



Zinc Limited

A large, diagonal aerial photograph of a rugged mountain range with deep blue glacial valleys and patches of snow. In the background, a large, light-colored body of water, possibly a lake or a coastal area, is visible under a clear sky. The image is partially obscured by a dark blue diagonal band on the left side.

# Feasibility Study

*“Confirms Citronen as One of the World’s Largest & Premier Zinc-Lead Projects”.*

September 2017

## CITRONEN ZINC-LEAD PROJECT FEASIBILITY STUDY – COST UPDATE

Ironbark Zinc Limited (“Ironbark”) (ASX: IBG) is pleased to provide results from the Feasibility Study Update of Ironbark’s 100% owned Citronen Project:

• <b>NPV<sup>8</sup></b>	<b>US \$1,034 Million (US \$909 Million post tax*)</b>
• <b>IRR</b>	<b>36% (35% post tax*)</b>
• <b>Capital Cost</b>	<b>US \$514 Million**</b>
• <b>Large Scale Production</b>	<b>3.3Mtpa Mine Rate/Production up to 200,000tpa zinc metal</b>
• <b>Site Cost</b>	<b>US\$0.52/lb Zn (Payable, Net of by-product credits)***</b>
• <b>Mine Life</b>	<b>14 years (open ended and with further inferred resources that could potentially be converted to reserves)</b>
• <b>Life of Mine Revenue</b>	<b>US\$6,364 Million</b>
• <b>Life of Mine Operating Costs</b>	<b>US\$3,025 Million</b>
• <b>Life of Mine NPAT</b>	<b>US\$1,836 Million*</b>

**There is a low level of geological confidence associated with inferred mineral resources and there is no certainty that further exploration work will result in the determination of indicated mineral resources or that the production target itself will be realised.**

### PROJECT HIGHLIGHTS

- **100% Owned Exploitation Licence 2016/30 (Mining Permit) Granted by the Greenland Government**  
– 30 year term
- **Open-Ended, Simple, Consistent Resource**
- **Simple Mining, Simple Processing using Standard Technology**
- **Ironbark is Working with China Nonferrous under a MOU to Deliver an EPC Fixed Price Contract and Assist in Project Financing**
- **Major Industry Shareholders – Glencore International AG & Nyrstar NV**

\* Excluding dividend withholding tax (Corporate tax rate of 30%, dividend withholding tax 37%). All costs and prices indexed at a CPI rate of 2.5% pa

\*\* Compared against the last Western Calculation dated 2011 is a 2.4% increase. NFC are currently working on a Chinese Feasibility study which is expected to have a lower Capital Cost

\*\*\* Smelter fees an additional US\$0.14/lb Zn payable

#### Cautionary Statement

Ironbark has concluded it has reasonable basis for providing the forward looking statements included in the announcement (Appendix 1). The detailed reasons for that conclusion are outlined throughout this announcement. This announcement has been prepared in accordance with the JORC Code (2012) and the ASX Listing Rules.

The Company believes there is a reasonable basis for the production targets and the forecast financial information and income-based valuation derived from those production targets provided in this document based on the detailed reasons and material assumptions which are outlined throughout this document. In addition, the forward-looking statements are based on the Company’s belief that it has reasonable grounds to expect that funding will be secured to advance the Project. The ‘Project Financing and Sources of Capital’ section in Appendix I of the attached Feasibility Study Report contains further detail on why the Company has a reasonable basis to believe the Project will be financed. There is no certainty, however, that sufficient funding will be raised by the Company when required.

## Introduction

The Citronen Feasibility Study is the culmination of a vast amount of work, the main body of which has been derived from the work released to the ASX in 2013 and from additional costing, engineering, metallurgical and design evaluation which is ongoing.

The Feasibility Study Update (2017) is based on the original Feasibility Study but has incorporated a recent review of capital and operating costs. Major changes that have been highly favourable include improved global benchmark smelter treatment terms, lower fuel prices, representing one of Ironbark's largest forecast costs of operation, and the long-anticipated recovery in the zinc metal price. Over the same period there have also been some cost increases including wages and some materials. The result is a far more robust project than ever before and it is well positioned on the starting blocks to become a major new zinc producer.

Further metallurgical test work will commence shortly to target feasibility-level engineering confidence in the highest levels of recovery achieved in earlier work (up to 90%) and also test a two stage DMS upgrade. Any improved recoveries will be reported in due course.

Commenting on the results of the updated cost evaluation of the Feasibility Study Ironbark Managing Director Jonathan Downes said:

*"We are extremely pleased with the confluence of a strong zinc price, which is widely forecast to continue to strengthen, low fuel prices and strongly improved smelter treatment charges. This has sharpened up the project economics and now has the project NPV exceeding US\$1B at spot metal prices and using 5 year Wood McKenzie zinc forecasts. Giving real significance to this is the recent grant of a 30 year Mining Licence finally allowing a rapid progression towards financing and production. The Citronen Project shows a highly profitable base metal development potential of global significance. Citronen's mine life of at least 14 years is defined only by the limits of drilling to date. As such, one of the Project's most exciting aspects remains its exceptional exploration potential with identified mineralisation remaining open in almost every direction."*

Ironbark is debt-free and has a strong shareholder base including Nyrstar NV and Glencore AG. Ironbark has an engineering and construction Memorandum of Understanding (MOU) with China Nonferrous Metal Industry's Foreign Engineering and Construction Co. Ltd (NFC) for a fixed price Engineering, Procurement and Construction (EPC) contract. The MOU encompasses a 70% debt funding proposal through Chinese banks and provides NFC with a right to buy a 20% direct interest in the Citronen Project. Citronen's Feasibility Study with all the supporting studies has been presented to NFC for the purposes of preparing the EPC and financing work. Ironbark is assessing the best financing pathway forward and is considering working with several potential partners.

The Citronen Project is a relatively simple predominantly underground room and pillar mining operation that concentrates the ore through industry proven Dense Media Separation (DMS) and Flotation techniques to produce saleable separate zinc and lead concentrates to the world markets.

Table A below demonstrates the sensitivity of the project's economics at a range of zinc prices. Every US\$100/t increase/decrease in the zinc price adds or reduces by approximately US\$100M to the pre-tax NPV and every reduction reduces the pre-tax NPV. The financial model applies annual indexing to all cost and prices using a CPI rate of 2.5%.

**Table A: Sensitivity**

Zinc Price Sensitivity	Zinc Price US\$2,904/t	Zinc Price US\$3,044/t	Zinc Price US\$3,144/t
NPV <sup>8</sup> before tax	US\$940M	US\$1,043M	US\$1,146M
IRR	34%	36%	38%
NPAT	US\$1,687M	US\$1,836M	US\$1,985M

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## APPENDICES

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## **SECTION 1 - INTRODUCTION**

## 1. INTRODUCTION

The Citronen Fjord Zinc deposit was discovered by Platinova A/S (Platinova) in 1993. Platinova conducted extensive geological mapping, geophysics and drilling programmes during the summers of 1993 to 1997; over 33,000 metres of diamond drilling for 143 holes were completed and four main prospects were identified (Discovery, Beach, Esrum and the Western Gossans).

Ironbark Zinc Limited (Ironbark) acquired the Citronen Project (Citronen or the Project) in early 2007 and during Greenland's 2007 summer completed an intensive sampling program of previously un-assayed Platinova drill core.

Ironbark has since actively explored the Project from 2008 and has completed 166 holes for 32,240 metres, bringing the total drilling completed at Citronen to 313 holes for 67,069 metres. This has resulted in a significant resource upgrade in terms of tonnes and confidence from the previous owners.

### 1.1 Regulatory Status at August 2017

In December 2016, the Greenland Government awarded Ironbark an Exploitation Licence 2016/30 (Mining Permit) for the Citronen Project. The licence provides Ironbark with the right to exploit for a period of 30 years.

Mining in Greenland is regulated by the Mineral Resources Act, December 2009. The Act aims to ensure that activities under the Act are securely performed with regard to safety, health, the environment, resource exploitation and social sustainability as well as performed according to acknowledged best international practices under similar conditions.

In order to advance its exploration licence into an exploitation licence, Ironbark applied to the MLSA for the exploitation licence pursuant to the provisions given in S.16 of the Act. The application for an exploitation licence was accompanied by a number of documents, including:

- A declaration that the deposit at Citronen Fjord is commercially viable and that Ironbark intends to exploit the deposit.
- A Feasibility Study of the Citronen Fjord deposit on which the declaration is based
- An Environmental Impact Assessment.
- A Social Impact Assessment, including an Impact Benefit Agreement with the public authorities.

The SIA and EIA were submitted to the Greenland Government in June 2016 and July 2016 respectively. Following that, negotiations were held between Ironbark and the four municipalities in Greenland to develop an Impact Benefit Agreement (IBA). The IBA will contribute to developing the Greenlandic mineral-resources sector in many different areas, and aims at ensuring Greenlandic jobs, involvement of Greenlandic enterprises, and skills upgrades for the Greenlandic workforce.

## **SECTION 2 - ZINC & LEAD METAL MARKETING**

## 2. ZINC & LEAD METAL MARKETING

### 2.1 Introduction to Zinc and the Zinc Market

Zinc is the fourth most used metal in the world. Its applications range from galvanising steel products for rust proofing including construction steel and car chassis, uses in bronze alloys and even as an essential fertiliser trace element additive. Zinc is not easily substitutable and is an essential metal to modern society.

The zinc market is largely balanced at an annual zinc production rate of approximately 13 million tonnes of metal per annum, with approximately 70% produced from mining and 30% from recycling. Zinc is typically produced on-site at mines to produce a concentrate level containing in excess of 50% zinc metal along with other waste elements such as sulphur, silica and iron.

In recent years, a growing list of zinc mines have depleted their mineral resources and shut down. In addition many operations have been under increasingly stringent environmental review due to poor historic practices and the result has been a tightening in the zinc market borne out by falling global stockpiles (Figure 2.1), reduced smelter treatment charges due to competition between smelters seeking to attract concentrates and most importantly rising zinc prices. Against this backdrop the growing globally economy is expected to require a further new 2.5-3% growth per annum in zinc production to meet demand which equates to an annual requirement for an additional ~350,000t of new zinc production each year.



**Figure 2.1 - Long running trend of falling zinc stockpiles in the London Metal Exchange**

The World Bureau of Metal Statistics summarises that zinc and lead stockpiles were in deficit in the first six months of the year. The zinc market was in deficit by 370,000t for the first six months of the year, more than the total 223,000t deficit recorded for 2016 which drove the price of zinc by approximately 60%. While zinc stocks were falling the world demand for zinc had risen by 270,000t year-on-year for the first six months of 2017.

## 2.2 Zinc Price Forecasting

Ironbark has assessed the work compiled by the Wood Mackenzie (WM), the owners of Brook Hunt, an independent and globally recognised authority on commodities.

The WM group has forecast global zinc stocks will stay at low levels for some time. WM predict to see zinc prices to run as high as US\$1.75/lb (US\$3,875/t) and average US\$3,044 for the next 5 years.

This compares favourably to the preceding years where zinc prices settled at relatively low levels for a prolonged period which resulted in little exploration or development of zinc projects. The zinc price during this period was influenced by some of the following factors:

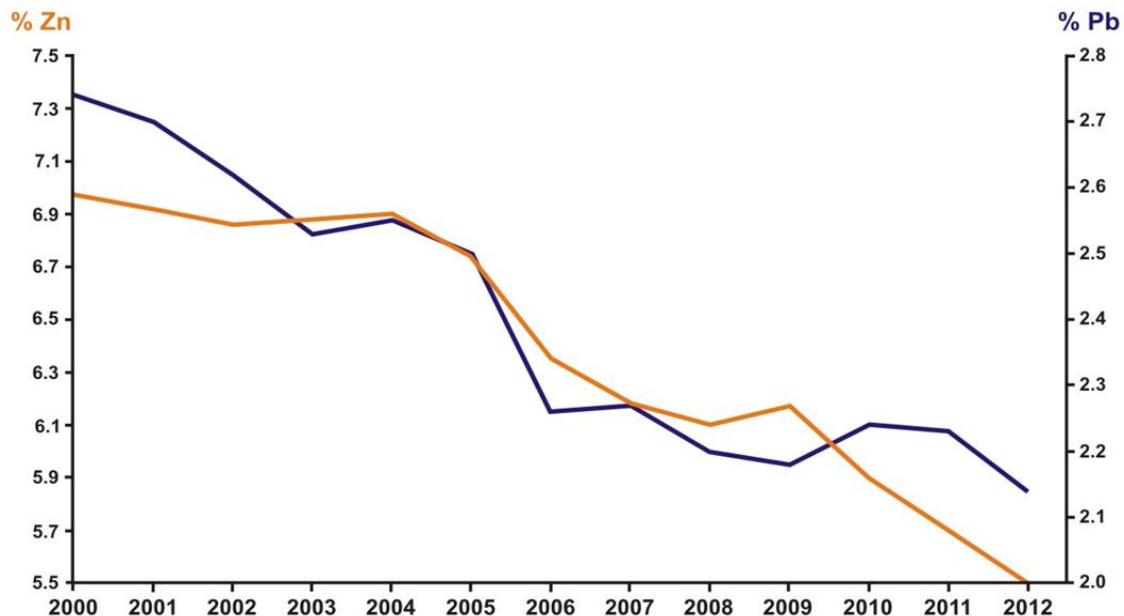
- Difficulty to secure mine financing, particularly for larger operations: this factor has compounded the effect of the current shortage in zinc production due to limited new production being built in the short to medium term.
- Several large zinc and lead mines closed due to ore body depletion and other factors including Century, Lisheen, Brunswisk and Perserverence..
- While Citronen represents one of the largest scale zinc discoveries of recent times, relatively few new deposits have been recently discovered. Consequently, the depletion of higher grade deposits is forcing the mining of lower grade deposits which will ultimately impact production costs and zinc prices.
- The global consumption of zinc will continue its increasing trend in line with the forecast global economy and population growth.
- Typically the zinc market is composed of smaller operations with an average annual production size of around 30,000 tpa.

Ironbark has applied a zinc price which has been modelled at US\$1.38/lb (US\$3,044/t) for the Citronen Project derived from the Wood McKenzie forecast. This is currently below the spot price. Ironbark has run some sensitivity analysis that shows positive returns at substantially lower metal prices. All costs and prices are escalated at an annual rate of 2.5%.

Ironbark has entered into individual offtake agreements for 35% (each) of the production from the Citronen project with two of its significant shareholders, Nyrstar NV (Nyrstar) and Glencore International AG (Glencore), both of which are global commodity market leaders.

Nyrstar is one of the world's largest integrated zinc producers, producing from their mining operations zinc in concentrate, special high grade zinc (SHG), zinc galvanising alloys and zinc die casting alloys, all of which are outcomes of their zinc smelting process. Nyrstar has its corporate office in Switzerland; its mining, smelting and other operations are located in Europe, the Americas, China and Australia.

Glencore is an Anglo-Swiss multinational commodity trading and mining company headquartered in Baar, Switzerland. Glencore is one of the world's leading integrated producers and marketers of commodities. As the world's largest commodities trading company, it holds an approximately 60% global market share of the internationally tradeable zinc market. In addition to the 35% offtake agreement for production from Citronen, Glencore has a marketing agreement with Ironbark for all the zinc and lead concentrate product produced from Citronen of \$10 per dry metric tonne (dmt), subject to meeting specific market conditions and commodity prices which are currently undefined. This marketing fee has been excluded from the material covered by Glencore's offtake allocation.



**Figure 2.2 Strong fall in zinc and lead mine head grades as high grade mines are depleted**

(Source: International Lead and Zinc Study Group)

### 2.3 Introduction to Lead and the Lead Market

Lead is used in lead-acid batteries, building construction, bullets and shots, weights, and in solders, pewters and fusible alloys. Total annual lead production is approximately eight million tonnes, approximately half of which is produced from recycled scrap. Over 50% of the US's lead production is consumed by the automobile industry due to the extensive use of the lead in car batteries.

Global lead demand has increased strongly over the past 11 years with demand of 7.3Mt in 2004 rising to 10.6Mt in 2015 representing a rise in consumption over that period of nearly 45%.

Representing approximately 75% of consumption, the largest market for lead is the production of automotive and other lead-acid batteries – a consistently growing market. Hybrid vehicles have continued to require lead acid batteries, particularly for continuous high load requirements such as engine stop/start features.

The global lead market was also in deficit by 195,000t from January to June, following a 172,000t deficit for 2016, while both mine production and demand increased.

### 2.4 Lead Price Forecasting

As with zinc, it is difficult to apply certainty to future forecast metal prices however lead prices tend to follow the zinc market. Market forecasters have determined that global lead consumption is set to remain robust, underpinned by the secure and positive outlook for lead-acid battery usage, with Asia highlighted to remain the main engine of global growth.

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Lead metal availability, like zinc, has fallen recently in global stockpiles and treatment charges have also fallen in line with increasing global competition. Ironbark has applied the current lead price which has been modelled at US\$1.05/lb (US\$2,315/t) for the Citronen Project which represents a small proportion of the expected revenue compared to the contribution made by zinc. Unusually there is no appreciable silver in the lead or lead concentrate.

The Citronen mine is projected to produce a simple lead concentrate separate to the zinc concentrate via traditional, proven processing techniques. While the quantities of lead produced will be substantially less than the planned zinc production, it will still be a saleable by-product of the Citronen mine. The lead concentrate is a widely traded commodity and is likely to be shipped to European and Asian smelters.

Ironbark's significant shareholders, Nyrstar and Glencore, are both also very active in the lead market. Nyrstar has a market leading position in lead, producing lead concentrate and refined market lead grading 99.9% lead. Ironbark has entered into an offtake agreement with Nyrstar for 35% of the production from the Citronen project.

Ironbark has also entered into an offtake agreement with Glencore for 35% of the production from the Citronen project. In addition, Ironbark shares the marketing rights with Glencore for the zinc and lead concentrate product produced from Citronen of \$10/dmt, subject to meeting specific market conditions and commodity prices which currently remain undefined. The marketing fee has been excluded from the material under Glencore's offtake agreement.

## **SECTION 3 - GEOLOGY & MINERAL RESOURCE**

### 3. GEOLOGY & MINERAL RESOURCE

#### 3.1 Status at August 2017

Ironbark reported the updated exploration and mineral resource estimates of the Citronen Base Metals Project in accordance with ASX Listing Rule 5.8 and compliance with the 2012 JORC Code in 2014 (ASX release 25 November 2014) and supersedes all earlier estimates. Ironbark's most recent Resource Report is current at the date of this Report and incorporates the drilling and other geological work undertaken. The estimates are summarised in Table 3.1 and Appendix II contains the JORC 2012 Table 1 information relating to the Resource.

**Table 3.1 – JORC 2012 Citronen Resource Estimates**

**70.8 million tonnes at 5.7% Zn + Pb**

Category	Mt	Zn%	Pb%	Zn+Pb%
Measured	25.0	5.0	0.5	5.5
Indicated	26.5	5.5	0.5	6.0
Inferred	19.3	4.9	0.4	5.3

*Using Ordinary Kriging interpolation and reported at a 3.5% Zn cut-off*

Including a higher grade resource of:

**29.9 million tonnes at 7.1% Zn + Pb**

Category	Mt	Zn%	Pb%	Zn+Pb%
Measured	8.9	6.6	0.6	7.2
Indicated	13.7	6.8	0.5	7.3
Inferred	7.3	6.2	0.5	6.6

*Using Ordinary Kriging interpolation and reported at a 5.0% Zn cut-off*

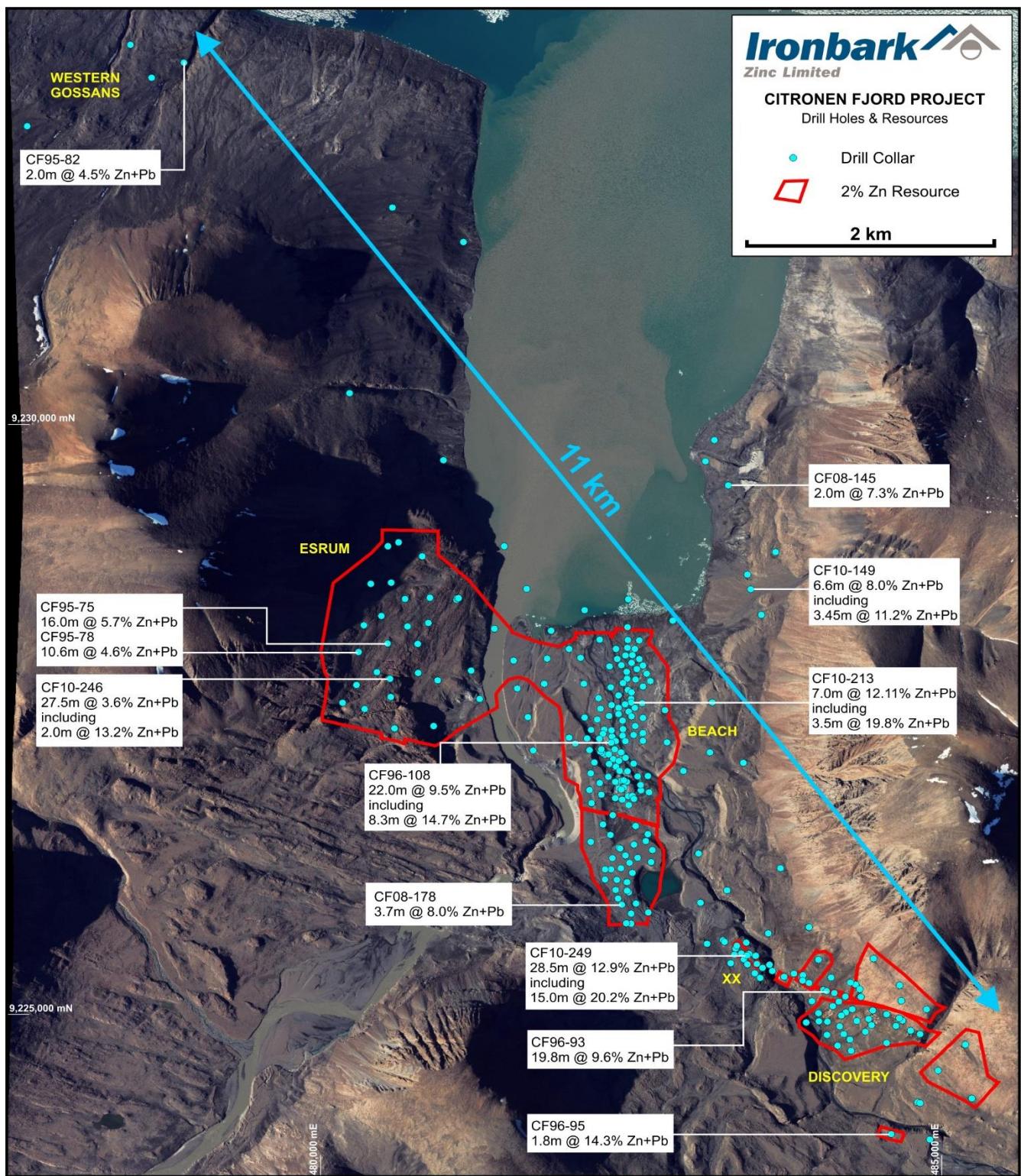
The resource estimates, as reported to the ASX on 25 November 2014, are based on:

- **315 holes totalling 67,083 metres of diamond drilling completed to date**
- **11km strike of drilling containing economic grade mineralisation\*\***
- **91% of effectively drilled holes intersected sulphide mineralisation**
- **73% of effectively drilled holes intersected economic grade mineralisation\* \***
- **Deposit open in every direction – huge exploration potential**

\*\*Economic grade mineralisation being a minimum of 2.0m @ 3.5% Zinc

A total of 315 diamond drill holes totalling 67,083 metres have been completed at the project since exploration began in 1993. The strike length of the mineralised holes of economic grade is 11 kilometres and the strike length of the area containing the current resource is over 6.5 kilometres. 91% of effectively drilled holes (holes completed to target depth) at the project have intersected sulphide mineralisation with 73% of the holes intersecting economic mineralisation of more than 2.0m at 3.5% Zinc. The project is open in almost every direction and many economic intercepts are outside the current resource wireframe.

Two significant early geology reports and their corresponding resource estimates have previously been calculated and reported however they do not meet the 2012 Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (“the JORC Code”). In February 2011 Wardrop completed a feasibility study report that included a section titled “Citronen Fjord Feasibility Study, Greenland – Volume 2: Geology”. This report includes the drilling and sampling programmes up to and including those undertaken in 2010.



**Figure 3.1 - Citronen Project drill holes and resource outline highlighting the strike length of known mineralisation and high grade drill intercepts including outside or at the edge of the current resource.**

The 2010 resource model completed by Ravensgate (dated 25 January 2011) is an update to the Ironbark in-house JORC 2004 resource estimate of November 2008. It also integrates Ironbark's drilling data from the 2009 and 2010 drilling programmes.

Wardrop's report included all geological investigations and drilling work up to and including the activities undertaken in 2010. The Wardrop report also included the Ravensgate Minerals Industry Consultants (Ravensgate) resource estimate (2010 model).

The summarised 2010 resource estimate is presented in Table 3.2.

**Table 3.2 - Ravensgate 2010 resource estimate**

Model	Measured			Indicated			Inferred		
	Mt	Zn (%)	Pb (%)	Mt	Zn (%)	Pb (%)	Mt	Zn (%)	Pb (%)
2010	33.23	3.77	0.47	52.22	3.69	0.48	47.20	3.34	0.40

2010 Resource Summary – as at January 25th, 2011 at 2% Zn lower cut-off grade – (OK block model) – all material reported within 2% Zn mineralisation shells using OK interpolation.

This estimate and reporting of identified mineral resources was undertaken in line with the mineral resource reporting guidelines as outlined in the JORC Code (December 2004).

Ironbark prepared a later report titled "Citronen Fjord Feasibility Study, Greenland - Volume 2: Geology" (dated 19 November 2012) that is similar to and represents an update of the aforementioned Wardrop geology report. Ironbark's November 2012 report is summarised in Section 3.2 of this report.

Ravensgate updated the resource model again following the 2011 field season. The resource model completed by Ravensgate titled "End of 2011 Resource Estimation Report on the Citronen Fjord Zinc Project, Northeast Greenland – Resource Block Model Revisions for Ironbark Zinc Limited" was finalised in February 2012 and is referred to as the "2012 Model".

**Table 3.3 - Ravensgate resource estimate "2012 Model"**

Model	Measured			Indicated			Inferred		
	Mt	Zn (%)	Pb (%)	Mt	Zn (%)	Pb (%)	Mt	Zn (%)	Pb (%)
2012	43.09	4.08	0.48	51.19	4.14	0.44	37.72	3.80	0.41

2012 Resource Summary – as at February 28<sup>th</sup> 2012 at 2% Zn Lower cut-off grade – (OK & ID2 block model Items) – all material reported within 2% Zn mineralisation shells using OK interpolation.

This estimate and reporting of identified mineral resources has been undertaken in line with the mineral resource reporting guidelines as outlined in the JORC Code relevant at the time.

This work was audited and updated in November 2014 to meet the 2012 Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves ('the JORC Code').

Ironbark's most recent report supersedes the 2012 Model and is current at the date of this Report and incorporates the drilling and other geological work undertaken.

Ironbark reported the updated exploration and mineral resource estimates of the Citronen Base Metals Project in accordance with ASX Listing Rule 5.8 and compliance with the 2012 JORC Code.

### 3.2 Geology & Mineral Resources

#### Project History

The sediment-hosted Citronen Fjord Zinc-Lead (Zn-Pb) Deposit represents a recent discovery and the first and only known Sedimentary-Exhalative (SEDEX) deposit in the Franklinian Basin of northern Greenland.

Gossanous material was first noted in the vicinity of Citronen Fjord in 1969 during a British Joint Services Expedition to Peary Land - Johannes V. Jensen Land. A Greenland Geological Survey regional mapping project in the late 1970s-1980s reported mineralised debris flow with Zn (5.4%) and minor copper (Cu), several kilometres south of Citronen Fjord. In 1993, Platinova A/S (Platinova) discovered significant massive sulphide mineralisation outcropping, in what is now known as the 'Discovery Gossan' (Figure 3.2).

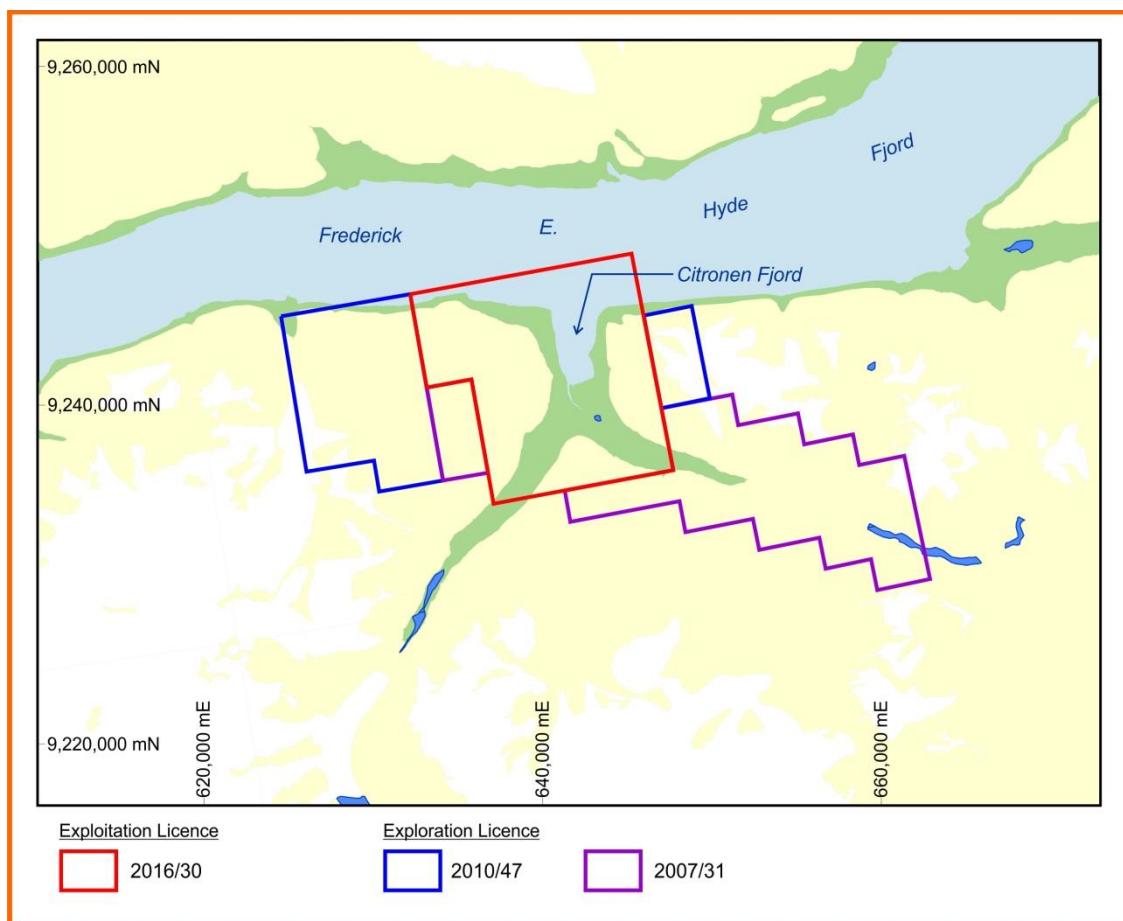


**Figure 3.2 - Gossanous outcrop of Level 1 sulphides at the Discovery Zone**

Platinova investigated the area between 1993 and 1997, drilling 148 diamond drill holes for a total length of 32,702 m, indicating mineralisation over a strike length of 15 km estimated to contain in excess of 1.5 Mt of Zn metal. A period of depressed base metal prices during the late 1990s and early 2000s saw fieldwork halted until the project was purchased by Ironbark in 2006.

In 2007, Ironbark initiated investigations via extensive re-sampling of Platinova diamond drill core, followed by the construction of a 40-person camp and a diamond drill programme in 2008. Ironbark has now completed four consecutive years of diamond drilling on the project for a total of 34,240 m, bringing the total metres drilled at the project to date to over 66,000 m.

The drilling conducted, the resource and camp are located within Exploitation Licence 2016/30 (Figure 3.3) held by Ironbark's Greenlandic registered company, Ironbark A/S. Ironbark additionally holds extensive exploration rights over the prospective ground surrounding the main Citronen licence, comprising of two licences; 2010/47 and 2007/31 (Figure 3.3).



**Figure 3.3 - Ironbark's licence holding in the Citronen Fjord region**

### Geological Setting

The Citronen Fjord Zn-Pb Deposit is located within the Lower Palaeozoic Franklinian basin of northern Greenland, which extends westward from Kronprins Christian Land in north-eastern Greenland for over 2,000 km into the Canadian arctic islands. The basin consists of a sequence of siliciclastics and carbonates, with sedimentation initiated during an interior sag phase in the Proterozoic and ceasing during the Devonian-Carboniferous Ellesmerian orogeny.

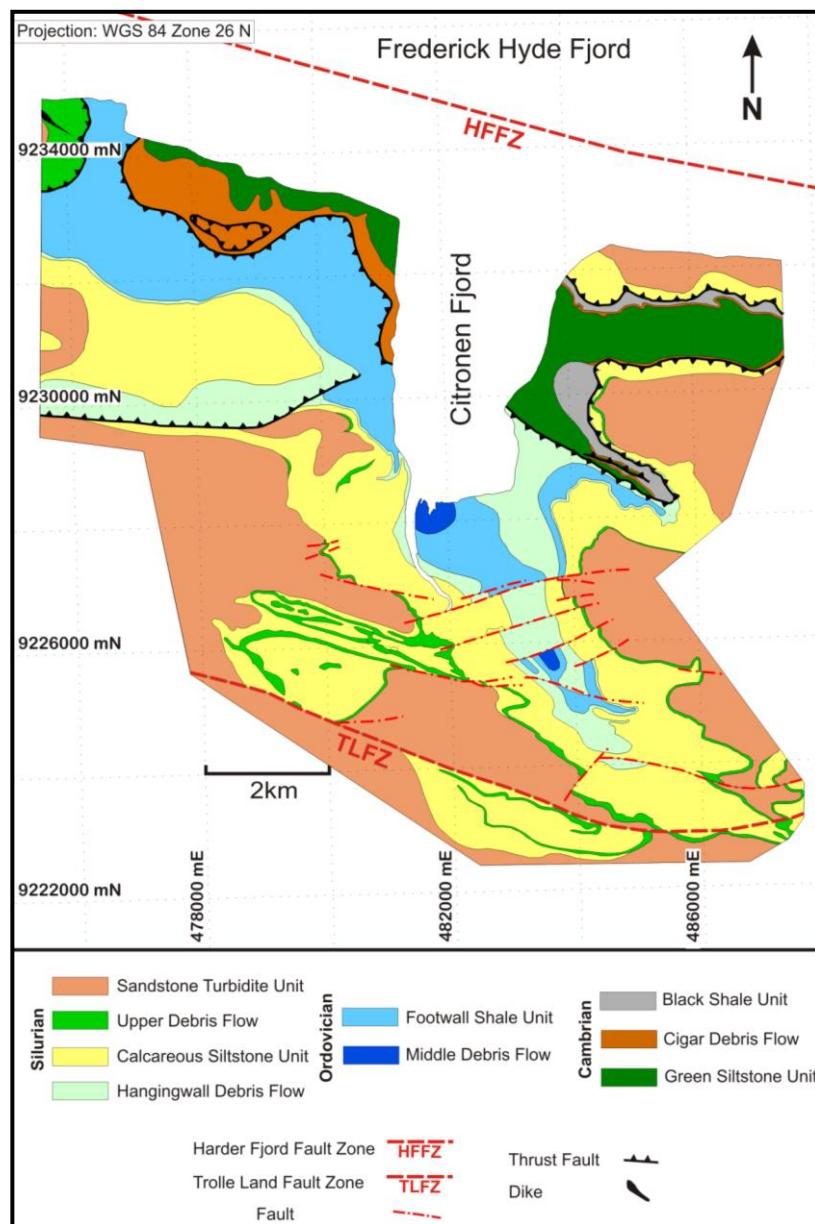
The basin architecture during deposition of the Palaeozoic sequences comprised a stable carbonate platform to the south and a deep-water trough to the north. The Citronen Fjord Zn-Pb Deposit is hosted within the Ordovician deep-water trough sedimentary rocks of the Amundsen Land Group, located in the eastern portion of the basin. The morphology of the eastern portion of the basin during its formation consisted of an inner carbonate platform to the south and a deep-water trough to the north, with the boundary between these two

environments being relatively abrupt and termed the Navarana Fjord escarpment (NFE). The Citronen Deposit formed approximately five kilometres north of the NFE.

During Ordovician expansion of the basin, the trough environment was oxygen starved and anoxic dark mudstones, black and green cherts and thin-bedded turbidites were deposited. Inter-bedded with these slowly accumulated fine-grained sedimentary rocks are thick carbonate conglomerates (debris flows) sourced from the carbonate platform.

The local geology at Citronen Fjord consists primarily of Cambrian to Silurian deep-water trough sediments punctuated with coarse carbonate debris flows overlain by Silurian sandstone turbidites (Figure 3.4). The carbonate debris flows are useful stratigraphic markers and are present at Citronen Fjord in the vicinity of the major sulphide horizons.

The region is part of a major fold and thrust belt, although the mineralised stratigraphy at Citronen is relatively undeformed with only minor folding and faulting. The Citronen Fjord Deposit sits between two major regional structures, the Harder Fjord Fault Zone (HFFZ) and the Trolle Land Fault Zone (TLFZ) (Figure 3.4). The TLFZ is interpreted to have been a conduit for mineralising fluids. Another major structural feature in the vicinity are thrust faults juxtaposing older Cambrian stratigraphy over younger material in the mountains surrounding the fjord; these thrust structures do not affect the mineralised domains.



**Figure 3.4 - Local geology of the Citronen Fjord area**

### Deposit Type

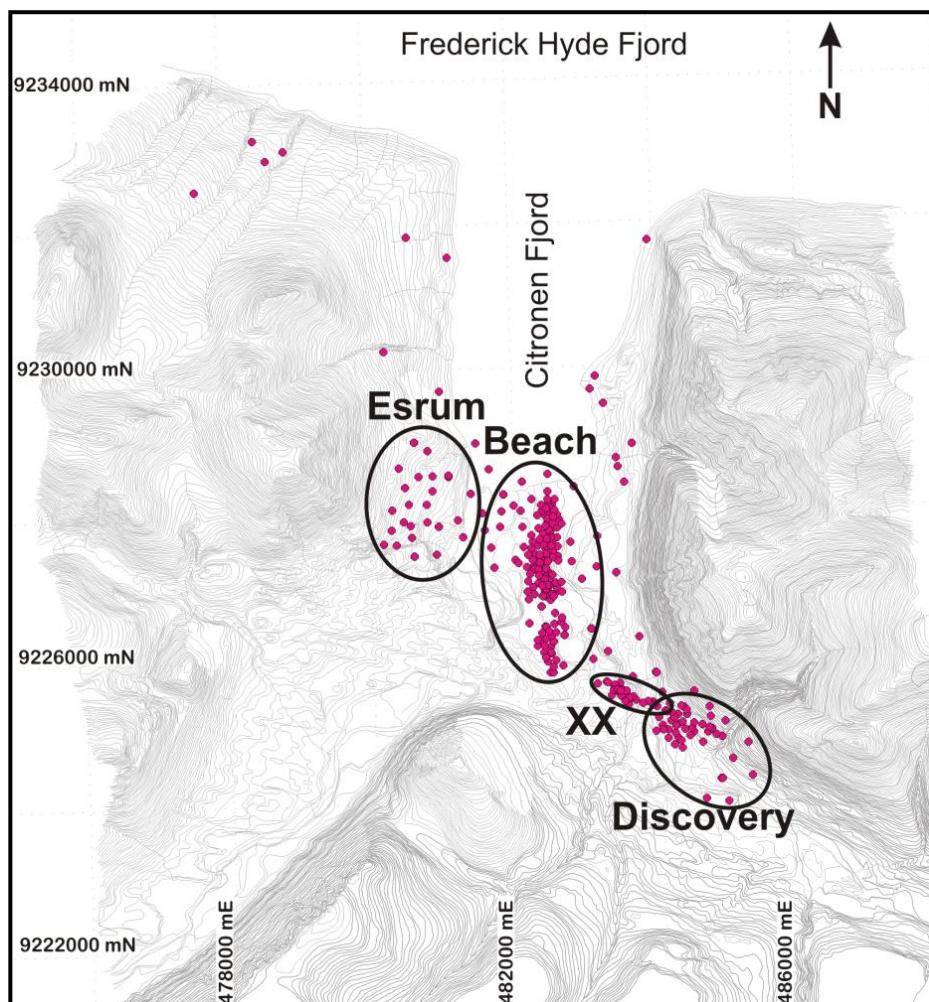
The Citronen Deposit is interpreted as belonging to the SEDEX deposit class, forming syn-depositionally with sedimentation. The geology of northern Greenland is contemporaneous to that of parts of the Canadian arctic islands, which also host several large base metal deposits of SEDEX and Mississippi Valley Type (MVT) type.

SEDEX deposits are formed in submarine environments by the precipitation of sulphides from metal bearing fluids introduced onto the seafloor through underlying fractures which act as metal-bearing fluid conduits. Large amounts of sulphur are precipitated principally as pyrite and focused around vent areas or 'mounds' on the sea floor. Base metal (Zn + Pb) bearing sulphides at Citronen are predominantly located within laminate horizons surrounding these larger sulphide accumulations.

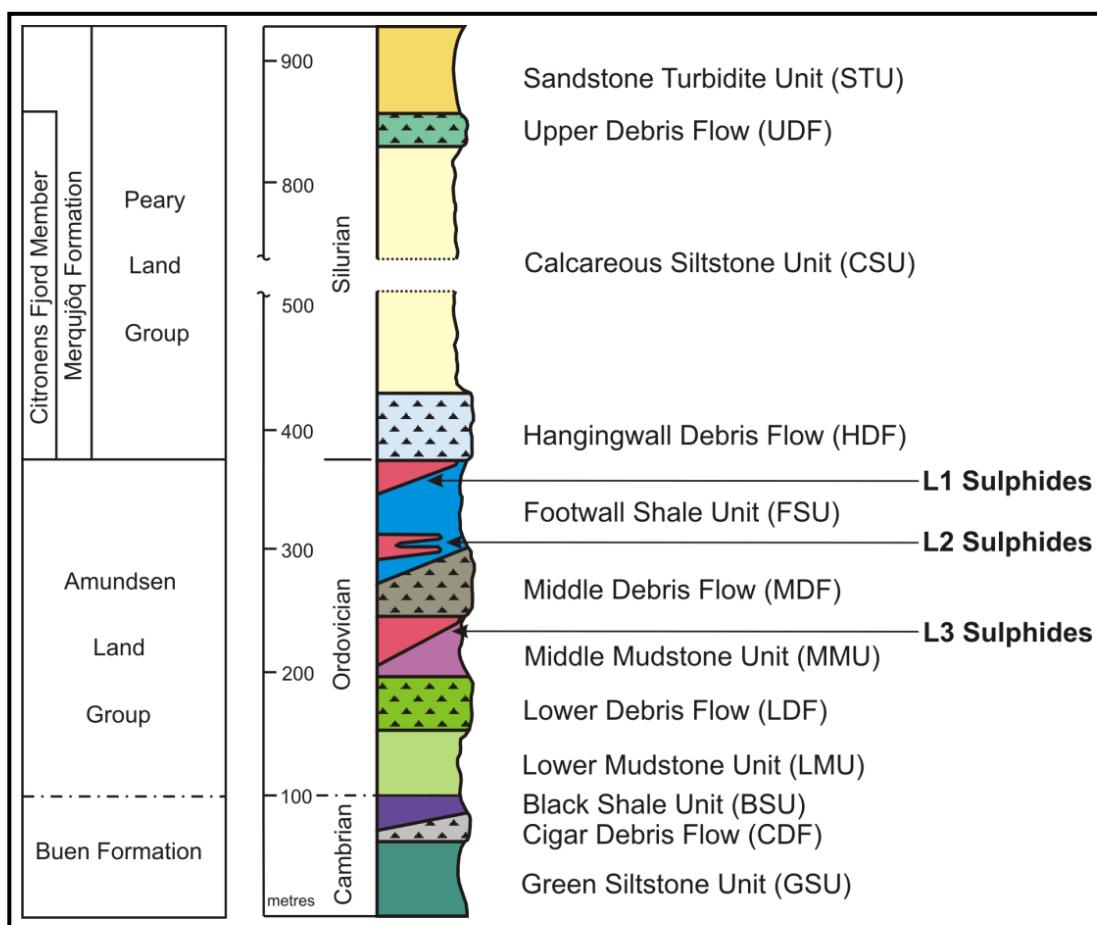
## Mineralisation

Mineralisation at the Citronen Fjord Zn-Pb Deposit comprises several distinct sulphide mounds containing massive and net-textured pyrite-rich mineralisation, interpreted to represent the focal point of fluid influx, flanked by pyritic laminated sulphides that are locally sphalerite and galena-rich. These laminated sulphides host the majority of economic grade mineralisation.

The deposit consists of multiple sulphide mounds forming in three lateral positions (“vents”), defined as the Discovery, Beach and Esrum ore bodies (Figure 3.5). The mounds are present within three stratigraphic positions, termed Levels 1, 2 and 3 (Figure 3.6). Level 3 represents the lowest and oldest stratigraphic position of mineralisation and Level 1 the highest and youngest (Figure 3.6).



**Figure 3.5 - Topographic map showing the location of the major ore bodies at Citronen (red dots signify diamond drill-hole collar locations)**



**Figure 3.6 - Stratigraphic column for the Citronen Fjord Zn-Pb Deposit**

The mineralisation is hosted within two fine-grained sedimentary units, separated by a mass carbonate debris flow. The majority of mineralisation is stratiform, with semi-massive net-textured to massive sulphides accumulating in the core of the mound structure. Structurally controlled stock-work style mineralisation is present within the carbonate debris flows, with the most notable termed the XX ore body (Figure 3.5). The stratiform mineralisation has been identified from outcrop to a depth of approximately 500 metres, with the mineralisation open at depth. Level 1 is located predominantly within the Discovery ore body, Level 2 is evident discontinuously across all three ore bodies and Level 3 contains the largest volume of sulphides, with a lateral extent of over 3,000 metres between the Beach and Esrum ore bodies.

The mineralisation is pyrite dominated with variable amounts of sphalerite ((Zn/Fe)S) and lesser galena (PbS) present as sulphide species. Minor chalcopyrite (CuFeS<sub>2</sub>) has been documented and interpreted as having formed during remobilisation and enrichment of primary stratiform-hosted mineralisation. No economically significant Cu or silver (Ag) has been identified to be associated with the sulphide mineralisation.

Primary mineralisation is generally fine to medium grained, weakly to moderately laminated and bedded parallel with regionally deposited sediments. Gangue mineralogy is primarily silt and clay from mudstones deposited contemporaneously with sulphide mineralisation.

## Zinc Exploration Potential

To date, exploration has not constrained sulphide mineralisation within the Citronen area. Several geophysical, geochemical and structural targets within the project area which have the potential to host further significant Zn and Pb mineralisation are yet to be tested.

On a local scale, the deposit shows considerable exploration potential based on open-ended drill results and geophysical survey data. Ironbark is progressively testing gravity anomalies identified by Platinova as part of its current exploration work and there is strong exploration potential to both extend zones of current resources and find new zones of mineralisation.

On a regional scale, SEDEX deposits do not tend to appear as single entities but are generally part of a larger scale 'camp' of deposits; examples include the Mount Isa-McArthur Basin in Australia with seven deposits, and the Selwyn Basin in Canada with 17 deposits. This highlights the prospectivity surrounding Citronen within Ironbark's extensive licence package in the underexplored Franklinian Basin. Ironbark holds in excess of 1,100 km<sup>2</sup> of 100%-owned tenure surrounding Citronen. The tenure covers the prospective Trolle Land Fault Zone, which has been interpreted to be the main feeder zone for the mineralisation at Citronen Fjord.

## Drilling

Platinova drilled 148 diamond holes for 32,702 metres between 1993 and 1997. Diamond drilling was by either NQ or, more commonly, BQ diameter. To date, Ironbark has completed 166 diamond holes in BQ, NQ, and HQ for 34,240 metres, bringing the total metres drilled at Citronen to date in excess of 66,000 metres.

Drilling at Citronen is conducted using heli-portable diamond drill rigs. There is extensive permafrost in the region and specialised drilling techniques are required to ensure productivity and avoiding loss of drilling equipment through freezing. Drilling is conducted from April to mid-September. Drill core is photographed and non-assayed material is stored on-site.

## Sampling Method and Approach

Sampling techniques will be discussed by company and period:

- Platinova: 1993-1997
- Ironbark: re-sampling 2007
- Ironbark: 2008-2011

### 1993-1997 Sampling Method

Drill core was logged on-site by geologists and zones of sulphide mineralisation were tested using a portable x-ray fluorescence (XRF) apparatus. Intercepts deemed to be of economic significance were split on-site and half-core samples were transported to assay laboratories in Canada. A broad consensus for economic significance was approximately 2-3% Zn over one metre. Sampling was done on a geological basis with sample lengths between 0.15 m and 1.3 m selected for chemical analysis in Canada.

Platinova collected 1,534 samples for analysis from drilling between 1993 and 1997.

### 2007 Sampling Method

Ironbark did not conduct new drilling in 2007; instead, all drill core was examined on-site using a handheld XRF and a lower cut-off of 1% Zn to select samples for chemical analysis. Further to this, samples were selected on a 0.5 m or 1.0 m basis. When sampling was conducted around zones of previously sampled material, sample interval lengths were selected so as to round-off intervals to multiples of 0.5 m. Samples were transported to ALS Chemex Laboratories Ltd (ALS Chemex) in Vancouver for analysis, using inductively coupled plasma (ICP) and XRF techniques. Ironbark analysed all material for Zn, Pb, and Fe.

Ironbark submitted 2,765 samples for analysis in 2007. The sampling procedure followed by Ironbark involved:

- drill core inspection by a geologist
- analysis by XRF
- samples selected, marked and then sawn in half with a diamond saw
- half-core samples placed in a calico bag, which were individually numbered referencing the drill hole identification and the sample number from that hole

In addition to core sampling, 54 sample standards were used in 2007, provided by Geostats Pty Ltd, Australia (Geostats). Three different standards were used.

Quality assurance/quality control (QA/QC) sampling was conducted to confirm Platinova's work and several zones of previously assayed material (remaining half core) were assayed.

### **2008-2011 Sampling Method**

Sampling of drill core obtained by Ironbark during the 2008-2011 drill programmes is as per Platinova/Ironbark methods (i.e. the drill core is logged, photographed, and sulphide intercepts checked by portable XRF on-site). Intervals deemed to be 1% Zn or greater were half-cored and transported for analysis. Samples were transported to ALS Chemex in Sweden for analysis using ICP atomic emission spectroscopy (ICP-AES) (laboratory technique ME-ICP81). A suite of 26 elements were analysed for, including Zn, Pb, Ag, Fe, Cu and S.

Duplicate analyses were conducted on an average of one per 25 samples. ALS Chemex performed the duplicate analyses on selected sample intervals, with two representative splits taken from the same interval.

As in 2007, Geostats standards were used for QA/QC control. On average, one standard was analysed for every 20 samples sent to the laboratory.

### **Data Verification**

Ironbark has undertaken adequate measures to ensure the integrity of assay data used in the resource estimation. Due to previous exploration being conducted relatively recently and by only one company, Ironbark has been able to produce a complete and very well audited database. Assay sample pulps from the 2007-2011 analyses were transported to Perth, Western Australia, and stored by Ironbark.

Since acquiring the Citronen Fjord Project, Ironbark has employed numerous consultant companies to review and assess the data validity for the Project. Expedio (based in Perth, Western Australia) managed Ironbark's database off-site from 2008-2010, with the small additional data obtained from the 2011 field season integrated in-house by Ironbark personnel.

A number of quality controls were undertaken during Ironbark's initial 2007 investigation of the deposit in order to correlate Ironbark's new data (original assaying of Platinova core) to that of the historic data compiled by Platinova. Ironbark took the remaining half core for 15 of Platinova's samples and had it assayed by the same laboratory (now ALS Chemex of Vancouver, Canada). Comparison of the Ironbark and Platinova assay data showed a 0.98 correlation coefficient for Zn and 0.96 for Pb.

Duplicate chemical assays were regularly performed with a total of 123 duplicate analyses performed during 2007-2011. The correlation of these beta samples to the original alpha sample was exceptional with both Zn and Pb having a correlation coefficient of effectively one (1) (0.9978 for Zn and 0.9973 for Pb).

Certified laboratory standards were regularly submitted with a total of 170 included during Ironbark's exploration. The six standard varieties comprised GBM301-6, GBM309-16, GBM901-5, GBM906-15, GBM907-14 and GBM996-3 and were produced by Geostats Pty Ltd (based in Perth, Western Australia). Five of the six standard varieties returned Zn and Pb values within acceptable limits; taking into account assay precision, these results are deemed acceptable (i.e. within 2 standard deviations). One standard (GBM906-15) returned numerous Zn and Pb values that fell outside of the acceptable range. This standard was irregularly submitted

over numerous batches and years (2009, 2008 & 2011). Other standards, duplicates and internal laboratory standards in the same batches all returned within acceptable ranges. It is assumed the batch of GBM906-15 reference standards used was not reliable.

To cross check assay results, and as an exploration aid, Platinova and Ironbark routinely took handheld XRF measurements of the drill core. Ironbark took readings every five centimetres and averaged these values to the corresponding sample interval. These results were compared with the actual assay values to provide a quality check of assays, i.e. any grossly different values would be obvious.

A detailed study of the 2010 season data, based on over 18,000 individual XRF readings and their corresponding 736 chemical assays, looked at the correlation and variations in relation to mineralisation style. The results were remarkably accurate with a correlation coefficient of 0.93 for all readings (with 98% of readings falling within  $\pm 5\%$  of the chemical assay), 0.96 for laminated sulphides (predominant host to economic mineralisation) and 0.89 for massive/dendritic sulphides. These results add another level of confidence to the chemical assay information.

### **Geological Modelling**

Geological modelling of the Citronen Fjord Deposit is aided by the relatively simple nature of the mudstone-debris flow horizons and the stratiform nature of mineralisation centred on vent-mound locations. Working with observed (mapping and drilling) geological information, a robust geological model has been prepared to allow for statistical analysis, domaining and resource estimation.

Three geological models and resource estimates have been produced by Ironbark since 2007. The first was by Wardrop in 2007 who modelled mineralisation as four geological solids as part of the National Instrument 43-101 resource estimate. The solids created were Hanging-wall Debris Flow (DF1), Inter-bedded Sulphide Level 1 (IBS1), Middle Debris Flow (DF2) and Inter-bedded Sulphide Level 2 (IBS2).

In 2007-2008, Ironbark developed the Wardrop model further, adding smaller zones of fault controlled (remobilised) mineralisation and further constraining zones around specific down-hole mineralised intercepts to reflect grade continuity; it should be noted that essentially the same geological horizons as defined by Wardrop were maintained during Ironbark's development of the Wardrop model. Ironbark's modelling was done in Perth using Maptek Pty Ltd's Vulcan™ software. Geological surfaces and solids include extrapolation of several normal faults associated with areas close to the Trolle Land Fault (outside resource and development areas) as well as within the Discovery Zone (the volumetrically minor XX Zone mineralisation is fault hosted).

In late 2009-2010, Ravensgate updated Ironbark's in-house JORC code resource estimate, using a model that integrated the drilling data from the 2009 drilling programme. The domains originally modelled by Ironbark were updated using Mintec Inc's MineSight® (MineSight) 3D modelling software to create a new JORC-compliant resource.

Ravensgate updated the model after the 2010 field season and then again after the 2011 field season. The current resource model completed by Ravensgate was finalised in February 2012 and is referred to as the "2012 Model".

The 2012 Model was reviewed in 2014 and the appropriate tables were included to ensure that the resource met the JORC 2012 requirements for reporting.

### **Bulk Density**

Ironbark conducted numerous empirical Specific Gravity (SG) measurements of drill core from a large range of different rock types and mineralisation styles from the deposit. Ironbark also examined statistical methods to calculate bulk density based on mineral abundance and stoichiometric density.

To calculate the bulk density in the deposit, Ironbark produced a theoretical density for each block in the model based upon the modelled value of Fe, Pb and Zn and rock type coding. This approach is thought to be more accurate than using an averaged density value for each domain.

The interpolated densities for each block were calculated using a formula that utilised the Ordinary Kriged Fe, Pb and Zn values for that block. The formula assumes that all Zn is reporting to sphalerite (SG of 4.05), Pb to galena (SG of 7.4) and Fe to pyrite (SG of 5.01), with the remainder consisting of mudstone gangue (SG of 2.78).

### **Variography**

The deposit statistics were thoroughly reviewed using both raw sample and composite data. A standard one metre length down-hole composite was used. All compositing, data processing and statistical analyses were conducted in MineSight Compass software by geological consultants Ravensgate.

It was determined the majority of mineralised domains display relatively low composite population variances and low coefficients of variation. The distribution of Zn and Pb within the defined domains at Beach, Discovery and Esrum is observed to be relatively predictable and mostly display low coefficients of variation.

A 340 m interpolation range was used for primary interpolation runs, based on the broad 'between hole' variography; the range is also a practical distance required to adequately 'fill' blocks within mineralisation shells in the block model. The nominal 50 x 50 m drilling pattern present throughout the main parts of the deposit is adequate to attain sufficient numbers of sample composites used within interpolation search ellipsoids.

### **Grade Estimation**

It was determined the optimal estimation block size, based on the data density and ore zone geometry, was 10 m x 10 m x 1 m – East (X), North (Y), Elevation (Z).

The current resource model was produced using the Ordinary Kriging interpolation technique for all block model interpolation and the resulting kriged items for Zn, Pb and Fe were used for all subsequent resource reporting.

A series of Ordinary Kriging and Inverse Distance Squared interpolation runs were conducted separately for each mineralised domain, with parameters adjusted for each particular domain orientation, statistics and variography. Each of the individual domains was assigned specific 'nugget', 'sill' and search ellipsoid parameters for Zn, Pb and Fe items.

## **SECTION 4 - MINING**

## 4. MINING

Two significant mining studies have been used in this Report, namely, the Wardrop Engineering Inc. (Wardrop) report of May 2011 and Mining Plus Pty Ltd (Mining Plus) report of March 2012. The mining methods and calculations were not altered in this report from the previous studies. There has however been some cost updating.

### 4.1 Wardrop Mining Report, June 2011

The Wardrop mining feasibility study report included both open pit and underground mine planning and design, potential mineable resource estimates, production schedules and cost estimates. The Wardrop report was completed in June 2011.

Wardrop used the 2010 Resource model (dated 25<sup>th</sup> January 2011) for mine planning and optimisation. The resource model was derived from the Ravensgate “2010 Resource Estimate Report”.

Total mining production from the surface and underground mines was set at three million tonnes per annum (Mtpa). The underground mine was planned to produce at a rate of 1.5 Mtpa initially with the additional 1.5 Mtpa to come from the open pit. Once the open pit resources were consumed, the production rate at the underground mine would ramp up to 3.0 Mtpa during Years 6 and 7 to give the project a total mine life from open pit and underground mine of 14 years.

### 4.2 Mining Plus Mining Report, March 2012

The second significant mining study is the Mining Optimisation, Design & Schedule of the underground and open pit zinc-lead resources prepared by Mining Plus (dated March 2012). The Mining Plus work represents the optimisation and further detail study of the Wardrop work.

A major difference between the Mining Plus and Wardrop reports is Mining Plus’ use of the updated 2012 Resource Model, which included the results of the 2011 drilling programme. The new resource model was derived from the Ravensgate “End of 2011 Resource Estimation Report” and is referred to as the 2012 Resource Summary. As a result of this work and the enhanced resource definition, the Wardrop mining schedules became redundant and are superseded by the Mining Plus data.

The Mining Plus underground and open pit mine designs were conducted, sequenced and scheduled based on three ore production rates of 3.0 Mtpa, 3.3 Mtpa, and 3.6 Mtpa using a 4.5% Zn cut-off grade. This is consistent with the current process plant design throughput of 3.3 Mtpa, with the capacity to increase to 3.6 Mtpa.

In addition to basing mine planning and optimisation on the updated resource block model, Mining Plus conducted optimisations and comparative evaluations.

The underground and open pit mining schedules are summarised respectively in Table 4.1 and Table 4.2. In order to take advantage of the significantly higher underground ore grades and for financial modelling purposes to enhance the project economics, the underground mining operation 3.3 Mtpa scenario is scheduled to take place in Years 1 to 11 (one year more or less for the 3.0 Mtpa and 3.6 Mtpa scenarios respectively). Following the depletion of underground resources, the open pit ore production will commence during Year 11 to maintain the 3.3 Mtpa ore production level. This reversing of underground and open pit schedules is a significant point of difference between the Mining Plus and the Wardrop reports.

**Table 4.1 - 3.3 Mtpa yearly underground schedule summary**

		Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Total
Ore Tonnes	Mt	0.1	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	2.6	35.8
Zn Grade	%	4.94	7.81	7.02	6.00	5.42	5.98	5.53	5.62	5.46	5.01	5.04	5.45	5.85
Pb Grade	%	0.52	0.65	0.65	0.62	0.51	0.46	0.44	0.37	0.41	0.36	0.41	0.64	0.50
Fe Grade	%	16.21	11.89	14.43	16.78	17.16	18.83	17.74	19.68	17.70	14.72	18.99	19.51	16.99

**Table 4.2 - 3.3 Mtpa yearly open pit schedule summary**

		Year 0	Year 1 <sup>(Note 1)</sup>	Year 2	Year 3	Year 4	Total
Ore Tonnes	Mt	Minimal	3.3	3.3	2.6	0	9.2
Zn Grade	%	3.35	3.23	2.82	3.31	0.00	3.10
Pb Grade	%	0.63	0.59	0.54	0.59	0.00	0.57
Fe Grade	%	27.03	22.70	22.43	19.43	0.00	21.70

Note 1: 0.7 Mt of this ore is combined with underground ore in Year 11 to maintain the 3.3 Mtpa ore mining rate.

### 4.3 Summary of Mining Plus Mining Study

#### Resource Model Comparison

The grade estimation conducted in the Resource model provided to Mining Plus for optimisation and evaluation involved two grade estimate techniques, namely Inverse Distance (ID) and Ordinary Kriging (OK). A comparison of the two grade fields on the overall potential underground project tonnes and grade was conducted by Mining Plus through interpolation of grade tonnage report curves.

The comparison of ID and OK techniques displays immaterial differences with regards to the mine design, sequence and final extraction data. At the proposed cut-off grade of 4.50% Zn there is a difference of 0.8 Mt for 145 Zn metal tonnes and 11 Pb metal tonnes in the 2012 Resource. This represents a difference in the order of 2.0% in tonnes and 5.0% to 6.0% in grade.

#### Underground Optimisations

Due to the nature of the ore zones indicated by the underground geological model, a comparative study was undertaken to quantify the potential benefits of implementing a mining width of two metres compared to the Wardrop mining study width of four metres. A software program was used to assess the resource block model to determine the optimal size, shape and location of stopes based on various input and grade cut-off criteria. The resultant potential mining inventory output allowed for an evaluation and determination of the most suitable stope shape (extraction dimensions) to pursue for a more detailed mine design.

Mining Plus concluded that at a 4.50% Zn cut-off grade the two metre minimum mining thickness displays a slightly greater tonnage and higher zinc grade than the four metre scenario. However, in the opinion of Mining Plus, this increase is not of sufficiently significant quantity to justify the specialised mining equipment and possible production rate constraints of a smaller capacity fleet. Mining Plus continued through mine design, sequencing and scheduling with the four metre minimum mining thickness scenario at a 4.50% Zn cut-off grade.

## Underground Design

Mining Plus continued with the Wardrop study information and data for room and pillar design, all geotechnical information, mining recovery ratios and all ventilation information.

Ironbark requested a dilution skin be added into the design to allow for over break. The design skin was calculated by adjusting the “pillar drive” and “ore drive strips” to be mined at a height of 0.3 m above the planned height.

With the mining method being room and pillar, a recovery factor of 100% recovery was assumed as ore loss should be negligible provided that a tele-remote bogging system is used for the recovery of the ore drive strip material. The likelihood of ore loss would increase if a line of site remote bogging system was used.

All mining has been planned for conduction via development jumbo and, as such, minimal overbreak (i.e. unplanned dilution) outside of the planned dilution skin is expected. As a result, no tonnage factors were applied to this design.

As reported by Wardrop, underground mine backfill will be from process plant tailings slurry that will be pumped into place and then freeze naturally due to the permafrost conditions. As deposition and freezing occurs, the excess water from the tailings will be pumped from the mine.

## Incremental Ore

Incremental ore is defined as that material that must be excavated in order to gain access ore. As such this material must be drilled, blasted and hauled as part of the course of mining. Typically it would be classified as waste because it is below the economic mining cut-off grade. However, should this material be suitably mineralised to cover the cost difference between hauling and dumping as waste and delivery to the mill, together with processing, shipping and royalty payments, it then becomes economically valuable and can be considered incremental ore.

For the Mining Plus evaluation, all material (stope and development) above an incremental cut-off grade of 3.50% Zn was progressed to the scheduling stage of the study.

## Underground Mine Scheduling

The underground mine has been scheduled at production rates of 3.0 Mtpa, 3.3 Mtpa and 3.6 Mtpa, with Year 1 considered to be the first year of full production. As per the schedules, the project has one year of pre-production and an overall mine life in the order of 10 to 12 years dependant on available material and scheduled production rate.

The majority of the resource is contained within the Esrum L3N, Beach L2N and Beach L3N domains. Mining Plus undertook detailed development and stope designs on these three domains for scheduling purposes. In addition to this, two smaller lodes in the South of the Beach deposit (Beach L2S and Beach L3S) contain material above the 4.50% Zn cut-off grade. This material contains relatively low tonnages and would require substantial additional development to access. However, as it would be extracted at the end of the underground mine life, the scheduled extraction of the Beach South material has also been included.

A comparative summary of the three production scenarios is presented in Table 4.3. A more detailed summary of the 3.3 Mtpa production rate is presented in Table 4.4.

### Figure 4.1 Mine Development Overview and Year -1 Developments

to Figure 4.6 show the mine developments by year.

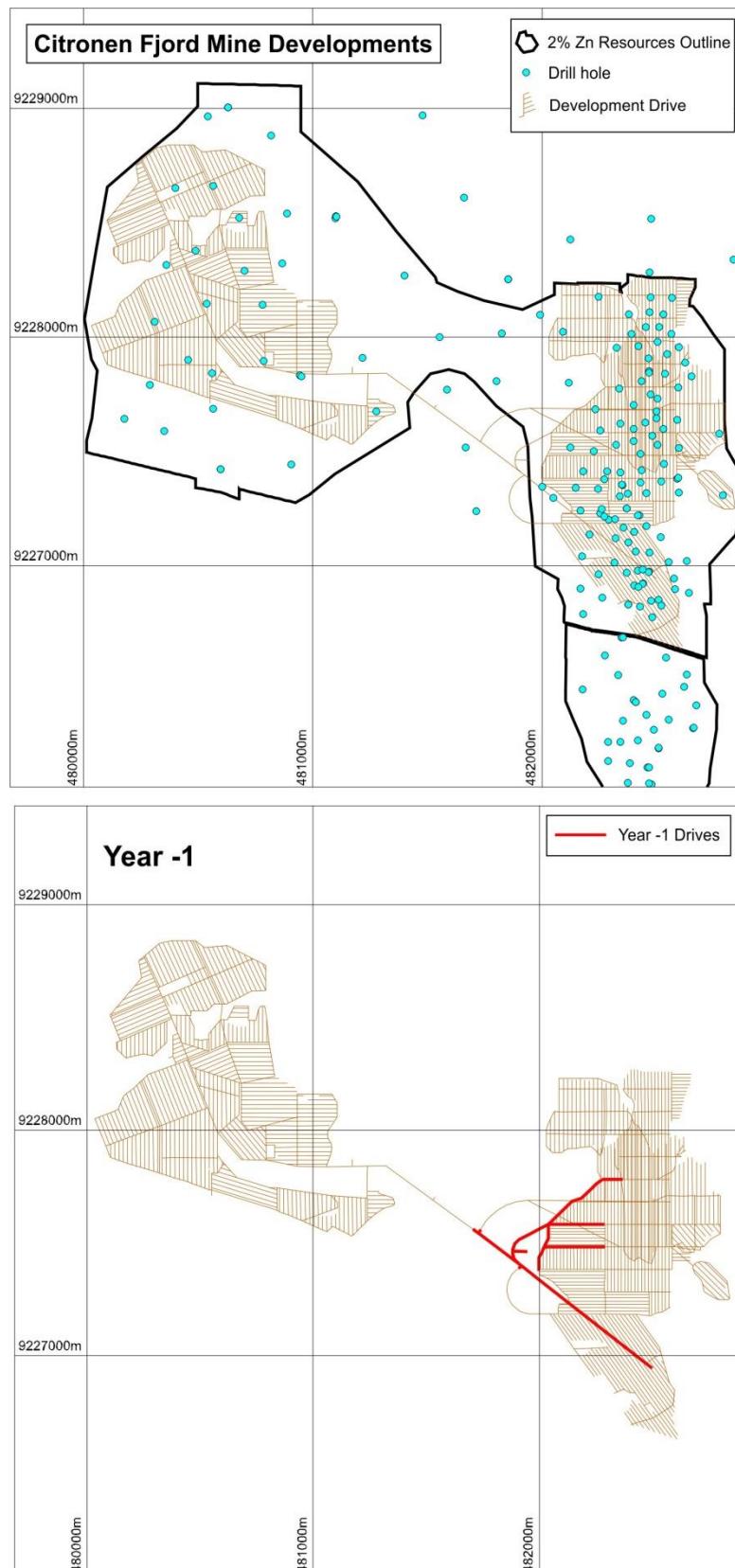
**Table 4.3 - Summary production schedule**

Item	Unit	Quantity
<b>Mine life</b>		
3.0 Mtpa production	Years	12.9
3.3 Mtpa production	Years	11.8
3.6 Mtpa production	Years	10.9
<b>Ore tonnes</b>	Mt	<b>35.8</b>
Zn grade	%	5.85
Zn metal	Kt	2,094
Pb grade	%	0.50
Pb metal	Kt	178.2
Fe grade	%	16.99
Fe metal	Kt	6,076
<b>Bogged waste</b>	Kt	410.3
<b>Total bogged</b>	Mt	36.2
<b>Total development</b>		
Lateral - capital	metres	5,903
Lateral - operating	metres	180,283
Vertical - capital	metres	1,906

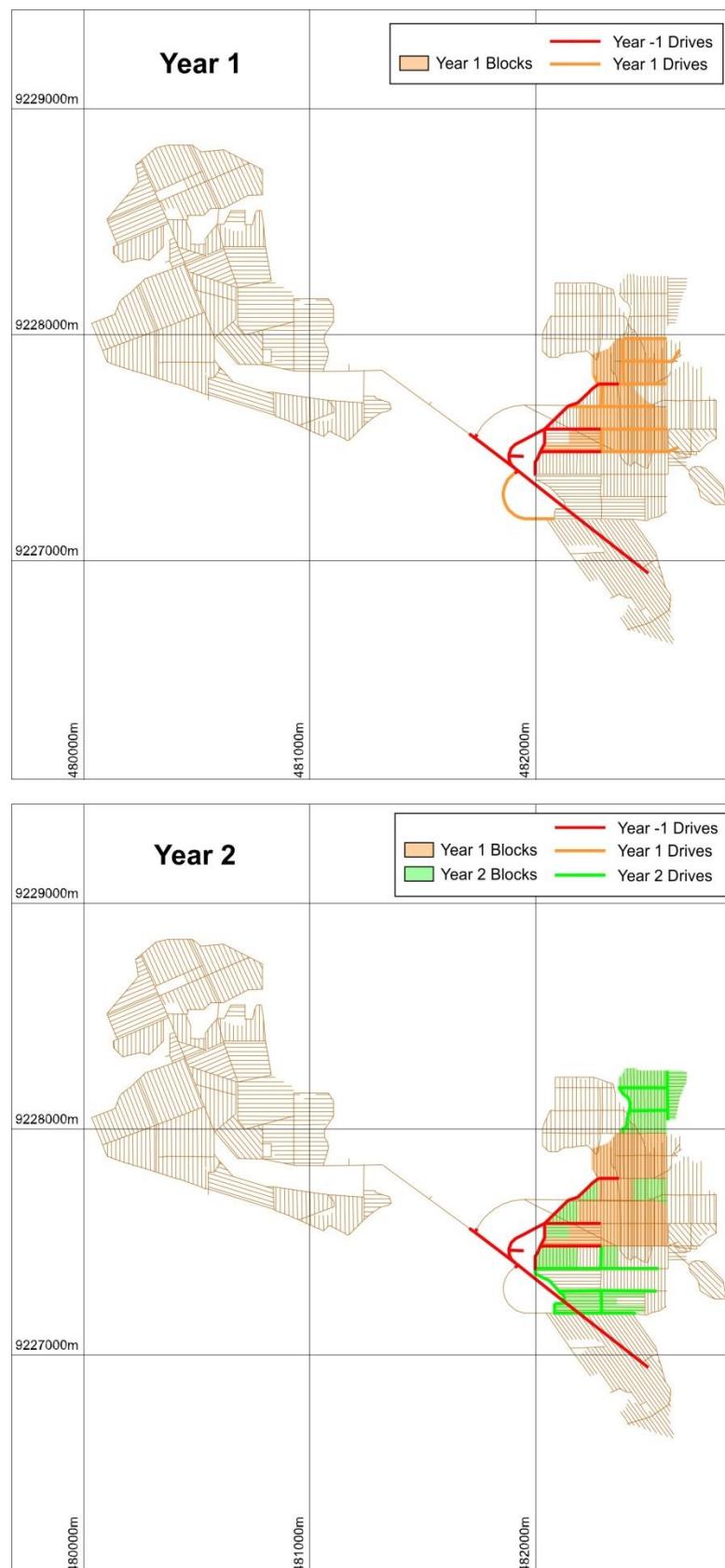
At the point in time when the underground resources are depleted the underground mine will be closed down, subject to further resources being discovered in the intervening period. Ironbark geologists consider that the open ended nature to the mineralisation will provide excellent scope to increase the potential mine life.

Table 4.4 - 3.3 Mtpa production schedule

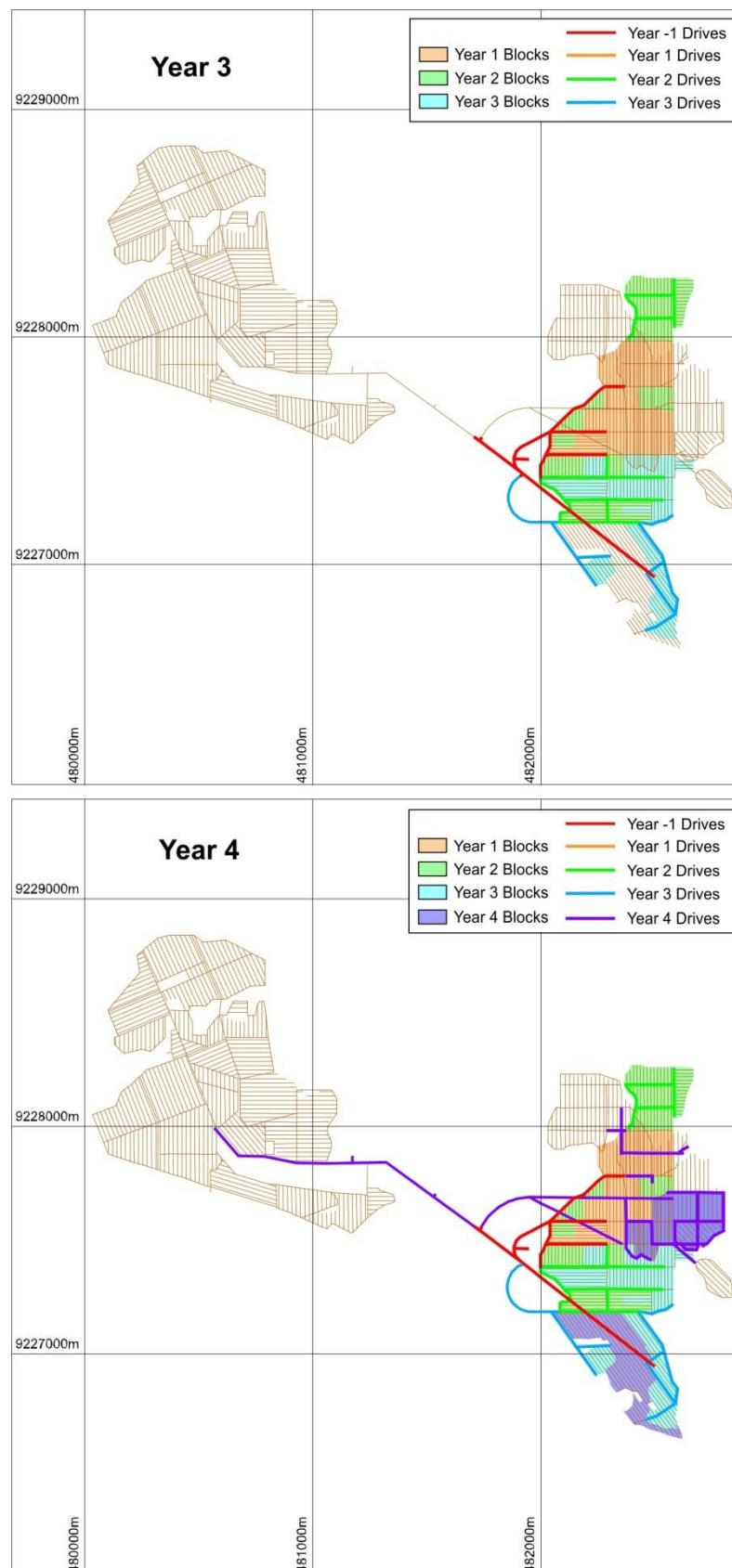
		TOTAL	YR -2	YR -1	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11
<b>Ore tonnes</b>	<b>Mt</b>	35.8		0.1	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	2.6
Zn grade	%	5.85		4.94	7.81	7.02	6.00	5.42	5.98	5.53	5.62	5.46	5.01	5.04	5.45
Zn metal	kt	2,094		3.6	257.7	232.8	198.8	179.9	197.4	184.3	186.2	180.3	165.7	167.2	140.3
Pb grade	%	0.50		0.52	0.65	0.65	0.62	0.51	0.46	0.44	0.37	0.41	0.36	0.41	0.64
Pb metal	kt	178.2		0.4	21.5	21.5	20.5	17.0	15.3	14.7	12.2	13.4	11.7	13.5	16.5
Fe grade	%	16.99		16.21	11.89	14.43	16.78	17.16	18.83	17.74	19.68	17.70	14.72	18.99	19.51
Fe metal	kt	6,076		11.6	392.4	478.7	556.2	569.5	621.7	590.7	652.0	584.1	486.5	630.1	502.3
<b>Development</b>															
Ore Tonnes	Mt	14.8		0.1	1.5	1.5	1.4	1.9	1.0	1.1	1.3	1.4	1.3	1.2	1.2
Zn Grade	%	5.34		4.94	7.75	6.78	5.85	5.31	5.77	5.49	5.68	5.32	4.90	4.89	0.05
Zn Metal	kt	788.8		3.6	113.3	102.5	82.8	98.3	56.5	61.2	72.0	75.1	64.8	58.0	0.6
Pb Grade	%	0.45		0.52	0.64	0.66	0.62	0.48	0.41	0.44	0.38	0.41	0.35	0.38	0.01
Pb Metal	kt	66.2		0.4	9.3	10.0	8.8	8.9	4.0	4.9	4.8	5.8	4.6	4.6	0.1
Fe Grade	%	15.42		16.21	11.96	15.22	16.89	17.72	18.01	18.10	19.84	17.22	14.46	18.99	0.20
Fe Metal	kt	2,276		11.6	174.9	230.3	239.1	328.2	176.3	201.6	251.5	243.0	191.4	225.5	2.3
<b>Stopes</b>															
Ore Tonnes	Mt	21.0		0.0	1.8	1.8	1.9	1.5	2.3	2.2	2.0	1.9	2.0	2.1	1.4
Zn Grade	%	6.21		0.00	7.86	7.22	6.10	5.56	6.07	5.55	5.58	5.57	5.09	5.12	9.88
Zn Metal	kt	1,305		0.0	144.4	130.3	115.9	81.6	140.9	123.1	114.2	105.2	100.9	109.1	139.7
Pb Grade	%	0.53		0.00	0.66	0.64	0.62	0.56	0.48	0.44	0.36	0.40	0.36	0.42	1.16
Pb Metal	kt	112.0		0.0	12.2	11.5	11.7	8.2	11.2	9.8	7.4	7.6	7.1	9.0	16.4
Fe Grade	%	18.09		0.00	11.83	13.76	16.69	16.45	19.17	17.55	19.59	18.06	14.89	18.99	35.35
Fe Metal	kt	3,800		0.0	217.5	248.3	317.1	241.3	445.4	389.1	400.5	341.1	295.1	404.6	500.0
<b>Bogged Waste</b>	kt	410.3		54.1	23.6	12.4	97.1	97.4	11.3	10.6	35.1	19.3	20.8	3.3	25.3
<b>Total Bogged</b>	<b>Mt</b>	36.2		0.1	3.3	3.3	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	2.6
<b>Total Dev (Lateral &amp; Vertical)</b>	<b>m</b>	186,392		3,052	19,134	17,878	19,199	23,840	15,639	14,245	15,892	16,906	14,342	13,400	12,865
Ore Development	<b>m</b>	169,910		1,256	18,468	17,649	16,417	20,972	14,792	13,380	14,075	16,474	13,755	12,355	10,316
Waste Development	<b>m</b>	16,482		1,796	666	229	2,782	2,868	847	865	1,817	432	587	1,044	2,550
<b>Lateral Dev Metres</b>															
Capital	<b>m</b>	5,903		1,784	262	0	1,941	206	0	0	9	0	0	0	1,700
Operating	<b>m</b>	180,283		1,268	18,639	17,878	17,039	22,879	15,639	14,245	15,884	16,906	14,342	13,400	12,165
<b>Vertical Dev Metres</b>															
Capital	<b>m</b>	1,906		0	233	0	218	755	0	0	0	0	0	0	700
Operating	<b>m</b>	0		0	0	0	0	0	0	0	0	0	0	0	0
<b>Fill Volume</b>	<b>m3</b>	2,567,906		0	222,924	251,320	287,899	257,112	298,729	230,158	412,308	189,935	81,553	265,156	70,812



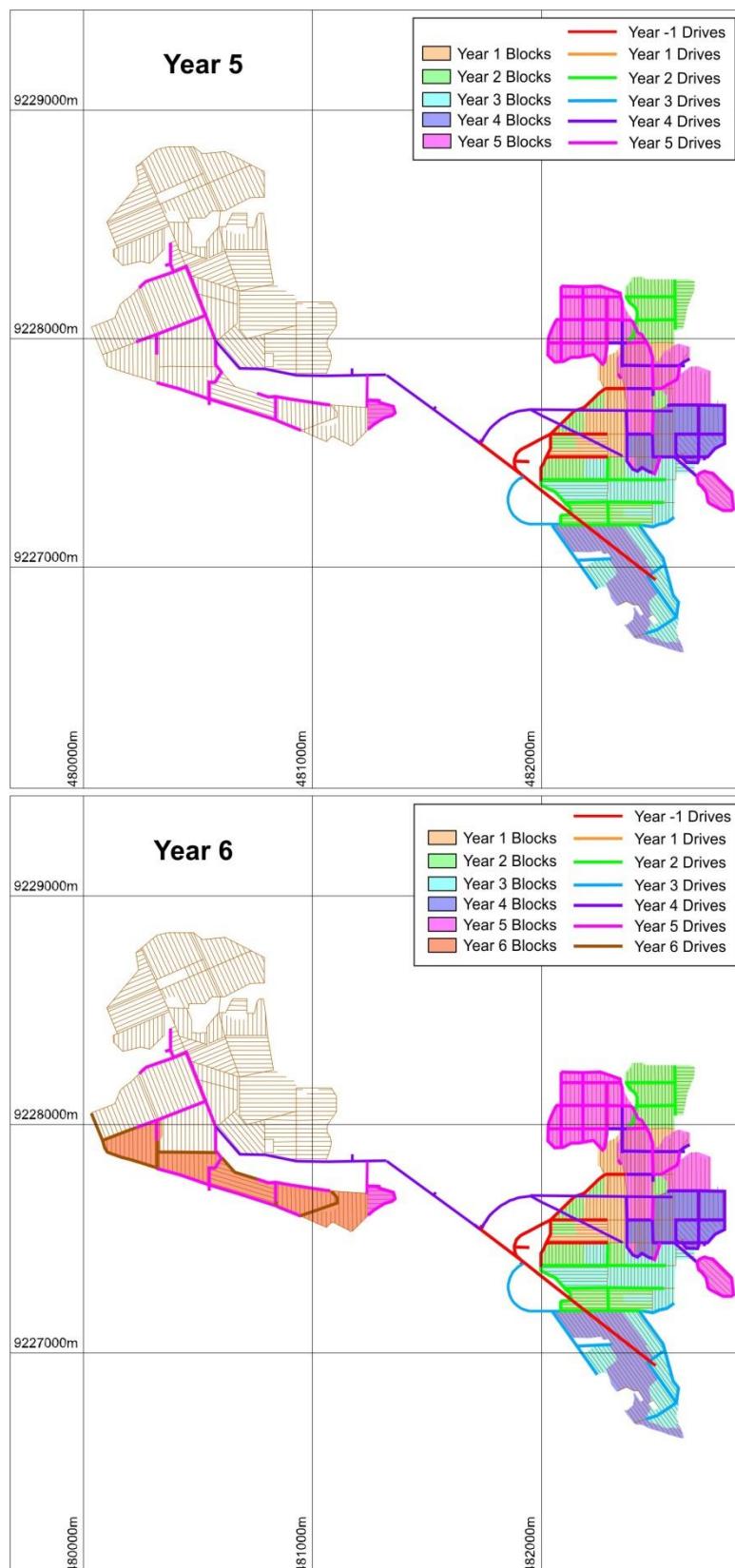
**Figure 4.1 Mine Development Overview and Year -1 Developments**



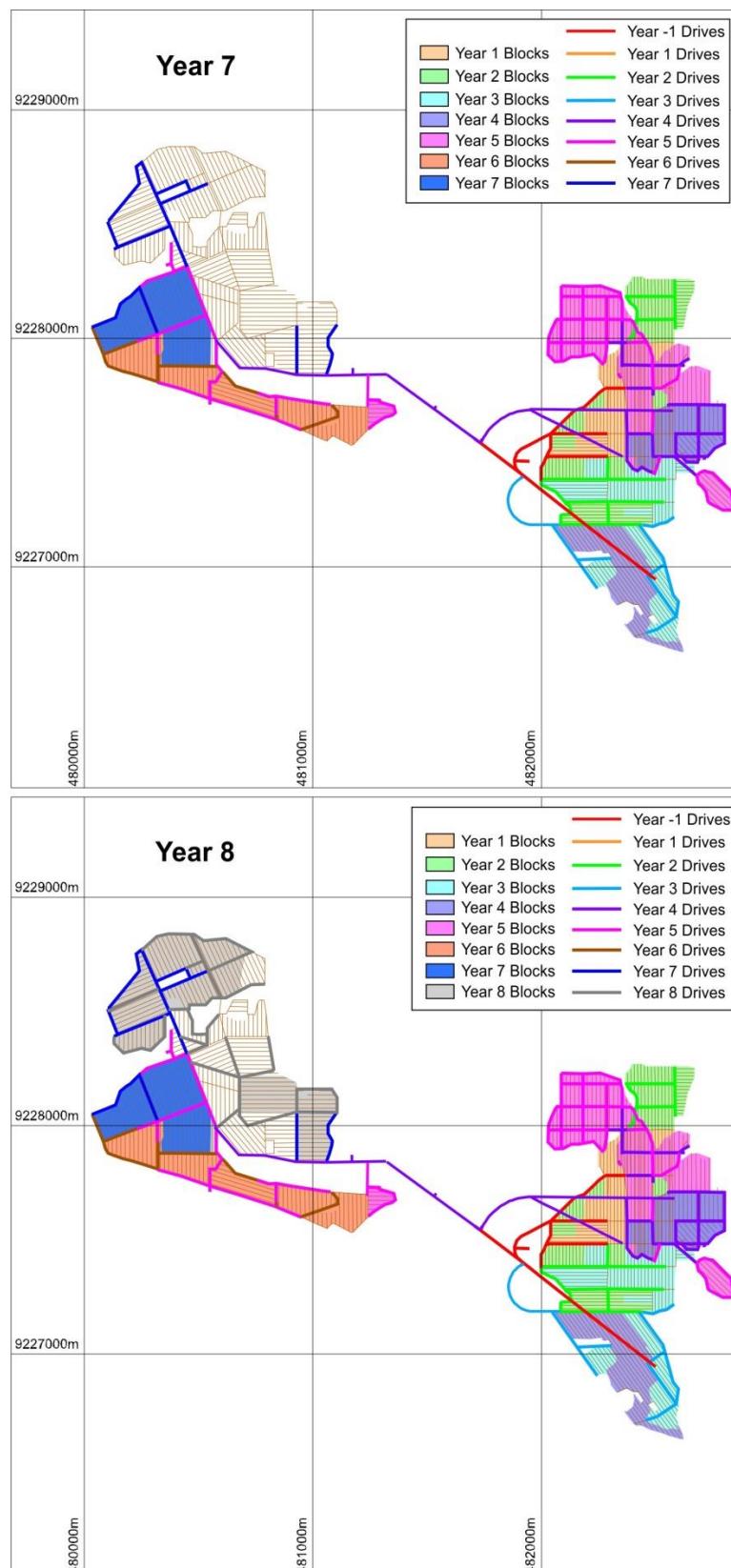
**Figure 4.2 - Year 1 and Year 2 Mine Development**



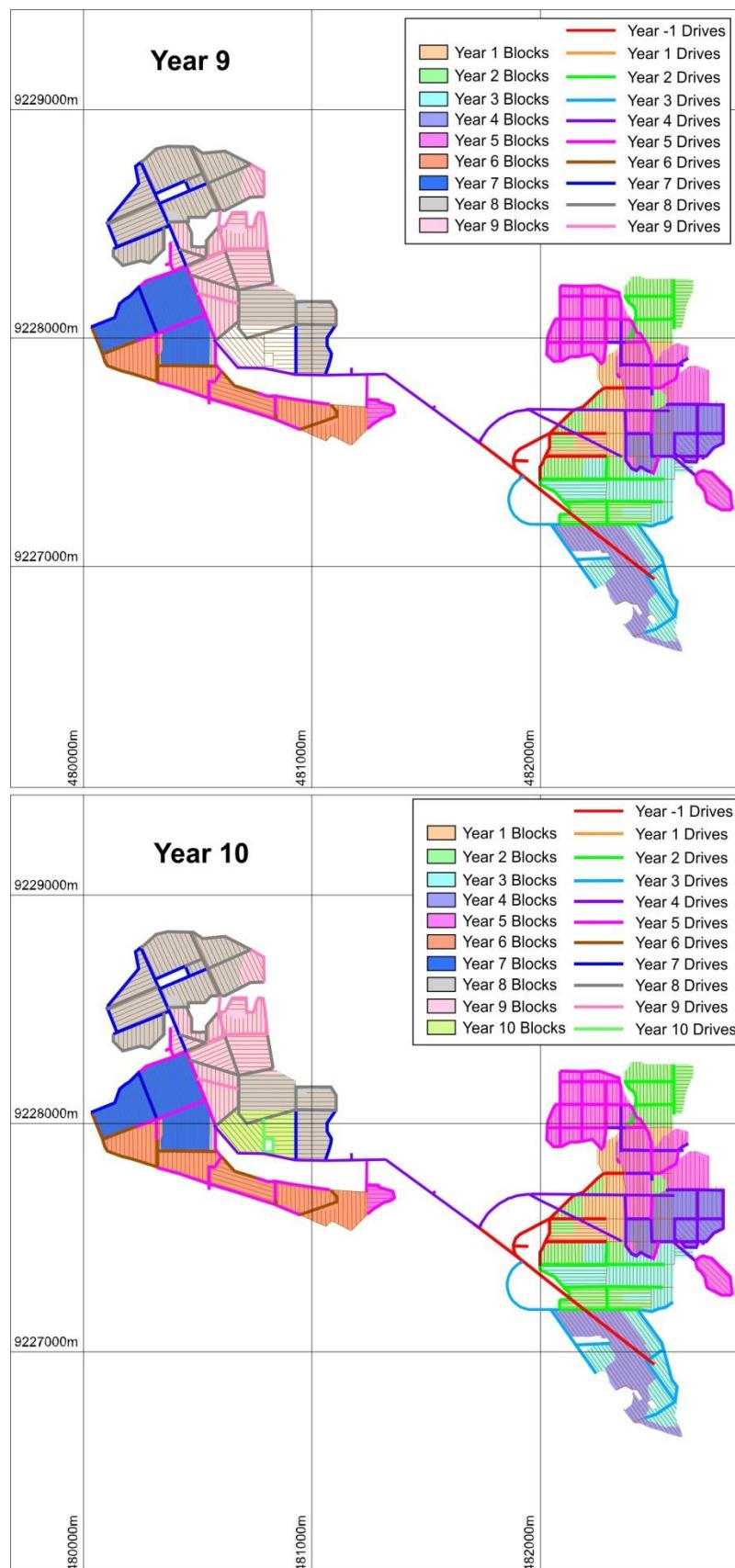
**Figure 4.3 - Year 3 and Year 4 Mine Development**



**Figure 4.4 - Year 5 and Year 6 Mine Development**



**Figure 4.5 - Year 7 and Year 8 Mine Development**



**Figure 4.6 - Year 9 and Year 10 Mine Development**

## Decline Haulage Capacity

The Mining Plus study shows ore haulage via the decline is feasible up to and including the highest ore production rate that has been studied (3.6 Mtpa). This conclusion is based upon using the 60 tonne capacity trucks suggested in the Wardrop report.

Mining Plus developed an underground haulage profile based on travel distances and road gradient. Trucking fleet requirements were calculated based on the possible production rates of 3.0 Mtpa and 3.6 Mtpa. The results indicate nine trucks are required for the 3.0 Mtpa case and 11 trucks for the 3.6 Mtpa case.

Haulage interactions were studied in various scenarios of truck and loader combinations. Mining Plus concluded the high level review conducted of the decline capacity adequately displays proof of concept and demonstrates within an acceptable level of accuracy that haulage of 3.0 Mtpa and 3.6 Mtpa can feasibly be moved. This is based on the current proposed design through the single access/entry decline.

## Open Pit Study

Based on the most recent geological model (Ravensgate End of 2011 Resource Estimation Report – “2012 Resource”), Mining Plus undertook open pit block model data validation and mining block model evaluation. Based on this work, an open pit optimisation study was carried out using Whittle Four-X (Whittle) pit optimising software and a final pit design was produced using Surpac software. The quality parameters applied to the optimisation study included using a zinc cut-off grade of 1.3%, a zinc price of US\$2512/t, a final selected strip ratio for the 3.3Mtpa case of 1:1.99 (ore:wastes) with overall pit angles of 37 degrees in the overburden and then steepening to between 45 and 55 degrees in the fresh rock. A dilution rate of 4% was applied with mine recovery rates of 98%.

Pit scheduling was done for the 3.0 Mtpa, 3.3 Mtpa and 3.6 Mtpa cases. The 3.3 Mtpa open pit schedule, which is the base case ore production rate for this Report, is presented in Table 4.5 below.

**Table 4.5 - 3.3 Mtpa yearly open pit schedule summary**

		Year 0	Year 1	Year 2	Year 3	Year 4	Total
Ore Volume	m <sup>3</sup>	1,100	840,514	855,765	695,236	0	2,392,615
Ore Tonnes	t	4,355	3,292,982	3,308,937	2,570,458	0	9,176,731
Zn Grade	%	3.35	3.23	2.82	3.31	0.00	3.10
Pb Grade	%	0.63	0.59	0.54	0.59	0.00	0.57
Fe Grade	%	27.03	22.70	22.43	19.43	0.00	21.70
Zn Recovery	%	83.16	82.29	81.41	82.31	0.00	81.97
NSR		46.63	44.7	39.4	45.8	0.0	43.1
Waste Volume	m <sup>3</sup>	393,922	1,517,890	2,445,897	2,181,208	0	6,466,899
Waste Tonnes	t	1,102,982	4,261,310	6,948,366	6,182,398	0	18,293,405
Stripping Ratio	W:O	253.0	1.29	2.10	2.41	0.00	1.99
Total Volume	m <sup>3</sup>	395,022	2,358,404	3,301,662	2,876,444	0	8,859,514
Total Tonnes	t	1,107,337	7,554,292	10,257,303	8,752,855	0	27,470,136

For the purpose of this Report, open pit mining operations have been scheduled to commence at the end of the life of the underground mine in Year 11 (3.3 Mtpa scenario). Thus, Year 0 in Table 4.5 becomes Year 11 and adjustments are made to the open pit mining rate to continue to maintain a total ore feed rate of 3.3 Mtpa to the process plant until the open pit is depleted. Mining will utilise 10 x 60t haul trucks and excavators until the point where the project is closed out, subject to the discovery of additional resources.

The Competent Person has been to site on several occasions. The modelling has shown a viable economic output and that the mine development is technically achievable from the planned open pits and underground operation with independent geological and geotechnical input. Mining by open pit methods is a widely adopted mining technique applied to similar ore bodies around the world and mining by room and pillar techniques is also an accepted and widely practiced mining technique for flat lying ore bodies.

## **SECTION 5 - TESTWORK & PROCESS PLANT**

## 5. TESTWORK & PROCESS PLANT

### 5.1 Status

In February 2011 Wardrop Engineering Inc. (Wardrop) completed a feasibility study which included a section on Process that is summarised in Section 5.4 of this Report.

In February 2012, Metso revised the study completed by Wardrop to review the plant capacity. The “Process Plant Capacity Review” report developed by Metso is summarised in Section 5.4 of this Report.

The status and corresponding nameplate applicable to key documents is presented in Table 5.1:

**Table 5.1 - Current status and corresponding nameplate applicable to key documents**

Key Deliverable	Author	Nameplate, Mtpa ore feed	Last Updated
Process Design Criteria	Metso	3.0	2010 (Note 1)
Process Flow Diagrams	Metso	3.0	2010
Mass Balance	Metso	3.0	2010
Equipment List	Metso	3.3 (Note 2)	2010
General Drawings	Wardrop	3.3 (Note 2)	2010
P&IDs	Metso	3.0	2010

Note 1: assumed

Note 2: subject to minor revisions

### 5.2 Introduction

Arcon (WA) Pty Ltd (Arcon) was appointed in mid-2012 to review the Feasibility Study (FS) prepared by Metso (under Wardrop as the lead contractor) for the Citronen Project. Arcon reviewed the FS and all existing testwork provided by Ironbark, and concluded the current concentrator design is conservative and throughput could be increased by 10% to 3.3 Mtpa.

In March 2012, Ironbark received Mining Plus’ Mining Optimisation Design Schedule (Section 4 of this Report), that designed, sequenced and scheduled underground and open pit ore production rates up to and including 3.6 Mtpa. Also in March 2012, Ironbark received an investigative report by Metso concerning the concentrator performance at 3.6 Mtpa, based on and developed from the Wardrop 2010 plant capacity of 3.0 Mtpa. The Metso Process Plant Capacity Review was completed in February 2012.

The Metso review concluded, *inter alia*, that all main equipment sections within the process plant, with the exception of the crushing plant, may have up to 20% additional capacity (i.e. to 3.6 Mtpa).

The DFS prepared by Metso has been revised by Arcon, utilising all available testwork data and Metso’s investigation into the increased throughput, to produce the Testwork and Process Plant section of the Report. This document is concise and highlights the major testwork updates and the critical features of the concentrator design.

### 5.3 Process Testwork

ALS Ammtec prepared new testwork reports in December 2011 and January 2012 to include Citronen Beach L2 North. Complementary testwork reports from 2010 were written by Metso.

## The Samples

In December 2011, ALS Ammtec performed grinding and heavy media separation testwork. The samples used for these tests were selected by Ironbark and were combined to produce the following composites:

- Citronen Beach L2 Composite
- Citronen Discovery Composite
- Citronen Beach L2 North Reject Drill Core Composite

## Testwork Results

### Head Assays

The head assay results are presented in Table 5.2.

**Table 5.2 - Head assays**

Analyte	Unit	Citronen Beach L2 Comp	Citronen Discovery Comp	Citronen Beach L2 North Comp
Pb	ppm	4307	3834	7580
Zn	%	3.89	2.78	9.35
Fe	%	17.1	13.6	16.0
SiO <sub>2</sub>	%	18.8	22.6	19.4
S <sub>TOTAL</sub>	%	22.7	16.9	21.7
S <sub>SULPHIDE</sub>	%	21.2	16.6	21.5
True SG	g/ml	3.4558	3.3294	3.4900

Table 5.2 shows almost all of the sulphur is present as sulphides, indicating the majority of the lead and zinc in each composite would be present as galena (PbS) and sphalerite (ZnS) type minerals. Iron in the composites would be expected to be present in pyritic minerals instead of oxide minerals such as hematite and magnetite.

### Unconfined Compressive Strength (UCS)

UCS testwork was carried out on ten (10) specimens selected from the Beach L2, Discovery and Beach L2 North Reject Drill Core composites.

A summary of results from the Beach L2 Composite UCS testwork is presented in Table 5.3.

**Table 5.3 - Beach L2 composite UCS testwork results**

Sample Identity	UCS (MPa)	Failure Mode	Strength Description
Beach L2 93.40–93.48 m	120.501	Columnar	Strong
Beach L2 93.48–93.68 m	105.887	Columnar	Strong
Beach L2 94.06–94.29 m	146.252	Columnar	Strong
Beach L2 94.29–94.55 m	124.702	Columnar	Strong
Beach L2 97.06–98.02 m	128.182	Cataclasis	Strong
Beach L2 98.02–98.22 m	115.453	Columnar	Strong
Beach L2 88.00–88.26 m	166.766	Cataclasis	Strong
Beach L2 88.32–88.50 m	194.438	Cataclasis	Strong
Beach L2 82.10–82.38 m	155.414	Columnar	Strong
Beach L2 89.00–89.21 m	126.193	Shear	Strong

A summary of results from the Discovery Composite UCS testwork is presented in Table 5.3.

**Table 5.4 - Discovery composite UCS testwork results**

Sample Identity	UCS (MPa)	Failure Mode	Strength Description
Discovery 29.10–29.28 m	135.639	Columnar	Strong
Discovery 29.28–29.53 m	89.922	Columnar	Strong
Discovery 29.53–29.71 m	57.920	Shear	Medium Strong
Discovery 25.77–26.00 m	110.671	Shear	Strong
Discovery 26.00–26.21 m	79.298	Shear	Strong
Discovery 24.08–24.40 m	110.846	Cataclasis	Strong
Discovery 24.40–24.61 m	70.626	Columnar	Strong
Discovery 24.61–24.85 m	98.522	Shear	Strong
Discovery 25.59–25.79 m	101.124	Shear	Strong
Discovery 11.52–11.76 m	75.561	Shear	Strong

A summary of results from the Beach L2 North composite UCS testwork is presented in Table 5.5.

**Table 5.5 - Beach L2 North composite UCS testwork results**

Sample Identity	UCS (MPa)	Failure Mode	Strength Description
Beach L2 North 157.0–158.5 m	112.897	Columnar	Strong
Beach L2 North 159.5–161.5 m	73.623	Columnar	Strong
Beach L2 North 129.9–135.7 m	128.027	Columnar	Strong
Beach L2 North 94.35–99.95 m	101.673	Columnar	Strong
Beach L2 North 108.1–113.75 m	111.463	Columnar	Strong
Beach L2 North 108.1–113.75 m	63.976	Columnar	Strong
Beach L2 North 91.35–96.95 m	58.385	Columnar	Medium Strong
Beach L2 North 85.70–91.35 m	65.825	Columnar	Strong
Beach L2 North 105.4–109.5 m	127.142	Columnar	Strong
Beach L2 North 106.95–112.65 m	54.076	Columnar	Medium Strong

### Bond Impact Crushing Work Index

The average Bond Impact Crushing Work Index for all three ore samples is compared in Table 5.6.

**Table 5.6 - Bond Impact Crushing Work Index test results**

Sample Identity	No. of Specimens Tested	Bond Impact Crushing Work Index (kWh/t)			
		Average	Maximum	Minimum	Standard Deviation
Beach L2 Composite	10	7.3	13.0	4.3	3.1
Discovery Composite	10	9.8	16.7	5.0	3.7
Beach L2 North Composite	10	6.5	13.7	3.4	4.0

### SMC Testwork

The Semi-Autogenous Mill Comminution (SMC) testwork results are shown below in Table 5.7.

**Table 5.7 - SMC testwork results**

Sample Identity	DWI (kWh/m <sup>3</sup> )	SG	Derived Values					
			A	b	Mia	Mih	Mic	t <sub>a</sub>
Beach L2 Composite	7.21	3.43	73.9	0.64	16.2	12.2	6.3	0.36
Discovery Composite	9.07	3.72	61.9	0.66	18.0	14.1	7.3	0.29
Beach L2 North Composite	7.21	3.12	77.9	0.56	17.9	13.4	6.9	0.36

### Bond Ball Mill Work Index

The Bond Ball Mill Work Index is shown below in Table 5.8.

**Table 5.8 - Bond Ball Mill Work Index**

Sample Identity	Micrometres		Gbp (g/rev)	Test Aperture Pi ( $\mu$ m)	Bond Ball Mill Work Index (kWh/t)
	F <sub>80</sub>	P <sub>80</sub>			
Beach L2 Composite	2600	55	0.792	75	19.1
	2686	31	0.893	45	14.0
Discovery Composite	2425	58	1.296	75	13.2
	2881	36	0.827	45	16.2
Beach L2 North Composite	2424	56	1.039	75	15.6

### Bond Abrasion Index

The Bond Abrasion Index is shown in Table 5.9.

**Table 5.9 - Bond Abrasion Index**

Sample Identity	Feed Particle Size (mm)	Bond Abrasion Index (Ai)
Beach L2 Composite	-19.0 + 12.7	0.3153
Discovery Composite	-19.0 + 12.7	0.1356
Beach L2 North Composite	-19.0 + 12.7	0.1361

### Heavy Liquid Separation: Crush Optimisation

Sub-samples of the Beach L2 and Discovery composites were utilised for heavy liquid separation at several crush sizes to establish the optimum size for the remainder of the test program. Separations were conducted at a solution SG of 2.95.

A summary of selected data is presented in Table 5.10 and Table 5.11.

**Table 5.10 - Crush optimisation tests on Beach L2 composite**

Product Identity	Weight (%)	Assay Pb (%)	Dist'n Pb (%)	Assay Zn (%)	Dist'n Zn (%)
<b>BEACH L2 COMPOSITE P<sub>100</sub>:38 mm</b>					
2.95 SG Sink	74.59	0.7675	98.00	6.24	99.29
2.95 SG Float	25.41	0.0459	2.00	0.1308	0.71
<b>BEACH L2 COMPOSITE P<sub>100</sub>: 32mm</b>					
2.95 SG Sink	73.42	1.03	98.68	6.07	96.87
2.95 SG Float	26.58	0.0382	1.32	0.5425	3.13
<b>BEACH L2 COMPOSITE P<sub>100</sub>: 25mm</b>					
2.95 SG Sink	72.08	1.89	98.18	9.71	99.53
2.95 SG Float	27.92	0.0214	1.82	0.1191	0.47
<b>BEACH L2 COMPOSITE P<sub>100</sub>: 19mm</b>					
2.95 SG Sink	60.34	0.5269	95.96	5.35	97.68
2.95 SG Float	39.66	0.0264	4.04	0.1930	2.32
<b>BEACH L2 COMPOSITE P<sub>100</sub>: 12mm</b>					
2.95 SG Sink	66.84	0.5435	95.83	5.35	97.66
2.95 SG Float	33.16	0.0340	4.17	0.2584	2.34
<b>BEACH L2 COMPOSITE P<sub>100</sub>: 9.5mm</b>					
2.95 SG Sink	76.98	0.6060	95.36	8.33	97.85
2.95 SG Float	23.02	0.0601	4.64	0.6133	2.15

**Table 5.11 - Crush optimization test in Discovery composite**

Product Identity	Weight (%)	Assay Pb (%)	Dist'n Pb (%)	Assay Zn (%)	Dist'n Zn (%)
<b>DISCOVERY COMPOSITE P<sub>100</sub>:38 mm</b>					
2.95 SG Sink	47.33	0.7167	96.44	6.53	96.56
2.95 SG Float	52.67	0.0238	3.56	0.2087	3.44
<b>DISCOVERY COMPOSITE P<sub>100</sub>: 32mm</b>					
2.95 SG Sink	51.94	1.42	98.12	4.89	97.62
2.95 SG Float	48.06	0.0294	1.88	0.1289	2.38
<b>DISCOVERY COMPOSITE P<sub>100</sub>: 25mm</b>					
2.95 SG Sink	62.15	0.9962	98.32	3.70	98.39
2.95 SG Float	37.85	0.0263	1.68	0.0997	1.61
<b>DISCOVERY COMPOSITE P<sub>100</sub>: 19mm</b>					
2.95 SG Sink	51.38	2.44	99.47	6.26	97.88
2.95 SG Float	48.62	0.0276	1.53	0.1433	2.12
<b>DISCOVERY COMPOSITE P<sub>100</sub>: 12mm</b>					
2.95 SG Sink	56.52	1.14	98.16	4.81	98.22
2.95 SG Float	43.48	0.0232	1.54	0.1133	1.78
<b>DISCOVERY COMPOSITE P<sub>100</sub>: 9.5mm</b>					
2.95 SG Sink	52.46	1.80	96.09	4.32	96.76
2.95 SG Float	47.54	0.0466	3.91	0.1597	3.24

### Bulk Heavy Media Separation Testwork

Sub-samples of the Beach L2, Discovery and Beach L2 North Reject Drill Core composites were utilised for bulk heavy media separation testwork. Separations were conducted at a crush size of 100% passing 38 mm, utilising an *Erickson* cone machine with a media SG of 3.0.

A summary of selected data is presented in Table 5.12.

**Table 5.12 - Bulk heavy media separation results**

Product Identity	Weight (%)	Assay Pb (%)	Dist'n Pb (%)	Assay Zn (%)	Dist'n Zn (%)
<b>BEACH L2 COMPOSITE P<sub>100</sub>:38 mm</b>					
+5 mm HMS Sink	67.45	1.160	93.27	9.81	92.21
+5 mm HMS Float	25.01	0.032	0.95	0.413	1.44
-5+2 mm HMS Sink	2.57	0.896	2.75	8.87	3.18
-5+2 mm HMS Float	1.13	0.036	0.05	0.253	0.04
-2+0.075 mm HMS Sink	2.16	0.960	2.47	8.80	2.65
-2+0.075 mm HMS Float	1.17	0.060	0.08	0.593	0.10
-0.075 Fines	0.51	0.692	0.42	5.38	0.38
<b>DISCOVERY COMPOSITE P<sub>100</sub>:38 mm</b>					
+5 mm HMS Sink	51.01	3.18	91.38	5.97	88.58
+5 mm HMS Float	39.68	0.120	2.68	0.341	3.94
-5+2 mm HMS Sink	2.09	1.72	2.02	5.62	3.41
-5+2 mm HMS Float	2.43	0.028	0.04	0.119	0.08
-2+0.075 mm HMS Sink	1.86	2.96	3.09	6.00	3.24
-2+0.075 mm HMS Float	2.16	0.040	0.05	0.258	0.16
-0.075 Fines	0.78	1.69	0.74	2.62	0.59
<b>BEACH L2 NORTH COMPOSITE P<sub>100</sub>:38 mm</b>					
+5 mm HMS Sink	63.43	1.48	94.45	13.6	94.43
+5 mm HMS Float	33.54	0.090	3.04	0.700	2.56
-5+2 mm HMS Sink	1.00	1.21	1.21	14.5	1.58
-5+2 mm HMS Float	0.62	0.080	0.05	0.600	0.04
-2+0.075 mm HMS Sink	0.73	1.45	1.07	14.9	1.20
-2+0.075 mm HMS Float	0.56	0.130	0.07	1.30	0.08
-0.075 Fines	0.12	0.880	0.11	7.87	0.11

#### SMC Testwork: HMS Sinks

SMC testwork was conducted on the +5.0 mm-heavy media separation sinks products for the Beach L2, Discovery and Beach L2 North composites.

The summary of selected results is presented in Table 5.13.

**Table 5.13 - SMC testwork results of HMS sinks**

Sample Identity	DWI (kWh/m <sup>3</sup> )	SG	Derived Values					
			A	b	Mia	Mih	Mic	t <sub>a</sub>
Beach L2 HMS Sinks	7.75	3.74	76.4	0.63	15.8	12.0	6.2	0.33
Discovery HMS Sinks	7.53	3.77	70.8	0.71	15.3	11.6	6.0	0.34
Beach L2 North HMS Sinks	5.81	4.21	72.2	1.00	11.1	8.0	4.1	0.45

#### Size-by-Size Analysis: HMS Products

A particle size distribution determination and subsequent size-by-size analysis was undertaken on a sub-sample of each +5.0 mm HMS SG 3.0 float and sink products.

The summary of selected results is presented in Table 5.14 and Table 5.15.

**Table 5.14 - Size-by-size analysis sinks**

Sample Identity	Calc'd P <sub>80</sub> (mm)	Lead Distribution % @ Size (mm)							
		+31.5	-31.5 +19.0	-19.0 +11.2	-11.2 +5.60	-5.60 +2.80	-2.80 +1.00	-1.00	
Beach L2 +5.0 mm HMS Sink	31.23	16.51	62.34	13.26	6.41	1.34	0.07	0.06	
Beach L2 +5.0 mm HMS Float	30.77	6.66	69.29	13.07	6.87	3.66	0.30	0.14	
Discovery +5.0 mm HMS Sink	32.62	6.72	81.49	7.93	3.46	0.11	0.06	0.22	
Discovery +5.0 mm HMS Float	32.67	19.16	45.73	13.70	19.07	1.73	0.19	0.43	
Beach L2 North +5.0 mm HMS Sink	30.66	8.60	56.81	21.29	10.92	2.27	0.08	0.03	
Beach L2 North +5.0 mm HMS North	27.69	1.96	59.85	19.43	13.53	5.00	0.13	0.10	

**Table 5.15 - Size-by-size analysis floats**

Sample Identity	Calc'd P <sub>80</sub> (mm)	Zinc Distribution % @ Size (mm)							
		+31.5	-31.5 +19.0	-19.0 +11.2	-11.2 +5.60	-5.60 +2.80	-2.80 +1.00	-1.00	
Beach L2 +5.0 mm HMS Sink	31.23	27.88	50.55	13.43	6.99	1.03	0.06	0.06	
Beach L2 +5.0 mm HMS Float	30.77	3.25	76.18	12.20	5.77	2.37	0.12	0.11	
Discovery +5.0 mm HMS Sink	32.62	21.22	62.31	11.32	4.57	0.47	0.04	0.06	
Discovery +5.0 mm HMS Float	32.67	15.02	50.71	15.88	15.44	2.26	0.31	0.38	
Beach L2 North +5.0 mm HMS Sink	30.66	8.45	56.22	22.02	10.54	2.60	0.12	0.04	
Beach L2 North +5.0 mm HMS North	27.69	1.49	64.35	18.85	11.48	3.60	0.16	0.08	

### Bond Rod Mill Work Index Determination: HMS Sinks

A sub-sample of each of the heavy media separation SG 3.0 sink products was tested using the standardised procedure detailed by F.C. Bond to determine the Bond Rod Mill Work Index at a closing screen size of 1180  $\mu\text{m}$ . A sub-sample of the Beach L2 North whole ore composite was also tested.

The summary of selected results is presented in the Table 5.16.

**Table 5.16 - Bond Rod Mill Work Index HMS Sinks**

Sample Identity	Micrometres		Grp (g/rev)	Test Aperture PI ( $\mu\text{m}$ )	Bond Rod Mill Work Index (kWh/t)
	F <sub>80</sub>	P <sub>80</sub>			
Beach L2 +5.0 mm HMS Sink	11211	678	3.880	1180	19.9
Discovery +5.0 mm HMS Sink	10827	711	4.600	1180	18.6
Beach L2 North +5.0 mm HMS Sink	11117	769	5.023	1180	18.4
Beach L2 North Comp Whole Ore	10366	821	4.405	1180	21.2

### Bond Ball Mill Work Index Determination: HMS Sinks

Sub-sample of the Beach L2, Discovery and Beach L2 North Composites HMS sink products were tested using the standardised procedure detailed by F.C. Bond to determine the Bond Ball Mill Work Index of each sample at the selected closing screen sizes of 850, 75 and 45 microns.

The summary of selected results is presented in the Table 5.17.

**Table 5.17 - Bond Ball Mill Work Index HMS Sinks**

Sample Identity	Micrometres		Grp (g/rev)	Test Aperture PI ( $\mu\text{m}$ )	Bond Rod Mill Work Index (kWh/t)
	F <sub>80</sub>	P <sub>80</sub>			
Beach L2 Comp HMS SG 3.0 Sink Prod	2733	648	2.906	850	21.5
	2519	50	1.282	75	12.2
	2823	29	0.864	45	13.9
Discovery Comp HMS SG 3.0 Sink Prod	2411	649	3.739	850	18.6
	2103	48	1.412	75	11.1
	2569	32	0.894	45	14.2
Beach L2 North Comp HMS SG 3.0 Sink Prod	2637	56	1.300	75	12.8

### Heavy Liquid Separation Testwork Optimised Conditions

A summary of selected data is presented in Table 5.18, Table 5.19 and Table 5.20.

**Table 5.18 - Heavy liquid separation of Beach L2 composite**

BEACH L2 COMPOSITE P <sub>100</sub> :38 mm					
Product Identity	Weight (%)	Assay Pb (%)	Dist'n Pb (%)	Assay Zn (%)	Dist'n Zn (%)
2.8 SG Float	0.07	INS	N/A	INS	N/A
2.9 SG Float	17.65	0.014	0.22	0.028	0.09
2.96 SG Float	7.93	0.028	0.20	0.062	0.09
3.1 SG Float	2.93	0.102	0.27	0.6095	0.33
3.2 SG Float	0.03	INS	N/A	INS	N/A
3.3 SG Float	0.00	INS	N/A	INS	N/A
3.3 SG Sink	71.39	1.54	99.31	7.67	99.50

**Table 5.19 - Heavy liquid separation of Discovery composite**

DISCOVERY COMPOSITE P <sub>100</sub> :38 mm					
Product Identity	Weight (%)	Assay Pb (%)	Dist'n Pb (%)	Assay Zn (%)	Dist'n Zn (%)
2.8 SG Float	1.47	0.016	0.03	0.2435	0.13
2.9 SG Float	34.63	0.012	0.58	0.0300	0.38
2.96 SG Float	7.31	0.100	1.02	0.1375	0.37
3.1 SG Float	0.37	0.046	0.02	0.1585	0.02
3.2 SG Float	1.11	0.172	0.27	2.53	1.03
3.3 SG Float	4.33	0.130	0.79	0.7820	1.24
3.3 SG Sink	50.77	1.37	97.28	5.22	96.84

**Table 5.20 - Heavy liquid separation**

Sample Identity	Calc'd P <sub>80</sub> (mm)	Weight % Passing @ Size (mm)						
		31.5	19.0	11.2	5.60	2.80	2.00	1.00
Beach L2 -38 mm HLS Feed	31.235	82.28	14.49	5.19	1.20	0.26	0.17	0.10
Discovery -38 mm HLS Feed	32.680	75.57	30.51	16.00	6.63	2.91	2.12	1.19

### Jar Mill (Verti-Mill) Testwork

Jar Mill testing was carried out on -850 µm products of the Beach L2 and Discovery composites using the method proposed by Metso Minerals.

A summary of selected results is presented in Table 5.21.

**Table 5.21 - Verti-Mill testwork results**

Sample Identity	Density % Solids (w/w)	Media	Measured P <sub>80</sub> @ Applied Run Time (mins)							
			0	5	10	20	40	60	80	120
Beach L2 Comp -850 µm	60.0	19 mm Steel Balls	656	166.8	157.6	106.9	84.8	46.5	37.1	N/A
Discovery Comp -850 µm	60.0	19 mm Steel Balls	644	167.6	169.7	104.8	42.2	28.2	N/A	N/A

### Heavy Liquid Separation Testwork: Variability Samples

Twenty-three selected variability samples were utilised for heavy media separation testwork. Separations were conducted at a crush size of 100% passing 38 mm, utilising an Erickson cone machine with a media SG of 3.0.

A summary of selected data is presented in Table 5.22 and Table 5.23.

**Table 5.22 - Heavy liquid separation testwork results**

-38+5.0 mm HMS SINK PRODUCT					
Sample Identity	Weight (%)	Assay Pb (%)	Dist'n Pb (%)	Assay Zn (%)	Dist'n Zn (%)
CF08-158 30-31 m	14.99	0.880	63.18	2.83	74.97
CF08-160 11-11.7 m	37.56	0.528	88.61	9.85	84.96
CF08-160 28.7-30 m	10.90	0.636	79.23	2.19	91.08
CF08-162 30.45-30.75 m	27.44	0.360	87.75	4.33	91.18
CF08-163 27.1-28 m	17.18	0.564	79.07	6.79	74.19
CF08-165 5-6 m	90.59	0.384	92.31	1.17	92.41

**Table 5.23 - Heavy liquid separation testwork results**

<b>-38+5.0 mm HMS SINK PRODUCT (Cont'd)</b>					
<b>Sample Identity</b>	<b>Weight (%)</b>	<b>Assay Pb (%)</b>	<b>Dist'n Pb (%)</b>	<b>Assay Zn (%)</b>	<b>Dist'n Zn (%)</b>
CF09-182 95-96 m	71.19	0.652	93.52	6.50	94.42
CF09-183 97-97.7 m	71.01	1.68	93.94	20.00	94.17
CF09-185 101-102 m	74.19	1.67	89.91	17.00	94.55
CF09-186 102-103 m	84.81	1.14	94.11	6.47	94.33
CF09-187 113-114 m	83.69	2.08	90.49	8.11	92.74
CF09-191 80-81 m	78.80	1.01	90.29	13.50	91.23
CF09-192 69-70 m	91.83	0.368	90.95	0.95	88.55
CF09-195 45-46 m	22.56	0.388	77.11	9.69	78.87
CF09-197 54-55 m	14.87	1.90	91.28	10.90	93.23
CF09-197 61-62 m	34.82	1.42	90.19	17.80	92.07
CF09-198 86-87 m	91.95	0.596	93.47	2.99	90.54
CF09-200 89.3-90 m	75.59	0.252	90.56	3.14	89.46
CF09-201 89-90 m	57.45	1.10	79.73	26.80	85.58
CF09-202 96-96 m	39.07	0.108	46.43	1.37	73.44
CF09-202 105.4-106 m	20.79	1.34	72.67	20.30	77.29
CF09-204 74.5-75.2 m	95.26	2.44	79.15	13.30	94.54
CF09-204 81-82 m	92.57	0.208	97.19	4.10	96.59

#### Quantitative Optical Mineralogical Examination

A defined programme of metallurgical testwork was conducted on spiral separation testwork tail samples from the Citronen Project in January 2012.

Samples were prepared for mineralogical testwork in ALS Ammtec and then sent for Qualitative Optical Mineralogical Examination via Roger Townend and Associates.

For the test programme, ALS Ammtec was supplied with three spiral separation testwork tail samples from the Ironbark Citronen Project in Greenland:

- Sample # 1: Spiral Cut 6 Product: 3285
- Sample # 2: Spiral Cut 7 Product: 3286
- Sample # 3: Spiral Cut 8 Product: 3287

Final results can be seen in Table 5.24.

**Table 5.24 - Mineralogical exam results**

Material	Sample ID		
	Spiral Cut 6 Product: 3285	Spiral Cut 7 Product: 3286	Spiral Cut 8 Product: 3287
Ores	Minor	Minor	Minor
Pyrite	Dominant	Dominant	Dominant
Sphalerite	Major	Minor	Minor
Galena	Accessory	Trace	Trace
Marcasite	Accessory	Trace	-
Hematite	-	-	Trace
Gangue	Dominant	Dominant	Dominant
Ankerite	Major	Major	Major
Quartz	Major	Minor	Minor
Calcite	Minor	Major	Major
Mica	Accessory	Minor	Minor

## 5.4 Process Plant

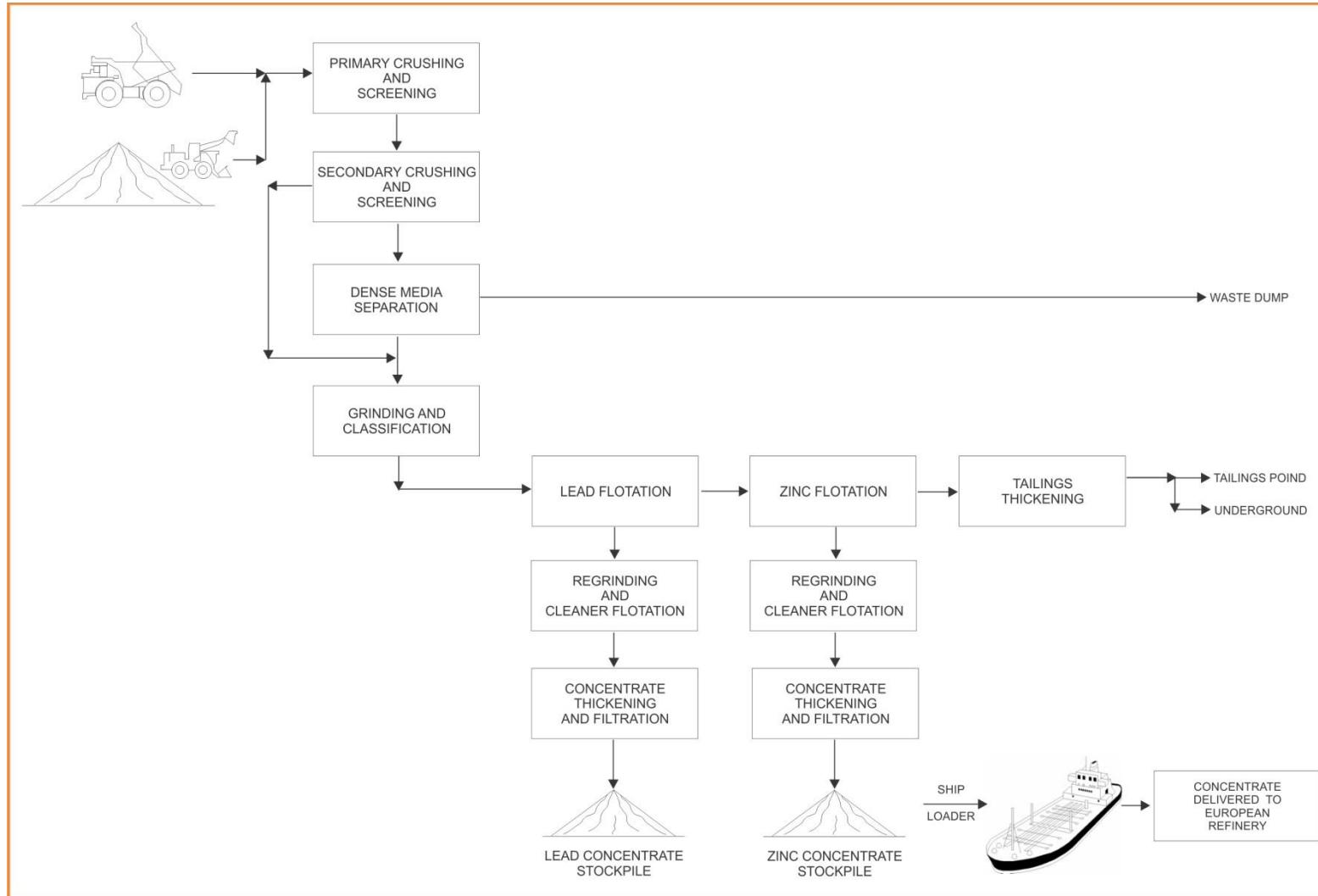
### Process Description

The process description was prepared by Wardrop in 2011 in line with the flow sheets developed by Metso; a transcript is included in this section.

The simplified flow sheet is shown on

Figure 5.1.

**Figure 5.1 - Simplified flow sheet**



## Crushing

Crushing equipment selection and circuit configuration is based upon UCS, Bond Crushing Work Index and Macon testing (Metso's in-house testing method) of both the Discovery and Beach ore composites. A compact two stage crushing plant has been selected, with DMS testwork indicating acceptable metal recovery and mass rejection can be obtained with a primary crusher discharge  $P_{80}$  of 130 mm reduced to a  $P_{80}$  of 35 mm in the second stage.

The circuit equipment has been selected to achieve approximately 550 t/h average throughput levels at 18 h/d operation (6.5 d/wk, 365 d/a). The ore is delivered by haul truck and either direct dumped into the run of min (ROM) bin or onto the ROM pad and later transferred by front-end loader (FEL) to the ROM bin. The ROM bin is protected by an 800 x 800 mm grizzly, and a rock breaker is mounted adjacent to break up oversize.

The ore is fed by a vibratory grizzly feeder drawing ore from the ROM bin and feeding into the jaw crusher where it is crushed to a  $P_{80}$  of 130 mm. A primary jaw crusher size has been selected to minimise the probability of blockages.

A high frequency vibratory double-deck secondary screen precedes the secondary cone crusher with undersize reporting to the crushed ore product transfer point. Tramp steel is removed by two magnets located over the conveyor. A metal detector is located on the secondary crusher feed bin feed conveyor with an interlock hardwired to the conveyors.

The secondary screen oversize is conveyed to the secondary crusher feed bin where a vibrating feeder feeds the secondary crusher. The secondary crusher discharge is conveyed to the high frequency vibratory double deck screen. The screen undersize is conveyed over a weightometer to the DMS feed bin.

Dust suppression is by individual suction hoods at transfer points ducted to a central fan and bag-house.

Buffer storage of crushed ore and mill feed is minimised due to space constraints.

## Dense Media Separation (DMS)

DMS performance at a 2.96 to 3.10 separation SG provides recoveries in excess of 97% of lead and zinc to the sinks plus the -1.0 mm fines product bypass throughout the size ranges tested.

The DMS feed bin discharges at an approximate average of 375 t/h by belt feeders to a wet feed preparation screen that removes all -1.0 mm material, with the screen oversize feeding into the DMS cyclone feed hopper.

The DMS cyclone pump feeds -38+1 mm material combined with dense medium to the DMS cyclones. The DMS cyclone overflow is stripped of medium on a drain-and-rinse dual screening system with screen oversize conveyed to the external floats stockpile. The DMS cyclone underflow is stripped of medium on a drain rinse screen system, and the screen oversize is conveyed to the sinks (ball mill feed) bin.

The DMS feed fines are separated at the wet feed preparation screen. Sixteen percent of the ore feed weight reports as -1 mm fines. The fines are directed to the fines dewatering cyclone feed hopper where they are pumped to the cyclone, which dewateres the stream. The fines are then directed to the secondary milling circuit

The sinks are drawn from the mill feed bin by belt feeders and conveyed to the primary mill feed, where the feeder rate is regulated by a weightometer.

## Grinding

### Ball Milling

A 4.42 m diameter x 7.5 m long 2.2 MW grate discharge primary ball mill operates at an approximate average of 298 t/h treatment rate in closed circuit with a scat recycle screen with a bottom deck aperture of 1.2 mm.

The screen separation at nominally 1 mm is facilitated by high volume water sprays, and uses the entire water requirement for the grinding circuit to achieve a clean separation. The screen undersize flows to a common pump hopper that also receives DMS fines spiral concentrate and secondary grinding mill discharge.

The mill has sufficient power to achieve the design grind size of 850  $\mu\text{m}$   $P_{80}$ . The mill is rubber lined, takes up to a 24% by volume steel charge and operates at 71% of critical speed. Balls of 90 mm to 120 mm size are added by kibble at the mill feed chute.

### Vertical Stirred Milling (VTM)

Primary screen undersize, VTM discharge and DMS fines spiral concentrate are combined in a hopper and then pumped to a cyclone cluster at a density that enables a 53  $\mu\text{m}$  cut point to provide a  $P_{80}$  of 45  $\mu\text{m}$  to flotation. The cyclone cluster holds 6+2 400 mm diameter cyclones. Cyclone underflow feeds the VTM circuit and cyclone overflow is gravity fed to a trash screen. The VTM unit discharges overflow back to the cyclone feed hopper.

Two 2.2 MW VTM units have been selected with 24 mm x 24 mm recharge size high chrome clypebs that are added by kibble at the mill feed chute. A proprietary blocker reagent (D200) may be added to the cyclone feed hopper.

## Flotation and Re-grinding

The mill cyclone overflow of  $P_{80}$  size 45  $\mu\text{m}$  gravity flows to a trash screen of 0.8 mm aperture. The trash screen undersize is pumped to a single conditioner that overflows to a pre-flotation circuit. The pre-flotation (pre-float) stage is necessitated by a carbonaceous population that would otherwise impact downstream grades and froth stability. Dextrin depressant and frother are dosed to the conditioner tank. Trash screen oversize is collected in a trash bunker for disposal.

The pre-flotation concentrate is discarded to the tailings thickener, and the intermediate tailing flows to two conditioner tanks in series (three minute residence time in each) in which lead circuit pyrite depressants and collector are dosed. The conditioners overflow in sequence to the lead rougher scavenger flotation cells at a design rate of approximately 310 t/h. Frother is dosed to the conditioner discharge and rougher cell junction boxes.

First rougher lead concentrates are diverted to final concentrate, cleaner feed or regrind feed depending on grade in the cleaner circuit. Second lead rougher and scavenger lead concentrates are pump-fed to 100 mm diameter dewatering cyclones and the cyclone underflow is reground to a  $P_{80}$  of 10  $\mu\text{m}$  to 15  $\mu\text{m}$  in two 185 kW stirred media detritors (SMDs) using 3 mm ceramic beads. Lime at 30% solids w/w concentration and ligno-sulphonate solution at 10% w/v strength are added to the lead regrind mills to depress pyrite.

The reground lead concentrate and first rougher lead concentrate are pumped to the first cleaner and first cleaner concentrate is pumped to the second cleaner feed. First cleaner lead tail is open circuited to the zinc flotation conditioners with the rougher lead scavenger tail.

Copper sulphate at 10% w/v strength is added to the zinc conditioner feed pump (Pb rougher tail) hopper for the re-activation of sphalerite.

The flotation of zinc is preceded by two conditioning tanks in series each of three minute residence time for the addition of lime and the flotation collector, respectively. Frother is added in stages to the zinc second conditioner discharge and rougher flotation cell junction boxes. The zinc conditioners overflow in sequence to the zinc rougher scavenger flotation cells.

Depending on grade, first rougher zinc concentrates can be diverted to final zinc concentrate, zinc cleaner feed or zinc regrind feed. The zinc second rougher and scavenger concentrates are pump-fed to 100 mm diameter dewatering cyclones and the cyclone underflow is reground to a  $P_{80}$  of 10  $\mu\text{m}$  to 15  $\mu\text{m}$  in five 355 kW SMDs. Lime and ligno-sulphonate are added to the zinc regrind mills to depress pyrite.

The reground zinc concentrate and the first rougher zinc concentrate with regrind zinc cyclone overflow are pumped to the first cleaner bank. The zinc cleaner circuit can be operated as either a three-stage cleaner, or a cleaner and re-cleaner system as required. The first zinc cleaner tail is pumped open circuit to the final tail thickener where it is combined with pre-flotation concentrate, DMS fines spiral lights, and rougher scavenger tailing.

### **Concentrate Dewatering**

Each concentrate is dewatered to a minimum of 60% solids by weight in a conventional thickener. The thickener underflow is pumped to an agitated stock tank. A plate and frame pressure filter is fed by a variable speed pump from the agitated concentrate stock tank and filtrate is recycled to the appropriate concentrate thickener feed.

The overflows from the zinc concentrate thickener and the lead concentrate thickener flow to the process water tank. The filter cake discharge is conveyed to and stacked in the covered storage area.

The filters selected have the capacity to filter at peak concentrate production rates of 4 t/h and 40 t/h for lead and zinc concentrates, respectively, and produce a filter cake with a design moisture allowance of 10% to 12%. The lead concentrate is batch filtered as required in one of the two filter units.

Concentrate is loaded to a reclaim conveyor by FEL from the covered storage area, using a load cell on the FEL to determine loaded wet weight. Moisture and assay samples enable calculation of the dry tonnes and metal contained for consolidation with the ship-loading weights and assays and customer shipment receival weights and assays. This concentrate production data is also used to back-calculate plant performance using the flotation shift sample assays and the mill feed weightometer.

### **Tailings**

The final tailings are made up of the zinc scavenger tail, zinc cleaner tail, pre-flotation concentrate and the silicate rich slime reject solids from the fines spirals. The final tailings are dewatered in an 18 m diameter high-rate thickener to 58% solids by weight and transferred by the underflow pumps to a pump hopper. The thickener overflow is returned to the process water tank.

Thickened tailings are pumped from the pump hopper with other effluent streams to the tailings storage facility (TSF) or diverted for use underground as frozen backfill when required.

The tails thickener overflow may require future installation of a clarification stage should carbonaceous material threaten to contaminate the process water. Thickener overflow clarity in a confined plant can be an operational issue; however, this is relieved by the design of the process water tank to promote settling and reclaim of solids. A separate process water tank may be installed at a future date should process water alkalinity build up and impact the lead circuit performance.

## Reagents

Pre-flotation of carbonaceous mineral requires IF6-3N frother and Dextrin depressant addition. Dextrin is mixed continuously, direct from the bulk-bag using a 'jet-wet'-style system to a 10% w/v strength.

Some proprietary carbonaceous blocker D200 may be added to the milling circuit and the pre-float conditioner. The D200 is in liquid form and is batch mixed with water to 25% w/v strength.

For mineral collection in the lead flotation circuit a Cytec 3406 dithio/monothio-phosphate blend at 100% w/v mix strength is added to the second conditioner and IF6-3N frother to the conditioner discharge and first lead rougher junction boxes. Additional stages of collector addition and frother are made through the cleaner circuit. A pH modifier or naphthalene sulphonate depressant is also added to the cleaner feed to depress pyrite.

Ligno-sulphonate is readily dissolved in water at 10% w/v and is mixed in batch mode. Addition is to both regrind circuits.

Lime is delivered as burnt lime (CaO) and is fed from a silo into a slaking mill which discharges to a slaked lime tank. The lime slurry at 25% solids w/w is added to both the lead and zinc concentrate regrind mills. The regrind mill additions maintain a pH setpoint at approximately 10.5 in the first cleaner of the cleaner flotation circuits. Lime can be added to the first conditioner in the zinc rougher circuit to control pH.

Copper sulphate solution is mixed at 10% w/v strength in batch mode and is used as an activator for flotation of zinc minerals. It is added to both the first zinc conditioner feed pump and the zinc regrind discharge hopper by a dosing pump.

The zinc flotation collector Cytec 9323 is a blend of dithiophosphates and mono-thionocarbamates. The collector is added at full strength to the second flotation feed conditioner tank by a dosing pump. Stage additions downstream of collector and frother may also be used by the operators. A facility is provided for dosing of a second collector.

IF6-3N frother is dosed as 100% solution by a dosing pump (as required) to sustain the optimum froth characteristics throughout the flotation circuits.

A pH modifier or naphthalene sulphonate depressant is mixed in batch mode to 10% strength w/v and is also added to both of the cleaner feeds to depress pyrite.

Flocculant is mixed from bulk powder storage in a packaged continuous mixing plant at 2.5 g/L and held in a storage tank for one hour for hydration. The stored flocculant solution is further diluted in-line and dosed to each thickener feed box and the thickener feed well sparger pipes at a volumetric flow determined by the thickener control system.

A spare jet-wet mixing facility is provided for an additional depressant (nominally PC100 poly-acrylamide) and spare pumps for an additional collector. All mixed reagents have a mixing system and tank that transfers the

mixed reagent to a storage tank. The reagents are dosed to the process from the storage tank by metering pumps.

## **Process Plant Services**

### Water Distribution

The continuous plant process raw makeup water requirement is approximately 180 m<sup>3</sup>/h (i.e. the loss to filtered concentrate and thickened tails). Some reduction is available through reclaim of a portion of the water from the tails dam (summer months only) or from underground mine dewatering.

#### Raw Water Pond Supply Pumps

The raw water supply design is based on delivery from Lake Platinova to a raw water tank. Raw water will be pumped to the process plant raw water tank using a submersible pump. The pump will draw water from the bottom of the lake to ensure availability year round. Further discussion is provided in Section 6, "Infrastructure", of this Report.

#### Plant Operational Requirements

The water demand is divided into:

- process water make-up from raw water for the losses to product streams and tails dam
- reagent mixing requirements
- machine seal and cooling requirements: crusher dust seals, lube system cooling and mill feed seal wash water

The raw water pumps deliver water to:

- the process water tank for make-up needs
- the gland water pump mains
- the reagent water pumps
- the process raw water pumps
- the clean water tank for potable and fire water supply

The clean water tank feeds the potable water treatment plant, which in turn maintains level in the potable water system. Separate pumps feed the domestic areas and safety showers from this tank. The clean water tank also provides a reservoir of firewater and supplies water to the process water tank for make-up as required.

No allowance has been made for gland water, based on the use of mechanical seals on centrifugal pumps.

No return from the tailings storage facility has been allowed.

#### Other Water Demands

The less well defined demands at this time are:

- dust suppression requirements
- hose-down water in plant

The dust suppression that may be required in summer months can be estimated by assuming that a 10 m<sup>3</sup> truckload is consumed five times per day on roads and crushing plant sprays operate at a continuous 3.6 m<sup>3</sup>/h. The hose-down demand is estimated to be a similar quantity at a continuous 3.6 m<sup>3</sup>/h. Neither usage is included in the water balance at this point.

## Air Supply and Distribution

Three separate 110 kW air compressors provide 700 kPa air for:

- instrument air and workshop service air into two separate receivers feeding driers and two area receivers
- general services plant air via two area air receivers

The air is distributed in steel lines around the plant for use in tools and general blowdown and auxiliary requirements.

The cake blow air supply for the lead and zinc concentrate filters is provided from the main air system at reduced pressure via dedicated local receivers.

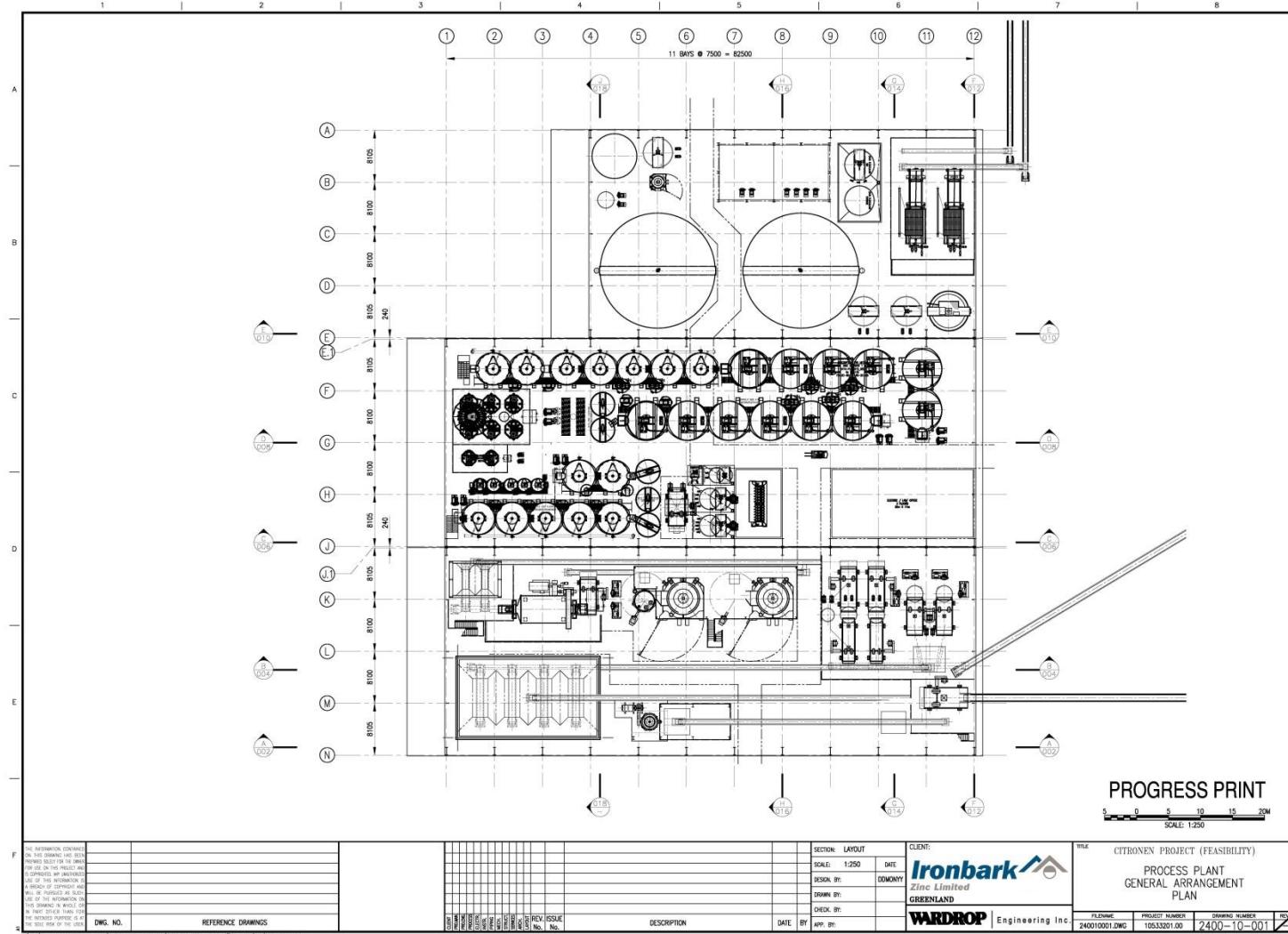
The air for flotation is provided via dedicated low-pressure blowers.

## Plant Layout

The plant layouts were developed by Wardrop (

Figure 5.2).

**Figure 5.2 - Processing plant general arrangement plan**



## 5.5 Electrical and Instrumentation

Power to the process ground floor main electrical room will be via two 6.9 kV feeder cable bus systems from the main power plant. These cable buses will be routed into the room via fire rated separations and will terminate in a 7.2 kV double-ended vacuum circuit breaker switchgear line-up.

Power from this switchgear line-up will:

- Be delivered to an adjacent 6.9 kV motor control centre for major motors.
- Be delivered (as 690 V power) to the process plant 690 V MCCs in the first floor electrical room.
- Provide 690 V power for low voltage motor and other loads through three step-down dry type transformers.

The dry type transformers are located adjacent to the main floor electrical room but outside of the electrical room ventilation envelope. A louvered wall with fans will be used to cool these main transformers without adding to the heat load of the electrical room.

Cables will be routed internally within the process plant via galvanized steel cable tray systems.

## 5.6 Plant Performance Guarantees

Metso has undertaken the provision of an overall process guarantee for the plant within the battery limits of supply, so long as the equipment listed is used and installed in accordance with the Metso instructions, other relevant sections of the process report and the process guarantee document.

## 5.7 Conclusions and Recommendations

Increasing throughput from 3.0 to 3.3 Mtpa will increase the operational revenue by 10%. Capital and operating costs will not increase by the same proportion and will therefore increase the profitability of the Citronen project.

The Metso review indicated the secondary crusher would currently operate at high load and may require upgrading to handle an increased load. Only minor modification to ancillary equipment such as pipes, pumps, conveyors etc will need to be made. All other equipment is expected to have contingency capacity such that a 10% increase in load is possible without modification.

It should be noted the equipment list, general arrangement drawings and layout drawings reasonably reflect the latest 3.3 Mtpa plant design.

## **SECTION 6 - INFRASTRUCTURE & ANCILLARY FACILITIES**

## 6. INFRASTRUCTURE & ANCILLARY FACILITIES

### 6.1 Introduction

The Citronen Fjord Zinc Project is located in north-eastern Greenland approximately 2,100 km north of the capital of Greenland, Nuuk. It is located at 83°05'N, 28°16'W.

There is no existing infrastructure at the site and consequently all infrastructure and ancillary facilities need to be developed as part of the project. The facilities and infrastructure to be developed are based on the original 2010 studies.

Figure 6.1 - General site layout

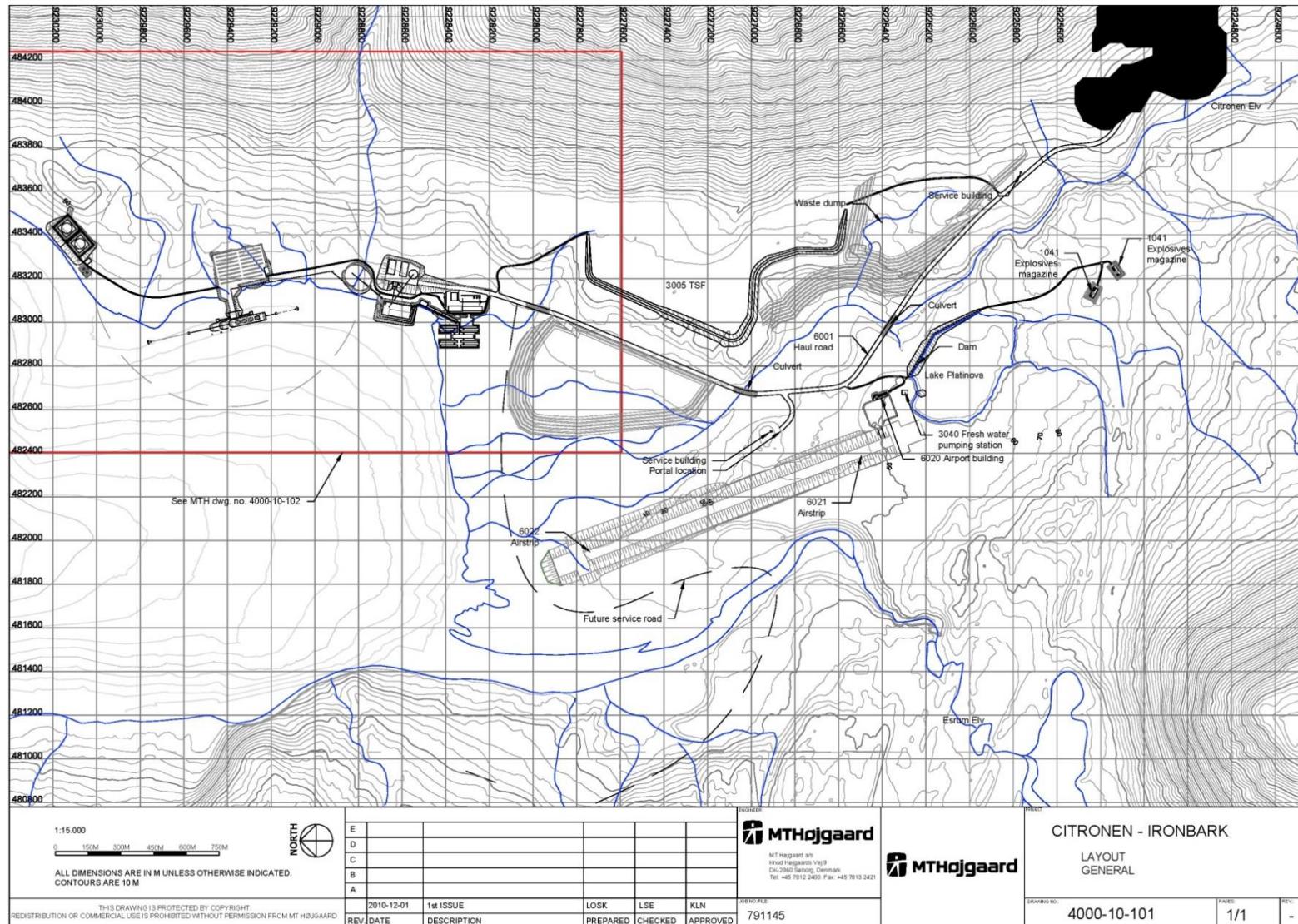
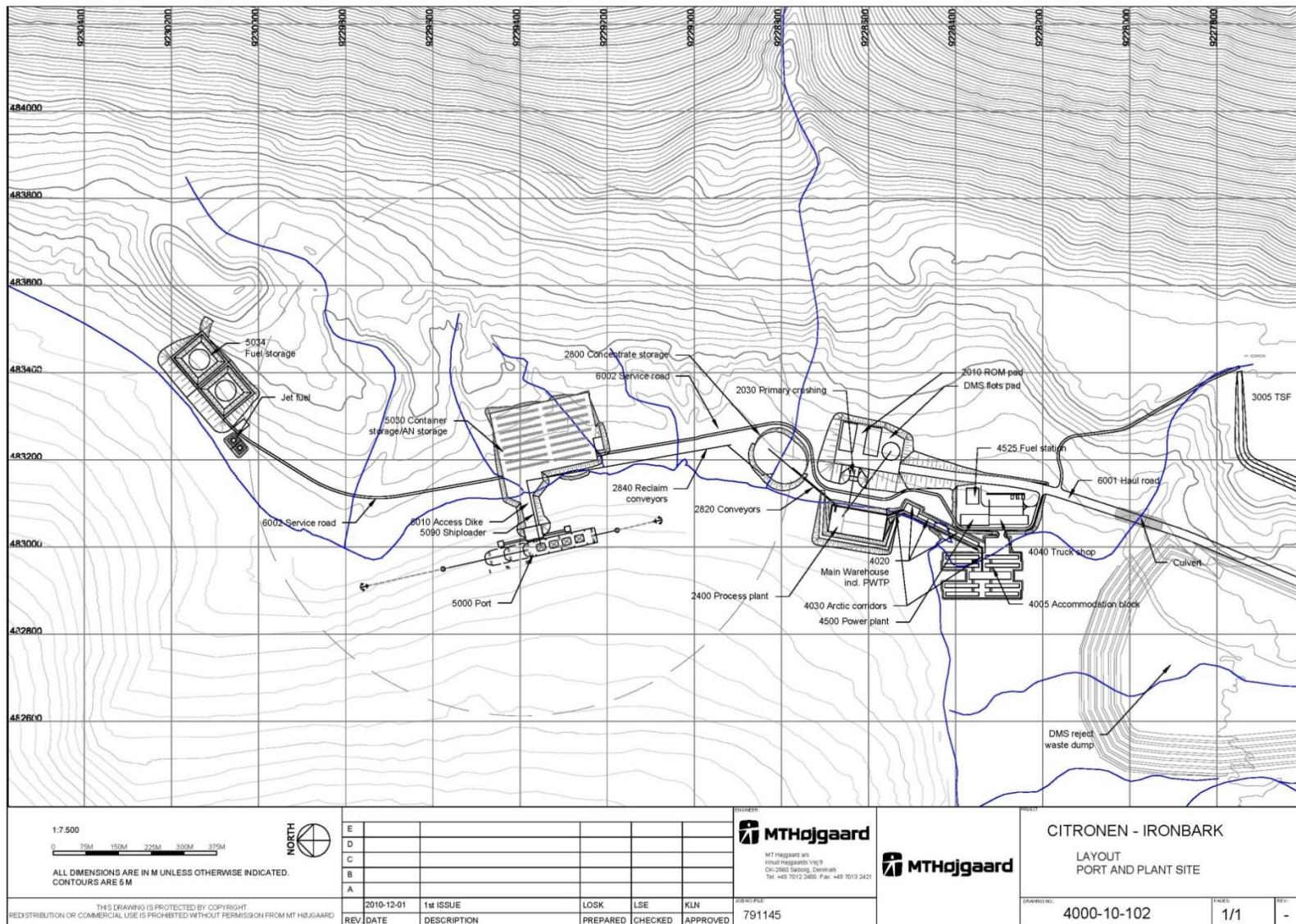


Figure 6.2 - Port and plant site layout



## 6.2 Haul and Service Roads

Roads will be established as privately financed roads and are to be used solely for mining works at Citronen. They will be designed, constructed and maintained in accordance with established mining industry practice.

Horizontal alignment will have a minimum radius down to 150 m for haul roads, and down to 20 m for service roads. The maximum longitudinal grade is 8% for haul roads and 12% for service roads. The general cross sections are based on normal road building practices in arctic areas.

In general, roads will be constructed upon the existing ground, either on bed rock or on permafrozen ground. The road substructure will generally be constructed with locally excavated soil reclaimed as part of cutting or from nearby borrow pits, depending on the earthworks balance. The road superstructure will generally be constructed with gravel soils from borrow pits or with quarry run.

Permafrost is present in the entire area and preliminary investigations show a thaw zone of approximately one metre. On permafrozen ground the road superstructure will be minimum of one metre thick, constructed from non-frost sensitive (NFS) gravel to build up permafrost in the underlying existing soil. It is assumed the NFS gravel can be taken from borrow pits in the area.

Culverts will be designed and placed to allow melting water and rainwater to cross the roads. Culverts will be constructed with steel pipes. All culverts will be designed for actual axle loads and to relevant design standards.

### Haul Roads

Haul roads required include open pit to run-of-mine (ROM) pad (approximately 3,880 m) and to portal location (approximately 200 m).

The dominant traffic on haul roads will be heavy off-highway trucks similar to 2-axle Caterpillar 777F.

Due to the planned standard of roads, the average speed will be relatively low, namely 40 km/h for surface mobile equipment and 30 km/h for underground mobile equipment.

The maximum speed will depend on grade, ability, and operating weight. Assuming a maximum operating load of 163 t and maximum grade of 8%, speed may locally be reduced to 8 to 10 km/h. At sharp bends in hilly sections, the speed will be even lower. Maximum speed on service roads should be set to no more than 40 km/h.

### Service Roads

The dominant traffic on service roads will be four-wheel drive multi-purpose vehicles (MPVs), off-roaders, and small to medium size trucks and fuel trucks.

Maximum speed on service roads should be set to no more than 40 km/h.

Service roads will be 3.5 m wide single-lane gravel roads. The total width of the roads will typically be 5.0 m, inclusive of shoulders. As the service roads are relatively short, passing places will not be provided.

### Safety Bunds

During the detailed design phase, a risk assessment will be carried out to determine where safety bunds are needed. They will be constructed according to general practice for mine haul roads, i.e. with the minimum height of berm being  $0.5 \times$  biggest wheel diameter.

The use of steel barriers in lieu of safety berms will not permit the removal of snow; consequently, this form of safety barrier has not been considered for the project.

## 6.3 Site Services and Utilities

### Fresh Water Distribution

Lake Platinova is the source for fresh, raw water for the project. Raw water will be pumped to the process plant raw water tank using a submersible pump. The pump will draw water from the bottom of the lake to ensure availability year round.

From the process, a raw water tank water will be pumped to the process plant and the water treatment plant at the main warehouse. Water piping will run in arctic corridors between the process plant and the main warehouse (potable water treatment plant) and on to the accommodation complex and truckshop.

### Potable Water Treatment, Supply and Distribution

Raw water will be pumped from the process plant raw water tank to the potable water treatment plant located within the main warehouse. Treated water will then be pumped to the permanent camp, administration facilities and process plant.

The average person in Greenland consumes approximately 155 litres (L) per day of potable water. With an expected manpower of 250 persons at Citronen, approximately  $35 \text{ m}^3/\text{d}$  of potable water is required. A small containerised treatment plant is proposed for the treatment of  $40 \text{ m}^3/\text{d}$  of lake water. This gives an average of 160 L per person per day.

The potable water treatment plant is a standard technology that is able to treat surface water taken from collection reservoirs in the mountains. The water is double filtered for the reduction of pollution from surface or groundwater. After filtration, the water will be disinfected by a UV unit.

### Fire Protection Systems

The plant site facilities will be protected with a pressurised fire protection system comprising a fire water reserve, an electric driven jockey pump, an electric driven fire pump and an emergency diesel driven fire pump. The fire water reserve will be contained in a dedicated portion of the raw water tank in the process plant.

Due to the cold climate and the geology, there will not be any buried firewater lines or any “standard” yard hydrants. The majority of fire piping will be within buildings and within connecting arctic corridors between buildings. In place of yard hydrants, there will be wall hydrants housed in heated and insulated wall cabinets mounted on the outside walls of the buildings. The wall hydrants will be served by fire water loops within the buildings.

The firewater demand has been based on established criteria for fire protection of similar projects.

The crushing plant will not be serviced by the firewater supply and the critical areas (such as the control room) will be protected with a clean agent suppression system. The lube oil system, the air compressor room and the conveyor within the structure will be protected by a dry chemical suppression system.

All areas will be provided with hand-held fire extinguishers.

On the process plant, sprinkler systems will be limited to the protection of hydraulic systems with an oil capacity in excess of 390 L and conveyors located in hard to reach confined areas. The laboratory and offices will also contain sprinkler systems.

Sprinkler protection in non-process areas includes the camp, warehouse and maintenance shops.

Provision for a digital fire alarm system has been included for the main process plant areas. This system will include a central password-protected operator interface terminal, graphic display of all operating zones, trouble and alarm logging historian, and control panel. The system will have the ability to incorporate a single alarm and trouble dry contact type signals from other standalone and pre-manufactured buildings into a centralised facility. Each separate facility will be tracked as a separate zone only.

### **Sewage Treatment and Disposal**

Sewage and waste water from buildings at the plant site will be sent to the sewage treatment plant. Dry closets will be used at the airport building.

The sewage treatment plant will be a standard containerised solution which can treat approximately 40 m<sup>3</sup> of waste water per day and is based on a three-step biological cleaning system:

1. Pre-treatment particle separation in a settling tank built into half of a 40-foot (ft) open top container.
2. Biological treatment built into the second half of the 40 ft container.
3. Sludge handling inclusive arrangement for placing and dewatering of the sludge bags before discharge into the incinerator (this system is built into a 20 ft sea container).

The sewage treatment plant and the dewatering system will be installed inside the main warehouse building close to the incinerator for ease the sludge handling.

Effluent from the camp site will be carried to the sewage treatment plant through pipelines running below the arctic corridors to the main warehouse. Effluent from waste water will go into the process plant.

### **Incinerator and Hydrocarbon Waste Facility**

An incinerator capable of dealing with combustible waste, lubricants, fuel and oil will be installed in the main warehouse. Installation in the warehouse will reduce the need for heating due to utilisation of the radiant heat from the combustion chamber.

A flue gas treatment plant is not included as it is anticipated it will be possible to obtain a dispensation from the rules regarding flue gas emission. This will need to be discussed with the MLSA during the detailed design phase of the project. The incinerator at Station Nord provides a precedent for this scenario.

Solid waste is fed into the combustion chamber in 120 L waste bags via the waste sluice. Likewise, sludge from the sewage plant can be collected and burnt as long as the water content in the sludge meets specifications. Medical waste and small metal parts such as frames from oil filters can be burnt.

Sludge oil will be fed into a sludge oil mixing tank and piped to the incinerator where it will be burnt. The incinerator can burn between 135 and 200 L of sludge oil per hour and it is able to continue with this capacity for as long as it is necessary.

The incinerator cannot be used for burning larger metal parts, batteries or chemical waste. These types of waste will be collected and stored for later disposal off site.

The incinerator has fully electronic-controlled burners with automatic spark ignition and safety devices. It is controlled by two temperature controllers and the operating temperature is 850-950°C, which should ensure clean emissions.

### **Lighting and Area Lighting**

Indoor lighting will be designed according to National Danish Code DS 700.

For area lighting, LED lighting fixtures have been selected and are assumed to be LED Light-type "CrystalLed" with 72 LEDs. The CrystalLed fixture is preferred as it has a life expectancy of more than 80,000 hours and the relative high output of more than 100 lm/W.

Light poles will be installed in order to obtain satisfactory light levels at various sites, roads and intersections. At roads and intersections, 10 m light poles are used with one fixture at each pole. On work sites, 12 m light poles are used with one or two fixtures at each pole.

Sites near buildings will be illuminated from fixtures installed in wall brackets on buildings and will serve as parking and entrance lighting. Roads will not be directly illuminated, however, as a minimum, the light poles at fixed locations will indicate the location of the road. Basic lighting will be installed at intersections and culverts for safety purposes.

On outdoor work site such as the fuel station, container storage, concentrate storage and ROM pad basic lighting will be installed to create an overview of the work site. A mobile lighting plant will be used for maintenance or other work on these areas.

Although there is no fixed lighting at the port, it will be possible to plug in some mobile lighting equipment should this be necessary.

Lighting will be controlled by locally installed daylight sensors and/or manually installed on/off switches. To reduce energy consumption, use will be made of two or more illumination level switches, motion detection switches, photocells and dimmer switches.

### **Site Control System and Communications**

#### **Fibre Optic Network and Site Control System**

A fibre optic network will be installed around the site to facilitate plant control system and communication between process areas. The fibre network will also be utilised for the process of closed circuit television (CCTV) system signal transmissions. Generally, the network routing will follow that of the site power distribution.

A programmable logic controller (PLC) based system will be used for monitoring and control of the entire site. PLC input/output (I/O) cabinets located in electrical rooms throughout the plant will be used to interface all field instrumentation, equipment and motor controls.

#### **External Site Communication**

Citronen is located above 83°N latitude and no communications satellites are visible. Consequently, external communications will be provided by Iridium Communications Inc. (Iridium), as this is the only option available. Iridium has an internet protocol (IP) data and voice service for the maritime market called Iridium OpenPort® (OpenPort) that, according to Iridium, is the best solution for the Citronen Project.

OpenPort provides a data capacity of 128 kb/s and three telephone lines working simultaneously while data is being transmitted. The installation of two OpenPort systems is recommended, which provides the opportunity for six telephones and 516 kb/s in data capacity.

The two OpenPort satellites are mounted as close to each other as possible on top of the process building. Three telephones and a data box are connected to each OpenPort satellite. One data box receives incoming mail and the other sends outgoing mail. The two data boxes are connected to a switch where users can connect externally to the internet.

To control data usage, an email server will be set-up in connection with the switch and will filter all emails larger than one megabyte. A similar mail server will be placed in, for example, Iceland where there is internet access, to catch all mail larger than one megabyte going to site. If an important email is stuck on the email server (given that it is larger than one megabyte), the sender or receiver will be able to contact the administrator and have the email released. Recent plans to launch new satellites has the potential to greatly increase communication and data capability. These advances will be adopted in due course.

External site communications will also be governed by the below guidelines:

- Employees will not be permitted to use the internet for personal reasons. All employees must have a Citronen email address so there is no need to connect to external email.
- Only approved personnel will be able use the telephones for external business calls. Two of the telephones will be placed in a locked office that only authorised personnel will be able to access.
- For private calls, one or two telephones will be placed in the camp library; these telephones will be monitored.
- Emergency telephones will be placed throughout the site. These telephones may be normal Iridium phones, which are not connected to the OpenPort satellite.
- For business related external internet communication, computers will be installed in the offices where external internet communication is needed.
- For private external internet communication, two or three computers will be installed in the camp library. Employees will not be allowed to surf the internet and use will be restricted to home contact.

## 6.4 Power Supply and Distribution

### Plant Power Generation

Electricity production and supply will comply with Greenlandic electrical regulations and will be based on European standards with 50 Hz frequency and 400/230 service voltage.

The required power consumption of approximately 23 MW will be met by a total of six generator units, with four in operation and two on stand-by duty/ maintenance.

The generators will be medium speed units rated for continuous operation in an arctic environment for a service life of at least 25 years. With four units running at a long-term average operating load of approximately 80%, the power plant will have a rated capacity of 23 MW.

Each generator unit has a rated capacity of 7.124 MW on 100% load. The engines are designed for a continuous base load operation and can operate at any load between 30% and 100%. The system will be complete with fuel handling, lubrication, air handling, exhaust system, starting equipment, electrical distribution switchgear, heat recovery system and ancillary equipment. Each generator unit is made up of a four stroke engine complete with direct injection and trunk piston. They will also be turbocharged and intercooled.

## Power Distribution

### General

Power from the generator plant is delivered at 6.9 kV throughout the facilities. Substations are complete with step-down transformers (6.9/0.4 kV) and are rated 200 kW, 500 kW or 1,000 kW, depending on the requirements at each substation. The substations will be located centrally within areas (to be determined at the appropriate time), where practical, to minimise distribution losses.

Generally, all indoor electrical equipment will be IP54-type enclosures with characteristics to suit the duty required. However the indoor electrical equipment located in accommodation, administration/mine dry and airport buildings will be IP20-type.

All cables for 6.9 kV distributions and 400 V main cables are aluminium cables. All other electrical cables will be copper conductors with an outer armour and PVC jacket. Cables will be installed in cable trays when necessary. Voltage, insulation class, colour and spacing will be as needed for the application. Generally, motor cables are de-rated by a minimum of 30% to account for proximity de-rating rules when installed in cable trays.

According to Greenlandic standards, all cables for distribution will run in T179 conduit in the terrain along roads and walkways. Cables will be placed under the surface to protect them from wind, weather and snowploughs.

The power distribution cables consist of three single conductor metal screened cables and a bare copper cable, twisted together and insulated with two blow tubes for later installation of fibre optic cables.

Substations will be installed in 20 ft containers placed directly on the ground with a 10 kV section (50%) and a 400 V section (50%) separated by wire mesh. Lighting and heating is included. In the 400 V section, a Main Distribution Panel (MDP) will be installed for supply of consumers, buildings, heat tracing, and outdoor lighting. All substations will be fully equipped before being shipped to site.

For ease of maintenance, where practical, most electrical equipment will be located in indoor electrical rooms, either in buildings or in the 20 ft containers in the 400 V end.

### Load Requirements

Voltages of 6.9 kV and 690 V are designated for motor application voltages for all but the smallest loads. Lower voltages such as 400/220 V may be used for control power and lighting.

Motors up to 250 kW are designated for full voltage starting. Larger motors at the 6.9 kV level will generally be full voltage started. The major mills will be provided with soft starting equipment. The remaining fixed speed medium voltage motors will be fed from 6.9 kV motor starters located in the main electrical room.

Electrical rooms will be pressurised and ventilated.

Within the process plant, a double ended 690 V switchboard will provide power feeds to the 690 V motor control centres located in the 690 V motor control centre (MCC) room above. The 690 V MCC's are complete with a communication link such that the plant control distributed control system (DCS) can communicate and control the motors without hardwiring of I/O points from MCC's to the DCS.

Medium voltage power distribution equipment will be located at the surface portal area of the underground mine in order to power the main vent fans. Power to the underground workings will be via armoured medium voltage cables extending into and throughout the mine.

As determined by load concentration and type, power for underground equipment will be tapped off the main underground medium voltage cables via standalone starters for major equipment and movable unit substations (disconnect switch, step-down transformer, and low voltage motor starters) for 690 V motors. Separate medium voltage and low voltage grounding systems will be established at each voltage step-down point in order to utilise separate neutral grounding systems ensuring personnel safety.

### **Low Voltage Installations**

Except for the main cables, all power cabling will use copper conductor. Buried cables will be underground in T179 conduits, as per the 6.9 KV cables. If the cables run along buildings raised above the ground, the cables may instead be attached to the buildings.

### **Emergency Power**

The main generating facility has a standby generator black start system which will provide power for the start-up of the facility after a complete shutdown or system failure. In the event of a catastrophic failure of the main power plant, emergency power for the accommodation camp, warehouse and airport will be supplied by mobile generators.

The backup generators at both the accommodation camp and warehouse are not large enough to maintain full power for the area, so during the detail design phase it will be necessary to outline the systems where back up power is critical. The units for these buildings will have to be manually started when the areas not included in the emergency power run have been shut down.

An emergency power unit is placed in the airport building for emergency power to the airstrip and control tower in case of breakdown of the power plant. The unit for the airport is designed as a short break unit, so that, theoretically, the airstrip can be without light for a maximum of 30 seconds before the power unit commences running correctly. Other facilities at the airport are not included in the power backup.

## **6.5 Fuel Storage and Distribution**

### **General**

The fuel storage area consists of:

- two tanks each with a capacity of 25,000 m<sup>3</sup> fuel for arctic diesel
- two tanks each with a capacity of 250 m<sup>3</sup> jet fuel
- hose station and lines
- pipelines for both arctic diesel and jet fuel
- fuel station for arctic diesel

The fuel storage area has a safety distance of at least 625 m to the ammonium nitrate storage located at the container storage by the port.

All the pumps and automation for fuel distribution at the site will be fully electrically integrated.

### **Arctic Fuel Storage Tanks**

The fuel tanks will be single shell, placed in a reservoir with a secondary safety containment of 1.15 times the tank containment. When entering the detailed design phase, the MLSA will need to approve the reservoir size.

The tanks are 48 m in diameter and 14 m high with a fixed roof and will be designed and constructed according to the EN 14015, including manholes, drainage etc. Oil is expected to be arctic gas oil (AGO); hence, thermal insulation and heating of the tanks is not included.

Due to the permafrost, each tank will be founded on a built-up NFS gravel pad and an in-situ concrete ring beam. The thickness of the gravel pad will be a minimum of two metres. To preserve the permafrost, the tank bottom will be placed on a heat insulation layer. The secondary containment reservoir will be lined with a HDPP membrane and drainage provisions will be built into the gravel fill embankments.

### **Jet Fuel Tanks**

The two jet fuel tanks have a capacity of 250 m<sup>3</sup> each. Spillage containment will be the same method used for the Arctic Fuel storage tanks.

The tanks will be nine metres in diameter, four metres high and will be designed according to EN 14015, including manholes, drainage and piping. As the tanks will not be insulated, they will be founded on a built-up NFS gravel pad similar to the arctic fuel storage tanks. The secondary containment reservoir will be the same as for the arctic fuel tanks.

### **Hose Station**

The hose station is placed at the pier of the port and is designed for filling both the arctic fuel storage tanks and the jet fuel tanks. Fuel is transported to Citronen Fjord on the concentrate vessels and the vessel is anchored in approximately 15 m of water depth and at a maximum distance of 150 m from the coast line. The vessels will have their own equipment for pumping fuel to the fuel storage tanks.

The hose station includes three lines: two lines for simultaneous emptying of the vessel tanks with arctic diesel and one line for emptying the vessel tank with jet fuel. The hoses from the pier head are connected to the pipelines running up to the fuel storage by a fixed pipeline placed along the access dike. Hoses will be running on top of the vessels and not in the water and will be placed by the crane.

### **Pipelines for Arctic Fuel and Jet Fuel**

The main arctic fuel pipeline will run from the fuel storage area to the power plant with a secondary pipeline running from the hose station at the port to the main pipeline. A connection pipeline from the main pipeline will be located at the concentrate storage area up to the fuel station and is located close to the power plant.

Pumps will be installed in the fuel storage area. Pumps on the vessels will pump fuel to the storage area and additional pumps at the fuel storage area will pump fuel to the power plant and the fuel station.

The jet fuel pipeline will run from the hose station to the fuel storage area and is only used when loading the tanks in the storage area. Jet fuel is transported from the tanks to the airstrip on an as required basis via a fuel bowser which is filled by a truck filling pump.

### **Fuel Station**

The fuel station is located next to the power plant/truckshop. It will be a containerised unit mounted on a concrete bottom plate for collection of any spilled oil.

The container is designed with a 5,900 L oil tank with pump and filling nozzle measured automatically for controlling fuel delivery. There will be one manually operated loading arm articulated in two links

to be used for loading vehicle tanks. The container will be connected to the main site power distribution grid and equipped with lights on the loading arm and on the container.

## 6.6 Plant Site

### Administration and Mine Dry Buildings

The buildings will be constructed from pre-fabricated modules. They will be elevated from the ground, integrated with the main warehouse and will be part of the walkway system between the camp and the process plant.

The administration building is a single story structure and will have a total area of 700 m<sup>2</sup>. It will include office space for 35 people, laboratories, meeting, instruction and conference rooms and other necessary facilities.

The mine dry building will be a single story structure with a total area of 730 m<sup>2</sup>. It will include dry room and bath facilities for 160 men and 30 women, a medical room, laundry and drying rooms, pre-shift briefing room with standing room for 50-60 people, a lamp room for underground personnel and other necessary facilities.

Heat traced sewage piping will be installed under the buildings and pumped to the sewage treatment plant. Water, electrical and heating services will be run along the building hallways.

Potable water will be supplied from the potable water treatment plant within the main warehouse and heating will be based on glycol which is distributed from the power plant through buried piping. Glycol heating systems will be utilised within the building.

### Main Warehouse and Plant Workshop

The main warehouse and plant workshop will be connected directly to the administration building and to the process plant via arctic corridors that form part of the walkway system between the process plant and the camp.

Access from the service road will be through a four metre by three metre door into the warehouse section via an air lock. The warehouse will be serviced by indoor forklifts. There is no provision for an overhead crane within the building.

The structure will be steel framed with steel cassettes for the roof and insulated panels for cladding. The floor and foundations will be reinforced concrete. The building will be placed on a gravel pad including insulation to preserve the permafrost.

The building facilities will include storage are for spare parts, a workshop area for fixing small equipment, the incinerator, potable water treatment plant, the sewage treatment plant and subsidiary facilities.

Potable water, heating systems, sewage piping and electrical services will be similar to the administration and mine dry buildings.

### Vehicle Parking

A vehicle parking area will be constructed as part of the gravel pad for the fuel station, truckshop and power plant. A ready line will be provided with outdoor parking for 10 vehicles and each stall will be sized to accommodate both small vehicles and a 163 t haul truck.

A ready rail will be constructed which will supply the parking stalls with 35 kW for truck warming and 2 kW for lighting. Electrical installations comprise of outlets for cars and trucks and outdoor lighting for the parking.

### **Truckshop**

The truckshop building will be a pre-engineered steel structure 98 m long by 21 m wide with 10.5 m height to underside hook of an overhead crane. The structure will be clad with insulated metal roof and wall sandwich panels.

The building has been sized to accommodate 90 t open pit trucks and 60 t underground haul trucks. The building and truck door height are sized to accommodate a 90 tonne open pit truck with its rock box in dump position.

The facilities will include four repair bays, a 25-t/10-t auxiliary crane, a wash bay with oil/water separator, a light vehicle repair bay, an emergency vehicle storage bay and offices and other subsidiary facilities.

### **Accommodation Complex**

#### **Accommodations and Centre Facilities**

The camp is designed to accommodate 290 people based on an 8+1 concept and comprises eight accommodation blocks spread around a central reception block. This layout was selected to enable camp residents to access central facilities through small connection corridors without having to go outdoors.

All buildings, ancillary facilities and electrics will be designed and constructed according to the Greenlandic Building Regulations, adhering to requirements including those for heating insulation and fire safety. The camp will be divided into several fire sections to avoid fire spreading.

It is planned to erect the camp as early as possible so that it can be utilised for the construction workers and subsequently refurbished for use by operations personnel.

The buildings will be delivered as fully fitted-out prefabricated modules equipped with on-site works being foundations, connection of services reticulation systems, fitting-up and furnishing. The foundations will comprise of prefabricated components and will consist of steel frames fixed to buried concrete slabs. The buildings will be placed with the floor level raised one metre above the ground to preserve the permafrost.

Sewage piping will be installed under the buildings and pumped to the sewage treatment plant and sewage piping will be heat traced. Water, electrical and heating services will be run along the building hallways.

The buildings are heated by glycol from the boiler plant placed in the power plant.

#### **Accommodation Blocks**

Accommodation blocks will be single storey and contain 31 to 33 single bedrooms, one common room and a plant room. Accommodation rooms will include a private bathroom with shower facility and will be completely furnished, inclusive of a TV with DVD player and phone/internet connection for internal communication.

Common rooms will include a small kitchen area with coffee machines and dishwasher, a relaxing area with sofas and armchairs and an area for dining.

Ventilation will be by two ventilation systems with heat recovery. Each room will be ventilated by an exhaust system in the bathrooms and with injection in the hallway.

### **Centre Facilities and Reception Block**

The centre block will be one storey and the total area will be 1,800 m<sup>2</sup>.

The facility will include a reception area with a lounge, camp manager's office, a meeting room, storage area, laundry, small supermarket, a fitness room, library with internet and telephone for external communication, canteen area for 132 persons dining at the same time, a kitchen and bakery with cooling and freezing storage, two open relaxing areas, staff office, and other facilities.

Glycol heat radiators are placed under each window and areas are ventilated by three ventilation systems with heat recovery.

### **Arctic Corridors**

Arctic corridors will be used for the connection of:

- accommodation blocks and centre building in the camp
- centre building and administration/dry/main warehouse
- main warehouse and the process plant

The corridors will also be utilised for distribution of services such as water, heating and electricity. Sewage pipes will run below the corridors.

The corridors will be constructed from prefabricated modules elevated from the ground similar to the camp.

The corridors are heated by glycol systems to a temperature of +5°C and exterior doors are heat traced to ensure they will open and close.

## **6.7 Heating, Ventilation and Air Conditioning System**

Due to the on-site climate conditions, it is necessary to provide heating to the plant site buildings to enable regular maintenance and operations to be carried out. The heating, ventilation and air conditioning (HVAC) system will utilise waste heat recovered from the power plant.

Initial indications show there will be sufficient waste heat at the generator heat exchangers to provide heating to all of the plant site buildings under normal operating conditions. When power generation is at lower than normal levels, an oil-fired boiler plant will be required which will consist of two 300 BHP boilers which will be located in a boiler room adjacent to the power plant.

The recovered heat will be in the form of a 60/40% glycol solution that will be delivered at 90°C into a piping distribution network. The heating distribution system is based upon a primary and a secondary system where the glycol solution will be pumped in loop from the power plant to all of the heated plant site buildings, and then back to the power plant. Secondary pumped loops will be installed at each heated building to provide an effective and flexible method of heating.

Distribution pipes between buildings will be insulated and will be within heated arctic corridors to minimise heat losses from the piping.

The primary pumps will be located close to the power plant where the heat is generated and secondary pumps will be located within the heated buildings.

The heating loops will be connected to unit heaters and air handling units. The unit heaters will be sized to maintain the space temperature above freezing when the plant is inoperative and the outdoor

air temperature is at the design winter condition. The air handling units will handle outdoor air to provide the required ventilation, or make up air quantities necessary to offset sensible and latent gains within the buildings.

Heat recovery fans will be provided in process areas to draw stratified air down to the lower levels and exhaust fans will be provided to remove excess humidity from the buildings.

## 6.8 Explosives Mixing and Storage Facilities

### General Concept

Ammonium nitrate and fuel oil (ANFO) will be mixed on-site which will require shipping of the following:

- ammonium nitrate
- initiation devices, including electronic detonators, non-electric (nonel) detonators, signal tube, programmable detonators, surface delays, down the hole delays, etc.
- high explosives (HE) – packaged cartridge explosives, cast primers, detonating cord, and perimeter products
- blasting accessories

The required storage capacity will correspond to one year's use of explosives requiring 2,000 t of ANFO. The corresponding quantity of explosives materials is assumed to be approximately 10%, i.e. 200 t/a.

The ammonium nitrate will be delivered in bulk-bags and containerised in containers which will be placed in a storage location at the port area. The explosives materials will be stored in two separate explosives magazines. A mobile mixing will be used to prepare the ANFO mixture.

### Explosives Magazines

The use of two explosives magazines instead of one ensures a supply of explosives in case of an accident and reduces the required safety distances to other facilities. Each magazine is designed to contain up to 100 t of explosives and will be barricaded by embankments.

Explosives materials will be stored in approved explosives containers. Initiation products (electric and nonel detonators, surface delays) will be stored in separate magazines to high explosives (packaged explosives, detonating cord, and blasting agents).

The required number of containers per magazine will be at minimum six containers for boosters, dynamite and detonator cord plus two separate containers with detonators and connectors. The containers with detonators are placed at a minimum distance of 10 metres from the other containers and embankments will be constructed to protect the HE/blasting agents from an explosion in the detonators magazines.

Containers will be founded on a levelled gravel pad and drainage ditches will be constructed as needed to deal with melting water. Wind loads at the site will require the containers to be fixed to steel frames anchored to buried slabs.

The design of the explosives magazines requires compliance with Greenland's MLSA guidelines (July 2010). These guidelines include the following considerations:

- Protection against avalanches, falling rocks, and flooding: avalanches and falling rocks are not considered a high risk in the area and flooding will be avoided by drainage ditches that will be built.

- Fences: Around the magazine, a fence must be established of at least 2.40 metre high with three strands of barbed wire at an angle of 45° outwards. It must be possible to remove snow on both sides of the fence.
- Safety distances: Safety distances to the magazines depend on the quantity of stored explosive materials. Safety distances are reduced when the magazine is protected by a barricade.

### **Explosives Mixing Facilities**

A mobile mixer unit will be utilised which will be built on a truck chassis and hold two tanks, one for ammonium nitrate and the other for fuel oil. The products are dosed from the tanks and travel down a hose where they mix at the nozzle. The mixer unit will be utilised to directly load open pit blast holes and will be used to load ANFO into 500 kg bulk bags for transport to the underground magazine and later use.

## **6.9 Port**

### **Introduction**

The marine facilities will be located in the south-eastern corner of the Citronen Fjord, behind the small cape where adequate land areas for container and winter storage yards are available.

The average shipping window for access to the Citronen Fjord is approximately six weeks each year and shipping requires assistance from icebreakers. During this period, loading of concentrate and unloading of supplies will take place on a 24 hour per day basis.

The proposed port facilities are of a simple design to enable them to be established swiftly with a reduced amount of site work.

The port facilities will comprise:

- pier head
- two berthing/mooring dolphins
- longitudinal moorings
- access dike
- land areas

Outside of the shipping season the buoys and fenders will be dismantled and moved onto land in order to avoid damage from ice.

### **Port Design Considerations**

#### **Tides**

The following tides are assumed:

- highest astronomical tide: plus 0.25 m
- mean sea level (MSL): 0.00 m
- lowest astronomical tide: minus 0.25 m

#### **Wind**

The mooring system will be designed for the characteristic one minute average design wind speed, as occurs during the expected shipping season expected to fall in the period of July, August and September

### **Current and Waves**

Limited information is currently available, however a small tidal current has been observed and some currents from the rivers flowing out into the Fjord are anticipated.

### **Ice**

In the winter season the ice thickness in the Fjord can reach 1.80 to 2.50 m. The pier head works must be designed for the adverse effects of this ice apron.

By and large, the bottom of the Citronen Fjord is expected to be ice-free during the shipping season, however, some ice floes must be expected and therefore have been considered in the design of the port elements.

### **Sea Bed Conditions**

In general, the sea bed is assumed to consist of deposits of clayey silt. There is a variable active layer of silt which needs to be considered during detailed design.

### **Offshore Moorings**

The offshore moorings will consist of mooring buoys, anchor chains and seabed drag anchors. Traditionally, the hawsers and associated mooring winches will be located on the vessel and these components are thus regarded as part of the ship's equipment.

For efficient loading operations, a control system where the winches and hooks are controlled from land by means of telemetry will be implemented. The system will include controls for tensioning and slackening of each wire as well as information on the actual tension level in the wires.

### **Mooring Buoys**

The mooring buoys will be fitted with quick release mooring hooks. Outside the shipping season the buoys will be separated from the anchor chains and lifted onto land for maintenance and repair.

### **Anchor Chains**

The mooring buoys are anchored to the seabed anchors by means of studless anchor chains, steel grade R3. Studless chains are preferred for permanent installations as they weigh less than stud link chains and are more elastic.

The chain cable will form a centenary curve between the buoy and the seabed and have a factor of safety of three for the minimum breaking load.

### **Anchors**

The anchor chains are anchored to the seabed by means of drag embedment anchors and will have a factor of safety of 1.5 to 2.0 on the ultimate holding capacity of the anchor. The ultimate holding capacity is conservatively assessed based on soft clay.

### **Fender Works**

Protective fenders will be provided to protect the pier head and dolphins from berthing impact damages by the concentrate vessels.

The ship impact calculations will be based on a fully laden concentrate barge with the fenders designed for a perpendicular berthing velocity corresponding to the fully laden displacement of the vessel assuming easy berthing and an exposed location.

A floating foam fender type fitted out with a chain tyre net for protection is proposed. Unlike floating pneumatic fenders, the foam fenders will not sink if the skin should be damaged. The fenders are loosely secured with chains to the sheet pile cells.

Outside the shipping season the fenders will be lifted on land for storage and maintenance.

### **Demands on the Berth**

The water depth requirements at MSL for the vessels are estimated from the following criteria:

- lowest astronomical tide: approximately 0.25 m
- draught of the fully loaded ships at least 12 m
- additional under-keel clearance, 20% of draught: 1.9 m

A bathymetric survey was carried out in the summer of 2010. Prior to commencement of detailed design, a depth sounding survey will be completed to ensure that this minimum water depth is available over the port area and its approaches, in order to avoid any requirements for dredging.

The quay elevation is determined to be +2.00 m relative to MSL, which will give a reasonable air gap to the highest water level.

### **Access Dike, Pier Head and Dolphins**

#### **General**

The access dike will be made of gravel from a borrow pit and will be finished with a compacted top wearing course and the sides will be protected by layers of large stones. To avoid stability failures, side slopes will be 1:3 for this arctic environment. The crown elevation is +2.00 at MSL, corresponding to the elevation of the pier head. The crown width will allow space for two-way heavy traffic and for a concentrate conveyor belt.

The pier head will be rectangular in shape and constructed from sheet pile filled with local gravel. Two berthing/mooring dolphins will also be constructed in the same manner. The sides of the pier and dolphins will serve as service quays for minor service vessels. The pier and the dolphins will be connected by bridges (e.g. old army bridges or similar).

The elevation of the quay aprons is +2.00 at MSL which will be satisfactory for the limited tidal range experienced at the site. The characteristic live load on the quay aprons is 20 kN/m<sup>2</sup>, which is valid for bulk quays.

#### **Design Particulars**

The sheet piles will be driven to the permafrost table or to refusal. No passive resistance from the limited active layer of soft soils will be taken into account, hence internal anchors are proposed. The sheet pile walls will be anchored by means of upper waling and mutual upper and lower anchor rods.

The quay apron on the pier will be finished with a compacted top wearing course, and the dolphins will be completed by a stabilising slab of structural concrete.

Ice aprons adhering to the walls will, in conjunction with a rise of the water level, cause vertical lift forces on the sheet pile walls. This will be prevented by uplift brackets welded to the inside lower part of the sheet pile walls.

## **Additional Facilities**

Additional facilities for navigational and personal safety will be implemented provided, as described below.

### **Craneage**

Craneage equipment will be available for lift of twenty-foot equivalent unit (TEU) shipping containers (maximum 30 t), buoys (approximately 20 t) and fenders (approximately 5 t).

### **Navigational Aids**

All requirements from the Danish Maritime Safety Administration or the Danish Maritime Authority must be complied with. It is envisaged these will include a system including navigational lights, fog horns etc.

### **Safety Equipment**

The access vessels and the pier head must be equipped with appropriate safety features including rescue ladders, rescue posts etc. as required by the Danish Maritime Authorities.

### **Inspection, Maintenance and Repair**

The inspection, maintenance, and repair activities will include the following:

- buoy inspected and repaired as necessary
- the access dike and the pier head will be inspected for damage from ice and repaired as required
- when the harbour area is ice-free, the anchor chains on the seabed must be inspected by a diver and replaced if necessary
- the level of the seabed in the harbour area must be checked from time to time

### **Shiploader**

A fixed shiploader has been selected for loading of vessels with lead and zinc bulk concentrate. The shiploader is designed to load vessels at a maximum rate of 2,000 t/h.

The shiploader consists of a fixed belt conveyor, fitted with a weigh belt, which is loaded from the reclaim system and a movable belt conveyor. To optimise loading, the movable part of the shiploader is fitted with a radial telescopic chute to enable trimming of the vessel.

To prevent pollution of the surroundings caused by the lead and zinc concentrate while loading the vessels, all the transfer points have a dust collection system. To protect the concentrate on the belt conveyors from the wind, the conveyors are covered and placed inside a covered bridge. The conveyor bridges are provided with one metre of free space on each side of the machinery for maintenance access.

### **Container Storage**

The container storage area has a total area of 42,550 m<sup>2</sup>. It is designed for handling and storage of:

- ammonium nitrate in 100 20-ft containers
- frozen groceries in 30 20-ft refrigerator containers (reefers)
- other supplies in 870 20-ft containers
- oil and grease storage: 600 m<sup>2</sup>

The prepared area will have a final drainage cross-gradient of four percent and will be covered with mechanically stabilised gravel. The thickness of the gravel layer will be minimum 0.5 m to build up permafrost in the underlying original soils.

Containers are placed in two layers in the north-south direction corresponding to the dominant wind direction. Due to heavy winds, it may be necessary to anchor containers, especially empty ones. This will be considered in the detailed design phase.

The storage area will be provided with exterior lighting for 24-hour operation which will be 12 m lighting poles equipped with two or three floodlights.

## 6.10 Shipping Logistics

### Introduction

The Citronen Zinc Project is located in north-eastern Greenland surrounded by the waters of Wandel Sea and Fram Strait. The assumptions for the navigational access have been made from the data given in a report by Enfotec (2011). Average opening dates for ice class PC 4-5 to navigate to the Citronen Fjord are indicated in this report to be from late July to early September every year.

In addition, Captain Kimmo Lehto, a private contractor, reviewed the ice situation in August 2010 between Citronen Fjord and South to latitude 80°37'N (Lehto, 2010) and supported the proposed sail route with a Polar Class vessel.

In October 2010, DMI Ice Services (DMI) was commissioned by Ironbark to look at the navigation route to Citronen in the light of the reports from Enfotec and Captain Lehto. DMI has submitted supplements to these earlier reports.

### Shipping Plan

Two solutions were considered for the transport of concentrate from Citronen Fjord: An icebreaking tug with barge versus two ice-class bulk carriers. The solution with the ice-class bulk carriers was chosen due to the greater load capacity, resulting in fewer required trips per year, ease of operation and greater economic benefit.

Shipping to and from Citronen will utilise two high ice class mine re-supply vessels.

- A. One Polar Class 3 (PC3), 65,000 Deadweight Cargo Capacity (DWCC) vessel designed to carry zinc and lead concentrates, arctic diesel and TEUs (Class & Non Class) without ice breaker escort.
- B. One Polar Class 4 (PC4), 55,000 DWCC vessel designed to carry zinc and lead concentrates, arctic diesel and TEUs (Class & Non Class) without ice breaker escort.

Concentrate production will be approximately 300,000 tonnes per annum (peaking at 320,000). Based on the selected ships capacity, this corresponds to a requirement for approximately 3 return trips per year.

The two Polar Class vessels would carry about 360,000 wet metric tons (wmt) of zinc and about 20,000 wmt of lead. At all times, the Polar Class vessels would sail in a convoy with the PC3 vessel, larger both in terms of dimensions and horsepower, acting as the escort for the smaller PC4.

As the ice cover varies from year to year there is no specific shipping route from the open waters of the Greenland Sea to Citronen Fjord. The sailing route will depend on the lead in the ice developing in the shear zone between the shore fast ice and the drift ice. Consequently, the final sailing route cannot be determined until closer to each shipping period and will have to be adjusted for each trip.

On the 'Northbound' voyage, the polar class vessels would load TEUs and arctic diesel at the designated marshalling port before sailing to Citronen Fjord. Arctic diesel would be discharged followed by TEU cargo.

The concentrate cargo would be carried on the 'Southbound' voyage. In addition to loading concentrate cargo, the two vessels would also load backhaul cargo, which would be comprised of either empty or loaded TEUs, thereby assisting the project with the maintenance of an efficient TEU supply chain. Dangerous goods (explosives) and controlled substance will be shipped in suitable approved containers (as per established shipping arrangements).

## 6.11 Airport

### Introduction

The airstrip will be used for transportation of staff to and from site and for supplies that are required to be flown in (e.g. fresh groceries and spare parts required at short notice). Outside the September to July shipping season the airstrip will be the only access to the project.

During the project operations phase air traffic is expected to be for personnel (50 people in and out) as well as supply of fresh groceries. This can be maintained by two aircraft flights per week on average plus one cargo aircraft for delivery of spares and replacement parts when needed. The planned transportation route for local employees will be from Kangerlussuaq directly to the project.

The airport facilities will be constructed in two stages. Aircraft which could potentially use the airstrip during each stage include:

- Stage 1: DHC-6 Twin Otter, DHC-7 and Hercules C-130H
- Stage 2: Dash 8 (Q400), Hercules C-130H and Fokker 50

In Stage 1, a temporary airstrip will include lighting and navigation systems to enable operation on a 24 hour basis. It will have a 900 m runway for the operation of passenger/freight aircraft similar in size to the Twin Otter or DHC-7.

In Stage 2, the temporary facilities will be upgraded to a permanent airstrip with a 1,500 metre runway to handle larger aircraft such as a Fokker 50. and Dash 8 (Q400).

### Design Criteria and Authorities Approval

With a runway of approximately 1,500 m, it is planned that the airstrip will only be used for the project and ongoing operations, however, it is expected the civil aviation authorities will request the airstrip also be open to other aircrafts in the event of an emergency.

The approval of the airport is to be handled by the Greenlandic aviation authorities and the MLSA.

All requirements of the airstrip, technical facilities, mobile equipment and staff required for operations are to be in accordance with international standards and require approval by the Greenlandic and Danish Civil Aviation Authorities.

The Danish Civil Aviation Authority usually requires a preliminary application of establishment before the detailed design. Overall processing time for this approval can be up to 12 months and technical approval up to three months before the start of construction.

Both the temporary and permanent runways are classified for non-precision approach with decision height at approach a minimum of 150 m above thresholds.

All aircraft must be approved for landing and take-off on a gravel runway.

### **Permanent Airstrip**

#### **General Arrangement**

The permanent facilities will comprise the following:

- runway
- taxiway and apron
- navigation and communication instruments
- runway approach lights
- control tower
- terminal building with check-in, security, etc.
- garage/technical building for mobile and emergency power unit
- parking area

The main power supply will be from the site grid. Emergency power will be available from a mobile generator placed in the airport building.

### **Temporary Airstrip**

The temporary airstrip will be the initial part of the permanent airstrip. Up to 650 m non-approved runway for DHC-6 (Twin Otter) will be constructed as soon as possible, to be continued by a 900 m runway approved for operation of a DHC-7. The existing runway for a Twin-Otter is situated west of the planned runway and may be used during a part of the construction phase with navigational lights.

#### **Jet Fuel Storage and Refuelling Facilities**

Jet fuel is brought to the airport from the fuel storage by a fuel bowser. Jet fuel will not be stored at the airport and only mobile refuelling facilities will be used.

## **SECTION 7 - TAILINGS & WATER MANAGEMENT**

## 7. TAILINGS & WATER MANAGEMENT

### 7.1 Status

Tailings and water management for the project remain the same as those described in the original feasibility study (2011). Any changes to the mining schedule since then have the potential to favour underground tailings disposal in the early project stages.

### 7.2 Tailings and Water Management

#### Introduction

For efficient environmental performance, the need of structural fill for mine stability and to increase underground mine ore recovery, the decision was made to use tailings as backfill underground. This is reported in further detail in Section 4 of this Report, "Mining". However, an on-ground tailings storage facility (TSF) will be required for the following operating conditions:

- when there is an imbalance between tailings produced by the mill and underground backfill requirements
- when open pit mining is conducted, with commensurate reduced tailings as mine backfill

The conceptual planning of the TSF through detailed design of each component of the operation is guided by the "design for closure" philosophy so that the overall development is consistent with an economically viable final closure plan.

Due to the complexity and variability of natural earth and rock formations and materials, significant variations may occur between or around the borings. It is possible that conditions encountered during construction may be substantially different from those indicated by the site investigation results. In these instances, design adjustments and construction modifications may be necessary.

#### Scope of Work

The scope noted below, provided the basis for the TSF design:

- field investigation and laboratory soils testing undertaken during the summer of 2010 by MT Højgaard (MTH)
- seismicity estimate based on literature review of Voss, Poulsen, Simonsen, and Gregersen (2007) for earthquake peak ground accelerations
- climatology and hydrology studies to develop storm events, recurrence periods and in-flow design floods
- feasibility level engineering analyses and design calculations for the TSF and Lake Platinova embankments, surface water management facilities around the TSF and for the tailings distribution system
- impoundment water and tailings mass balance analyses
- freshwater reclaim system from Lake Platinova
- preliminary closure and reclamation plan
- recommendations for additional work required to develop project further

## Site description

In-situ soils at the tailings facility primarily consist of gravels (GP-GM) and silty sands (SM) according to the Unified Soil Classification System (USCS). The geologic map of Greenland shows the project area to be mainly covered by quaternary sediments from glacial and postglacial marine deposits. The sediments predominantly consist of glacial sand, gravel and boulders ranging from 0 to 60 m in thickness.

The seismicity evaluation for this study consisted of a literature review of available information.

## Geotechnical Investigations

A geotechnical site investigation was conducted by MTH at the TSF site during the period of May to August 2010. The primary objectives of the investigation were to:

- characterise the depth and geotechnical properties of the soils beneath the dam footprint
- characterise the permafrost conditions of the site
- characterise the surficial soils in the impoundment basin
- identify possible borrow sources for dam fill materials

Investigations performed to support the design included geotechnical drilling, test pit excavation, soil sampling, and laboratory soil testing.

A total of 18 boreholes were drilled around the Citronen Fjord area, from which only three were drilled within the footprint of the tailings facility. Standard Penetration Testing (SPT) was not carried out in the field due to the permafrost in the ground.

Test pit exploration and sampling was performed in the impoundment area to characterise geology and engineering properties of surficial soils. A total of 28 test pits were excavated to investigate near surface geology and collect soil samples, six of them being located in the footprint of the dam.

Laboratory testing performed on selected samples indicates primarily gravels (GP-GM) and silty sands (SM) classification. Gravel ranges from 0% to 88% of the overall material and fines are between 3% and 100%.

## Climatology

The climate of the Northern Greenlandic area is arctic desert, meaning it is cold with daily maximum temperatures rarely exceeding 10°C. The warmest month, July, has an approximate average daily temperature of 2.1°C (35.8°F). Citronen Fjord is also very dry, averaging less than 200 mm of precipitation per year with monthly averages of less than 30 mm during wetter months. Based on regional weather stations, most of the precipitation occurs during the months of July, August, and September, with September normally being the wettest month. February is the coldest month of the year. Citronen Fjord experiences polar night from the middle of October with twilight lasting until the end of the month, there is total darkness until the end of February with twilight commencing around the middle of the month. The sun does not set at the Citronen site from approximately the first week of April until the first week of September.

## Design Criteria

Site-specific design criteria for the TSF study were developed based on the following agency publications:

- International Committee on Large Dams (ICOLD) – Various Bulletins
- Canadian Dam Association (CDA) – Dam Safety Guidelines, January 1999

- The Mining Association of Canada – A Guide to the Management of Tailings Facilities, September 1998

Table 7.1 summarises the design criteria and assumptions used for the Citronen Fjord TSF feasibility design.

**Table 7.1 - Summary of design criteria and assumptions**

<b>1.0 Basic Data</b>	
<b>1.1</b>	Total tailings is 9.0 Mt
<b>1.2</b>	Tailings produced at 240 t/d
<b>1.3</b>	580,557 m <sup>3</sup> tailings storage requirement for year 1; 371,000 m <sup>3</sup> capacity required for years 2 through 8
<b>1.4</b>	Tailings solids specific gravity = 3.6
<b>1.5</b>	Tailings slurry consists of 58% solids by weight
<b>2.0 Dam Stability</b>	
<b>2.1</b>	Minimum factors of safety – refer to Table 7.2
<b>2.2</b>	Maximum Design Earthquake (MDE) = Maximum Credible Earthquake (MCE)
<b>2.3</b>	Use pseudo-static methods of analysis
<b>2.4</b>	Peak Ground Acceleration (PGA) factored by 50% for pseudo-static analysis
<b>2.5</b>	Assume tailings fully liquefy under earthquake conditions
<b>3.0 Storm Water</b>	
<b>3.1</b>	Diversions designed for 100-year, 24-hour storm event
<b>3.2</b>	During operations, the impoundment will completely contain runoff resulting from the 24-h 50% PMP event in addition to the normal operating pool volume as determined from the impoundment water balance while maintaining 1 m (minimum) of residual freeboard between the dam crest and the maximum water level
<b>3.3</b>	Emergency spillway designed to pass the 24-hour PMP event while maintaining 1-m (minimum) of residual freeboard between the dam crest and the maximum water level
<b>3.4</b>	Use Soil Conservation Service (SCS) Technical Release 55 (TR-55) methods of analysis
<b>3.5</b>	Antecedent Moisture Condition (AMC) II assumed

Acceptable slope stability design criteria for earth and rock fill dams advocated by the ICOLD and the Canadian Mining Association were adopted for design of the Citronen Fjord tailings dam. These requirements are summarised in Table 7.2.

**Table 7.2 - Minimum factors of safety for dam stability**

<b>Loading Condition</b>	<b>Minimum Factor of Safety</b>	<b>Slope</b>
Steady state seepage with maximum storage pool	1.5	Downstream
Earthquake	1.1	Downstream

### Tailings Embankment Design

Based upon the data available regarding available construction materials at the site, a conventional earth and rockfill dam with a geomembrane lined upstream slope was chosen for this stage of design.

The dam will be constructed in stages with locally available materials placed and compacted in lifts. In general, the tailings dam will include fine grained lower permeability materials placed in the upstream portion of the dam and coarse high strength rock materials in the downstream portion of the dam.

The location of the facility was based on the following considerations:

- proximity to the proposed milling facility
- impoundment storage to dam fill ratio
- water management considerations
- environmental
- geotechnical
- topography

The selected TSF location is within the licence owned by Ironbark. Based on site investigations conducted to date, the entire impoundment area and dam foundation is covered with a thick layer of gravel interbedded with thin layers of ice. The impoundment area consists of terrain slopes ranging from 2% to 6%.

The zoned earth embankment proposed for the tailings dam is as per standard practice for tailings dam construction. It provides a cost effective, environmentally responsible and safe manner in which to store tailings.

The dam will contain five primary earth fill zones (Figure 7.1).

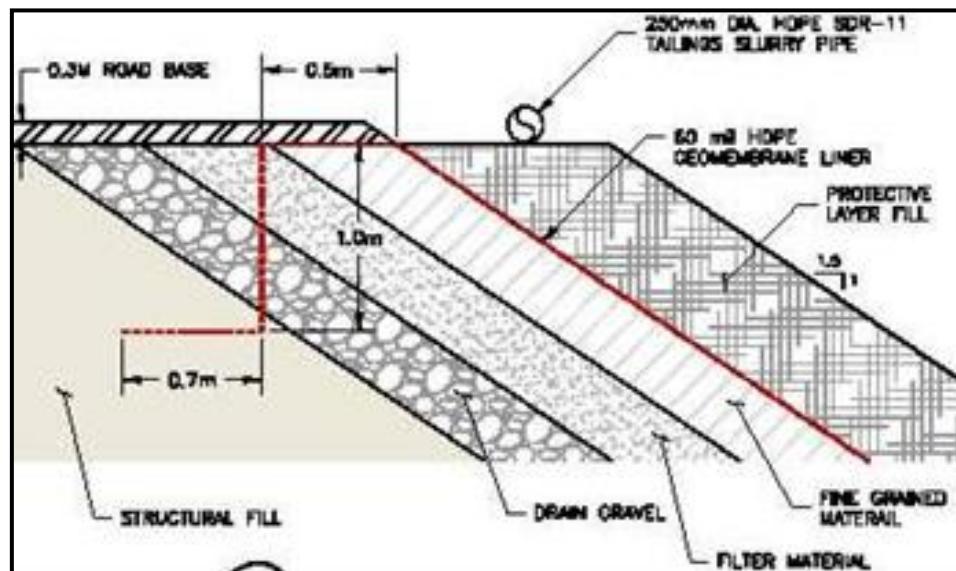
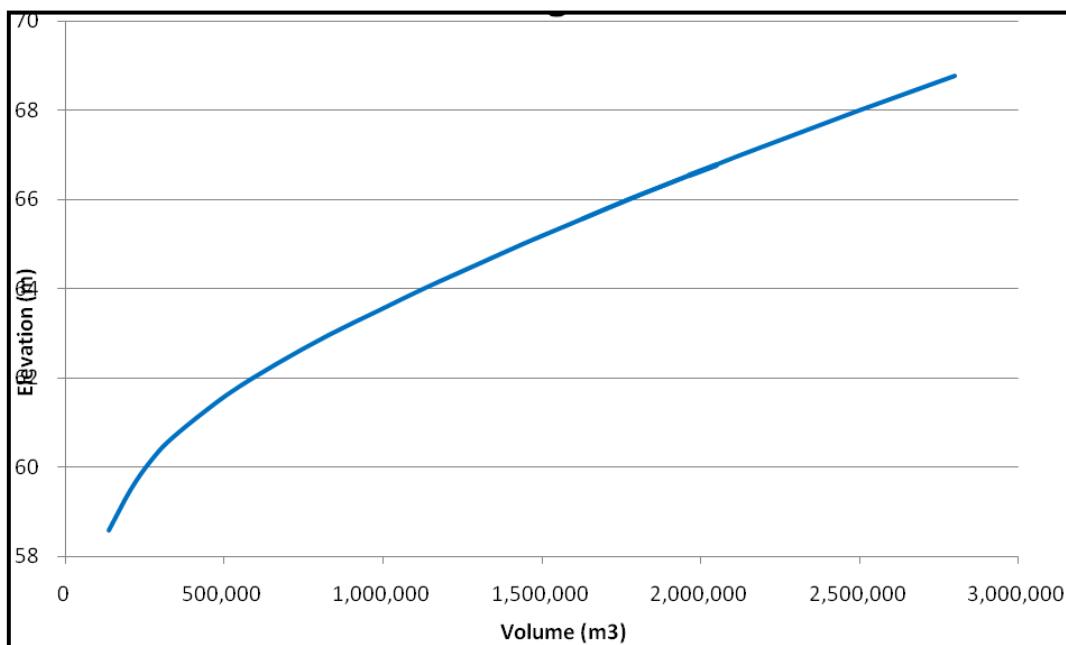


Figure 7.1 - Primary earth fill zones

### Tailings Impoundment Design

Embankment geometry has been designed to maximise impoundment volume while maintaining a footprint that remains above the Eastern River floodplain. The layout also minimises the rate of rise of the facility to allow the tailings to freeze. Figure 7.2 presents the height-capacity relationships for the facility.



**Figure 7.2 - Tailings facility storage curve**

The initial starter stage embankment provides capacity for approximately 4.5 years of operations at the tailings production rate anticipated for the project. The anticipated tailings to be stored in the facility are a function of mill production and underground backfill operations. The TSF storage volumes are approximately 580,000 m<sup>3</sup> for Year 1, and 371,000 m<sup>3</sup> for Year 2 through Year 8.

A portion of the tailings in Year 2 through Year 8 are anticipated to be placed back in the underground workings. The final raise provides eight years of capacity at the current anticipated production rate.

#### **Lake Platinova Embankment Design**

The Lake Platinova Embankment Design type takes into consideration some of the same factors as the TSF, including earthquake resistance, relative cost, environmental performance, ease of closure and the ability to construct the embankment during the designated construction season. Based upon the data of available construction materials at the site, a conventional earth and rockfill dam with a low permeability core was chosen for this stage of design.

This embankment will be built in one stage with locally available materials placed and compacted in lifts. In general, the embankment will include fine grained lower permeability materials placed in the core of the dam and coarse high strength rock materials in the downstream and upstream portions of the dam. Intermediate filter materials will be required to transition between the fine and coarse grained materials. The advantages of this type of embankment design include:

- rockfill dams provide structural resistance to earthquake forces
- embankment construction can be performed with conventional earth moving or mining equipment
- suitable borrow sources for embankment construction are anticipated to be located in close proximity to the dam site
- clay core dams are very common in the industry and provide a cost effective method of storing water

The general location and arrangement of Lake Platinova and the location of the embankment was based on the following considerations:

- location with respect to the existing level of Lake Platinova
- water management considerations
- topography

The selected location of the embankment was chosen to allow for an overall capacity of 1.8 million cubic metres of water storage. The location of the embankment provides the most efficient use of the existing topography and most effectively stores the required volume.

Based on the stability modelling conducted, the proposed Lake Platinova embankment adequately meets or exceeds the minimum required factors of safety for all conditions.

### **Storm Water Control**

The storm water management approach for the Citronen Fjord TSF will be to limit to the maximum extent practical the volume of storm water runoff that enters the TSF. This will be accomplished by constructing a surface water diversion channel along the east side of the ultimate TSF. Due to the small quantity of runoff anticipated, the access roads in the area of the TSF will have a roadside ditch that will be used as the diversion channel. The surface water diversion is designed to convey the 100-year frequency, 24-hour duration rainfall event.

Extreme precipitation events in excess of the 100-year frequency event may result in overtopping of the surface water diversion. If a failure of the surface water diversion occurs, surface water flows will be conveyed to the TSF. During operations, adequate storage will be maintained within the TSF to completely store runoff resulting from the 50% peak maximum flow (PMF) event (assuming surface water diversion failure at the onset of the event) while maintaining one metre (minimum) of residual freeboard to the tailings dam crest. Excess water stored within the TSF during operations will be discharged through a temporary reclaim system as required during the summer months.

At closure, the tailings impoundment will be capped, isolating the tailings from the environment. Surface water flows will be conveyed to the emergency spillway, minimising the accumulation of water on the covered tailings.

### **Water and Tailings Management**

A detailed water and tailings mass balance computer model was developed for the Citronen Fjord TSF. The model simulates all inflows and outflows to the system during the life of the TSF.

The mill will receive water from multiple sources including Lake Platinova, the TSF and from the underground backfill process. The source of fresh raw water is Lake Platinova. Reclaim water will be provided by the TSF in the summer months and from the underground backfill process when running and supplemented by fresh water as required.

### **Closure & Reclamation**

Closure of the tailings embankment will consist primarily of vegetating the dam crest and downstream slope (if required). Progressive reclamation of the downstream slope can occur immediately following construction of the final embankment. During operations, an evaluation of the performance of the embankment with regards to erosion will be made. If unacceptable levels of erosion are noted, re-contouring of the downstream slope may be required at closure.

All diversion ditches constructed to limit inflow to the tailings facility will be left in place and allowed to naturally fill-in with eroding rock and soil from the slopes that exist above the ditches.

At closure of the facility, the Lake Platinova embankment will be breached and the lake will be allowed to return to its natural level.

More comprehensive closure plans will be developed as the project evolves during later phases of the project.

### **Emergency Spillway**

As the TSF nears the end of its operating life, adequate storage of the 50% PMF event will no longer be achievable. At that time, an emergency spillway will be constructed to protect the tailings dam from overtopping during extreme precipitation events.

The spillway was designed based on the below criteria and factors:

- The spillway must handle runoff for the PMP, 24-hour duration storm event
- Rainfall from the emergency spillway design storm event was estimated to be 81 mm
- The spillway must be capable of conveying the peak flow during the spillway design storm while maintaining a minimum of 1m of residual freeboard at closure conditions
- The north and south diversion channels are assumed to fail at the onset of the spillway design storm
- The emergency spillway is assumed to be rip-rap-lined with a corresponding Manning's roughness coefficient as given in "Open Channel Hydraulics" (Chow, 1959) of  $n = 0.035$
- The initial surface elevation in the Citronen Fjord TSF impoundment at the onset of the PMP, 24-hour duration storm event is assumed to be 68.75 m, which corresponds with the invert of the proposed emergency spillway

The emergency spillway is designed to discharge runoff from storms up to and including the full PMF event, while still maintaining a minimum of one metre of residual freeboard to the tailings dam crest throughout operations and closure. For the design of the emergency spillway, the diversion channels around the TSF are assumed to fail at the onset of the Probably Maximum Precipitation (PMP) storm and runoff from the entire 155 ha catchment area is routed through the tailings facility.

The spillway will be located at the northern end of the TSF. Discharge from the spillway will be directed away from the TSF and follow the natural topographic gradient towards the Citronen Fjord. It is not anticipated that a sedimentation basin will be required for the spillway at this stage due to the low risk of environmental contamination. The reasons for this are:

- During a PMP event, one metre freeboard allowance will remain allowing some settling of tailings solids prior to overflow.
- The majority of tailings will be frozen and will not enter the rainfall solution.
- Ecotoxicity test results concluded that concentrations of tailings decant water (including 100%) are not toxic to lower level aquatic communities.

However, during operations further testing of supernatant will be conducted to monitor the toxicity level of the supernatant and the likely solids suspension rate. Results of this monitoring will then be used to re-evaluate any risk of the supernatant to the environment in a flood situation.

### **Emergency Action Plan**

A comprehensive emergency action plan (EAP) will be developed as part of the final facility design to guide the Citronen Fjord tailings facility operators in tailings and water management. The EAP will include recommendations covering both structural and environmental upset conditions. The EAP will define responsibilities and provide procedures designed to identify unusual and unlikely conditions

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which could endanger the Citronen Fjord tailings facility, in time to take remedial action and to notify the appropriate entities and agencies of possible, impending, or actual failure of the dam.

#### **Additional Studies and Recommendations**

The goal at this stage of project development is to provide the feasibility level design of a tailings facility to support financing and permitting efforts. In order to advance the facility design to final detailed design, the following activities are recommended:

- further develop site data, refine design criteria and further define plant information
- additional tailings characterisation studies
- additional evaluations regarding embankment design and geometry
- storm water and process fluid management evaluations
- additional embankment stability evaluations to include data from a detailed geotechnical investigation
- development of a tailings storage facility management master plan
- additional hydrogeochemistry analyses and modelling of tailings supernatant for water quality treatment
- update the tailings disposal plan in relation to the current mining schedule

## **SECTION 8 - PROJECT EXECUTION**

## 8. PROJECT EXECUTION

### 8.1 Introduction

Wardrop Engineering Inc. (Wardrop) prepared a feasibility study report that included the section titled “Citronen Fjord Feasibility Study, Greenland – Volume 7: Project Execution”. It describes the requirements, timeframes and execution instructions required for the successful completion of the project, also recognising the unique challenges facing the Citronen Project (Project).

The Wardrop project plan was to initially split fabrication and erection into two main locations and organise the work as follows:

- Equipment and materials for the Project originating in Europe, Canada, North America, and Asia to be consolidated in Denmark or Iceland.
- The process plant to be erected on barges at Akureyri in Iceland and towed to the Citronen site by icebreaker tug boat.
- The main infrastructure components and primary crusher etc. to be erected at the Citronen site where the completed project will eventually be located.

For the purpose of the feasibility study report it was suggested that Wardrop Vancouver and MT Højgaard A/S Copenhagen would form an engineering, procurement and construction management (EPCM) joint venture relationship style with Metso nominated as the main vendor for all process equipment.

The EPCM contractor will provide all design services, procurement and contracts services, quality assurance, construction management and commissioning services. The EPCM contractor will supplement its in-house expertise with specialist sub-consultants where required.

Execution of the project will involve tasks that are common to the development of any project in the mining industry but also with the complexities of executing a project in Greenland. These include the complexities below:

- Carrying out construction in a sensitive environmental ecosystem and the need to minimise potential impacts.
- Working in harsh climatic conditions including very low temperatures and permafrost.
- Safety considerations for personnel working in these harsh climatic conditions.
- Logistics constraints arising from limited site access during a restricted shipping window from July through early September and a requirement to use ice-classed vessels.
- Schedule considerations resulting from the restricted shipping window.
- The consequential need to construct buildings early in the construction phase so that the project facilities can be erected within them on a year round basis with workers thereby protected from the elements.

The following sections discuss these issues and present the revised project execution plan in more detail.

### 8.2 EPCM Model of Project Delivery

The EPCM method of development for the Project by Wardrop requires that Ironbark award an EPCM services contract to a suitably qualified and experienced contractor who will develop the Project in conjunction with Ironbark as the Owner.

The role of the EPCM contractor will include the provision of personnel and expertise to:

- optimise the facility layout
- undertake detail engineering
- manage the tendering and award of purchase orders and contracts that are entered into by the Owner
- provide expediting and quality control services for the manufacture and fabrication of equipment and material supplies
- coordinate logistics and transportation globally
- coordinate and manage construction and commissioning activities
- provide project wide cost and schedule controls and reporting services

The EPCM contractor will be engaged to act as agent on behalf of Ironbark and this requires the EPCM contractor to seek Ironbark's approval for all aspects of the key decision making processes. This delivery model will enable Ironbark to maintain significant influence on the budget, schedule and quality outcomes through all stages of project development. This approach requires the Ironbark Owner's Team to be comprised of experienced personnel who are able to manage and provide an experienced overview of the EPCM contractor.

The complexities of the Project may require the EPCM contractor to utilise the services of specialist sub-consultants to incorporate cold weather expertise into the facilities design and logistics sub-consultants who are experienced in shipping in the Arctic region.

The EPCM contractor will need to demonstrate expertise in procurement in China or plan to utilise suitably qualified and experienced sub consultants for these activities to ensure tier one manufacturers are used to achieve the specified quality outcomes. Also, with the plan to engage primarily Chinese construction workers, the EPCM contractor will need to demonstrate experience working in such an environment.

### 8.3 Project Schedule

#### Key Activities

The key activities identified in the Wardrop report are as follows:

- MLSA approval of early mobilisation according to Section 702 of the Standard Terms for Exploration of Minerals (mobilisation and construction under the exploration licence).
- MLSA approvals according to Sections 19 and 43 of the Act on Mineral Resources in Greenland (Exploitation Licence).
- Detailed design, planning and approval of critical items according to Section 86 of the Act on Mineral Resources in Greenland (Exploitation Licence).

With the new plan of constructing and erecting the plant on-site within a building and utilising Chinese contractors, the following items will also be critical to project execution:

- Obtaining statutory approvals to utilise foreign contractors for the majority of the work, with limited use of local contractors.
- Early design and fabrication of buildings within which the ongoing construction and erection of the project facilities can proceed on a year round basis.
- Shipping these buildings to site during the first available shipping window between July and early September to avoid delays to project completion.
- Establishment of a detailed procurement schedule which will enable equipment to be purchased and shipped to a consolidation point for transhipping to site during the annual shipping windows.

## Schedule Development

A preliminary schedule was developed as part of the Wardrop Feasibility Study which was split into two key areas, those being on-site works at Citronen and off site pre-assembly of the process plant facilities on barges at Akureyri, Iceland, prior to towing to Citronen.

A detailed schedule will need to be produced at the commencement of the project to reflect the requirement to erect a building(s) at Citronen for subsequent process plant construction and assembly rather than pre-assembly at Akureyri and to review and finalise procurement delivery requirements to suit shipping windows based on assembly at Citronen.

The key items to be considered in revising the schedule are as follows:

- Early provision of temporary facilities to enable on-site works to commence.
- Erection of building shells including all insulated wall and roof sheeting together with all doors.
- Only the foundations for the building shell need to be constructed in the summer months.
- The other concrete works can be completed internally following erection of the buildings and the provision of temporary heating.
- A procurement strategy which ensures that equipment and materials are delivered to a staging point for subsequent transhipping on ice-classed vessels to Citronen during the shipping windows.

The basic parameters used for the schedule developed by Wardrop are:

- One working shift is 12 hours (11 working hours).
- One working week is six days.
- The site is closed for three weeks during Christmas.
- Due to the expected severe weather, the work efficiency for outdoor work will be planned as 70% efficiency for April, October, and November.
- Two shifts are planned for all outdoor activities from May to August.
- Due to the expected severe weather, no outdoor work that involves “winter sensitive” activities such as concreting is planned for December through to March.
- The shipping window is from late July to early September each year.
- The first season is “extended” through an early mobilisation using Hercules Aircraft landing on the fjord ice in April/May, and through the supply of equipment, materials, and other supplies by ice breaking tug boat in August.

The use of Chinese contractors during construction may enable a 13 day fortnight with the 14th day being taken as a day off. Closing of the site over the Christmas New Year period needs to be reconsidered as it may be appropriate to close the site over the Chinese New year period rather than as currently planned.

Concrete works can continue within the building shells provided they are adequately sealed and heating is provided.

Initial EPCM activities will include the following:

- finalisation of process design criteria, mass balance and flow sheets
- finalisation of site and plant layouts
- finalisation of discipline design criteria
- production of a detailed project execution plan
- finalisation of a contracting strategy and associated bidders list
- finalisation of the work breakdown structure (WBS)

- finalisation of the project schedule to establish critical paths and for ongoing monitoring and progress updating
- finalisation of budget allocations to procurement and contract packages
- tender and award of early works contracts for initial construction works including earthworks, concrete works, fabrication of building shell steelwork and cladding
- logistics planning
- production of standard drawings and specifications which incorporate requirements of codes and standards applicable to the works
- preparation of standard terms and conditions for contracts and purchase orders

#### **8.4 Construction Manning**

The approach of constructing the facilities on-site at Citronen rather than via pre-assembly will increase the site-manning requirements as personnel who were going to assemble the facilities off site will now be required on-site.

Actual requirements for construction manning will be finalised during development of the detailed schedule for the project. As temporary accommodation includes expansion of the existing tent facilities it is not envisioned that any increased accommodation requirements will result in delays to project execution.

#### **8.5 Engineering**

Detailed engineering will commence following the finalisation of process design criteria, mass balances, flow sheets, site layouts and discipline design criteria.

Design deliverables will be assigned to procurement and contract packages and this will enable resources to be optimised based on final schedule requirements. These deliverables will include technical specifications, data sheets, functional specifications, vendor data requirements and associated drawings.

Engineering progress will be monitored to ensure activities are undertaken in the correct sequence and are delivered on time.

#### **8.6 Procurement and Contracts**

Procurement and contract packages will be prepared and issued to the pre-qualified and approved bidders. The procurement and contracts group will monitor the tender process and, in conjunction with the relevant discipline engineering leads, evaluate tenders received and prepare recommendations for award.

Following award of the purchase orders, expeditors and inspectors will be assigned to the packages to monitor progress and quality of the work being carried out.

Contract and orders will be entered into between Ironbark on the one part and the successful approved bidder on the other part. Management of orders and contracts will be undertaken by the EPCM contractor.

Expeditors will liaise with logistics personnel to ensure that shipping activities are arranged in a timely manner.

## 8.7 Project Controls

The EPCM project controls group will carry out the functions described in the following sections associated with schedule and budget monitoring, control and reporting.

### Cost Control

Cost control personnel will:

- monitor commitments with respect to budget
- monitor actual costs
- forecast cost at completion in conjunction with the project manager
- prepare trend notices, which may have both a cost and schedule impact, so that mitigation strategies and actions can be put in place
- prepare scope changes where approved
- estimate cost and schedule implications of trends and scope changes
- provide input into monthly reporting including cost reports, scope and trend registers

### Schedule

The project schedule group will update the master schedule for the project based on information received from:

- expeditors with respect to equipment and materials supply
- the construction manager for all site activities being undertaken by contractors
- design progress by deliverables
- procurement and contract award
- the commissioning manager for all commissioning activities

Updated progress information will be provided for inclusion in monthly reports which will include planned and actual progress and an updated schedule.

## 8.8 Construction Infrastructure

To initiate construction works on-site, the construction camp, fuel storage facility and communications will need to be in place prior to mobilisation of the initial construction workers. This will also include the need to mobilise construction equipment and materials including explosives, cement, reinforcing steel, building shell materials and process plant building shell materials during the initial shipping window.

The existing communications system comprising of Iridium units will be expanded to meet construction requirements because Citronen's location precludes other systems from working.

To support the initial construction effort a number of service contracts must be put in place, including:

- fuel supply
- geotechnical laboratory
- fixed wing air transport
- helicopter transport
- icebreaker transport
- camp management

## 8.9 Labour Relations and Manpower Training

Good labour relations are essential for the efficient and safe execution of the Project. It is planned to execute the Project on an 'open-shop' basis which permits both union and non-union contractors to execute work at the Citronen Fjord site.

The preassembly activities at Akureyri are undertaken by qualified subcontractors. The availability of these qualified resources is regarded as being high and is therefore not deemed to be a major issue for the project. Hence, the following considerations are for the Greenlandic site only.

The following items have been reviewed:

- Construction Employer Organisation- Grønlands Arbejdsgiverforening (Greenlandic Employer's Association "GA") coordinates and represents employers in Greenland within all business areas including transport, electrics, plumbing, building and general contracting
- Collective Agreements in Greenland- Collective Agreements applying to the construction industry in Greenland are negotiated by GA and the Sulinermik Inuussutissarsiuqartut Kattuffiat (SIK) union in Greenland
- Government Labour Codes: The Greenlandic and Danish working environment is regarded as being very free and unregulated (the so called "Danish Model" or "Flexicurity Model"). The most important rules and regulations are the Employer's and Salaried Employees' Act, the Working Environment Act, the Holly Day Act and the Leave and Maternity Act
- Labour Strategies, Communications and Support including employee orientation and site indoctrination program and procedures for controlling and resolving labour disputes or disruptions
- Manpower Training: To assist construction contractors in securing qualified and trained Greenlandic local workers on the Project, it is recommended to enter early discussions with the Greenlandic authorities to encourage and support them in their work with training programs for the local work force. At this stage it is difficult to give any number on potential local employees. The number of persons living on the east coast of Greenland is limited and therefore the available workforce also
- Training Programs during Construction: During the construction phase, the possibility for on-the-job training will be evaluated as the project develops. This will also include the possibilities of having more formal training like apprenticeship programs on-site. Apprenticeship programs are best planned together with the local educational institutions
- Orientation Training: During the construction phase, orientation or site induction programs will be required for all first time employees. The orientation program will be completed in 4 hours and will be conducted by the Camp Manager, Safety and Environmental Coordinator.
- Operations Build-Up: The turnover will be coordinated with Ironbark to ensure proper staffing levels are available from the operations workforce to assume responsibility for the facilities

The handover of completed facilities and systems will be coordinated by the EPCM contractor with Ironbark to ensure operations staffing levels are pre-emptively built-up so the operations workforce will be available to assume the required responsibilities.

## 8.10 Pre-Operational Testing and Start-Up

The EPCM Project Team will provide commissioning management services which will include the provision of:

- commissioning manager and commissioning engineers

- coordination of commissioning activities between all parties involved in the commissioning process
- co-ordination and management of safety issues between operations, construction and commissioning groups
- production, implementation and management of the commissioning procedures
- liaison with the design consultants to ensure that the engineering requirements of commissioning are met
- review of activities leading up to commissioning and subsequently auditing site compliance with procedures, standards and site and statutory regulations and the design drawings and specifications
- authorisation of commissioning work permits
- ensuring that all data collected during commissioning is provided for review and inclusion as necessary in operating and maintenance manuals
- co-ordination of an overall commissioning report detailing all on-site activities relating to commissioning and including copies of all test and check forms completed with data relating to physical checks, settings, clearances, temperatures, etc. plus manufacturers' reports and certificates
- ensuring documented and formal approval of facilities handed over to operations for care, custody and control

Design consultants, where required, together with the EPCM design team will provide the following:

- technical support during the commissioning process
- commissioning detailed procedures and checklists
- provision of commissioning engineers where required
- updating of all engineering documents to as built status

Construction contractors will provide personnel, materials and equipment to support the commissioning team and under the direction of the commissioning manager will rectify/modify any items identified during the commissioning process. The quantity and mix of personnel will be agreed with the commissioning manager.

A list of vendors recommended for inclusion in the commissioning process will be developed during the detailed design phase of the project. The list will include vendors whose contractual requirements to accept warranty obligations requires them to be present for pre-commissioning checks and commissioning supervision.

The Ironbark operations group will provide suitably trained personnel to operate the various systems and equipment during commissioning and ramp up phase. Operations personnel will be under the direction of the Ironbark operations manager who will report to the commissioning manager until the Project is formally handed over to the operations group.

## 8.11 Logistics

Due to the isolated location of the site and the limited shipping windows available, logistics management is a critical activity that will need to be closely monitored. Expediting of materials and equipment is a critical activity for the success of the Project.

Access to the Project by sea requires the use of icebreaker tugs and ice-class vessels and is only available from late July to beginning of August in the Citronen Fjord area. A permanent airstrip will also be established in the project area.

Factors such as the remote location of the Project site, the limited shipping window, environmental and safety concerns, together with the high cost to transport materials, equipment, fuel and personnel to the site, will require detailed planning and close co-ordination of activities throughout the design and construction phases of the Project.

The scope of the logistics plan will encompass the services necessary for the efficient expediting, transport, traffic, warehousing and marshalling of personnel, materials and equipment, including living quarters, food, fuel and cement required to construct the facilities. It is imperative that materials and equipment transported during the shipping window arrive at the site according to the planned window sequences to enable all work to be completed on schedule.

The Project will require one main marshalling point close to the site to take advantage of the limited shipping window. This will be a location suited to the transfer of equipment and materials from normal ocean-going ships onto ice-classed vessels. The Wardrop Feasibility study identified this location as being Akureyri in Iceland. Pre-assembly of the process plant at Akureyri made this an attractive location for a marshalling point, however other alternatives can be considered.

It is estimated the project will have approximately 30,000 t of process and mobile equipment, structural steel and other architectural materials, pipe, valves, fittings, cement, ammonium nitrate and other equipment, materials and consumables together with process plant equipment for its construction and development.

The majority of the process plant equipment and steelwork will come from China and other goods will originate from Europe, North America, Asia and Australia.

The shipping season can vary from year to year depending on actual weather and ice conditions transiting to and from Cap Nordøstrungen and Citronen Fjord. The average shipping window is from late July to early September for ice-class PC 1 icebreaker/tugboats together with ice-classed PC 5 vessels.

During the first mobilisation to site, a vessel will be equipped with a 200 t capacity crawler crane to discharge equipment and materials to site. This machine will later form part of the port mobile equipment. During the operations phase all loading of concentrate and unloading of vessels will be done by the crawler crane and shiploader.

Load plans will be established based on the priority cargo to be shipped and the configuration of the nominated vessel prior to vessel loading.

The port facilities will not be constructed during the first shipping season and special allowance will be made to handle offloading at Citronen Fjord. A smaller temporary pier head will be constructed prior to the landing by equipment brought to site by Hercules flights landing on the ice.

## **SECTION 9 - ENVIRONMENTAL & SOCIAL ASSESSMENT**

## 9. ENVIRONMENTAL & SOCIAL ASSESSMENT

### 9.1 Status at August 2017

The Environmental Impact Assessment (EIA) (Revision 8) was submitted to the Mineral License and Safety Authority (MLSA) in July 2016. It follows the *Guidelines for Preparing an Environmental Impact Assessment (EIA) for mineral exploitation in Greenland 2015* issued by the Mineral Resource Authority. The EIA includes baseline studies and other relevant studies on waste characterisation and ecotoxicity. The EIA is in two volumes comprising the EIA and its appendices and is summarised in Section 9.2 of this report.

The Social Impact Assessment (SIA) (Revision 9) was submitted to the Mineral License and Safety Authority (MLSA) in June 2016. It is in line with the MSLA guidelines for *Social Impact Assessment – Guidelines on the process and preparation of the SIA report for mineral projects, 2016*. The SIA includes records of meetings with potential stakeholders including the MSLA, the association of local governments and municipalities, local business groups, employer associations and trade unions and other potential stakeholders. The SIA is summarised in Section 9.3 of this report.

Following preliminary approval by the MSLA, the EIA and SIA were made available for public comment. Any affected organisations and authorities, as well as the general public, had the opportunity to express their opinion on the assessment. Comments were evaluated and considered for inclusion in the decision-making process and included in the final versions of both reports.

### 9.2 Environmental Impact Assessment

#### Regional Context

Citronen Fjord is located in Peary Land and is an appendage of the much larger Frederick E. Hyde Fjord (FEHF). Citronen Fjord is approximately 2,000 km north-northeast from Greenland's capital, Nuuk and 940 km from Qaanaaq – the nearest Greenlandic settlement. The Project lies at the head and east shore of Citronen Fjord, in the junction of two glacial valleys in which the Esrum and Eastern Rivers run, and is surrounded by bare mountains up to 1,000 m high. Access to the site is currently via aircraft, with ocean access possible during the summer months via FEHF.

The Citronen Fjord area is in the High Arctic Region with continuous permafrost (whereby the ground stays frozen all year long) across cold winters and short, cool summers. Mean daily temperatures above freezing occur from June until September. Precipitation is very low (in the order of 200 mm/a) and mainly falls as snow. The FEHF and Citronen Fjord are ice-locked most of the year.

#### Legislative Framework Affecting the Project

Greenland is part of the Kingdom of Denmark. Autonomous local governance was introduced to Greenland in 1979. On June 21, 2009, a new *Act on Greenland Self Government* came into force, stating Greenland could take over the administration of natural resources from Denmark. Consequently, the Naalakkersuisut (Government of Greenland) immediately took control of the mineral resource sector. The MSLA (under the Greenland Self Government) is responsible for the management of mineral resource activities in Greenland.

The 2009 Mineral Resources Act (the Act) came into force on January 1, 2010 (*Greenland Parliament Act no. 7 - 7 December 2009* on mineral resources and mineral resource activities). This law regulates

all matters concerning mineral resource activities, including environmental matters (such as pollution) and nature protection.

The 2009 Mineral Resources Act specifically stipulates that an Environmental Impact Assessment (EIA) must be prepared before permission to exploit minerals can be granted. Of particular relevance to the EIA is the regulation of environmental protection. This is included in Chapter 13 of the Act, which is divided into three sections on environmental protection, climate protection, and nature conservation.

Under *Environmental Protection*, the following provisions are of particular importance for the Project:

- The use of best available techniques should be applied, including less polluting facilities, machinery, equipment, processes, and technologies.
- When selecting measurements to prevent and mitigate pollution, attention should be paid to the environment of the site and how metals and other pollutions can have an influence on specific species and the ecosystem.
- When selecting a site, a place should be chosen where the pollution has least impact on the environment. Furthermore, when choosing machinery and working processes, the best available techniques should be selected that generate least pollution, emissions and waste.

### **National Park of North and East Greenland**

Citronen Fjord is situated in the northern part of the National Park of North and East Greenland. With an area of 972,000 km<sup>2</sup>, of which 200,000 km<sup>2</sup> is snow and ice-free during summer, it is the largest national park in the world.

The national park was created in 1974 and has no permanent human population. During winter, the personnel of three small military bases, a civilian weather station and a research station (numbering around 30 personnel) are the only inhabitants in the national park. This number increases in summer when many scientists work in the national park.

Applications for prospecting, exploration, and exploitation of minerals in the national park are administrated according to the Mineral Resources Act.

It has been proposed to divide the national park into three levels of management:

- Level 1: species specific core areas (i.e. “biodiversity hot spots”), which are often of small size and with vaguely defined borders.
- Level 2: fauna and flora protection areas, which are larger areas often with many specific core areas or special nature types.
- Level 3: the national park outside the specific core areas and the fauna and flora areas.

According to these anticipated management levels, the proposed Project would be managed within Level 3 as it is located outside any species specific core areas and fauna protection areas.

### **Baseline Studies**

The MLSA requires two to three years of environmental baseline studies to adequately characterise an area prior to project start. Prior to 2010, two years of detailed baseline studies were completed in the Citronen Fjord area, in 1994 and 1997, as well as a reconnaissance study in 1993 and marine water sampling in Citronen Fjord in the winter of 1995.

In 2010, Ironbark and Orbicon A/S (Orbicon) conducted another baseline study of the Project during the summer months of July to September.

The results of the 2010 environmental baseline study are comparable to the previous baseline studies undertaken in 1994 and 1997, with much of the same flora and fauna species identified in the Citronen Fjord area, as well as similar spatial and temporal variations in heavy metal concentrations measured in the Eastern River and Citronen Fjord.

All marine and fresh water samples were analysed for a full suite of metals and major ions. Sample collection is summarised in Table 9.1.

**Table 9.1 - Summary of sample collection for all baseline studies at Citronen Fjord**

Sample Type	1994	1995	1997	2010
Eastern River Water	X	X	X	X
Esrum River Water	X		X	X
Lake Platinova Water				X
Lake Platinova Sediment				X
Eastern River Sediment	X		X	X
Esrum River Sediment	X		X	X
Marine Water (CF)	X	X	X	X
Marine Sediment (CF)	X			
Higher Plants	X		X	X
Animal Scats	X		X	X
Seaweed	X		X	X
Fish	X		X	X
Soil	X		X	X
Reference Marine Water Column				X
Reference Sediment (Marine)				X
Reference Seaweed				X
Reference Plants				X
Reference Animal Scats				X
Reference Soil				X
Fauna Observations	X		X	X

### Fresh Water

The Eastern and Esrum rivers cross through a large alluvial floodplain prior to entering the Citronen Fjord. While the Eastern River drains precipitation and groundwater following melting of the upper active layer, the main water source is from melting of snow and ablation from local glaciers. Due to the rare rain events in the area, it is apparent the direct runoff is mainly controlled by air temperature and solar radiation.

Elevated metal concentrations in Eastern and Esrum rivers are affected by natural processes related to the geological background and vegetation coverage in the catchment areas of these rivers. There are exposed areas of intensely oxidised sulphide minerals located within the catchment area of Eastern River. Considerable amounts of metals (zinc, lead, iron, cadmium, aluminium and nickel) are naturally washed into the Eastern River via runoff following precipitation, melting of permafrost and, in particular, melting of snow and erosion of local glaciers. High concentrations of some metals such as iron, cadmium and particularly aluminium are also found in Esrum River water.

Lake Platinova is the only lake in the immediate vicinity of the Project. It is a small, rounded depression fed by precipitation and melting of the active layer surrounding the lake. The maximum depth is approximately 11 m and the lake is ice free in summer. An interconnecting flood channel received by the Eastern River receives inflows from the outlet of Lake Platinova during flood periods, however, the passage of water in the channel is limited due to the low annual precipitation, and the channel typically remains dry for most of the season. The lake has a sedentary population of arctic char.

### Marine Water

Citronen Fjord is a relatively small fjord that extends about four kilometres southwards from the FEHF. Concentrations of zinc, copper, and lead in the water column of Citronen Fjord vary considerably over depth, with other metals showing similar trends in concentration.

Measurements in August 2010 found the highest concentrations of zinc, copper, and lead in the lower part of the fjord, in proximity to the mouth of Eastern and Esrum Rivers. These high metal concentrations were recorded several weeks after the peak concentrations of zinc were recorded in Eastern River.

There is thermal stratification evident in the water column of Citronen Fjord, with the fresher surface waters showing higher temperatures than the lower denser waters which appear to correlate with the fluctuations in metal concentrations over depth.

Concentrations of zinc, copper and lead in Citronen Fjord were found to exceed the proposed DCE guidelines at some depths. Metal concentrations above MLSA guideline (2015) levels were recorded in a few cases in FEHF.

### Sea Ice

Fast ice is a form of sea ice which is fastened to a shore. Fast ice covers all the fjords and a shelf along the outer coast of north Greenland most of the year. This includes Citronen Fjord and FEHF. In recent years, the sea ice in Citronen Fjord has thawed during late July and the fjord has been free of fast ice during much of August. Occasionally FEHF becomes more or less ice free, as was observed in 2010.

Drift ice is unattached sea ice that floats on the surface of the water. When the drift ice is driven together into a large single mass, it is called pack ice. Off the east coast of Peary Land, a long wide stretch of open water (a lead) usually develops during summer in the shear zone between the shore fast ice and the drift ice. To the northeast of this lead, multi-year polar drift ice covers the ocean. The drift ice consists of a mixture of multi-year and first-year ice with scattered icebergs from the glaciers on the coast. The drift ice is transported south along the coast by the East Greenland Current.

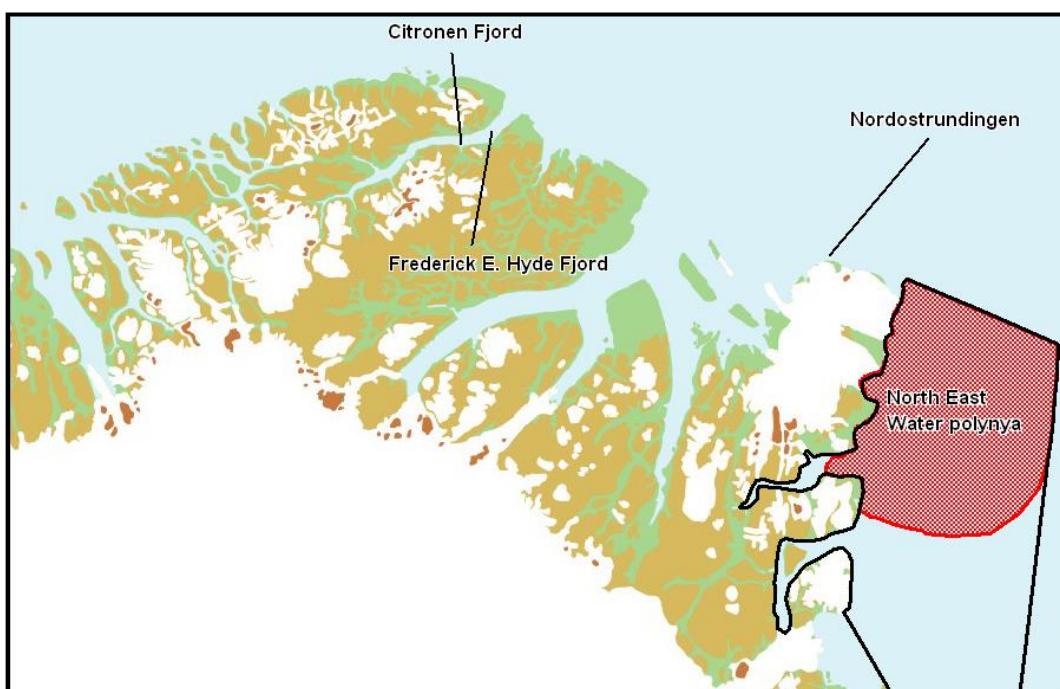
Polynyas are open waters in otherwise ice-covered waters which occur seasonally at the same time and place each year. The most significant polynya off northeast Greenland is the North East Water (NEW) off Kronprins Christian Land (Figure 9.1). The NEW typically begins to open in April and closes in September, however, fractures and leads of open water are present during winter months. The predictability of the NEW makes it an important habitat for birds and mammals.

There are several breeding and non-breeding seabird colonies that occur throughout the open water parts of the NEW and on the cliffs along the shore close to the NEW. During the shipping period in summer (July-August), breeding and non-breeding fulmars are the seabirds most susceptible to disturbance, as they have been recorded in low densities throughout the NEW in summer and leave

the NEW shortly before it freezes over again in September. The fulmar is not listed on the Greenland Red List of threatened species.

Walruses, ringed seals, and small numbers of polar bear are present in the NEW throughout the year. From May to June, when larger areas of open water appear, other marine mammals migrate into the NEW. Bearded seals and narwhals are common and widespread throughout the NEW in August and large numbers of bowhead whales have been recorded from the NEW and the sea just off the NEW in recent years. There are a number of marine mammals that are listed on the Greenland Red List of threatened species that occur in the NEW. The bowhead whale is listed as Critically Threatened, the polar bear as Vulnerable and the walrus as Near Threatened. The narwhal and bearded seal are both listed as Data Deficient.

**Figure 9.1 - Location of the NEW off the East Coast of Greenland**



Note: The area of NEW open water varies considerably during the year but also between years. The black line marks the protection zone for marine mammals (narwhals, bowhead whales, and walruses) in the northern part of East Greenland.

## Flora and Fauna

Citronen Fjord is situated in the High Arctic Region, defined as an area with very low precipitation, four months of semi-darkness during winter and a very short and cold growing season. As such, the Citronen Fjord region is an extremely harsh environment supporting only a small number of plant and animal species which have adapted to these extreme conditions.

For the purpose of the EIA, higher plants, seaweed, and vertebrates have been used as a guide to the overall biodiversity of the area. Within Greenland, these flora and fauna elements are best known in terms of habitat requirements, diet and sensitivity to disturbance and pollution. An annotated list of all species of higher plants, birds, mammals and fish recorded from the area is included in the 2010 baseline survey.

### Flora

The vegetative cover in Peary Land, including the Citronen Fjord region, is sparse and discontinuous. A study in 1988 of the vegetation cover in North Greenland using satellite images showed the vegetation cover exceed 8% in only a few areas. The amount of vegetation cover in Peary Land in August 2004 monitored from multispectral satellite data show that the Citronen Fjord region has particularly sporadic plant cover, indicating low amounts of green vegetation.

Field observations in the Citronen Fjord area in August 2010 confirmed the overall vegetation cover is very low and that large expanses have virtually no vegetation at all. With less than two months of summer-vegetative growth and very low precipitation, only the most cold-hardy plant species grow in the Citronen Fjord area. This is most likely why only approximately 50 species of higher plant species have so far been recorded in this area.

The higher plant species known from the Citronen Fjord area consist of widespread and common species in Greenland that reach their most northern distribution at Citronen, as well as specific high-arctic plants with their distribution limited to North Greenland.

### Fauna

Sixteen species of birds have been recorded in the Citronen Fjord area. Of these, eight species are believed to breed occasionally in the area. Most notably among the non-breeding bird species are large numbers of geese that spend the summer in Peary Land. In winter (October to February), no birds occur at Citronen Fjord. All birds that occur regularly in the area during summer occur throughout large parts of the National Park.

Six terrestrial and one marine mammal occur throughout the year in the Citronen Fjord region. The polar bear is an uncommon visitor to the FEHF, but has so far never been officially recorded from Citronen Fjord.

Only two fish species are known with certainty to occur in Citronen Fjord area: arctic char and four-horned sculpins. It must be assumed that at least some of the additional nine species of fish recorded in Jørgen Brønlund Fjord in South Peary Land also occur in Citronen Fjord.

Four animal species occurring in the Citronen Fjord area are listed on the regional Greenland Red List of threatened species:

1. Wolf: listed as *Vulnerable* because of its small (<1,000 animals) population in Greenland
2. Polar bear: listed as *Vulnerable* because its small population is declining
3. Ivory gull: listed as *Vulnerable* because of its very small and declining population

(approximately 2,000 adults) in Greenland

4. Arctic tern: listed as *Near Threatened* because of its large decline in Greenland

The polar bear and ivory gull are also on the International Union for Conservation of Nature Red List of threatened species.

Except for the wolf, the red-listed species recorded from the Citronen Fjord area are uncommon or rare visitors with no known breeding grounds in or near the fjord. Small numbers of wolves have been observed in the Citronen area, however, the Citronen area is not known to be of particular importance for wolves or any of the other red-listed species.

The Greenland Red List also recognises a number of national responsibility species. These are species where more than 20% of the global population occurs in Greenland and for which Greenland therefore has a special responsibility to protect. Four national responsibility species have been recorded from the Citronen Fjord area (Table 9.2).

**Table 9.2 - National responsibility species occurring in the Citronen Fjord Region**

Species	Percentage of Total World Population in Greenland	Status in Citronen Fjord Area
Polar Bear ( <i>Ursus maritimus</i> )	>20%	Uncommon visitor to FEHF
Pink-footed Goose ( <i>Anser brachyrhynchus</i> )	>30%	Common summer visitor
Knot ( <i>Calidris canutus</i> )	>50%	Uncommon breeding bird
Arctic Redpoll ( <i>Carduelis hornemannii</i> )	>50%	Occasional visitor

### Archaeology and Cultural Heritage

In July of 1994, the Greenland National Museum and Archives conducted an archaeological survey of the Citronen Fjord area to ensure no protected sites or other archaeological interests would be affected by exploration activities undertaken by Platinova A/S at the time.

The archaeological survey covered an area of 6.5 km<sup>2</sup>, including the river delta, investigating the eastern side of Citronen Fjord to FEHF and the Eastern and Esrum River valleys to a distance of four to five kilometres from Citronen Fjord.

No evidence of former Eskimo settlements were found within the area, with the only sign of potential pre-historical activities being a site on the eastern shore of Citronen Fjord, marked as "A2". This site comprises of three stones arranged in a row, and may have been placed by members of the Thule culture to support an "umiak" – an eight to ten metre-long open boat used in summer to move people and possessions to seasonal hunting grounds.

Subsequent discussions with the Greenland National Museum and Archives expressed the report sufficiently characterises the archaeology of the Citronen Fjord area. However, prior to works, there is a need for an archaeological registration and documentation of the probable anthropology structure (A2) and near surroundings.

In the 2010 field season, the A2 site was located during the environmental baseline studies. The structures were photographed, measured and a GPS location of the site was recorded. Prior to any disturbance of the area, a staff member of the Greenland National Museum and Archives will further photograph and measure the A2 structure and 10 m to 15 m around the site as part of the archaeological registration and documentation of the site.

The site will be appropriately marked and all Ironbark staff and contractors will be made aware of the site. No disturbance of the site will take place prior to archaeological registration and documentation, and approval to disturb the site is granted.

### **Key Environmental Issues**

The EIA has identified the following environmental issues as being the key areas requiring detailed assessment and management for the Citronen Project.

#### **Contamination of Fresh Water or Marine Water Resources**

To assess and describe potential transport and exposure pathways from contaminant sources (i.e. waste rock dumps and tailings storage facility) to potential ecological receptors, a Screening-Level Ecological Risk Assessment (SLERA) including toxicity testing was conducted. The SLERA identified parameters within surface water, sediment and surface soils as potentially affecting receptors at the site. Fish, aquatic invertebrates and aquatic plants in the Citronen Fjord at the mouth of the Eastern River were identified as the main community receptors. Toxicity testing indicated there is no toxicity associated with the tailings supernatant to either marine invertebrates or fish.

The SLERA study concluded that mine wastes will not significantly increase the levels of metals in the aquatic or terrestrial environment of the Citronen Fjord area. There is no anticipated impact to the upper trophic aquatic life (including birds, fish and mammals) or lower trophic level communities (including benthic macro-invertebrates and aquatic communities).

#### **Seepage and Release of Leachates from Mine Waste Facilities**

Geochemical characterisation was conducted on various mine wastes (waste rock, tailings and DMS rejects) to assess the potential for release of contaminants to the environment. The main focus was on the potential leaching of metals and the generation of acid which could release metals from the surroundings.

The geochemical testing studies indicate the potential for acid rock drainage and metal leaching from waste rock is low and will lead to no or very limited contamination of the localised terrestrial ecosystem at the dump. The acid-based-accounting shows waste rock samples with low total sulphur are likely to be classified as non-acid-generating due to the presence of excess neutralisation potential in the form of calcite and/or dolomite. The total sulphur content of the waste rock can assist with waste rock management during operations.

The testing indicated tailings will most likely generate acid after long-term exposure to oxygen and water and as such will require an additional level of containment normally accepted in conventional tailings facilities. Accordingly, the dam area will be lined with a geomembrane to contain seepage.

#### **Dust Emissions**

Air dispersion modelling was conducted to assess the potential dispersal of dust at the proposed Project site. Dust emissions were developed and ground level particulate matter concentrations and deposition estimates were predicted for the mining operations based upon meteorological data and air emission sources.

The dust modelling showed the highest dust concentrations will occur along the haul roads; however, this is mainly caused by vehicle turbulent wake and contains little dust from the loads containing metals such as zinc and lead. Contamination with dust containing zinc and lead mainly occurs at the pit and the crusher with local dust dispersal from the underground vent raises. Except for small areas close to the pit, crusher and underground vent raises, the maximum annual zinc and lead dust deposition in and outside the mine area is predicted to be less than 0.5 g/m<sup>3</sup> and 0.016 g/m<sup>3</sup>, respectively.

### **Disturbance to Fauna**

The construction and operation of a mine at Citronen has the potential to impact local fauna of the region. It is considered the fauna in the region will not be significantly impacted by the Project for the following reasons:

- No fish occur in Eastern River; therefore, it is anticipated that the Project will not impact on the fauna of the river.
- The construction of the port facility only relates to a minor loss in habitat for marine fauna. Any change in water quality from suspended material during construction will be temporary.
- Shipping will be limited to 10 return trips in the summer in the fjords and open water.
- Fauna that normally inhabit areas at the Project are likely to move to areas outside the mine once disturbance and construction begin.
- Limited vegetation within the Project area will not attract fauna for feeding purposes.
- Hunting is forbidden on the mine site, as is regulation in National Parks.

There is potential for some adverse impacts to the Lake Platinova arctic char population due to the fluctuations in water quantity and quality within the lake as a result of the pumping of water from Eastern River.

### **Loss of Vegetation and Terrestrial Habitat**

On average, the vegetation cover in the Citronen area is about 5% including some areas characterised by almost bare ground with loose rubble and broken slopes with very little or no vegetation cover. Continuous vegetation is mostly found in depressions and along streams. This vegetation is dominated by a few plant species that are common and widespread in North Greenland; therefore, clearing within the Project will not impact representative flora of the area. Among the flora species known to occur in the Citronen area, none are rare or endangered.

The vegetation in the Citronen area provides food for a number of mammals and birds (and invertebrates), in particular muskoxen, arctic hare and collared lemming as well as ptarmigan and staging geese. The loss of fauna habitat is considered very small in relation to the surrounding available vegetation given that:

- plants cover only a small percentage of the ground in the Citronen area
- the overall footprint of the Project is relatively small
- some of the major facilities are proposed in areas with almost no vegetation (e.g. pit and airstrip)

### **Alteration to Surface Water Regimes**

The Eastern River flows during the summer and, as required by the Project, it is planned to pump 1.3 million m<sup>3</sup> of water from the river into Lake Platinova for use on-site (corresponding to 1,000 m<sup>3</sup>/h of water). Removal of this volume of water has the potential to alter the flow dynamics of the Eastern River. Pumping the required volume of water to Lake Platinova from Eastern River equates to 8.8% of the total runoff.

In order to contain this increase in volume as required by the Project, an embankment will be constructed along the northeast shore of the lake. The use of lake water for production will cause the

water level to vary between a low level in spring (May) and a high level in July/August after water has been pumped into the lake from Eastern River.

The change in water volume of Lake Platinova will have little impact on the overall surface water regime in the Project area. Some negative impacts are anticipated for the lake ecosystem, including the arctic char population, due to fluctuations in water quantity and quality within the lake due to pumping. No impact to the Eastern River is anticipated because the river is already experiencing varied water levels from melting snow and ice.

Diversion drains will be constructed around the underground decline, tailings storage facility, pit crest and waste rock dumps to prevent water from entering these facilities, particularly melting water in spring and summer. The water will be diverted to Eastern River and/or Citronen Fjord. A few small temporary streams may also be diverted around the mine facilities at the shore of the fjord. The diversion drains at the pit, decline, tailings storage facility and waste rock dumps will remain on closure while the other diversions (not required for long term stability) will be removed during the rehabilitation of the mine.

Precipitation in the Project area is very limited and the annual runoff of the local catchment area is small and limited to June to September. The diversions around the mine facilities will therefore only be diverting small amounts of water during a short time of the year. The diverted water will be directed to its original outflow destination.

### **Unplanned Release of Hazardous Materials to Land or Water**

Unplanned releases in connection with transport, storage and handling of hazardous materials such as fuel, grease, paint and chemicals could potentially cause contamination of soil or water resources at the Project.

Fuel, cargo and concentrate will be shipped to and from the Project each summer. Diesel (for use on-site) will be pumped into purpose-built sealed tanks within the vessels and scantling is increased where the fuel tanks sit. Dangerous goods (explosives) and controlled substance will be shipped in suitable, approved containers (as per established shipping arrangements).

The risk of potential contamination of the marine environment due to accidental release of concentrate or fuel during shipping is considered moderate. This is due to the potential severity of this event if it occurs, even though the probability is very low.

Hydrocarbons (such as oil, petrol and diesel) can also cause localised contamination on-site. Appropriate storage (consistent with Greenland government regulations and guidelines) and handling of hazardous materials will reduce the risk of contamination from these materials. Bulk hydrocarbons will be stored within bunded tanks and pipelines carrying such materials will also be bunded to capture leaks or spills.

It is considered the risk of contamination from hazardous surface soil or water resources in and around the mine area is low. None of the planned mine activities would lead to more than very limited and localised contamination.

### **Greenhouse Gas Emissions**

Carbon dioxide and other greenhouse gases will be generated by the diesel power plant and vehicles. Visiting aircraft and ships will also generate greenhouse gases. Approximately 50 million litres of diesel will be consumed annually by the Project (80% power generation and 20% mobile equipment).

Emissions have been calculated as approximately 132,700 t of carbon dioxide (assuming one litre of diesel generates 2,654 g of carbon dioxide).

By adopting the Best Available Technique (BAT) principle, Ironbark will ensure emissions from the power plant, trucks and other sources are kept at a minimum and these emissions are not considered to have a significant impact on the air quality in the area.

### **Rehabilitation and Closure**

Once the end of mine life has been reached, it is Ironbark's goal to restore the land to an environmentally acceptable state, managing the environment through a program of post-closure care and maintenance. Ironbark plans to develop a rehabilitation and closure strategy that allows life-of-mine closure planning that is responsive to Project planning decisions and changing regulatory framework.

The closure planning process Ironbark proposes to adopt for Citronen is a phased approach permitting the development of a Conceptual Closure Plan which will be updated and refined throughout the life of the mine. A Final Closure Plan will be developed near the end of the mine life that takes into consideration the results of the testing and monitoring as well as any changes to the environmental, regulatory and social environment that may have occurred over the life of the mine.

### **Conclusions**

Overall, the risk analyses conclude that most mine activities have a low risk level of disturbing or contaminating the environment at Citronen Fjord. This generally low level of risk is consistent with the nature and scale of the Project, which includes the below factors:

- The Project is located in a remote area of Greenland with the nearest permanent habitation being the Danish army base at Station Nord, 240 km southwest of the Project.
- The Project is located in an arctic environment with limited rainfall, as well as permafrost, and sub-zero temperatures most of the year resulting in reduced weathering/oxidisation of materials, freezing of mine wastes, limited runoff during a short period of the year, and small numbers of plant and animal species that are able to adapt to these extreme conditions.
- Tailings waste will be contained within a fully-lined facility or underground.
- Waste rock is characterised as being non-acid generating.
- There is a relatively small scale of disturbance, with only limited clearing of vegetation in a sparsely vegetated region.
- No populations of flora or fauna are unique to the Project area.
- Most potential impacts only have a localised affect, which can be readily managed or remediated.

### **9.3 Social Impact Assessment**

The Social Impact Assessment (SIA) report has been prepared by Grontmij a Danish company on behalf of Ironbark.

The following areas have been the primary focus of the social impact assessment:

- recruitment of Greenland labour
- engaging Greenland enterprises
- transfer of knowledge (e.g. education programmes) to ensure long-term capacity-building of local competence within the mining industry and mining support industries

- preservation of socio-cultural values and traditions

The guidelines issued by the MLSA outline five major goals of conducting the SIA process:

1. To engage all relevant stakeholders in consultations and public hearings.
2. To provide a detailed description and analysis of the social pre-project baseline situation as a basis for development planning, sustainability initiatives and future monitoring.
3. To provide an assessment based on collected baseline data to identify both positive and negative social impacts at both the local and national level.
4. To optimise positive impacts and minimise negative impacts from the mining activities throughout the project lifetime.
5. To develop a Benefit and Impact Plan for implementation of the Impact Benefit Agreement.

The SIA report meets the above criteria.

## **Employment**

The project is divided into the construction and the operation phases. The construction phase will require approximately 300 workers, both local and foreign, over a period of two years. Once construction is completed and operations have commenced, the number of employees per year will increase to approximately 470 per year for the first ten years of operation and thereafter the number of employees will decrease until the end of the Project.

The aim of the Project is to operate with a maximum of local workforce in all job categories. The share of the local workforce is aimed to reach a level of 20 percent during the construction phase if personnel with appropriate qualifications and experience can be recruited on competitive terms. This goal of local employment will increase to 50 percent by year 3 of the operation phase, and increase further to 90 percent by year 7 of operation.

A construction contractor will be chosen to complete the plant construction and hence foreign workers will account for the majority of workers in the initial construction phase. Foreign operators will be progressively replaced by local workers during the construction phase with support and guidance from Greenland government agencies.

It has been recognised that barriers may exist in achieving the expected high share of local workforce. Some identified barriers are:

- The remote location of the project will make the location less attractive compared to other mining projects in Greenland;
- Lack of minimum qualifications/experience for the required positions;
- Competition with other mining and oil projects for qualified workers;
- Lack of access to communication (such as telephone and IT) to keep in touch with home, as Greenlanders have a very strong relationships with their family;
- Language barrier: it is expected that a basic level of English will be required (primarily for safety procedure communication).

Potentially, unemployed workers can benefit from the job opportunities created by the Citronen Fjord Project during the construction and operation phase. However, the most likely scenario is that the project will attract mainly workers already employed in other sectors and new graduates. Indirectly, this will create new opportunities for the unemployed workers throughout Greenland.

The impact of the direct employment during the operation phase will be positive but small. The Citronen Fjord Project does not require the employees to move close to the mine, and therefore the positive effects of local employment will not be geographically concentrated, but distributed around Greenland.

### **Industry and Commerce**

The remote location of the Project is the most important factor when considering using local businesses and the provision of goods. The majority of equipment and supplies will require to be shipped to site. It is imperative that materials and equipment transported during the shipping window arrive at the site according to the planned window sequences to enable all work to be completed on schedule.

The majority of the process plant equipment and steelwork will come from overseas. Equipment for the mining activities such as dump trucks, excavators etc. are expected to be purchased directly from outside Greenland.

Other consumables to be purchased during the operation phase of the project are light vehicles and vehicles supplies, furniture and equipment for the camp, stationery, clothes and safety shoes, protective gear and equipment. Most of these articles are likely to be purchased from outside Greenland. Unfortunately, Greenland does not yet have the large scale fabrication yards and employment pool with appropriate skills in sufficient quantities to enable Citronen to be exclusively using local resources.

Ironbark will outsource activities related to transportation of goods and staff as well as servicing of the camp, including catering and cleaning. Where possible and competitive, local businesses will provide these services.

### **Employee Transportation and Other Opportunities for Greenlandic Businesses**

The planned transportation route for local employees will be from Kangerlussuaq directly to the Project. This flight will be paid for and organised by Ironbark. Ironbark will also provide a travel allowance that will notionally cover the cost of flights from the capitals cities of each municipality to Kangerlussuaq. Foreign employees will fly to site via Longyearbyen in Svalbard.

Local transportation companies as Air Greenland and other companies who operate in Greenland such as Air Iceland and Norland air could provide the transport of staff.

There are opportunities related to the Project with regards to local provision of goods and services. However, it will be difficult (primarily due to transport issues to the remote location) and initiatives such as planning and corporation with local suppliers need to be in place.

## **Salary boost**

It is expected that there will be an increase in the economic activity due to the Project. This is as a result of salary increase for the local workers which will boost the economic activities through an increased demand for services and goods. As there is no local community near the Project, the impact of the salary boost will be spread all over Greenland and thus it will be difficult to accumulate and stimulate the local economic environment within a small community.

## **Taxes and revenues**

The main direct economic benefits from the Ironbark Citronen Zinc Project arrive from corporate taxes and income taxes from local and international employees whom will be liable to pay tax in Greenland according to the Greenland tax regulation (Act on income Taxes no. 12 of 2 November 2006).

As the Project generates income and corporate taxes this is assessed to have a positive major impact during the construction phase and a significant impact during operation.

## **Education and training**

In Greenland, there is a general need and wish to improve and further develop the skills and competences of labour, in order to be prepared for potential future activities such as in the extraction industry.

Working on a mine site and a processing plant requires certain skills and education which are currently not 100 percent available in Greenland. It is anticipated that initially 80 percent of the workforce will be held by foreign employees. However once construction is finished and as the project progresses (training and education programs are completed), Ironbark aims to increase the local percentage of employment to 50 percent by year 3 and 90 percent by year 7.

It is considered that projects such as Citronen project will contribute to the general development of skills in Greenland.

## **Existing infrastructure and Public Services**

No infrastructure exists at the Project site, other than a temporary camp and a gravel airstrip. All required infrastructure will have to be established by Ironbark.

Transport of equipment and materials will primarily be on ships originating from outside Greenland. Greenlandic shipping company Royal Arctic Line was consulted regarding shipping options for the project. Although they do not have suitable ships for this type of transport they would be available for consultation and provide advice on shipping and routes for the project.

As the international workforce will be transported directly to the site from an airport outside Greenland, and as Ironbark will organise chartered transport from Kangerlussuaq to the site for local workforce, the pressure on the existing infrastructure and services are considered to be minimal.

Increases in some public services are expected due to the Project during the construction phase and operation phase. These are customs control (police), immigration authorities and health services. Emergency management at site will also require assistance from the police.

There is potential for increased pressure on the health system during both construction and operation. There is the possibility that medical assistance may be required outside the expertise provided by site. The Greenland health service is already under pressure due to cost of infrastructure, the lack of sufficient personnel resources and a small Government budget. These concerns were raised by the health authorities during the stakeholder consultation.

### **Demography and Population**

The Citronen Fjord Project is expected to employ up to 470 employees per year. During construction and the first years of the operation, the majority of the employees will be foreigners. During the operation phase an increasing number of local employees are expected.

A possible positive impact of the Citronen Fjord Project is an expected reduction in the negative net migration rates of Greenlanders, as a result of increased job and business opportunities. This positive impact will be obtained both if more people choose to stay in Greenland, and if Greenlanders who have earlier moved away from Greenland choose to return.

### **Occupational health and risk of accidents**

There is a potential risk of accidents during the construction, operation and closure of the mine, mainly related to the operation of heavy machinery, explosives, and processing. Adverse weather conditions can also lead to accidents during transportation of goods, staff and concentrate. Furthermore, the long distance to health facilities outside Project area is also a risk factor.

Even though the likelihood of accidents is low, the repercussions are very serious if anything is to happen to workers and transporters. Due to the number of workers involved and type of potential accidents involving explosives and heavy machinery the risks are significant.

Working at a mine can have adverse effects on personal health, including illness from dust exposure, hearing issues, respiratory disease and mental health issues (due to the remote location of the Project).

Communicable diseases are also a risk due to many employees living in a small community.

### **Health - public health**

A mining project's operations will have an impact on the health and quality of life of the employees and the public in general. These negative impacts are often related to interactions between the local community and the influx of staff.

Due to the remote location of the Project, where foreign employees are expected to fly to the site from outside Greenland, there will be no influence of foreign workers on towns and settlements.

With many employees from different countries and cultures living full time at the mine site for several weeks, the largest risk for impacts of the public health derives from infections received at the mine site and brought back to the home communities. A health screening for STD and HIV/AIDS will be required before employment. This impact is assessed to be negative negligible.

### **Cultural and Natural Values**

Peary Land, including Citronen Fjord, is not used for fishing, hunting or other human activities by the Greenlandic population or people from other nations. This is due to the remoteness and the fact that sea ice covers the ocean around North Greenland most of the year. Furthermore, as the licence area is located in the National Park, hunting and fishing activities are not allowed unless you have obtained a permit (Order no. 7 of 17<sup>th</sup> June 1992). Accordingly, it was decided that a local use study was not necessary due to the remote nature of the project and Peary Land has been un-inhabited for the last 600 years. Based on this the impact of the access to natural areas are considered to be not significant.

## **SECTION 10 - CAPITAL COST ESTIMATE**

## 10. CAPITAL COST ESTIMATE

### 10.1 Introduction

In February 2010, Wardrop completed a feasibility study report that included a Capital Cost Estimate. The Wardrop estimate is a Class 3 estimate with an accuracy range of  $\pm 15\%$  prepared in accordance with the AACE International estimate classification system. It was prepared with a base date of Q4-2010 and did not include any escalation beyond that date. The various quotations on which the estimate was based were obtained in Q4-2010 and had a validity period of 90 days.

The Wardrop cost estimate responsibility matrix was as follows:

- Wardrop Engineering Inc.: mining, layout and general arrangements, plant infrastructure, dust control, building services such as heating, ventilation, air conditioning (HVAC), heat recovery, fire protection, instrumentation and controls, piping, process plant electrical distribution, mechanical equipment (excluding Metso supplied equipment).
- Wardrop/Tetra Tech: tailings and water management.
- Metso: process mechanical equipment (Metso supplied)
- MT Højgaard: site layout, site civil works, site infrastructure and services, construction costs
- Ironbark Zinc Limited: Owner's costs

Wardrop was responsible for the development of the overall capital cost estimate with inputs from the aforementioned companies.

CPC Engineering has reviewed the 2010 estimate prepared by Wardrop with approximately 60% of the line items updated or confirmed with 2017 pricing. This equates to approximately 57% of the total cost of the project. The 2017 updated capital cost comes to US\$ 514.2 million excluding first fills which is an increase of 2.4% over the original Wardrop result.

Major items that were not reviewed include:

- the process plant enclosure (no design details available)
- site power distribution network (no design details available)
- port capital equipment including shiploader, mooring, bollards (no design details available)
- airstrip capital equipment (no details available)
- construction camp and catering/ housekeeping costs
- project indirects (except for labour rates, Metso spare parts and other unit costs)

The estimate has been modified slightly at a high level from the 2010 Wardrop estimate to encompass the following changes:

- Supply of steelwork and platework from Asia.
- Building the process plant on-site rather than on permanent barge platforms at Akureyri (Iceland).
- Allowance for increased plant throughput to 3.3 Mt/y (excluding minor items).
- Commencing the project with full capacity from the underground mine and deferring commencement of the open pit mine until the underground resources are depleted.

This capital cost update is based on the design and quantities from the 2010 FS completed by Wardrop Inc. and other associated sub-consultants as outlined in Section 10.1. The design was not reviewed during this exercise nor were any changes made to material take offs (MTO's) or items specified in the design. There may be opportunities to refine the design in the future should an updated detailed design phase be undertaken.

The overall capital cost estimate, based on the project execution strategy listed above, is presented in Table 10.1.

**Table 10.1 - Capital Cost Estimate Summary**

Area/Description	Cost (US\$)
Direct Works Total	327,775,114
Indirect Works Total	150,778,946
First Fills	excluded
Contingency	35,654,584
<b>Total Project Capital Costs</b>	<b>514,208,644</b>

A summary for the major areas for the cost estimate can be found in Table 10.2.

**Table 10.2 - Summary of Capital Costs by Major Area**

Area	Description	Cost (US\$)
<b>Direct Works</b>		
1000	Mining - Surface Infrastructure	619,978
1100	Mining - Open Pit Pre-production*	8,901,367
1500	Mining - Underground Pre-production	54,856,986
2000	Crushing Plant & Fine Ore Feed	14,368,552
2400	Process Plant	103,414,924
2800	Concentrate Storage/Reclaim	10,363,591
3000	Tailings and Water Management	18,339,487
4000	Plant Site	24,631,893
4500	Site Power and Heating	42,720,951
5000	Port Facilities & Storage	18,893,114
6000	Infrastructure	12,555,212
6500	Site Services & Utilities	5,723,987
8500	Temporary Services	12,385,072
<b>Direct Works Total</b>		<b>327,775,114</b>
<b>Indirect Works</b>		
9000	Construction Indirects	29,906,451
9100	Project Indirects	103,482,495
9200	Owners Costs	17,390,000
9900	Contingencies	35,654,584
	First Fills	excluded
<b>Indirect Works Total</b>		<b>150,778,946</b>
<b>Total</b>		<b>514,208,644</b>

\*Note: Area 1100 includes ancillary mining equipment common to both the underground and open pit production

## 10.2 Project Currency and Foreign Exchange

All project capital costs in the 2017 estimate are expressed in United States dollars (US\$) with the following provisions:

- The capital cost estimate was prepared in US dollars based on the exchange rates shown in Table 10.3.
- For the purposes of developing the capital cost estimate, any costs submitted in other currencies were converted to US dollars.
- No provision was made for fluctuations in the currency exchange rates.

**Table 10.3 - Exchange Rates**

Currency/Country	Exchange Rate (Note 1)
Denmark Krone	DKK 6.52
Euro	EUR 0.877
Canada Dollar	CAD 1.27
United Kingdom Pounds	GBP 0.773
Sweden Kronor	SEK 8.357
Icelandic Króna	ISK 105.196
Australia Dollar	AUD 1.293

Note 1: Exchange rate as of 14<sup>th</sup> July 2017.

### 10.3 Quantities

Quantities used in the Wardrop estimate were based on the following:

- Bulk earthworks quantities were based on rough grading designs completed using Autodesk Land Development Desktop and Civil Design.
  - Excavation of overburdens and allowance for rock excavation were based on any geotechnical information available at the time of the study.
  - In general, the cost of structural fill was based on material used directly from borrow pits without crushing and screening.
  - Earthwork quantities did not include an allowance for bulking or compaction of materials, these allowances are included in the unit prices.
- Underground services (firewater and sewage) quantities were based on engineering designs, sketches and the piping diagrams, which identify pipe sizes and routing.
- Concrete quantity MTOs were based on “neat” line quantities from engineering designs and sketches with any appropriate allowances by the estimator.

The current proposed project execution plan is to erect the process plant on-site within enclosed buildings rather than as per the Wardrop plan of erection on barges which would subsequently be towed to site and secured in-situ.

The Wardrop steel quantity MTOs were based on quantities developed from engineering design and sketches and allowances were included for cut-offs, bolts and connections.

In the Wardrop estimate, quantities for all platework and metal liners for tanks and chutes were calculated on detailed MTO's developed from design drawings and sketches and provided in kilograms of steel. Wear plate liners (abrasion resistant plates) for the chutes are calculated from the design sketches based on layout and included as appropriate.

Mechanical equipment requirements were based on process flow diagrams and equipment lists developed during the 2010 FS.

Piping and valve allowances were based on drawings supplied by Metso. Fittings quantities were based on detailed MTO's for pipe three inches (75 mm) and above in diameter. Small bore components, with the exception of valves, were calculated on a percentage basis, based on Wardrop's in-house experience.

Quantities for electrical and instrumentation major cable runs for motor and power distribution were estimated based on cable lists provided by Metso. Instrumentation quantities were as specified by Metso and based on the Piping and Instrumentation Diagrams (P&IDs) developed during the 2010 FS. Other materials and allowances included are based on Wardrop's experience with items such as electrical room cable tray systems, indoor lighting, etc.

## **10.4 Direct Costs**

### **Quantities**

Quantities used in the Wardrop estimate were based on the following:

- Earthworks for the access dike and pier were based on MTO's; quantities for civil works, concrete and sheet piling were included in the estimate based on MTH MTO's.
- Container storage earthworks were estimated for costing purposes.
- Tailings facility quantities were generated from Civil3D AutoCAD for embankments, spillway and access roads; pipeline lengths were estimated measuring the length of the different pipelines.
- Underground services (firewater and sewage) quantities were based on engineering designs, sketches and the piping diagrams, which identify pipe sizes and routing.
- Concrete quantity MTO's were based on "neat" line quantities from engineering designs and sketches with any appropriate allowances by the estimator.

### **Labour Rate and Productivity Factor**

It is anticipated that the work force will come from Greenland, Iceland, Denmark and Eastern Europe.

Labour rates were provided for a number of positions from local companies that are contracted in the region. The rates were blended to come up with average rates to be used in the update ranging from approximately \$50-\$62 per hour for general labour through to \$120 per hour for vendor assistance and specialist work.

During the 2010 FS, there was a large portion of the workforce in need of work which meant lower labour rates than those currently available as there is less people in need of work. Table 10.4 below shows the variation between the 2010 FS rates and those used in the 2017 capital cost update.

**Table 10.4 - Labour Rates 2017 vs 2010**

Code	Position	2017 Rate US\$/h	2010 Rate US\$/h	Increase
Lrate0	General Labour	49.88	38	31.3%
Lrate1	Skilled Labour	53.67	41	30.9%
Lrate2	Services	61.97	54	14.8%
Lrate3	Supervisors	101.77	88	15.6%
Lrate4	Special 1	60	60	-
Lrate5	Vendor Assistance	120	120	-
Lrate6	Divers (port construction)	200	200	-

Labour rates for vendor assistance were unchanged based on the rates provided by Metso with their revised pricing. The updated blended hourly rate based on 12 hour days, 7 days per week is approximately US\$ 200/h.

Updated rates for Special 1 and Divers were not available however the impact on the overall estimate is minor as the hours for each of these items are insignificant to the project.

The labour rates above include allowances for:

- vacation and statutory holiday pay
- sick leave
- overtime and shift premiums
- contractors rate premium of 14%
- pensions and other social fee entitlements.

The location factors exclude the labour impacts of:

- strikes
- other unforeseen major delays.

The following labour rated items are calculated separately and included in the indirects section (unless stated otherwise):

- travel and living allowances
- mobilisation and demobilisation costs
- freight costs relating to contractor's materials are included in the mobilisation and freight sections
- turnaround costs – all personnel.

The productivity factor on labour hours for the capital cost is 1.0 for direct costs.

### **Bulk Earthworks**

Bulk earthworks quantities are based on the 2010 FS with updated rates for equipment used for the work.

A local contractor provided updated costs for some of the equipment with the rest being estimated based on pricing for new machines. Where updated equipment pricing was not available, a 20% mark-up on the 2010 prices were used. Where the 2010 equipment pricing was based in DKK currency, a 20% mark-up to the original price was used which in some cases provided a value lower than what was used in 2010 based on current favourable exchange rates. In these instances, the same rates were used as those in 2010.

### **Concrete and Other Construction Materials**

Concrete and other construction MTO's are based on the 2010 FS. A local contractor provided unit rates for many of the key items based on their experience in the region and these were used in the updated cost estimate.

Costs provided were in DKK and ISK and were used as provided with current exchange rates applied within the cost estimate.

Concrete unit rates include formwork, reinforcing steel, placement, finishing and related equipment.

### **Structural Steel**

Steel quantity MTO's are based on the 2010 FS. Updated pricing was sourced through a supply company in Thailand. In the 2010 estimate steel was priced from China so based on proximity to the site, freight quantities and distance are assumed to be similar.

The updated costs have been based on the following breakdown of material:

- light weight steel sections – 0 to 30 kg/m (tonnes)
- medium weight steel sections – 31 to 60 kg/m (tonnes)
- heavy weight steel sections – 61 to 90 kg/m (tonnes)
- extra heavy weight steel sections – >90 kg/m (tonnes)
- grating (m<sup>2</sup>)
- checker plates (m<sup>2</sup>)
- handrail complete with kickplate (m)

Cold weather steel and additional items including girts and purlins, staircases and ladder pricing was not received in the updated tender however comparing 2010 pricing to 2017 pricing indicated that there was very little change to the rates and therefore items not costed were kept the same.

### **Mechanical Equipment**

In the 2010 FS, Metso provided the process plant design and included pricing for the majority of the mechanical equipment based on their own supply or from their own sub-vendors. This approach was utilised for the 2017 capital cost update.

Metso provided equipment pricing and hour estimates for vendor assistance which have been included in the estimate. In 2010 Metso included an overall savings of 7.5% on their equipment supply should the entire package be contracted to them. Updated confirmation from Metso in 2017 indicated that should their scope of supply be more than \$US 35 million then an 8% discount would be available overall. This has been applied by line item in the updated capital cost estimate.

Some additional equipment outside of Metso supply was updated based on revised tenders from the vendors selected in the 2010 FS. These items included conveyors, lime system, overhead cranes, water reclaim pumps, slurry pumps, platework, tanks and tailings and water transfer pipelines.

### **Heating, Ventilation and Air Conditioning (HVAC)**

The costs of HVAC equipment were not revised in this estimate update, however this is considered to be acceptable as the total overall cost of HVAC represents 1.5% of the overall project costs and any fluctuations are deemed to be minor overall.

### **Piping and Valves**

Piping and fitting MTO's are based on the 2010 FS which accounted for piping 75 mm (3") diameter and over.

Updated pricing was sourced from Thailand by item type and applied to the estimate.

Piping is provided as separate line items and sorted by WBS area and pipe specification. Small bore components with the exception of valves were calculated on a percentage basis of the overall cost of piping in each area. The percentages from the 2010 FS were kept the same and applied to the 2017 updated costs.

Pipe support quantities in the 2010 estimate were not developed. Pipe support pricing was based on a percentage of the overall piping material cost and this approach was taken for the 2017 update.

For small bore piping (<80 mm), an allowance was made based on 15% of the large bore piping costs. Pipe supports were assumed as a percentage of piping costs (10% for large bore, 3% for small bore).

Pipe insulation is not included as all piping is assumed to be indoors or in heated corridors; the only exception is the tailings line, which is specified as a pre-insulated pipe. Updated pricing for the tailings line was not obtained for the capital cost update and therefore 2010 pricing remained unchanged.

All costs such as taxes, duties, freight, and packaging were covered separately in the indirect section of the estimate.

### **Electrical**

Electrical costs are structured based on the project WBS. Updated pricing was obtained based on the 2010 FS specifications and tender documents for the following items:

- low voltage (LV) motor control centres (MCC's)
- LV variable frequency drives (VFD's)
- medium voltage (MV) MCC's
- MV switchgear
- MV transformers
- Power cables (medium and low voltage)
- Gensets.

## **Modular Buildings**

The following modular buildings were included in the 2010 FS and estimated by MTH.

- plant site – administration and mine dry (laboratory is included in the administration building and medical is included in the mine dry building)
- accommodation camp.

Design specifications were not available for this cost update and therefore no changes were made to the costs from 2010. There is a possibility that this may impact the overall estimate however this is not considered a substantial risk to the project as there are many suppliers of these types of buildings.

## **Pre-engineered Buildings**

From the 2010 FS, The following buildings were identified to be pre-engineered (fabricated offsite and erected onsite) due to their size and complexity:

- plant site – main warehouse
- plant site – truck shop
- plant site – power plant.
- Concentrate storage shed

Updated pricing for the truckshop was obtained based on the 2010 FS specification. Pricing of this building based on the same specification was less than the 2010 FS.

Pricing for the concentrate storage shed was obtained from the same vendor that provided costing in 2010. In 2010, the structure designed was an elongated dome as the company who engineered the shelter was not able to provide a dome large enough to contain a years' worth of zinc concentrate. In the last 6 years however, they are now able to provide a much larger dome than previous and given the design and construction advantages of a dome structure over an elongated dome pricing for two separate smaller domes was used which is overall less than the current pricing for an elongated structure. This will have little overall impact on the earthworks, foundations and conveying to the domes and therefore is considered suitable to use in the estimate.

Updated pricing was not obtained for the main warehouse and power plant buildings as the details of the design were not available (MTH provided the pricing in the 2010 FS). Given that the cost are smaller in size The main warehouse and power plant buildings are both similar to or smaller in size than the truckshop so it is unlikely that the costs will be vastly different in 2017 pricing therefore this is not considered to be a risk to the overall estimate.

## **10.5 Project Indirects**

As with project direct costs, project indirect costs are based on advice from NFC and all equipment and materials pricing has been reduced by 15% for Chinese supplied materials; a productivity factor of two has been applied to installation man-hours. Labour rates have also been adjusted to reflect utilisation of Chinese installation contractors.

The Wardrop estimates included the following:

- Two generators for temporary power which were priced based on MTH in-house data as well as supplier information.
- Temporary fuel storage facilities comprising of bladder tanks complete with containment berms based on MTH in-house data and by a supplier.
- Temporary warehousing and workshops in the estimate comprising of a carpenter workshop, reinforcement workshop, mechanical workshop, electrical workshop, as well as general storage facilities (including inventory) based on MTH in-house data and on supplier information.
- A nominal allowance for the supply and treatment for any water requirements not captured under the MTH scope.
- Temporary sanitation services, piping and collection estimates based on MTH in-house data.
- The Iridium-based communication system and handheld radio communication system were quoted by a supplier.
- Estimates for office running, health and safety, storage facilities, workshop facilities, general site labour, general transport, travel staff, travel freight, travel management, site running, purchase and running of light vehicles, general equipment, earthworks, concrete, small tools, structural steel, survey equipment, standby costs for earthworks equipment, site installations, storage containers, computers and accessories based on MTH in-house data and from supplier information.
- Spare parts for all mechanical equipment were specified and costed by Metso. Wardrop's estimate was based on past project experience for spare parts on equipment and materials within the MTH and Wardrop scope. Additionally, Metso provided costs for commissioning spares and these were also included in the estimate by Wardrop.
- Cost of all reagents and consumables required for one year of operation based on quantity estimates and budget quotations.
- Freight and logistics inclusions in the Wardrop estimate were inclusive of, loading at country of origin, overland freight country of origin, marshalling areas, unloading and loading at port of origin, shipping to Akureyri and Citronen, ship unloading, air freight charges and customs/duty fees.
- Costs for power plant training and technical assistance which were quoted by a supplier.
- Port commissioning and start-up which was estimated based on MTH in-house data.
- Airport test flight and airstrip commissioning estimated based on MTH in-house data and from supplier information.
- MTH, Wardrop and Metso all provided engineering and procurement estimates for their respective scopes of work and MTH, in conjunction with Wardrop and Metso, estimated construction management costs.
- Owners costs were inclusive of, home office staffing and travel, field staffing and travel, legal costs, product marketing, land taxes, reclamation bonds, project funding or financing costs, environmental programs and permitting, licenses, import duties and tariffs, miscellaneous allowances for deductible claims, geotechnical work and drilling programs, metallurgical testwork programs, commissions and royalties, good will and local infrastructure contributions, training program development – systems training, general training and orientation, safety equipment and supplies, site orientation and security.

- Wardrop included overall construction cost insurance together with marine and ocean insurances in the estimate.
- No changes have been made to the Owners costs for the updated estimate. They remain as per Wardrop's 2010 estimate.

## 10.6 Contingency

The contingencies allowance included by Wardrop in the estimate were intended for undefined items of work that are incurred within the defined scope of work covered by the estimate and cannot be explicitly foreseen or described at the time the estimate is completed due to a lack of complete, accurate and detailed information.

The contingency allowance in the Wardrop estimate was not considered a compensating factor for estimating inaccuracy nor was it intended to cover items such as any potential labour disputes, currency fluctuations, escalation, force majeure, or other uncontrolled risk factors.

Wardrop considered it should be assumed that the contingency amount will be spent over the engineering and construction period. Contingency was estimated as a percentage for each line item. There has been no attempt to review contingency for this estimate.

In the 2010 FS cost estimate, contingency has been estimated as a percentage for each line item and totalled approximately 10% overall. For the 2017 update, the overall contingency of 10% was reviewed and remained unchanged given the level of detail captured in the estimate and the similar overall updated cost.

## 10.7 Qualifications and Exclusions

### Qualifications

For the capital cost estimate Wardrop assumed the below:

- Concrete aggregate and suitable backfill material will be locally available.
- Soil conditions will be adequate for foundation bearing pressures.
- Construction activities will be continuous, except with respect to the TSFs.
- Bulk materials such as cement, reinforcing steel, structural steel and plate, cable, cable tray and piping will be available when they are required.
- Capital equipment will be available when it is required.

### Exclusions

The following were excluded from the estimate by Wardrop:

- cost escalation during construction
- major scope changes
- interest during construction
- schedule delays and associated costs, such as those caused by the following:
  - scope changes

- unexpected ground conditions
- extraordinary climate events
- labour disputes
- receipt of information beyond the control of EPCM contractors
- schedule recovery or acceleration
- financing costs
- taxes and duties
- overtime
- cost outside battery limits
- sunk costs
- research and exploration drilling costs
- permitting costs
- project risks
- pipe supports (supports quantities will be confirmed at a later date with equipment location and final pipe routing); for this study, a percentage of the total piping material cost was assumed for pipe supports (both large and small diameter)
- any last minute scope changes to the process and layout
- receipt of information beyond the control of Wardrop
- cost outside battery limits
- pipe insulation is not included as all piping is assumed to be indoors or in heated corridors; the only exception is the tailings line, which is specified as a pre-insulated pipe
- all pricing of the piping and fittings for raw water, tailings and surplus water are in the mechanical scope of work.

The following items were excluded from the capital cost estimate by Wardrop, but were included in the financial model at that time:

- sustaining capital
- working capital
- closure costs (sustaining capital)
- salvage values (sustaining capital)

## **SECTION 11 - OPERATING COST ESTIMATE**

## 11. OPERATING COST ESTIMATE

### 11.1 Introduction

In February 2010 Wardrop completed a feasibility study report that included estimating the operating costs associated with the Citronen Project. CPC Engineering has reviewed the estimate at a high level, and applied updated unit rates where available. The operating cost estimate for this report is based on CPC Engineering's review and update of the Wardrop operating cost estimate as summarised in this chapter.

The main points of difference between the current Ironbark and Wardrop estimates are that underground mining is now scheduled to commence first and the process plant throughput is now 3.3 Mt/y compared to 3.0 Mt/y in the Wardrop estimate. The mining mobile fleet has been aligned to account for full production from the underground operations in year 1 and the increased production rate have been accounted for on a yearly basis to items that are calculated based on tonnages.

The operating cost estimate for the LOM operations for the Citronen Project is calculated in US dollars and is presented in Table 11.1 in total dollars, dollars per tonne ore and dollars per tonne of zinc concentrate produced. The operating cost estimate uses prices obtained in, or evaluated and kept per the 2010 FS. It has a base date of the third calendar quarter of 2017 (Q3 2017).

The projected LOM average operating cost for the Citronen Project is calculated to be \$US 49.69/t ore mined.

The Year 1-5 average cash costs are US\$ 0.48/lb Zn (payable, net of by-product credits, smelter fees additional US\$ 0.14/ lb Zn payable. The LOM average costs are US\$ 0.52/lb (payable, net of by-product credits, smelter fees an additional US\$ 0.14/lb Zn payable)

All costs are exclusive of taxes, permitting costs, or other government imposed costs unless otherwise noted.

**Table 11.1 - Citronen Project Operating Costs Summary**

Description	Annual Cost (US\$ x 1,000)	Unit Costs (US\$/t Ore)	Unit Costs (US\$/t Zn Concentrate)
Underground Mining	81,723	20.00	240.36
Open Pit Mining	14,834	1.32	15.87
Process	35,467	11.05	132.76
Shipping & Logistics	31,003	9.66	116.05
General & Administration (G&A)	24,593	7.66	92.06
<b>Total Operating Costs</b>	<b>159,512</b>	<b>49.69</b>	<b>597.10</b>

Note: large first fill (Year 1 consumables) have been capitalised and that costs per tonne for both underground and open pit are lower than actual as they have been averaged over total LOM not just operating period.

## 11.2 Mining Operating Costs

### Underground Mining Operating Costs

Operating costs for the underground mine were divided into two categories: direct costs and indirect costs. Operating costs were calculated on a yearly basis and then divided by the expected production tonnage to arrive at a cost per tonne.

#### Direct Costs

Direct costs were generated based on the mining schedule. Quantities were updated to reflect the most recent production schedule with updated costs for consumables and fuel applied to the quantities. Consumables costs (where available) were taken from the Orica Australia National Price List (1 July 2017) and converted to US dollars.

Direct costs were based on the following major components:

- Drilling and blasting
- Roof control
- Utility
- Labour
- Load-haul-dump (LHD)
- Haulage
- Miscellaneous equipment and support.

Each component was the result of specific unit cost breakdown based on production rates and unit cost. The unit used in the cost model included time and meters and varied depending on the requirements of the cost component. For example, LHD costs were based on the time required to muck a stope or drift, while utility costs were based on the meters of drift that require utility installation.

#### Indirect Costs

Indirect costs consisted of indirect labour (typically hourly miners) along with various surface support costs associated with operating an underground mine. Indirect costs were applied in the same manner as direct costs. There is a slight decrease in indirect costs in the final production year of the underground mine; this is caused by a decreased production from the underground in year 12 and therefore shift in the labour force to the open pit operation.

#### Total Operating Costs

The LOM average operating cost for the underground mine was determined to be US\$ 25.13/t ore mined (US\$ 24.85/t mined – ore and waste). Table 11.2 summarises the costs on a yearly basis.

**Table 11.2 - Underground Operating Costs by Year**

Production Year	US\$/t mined	US\$/t ore
Year 1	22.94	23.32
Year 2	25.15	25.33
Year 3	25.16	25.25
Year 4	24.81	25.53
Year 5	24.71	25.44
Year 6	25.21	25.29
Year 7	24.99	25.07
Year 8	25.05	25.32
Year 9	25.18	25.33
Year 10	25.11	25.27
Year 11	25.08	21.25
<b>Average</b>	<b>24.85</b>	<b>25.13</b>

### Operating Costs by Area

The underground operating costs fall into four main areas: consumables, labour (further details in Section 11.6), mobile equipment and power (associated with the underground mining operations).

Table 11.3 shows the breakdown of the costs for each area over the life of the underground operation.

**Table 11.3 - Underground Operating Costs by Area**

Area	LOM Cost (000's US\$)	Unit Cost (US\$/t mined)	Unit Costs (US\$/t ore)
Consumables	244,987	6.77	6.85
Labour	363,292	10.04	10.16
Mobile Equipment	244,167	6.75	6.83
UG Power	46,509	1.29	1.30
<b>Total</b>	<b>898,955</b>	<b>24.85</b>	<b>25.13</b>

### Open Pit Mining Operating Costs

Over the life of the open pit mine, operating costs were calculated to be US\$ 6.47/t ore (US\$ 2.16/t mined – ore and waste).

### Total Operating Costs

Expected maintenance, parts, fuel consumption, and lube unit rates were provided by equipment vendors and remained unchanged from the 2010 FS except where tonnages mined differed. These rates were applied to the calculated number of operating hours for each piece of equipment to determine yearly costs. An updated diesel cost was applied to the fuel components of the power and

mobile equipment. Consumables costs (where available) were taken from the Orica Australia National Price List (1 July 2017) and converted to US dollars.

A breakdown of the yearly operating costs for the open pit can be found in Table 11.4.

**Table 11.4 - Open Pit Operating Costs by Year**

Production Year	US\$/t mined	US\$/t ore
Year 12	1.36	5.42
Year 13	2.55	5.86
Year 14	1.96	6.07
Year 15	2.26	8.35
<b>Average</b>	<b>2.16</b>	<b>6.47</b>

### Operating Costs by Area

The underground operating costs fall into three main areas: consumables, labour (further details in Section 11.6) and mobile equipment.

Table 11.5 shows the breakdown of the costs for each area over the life of the open pit operation.

**Table 11.5 Open Pit Operating Costs by Area**

Area	LOM Cost (000's US\$)	Unit Cost (US\$/t mined)	Unit Costs (US\$/t ore)
Consumables	6,041	0.22	0.66
Labour	42,174	1.53	4.60
Mobile Equipment	11,121	0.40	1.21
<b>Total</b>	<b>59,337</b>	<b>2.16</b>	<b>6.47</b>

## 11.3 Process Operating Costs

### Total Operating Costs

The LOM average process operating cost is calculated as US\$ 11.05/t ore crushed based on a yearly average throughput of 3.3 million tonnes of ore (pre-dense media separation [DMS]). Process consumable usage in the 2010 FS were outlined on a per tonne of ore basis and were solely recalculated based on the most recent mine plan. Reagent unit costs were kept the same. An updated diesel cost was applied to the fuel components of the power and mobile equipment.

### Operating Costs by Area

The process operating costs are comprised of fixed costs (mobile equipment, process labour, spares/wear parts and power) and variable costs (reagents and consumables). The fixed costs are based on

total tonnes of ore delivered to the crushing plant whereas the variable costs are based on the DMS sinks. The correlation for determining the ratio of DMS sinks to the overall feed is built into the operating cost calculations and applied to the variable costs as required. This variable cost is the reason for the variation in operating costs by year above.

Table 11.6 shows a breakdown of LOM costs by area.

**Table 11.6 - Process Operating Costs by Area**

Area	LOM Cost (000's US\$)	Unit Costs (US\$/t ore)
Reagents	216,091	4.81
Spares/Wear Parts	65,544	1.46
Power	135,517	3.02
Labour	71,316	1.59
Mobile Equipment	8,071	0.18
<b>Total Process Operating Costs</b>	<b>496,538</b>	<b>11.05</b>

#### 11.4 General and Administration Costs

Ironbark provided the G&A operating costs in the 2010 FS. They have remained unchanged in this estimate and are calculated to be \$US 7.66/t ore. This cost includes management and administrative support functions as follows:

- Building maintenance
- Camp accommodation
- Communication systems (external)
- Consultants
- Environmental permits
- External assays/ testing
- Government affairs & public relations
- Head office expenses
- Insurance
- Land leases/ right of way
- Legal services
- Light vehicles
- Marketing
- Medical supplies
- Property taxes

- Recruitment
- Regulatory compliance
- Road maintenance
- Safety and training supplies
- Security supplies
- Site environmental management
- Training programs
- Waste management

### Operating Costs by Area

The G&A operating costs are comprised of fixed costs associated with general operation of the overall site. These items include those listed above and are broken down generally into power, labour, mobile equipment, regulatory compliance and miscellaneous.

Table 11.7 shows a breakdown of LOM costs by area.

**Table 11.7 - G&A Operating Costs by Area**

Area	LOM Cost (000's US\$)	Unit Costs (US\$/t ore)
Power Costs	23,496	0.52
Total G&A Labour	262,749	5.85
Total G&A Mobile Equipment	14,709	0.33
G&A Regulatory Compliance	7,000	0.16
G&A Operating Misc.	36,347	0.81
<b>Total</b>	<b>344,300</b>	<b>7.66</b>

### 11.5 Shipping and Logistics Costs Shipping

Shipping and logistics unit costs per tonne of concentrate were as per the 2010 FS with only the daily rate charter rate per vessel decreased due to changes in fuel pricing.

The 2010 FS contained costs for leasing of the concentrate vessels, shipping from site to Citronen including yearly mobilisation and demobilisation costs, storage at an offsite port and onward shipping to the smelter.

The LOM average cost for shipping and logistics is US\$ 109.24/ tonne total concentrate (zinc plus lead).

### 11.6 Labour Costs

Labour costs remained the same from the 2010 FS with the only change being alignment in the number of operators with the amended mining fleet based on the most recent mine plan.

Costs were built up from annual salaries per job description and include flights per rotation, associated travel costs and food allowances. Unit salaries include all payroll burdens.

Roster rotations and annual salaries by job description are outlined in Table 11.8.

**Table 11.8 - Yearly Salaries Based on Job Description**

Job Description	Scale	Roster	Salary (000 \$)
Site Manager	1	6	270
Senior Management	2	6	210
Middle Management	3	6	170
Senior Technical	4	6	150
Technical	5	6	120
Junior Technical	6	6	90
Assistant	7	6	70
Senior Supervisory	8	9	200
Supervisory	9	9	170
Operator Class 1	10	9	150
Operator Class 2	11	9	135
Operator Class 3	12	9	120
Operator Class 4	13	9	105
Operator Class 5	14	9	90
Trainee Operator	15	9	75
Trade Class 1	16	9	135
Trade Class 2	17	9	120
Process Class 1	18	9	105
Process Class 2	19	9	90
Trainee Process	20	9	70
Surface Class 1	21	9	80
Surface Class 2	22	9	70

Roster '6' refers to a 3 week on/ 3 week off rotation whereas Roster '9' refers to a 6 week on/ 3 week off roster. Flights and travel are calculated to both respectively and added into the yearly costs per person.

The number of labourers by area are outlined in the sections below.

### **Underground Mining Labour**

### **Underground Mining Management**

Underground mine management personnel based on a production rate of 3.3 Mt/y is outlined in Table 11.9.

**Table 11.9 - UG Mine Management Annual Labour Costs**

Job Description	Scale	No.	Salary (000's US\$)	F&A (000's US\$)	Annual Cost (000's US\$)	Total Costs (000's US\$)
Mining Manager	2	2	210	6.37	216	433
UG manager	3	2	170	6.37	176	353
Senior Mining Engineer	4	2	150	6.37	156	313
Mine Planning	5	4	120	6.37	126	505
Mining Engineer	5	8	120	6.37	126	1011
Senior Geotech Engineer	4	2	150	6.37	156	313
Geotech Engineer	5	4	120	6.37	126	505
Geology Manager	3	2	170	6.37	176	353
Senior Geologist	4	2	150	6.37	156	313
Geologist	5	8	120	6.37	126	1011
Geological technician	7	4	70	6.37	76	305
Surveyor	6	8	90	6.37	96	771

### Underground Mine Operations

Underground mine operations personnel based on a production rate of 3.3 Mt/y outlined in Table 11.10.

**Table 11.10 - UG Mine Operations Annual Labour Costs**

Job Description	Scale	No.	Salary (000's US\$)	F&A (000's US\$)	Annual Cost (000's US\$)	Total Costs (000's US\$)
Mining Foreman	8	3	200	8.49	208	625
Shift boss	9	9	170	8.49	178	1606
Jumbo Operator	10	27	150	8.49	158	4279
Long-hole Operator	11	6	135	8.49	143	861
Boltec Operator	12	12	120	8.49	128	1542
LHD Operator	11	21	135	8.49	143	3013
Truck Driver	13	30	105	8.49	113	3405
Shotfirer	13	9	105	8.49	113	1021
Nipper	15	9	75	8.49	83	751
Service Crew	14	15	90	8.49	98	1477
Backfill Operator	14	9	90	8.49	98	886
Explosives Facility/Mag keeper	14	3	90	8.49	98	295
Relief Operators	11	18	135	8.49	143	2583
Grader Operator (UG)	12	3	120	8.49	128	385

## Underground Mining Maintenance

Underground mine maintenance personnel based on a production rate of 3.3 Mt/y is outlined in Table 11.11.

**Table 11.11 - UG Mine Maintenance Annual Labour Costs**

Job Description	Scale	No.	Salary (000's US\$)	F&A (000's US\$)	Annual Cost (000's US\$)	Total Costs (000's US\$)
Electrician -UG/OP	16	3	135	8.49	143	430
Fitter- Heavy Diesel	16	18	135	8.49	143	2583
Fitter- Light Vehicle	17	3	120	8.49	128	385
Fitter- Drill	16	6	135	8.49	143	861

Note that all mining labour yearly rates have been prorated in the final year of UG operations where less than 3.3 million tonnes are being mined.

## Open Pit Mining Labour

### Open Pit Mining Management

Open pit mine management personnel based on a production rate of 3.3 Mt/y is outlined in Table 11.12.

**Table 11.12 - OP Mine Management Annual Labour Costs**

Job Description	Scale	No.	Salary (000's US\$)	F&A (000's US\$)	Annual Cost (000's US\$)	Total Costs (000's US\$)
Mining Manager	2	2	210	6.37	216	433
OP Manager	3	2	170	6.37	176	353
Senior Mining Engineer	4	2	150	6.37	156	313
Mine Planning	5	4	120	6.37	126	505
Mining Engineer	5	8	120	6.37	126	1011
Senior Geotech Engineer	4	2	150	6.37	156	313
Geotech Engineer	5	2	120	6.37	126	253
Geology Manager	3	2	170	6.37	176	353
Senior Geologist	4	2	150	6.37	156	313
Geologist	5	2	120	6.37	126	253
Geological technician	7	2	70	6.37	76	153
Surveyor	6	4	90	6.37	96	385

## Open Pit Mine Operations

Open pit mine operations personnel based on a production rate of 3.3 Mt/y is outlined in Table 11.13.

**Table 11.13 - OP Mine Operations Annual Labour Costs**

Job Description	Scale	No.	Salary (000's US\$)	F&A (000's US\$)	Annual Cost (000's US\$)	Total Costs (000's US\$)
Mining Shift Boss	10	3	150	8.49	158	475
Driller	11	6	135	8.49	143	861
Excavator Operator	11	3	135	8.49	143	430
Truck Operator	14	13	90	8.49	98	1280
Grader Operator (OP)	12	6	120	8.49	128	771
Dozer Operator	13	6	105	8.49	113	681
Shotfirer	13	6	105	8.49	113	681
Shotfirer assistant	14	6	90	8.49	98	591
MMU Operator	13	6	105	8.49	113	681

### Open Pit Mining Maintenance

Open pit mine maintenance personnel based on a production rate of 3.3 Mt/y is outlined in Table 11.14.

**Table 11.14 - OP Mine Maintenance Annual Labour Costs**

Job Description	Scale	No.	Salary (000's US\$)	F&A (000's US\$)	Annual Cost (000's US\$)	Total Costs (000's US\$)
Electrician -UG/OP	16	3	135	8.49	143	430
Fitter- Heavy Diesel	16	18	135	8.49	143	574
Fitter- Light Vehicle	17	3	120	8.49	128	385
Fitter- Drill	16	6	135	8.49	143	861

Note that all mining labour yearly rates have been prorated in the first year of open pit operations where less than 3.3 million tonnes are being mined.

### Process Labour

Process personnel have been specified by Metso for operation of the process plant. Additional maintenance personnel requirements have been specified by Ironbark.

### Process Management

Process management personnel based on a production rate of 3.3 Mt/y is outlined in Table 11.15.

**Table 11.15 - Process Management Annual Labour Costs**

Job Description	Scale	No.	Salary (000's US\$)	F&A (000's US\$)	Annual Cost (000's US\$)	Total Costs (000's US\$)
Process Manager	3	2	170	6.37	176	353
Plant Metallurgist	4	4	150	6.37	156	625
Chemist/ Environ Monitor	5	4	120	6.37	126	505

### Process Operations

Process operations personnel based on a production rate of 3.3 Mt/y is outlined in Table 11.16.

**Table 11.16 - Process Operations Annual Labour Costs**

Job Description	Scale	No.	Salary (000's US\$)	F&A (000's US\$)	Annual Cost (000's US\$)	Total Costs (000's US\$)
Loader Operator	14	3	90	8.49	98	295
Crushing Operator	14	3	90	8.49	98	295
HMS & Grinding Operator	13	6	105	8.49	113	681
Floatation & Filter Plant Operator	13	6	105	8.49	113	681
Tailings/Relief Conc Loadout	14	3	90	8.49	98	295
Plant sampling & lab assistant	15	3	75	8.49	83	250
Lab Tech	15	3	75	8.49	83	250

### Process Maintenance

Process maintenance personnel based on a production rate of 3.3 Mt/y is outlined in Table 11.17.

**Table 11.17 - Process Maintenance Annual Labour Costs**

Job Description	Scale	No.	Salary (000's US\$)	F&A (000's US\$)	Annual Cost (000's US\$)	Total Costs (000's US\$)
Electrician- Mill	16	3	135	8.49	143	430
Fitter- Mill	16	3	135	8.49	143	430

Note that all process labour yearly rates have been prorated in the final year of operations where less than 3.3 million tonnes are being mined.

### G&A Labour

G&A Labour numbers were specified in the 2010 FS and remain unchanged.

G&A labour encompasses all personnel that are shared within the site including site operations, maintenance management and shared services, camp operations, warehouse and logistics operations, and offsite personnel associated with the project.

G&A personnel based on a production rate of 3.3 Mt/y is outlined in Table 11.18. Note that all G&A labour yearly rates have been prorated in the final year of operations where less than 3.3 million tonnes are being mined.

**Table 11.18 - G&A Operations Annual Labour Costs**

Job Description	Scale	No.	Salary	F&A	Annual Cost	Total Costs
			(000's US\$)	(000's US\$)	(000's US\$)	(000's US\$)
General Manager	1	2	270	6.37	276	553
Administrators	7	8	70	6.37	76	611
IT Technical Staff	6	4	90	6.37	96	385
Occupational Health Advisor	6	2	90	6.37	96	193
Occupational Health Technician	7	2	70	6.37	76	153
Safety Advisor	6	4	90	6.37	96	385
Environment & Communications Advisor	6	2	90	6.37	96	193
Medic	5	4	120	6.37	126	505
Security/Emergency Response	6	4	90	6.37	96	385
Maintenance Manager	3	2	170	6.37	176	353
Electrical Engineer	5	4	120	6.37	126	505
Mechanical Engineer	5	4	120	6.37	126	505
Maintenance Planner	5	4	120	6.37	126	505
Maintenance Foreman	9	4	170	6.37	176	705
Electrical Foreman	9	4	170	6.37	176	705
Mechanical Foreman	9	4	170	6.37	176	705
Boiler Maker	17	9	120	8.49	128	1156
Process Plant Operators	13	9	105	8.49	113	1021
Warehouse & Stores Manager	4	2	150	6.37	156	313
Warehouse Personnel	21	9	80	8.49	88	796
Port Personnel	22	9	70	8.49	78	706
Camp Manager	4	4	150	6.37	156	313
Cooks	21	21	80	8.49	88	796
Kitchen Hands	22	22	70	8.49	78	1413
Cleaners	22	22	70	8.49	78	1177
Maintenance	21	21	80	8.49	88	531
Operations Manager	1	1	270	0.49	270	270
Finance Manager	3	1	170	0	170	170
Business Analyst/Accounts	5	3	120	0	120	360
Accounts Clerks	7	3	70	0	70	210
Supply Manager	4	1	150	0.49	150	150
Supply Officer	6	5	90	0.49	90	452
Logistics Manager	4	1	150	0.49	150	150
HSEC Manager	4	1	150	0.49	150	150
Occupational Health Co-ordinator	5	1	120	0	120	120

Job Description	Scale	No.	Salary	F&A	Annual Cost	Total Costs
			(000's US\$)	(000's US\$)	(000's US\$)	(000's US\$)
Safety Co-ordinator	5	1	120	0	120	120
Environmental & Communications	5	1	120	0	120	120
Co-ordinator						
Human Resources Manager	4	1	150	0	150	150
Recruitment Advisor	7	3	70	0	70	210
HR Advisor	7	2	70	0	70	140
Payroll	7	2	70	0	70	140
Travel & Accommodation Staff	7	4	70	0	70	280

## **SECTION 12 - RISKS & OPPORTUNITIES**

## 12. RISKS & OPPORTUNITIES

### 12.1 Introduction

The Citronen Project (Project) has a range of associated risks common to many mining operations and some specific to the Project. The focal risk is on potential challenges associated with the geographical location of the project and sensitivity to the zinc price. Numerous opportunities exist, as identified below, to increase the profitability of the Citronen Project.

### 12.2 Risks

#### Market Risk

This Project is sensitive to the zinc price. The various market forecasts for future zinc price are very favourable;

The operation of the Citronen Project involves several currencies (including the Australian, US & Canadian Dollars, Danish Kroner, and Chinese Yuan) and is therefore also sensitive to the fluctuation in foreign rates.

#### Geographical Location & Access

The mine site is located at latitude 83 degrees north and is 940 km from the nearest Greenlandic settlement. The project location comes with inherent weather and access difficulties. While year round access to site may be obtained via aircraft, ocean access is possible only during the summer months; this is due to sea ice and requires the use of special ice class of vessels. This circumstance influences on the import to site of bulk supplies and the export of concentrate products.

#### Project Execution

The above mentioned geographical difficulties could result in delayed project completion due to the missing of weather windows required for shipping access. Such a delay would have a negative effect on financial indicators.

#### Mining Risks

There is a relatively low risk associated with the mining and extraction of ore at Citronen. The ore body's nature and orientation is well understood and the room and pillar mining method has been selected as the most appropriate for this style of deposit. Ironbark is confident this understanding will achieve the maximum possible head grade for the mine.

Ironbark has completed extensive metallurgical testing and testwork has returned zinc recoveries over 90%. Ironbark is confident that the recoveries achieved during mining will reflect the testwork completed to date and the risk of poor recoveries is very low.

#### Finance Risk

The Citronen project will require large scale financing to be successfully completed and there is no certainty that this can be achieved. At current zinc prices the project appears to generate returns that will support financing.

## 12.3 Opportunities

### Resource

The resource estimate as shown in Section 3 has taken into consideration only a small area of the existing lease. There are several areas with the potential to increase resources and convert them into reserves. Further drilling is required to confirm this potential. However, the prospects for delineating further resources and reserve is considered very good as the current resource is open to further mineralisation in every direction.

Recent metallurgical testwork has shown zinc recoveries exceed 90%. Further engineering work is required before this could be raised to the level of engineering confidence required for inclusion in the Feasibility Study.

### Plant Throughput

The study performed by Metso in 2012 indicates it is possible to increase the plant throughput beyond 3.3 Mtpa without major changes to the process equipment or capital cost increases.

## APPENDIX 1 – FORWARD LOOKING AND CAUTIONARY STATEMENTS

Ironbark Zinc Limited (“Ironbark” or the “Company”) has concluded that it has a reasonable basis for providing the forward-looking statements and production targets discussed in this announcement. Ironbark also considers that it has reasonable basis to expect that it will be able to fund the development of the Citronen base metal mine. The detailed reasons for those conclusions are outlined throughout this announcement and all material assumptions are disclosed in this document and in the JORC table disclosures of the relevant Resource & Reserve Statements.

This announcement has been prepared in accordance with the JORC Code (2012) and the ASX Listing Rules. The Company advises that it completed a Feasibility Study in April 2013 and has now completed the re-costing update detailed in this announcement following the grant of the Mining Licence over the Project. The Production Targets and Financial Information contained in this announcement are preliminary in nature and some of the conclusions are in part based on technical and economic assessments and are subject to certain risks. The outcome of this study provides a reasonable basis for the company to release the results whilst not providing an assurance of the economic development of the Project. This is based on the current mining inventory indicating that for the 14 years following commencement of production the material can be sourced from the resource base.

This announcement includes certain statements that may be deemed ‘forward-looking statements’. All statements that refer to any future production, resources or reserves, exploration results and events or production that Ironbark expects to occur are forward-looking statements. Although the Company believes that the expectations in those forward-looking statements are based upon reasonable assumptions, such statements are not a guarantee of future performance and actual results or developments may differ materially from the outcomes. This may be due to several factors, including market prices, exploration and exploitation success, and the continued availability of capital and financing, plus general economic, market or business conditions. Investors are cautioned that any such statements are not guarantees of future performance, and actual results or performance may differ materially from those projected in the forward-looking statements. The Company does not assume any obligation to update or revise its forward-looking statements, whether as a result of new information, future events or otherwise.

The Company believes it has a reasonable basis for making the forward-looking statements in this announcement, including with respect to any Production Targets and economic evaluation based on information contained in this announcement. All material assumptions on which the forecast financial information are based, have been included in this announcement.

## Project Financing and Sources of Capital

The Company has commenced work to appoint a financing advisor to assist with establishing a debt facility. The Company has received a number of expressions of interests in the role of financial advisors and/or facilitator of the Project. The Company plans to progress the selection of a Financial Advisor as soon as possible.

There are no assurances that Project finance will be obtained. However, Ironbark believes there are reasonable grounds that the approximate US\$514 million in initial capital required to develop the Project, plus working capital of approximate US\$50 million for first fills and commissioning costs to be incurred prior to first receipt of sales proceeds, will be funded on the basis of the following:

- The Company has completed a Feasibility Study in April 2013 and this has been re-costed and updated in 2017.
- Ironbark has a highly experienced management and operations team with significant experience in developing and operating mines.
- The Citronen project and 100% of the Resources and Mining Inventory are located on a granted Mining Lease.
- Ironbark owns 100% of the Citronen Project.
- Ironbark's management, operations team, contractors and consultants have many years of experience in economic studies and evaluation, geotechnical, mining, processing, engineering and environmental assessments and have sufficient experience on matters relating to underground and open pit mining for the Citronen Operation.
- Ironbark is working with China Nonferrous (NFC) under an agreement to:
  - Incorporate current Chinese equipment and construction costs into the Citronen Feasibility Study
  - Prepare a project study report in compliance with the financing requirement of China's banks
  - Ensure the technical criteria is in compliance with local laws, regulations, standards and codes in Greenland and China
  - Assist Ironbark in securing Chinese project debt financing for the development of Citronen under the terms of the earlier Memorandum of Understanding

Ironbark considers that NFC provide a technically capable, fast moving and competitive construction engineering solution to deliver a turnkey, fixed price EPC solution to developing and commissioning Citronen. Moving beyond the existing Memorandum of Understanding with NFC, Ironbark will see the Citronen Feasibility Study updated and tailored to meet the Chinese banking requirements that will target 70% debt financing and provide NFC with an option to acquire up to 19.9% of the Citronen project. Recently discussions have included exploring options for even higher levels of financing from China.

In addition to progressing the financing plan through the NFC pathway, Ironbark continues planning and holding discussions with major international banking groups and corporate advisors to provide alternative financing options. The Citronen projects location in Europe makes it a candidate for European Export Credit Agency (ECA) finance funding as well as traditional debt and equity financing options. These options have required the completion of the updated Feasibility costs before they can be advanced any further.

- Ironbark has major base metal industry shareholders in Glencore AG and Nyrstar NV
- Financing for the construction of the mine Plant and infrastructure required for the Project to achieve the production targets outlined in this report has not yet been secured, which is typical for a project at this stage.
- Citronen financial model makes no assumption about the source of financing, however, it will likely be a mix of debt and equity funding (reflected in the nominal discount rate used of 8%). Ironbark will consider a range of financing alternatives outside of regular debt and equity sources, including potential equity-sharing arrangements with future offtake partners, mine contractors or other interested parties, as well as the potential for further forward sale of metals.
- The Project economics support a decision to invest. The Project is forecast to generate strong cashflows, an NPV in excess of US\$1B and a strong IRR with a short potential pay-back period.
- Capital, mining and processing costs are well understood.
- The Project is located in the favourable mining jurisdiction of Greenland, which has a history of zinc and lead mining and has been awarded a Mining Licence.
- The Project hosts attractive key commodities of zinc and lead which are both expected to have continuing strong global role into the near future.
- Ironbark has always been able to raise equity capital over its 10 year history to fund its mineral exploration and project development activities.
- The Board and senior management of Ironbark have experience in financing and developing mining projects in Australia and overseas and have an appropriate mix of skills and expertise to oversee and direct the progression of the Project through to a decision to mine.

Investors should note that there is no certainty that the Company will be able to secure the amount of funding required. Given the uncertainties involved, investors should not make any investment decision based solely on the results of the re-costed Feasibility Study.

### **Dilution to existing Shareholders**

Any significant tradition financing activities has the potential to significantly dilute existing shareholders. Ironbark will seek to secure debt financing before seeking to finalise the equity component of the capital requirement. The high level of debt gearing at 70%, is particularly enticing to minimise dilution as highlighted in the NFC Memorandum of Understanding. Traditional Western debt providers are more likely to offer a debt gearing of no higher than 60%.

## APPENDIX II – JORC 2012 TABLE 1

### Citronen Fjord Project

#### Section 1: Sampling Techniques & Data

Criteria	JORC Code explanation	Commentary
Sampling techniques	<p><i>Nature and quality of sampling (eg cut channels, random chips, or specific specialised industry standard measurement tools appropriate to the minerals under investigation, such as down hole gamma sondes, or handheld XRF instruments, etc). These examples should not be taken as limiting the broad meaning of sampling.</i></p>	<p>All samples are from diamond core, and include a mixture of quarter, half or whole core and BQ, NQ or HQ sizes. Samples are taken from varying intervals from 40cm length to 2.5m length depending on visual differences and compositions analysed by a hand-held Niton XL3t Analyser. Mineralised zones were analysed with a 30 second reading every 5cm along the core. These results are only used for onsite interpretation and form the basis of the samples chosen for laboratory assay. Sampling is carried out under QAQC procedures as per industry standards.</p>
	<p><i>Include reference to measures taken to ensure sample representivity and the appropriate calibration of any measurement tools or systems used.</i></p>	<p>Certified sample standards and duplicate samples are added in a ratio of one sample per every 10 samples. Most hole collars have been surveyed using a Trimble DGPS system which has an accuracy of &lt;1m; the remaining holes have been surveyed by hand-held GPS with an accuracy of &lt;5m.</p>
	<p><i>Aspects of the determination of mineralisation that are Material to the Public Report. In cases where 'industry standard' work has been done this would be relatively simple (eg 'reverse circulation drilling was used to obtain 1 m samples from which 3 kg was pulverised to produce a 30 g charge for fire assay'). In other cases more explanation may be required, such as where there is coarse gold that has inherent sampling problems. Unusual commodities or mineralisation types (eg submarine nodules) may warrant disclosure of detailed information.</i></p>	<p>Two distinct exploration drilling campaigns have been conducted at Citronen. The first, between 1993 and 1997, was conducted by Platinova A/S who drilled 149 holes totalling 32,842.95m. Sample intervals varied from 0.15 - 2.5m, the average sample width was 1.0m.</p>
		<p>The second drilling campaign, between 2008 and 2011, was conducted by Ironbark Zinc Limited who drilled 166 diamond holes totalling 34,239.93m. Sample intervals varied from 0.2 - 1.5m and the average sample width was 0.9m.</p>

Criteria	JORC Code explanation	Commentary
		A sampling program was conducted by Ironbark in 2007, where 2,645 samples were taken from the Platinova drill core. Samples varied from 0.2 - 1.3m and the average sample width was 0.95m. Some of these samples were from previously unsampled drill core and other samples were quarter core samples from previously assayed intervals, used as a quality control check.
		Core samples from the 1993 drilling were sent to Chemex Labs Ltd of North Vancouver B.C. Canada. Samples were crushed, split and a portion pulverised followed by a four-acid digest and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) finish.
Sampling techniques		Core samples from the 1994 drilling were sent to Bondar Clegg Inchcape Testing Services of Ottawa, Ontario, Canada. These samples were crushed split, and a portion pulverised to minus 200 mesh. A four-acid digest was used followed by ICP-MS and also AAS for samples greater than 20% Fe and 15% Zn.
		Core samples from the 1995 drilling were sent to Chemex Labs Ltd of Vancouver, B.C., Canada. Samples were crushed, split and a portion pulverised to minus 150 mesh followed by reverse Aqua-Regia digest finished by Atomic Absorption Spectrometry (AAS).
		Core samples from the 1996 and 1997 drilling were sent to Cominco Ltd. Laboratory in Rexdale, Ontario, Canada. Samples were crushed, split and a portion pulverised to minus 150 mesh followed by reverse Aqua-Regia digest finished by AAS.
		The core samples taken in 2007 by Ironbark were sent to ALS Chemex in Vancouver, B.C., Canada. The samples were crushed, split and a portion pulverised to 75µm, followed by a four-acid digest and an AAS technique.

Criteria	JORC Code explanation	Commentary
		The core samples taken between 2008 - 2011 by Ironbark were sent to ALS Chemex in Ojebyn, Sweden. The samples were crushed, split and a portion pulverised to 75µm, followed by a four acid digest and an Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) finish.
Drilling techniques	<i>Drill type (eg core, reverse circulation, open-hole hammer, rotary air blast, auger, Bangka, sonic, etc) and details (eg core diameter, triple or standard tube, depth of diamond tails, face-sampling bit or other type, whether core is oriented and if so, by what method, etc).</i>	All drilling at the Citronen Project has been standard tube diamond drilling, of either BQ, NQ or HQ diameter. In areas with overburden either a tri-cone roller bit or shoe bit was used to drill down to competent rock. Overburden material was discarded.
Drill sample recovery	<i>Method of recording and assessing core and chip sample recoveries and results assessed.</i>	Recovered drill core was measured every 3m run and any core loss was recorded.
	<i>Measures taken to maximise sample recovery and ensure representative nature of the samples.</i>	Core recoveries were excellent throughout the project and the need for triple tube drilling was not required. All core was checked and measured by a geologist and rod counts were conducted by drillers.
	<i>Whether a relationship exists between sample recovery and grade and whether sample bias may have occurred due to preferential loss/gain of fine/coarse material.</i>	Information from the diamond drilling does not suggest there is a correlation between recoveries and grade. Diamond drill core from the Citronen deposit has a very high recovery.
Logging	<i>Whether core and chip samples have been geologically and geotechnically logged to a level of detail to support appropriate Mineral Resource estimation, mining studies and metallurgical studies.</i>	All drill holes were logged for a combination of geological and geotechnical attributes to a level of detail to support a Mineral Resource estimation.
	<i>Whether logging is qualitative or quantitative in nature. Core (or costean, channel, etc) photography.</i>	Logging is both qualitative and semi-quantitative in nature. All drill core was photographed.
	<i>The total length and percentage of the relevant intersections logged.</i>	The total length of all recovered drill core was logged in detail.
Sub-sampling techniques and sample preparation	<i>If core, whether cut or sawn and whether quarter, half or all core taken.</i>	Of 7,396 samples, 6,422 were half-core (87%), 968 were quarter-core (13%) and six samples were whole core samples. All core was sawn with a core-saw.

Criteria	JORC Code explanation	Commentary
	<i>If non-core, whether riffled, tube sampled, rotary split, etc and whether sampled wet or dry.</i>	All drilling conducted at Citronen was diamond drilling.
<i>Sub-sampling techniques and sample preparation</i>	<i>For all sample types, the nature, quality and appropriateness of the sample preparation technique.</i>	All samples were crushed, split and pulverised at a laboratory. The sample preparation is industry standard for the fine-grained nature of this Sedimentary-Exhalative (SEDEX) mineralisation style.
	<i>Quality control procedures adopted for all sub-sampling stages to maximise representivity of samples.</i>	Laboratory certified standards and duplicates were used alternatively every 10 samples as a quality control measure.
	<i>Measures taken to ensure that the sampling is representative of the in situ material collected, including for instance results for field duplicate/second-half sampling.</i>	One duplicate per 20 samples was taken.
	<i>Whether sample sizes are appropriate to the grain size of the material being sampled.</i>	The sample sizes are appropriate to the fine-grained mineralisation of this SEDEX mineralisation style.
<i>Quality of assay data and laboratory tests</i>	<i>The nature, quality and appropriateness of the assaying and laboratory procedures used and whether the technique is considered partial or total.</i>	The assay methods used are considered appropriate and near total digestion.
	<i>For geophysical tools, spectrometers, handheld XRF instruments, etc, the parameters used in determining the analysis including instrument make and model, reading times, calibrations factors applied and their derivation, etc.</i>	A Niton XL3t hand-held XRF analyser was used to determine the appropriate core intervals to send for laboratory assay. Each reading was 30 seconds long, taken each 5cm along the drill core.
	<i>Nature of quality control procedures adopted (eg standards, blanks, duplicates, external laboratory checks) and whether acceptable levels of accuracy (ie lack of bias) and precision have been established.</i>	Duplicate samples and laboratory certified standards have been used alternatively every 10 samples. All samples have returned results within an acceptable range.
<i>Verification of sampling and assaying</i>	<i>The verification of significant intersections by either independent or alternative company personnel.</i>	Ravensgate Consultants conducted a verification procedure on the Citronen database during the resource estimation process.

Criteria	JORC Code explanation	Commentary
	<p><i>The use of twinned holes.</i></p>	<p>Several drill holes have been twinned and have shown comparable results including the below.</p> <p>Holes CF08-153 &amp; CF08-153A (both vertical holes) were drilled 9m horizontally apart at surface with an elevation difference of 12cm. CF08-153 returned 9.1m @ 5.16% Zn from 14.0m and CF08-153A returned 9.0m @ 5.92% Zn from 14.0m.</p> <p>Holes CF10-245A and CF10-245B (both vertical holes) were drilled 1m apart at surface. The drill holes intersected 12.2m and 13.7m of overburden (glacial till) respectively and intersected the Hangingwall Debris Flow Unit at 175.5m and 174.5m depth respectively.</p>
<i>Verification of sampling and assaying</i>	<p><i>Documentation of primary data, data entry procedures, data verification, data storage (physical and electronic) protocols.</i></p>	<p>Primary data was either collected as paper logs, or entered into a database program or Excel spreadsheet. Paper logs were later transferred to a digital database. Data was verified and checked by senior Ironbark staff and by external consultants - Expedio, Ravensgate &amp; Mining Plus. Database was stored as Excel spreadsheets and a Microsoft Access Database.</p>
	<p><i>Discuss any adjustment to assay data.</i></p>	<p>There has been no adjustment to the assay data.</p>
<i>Location of data points</i>	<p><i>Accuracy and quality of surveys used to locate drill holes (collar and down-hole surveys), trenches, mine workings and other locations used in Mineral Resource estimation.</i></p>	<p>All drill holes prior to 2011 were surveyed using a DGPS which has an accuracy of &lt;1m. 2011 holes were picked up by handheld GPS which has proven to have an accuracy of approximately 5m. Downhole surveys were conducted on all angled drill holes using REFLEX (industry standard) equipment.</p>
	<p><i>Specification of the grid system used.</i></p>	<p>The Grid System used for all location data points at Citronen is UTM WGS 84 Zone 26.</p>
	<p><i>Quality and adequacy of topographic control.</i></p>	<p>Ironbark purchased a Digital Elevation Model, produced from satellite imagery, for the Citronen Region that has an accuracy of approximately 2.5m.</p>

Criteria	JORC Code explanation	Commentary
Data spacing and distribution	<i>Data spacing for reporting of Exploration Results.</i>	Hole spacing in the Beach Zone and Discovery Zone averages 50m, and 150m in the Esrum Zone.
	<i>Whether the data spacing and distribution is sufficient to establish the degree of geological and grade continuity appropriate for the Mineral Resource and Ore Reserve estimation procedure(s) and classifications applied.</i>	The data spacing and distribution is sufficient to determine geological and grade continuity as determined by the JORC code 2012.
	<i>Whether sample compositing has been applied.</i>	A composite length of 1m was selected after analysis of the raw sample lengths for use in resource calculations.
Orientation of data in relation to geological structure	<i>Whether the orientation of sampling achieves unbiased sampling of possible structures and the extent to which this is known, considering the deposit type.</i>	The orientation of the drilling is approximately perpendicular to the strike and dip of the mineralisation and therefore should not be biased. Angled drill holes provided a check against mineralisation width in vertical holes.
	<i>If the relationship between the drilling orientation and the orientation of key mineralised structures is considered to have introduced a sampling bias, this should be assessed and reported if material.</i>	There are no known biases caused by the orientation of the drill holes.
Sample security	<i>The measures taken to ensure sample security.</i>	Drill core was kept on site at Citronen and sample dispatch was overseen by the site manager. Samples were transported by aircraft to Svalbard (Norway), then air freighted to the laboratory by a local logistics company.
Audits or reviews	<i>The results of any audits or reviews of sampling techniques and data.</i>	Ravensgate reviewed original laboratory assay files and compared them with the database. No errors were found.

## Citronen Fjord Project

**Table 1 - Section 2: Reporting of Exploration Results**

Criteria	JORC Code explanation	Commentary
Mineral tenement and land tenure status	<p><i>Type, reference name/number, location and ownership including agreements or material issues with third parties such as joint ventures, partnerships, overriding royalties, native title interests, historical sites, wilderness or national park and environmental settings.</i></p>	<p>The Citronen Fjord Deposit is located wholly within Exploitation Licence 2016/30 which is held in the name of Ironbark A/S a wholly owned subsidiary of Ironbark Zinc Limited. EL2016/30 lies within the Northeast Greenland National Park. A 2% royalty is payable to vendors.</p>
	<p><i>The security of the tenure held at the time of reporting along with any known impediments to obtaining a licence to operate in the area.</i></p>	<p>The licence is in good standing.</p>
Exploration done by other parties	<p><i>Acknowledgment and appraisal of exploration by other parties.</i></p>	<p>The deposit was previously explored by Platinova A/S between 1993 and 1997.</p>
Geology	<p><i>Deposit type, geological setting and style of mineralisation.</i></p>	<p>The Citronen Fjord deposit lies within the Palaeozoic Franklinian Basin, a sedimentary basin which extends across Northern Greenland and into Canada. The deposit lies within Ordovician deep water argillaceous rocks, interbedded with carbonate debris flows sourced from the carbonate platform to the south. Base metal mineralisation at Citronen is primarily contained within the Amundsen Land Group mudstones. Three main stratigraphic horizons of mineralisation were identified by Platinova A/S. Known sulphide and zinc mineralisation occurs over an area of 12km in strike (identified to date). The main sulphides present are pyrite, sphalerite and galena. Three types of sulphide mineralisation are present: mound-like masses, interbedded sulphides that form laminae and beds within the mudstones and cross-cutting epigenetic mineralisation that is primarily found in the carbonate debris flows.</p>
Drill hole Information	<p><i>A summary of all information material to the understanding of the exploration results including a tabulation of the following information for all Material drill holes:</i></p>	
	<ul style="list-style-type: none"> <li>o <i>easting and northing of the drill hole collar</i></li> </ul>	
	<ul style="list-style-type: none"> <li>o <i>elevation or RL (Reduced Level – elevation above sea level in metres) of the drill hole collar</i></li> </ul>	<p>Refer to ASX release 25 November 2014 for a complete list of drill holes.</p>
	<ul style="list-style-type: none"> <li>o <i>dip and azimuth of the hole</i></li> </ul>	
	<ul style="list-style-type: none"> <li>o <i>down hole length and interception depth</i></li> </ul>	
	<ul style="list-style-type: none"> <li>o <i>hole length.</i></li> </ul>	

Criteria	JORC Code explanation	Commentary
Data aggregation methods	<i>In reporting Exploration Results, weighting averaging techniques, maximum and/or minimum grade truncations (eg cutting of high grades) and cut-off grades are usually Material and should be stated.</i>	
	<i>Where aggregate intercepts incorporate short lengths of high grade results and longer lengths of low grade results, the procedure used for such aggregation should be stated and some typical examples of such aggregations should be shown in detail.</i>	All reported assays have been length weighted.
	<i>The assumptions used for any reporting of metal equivalent values should be clearly stated.</i>	No metal equivalents have been reported.
Relationship between mineralisation widths and intercept lengths	<i>These relationships are particularly important in the reporting of Exploration Results.</i>	
	<i>If the geometry of the mineralisation with respect to the drill hole angle is known, its nature should be reported.</i>	The mineralisation is interpreted to be flat-lying to gently dipping and drill holes have been angled (either vertical or at 60 degrees) to intercept the mineralisation as close to perpendicular as possible, therefore resulting in true widths of mineralisation.
	<i>If it is not known and only the down hole lengths are reported, there should be a clear statement to this effect (eg 'down hole length, true width not known').</i>	
Diagrams	<i>Appropriate maps and sections (with scales) and tabulations of intercepts should be included for any significant discovery being reported. These should include, but not be limited to a plan view of drill hole collar locations and appropriate sectional views.</i>	Refer to Figures in text
Balanced reporting	<i>Where comprehensive reporting of all Exploration Results is not practicable, representative reporting of both low and high grades and/or widths should be practised to avoid misleading reporting of Exploration Results.</i>	All results have been reported.
Other substantive exploration data	<i>Other exploration data, if meaningful and material, should be reported including (but not limited to): geological observations; geophysical survey results; geochemical survey results; bulk samples – size and method of treatment; metallurgical test results; bulk density, groundwater, geotechnical and rock characteristics; potential deleterious or contaminating substances.</i>	Geological mapping, geotechnical and metallurgical studies have been conducted and are included in this Report.

Criteria	JORC Code explanation	Commentary
<i>Further work</i>	<p><i>The nature and scale of planned further work (eg tests for lateral extensions or depth extensions or large-scale step-out drilling).</i></p> <p><i>Diagrams clearly highlighting the areas of possible extensions, including the main geological interpretations and future drilling areas, provided this information is not commercially sensitive.</i></p>	<p>The project is being developed to become an operating mine and as the deposit is open in every direction further exploration (drilling) will be conducted in the future.</p>

## Citronen Fjord Project

**Table 1 - Section 3: Estimation and Reporting of Mineral Resources**

Criteria	JORC Code explanation	Commentary
Database integrity	<p><i>Measures taken to ensure that data has not been corrupted by, for example, transcription or keying errors, between its initial collection and its use for Mineral Resource estimation purposes.</i></p>	<p>All drilling data has been reviewed and audited by several internal personnel and external consultants. Data validation techniques include: re-assaying historic core, surveying hole collars, use of laboratory standards and duplicates, three internal cross-checks of all drill hole data by geologists and several external consultant cross-checks of all available data.</p>
	<p><i>Data validation procedures used.</i></p>	<p>Three Resource Estimates have been calculated prior to the Ravensgate Resource 2012:</p> <ul style="list-style-type: none"> <li>- Wardrop Consulting, 2007</li> <li>- Ironbark, 2008 (in-house)</li> <li>- Ravensgate, 2010</li> </ul> <p>Examination of the prior estimate reports were used as part of the data validation procedures for the Ravensgate Resource Report 2012.</p>
Site visits	<p><i>Comment on any site visits undertaken by the Competent Person and the outcome of those visits.</i></p>	<p>One of the Ravensgate Resource Report 2012 authors was involved in the drilling and project development at an early stage and visited the site. The author was integral in the establishment of industry best QA/QC practices and has an intimate knowledge of all procedures used on site.</p>
	<p><i>If no site visits have been undertaken indicate why this is the case.</i></p>	<p>The author of the Wardrop 2007 Resource Estimate Report was involved in the planning and execution of the 1990's drilling.</p> <p>The author of the Ironbark 2008 in-house Resource Estimate was involved in the planning and execution of the 2007 sampling and 2008 drilling programs.</p>
Geological interpretation	<p><i>Confidence in (or conversely, the uncertainty of) the geological interpretation of the mineral deposit.</i></p>	<p>The Ravensgate Resource Report 2012 states "Interpretation of the lithological boundaries model for the mineralisation interpretation used for the resource modelling is supported by a significant amount of drill logging or surface mapping and is at an advanced level". Ravensgate classified the Geological Interpretation as a low-moderate risk in the Resource Calculation Risk Assessment.</p>
	<p><i>Nature of the data used and of any assumptions made.</i></p>	<p>Zinc-lead mineralised domains were initially modelled using MineSight 3-D modelling software. Interpretation was primarily done in cross-section using geological logging and the 3D geological model. Cross sections were oriented on 100m and 50m sections oriented perpendicular to the dominant strike of the domain being modelled.</p>
	<p><i>The effect, if any, of alternative interpretations on Mineral Resource estimation.</i></p>	
	<p><i>The use of geology in guiding and controlling Mineral Resource estimation.</i></p>	
	<p><i>The factors affecting continuity both of grade and geology.</i></p>	

Criteria	JORC Code explanation	Commentary
Dimensions	<p><i>The extent and variability of the Mineral Resource expressed as length (along strike or otherwise), plan width, and depth below surface to the upper and lower limits of the Mineral Resource.</i></p>	<p>The area containing the Citronen Resource stretches 6.5km from the north-west corner of the Esrum Zone to the south-east corner of the Discovery Zone. The deposit is exposed at surface in the Discovery Zone and reaches a depth of 575m below surface in the Esrum Zone. The deposit is open along strike and at depth.</p>
Estimation and modelling techniques	<p><i>The nature and appropriateness of the estimation technique(s) applied and key assumptions, including treatment of extreme grade values, domaining, interpolation parameters and maximum distance of extrapolation from data points. If a computer assisted estimation method was chosen include a description of computer software and parameters used.</i></p> <p><i>The availability of check estimates, previous estimates and/or mine production records and whether the Mineral Resource estimate takes appropriate account of such data.</i></p> <p><i>The assumptions made regarding recovery of by-products.</i></p> <p><i>Estimation of deleterious elements or other non-grade variables of economic significance (eg sulphur for acid mine drainage characterisation).</i></p> <p><i>In the case of block model interpolation, the block size in relation to the average sample spacing and the search employed.</i></p> <p><i>Any assumptions behind modelling of selective mining units.</i></p> <p><i>Any assumptions about correlation between variables.</i></p> <p><i>Description of how the geological interpretation was used to control the resource estimates.</i></p> <p><i>Discussion of basis for using or not using grade cutting or capping.</i></p> <p><i>The process of validation, the checking process used, the comparison of model data to drill hole data, and use of reconciliation data if available.</i></p>	<p>Resource estimations were generated using standard 3D 'uniform block size' modelling techniques. The Ordinary Kriging interpolation technique was employed owing to the low coefficients of variation observed for sample composites for each domain area. Three separate block models were created - one each for the Beach, Esrum and Discovery Zones due to the large file sizes.</p> <p>Variable upper high grade Zinc cut-offs were applied to the 1m down-hole composite data set prior to carrying out interpolation.</p> <p>In Ravensgate's opinion a general level of cut-off at the 98th or 99th percentile level be implemented in conjunction with local domain statistics to help minimise the change of over-estimation of grades.</p> <p>Major, minor and down hole axis length for interpolation were obtained by using variograms. These vary depending on Zone.</p> <p>Higher Zn grade domains were restricted according to the probability statistics observed within each mineralisation domain. Generally the grade cut-off - distance restriction regime was applied to at the 98th or 99th percentile level. A composite length of 1m was used as it was deemed this length was short enough to honour the dimensions of geological and mineralisation domains being modelled. The composite, subsequent data processing and statistical analysis, were carried out in MineSight Compass Software. Wireframe development was guided using a minimum true width of 2m.</p> <p>An approximate 'half of drill hole spacing' distance of influence approach was used for extrapolating.</p> <p>Block size was 10m x 10m with bench height of 1m. No assumptions behind modelling of selective mining units were made.</p> <p>No assumptions about correlation between variables were made.</p> <p>Zinc and lead distribution within the defined domains is relatively predictable and mostly display low coefficients of variation (CV 0.4-1.0).</p>

Criteria	JORC Code explanation	Commentary
<i>Estimation and modelling techniques</i>		<p>In Ravensgate's opinion, considering the relatively low coefficients of variations observed for the three main Citronen project areas, only minimal outlier treatment need be considered. Ravensgate used the 98-99th percentile level as the main starting point for the grade restriction implementation level. The restriction distance was also set as 60 to 80 metres depending on the drilling density available within any given mineralisation domain.</p> <p>Wardrop Consulting completed a resource estimate in 2007 and in 2008 an in-house resource was calculated by Ironbark. Ravensgate consultants were contracted in 2010 to calculate a resource to include the 2008, 2009 and 2010 drilling. Ravensgate were contracted again after the 2011 drilling was completed to provide a resource encompassing all drilling to date at the project. The resource estimates from 2007, 208 and 2010 were used as check estimates against the 2012 Resource.</p> <p>No by-product recovery assumptions have been made. Deleterious elements have not been considered in the Resource Calculation based on the results from metallurgical testwork to date.</p> <p>The resource estimate was reviewed by two Competent Persons from Ravensgate and the block model cross-checked with the drilling data both by Ravensgate and in-house.</p>
<i>Moisture</i>	<p><i>Whether the tonnages are estimated on a dry basis or with natural moisture, and the method of determination of the moisture content.</i></p>	<p>Bulk densities were based on dry tonnes.</p>
<i>Cut-off parameters</i>	<p><i>The basis of the adopted cut-off grade(s) or quality parameters applied.</i></p>	<p>A lower cut-off grade of 2% zinc was used, which is based on deposits of similar style and mining method.</p>
<i>Mining factors or assumptions</i>	<p><i>Assumptions made regarding possible mining methods, minimum mining dimensions and internal (or, if applicable, external) mining dilution. It is always necessary as part of the process of determining reasonable prospects for eventual economic extraction to consider potential mining methods, but the assumptions made regarding mining methods and parameters when estimating Mineral Resources may not always be rigorous. Where this is the case, this should be reported with an explanation of the basis of the mining assumptions made.</i></p>	<p>No specific assumptions were made about mining methods by Ravensgate whilst calculating the resource estimate, other than considering the use of standardised surface (Discovery Zone) and underground mining (Esrum &amp; Beach Zones) methods. Mining Plus consultants have proposed the room and pillar underground mining method to maximise recovery. Further information on mining methods can be found in Ironbark's Feasibility report released 29 April 2013.</p>

Criteria	JORC Code explanation	Commentary
Metallurgical factors or assumptions	<p><i>The basis for assumptions or predictions regarding metallurgical amenability. It is always necessary as part of the process of determining reasonable prospects for eventual economic extraction to consider potential metallurgical methods, but the assumptions regarding metallurgical treatment processes and parameters made when reporting Mineral Resources may not always be rigorous. Where this is the case, this should be reported with an explanation of the basis of the metallurgical assumptions made.</i></p>	<p>Metallurgical testing has been carried out on Citronen drill core after the 2008, 2009, 2010 and 2011 drilling campaigns. The testwork has been conducted by Burnie Laboratories in Tasmania (now part of ALS Global). Ore processing will incorporate the following stages: primary &amp; secondary crushing, dense media separation, grinding and classification, flotation and concentrate thickening and filtration. Very high zinc flotation recoveries of 85% have been achieved. Further information on metallurgical and process testwork can be found in the Ironbark Feasibility Report released 29 April 2013.</p>
Environmental factors or assumptions	<p><i>Assumptions made regarding possible waste and process residue disposal options. It is always necessary as part of the process of determining reasonable prospects for eventual economic extraction to consider the potential environmental impacts of the mining and processing operation. While at this stage the determination of potential environmental impacts, particularly for a greenfields project, may not always be well advanced, the status of early consideration of these potential environmental impacts should be reported. Where these aspects have not been considered this should be reported with an explanation of the environmental assumptions made.</i></p>	<p>A full Environmental Impact Assessment has been completed and submitted to the Government of Greenland. Environmental factors and management solutions are outlined in the Feasibility Study Report for Citronen released to the ASX on 29 April 2013. Tailings from the mine will be used as backfill underground or stored in an on-ground Tailings Storage Facility. Waste rock will be stored in a waste-dump on surface. Environmental studies concluded that mine wastes will not significantly increase the levels of metals in the aquatic or terrestrial environment of the area.</p>
Bulk density	<p><i>Whether assumed or determined. If assumed, the basis for the assumptions. If determined, the method used, whether wet or dry, the frequency of the measurements, the nature, size and representativeness of the samples.</i></p>	<p>Ironbark conducted numerous empirical Specific Gravity (SG) measurements of drill core from a large range of different rock types and mineralisation styles from the deposit. Ironbark also examined statistical methods to calculate bulk density based on element assay and stoichiometric density. To calculate the bulk density in the deposit, Ironbark produced a theoretical density for each block in the model based upon the interpolated value of Fe, Pb and Zn and rock type coding. This approach is thought to be more accurate than using a constant density value for</p>

Criteria	JORC Code explanation	Commentary
	<p><i>The bulk density for bulk material must have been measured by methods that adequately account for void spaces (vugs, porosity, etc), moisture and differences between rock and alteration zones within the deposit.</i></p> <p><i>Discuss assumptions for bulk density estimates used in the evaluation process of the different materials.</i></p>	<p>each domain. The interpolated densities for each block were calculated using a formula that utilised the Ordinary Kriged Fe, Pb and Zn values for that block. The formula assumes that all Zn is reporting to sphalerite (SG of 4.05), Pb to galena (SG of 7.4) and Fe to pyrite (SG of 5.01), with the remainder consisting of mudstone gangue (SG of 2.78).</p>
Classification	<p><i>The basis for the classification of the Mineral Resources into varying confidence categories.</i></p>	
	<p><i>Whether appropriate account has been taken of all relevant factors (ie relative confidence in tonnage/grade estimations, reliability of input data, confidence in continuity of geology and metal values, quality, quantity and distribution of the data).</i></p>	<p>The Citronen Resource was classified into Measured, Indicated &amp; Inferred categories using a mathematical calculation based on distance to the nearest composite and the number of composites used in each ore domain. The resource estimate calculated by a Competent Person of Ravensgate Consultants has adhered to the JORC (2004) guidelines and the resource estimate and all its working has been verified by another Competent Person. Both Competent Persons signed off on the resource calculation. The Resource calculation has not been recalculated since 2011 as no further drilling has been completed nor have any modifying factors materially changed.</p>
	<p><i>Whether the result appropriately reflects the Competent Person's view of the deposit.</i></p>	
Audits or reviews	<p><i>The results of any audits or reviews of Mineral Resource estimates.</i></p>	<p>A JORC compliant resource for Citronen was initially calculated in 2007 by Wardrop Consulting. In 2008 a JORC compliant in-house resource was calculated by Ironbark, then Ravensgate calculated a JORC compliant estimate in 2010 and 2011 to include the latest drilling. Each of these Resource Estimates and Reports have been extensively reviewed in house and the latest resource was reviewed by Mining Plus Consultants to ensure its suitability for underground mining optimisation.</p>

Criteria	JORC Code explanation	Commentary
Discussion of relative accuracy/ confidence	<p><i>Where appropriate a statement of the relative accuracy and confidence level in the Mineral Resource estimate using an approach or procedure deemed appropriate by the Competent Person. For example, the application of statistical or geostatistical procedures to quantify the relative accuracy of the resource within stated confidence limits, or, if such an approach is not deemed appropriate, a qualitative discussion of the factors that could affect the relative accuracy and confidence of the estimate.</i></p>	
	<p><i>The statement should specify whether it relates to global or local estimates, and, if local, state the relevant tonnages, which should be relevant to technical and economic evaluation. Documentation should include assumptions made and the procedures used.</i></p>	
	<p><i>These statements of relative accuracy and confidence of the estimate should be compared with production data, where available.</i></p>	

## **APPENDIX III – COMPETENT PERSON DISCLOSURE**

In relation to Mineral Resources, the Company confirms that all material assumptions and technical parameters that underpin the relevant market announcement continue to apply and have not materially changed.

The estimated mineral resources underpinning the production target have been prepared by competent persons in accordance with the requirements in Appendix 5A (JORC Code).

### **Competent Person Statement**

The information included in this report that relates to Exploration Targets, Exploration Results and Mineral Resources is based on information compiled or reviewed by Mr Jonathan Downes (B. Sc, MAIG) and Ms Elizabeth Laursen (B. Esc (Hons.), MAIG, MSEG, Grad Dip App Fin), both employees of Ironbark Zinc Limited. Mr Downes and Ms Laursen have sufficient experience that is relevant to the style of mineralisation and type of deposit under consideration and to the activity which is being undertaken to qualify as a Competent Person as defined in the 2012 Edition of the Australasian Code for Reporting of Exploration Targets, Exploration Results, Mineral Resources and Ore Reserves. Mr Downes and Ms Laursen consent to the inclusion in the report of the matters based on this information in the form and context in which it appears.

### **Competent Persons Disclosure**

Mr Downes and Ms Laursen are employees of Ironbark Zinc Limited and currently hold securities in the company.