Current Rate (t/year)**
FINE DUST AND FUME	
SRNZ slag tipping	55
Plating	43
Fume ex the VRU2 building	23
Fume ex the EAF enclosure	11
SRNZ ladle deskulling	2
COARSE DUST	
Coal handling and coal pile losses	131
SRNZ slag processing	100
Unsealed roads	58
RPCC dumping	28
Dust ex the bottom of the EAF and KOBM baghouses	25
Dust ex the melter baghouses	4
Ironsand and stockpile losses	2
Sealed roads	2
Dust ex the RPCC transfer system	1
TOTAL	**485**

Dispersion modelling of the BHP NZS mill site and surrounding districts has been performed for particulates. Contours, showing the different concentration levels, have been charted. Although there is no air quality guideline for deposited particulate, it is recognised that deposition levels above about 4 mg/m^2 per 30 days can result in public complaints. The USA EPA guideline for that period is 5 g/m^2 for residential and 10 g/m^3 for industrial areas[10]. Modelling was based on figures published by the USA EPA for a variety of metallurgical processes (the exception to this was the KOBM baghouse, where field testing data could be used). Through modelling, it was found that without exception, the predicted emission values from the 14 major point sources (equating to 90% of all emissions) were below those required for the licence emission limits.

Table 11: Modelled particulate emissions from major *point* sources only.

BHP NZS: MAJOR POINT SOURCE PARTICULATE EMISSIONS FOR PRIMARY PRODUCTION ONLY[29]				
Source	**Current Rate (g/s)**	**Operating hours/year**	**Annual Output (t/year)**	**Licence (g/s)**
MHF's (x4)	*1.0*	*8600*	*124*	*3.5*
Kilns (x4)	*1.1*	*8600*	*136*	*2.2*
Slagside baghouse	*0.7*	*4000*	*10*	-
KOBM flare	*1.0*	*8200*	*30*	*1.4*
KOBM baghouse	*7.8*	*8200*	*230*	-
VRU	*2.2*	*1000*	*8*	*1.3*
EAF baghouse	*3.9*	*8000*	*112*	-
Melter flare stacks (x2)	*0.3*	*8000*	*16*	*0.3*
Consumption flare	*0.1*	*8000*	*3*	-
Metalside baghouses (x2)	*0.1*	*4000*	*2*	-
RPCC hopper	*0.2*	*2000*	*1*	-
		(total)	***(672)***	

Occasionally, molten iron cannot be processed into steel. This may be due to plant break-down, out-of-specification metal, or other process reasons. Usually, this results in the pouring of the metal onto the ground in a dedicated area - this is called 'plating'. This steel is later recycled back into the steel-making process. During the pouring of the steel, particulate is released and carried into the air as the large surface area oxidises (forming iron oxide fumes) at a high temperature.

The annual emissions from plating are significant – accounting for about 3% of total site emissions. Lately, improved equipment reliability and coordination have lead to reductions in the levels of plating: 1994/95 – 51,900 tonnes; 1995/96 – 41,700 tonnes; 1996/97 – 37,900 tonnes; and most recently, 1997/98 – 46,000 tonnes.

Total primary production particulate emissions from the BHP NZS site for plate production (both fugitive and point sources) equal 1,157 t/yr (or **1,841 g/t slab** produced). This value is less than the 1,387 t/yr quoted in correspondence with BHP[38] which also accounts for processes not associated with plate production. The emissions due to secondary production are assumed to be negligible, as the steel is essentially only being rolled.

6.4.4 Pacific Steel particulates

For the Steel Plant: The main dust and fume emissions are from scrap handling (minor), the EAF when charging up the scrap in particular (major), the stack of the EAF bag house, and from the water spray chamber of the continuous casting machine (steam). Fumes from the ladle furnace are minor to the external atmosphere.

At a resource-consent related hearing meeting[39] Pacific Steel stated that:

- fine particulates (PM_{10}) are greater than the Ministry for the Environment's guideline of 120 ug/m^3 for less than 1% of the time.
- deposited particulate monitoring was discontinued in January 1996, but it is expected that levels will still be causing a nuisance off-site at times.

There was an estimated total of 1,900 tonnes of dusts produced, mainly resulting from the operation of the electric EAF, but also from the spark arrester chambers, in 1998. This figure does not include some fugitive emissions, but a more detailed breakdown was unavailable.

6.4.5 BHP NZS landfilled material

Most of the information in this section was either sourced from the BHP NZS pamphlet[40] or from a cleaner production report[12].

BHP NZS operates a landfill on site, for unwanted materials that are not hazardous (hazardous materials are taken offsite for treatment). About 150,000 tonnes of waste material is deposited in this landfill each year (see Table 12). The 12 major waste streams summarise the landfill wastes for the 1995/1996 year. Table 12 does not include wastes which are reused/recycled/sold.

Table 12: BHP NZS's landfill waste stream source[12].

BHP NZS WASTE STREAM TO LANDFILL	1996 Quantity (tonnes)
Clay minerals (from slurry)	19,852
Prime RPCC dumped	2,658
Reject RPCC dumped	5,718
Accretions	11,573
Other RPCC (cleaning)	7,000
Melter bag house dust (metal/slag)	493
Ladle deskulling scrap	4,401
VRU1 knock-out box dusts	2,050
VRU1 and KOBM bag house dusts	1,323
EAF Baghouse dusts	3,116
Dewatered waste gas sludge	80,934
Pond cleaning wastes	11,388
TOTAL	**152,502**

Notes on Table 12

1. 'Total' weight includes the moisture content of the material. For example, the dewatered waste gas sludge is comprised of about 15% solids; and the clay minerals have a solid content of about 60%.
2. Based on a proportion of production, the amount of landfilled wastes from the sources above for the 1998 year (as opposed to the 1996 year) would be approximately 130,500 tonnes (which equates to **208 kg/t slab**).
3. The wastes are a mixture of carbon, iron, calcium oxide, silicon dioxide, aluminium trioxide, sodium dioxide and zinc.
4. These figures are (for the most part) estimations, and may be out (due to 'unaccountabilities') by up to 18% for the iron and steel-making process, and 43% for the slag-related operations[12].
5. It is assumed from the production flow charts that all of the slag going into SRNZ is reused, not tipped.
6. The figures above account for the amount of steel that is extracted from the slag by-products, and is then reused in the steel slab-making process, i.e. metallic recovery.
7. The figures do not account for any material landfilled as a result of plate production.

6.4.6 Pacific Steel landfilled material

It was estimated that in 1998 approximately 33,145 tonnes of bag house dust was landfilled. This estimation is based on the known production/dust ratio, using on 1995 figures.

6.4.7 BHP NZS ferrous metal recovery

In BHP NZS's operations, about 100,000 tonnes of ferrous scrap is used yearly[41]. As of October 1998, BHP NZS discontinued to buy-in scrap as the EAF closed down[41].

6.4.8 Pacific Steel metal recovery

At Pacific Steel, all scrap steel was sourced externally. In 1998, this equated to 163,000 tonnes, all sourced from SIMS Pacific Metals.

6.5 Summary of Solid Wastes

6.5.1 BHP NZS

Table 13 shows the waste materials as a proportion of the total production for the year.

Table 13: Summary of solid wastes for BHP NZS steel-making process.

Waste Material	BHP NZS (tonnes per year)	BHP NZS - Slab (kg waste/t slab)
(Slag - all reused)	*(367,000)*	*(584)*
Particulates		
– raw material extraction	371	0.590
– transport	neg.	neg.
– manufacturing	1,157	1.841
TOTAL		**2.431**
Landfilled	130,500	0.208

6.5.2 Pacific Steel

Table 14 shows the solid wastes as a proportion of billet production (143,000 tonnes for 1998). Note that, for Pacific Steel, steel plate is not produced, so solid wastes are only accounted for up to the end of billet production.

Table 14: Summary of solid wastes for Pacific steel-making process.

Waste Material	Pacific (tonnes per year)	Pacific - Billet (t waste/t billet)
Slag	23,187	0.162
Particulates*	1,900	0.013
Landfilled	33,145	0.232

* *Air emissions from only the EAF bag house and some fugitive sources. Thus this is likely to be an underestimation.*

7. SUMMARY OF ENVIRONMENTAL PROFILES

7.1 BHP NZS Environmental Profile

Table 15: BHP NZS Resource Inventory Table.

FOR ONE TONNE OF PRODUCT	
INPUTS	**STEEL PLATE**
Carbon Electrodes (kg)	**2.21***
Coke (kg)	**14.61***
Coal (GJ)	**22.38***
Coal (kg)	**1,087**+
Diesel (GJ)	**0.24**
Diesel (L)	**6.546**#
Electricity off-site (MWh)	**1.194**#
Iron Sand (kg)	**1,548**
Limestone (kg)	**54.43***
Natural Gas (GJ)	**4.058**#
Processing Water (L)	**11,153**
Slurry Water (L)	**1,545**
Scrap Metal (kg)	**283**+
EMISSIONS	
Carbon Dioxide (g)	**2,446,542**
Volatile Organic Compounds (g)	**16**
Methane (g)	**64**
Nitrogen Oxides (g)	**1,943**
Carbon Monoxide (g)	**410**
Sulphur Oxides (g)	**1,150**
EFFLUENTS	
Suspended Solids (g)	**65**
Zinc (g)	**1**
Iron (g)	**3**
Chromium (g)	**0.04**
SOLID WASTES	
Particulates (kg)	**2.431**
Slag (kg)	**Nil - all reused**
Landfilled (kg)	**208**

KEY
* Sourced directly from BHP NZS's Voluntary Agreement Paper[6].
# See Appendix H for a contribution breakdown, by stage.
+ From personal communication with Claire Jewell, BHP NZS 23 Feb 1999.

7.2 Pacific Steel Environmental Profile

Table 16: Pacific Steel Resource Inventory Table.

FOR ONE TONNE OF PRODUCT	
INPUTS	**BILLET**
Burnt Lime (kg)	**48.5**
Silico Manganese (kg)	**11.5**
Coal (kg)	**11.5**
Electricity-off-site (GJ)	**1.72**
Diesel (L)	**1.1**
Processing Water (L)	**398**
Scrap Metal (kg)	**988**
Carbon Electrodes (kg)	**3**
Oxygen (m^3)	**24.7**
EMISSIONS	
Carbon Dioxide (g)	**253 567**
Volatile Organic Compounds (g)	**97**
Methane (g)	**39**
Nitrogen Oxides (g)	**998**
Carbon Monoxides (g)	**194**
Sulphur Oxides (g)	**126**
EFFLUENTS	
Suspended Solids (kg)	**unknown**
Zinc (kg)	**unknown**
Iron (kg)	**unknown**
Chromium (kg)	**unknown**
Nickel (kg)	**unknown**
Copper (kg)	**unknown**
Dioxins/Furans (kg)	**unknown**
SOLID WASTES	
Particulates (kg)	**13**
Slag (kg)	**162**
Landfilled (kg)	**N/a**

8. CONCLUSIONS AND RECOMMENDATIONS

This study investigated steel-related environmental inputs and outputs resulting from the raw material extraction, transportation and manufacture, for the New Zealand case. Two steel manufacturing plants were investigated: BHP NZS and Pacific Steel. The secondary manufacture of only one steel product was examined – structural steel plate. The methodology used was based on a Canadian study conducted in 1993.

8.1 Conclusions

- The environmental profile established for New Zealand-made steel (plate) is preliminary, due to the:
  - complexity of the steel mills' operations (making a detailed study problematic), and
  - difficulty in obtaining representative (i.e. 'typical') operational figures due to changing manufacturing technologies and the amalgamation of data.
- The environmental profiling of BHP NZS's operations was able to be conducted in significantly more detail than Pacific Steel's, largely because of a masters thesis produced by a BHP NZS employee in 1997. Thus, the level of accuracy and detail of environmental reporting is likely to be greater for BHP NZS's operations.
- A comparison of the New Zealand inventory data (circa 1998) with the Canadian inventory data (pre-1993) was not performed (with the exception of total embodied energy requirements), due to:
  - the vastly differing methods of manufacture – with the New Zealand manufacturing method being unique in the world, where the principal raw ingredient is titanomagnetite-rich sand, and
  - the studies being conducted nearly a decade apart, which has implications for technology, energy efficiency and related emissions.
- The total energy requirement for the 'cradle-to-the-gate' production of steel plate (at approximately 32 GJ/tonne) aligns very closely to a previous independent New Zealand embodied energy studies[44]. Surprisingly (considering the significantly different manufacturing techniques), this embodied energy figure is comparable to Australian data as well (for example Lawson[45], gives an embodied energy value of 34 GJ/t).

8.2 Recommendations

- A more industry-targeted questionnaire be produced and sent out to the two New Zealand steel manufacturers, for the next update (or follow-up study). The questionnaire would largely be based on (and extend) the information found in this study report.
- A follow-up industry study should be performed every four years, to keep up with advances in processing technology and changing operations.
- The environmental profiles and resulting contributions of recycled steel-use and electrode manufacture should be further explored. This study report was unable to explore this to a satisfactory depth. The latest treatment of recycled steel, in particular, in international environmental profiles should be examined, to keep abreast of any progress towards an international accepted standardised methodology.
- The environmental profiles resulting from the many treatments and coatings incurred as part of steel's secondary manufacturing processes should be further explored. Examples of these treatment systems include: pickling; annealing; zinc-aluming; galvanising; and anodising. The environmental significance of these is currently unknown.

This study report was heavily reliant on the participation of the environmental officers of the two steel manufacturing plants and their collected (whether for resource consent information or other purposes) data.

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APPENDIX A: CONVENTIONS USED

1. System Boundary Limits

Essentially, the "*boundary serves to include all the essential information while excluding externalities which would not significantly increase the accuracy of the estimates*"[5]. The depth of analysis for this study is equivalent to a Level II analysis as determined by the International Federation of Institutes for Advanced Studies[42], which typically captures 90-95% of the full impacts. Thus, the boundary includes the acquisition, storage and transfer of raw materials. The boundary does not include the construction of plant and vehicles, maintenance and administration and transportation of people.

This research project focus is on the production of steel billet and two structural steel products. The Forintek study[4] is considerably more comprehensive than this BRANZ study, examining many structural and non-structural end products. The boundary limit for this study is "*the acquisition (i.e. raw material extraction and transport to plant, storage, and production) of two structural (engineering) products*". It does not include the transport of the finished engineering products to the various wholesale markets.

Accounting for ancillary materials, that is material which is not used directly as a part of the product, is done in the following manner. If ancillary materials make up 2% of inputs, then they should be accounted for. The exception to this is the inclusion of any material (no matter how small), which has extraordinary effects in its extraction/use/disposal.

2. Data Categories and Quality

The following standard data categories and quality (adapted Forintek[5]) are used in this report:

- Data provided by industry should be designated as measured (M), calculated or modelled (C), or estimated (E).
- The most recent data should be used for unit factor calculations and the dates of the data should be noted.
- The figures used should all be industry averages, with regional breakdowns where feasible.
- For broad categories (such as particulates), some further characterisation should be provided.
- Ancillary materials must be accounted for if any single material makes up greater than or equal to 2% of inputs (by mass), or any group of ancillary materials which make up greater than or equal to 10% (by mass).
- Estimations for transportation energy use include only the combustion energy and the empty back hauls. Emissions to air from transportation to be included in the inventory.
- All quantities to use SI units.
- The units for energy, air emissions, liquid effluents and solid wastes for production will be normalised by unit of output (i.e. ensuring year to year comparability of figures by adjusting them for changes in production).

3. Standard Concepts

The following standard conventions[5] are used in this report:

Non-domestic Production: Imported materials will be factored into the domestic product based on the proportion of imports. Transportation factors for imports will be added based on the location, haulage distances and typical modes of transportation.

Process Feedstocks: The energy value of fossil hydrocarbons used as process feedstocks will be included in the gross energy figures for the product as if they were burnt as fuels.

Wastes and Recycling:

- Wastes that are dumped must be environmentally accounted for.
- The use of industrial waste from other industries (feedstock) is considered to be 'free input' carrying no resource-use, energy or pollution impacts except for that from transport.
- Post consumer waste is assumed to have no energy or other environmental cost for its extraction or original processing, and only transportation energy and the environmental impact of its use in the new production process is accounted for.
- Internal recycling is translated to improved efficiency (input/useful product) and reduced waste.
- Waste energy reclaimed from within a plant will not be treated separately, but will appear as improved overall energy efficiency of the process.

Multiple Products: If several products are derived from one plant, with no way of separating the data:

a) if the differences in product processing are relatively minor, the energy and emissions will be apportioned on a mass or volume basis, or

b) if there are significant differences (i.e. $\geq 10\%$ of the gross figures for raw material, energy or emissions), the energy and emissions should be apportioned on the basis of the different steps required for each product.

APPENDIX B: CONVERSION FIGURES AND EMISSION RATES

1. TRANSPORTATION EMISSION RATES

Table 17: Transportation energy emissions (adapted from Forintek[5]).

Fuel Type/Units	CO_2 t/TJ	VOC's t/PJ	CH_4 t/PJ	NO_x t/PJ	CO t/PJ	SO_2 t/PJ
Road Diesel	70.7	86.9	21.7	807	443	-
Marine Diesel	70.7	390	45.0	240	180	-
Rail Diesel	70.7	390	45.0	240	180	-

2. ATMOSPHERIC EMISSION RATES FOR ELECTRICITY GENERATION

Table 18: Emission rates[16] for various fuel-types.

Emission rates for electricity generation-related fuel types (t/PJ)				
Gases	**Black Coal**	**Natural Gas**	**Hydro**	**Geothermal**
CH_4	0.7	3	0	254
NO_x	361	220	0	0
CO	9	32	0	0
SO_x	387	0	0	0
VOC's	5	5	0	0

Note: Black coal having a calorific value of 21.5 GJ/t is approximately of the 'medium' grade (see Table 12.2.7[16]). This gives a corresponding SO_x emission factor of 387 kg/TJ.

3. ATMOSPHERIC EMISSIONS FOR NATURAL GAS

Table 19: Emission rate for natural gas[43].

Component	Emissions Rate for *Natural Gas* (t/PJ)
CH_4	1.4
NO_x	250
VOC's	5
N_20	0.01
CO	18
CO_2	57 300

APPENDIX C: EMISSIONS TO AIR

BHP NZS

BHP NZS production for the year 1998 is 628,360 tonnes of steel slab.

Table 20: BHP NZS emissions to air due to raw material extraction.

BHP air emissions due to **Raw Material Extraction**	Fuel Type	Tonnages	Mining/quarrying energy	Energy Used	CO_2 emissions	VOCs emissions	CH_4 emissions	NOx emissions	CO emissions	SOx emissions
Material / Units		**(t)**	**(MJ/t)**	**(MJ)**						
Coal	Diesel	657,177	27	1.77E+07	1,254	1.54	0.39	0.00	0.00	0.00
Limestone	Diesel	70,590	27	1.91E+06	135	0.17	0.04	0.00	0.00	0.00
Totanomagnetite	Electricity	972,546	17	1.65E+07	645	0.02	0.22	0.75	0.10	0.00
TOTALS (t/yr)					**2,034**	**1.72**	**0.65**	**0.75**	**0.10**	**0.00**
TOTALS (g/t slab)					**3,237**	**3**	**1**	**1**	**0**	**0**

Table 21: BHP NZS emissions to air due to transportation.

BHP air emissions due to **Transport**	Material	Distance (incl. backhaul)	Transport Mode	Combustion energy	Energy Used	CO_2 emissions	VOCs emissions	CH_4 emissions	NOx emissions	CO emissions
Material / Units	**(t)**	**(km)**		**(MJ/t-km)**	**(MJ)**					
Scrap Steel (Nth Is)	88,921	200	Road	1.18	2.10E+07	1,484	1.82	0.46	16.94	9.30
Scrap Steel (Auckland)	44,460	120	Rail	0.49	2.61E+06	185	0.18	0.02	3.66	0.15
Scrap Steel (Hamilton)	44,461	210	Rail	0.49	4.58E+06	323	0.32	0.04	6.41	0.26
Limestone (Waitomo)	70,590	310	Rail	0.49	1.07E+07	758	0.75	0.08	15.01	0.61
Coal (Huntly)	657,177	140	Rail	0.49	4.51E+07	3,187	3.16	0.35	63.12	2.57
TOTALS (t/y)					8.E+07	**4,269**	**4.23**	**0.47**	**84.53**	**3.44**
TOTALS (g/t slab)						**6,794**	**7**	**1**	**135**	**5**

Table 22: BHP NZS emissions to air due to secondary production.

BHP STEEL PLATE MANUFACTURE EMISSIONS	*Source*	**Operating Hours (per yr)**	**ENERGY USED (GJ)**	CO_2 emission	CO emissions	SOx emissions	NOx emissions	CH_4 emissions	VOC emissions	Particulates
Gross emissions (t/yr)	*Re-heat furnace*	6,000	9.99E+05	5.72E+10	2.E+07	neg	2.60E+08	1.40E+06	4.99E+06	3.46E+06
NETT emissions (t/yr)	*Re-heat furnace*	6,000	2.00E+04	1.14E+09	3.59E+05	neg	5.19E+06	2.80E+04	9.99E+04	6.91E+04
Gross Emissions (t/yr)	*Hot Strip Mill*	4,000	3.00E+05	1.17E+10	1.85E+06	1.16E+06	1.36E+07	3.98E+06	3.00E+05	5.47E+06
NETT emissions (t/yr)	*Hot Strip Mill*	4,000	6.00E+03	2.34E+08	3.70E+04	2.32E+04	2.72E+05	7.97E+04	6.00E+03	1.09E+05
	TOTAL NETT emissions (t/yr)			**1.38E+09**	**3.96E+05**	**2.32E+04**	**5.46E+06**	**1.08E+05**	**1.06E+05**	**1.79E+05**
	TOTAL NETT emissions (g/t slab)			**47511**	**14**	**1**	**188**	**4**	**4**	**6**

PACIFIC STEEL

Pacific Steel production for the 1998 year is 143,000 tonnes of steel billet.

Table 23: Pacific Steel emissions to air due to raw material extraction.

Pacific Steel emissions due to raw material extraction	Fuel Type	Tonnages	Mining/quarrying energy required	Energy Used	CO_2 emission	VOCs emissions	CH_4 emissions	NOx emissions	CO emissions
Material / Units		(t)	(MJ/t)	(MJ)	(t/y)	(t/y)	(t/y)	(t/y)	(t/y)
Burnt Limestone	Diesel	8,000	27	216,000	15.271	0.019	0.005	0.000	0.000
Coke (from China)	Diesel	1,900	27	51,300	3.627	0.004	0.001	0.000	0.000
Silico Manganese (Australia)	Diesel	1,900	27	51,300	3.627	0.004	0.001	0.000	0.000
TOTAL emissions					**22.525**	**0.028**	**0.007**	**0.000**	**0.000**

Table 24: Pacific Steel emission to air due to transportation of raw materials.

Pacific Steel emissions due to transportation	Energy					Emissions				
	Tonnage	Distance (incl. backhaul)	Transport Mode	Combustion energy required	Energy Used	CO_2 emission	VOCs emissions	CH_4 emissions	NOx emissions	CO emissions
UNITS	(t)	(km)	-	(MJ/t-km)	(MJ)	(t/y)	(t/y)	(t/y)	(t/y)	(t/y)
FROM Overseas										
Coke (China)	1,900	18,400	Marine	0.12	**4,195,200**	297	1.64	0.19	1.01	0.76
Silico Manganese (Australia)	1,520	4,400	Marine	0.12	**802,560**	57	0.31	0.04	0.19	0.14
Silico Manganese (China)	380	18,400	Marine	0.12	**839,040**	59	0.33	0.04	0.20	0.15
FROM North Is										
Scrap Steel (via Auckland)	72,000	500	Rail	0.49	**17,640,000**	1,247	1.23	0.14	24.70	1.01
Coke (Port Auckland)	1,900	20	Rail	0.49	**18,620**	1	0.00	0.00	0.03	0.00
Burnt Limestone (Waitomo)	8,000	350	Rail	0.49	**1,372,000**	97	0.10	0.01	1.92	0.08
FROM South Is										
Scrap Steel	21,000	3,400	Marine	0.12	**8,568,000**	606	3.34	0.39	2.06	1.54
Scrap Steel	21,000	600	Rail	0.49	**6,174,000**	437	0.43	0.05	8.64	0.35
Scrap Steel	21,000	192	Marine	0.12	**483,840**	34	0.19	0.02	0.12	0.09
Scrap Steel	21,000	1,360	Rail	0.49	**13,994,400**	989	0.98	0.11	19.59	0.80
FROM both Nth + Sth Is										
Scrap Steel (all)	186,000	200	Road	1.18	**43,896,000**	3,103	3.81	0.95	35.42	19.45
TOTAL emissions for all Raw Materials						**6,927**	**12.4**	**1.9**	**93.9**	**24.4**

Table 25: Pacific emissions to air due to primary production.

Emmisions (grammes per tonne of slab)	**CO_2 emission**	**CO emissions**	**SOx emissions**	**NOx emissions**	**CH_4**	**N_2O**	**VOCs**
Primary	204,965	24	126	342	26	0	11

APPENDIX D: WATER QUALITY AND MONITORING STANDARDS

Table 26 shows the maximum range for a variety of discharges that are not to be exceeded – averages achieved are much lower[28].

Table 26: Outfall water quality standards and monitoring.

OUTFALL WATER: FOR COMBINED STORMWATER AND WASTE WATER DISCHARGES		
Parameters	**Maximum or range not to be exceeded#**	**Monitoring to establish averages**
Waste Water Discharge Flow	2,100 m^3/day - Southside Outfall 7,800 m^3/day - Northside Outfall	-
pH	6 - 9.5	-
Temperature (^oC)	3 degrees.>sea temp after dispersion	-
Suspended Solids	30	a
Dissolved Oxygen	4 (min)	-
Chemical Oxygen Demand	40 based on daily composite	-
Oil and Grease	10 based on daily composite	b
Zinc	1.5	c
Chromium 3+	0.2	c
Nickel	0.5	c
Lead	0.2	c
Copper	0.2	c
Mercury	0.0025	c
Silver	0.02	c
Antimony	-	c
Cadmium	0.6	c
Arsenic	5	c
Cyanide	0.3	c
Iron	12.5	c
Aluminium	-	c
Phosphorus	-	c
Fluoride	-	d

#Units in mg/l except for flow pH and temperature.

Monitoring Code

a - single grab sample taken and analysed once daily, seven days a week.
b - a 24-hour flow proportioned composite sample taken and analysed once per week.
c - a monthly composite sample of flow proportioned aliquots of the daily (24 hour) composite sample.
d - a weekly composite sample of flow proportioned from the daily (24 hour) composite sample.

APPENDIX E: SLURRY WASTE WATER DISCHARGE

The table below shows the concentration of dissolved metals in slurry water before and after use, to assess the effect of transportation of iron sand. Sample taken on 27 April 1998. The table is adapted from BHP NZS Resource Consent document Appendix 6-2. June 1998. "*Assessment of Environmental Effects for Water Extraction, Discharge and Associated Activities*".

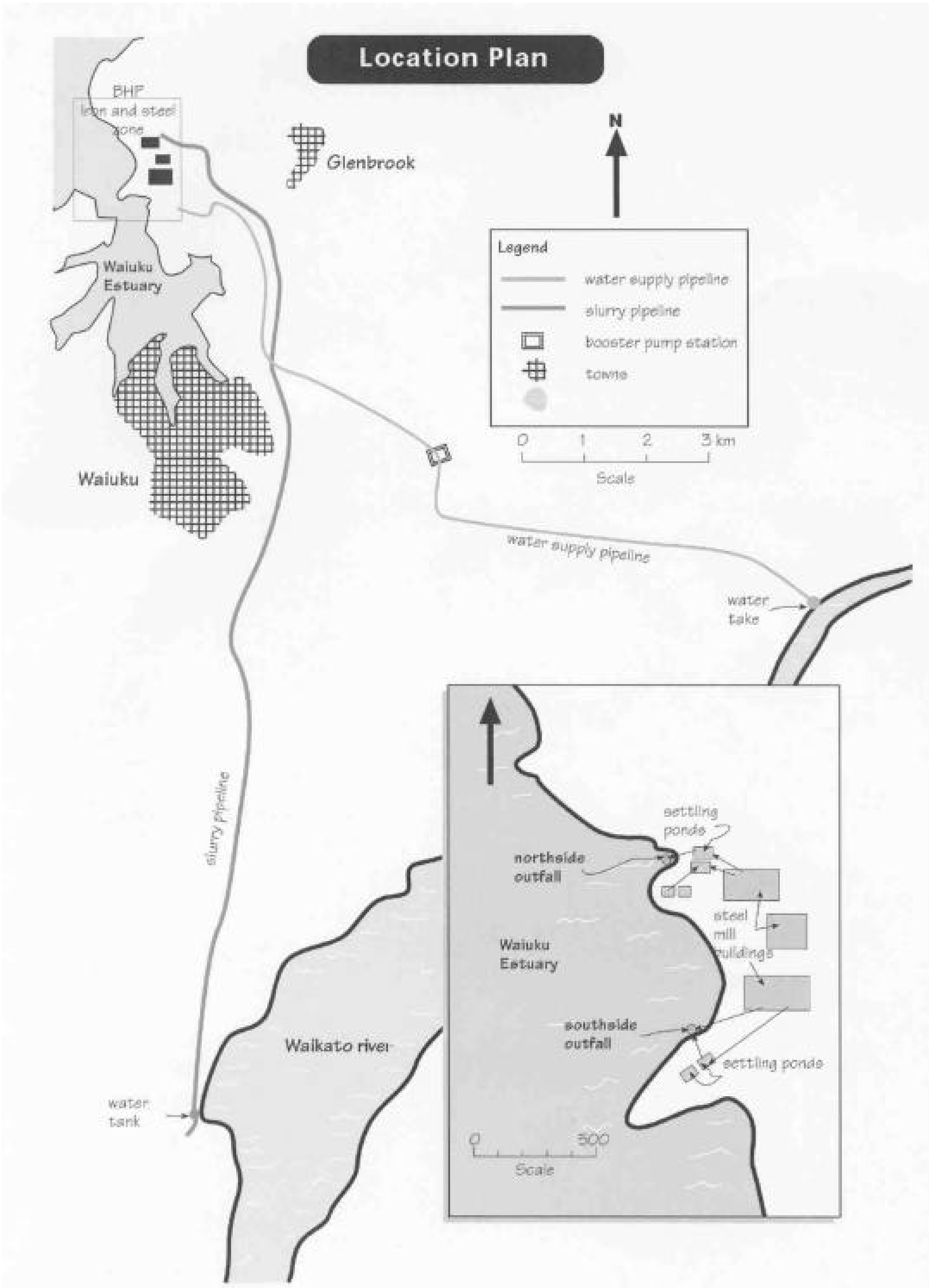
Table 27: Concentrations of dissolved metals in slurry water.

Element	Before use (in parts per million)	After use (in parts per million)
Sulphur	3.1	4.1
Zinc	0.016	< 0.005
Phosphorous	<0.5	<0.5
Lead	<0.04	<0.04
Cadmium	<0.005	<0.005
Nickel	<0.01	<0.01
Boron	0.17	0.18
Manganese	0.07	0.07
Iron	0.23	1.07
Chromium	<0.005	< 0.005
Magnesium	3.7	3.2
Aluminium	<0.1	0.3
Calcium	6.6	4.2
Copper	<0.006	<0.006
Potassium	3.2	2.8

APPENDIX F: BHP NZS WATER UPTAKE AND DISCHARGES

The following is a schematic plan of the water uptake for the slurry and process water, as well as the waste water discharges after use within the BHP NZS mill. Figure 6 is adapted from BHP NZS's *Assessment of Environmental Effects for Water Extraction, Discharge and Associated Activities*, June 1998. Resource Consent Application, Figure 1-1, Vol. 1 - Main Report.

Figure 6: BHP NZS water uptake and discharges



APPENDIX G: BHP NZS PROCESS WATER POLLUTANTS

Table 28 and Table 29 are adapted from the BHP NZS consent document[31].

Table 28: Concentration of pollutant levels for the Northside Outfall.

For the April 1997/ March 1998 Year			
Pollutant	**Licence Condition**	**Daily Average Concentrations or Range (g/m^3)**	**Comment**
Zinc	0.2	0.1 - 0.2	
Suspended Solids	15	7 - 18	
Iron	3.0	0.2 - 0.8	
Chromium	0.01	0.005 - 0.008	at detection limit
Nickel	0.03	0.02	at detection limit
Copper	0.03	0.006	at detection limit

Table 29: Concentration of pollutant levels for the Southside Outfall.

For the April 1997/ March 1998 Year			
Pollutant	**Licence Condition**	**Daily Average Concentrations or range (g/m^3)**	**Comment**
Zinc	0.05	0.02 - 0.06	
Suspended Solids	15	2 - 6	
Iron	3.0	0.4 - 1.7	
Chromium	0.01	0.005 - 0.007	at detection limit
Nickel	0.03	0.002	at detection limit
Copper	0.03	0.005	at detection limit

APPENDIX H: BHP NZS ENERGY REQUIREMENTS

Table 30: BHP NZS energy requirements, by stage.

BHP NZS Energy Requirements, by Stage of Manufacture (in GJ/t)					
	PRODUCTION STAGE				
FUEL TYPE	*Extraction*	*Transportation*	*Primary*	*Secondary*	**TOTAL**
Diesel	0.031	0.134	0.075	0	0.240
Natural Gas	0	0	3.370	1.700	5.070
Coal	0	0	22.380	0	22.380
Electricity	0.026	0	3.830	0.510	4.366
				TOTAL	**32.056**