The DSTP Initiative:

2014 Knowledge Workshop Report

Final Report
May 2014

Table of Contents

Executive Summary v
- A National Issue v
- A New Approach v
- Research Guidance v
- Input to a Conceptual Framework for Using the Research Results vi
- Guidance for Socially Responsible Research vi
- Guidance for Ongoing Stakeholder Engagement vi
- The Path Forward vi

I. Introduction 1
- Purpose and Scope of this Document 2
- Document Structure 2

II. The DSTP Consortium 5
- Role of the Consortium Going Forward 5
- Principles of Operation 6

III. The DSTP Initiative 7

IV. Transition from the 2013 DSTP Roadmap to the 2014 Knowledge Workshop 9
- Identification of Research Studies 9
- How the 2014 Knowledge Workshop builds on the 2013 DSTP Roadmap 11

V. Research Program Guidance 13
- Structure of the Research Guidance 13

VI. Conceptual Framework – Evaluation of Relative Risk 33
- Basis for Comparing DSTP versus Land Tailings Disposal 33
- Methodological Options 34

VII. Social Issues Research and Community Outreach 37
- Community Outreach and Engagement 37
- Social Issues Research 38

VIII. Stakeholder Engagement 39
- Stakeholder Concerns, Issues, and Potential Barriers 39
- Best Practices for Engaging Stakeholders 40

IX. The Path Forward 41

Appendix A: Participant List A-1

Appendix B: Small Groups B-1

Appendix C: Glossary of Terms and Acronyms C-1

This page intentionally left blank

Executive Summary

A NATIONAL ISSUE

The competition for land use in the central region of Chile is a national issue. The Central region is the most densely populated region of Chile and the land is ideal for a range of agricultural activities. The Central region also has abundant copper deposits and copper production presents another source of competition for land use. Copper production is an important driver of economic prosperity and has helped to make Chile's economy one of the strongest and most robust of Latin America. However, copper production in the central region will soon be limited by the availability of land for tailing disposal. Copper mines in the central region currently dispose of their tailings in land based tailings dams. As current tailings dams reach their capacity, additional disposal capacity will have to be developed either through the construction of additional dams on land currently used for agricultural purposes or the development of alternative disposal methods. The combination of land scarcity and the need for additional disposal capacity present a significant challenge for the mining industry and, given the economic importance of both agricultural production and copper production, Chile as a nation.

A NEW APPROACH

Mining companies in the central region have recognized this challenge and been searching for alternatives to land-based disposal. A viable alternative would alleviate the land-use issue and enable the continued development of the copper industry in the country. The mining companies recently formed an independent Consortium to carry out an impartial evaluation of Deep Sea Tailing Placement (DSTP), an alternative method of disposal that is currently being used in other countries.

Chile and the mining industry will only use DSTP if it can be shown to be viable from human health, social and environmental perspectives. However, the current scientific and technical knowledge about DSTP is not sufficient to make such a determination. The Consortium will manage and oversee a comprehensive research program to close the gaps in the current knowledge. In addition, the Consortium will design and implement a plan for involving and engaging with stakeholders. The DSTP Initiative represents a different approach to determining the direction of the mining industry. Rather than treating the evaluation as a unilateral business decision, it is being carried out in a spirit of openness and collaboration. The Consortium will foster a collaborative effort with industry, government, communities, environmental NGOs, academia, and other key stakeholders in order to make an informed decision about DSTP.

As part of this new approach, the Consortium sponsored a Knowledge Workshop that brought together a wide range of stakeholders. The purpose of the workshop was to generate guidance and input to help the Consortium map out a path forward.

This document presents the results of that workshop. Chapters V through VIII focus on different areas of guidance developed at the workshop.

RESEARCH GUIDANCE

Chapter V of this document presents guidance for carrying out specific research programs which were identified as necessary to close the gaps in the technical and scientific knowledge required to evaluate DSTP. The guidance includes both research design guidance and implementation guidance. The research design guidance is intended to help the Consortium ensure that the research studies are maintaining a high degree of methodological rigor and producing valid scientific and technical knowledge. The implementation guidance is intended to help the Consortium oversee the coordination and execution of the actual research activities.

INPUT TO A CONCEPTUAL FRAMEWORK FOR USING THE RESEARCH RESULTS

The purpose of the DSTP Initiative is to develop the scientific and technical knowledge needed to evaluate the human health and environmental viability of the technology. Even if the technology is found viable, a decision will still have to be made about whether or not to implement the DSTP. This decision must be in the context of a comparative analysis relative to the current practice of land-based disposal methods. The need for this comparative analysis stems from the understanding that risk-free options do not exist. To decide not to use one method is a decision to use the alternative method.

Chapter VI presents the participants' input into a conceptual framework for using the results of the research to compare the relative risk of DSTP versus land-based disposal of tailings. In particular, participants identified five broad categories of risk common to both land tailings disposal and DSTP: Environmental/Ecological, Natural Hazards, Economic Risk, Social Risk, and Operational/Technological Risk. Participants also provided methodological suggestions or options for carrying out the risk analysis.

GUIDANCE FOR SOCIALLY RESPONSIBLE RESEARCH

The Consortium recognizes that some of the research must be conducted at the potential DSTP sites and as a result may impact the local community. Responsible management and oversight of the research studies must therefore go beyond the technical methodological issues and consider the social impact of conducting the research.

Chapter VII presents participants' guidance for an effective strategy of communication and outreach to the communities where the field research will take place. Participants indicated that, in keeping with its principles of operation, the Consortium's primary means for mitigating the adverse effects of the field research would be open communications and collaborative engagement with community members. In addition, participants suggested that the Consortium conduct social issue research to create a demographic profile of the potentially affected communities and assess the potential for discord and controversy within those communities. These baselines are necessary to help the Consortium understand the social issues surrounding the research activity and the potential for impact.

GUIDANCE FOR ONGOING STAKEHOLDER ENGAGEMENT

DSTP is an issue that is of interest to a diverse group of stakeholders. In order for the Initiative to be successful, it is essential that stakeholders are involved in the process and understand its purpose is to evaluate the technology not to implement it. In addition, stakeholders must perceive the evaluation as a credible and unbiased effort. Establishing and maintaining stakeholder trust will require ongoing communication and regular engagement with them.

Chapter VIII presents the guidance from participants about possible barriers or concerns to consider during the development of a stakeholder engagement strategy. The key concerns or barriers include: trust, public understanding of DSTP, misperceptions or a lack of knowledge about DSTP, regulatory, and technical issues. Participants also identified best practices for stakeholder engagement.

THE PATH FORWARD

In 2013, the Consortium engaged a group of technical experts to identify knowledge gaps and research needs. In the 2014 workshop, the Consortium reached out to a wider range of stakeholders to gather additional guidance on how to implement the studies and foster collaboration. The Consortium has obtained feedback from a wide range of stakeholders and will use this guidance to develop a path forward. The Consortium is committed to keeping stakeholders informed of the Initiative's progress and maintaining full transparency while the research is carried out.

I. Introduction

The competition for land use in the central region of Chile is a national issue. The central region enjoys a relatively mild climate and land in the central region is fertile. It is ideal for agriculture, including farming, cattle, and wine production. It has recreational uses and is used for residential living. It also provides a habitat for wildlife. The desirability of the land and its multiple uses have created a situation where the competition for land is continuing to increase and becoming an increasingly important national issue.

Since the central region also has copper resources, copper production presents another source of competition for land in the central region. Copper production is tremendously important to Chile as a driver of economic prosperity. It has helped to make Chile's economy one of the strongest and most robust of Latin America. In addition, copper is an important material that serves a variety of uses within the global electrical, electronic, construction, transportation, industrial machinery, and consumer product sectors. Copper production in Chile accounted for over one-third of the world copper mine production in 2012, with a mine output of over 5.4 million tonnes of copper.

The importance of copper nationally and globally exacerbates the land use issue. Copper mines in the central region currently dispose of their tailings in land based tailings dams. Tailings dams are designed to isolate the tailing residue from the surrounding environment and water table but require large areas of land. Permitting regulations require each mine to provide a viable option for tailing disposal prior to the start of mining operations. Thus, the amount of copper available to be mined is limited by the capacity of tailing disposal options.

The sizes of the ore deposits in the central region are such that the production capacity of the mines exceeds the disposal capacity of current tailings dams. As current tailings dams reach their capacity, the mines will have to establish additional disposal capacity either through the construction of additional dams or the development of alternative disposal methods. The construction of additional dams will be a serious challenge given the current multiple uses of land in central Chile. It is therefore of national importance to explore alternative methods of tailings disposal.

One alternative method of disposal that is currently being used in other countries is Deep Sea Tailing Placement (DSTP). As with all methods of disposal, DSTP has potential benefits and potential risks. Chile and the mining industry will only use an alternative method such as DSTP if it can be shown to be viable from human health, social, and environmental perspectives. For this reason, a group of mining companies has joined together in a consortium for the purpose of implementing a comprehensive research initiative. This DSTP Initiative is designed to develop the scientific and technical knowledge necessary to conduct an objective and informed assessment of DSTP and determine whether or not it should be pursued as a viable alternative to land based disposal.

[1] Jamasmie, Cecilia. "Chile the largest copper producer and the country with the biggest reserves – USGS." *MINING.com*. http://www.mining.com/chile-the-largest-copper-producer-and-the-country-with-the-biggest-reserves-usgs/

[2] International Copper Study Group, *The World Copper Factbook 2013* (Lisbon, Portugal: International Copper Study Group, 2013), http://www.icsg.org/index.php/component/jdownloads/finish/170/1188

PURPOSE AND SCOPE OF THIS DOCUMENT

This proceedings document presents the results of a 2014 Knowledge Workshop, which took place on January 22-23, 2014 in Viña Del Mar, Chile. This workshop is part of the DSTP Initiative. It builds on and expands the work presented in the 2013 Deep Sea Tailing Placement Roadmap. The DTSP Roadmap engaged national and international technical experts, scientists, and researchers to identify key knowledge gaps regarding DSTP and map out a set of research programs to address those gaps. The 2014 Knowledge Workshop Report engaged a broader range of stakeholders to develop more specific guidance regarding the actual design and implementation of the research studies to ensure that the research is carried out in a socially responsible manner and that valid and useful knowledge is produced. In addition, the 2014 Workshop addressed nontechnical issues not covered in the technically focused roadmap. Specifically, these proceedings present guidance for maintaining engagement with stakeholders and addressing the potential social impacts of the research.

Existing Practices of Sea-based Disposal

There are three types of sea-based disposal practices: Shoreline Disposal, Shallow Waters Disposal, and DSTP.

Shoreline Disposal: Disposal of tailings directly on the surface of rivers, lakes, and sea.

Shallow Tailings Disposal (STD): Disposal of tailings below the upper stratified layer.

Deep Sea Tailing Placement (DSTP): A method whereby the tailing slurry is deposited below the mixing zone by the force of gravity from a submerged pipeline into a depth that does not allow transfer of tailings to surface waters.

The DSTP Initiative does not include Shoreline or Shallow Tailings Disposal and will only evaluate DSTP as a possible alternative to land-based disposal.

DOCUMENT STRUCTURE

The remainder of this document is organized as follows:

- Chapter II focuses on the Consortium Research Group, the entity that will carry out the research program.
- Chapter III presents a brief overview and history of the overall DSTP Initiative.
- Chapter IV presents an overview of the 2013 Deep Sea Tailing Placement Roadmap and the transition from the DTSP Roadmap results to the 2014 Knowledge Workshop Report.
- Chapter V presents the detailed guidance for carrying out the research studies.
- Chapter VI presents a conceptual framework for analyzing the relative risks of land versus deep sea disposal of tailings.
- Chapter VII outlines the social issues research and community involvement guidance.
- Chapter VIII outlines key considerations for stakeholder engagement.
- Chapter IX discusses the path forward.

DSTP CASE STUDY: Batu Hijau (Indonesia)


Photo Courtesy of Google Earth, © 2013 GeoEye

The Batu Hijau mine is located on the island of Sumbawa, which is in the eastern part of the Indonesian Archipelago. The mine has been in operation since 2000, and plant treatment is 160 kilotons per day. The property is owned by PT Newmont Nusa Tenggara (PTNNT), a subsidiary of Newmont Mining Corporation.

Deep sea tailing placement (DSTP) was chosen for tailing disposal during an environmental impact analysis because of numerous reasons related to minimizing the impact on the environment. PTNNT concluded that on-land disposal would have introduced the potential for numerous environmental risks resulting from the area being susceptible to earthquakes, complications due to high annual precipitation, and the impact on productive jungle and agricultural lands. Instead, it was determined that placing tailings below the biological productive photic zone of the sea reduces the potential impact tailing disposal can have on the environment.

In the Batu Hijau DSTP operation, a pipeline carrying tailings in slurry form runs from the ore processing facility to the Senunu Submarine Canyon, ending about 125 meters below the surface of the sea and approximately 3.2 kilometers from the shoreline. The tailings sink because the density of the tailing slurry exceeds seawater; most deposit around 3,000 meters, while some continue to the bottom of the Lombok basin, a depth that exceeds 4,000 meters.

The Batu Hijau DSTP system is subject to an intense monitoring program that measures the chemistry of tailings, water, and sediment; the tailings' footprint; and plume tracking. In addition, independent researchers have conducted multiple studies on the area. In 2004 and 2009, scientists from the Commonwealth Scientific and Industrial Research Organisation and an Indonesian peer-review team provided an independent review of PTNNT's data. The study confirmed that the tailings are not polluting seawater in the area. The researchers found that the tailings did not disperse to surface waters, to the coastal environment of Sumbawa, or toward the Alas Strait and Lombok. The study also revealed that fish from Senunu Canyon displayed levels of metal concentrations similar to those found in fish from control sites. Dissolved metal concentrations at all sites and depths were found to be below the defined standards.

In 2003 and 2009, the Research Centre for Oceanography-Indonesian Institute of Sciences conducted deep sea surveys that found that the water quality outside of the tailings mixing zone complied with the government of Indonesia's marine water quality standards. Findings indicated that the tailings' only impact on water quality occurred in the bottom waters of Senunu Canyon.

Source: Aurys Consulting. Case Studies of STD and DSTP in the World. Santiago, Chile.

This page intentionally left blank

II. The DSTP Consortium

The combination of land scarcity, high density population areas in central Chile and the need for expanded disposal capacity challenge the future development of the mining industry in this area. The anticipation of this future challenge motivated mining companies operating in Central Chile to search for alternatives that will allow continued development of the industry and the country. This search led to the launch of the DSTP Initiative and the creation of an independent Consortium to manage it. The independence of the Consortium enables it to provide objective and impartial oversight.

Given the lack of information about DSTP in Chile, an exploratory stage was started in 2011. The objective was to gather information, review the relevant scientific information that is currently available, identify relevant stakeholders, compile international experience, and conduct site visits (see Batu Hijau case study above).

This exploratory process indicated that DSTP is a feasible and applicable technology. It also indicated that while there are diverse experiences with the technology, the good experiences were based on solid scientific investigation and best management practices. Accordingly, the Consortium convened a workshop of international experts, national and international scientists to identify critical gaps in the knowledge required to make a scientific and technical evaluation of DSTP. This workshop was held in August 2012 and delivered the DSTP Roadmap that identified different research studies.

ROLE OF THE CONSORTIUM GOING FORWARD

Given the work already completed, the Consortium is now charged with two primary tasks. The first is to provide independent oversight and management of the research studies identified in the DTSP Roadmap. The Consortium will ensure that they produce the scientific and technical knowledge necessary to objectively assess the feasibility of DSTP in Central Chile. The Consortium's oversight and management role will involve a number of challenges, including the selection of research teams, the oversight and coordination of their efforts, the validation and integration of the findings, and so on.

The second task for the Consortium is to design and implement a plan for involving and collaborating with stakeholders. DSTP is an issue that is of interest to a diverse group of stakeholders. In order for the Initiative to be successful, it is essential that stakeholders are involved in the process and understand its purpose is to evaluate the technology not to implement it. In addition, stakeholders must understand the evaluation as a credible and unbiased effort. Establishing and maintaining stakeholder trust will require ongoing communication and regular engagement with them.

In addition, to these primary tasks the Consortium will also be looking for alternative sources of funding for the research programs. To this point, the DSTP Initiative has been funded by mining companies. However, in order for the Consortium to maintain its independence and be acknowledged as generating credible and unbiased research results, in addition to ensuring scientific excellence, alternative sources of funding must be found.

Finally, the Consortium recognizes that if DSTP is found to be a viable option, its use will require a strong regulatory framework. Accordingly, the Consortium will work with Chilean regulatory authorities to strengthen the regulatory framework and enhance their capacity to assess and regulate the use of DSTP if it is deemed a viable disposal option.

PRINCIPLES OF OPERATION

The Consortium recognizes the importance of establishing and maintaining stakeholder trust. It also recognizes that trust is earned through the demonstration of integrity and principled action. The Consortium is committed to carrying out the DSTP Initiative in accordance with the values of transparency and openness, scientific integrity, sustainability and service to the greater good. The Consortium is also committed to using Chilean-based resources whenever possible.

The Consortium will also maintain a strong sense of purpose and a focus toward informing a decision about the viability of DSTP. The DSTP Initiative represents a different approach to determining the direction of the mining industry. Rather than treating the evaluation as a unilateral business decision, it is being carried out in a spirit of openness and collaboration.

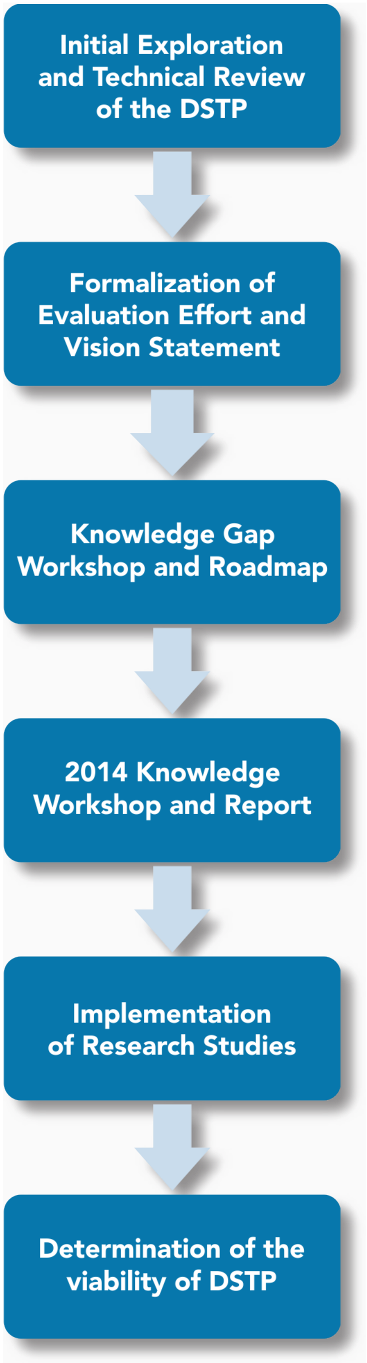
III. The DSTP Initiative

This document presents the results of the 2014 Knowledge Workshop. This workshop is part of a larger initiative to evaluate the viability of DSTP from environmental, social, and human health perspectives. This chapter presents a brief overview of the DSTP Initiative as a context for understanding the information presented in this proceedings document.

The graphic and narrative below explain the key milestones of the DSTP Initiative both before and after the Knowledge Workshop.

The evaluation of DTSP began with an ***initial exploration and technical review*** of the technology. Mining engineers and technical experts from Chile visited the sites where DSTP is currently being used and tapped the knowledge of international experts on DSTP. The technical review led to the conclusion that there was insufficient scientific and technical knowledge to evaluate the human health and environmental viability of DSTP for Central Chile.

Based on the results of the technical review, the ***evaluation effort was formalized*** and the following ***vision statement*** was developed: *"To generate the information and scientific and technological knowledge needed to evaluate a sustainable deep sea tailings placement, ensuring their viability from the human health and environmental perspectives."*



The vision statement provided the basis for the ***Knowledge Gap Workshop*** and the production of the ***2013 DSTP Roadmap***. The workshop engaged national and international scholars and subject matter experts to identify key knowledge gaps and outline broadly the research studies that would be needed to address those gaps.

Although the roadmap produced high-level plans for the research studies, they were not sufficient to allow the Consortium to fully and effectively manage the research. In addition, the roadmap did not address either the stakeholder communication and engagement or the social impact of the field research on the local communities (see Chapter VII). The **2014 Knowledge Workshop** was designed to address these additional issues and provide more detailed on the studies.

The next step will be for the Consortium to ***implement the research studies***, including the selection of the research teams, the execution of the studies, and the review and validation of the results. This step will also include the assessment and mitigation of the social impact of the research itself. Finally, the Consortium will be maintaining ongoing communication and engagement with stakeholders.

After the research is completed, the results will be used to ***determine the human health and environmental viability of DSTP***. Included in this study will be an assessment of the relative risk of DSTP and land-based disposal of tailings (see Chapter VI.)

This page intentionally left blank

IV. Transition from the 2013 DSTP Roadmap to the 2014 Knowledge Workshop

The Consortium will only pursue DSTP as a potential alternative to land-based disposal if it can be shown to be viable from a human health, social, and environmental perspective. Although, DTSP is being used by other countries, the current state of scientific and technical knowledge is not sufficient to make an informed determination of its human health and environmental viability for Chile. The purpose of the DSTP Roadmap was to identify the critical knowledge gaps and map out a comprehensive research program to address those gaps.

The 2014 Knowledge Workshop builds upon the results in the DTSP Roadmap by drawing on the perspectives, experience, and expertise of a broader range of stakeholders and by considering a broader range of issues. This chapter provides an overview of the process used in the DSTP Roadmap Workshop and the subsequent transition to the 2014 Knowledge Workshop.

IDENTIFICATION OF RESEARCH STUDIES

The DSTP Knowledge Gap Workshop led participants through a structured process to identify the research studies needed to address the key knowledge gaps regarding DSTP. As a starting point, participants were provided with the vision statement:

> *To generate the information and scientific and technological knowledge needed to evaluate a sustainable deep sea tailings placement, ensuring their viability from the human health and environmental perspectives.*

The structured process involved three main activities that followed a logical flow designed to help the participants make effective, focused, and systematic judgments—each activity provided the conceptual context for the following activity. In order of occurrence the workshop activities were:

- Identify the determining factors that establish the scope of information and technical/scientific knowledge necessary to evaluate DSTP in accordance with the vision.
- Within that scope, identify the critical knowledge gaps that must be addressed to evaluate DSTP in accordance with the vision.
- Determine the research studies to address key knowledge gaps and produce the scientific and technical knowledge necessary to evaluate DSTP in accordance with the vision.

Figure 1 (on the next page) provides a graphical representation of the logical progression of the structured process from vision to research programs.

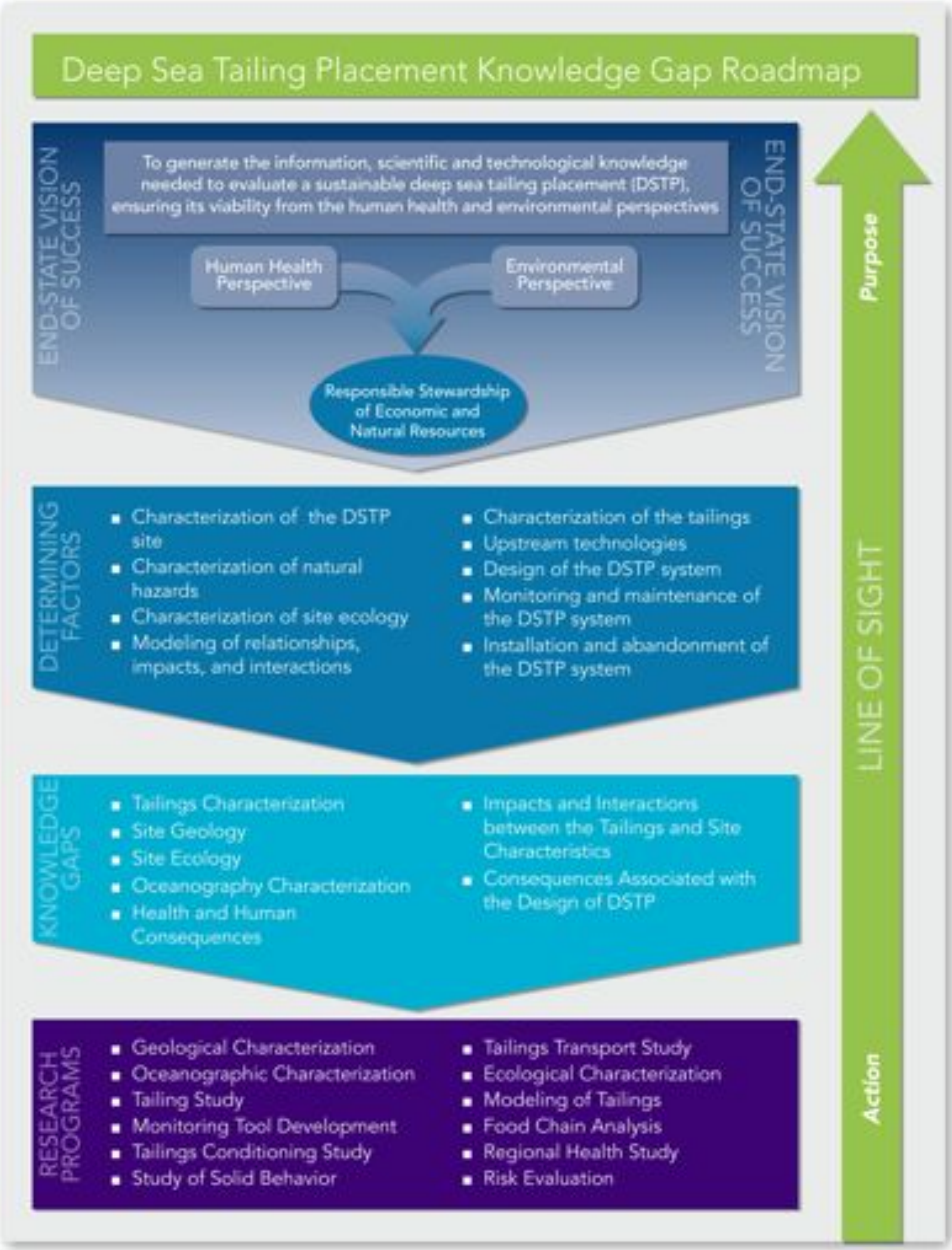
Determining Factors

The determining factors are the range of variables, phenomena, interactions, etc. that determine the potential environmental and human health impacts of DTSP. They represent the entire realm of relevant information and technical and scientific knowledge. They provide the basis for identifying knowledge gaps—what is not known that needs to be known in order to evaluate the feasibility of DSTP. Each determining factor provides a bridge for linking the knowledge gaps to the vision.

The DTSP Roadmap identified nine determining factors that can be organized into three categories:

- *Technology Related Factors* characterize the scope of technical and engineering knowledge about the DSTP technology and its installation, deployment, and termination.

Figure 1: DSTP Roadmap Structure and Content



- *Site Related Factors* characterize the scope of knowledge concerning the area of the site where the tailings may be deposited, including any conditions or features that may affect and be affected by the deployment of DSTP.
- *Cause-Effect Related Factors* subsume all of the phenomena related to the use of DSTP. It defines the scope of knowledge about the interaction between the technology factors and the site factors.

Knowledge Gaps

Knowledge gaps are gaps in what is known among the nine determining factors that are critical to evaluation of the viability of DSTP. These gaps represent characteristics, variables, or results that have not been systematically researched, tested, or validated, or are insufficient or ambiguous understanding of the interactions among variables or substances.

Research Studies

The careful progression from the vision through the determining factors and knowledge gaps was designed to enable experts to identify a complete and comprehensive set of research studies aligned to the vision.

The Knowledge Gap Roadmap presented high-level plans for 12 research programs.

1. Bathymetry, Seismology, and Geological Characterization Study
2. Oceanographic Characterization Study
3. Tailing Characterization Study
4. Monitoring Tool Development
5. Tailing Conditioning Study
6. Study of Solids Behavior
7. Tailing Transport Study
8. Ecological Characterization Study
9. Modeling of Tailings
10. Food Chain Analysis Study
11. Regional Health Study
12. Theoretical Evaluation of Relative Risk

HOW THE 2014 KNOWLEDGE WORKSHOP BUILDS ON THE 2013 DTSP ROADMAP

The high-level plans presented in the DTSP Roadmap provide a general understanding of the purpose, rationale, outcomes of each study and are intended as a starting point for selecting and directing the research teams conducting the studies. The 2014 Knowledge Workshop sought to build on the high-level plans and provide more detailed guidance to the Consortium Research Group.

Down Selection of Studies

Prior to the Knowledge Workshop, the decision was made to postpone the consideration of the Regional Health Study and Monitoring Tool Development because they both assume that DSTP has already been found to be viable. Their inclusion into the workshop would be premature and could be misinterpreted as indicating that the evaluation of DSTP's viability had already been made.

Bathymetry, Seismology, and Geological Characterization were not considered in the Knowledge Workshop because the studies are underway.

Consolidation and Addition of Research Studies

Accordingly, the workshop focused on nine studies. In order to make the task more manageable for the workshop participants, some of the remaining studies were consolidated. In particular, the Tailing Characterization Study and the Tailing Conditions Study were combined due to their considerable overlap. Similarly, the Study of Solids Behavior, the Tailing Transport Study, and the Modeling of Tailings were also combined.

For purposes of the 2014 Knowledge Workshop, participants were asked to develop guidance for the following lines of research:

1. Oceanographic Characterization Study
2. Tailings Characterization and Conditioning Studies
3. Study of Solids Behavior, Tailings Transport Study, and Modeling of Tailings
4. Ecological Characterization Study
5. Food Chain Analysis
6. Theoretical Evaluation of Relative Risk
7. Study of Social Issues and Community Impact

The Study of Social Issues and Community Impact is focused on understanding the social impact of the DSTP initiative on communities. This has always been an important consideration within the DSTP Initiative, but was outside the technically focused DSTP Roadmap Workshop. It was, however, deemed an appropriate consideration for the 2014 Knowledge Workshop with its broader range of participants.

This page intentionally left blank

V. Research Program Guidance

The 2013 Deep Sea Tailing Placement Roadmap presented high-level plans for the research studies needed to address the gaps in the current scientific and technical knowledge regarding DSTP. These high-level plans outlined the purpose, rationale, and overall outcomes of each study, but did not go into detail about how that research program should be carried out. One of the purposes of the 2014 Knowledge Workshop was to develop more specific guidance to help the Consortium provide independent oversight and management of the research studies.

The consolidation and addition of research studies described in the previous chapter resulted in seven lines of research. The next three chapters present the guidance for the lines of research developed by the 2014 Knowledge Workshop. This chapter presents the guidance for the first five lines of research:

1. Ecological Characterization Study
2. Oceanographic Characterization Study
3. Tailings Characterization and Tailing Conditioning Studies
4. Study of Solids Behavior, Tailings Transport Study, and Modeling of Tailings
5. Food Chain Analysis Study

The scope of the scientific program is to generate scientific knowledge necessary to analyze the sustainable viability of DSTP in Central Chile and has a value in itself. Considering the stakeholder involvement in the 2014 Knowledge Workshop the program incorporates different points of view, (scientific, industry, NGO, regulatory agencies). This information will not be site specific and will be available for the community.

Besides the funds the Consortium will provide to ensure the deployment of the Research Program, Chile should increase its own capacity for applied research.

Additionally, the research program should promote international collaborations – training by research consortiums, including international scientists. Training should include mining company employees to ensure everyone has the same vision and opportunity for training. Companies should employ staff with knowledge of environment.

The guidance for the Evaluation of Relative Risk and the Study of Social Issues and Community Impact are presented in Chapter's VI and VII respectively. These two areas are treated differently from the research programs because they have a different scope

STRUCTURE OF THE RESEARCH GUIDANCE

The guidance provided by the workshop participants is structured around both the design of the research and issues regarding the practical implementation of the research studies.

Research Design

Research Design establishes the basic structure and logic for the creation of scientific knowledge from the application of research methods. Guidance was provided on the following elements of research design:

Research Questions establish the focus of the study and help define the purpose of the study and the nature of the results. Research questions also help to ensure that the study has a purpose that lends itself to empirical investigation.

Research Inputs and Assumptions establish the starting point of the research and the foundation on which the study will build. The inputs and assumptions establish the facts and knowledge that are taken as given. The inputs in particular help to identify a study's dependencies to the other studies in the DSTP Initiative.

Data Analysis Guidance provides advice about how the data should be analyzed in order to answer the research questions. This advice may include suggestions for specific analyses or tests to be conducted, the range or types of analyses to be used, or recommended analytic approaches.

Data Collection Guidance helps to identify what data is to be collected for the study. This includes the scope of the physical phenomena, events, organisms, etc. to be studied and the measurements to be taken of the phenomena, events, organisms, etc., and when, where, and for how long the measurements are to be made.

Data Collection Methods, Tools, or Approaches comprise advice and suggestions for how the data should be collected.

Implementation

Implementation concerns the concrete decisions, activities, and considerations that address the practical challenges of actually carrying out a research study. Guidance was provided on the following elements of implementation:

Suggested Resources – This section provides guidance regarding the specific people, groups, institutions who are qualified to conduct the research. Since the evaluation is focused on the use of DSTP in Chile, participants were directed to identify resources within Chile first, and only identify international resources as needed.

Regulatory Frameworks and/or Standards – This section identifies the regulatory frameworks that are relevant to conducting the field research within Chilean waters and that need to be considered and understood by the research teams. This section also identifies official and/or scientific standards that should be considered or applied to the research.

Suggested Criteria for Completion of Study – This section identifies the criteria that must be met in order to consider the research study to be complete. It recognizes that there are practical limitations to every research study even though it is always possible to collect more data.

Suggested Phases/Milestones – This section maps out a set of suggested steps or milestones that the research team will have to implement in order to carry out the study.

Specific Questions – For some lines of research there is a set of specific questions that ask for additional guidance about specific issues in the design or implementation of the research.

Keep in mind that the workshop participants provided this guidance to help the Consortium in its role of providing independent oversight and management of the research. The guidance is made up of suggestions, ideas, and information for the Consortium to consider, but is not intended as a set of mandatory directives.

Ecological Characterization Subprogram

Research Design Guidance

Research Questions

Possible Research Questions

1. What is the species composition of the deep sea community?
2. What is the scale and variability (temporal and spatial) of some phenomena, such as El Niño, and how do they affect relevant communities (pelagic, benthic and planktonic)?
3. What are the endemic species or communities and their characteristics (endangered, have economic value, etc.) that exist at the study area, at the depth of disposal (end of the pipe line), at the DSTP site (depth at which the tailing comes to a rest), and in nearby areas?
4. What are the population relevant interactions between sediments and the microbial communities associated to the oxygen minimum zone (synergistic effects with metals)? How upwelling can affect distribution of the oxygen minimum zone and hence redox conditions in the benthic and pelagic systems?
5. Is the study area sinks or sources of propagules or nursery areas?
6. Are the study areas critical in terms of marine conservation, upwelling and marine mammals' migration routes and need to be avoided?
7. Will sediment plumes from tailings and re-suspension affect species with dependency on light (population relevant effects)?
8. Are mechanisms/functions seen in shallow species similar to those present in deep sea organisms?

Research Inputs & Assumptions

Suggested Inputs:

- Definition of study area.
- Bathymetric, oceanographic and meteorological information (before and during all the ecological studies).
- Literature review and gap analysis of information.
- Given the complexity and difficulties to measure oxygen at depth over 1000 meters, consider mesocosmos experimental studies to assess redox processes at the sediment-water interphase.

Assumptions:

- Tailing deposits have an estimated footprint, and a turbidity plume.

Data Analysis Guidance

- Data analysis should include gathering of existing data sets.
- Data analysis should include traditional analyses (bug counting) as well as ecogenomics (eDNA) and other more holistic approaches that are complementary to traditional methods.
- Statistical analyses of data will likely include both univariate and multivariate methods.

Data Collection Guidance
Scope or population of variables to be considered or included in the study:
• Structure and dynamics of communities: (benthic, pelagic and planctonic): including diversity, abundance, taxonomy, biomass, etc., for both in-shore and off-shore of the study areas. • Microbial communities in the oxygen minimum zone. • Other communities, such as marine mammals and birds. • Paleo oceanography (for interdecadal phenomena). • Key input: long-term (4-5 years) understanding of the particulate/dissolved matter suspended and re-suspended in the water column.
Measurements to be taken of the variables – attributes, properties, parameters to be assessed, tracked, compared, baselined:
• Turbidity is needed to identify the whole range of possible turbidity data in the area. • Need to understand and assess the "function" of organisms and organism traits within the ecosystem. (The aim is to not change the "functioning" of the ecosystem – some individual species may be lost, but the function may be replaced by others).
Temporal and spatial requirements for data collection, including options and parameters for sampling:
• Ongoing monitoring for key parameters (oceanographic buoys, current meters, ROVs) during the duration of the research programs. • Frequency of ecological sampling should be determined based on expert judgment and nature of the variable to be sampled.

Data Collection Methods, Tools, or Approaches		
Methods	Tools	Models
• Satellite • ROVs • Oceanographic ship • Scuba diving • Underwater in situ visualization (UVP) • Any other available method	• Box core • Piston core • Plankton nets • Nets and training equipment • Mega corer • Any other available tool	• Ecosystem local, mid-scale and large-scale models

Implementation Guidance

Suggested Areas of Expertise and/or Resources (people, groups, institutions) for this Subprogram

For the development of this sub-program, the following main areas of expertise were suggested

- Benthos soft bottom
- Benthos hard bottom
- Paleo oceanography
- Mammals/birds
- Meroplankton
- Holoplankton
- Icththyoplankton
- Pelagic nekton
- Pelagic microbiology
- Microbiology of seabed
- Modelers
- Processor/ Sedimentation biogenic matter

Regulatory Framework &/or Standards to Consider

- Notices of Intent.
- Permits for research studies (Navy).
- Standards for sampling and analysis (scientific).
- Standards for modeling (scientific).

Suggested Phases/Milestones of this Subprogram

1. Literature review, inputs from other groups (study area definition), scenarios/assumptions of the research program (key inputs suspension and re-suspension).
2. Planning and sampling design.
3. Exploratory campaign and methodological adjustment.
4. Research campaigns.
5. Modeling, analysis (with inputs from other groups).
6. Scientific validation and dissemination.
7. The Subprogram on Ecology should also produce scientific reports and publications, conduct workshops, develop websites (raw data available on websites).

Suggested Criteria for Completion of this Subprogram

- Information is exhaustive, representative, and statistically significant.
- Inter-annual variability is characterized.
- Inter-decadal phenomena (Niño) using proxies (paleoceanography) is known or at least is understood.
- Through scientific community validation (peer reviews, journals, etc.).
- This subprogram will produce scientific reports and publications, conduct workshops, develop websites (raw data available on website).

Other Considerations & Guidance

- Need to disseminate results and "translates" into understandable messages to all stakeholders.
- A good interaction between groups is needed.
- Taxonomy and functionality of different groups (structure and functioning of ecosystems) should be identified.
- Need to evaluate ecosystem singularity.
- Information should be able to be rated in terms of relevance (uniqueness).
- Mesocosms experts should be considered as a possible resource to count on.
- Diversity, abundance, taxonomy, biomass and structure, in conjunction with oceanographic monitoring (chemical, physical) and granulometry, organic matter, pH, sedimentary and water column organic carbon.

Oceanographic Characterization Subprogram

Research Design Guidance

Research Questions

Possible Research Questions

1. What are the properties of the upwelling at the study area?
2. What polar currents are relevant to the study area?
3. What is the stratification of the water column due to water masses at the study area?
4. What are the sediment properties (grain size) at different sites in the study area?
5. What is the natural sedimentation rate at the study area?
6. What are the near bottom physics, including the nepheloid layer?
7. What are the water column characteristics (oxygen, redox) at the study areas?
8. What is the phytoplankton production at different levels of the water column at the study area?
9. What is the microbial mineralization at different levels of the water column at the study area?
10. What is light penetration and quality in the water column? This parameter is affected by suspended material.
11. What are heavy metals, TOC in the sediments at the site and in nearby areas?

Research Inputs & Assumptions

Suggested Inputs:

- Overview of existing data and publications.
- Servicio Hidrografico Oceanografico de la Armada de Chile (SHOA) including bathymetry.
- Quality assurance of existing data.
- Fishery institutes, universities, research institute (data bases).

Data Analysis Guidance

- Conduct long data series statistical analyses (2-3 years).
- Analyze inter-annual changes and seasonal variability.

Data Collection Guidance

Scope or population of variables to be considered or included in the study:

- Upwelling, internal waves, turbidity currents triggered by slumps, wind based waves, tsunamis triggered by slumping and earthquakes. El Niño and climatic effects.
- Seismological (seismicity) with tsunami characterization.
- Chemical constituents (nutrients, etc.).

Measurements to be taken of the variables – attributes, properties, parameters to be assessed, tracked, compared, baselined:

- Current speed/direction, sea level variation, salinity, temperature, DOX, nutrients, pH, chemical analyses of heavy metals and other relevant chemicals to DSTP project (floatation chemicals and flocculants), wind speed, biodiversity (pelagic/benthic).
- Inter-calibration of collections and analyses of samples.

Temporal and spatial requirements for data collection, including options and parameters for sampling:

- The frequency and the duration of the sampling will depend on the variability of the parameters to be measured.
- Ensure seasonality is taken into account.
- Moorings to measure upwelling for a minimum of 2 years, but then use vortex mesocosms.

Data Collection Methods, Tools, or Approaches

- Stable (permanent) system, sampling of water/sediments, satellite use (wave, wind).
- Meteorological stations.
- Sampling grid (spatial variability).
- ADCP, HF Marine Radar.
- OBS (observation systems), turbidity sensors.
- Sensors for nutrients and turbidity.
- Mooring systems by slope.
- Ocean glider/sea glider, AUV with multi-beams, benthic landers, ROVs.

Implementation Guidance

Suggested Areas of Expertise and/or Resources (people, groups, institutions) for this Subprogram

For the development of this sub-program, the following main areas of expertise were suggested

- Deep sea-offshore.
- Sediment transport.
- Modeling of distribution.

Selected resources also need:

- Infrastructure for carrying out studies in field.

Potential resource:

- Universities and institutes related to marine science in Chile and abroad.

Regulatory Framework &/or Standards to Consider

- Servicio Hidrografico Oceanografico de la Armada de Chile (SHOA) regulations (D.S. N° - 711).
- Maritime Safety Regulation (Permission for sailing, diving, etc.).

Suggested Phases/Milestones of this Subprogram

1. Overview of existing data (collection, database development, data quality assessment).
2. Identification of gaps coupling to ToR.
3. Design program to fill gaps, e.g., modeling, look for expertise and resources.
4. Carry out research program, e.g., deployment of moorings – current meters, instruments, sampling (include Ph.D. students).
5. Produce scientific reports and publications, conduct workshops, develop websites (raw data available on website).

Suggested Criteria for Completion of this Subprogram

- Information is exhaustive, representative, and statistically significant.
- Inter-annual variability is characterized.
- Inter-decadal phenomena (Niño) using proxies (paleooceanography) is known or at least is understand.
- Through scientific community validation (peer reviews, journals, etc.).

Other Considerations & Guidance

- Long-term (2-3 years) monitoring of effects and trends.
- Information should be able to be compared in terms of local/regional context.
- Geochemical transformation of metals in sediments, e.g., oxic vs anoxic conditions, Consider to use mesocosmos experiment protocol.
- Baseline ultratrace metals in water (e.g., parts per trillion is background), sediments, biota.
- Must include microbial communities for oceanographic characterization.
- Must use correct sampling techniques – not excluding box coring for sediment. Special care should be taken to avoid that waves remove surface sediment at the sediment/water interface where most of the chemical transformations take place and where micro and macro fauna are found.
- Important to understand what biogeochemical processes predominate in "baseline" conditions of site as that data will be required for predicting behavior of tailings when deposited on sea bed, including determination of metal release and availability. Do not exclude mesocosmos experimental studies.
- Research and collected data should last as long as decisions can be fed with field measurements.

Specific Questions

What data is needed to conduct a good model?

- Topography-bathymetry.
- Time series measurements.
- Currents.
- Wind.
- Surface heat fluxes.
- Sea level – tide gauges.
- Oceanographic data from water column (temperature, salinity, nutrients, DO).

Tailing Characterization & Tailing Conditioning Subprogram

Research Design Guidance

Research Questions

Possible Research Questions

Characterization:

1. What are the chemical, physical, and toxicological properties of the tailings?

Conditioning:

2. Can we reduce metal load before discharge?
3. Preconditioning, how can we increase particle size, flocculation/aggregation and what possible after effects could that have?
4. Can we reduce amount of flotation-chemicals/reduce toxicity of flotation chemicals?
5. Quality of production water; determine how variation in the quality of the production affects the tailings composition and behavior.
6. What is the bioavailable fraction in the tailings?
7. What are the implications of variations on the mine material and its combination with water quality on physic-chemical composition and flow of the tailings?
8. What are the absolute limits of solids physical and physic-chemical characteristics? This is required to properly assess the flow properties and the corresponding mixing characteristics of tailings?

Research Inputs & Assumptions

Suggested Inputs:

- A previous assessment of the possibilities regarding tailings pre-treatment and flocculation is needed. This should be made in connection with the team that assesses the environmental impact of the deposited substances.
- Samples that cover all possible types of tailings depending on state/age of tailings that will be processed, including pile stocks and study a site where Cu-tailings were deposited in the past and to measure release rates of metals, etc.
- Mine-held data - original data etc. on tailings gathered by mine, including information on methods of aggregation/flocculation (chemicals & physical).
- Water and solid characterization of each operation.

Data Analysis Guidance

Suggested Analyses:

- Metal bioavailability studies – both chemical approaches and biological – direct methods. A range of approaches, both chemical and biological, may be required to assess the potential bioavailability to organisms of DSTP-derived metals in the waters, suspended solids and sediments. These may be generic, or specific to individual types of organisms. As bioavailability is fundamental to risk assessment, the assessment of bioavailability will be considered in many of the Research Subprograms, particularly within the 'Tailings Characterization and Conditioning' and 'Food chain Analysis' Subprograms.
- Direct toxicity assessment of waters. Whole-sediment ecotoxicology using lethal and sub-lethal (chronic) endpoints – tailings and tailing/sediment mixtures; Link ecotoxicology to speciation; Link ecotoxicology to bioavailability; Link ecotoxicology to guidelines (site-specific) and link to ecology (recolonization of covered areas).
- Compare bioavailable concentrations with sediment quality guidelines, rather than total concentrations → risk-based assessment approach.
- Consider fine and coarse grained fractions to analyze metal reduction load before discharge.
- Estimate the bulk input of heavy metal to the bottom[3].
- Identify boundaries for accepted chemical substances that may be used, e.g., in the case of flocculants.

Indicative list of tests to fully characterize the toxicity of tailings in seawater

1. Surface charge
2. Surface area, BAT
3. Particle size distribution
4. Chemical composition
5. Specific gravity
6. Water content
7. Mineralogy composition
8. Particle shape
9. Settling velocity
10. Apparent viscosity
11. Liquid density
12. Metal partition coefficients Kd
13. Dissolution transformation
14. Sequential leaching
15. pH, DO, etc., standard quality measurements
16. Speciation of metals in solution
17. Organic content
18. Bioavailability of metals

Data Collection Guidance

Scope or population of variables to be considered or included in the study:

- At this stage, it is important to look at metal release and the effect on representative organisms (including mechanisms of protection[4]). It is important to consider deep sea benthic organisms.
- Temperature of the tailing slurry should comply with Chilean discharge limits indicated in the regulations. Also consider whether temperature can be modified to reduce impact and help with coherent discharge/reduce risk of buoyancy).
- Whole-sediment ecotoxicology – impacts to reproduction (lethal and sub-lethal impacts to populations[5]).

[3] Estimation of the amount of heavy metals should come from tailings characterization and tailings dispersion/behavior modeling. This will need to be assessed through monitoring if DSTP is actioned

[4] This will be addressed in the Food Chain Subprogram, see section on Scope or Population of Variables to be considered or included

[5] Ibid

Measurements to be taken of the variables – attributes, properties, parameters to be assessed, tracked, compared, baselined:

- Interaction with seawater, portioning between solution and solid, separation of metals, how the speciation will change with seawater variables, for example, Fe(II)/Fe(III), U(IV)/U(VI), As(III)/As(V), Cr(III)/Cr(VI), Cr have a number of oxidation states, some have more bioavailable and higher toxicity than others.
- Bioavailability of metals – representative[6].
- Need to ensure that toxicity tests are carried out on representative/relevant organisms[7].
- Full range of tailing measurements to track material changes.

Temporal and spatial requirements for data collection, including options and parameters for sampling:

- Understand the effects of temperature, pressure, time (Age of the slurry), salinity, microbial processes, DO, organic matter on transformations.
- Before DSTP decision taken, construction of a statistically valid experiment to deliver results.
- Repeated each time there is a significant change in ore body or processes.
- Need to ensure that all types of tailings are tested.
- Mainly onsite – in the first instance, but then use mesocosms vortex moving on to pilot study at chosen site.

Data Collection Methods, Tools, or Approaches

- Desktop review of all available data and state-of-the-art methodology (International standards).
- Internationally recognized analytical and sampling methods (CPMS, Laser diffraction, etc.).
- Quality assurance/protocol (via accreditation or protocol and quality control).
- Theoretical thermodynamic models are available that can predict behavior but must collect data for each specific case.
- Consider plume shearing and dispersion when modeling the plume. Data collection should be consistent with plume shearing and dispersion.

Implementation Guidance

Suggested Areas of Expertise and/or Resources (people, groups, institutions) for this Subprogram

1. Suggested expertise for physical characterization:
(BET analysis, particle size analysis, including below micron particle size, etc.).

2. Suggested expertise for chemical characterization:

- Metals in, sediment, tailing, water column, Ecotox media, dissolution/transformation protocol (GHS, Annex 10).
- Mineralogy.
- Ecotox in Sediment and water column.
- Mesocosm studies.

3. Other suggested criteria

- People need to be effective researchers – using Good Laboratory Practices (GLP) – and not just produce data and hopefully certified labs or maintain an appropriate record of scientific publications.

---

6 Ibid

7 Ibid

Regulatory Framework &/or Standards to Consider
• Chile needs to determine and set water and sediment quality standards, and toxicity standards. Without this it will be extremely difficult to develop regulations to manage DSTP at a national level. Encourage collaboration to achieve the first goal starting from international expertise. • Key to getting an answer on whether "DSTP" is a viable option is the quality of the results. Each lab identified and asked to participate will need to undergo an independent review of the data they produce (Does Chile want to develop its own capability or use international expertise?).
Suggested Phases/Milestones of this Subprogram
1. Establish chemical composition/physical characteristics. A plant follow-up phase to assess variability on tailings characteristics and additive testing and use of historical data is suggested. 2. Conduct transformational studies (microbial) biogeochemical cycling – use data in available thermodynamic models. 3. Conduct mesocosm studies for transformational/ecotoxic fluxes, controlled (tested against model results) sedimentation. 4. Determine ecotoxicology of waters (determination of mixing zone). 5. Determine ecotoxicology of sediments and biogeochemical cycling (species sensitivity distribution). 6. Conduct pilot studies.
Suggested Criteria for Completion of this Subprogram
• When we obtain a quality and quantity of information that allows us to answer research questions with a high degree of confidence to produce research publications in high-impact journal that are peer reviewed. • Data meets the requirements of interlinked projects and we are confident we have considered worst case scenario. • Modelers are confident that they have the correct data and variables. • When the objectives established in ToR are reached.
Other Considerations & Guidance
• Ecotoxicology of tailings for deep sea species[8]. • Define: methodology for SW – sediments chemical analysis in natural waters, not developed in Chile (remind that pollution in Chile means do not comply with the current regulations), also need quality criteria standards.
Specific Questions
• Do operational managers and companies need to consider nontoxic or more efficient flotation chemicals? • What will be the quality criteria standards needed to decide what is nontoxic? • Does the tailing being studied represent the long term development of the mine? • Should a pretreatment of tailings an option to: a. Removal of fines to landfill? b. Chemical-physical treatment of heavy metals? c. Increase particle size (by aggregation) to prevent fine particle shearing and ensure coherent gravity flow? • Should a modification of processes to eliminate toxic chemicals in tailings be an option? • Is it feasible to use capping with natural sediments as a remedial action?

[8] Ibid

Solids Behavior, Tailings Transport, and Modeling of Tailings Sub-Program

Research Design Guidance

Research Questions

Possible Research Questions

1. What are the available models? Their precision and information needs.
2. What is the predicted "final" destination of discharged tailing within a maximum dispersion or variance?[9]
3. What is the physical, chemical, and biological interaction between tailing and the environment?[10]
4. What kind of sediment is formed?
5. Which are the chemical transformations (catalyzed or not by bacteria) of the fluid?[11]
6. What is the predicted footprint? (Use more than one model to predict footprint and ensure high quality, high resolution oceanography (a-physical) is collected as variables will control model outputs.).
7. Is there a biological solution that would help, after the tailings are discharged in the ocean (such as bacteria)?[12]

Research Inputs & Assumptions

Suggested Inputs:

- Physical and microbiological characterization of the tailings (should take into account information from mining extraction phase).
- Reactivity of tailings with environment due to chemistry and biology of the release.
- Existing known information:
  - Predictive models
  - Simulators
- Representative oceanography.
- Settling velocity.
- Currents and upwelling.
- Tailings rheology (identify models, time-dependency, etc.).
- Static and dynamic angles of repose and/or yield conditions.

[9] This question should be answered when Oceanography subprogram finishes

[10] This question should be answered when Oceanography and Ecology subprograms finish

[11] This question should be answered when Oceanography and Ecology subprograms finish

[12] This question should be answered when Oceanography and Ecology subprograms finish

Data Analysis Guidance
• Conduct chemical and microbiological characterizations. • Conduct in situ oceanographic measurements (long-term). • Analyze the size distribution of tailings. • Conduct a water characterization of the study areas. Natural flocculation in seawater increases the settling rate of fine particles in a factor 100, which contribute to a smaller foot print on the bottom in terms of area. • Consider the dissolved component, not only solids. • Analyze grain size distribution of the natural sediments because if grain size at the site does not change very much the tailing deposit will be physically stable (no transportation after deposition). • Measure in situ and at laboratory scale, flow and segregation patterns according to the environmental conditions (pressure, temperature, background flow, natural sediment characteristics, etc.).
Data Collection Guidance
Scope or population of variables to be considered or included in the study:
• Those related to study areas[13]. • Those related to the tailings themselves. • Those related to biology, etc.[14].
Measurements to be taken of the variables – attributes, properties, parameters to be assessed, tracked, compared, baselined:
• Full range of footprint measurements. • Invasive/non-invasive measurements (concentration, pH, etc.) as well as velocity to assess mixing in the column line to the flow of the particle – laden gravity current.
Temporal and spatial requirements for data collection, including options and parameters for sampling:
• 1 to 2 year timeframe. • Primary material, mineral is dynamic so it is very important to define ranges. • Focus on central region. • Extension depth of settled sediment in specific sites of the study area. • Block modeling applied to tailing material, according mining plan. • Sea water changes, column sampling[15]. • A campaign to have enough tailing samples for modeling. • Tomography to make non-invasive measurements of concentration profiles.
Data Collection Methods, Tools, or Approaches
• Block models. • Bathymetry. • Drilling campaign (sediments and core sampling). • Physic and numeric modeling in lab and computer. • ADCP and the all the normal oceanographic instruments: ROVs, dredges, gliders. • Use of thermodynamic models to help set end limits for tailing composition rather than carryout modeling. • A 3-d model, which has a sedimentation module and take into account natural flocculation of fine particles is recommended.

[13] Addressed in Ecological and Oceanographic Subprograms.

[14] Ibid

[15] Addressed in Oceanographic Subprogram

Implementation Guidance

Suggested Areas of Expertise and/or Resources (people, groups, institutions) for this Subprogram

Suggested resources inside of Chile:

- School of engineering at Universidad de Chile.
- School of engineering at Universidad de Concepcion.

Suggested resources outside of Chile:

- Commonwealth Scientific and Industrial Research Organization (CSIRO).
- MetOcean Solutions Ltd (MSL).
- Woods Hole Oceanographic Institution.
- University of California Davis.
- Australian Society of Rheology.
- Groupe Ecoulements de Particules (GEP) IUSTI, Polytech Marseille.
- University of Cambridge.
- Danish Hydraulic Institute.

Regulatory Framework &/or Standards to Consider

- There are no regulatory frameworks for modeling, but there are regulations that could be adapted from:
  - Hydrographic and Oceanographic Service of the Chilean Navy (SHOA)
  - International Maritime Organization's guide for dredged materials disposal
  - Intergovernmental Oceanographic Commission, UNESCO Southwest Pacific Treaty
- Investigate any existing frameworks from the petroleum exploration industry.
- Use of international standards for EQS of tests:
  - Full set of physical, oceanographic variables (vertical and horizontal currents, temperature, salinity, oxygen, etc.)
  - Chemical characterization of water column at different depths
  - Physical/chemical/biological characterization of natural sediment
- In conclusion, work has to be done to synthesize a scientific/technical benchmark.

Suggested Phases/Milestones of this Subprogram

1. Definition of results to validate (6-12 months).
2. Evaluate the consistence and coherence of existing models and their application.
3. Investigative phase (conduct research).
4. Scientific validation phase – specific group validation.
5. Pilot phase (1 year).
6. The deliverable is a scientifically validated model which explains the final destiny of the tailings, physically and chemically – (4 years from the formation of the team).

Suggested Criteria for Completion of this Subprogram

- Model is validated by the scientific community – the scientific validation should be done in peer review journals and by a peer reviewed panel.
- Model is validated by regulatory bodies (Ministry of the Environment, Sub-secretariat for Fisheries, Dirección General del Territorio Marítimo y Marina Mercante de Chile, (DIRECTEMAR)).

Other Considerations & Guidance

- Consider the creation of capabilities at the national level (infrastructure, human resources, etc.).
- Study the development model of the geophysical department of the University of Chile.
- Tailing transport should be coupled to upwelling events, plume splitting, particle size distribution of the tailing, ratio between solids: freshwater seawater in the plume, the need of deareation of the plume, etc. A new research Subprogram is suggested: "Tailing Properties, Disposal and Transport". Disposal covers how to establish an infrastructure which is designed to allow tailings being piped to 100-200m depth and which create a gravitational flow down the slope and end up where want it to rest.

Specific Questions

(1) What are some of the aspects of the in the numeric model of tailings behavior that need to be included?

- Rheology
- Segregation
- Sedimentation
- Ambient conditions (salinity, depth)[16]
- Conditions of the seafloor[17] and the tailings themselves
- Bathymetry
- Slope
- Current fields
- Physico chemical characteristics of tailings, especially those pertaining the finest fractions

(2) How is the in the numeric model of tailings behavior to be validated?

- Research phase
- Validation phase
- Pilot phase

[16] Addressed in the Oceanographic Subprogram

[17] Addressed in the Oceanographic Subprogram, as Bathymetry, Slope and Current fields

Food Chain Analysis Subprogram

Research Design Guidance

Research Questions

Possible Research Questions

1. What are the dominant trophic links between benthic and pelagic zones?
2. What is the rate of release of bioavailable trace metals from the tailing[18]?
3. What is the concentration of the different bioavailable fractions of the tailings?
4. What is the rate of release bioavailable fractions from tailings as compared to the background bio-available fractions in sea water and the sediments[19]?
5. Is carbon from chemosynthetic ecosystems a significant contribution to the food chain[20]? If yes, please consider it in the analysis, data acquisition and so on.
6. Does bioturbation process increase metal release from tailing sediment[21]? If so, how significant is the process compared with diffusive flux?

Research Inputs & Assumptions

Suggested Inputs:

- Tailing characterization (samples available from different types of tailings from different origins if it applies, such as mines, stockpiles, different ages stocked, phases of exploration, etc.).
- Species composition of food chain.
- The spatial distribution of food chain components (especially fish)[22].
- Food chain analysis study should cover the coupling of benthic and pelagic food chain. Main assumption here is that if the benthic ecosystem is disturbed, some consequences for the pelagic ecosystem and vice versa would occur. Food chain analysis should address the possibility of uptake of harmful substances which is accumulated in the different part of the food chain or even being biomagnified in the food chain.

Assumptions:

- Any bioavailable trace metal from the tailings will be differentially incorporated into the food chain.
- A fraction of the tailing (fine-grained and dissolved) will remain in the water-column.
- Age of the stockpile of low grade mineral will influence the release rate of trace metals.

---

[18] Addressed in the Tailing Subprogram in regard to the different bioavailable fractions of the tailings

[19] Addressed in the Tailing and Oceanographic Subprograms

[20] Addressed in the Tailing and Oceanographic Subprograms

[21] Addressed in the Oceanographic Subprogram

[22] From the Ecology Subprogram

Data Analysis Guidance

Suggested Analyses:

- Analyze spatial GIS and distribution of component species of the food chain.
- Use trophic modeling to estimate biomass transfer rates (ECOSIM/ECOPATH).
- Use estimated transfer rates for isotopic and trace metals analysis.
- Measure bio-available trace metals in the different components of the food chain.
- Use radioisotopes models of transformation in water column (transfer rates).
- Ecogenomics (eDNA) and other similar techniques and methodologies may assist in analyzing food web and aid in linking food-web (ecogenomics can analyze dietary materials and stomach contents). Those techniques and methodologies should be used if needed and if they help to answer specific questions.
- Essential metals, such as copper, are well "regulated," and analyses of tissues should target the "metabolically available fraction" of the metals (copper) in order to relate to potential effects (ecotoxicology). (Total body concentration relates poorly to effects.)
- A range of approaches, both chemical and biological, may be required to assess the potential bioavailability to organisms of DSTP-derived metals in the waters, suspended solids and sediments. These may be generic, or specific to individual types of organisms.
- As bioavailability is fundamental to risk assessment, the assessment of bioavailability will be considered in many of the Research Subprograms, particularly within the 'Tailings Characterization and Conditioning" and 'Food Chain Analysis' Subprograms.

Data Collection Guidance

Scope or population of variables to be considered or included in the study:

- Species could be selected based on:
  - Those that are consumed by humans
  - Key species (number of connections in the food chain)
- Estimate the mixed trophic impact to determine scope of component species in food chain.
- Consider the biogeochemical cycling of metals within the water column and at the benthic water interface.
- Consider effects of nephloid layers in the transport of tailings and heavy metals.
- Establish baseline by:
  - Using available information
  - Conducting synoptic surveys in central regions (IV – VI)

Measurements to be taken of the variables – attributes, properties, parameters to be assessed, tracked, compared, baselined:

- Concentration of trace metals.
- Measure differential dispersal of bio-available fractions with seasons (strong seasonality in the system).
- Allow for re-speciation of chemical species in sea water.
- Need to consider both dissolved (water) and dietary exposure (sediment ingestion) to copper – major route of uptake for most benthic invertebrates.

Temporal and spatial requirements for data collection, including options and parameters for sampling:

- At least two seasonal cycles.
- Area: From Coquimbo 30° Lat S to Constitución 35° Lat S.
- When: During the upwelling (spring – summer) and non-upwelling (down welling) in April – August.

Data Collection Methods, Tools, or Approaches

- R/V
- ROV – deep sea community observation
- Trawling (Multiple Opening/Closing Net and Environmental Sensing System - MOCNESS)
- Deep water sampling

Available:

- Trophic models (ECOSYM/ECOPATH/ECOSPACE)
- Mass spectrometry
- X-ray spectrometry

Implementation Guidance

Suggested Areas of Expertise and/or Resources (people, groups, institutions) for this Subprogram

For the development of this subprogram, the following main areas of expertise were suggested

- Trophic Modeling
- Deep Sea Benthic
- Trace Metals
- Ecotoxicology

Regulatory Framework &/or Standards to Consider

- Authorized by SHOA – Comité Oceanogréfico Nacional (CONA).
- Use of restricted access data (fish & crustaceans – IFOP).
- Ministerio de Medio Ambiente, Subsecretaría de Pesca, Subsecretaría de Salud Pública.
- Decreto 461 – Establishes the requirements to be met by applications for fishing research purposes.
- No drilling standards for trace metals (USA – EPA).
- Mussel watch and its sources.

Suggested Phases/Milestones of this Subprogram

1. Full description of dominant food chain in the region.
2. Natural background (baseline) of trace metal in water and sediments.
3. Trophic model results (flux of trace metals in food chain).
4. Baseline: potential impact on human health.

Suggested Criteria for Completion of this Subprogram

- The objectives established in ToR are reached.
- There is sufficient information to have an accurate and precise description of the natural content of some key trace metals in the food chain (main species by each trophic level).

Other Considerations & Guidance

- Climate change impact on food chain.
  - Expansion of anoxic sub-system
  - Cooling (0.6°C)
- Strong international collaboration for specific aspects.
- Publish results in peer reviewed journals.

This page intentionally left blank

VI. Conceptual Framework – Evaluation of Relative Risk

The 2013 Deep Sea Tailing Placement Roadmap identified the need for a conceptual framework for evaluating the relative risk of DSTP and land-based tailings disposal. If mining operations are to continue in Central Chile, the tailings will have to be disposed of either through traditional land-based methods or an alternative method such as DSTP. Chile and the mining industry will only use an alternative method such as DSTP if it can be shown to be viable from human health, social, and environmental perspectives. A comparative analysis or relative risk is necessary because there are no risk-free options for tailings disposal. All methods of disposal have potential benefits and potential risks.

While DSTP and land-based disposal have some mutual risks, many of their risks are not directly comparable and cannot be quantified on a common basis. An effective evaluation of the relative risks will require a conceptual framework that enables the combined risks of each option to be compared in a meaningful way. The participants of the 2014 Knowledge Workshop provided input for the development of this conceptual framework.

BASIS FOR COMPARING DSTP VERSUS LAND TAILINGS DISPOSAL

The starting point for the conceptual framework is the identification of the range of potential risks associated with the two options. Workshop participants generated a list of risks and concerns associated with each option that could be considered for the conceptual framework. The individual risks were organized into five broad categories that could be applied both to DSTP and land-based disposal of tailings:

Environmental/Ecological

Environmental/ecological risks were one of the most frequent types of risks participants identified and include negative impacts on the environment or the ecology of the site where the tailings are disposed of. Concerns for DSTP include the effects of DSTP on the food chain, ecosystems, bivalves, transvectors, microbes, and plankton. Other concerns about DSTP include the dissolution of copper and other heavy metals, the effect of upwelling on tailings dispersion, the unknown ecosystem diversity in the sea, and the notion that remediation efforts may require more knowledge and hard work in sea than in land.

Environmental/ecological risks identified for land tailing disposal include flooding due to heavy rains, flooding or dam failure resulting in contaminant infiltrations into groundwater. There is also the potential for dust dispersion of contaminants into the surrounding environment. Either occurrence could have an impact on the health of human populations, vegetation, and wildlife around disposal sites. The land-based placement of the tailing can ultimately increase the risk of extinction of some plants and animals at the sites, particularly in Central Chile's biodiversity hot spots.

Natural Hazards

Natural hazards are negative outcomes or consequences resulting from the impact of natural hazards on the disposal facilities. Earthquakes were identified as potential threats to both land and deep sea tailings disposal. Seismic activity could affect the integrity of piping systems in DSTP operations and tailing dams in land-disposal operations. Tsunamis were also identified as a potential natural hazard for DSTP and landslides as potential natural hazards for land disposal.

Economic Risk

Economic risks are financial burdens incurred by stakeholders from the construction or operation of disposal facilities. Economic risks identified for DSTP focused on economic losses for fishing communities. Metrics for the Consortium to consider include the number of years and the impact of fishing that could be affected and the number of people that could be affected.

Economic risks for land-based disposal include the economic effect of having a tailing dam located in or near one's community. There may be an opportunity cost from the loss of land that could have been used as an economic resource for the community. In addition, land-based disposal increases the competition for land and may thus raise real estate prices to a point where they are out of range for residents.

Participants also indicated that both options involve economic risk for the mining industry; including the relative costs of constructing, operating, and closing a DSTP facility versus a land facility. There is also a liability cost of claims against mining companies for damages caused by each option (e.g., loss of livelihood by fishing communities).

Finally, there is the economic loss for Chile from discontinuing operations in the Central Region. Copper production has been an important driver of economic prosperity. The loss of this driver would have a significant negative impact on the Chilean economy.

Social Risk

Social risks include negative impacts on the perceptions, attitudes, and mental well-being of stakeholders, communities, and individuals. Given that land-based disposal has been used for many decades, it is a familiar and accepted practice and is governed by a well-developed regulatory framework. In contrast, DSTP is a "new" process. Government agencies, communities, and NGO's in Chile are not familiar with it and there is a lack of a regulatory framework for the construction and operation of DSTP facilities. Participants also suggested that there is a risk of damaging Chile's international image should DSTP be deployed without careful consideration. As a result, the use of DSTP carries a larger social risk. A potential metric for social risk would be public awareness and public opinion. This information could be gathered by polling.

Operational/Technological Risk

Operational and technological risks identified for DSTP include negative consequences associated with issues or problems in the ongoing operation and control of the facilities, such as technology failure and human error, or disruptions in operation caused by blockage due to roughness or the slope of the seafloor.

METHODOLOGICAL OPTIONS

Participants provided methodological suggestions for carrying out the risk analysis, which included the following:

- A retrospective analysis of existing operations in Indonesia, Norway, and Papua New Guinea (PNG) could be used to provide some data to help assess the risk of DSTP. The retrospective analysis could consider investigating past failures, incidents, and even conflicts associated with DSTP and other sea-based disposal practices.
- Environmental assessments, such as the National Environmental Policy Act (NEPA) assessments and Environmental Impact Assessments may also provide data to help assess risks.
- Other specific analyses identified during the workshop include failure analysis, defect analysis, international and national legal analyses, and habitat mapping, monitoring and modeling.

The methodology for the comparative analysis should also incorporate a provision for involving stakeholders. Participants identified key roles for stakeholders. Stakeholders could help with the analysis of the research results as they are produced. This would be an ongoing role during the course of the initiative. Stakeholder participation would also be required to validate the results of the comparative analysis once the research has been completed. Finally, selected stakeholders could provide a general touchstone or reference point for social acceptance of the Consortium's efforts. Participants identified a range of groups and organizations that could play a role in the comparative analysis. Among others, the following groups were mentioned:

Government:

- Ministries of health, environment, mining, and economy (including the Undersecretaries of fisheries and tourism)
- Maritime Authority

- Chilean Navy
- Ministry of Agriculture
- Ministry of Foreign Affairs

Scientific Community:

- Geographical survey of Chile
- Academia – Chilean and international universities
- Oceanographic and geological surveys
- Japan Agency for Marine-Earth Science

Communities:

- Fisheries
- Community representatives in coastal cities and villages
- Labor unions

NGO's and Other Organizations:

- Deep Ocean Stewardship Initiative
- United Nations, including the Food and Agricultural Organization and the World Health Organization
- International Maritime Organization
- U.S. Environmental Protection Agency
- Fishery associations and federations
- Political think tanks
- Oceana
- Green Peace

This page intentionally left blank

VII. Social Issues Research and Community Outreach

The 2013 DTSP Roadmap was focused on identifying gaps in knowledge from a scientific and technical point of view. It identifies a comprehensive program of research to address those gaps. Some of the research will involve laboratory study or the construction of models, but some of the work must be conducted at the potential DSTP sites. The research at these sites will likely involve multiple researchers, specialized research equipment, and mobile research platforms either on land or at sea. The arrival and deployment of the people and equipment at the sites is likely to raise questions and concerns within the communities at those sites. It may interrupt fishing and recreational activities that take place off the shore of these communities. The point is that the field research will have a social impact on the local community.

The Consortium recognizes that responsible management and oversight of the research studies must go beyond the technical methodological issues and consider the social and community impact of conducting the research. Accordingly, the line of research – the Study of Social Issues and Community Impact – was included in the DSTP 2014 Knowledge Workshop. Participants were asked to provide guidance about how to manage this social impact and steps that could be taken to mitigate any negative effects that may occur.

The guidance provided by the workshop participants focused on two elements:

- Community outreach and engagement
- Social issues research to establish a community baseline

COMMUNITY OUTREACH AND ENGAGEMENT

The workshop produced guidance for an effective communication and outreach strategy. In keeping with its principles of operation, the Consortium's primary means for mitigating the adverse effects of the field research is open communications and collaborative engagement with community members.

The Communication Strategy

Participants recommended that the Consortium define a communication strategy for the local communities that is embedded in the research and begins before the research teams start conducting the research. The central message should be designed to transmit the principles of the initiative. In particular, it could include:

- This is a scientific research initiative to study the ocean to determine if DSTP is feasible from environmental and human health perspectives.
- The model of research is based on high standard science and even if it is decided that DSTP is not a feasible option, the research will put Chile in a leading position in marine sciences.
- The research initiative is a proactive way of approaching the national issue of tailing placement.
- The Consortium's approach is based on transparency and inclusiveness and a cooperative model of research and represents a new way of doing things.

Participants also recommended that the Consortium establish and communicate the governance mechanisms that will maintain these principles and ensure the relevance and legitimacy of the scientific results. The communication strategy should be designed to "level the pitch" and make the information about the research as accessible as possible to the various community stakeholders. Ideally, tailings disposal could be framed as a country-level issue.

Community Engagement

Participants also provided guidance for engaging the community. Participants noted that engagement is important because the dialogue with the local community will preconceive notions and opinions about DSTP and the mining companies. Participants suggested that the Consortium conduct an open house and employ other participatory methodologies, including the use of "touch tables" to gather and distribute information to the community. The Consortium should also encourage community participation to ensure that the scientific research program incorporates local knowledge of the area, including local currents and other site specific characteristics. Community members could also participate in the research by providing boat rental and diving services, as well as participative monitoring.

SOCIAL ISSUES RESEARCH

In order for the Consortium to manage the community impact and mitigate any negative effects, it must first develop an understanding of the social issues and potential for impact once the studies conclude that a sustainable deep sea tailings placement is possible and ensure viability from the human health, social, and environmental perspectives. From that moment on, it is possible to begin with more specific site studies that will requires social issues research to establish a community baseline. Participants suggested that the social issue research be focused on two areas: Creating a demographic profile and assessing potential for discord and controversy, as well as creating a mechanism to discuss and decide on specific controversial topics.

Demographic Profile

The first part of the social issues research would be focused on creating a demographic profile of the communities surrounding the potential DSTP sites within the Central Region. The results of this research would provide the Consortium with a foundation for understanding community needs and concerns and for monitoring potential impacts from the research. Participants suggested the following topics within this area of research:

- Livelihoods of people in the community
- Key actors and/or opinion leaders in the community
- Types of stakeholders & demographics of the community residents

Potential for Discord and Controversy

The second part of the social issues research would be focused on assessing the potential for discord and controversy within the community regarding DSTP. DSTP is a sensitive subject that can evoke strong opinions and disagreement. Even though the Consortium's intent is to evaluate DSTP, the research activities may incite the same controversy that surrounds the technology itself and polarize the community. This research would help the Consortium mitigate these negative impacts. Participants suggested the following topics within this area of research:

- History of social-environmental conflicts within the community
- Current attitudes/perceptions about mining industry, DSTP, and outfall pipes
- Baseline trust

VIII. Stakeholder Engagement

The previous three chapters presented guidance to help the Consortium carry out the task of providing independent oversight and management of the research programs identified in the 2013 DTSP Roadmap. This chapter presents guidance to help the Consortium carry out its other primary task of designing and implementing a stakeholder engagement plan for involving and collaborating with stakeholders.

STAKEHOLDER CONCERNS, ISSUES, AND POTENTIAL BARRIERS

The Consortium understands that ongoing engagement is important to establishing and maintaining stakeholder trust. To help the Consortium design an effective engagement strategy, participants identified a range of stakeholder concerns and barriers that will have to be addressed.

Key Stakeholder Concerns

Participants identified the primary issues and concerns that stakeholders are likely to have regarding DSTP and/or the DSTP Initiative. The Consortium could target these issues and concerns in its efforts to engage with and communicate to stakeholders. The primary issues and concerns include:

Trust – It is a struggle for the mining industry to project a trusting image to the Chilean society. A recent publication titled "Confianza Ciudadana Hacia las Empresas en Chile" describes a survey in which the mining industry in the Antofagasta region is described as having high revenues but not providing commensurate benefits to the community. Those surveyed for the study also identified as highest priority their desire for the mining industry to provide better work conditions and to avoid environmental contamination practices. The stakeholder engagement message should emphasize that research efforts of this initiative will be used to discover facts, validate technology, and test hypotheses; not to endorse or approve DSTP. It was also mentioned that if the adoption of DSTP materialized, there should be continuing efforts to evaluate the DSTP process and its effects on the environment and communities.

Public perception of DSTP – DSTP can be misperceived as a problem of the mining companies, rather than a national challenge. The inherent nature of the DSTP process can also be misperceived as an "out-of sight/out-of-mind" attitude threatening marine resources and human health. Another concern related to public perception includes that inland tailings are often believed to be poisonous.

Knowledge Gaps – Both lack of knowledge about DSTP and lack of understanding of the Consortium's initiative were identified as potential concerns. Other concerns include the eventual approval of DSTP without sufficient knowledge, such as the social and economic impact of DSTP, and a lack of DSTP and marine science knowledge in governmental-regulatory agencies.

Regulatory – The lack of a legal framework is a potential stakeholder engagement challenge, because it will be more difficult to encourage public participation. It was also mentioned that new regulations could be established that could affect the viability of DSTP during the permiting process if the project is technically viable. Participants also identified the need for the government's commitment for participating in the research program as a valid and relevant counterpart.

Attitude – Participants identified concerns regarding people's attitudes, saying attitudes could adversely affect the initiative and/or stakeholder engagement efforts. These include anti-mining bodies not willing to participate in the engagement process; communities perceiving that they have a lot to lose and nothing to win; and the combination of passionate opposition with a lack of regulation resulting in prohibition.

Other general barriers to consider, not related to stakeholder engagement

Participants also identified two general barriers that could delay the research and affect people's perceptions of the DSTP Initiative. The Consortium will need a strategy to maintain stakeholder engagement, trust, and credibility should these barriers occur.

Resources – A lack of sufficient resources could impede the research programs. For example, the Consortium will need human resources to carry out the studies and coordinate the different research efforts. The lack of expertise and/or the health risks of carrying out the research may create a resource barrier. The Consortium will also need financial resources to acquire the necessary expertise and pay for the high-cost equipment needed for the oceanographic research. The Consortium should consider how it will communicate and explain why these barriers occurred and how the delays will be addressed.

Technical – Technical challenges such as the identification of the proper site to do in situ research and the slow maturity of technologies required to do the research could also impede the Consortium's efforts. Again, the Consortium should be prepared to explain why they occurred and what is being done to address them.

BEST PRACTICES FOR ENGAGING STAKEHOLDERS

Participants provided a range of guidance about best practices the Consortium could employ to effectively engage stakeholders during the course of the DSTP Initiative. This guidance is presented below, organized around three themes:

The message – Participants emphasized the importance of being honest, direct, transparent, communicating both the pros and cons identified during the research, and communicating results in advance and in an ongoing basis, rather than after the fact. The stakeholder engagement message could communicate that this initiative can solve problems of inland tailing dumps in the future, improve the national reputation of waste management, and change the way companies relate with the local communities. Overall, the stakeholder engagements effort should provide good information flow between scientists and the general public. The message should emphasize that DSTP is a country decision in a context of national resource management.

Engagement Strategies – Participants identified several strategies that could be employed in the stakeholder engagement effort. These include the development of frequently asked questions to educate and disseminate knowledge, the use of social media, the dissemination of DSTP videos, the use of a citizen jury approach, and the use of seminars or forums.

Other Engagement Best Practices – To help develop trust, the community could be engaged in the research by allowing them to participate or observe in research programs. Participants identified the potential need for a champion to spearhead stakeholder engagement efforts. Another best practice is to ensure results are being communicated at appropriate points by reviewing communication strategies for each research project. International Maritime Organization regulations could be used as a guideline for decision making.

The Consortium is committed to keeping stakeholders informed and maintaining full transparency while the research is carried out. The Consortium is in the process of determining the optimal stakeholder engagement approach and the guidance described above will help ensure the effectiveness of its efforts. At a general level, the Consortium anticipates the use of various forms of communication, such as publications and forums, to disseminate information and support the productive exchange of ideas.

IX. The Path Forward

Finding a viable alternative to traditional tailing dams is an important challenge. A viable alternative would alleviate the increasing scarcity for land use in the Central Zone of Chile and enable the continued development of the copper industry in the region, where copper resources are abundant. To meet this important, yet complex, challenge, the Consortium is developing a new approach that involves creating a partnership between industry, government, communities, and other stakeholders.

In 2013, the Consortium engaged a group of technical experts to identify knowledge gaps and research needs to evaluate the viability of DSTP. In the 2014 Knowledge Workshop described in this document, the Consortium reached out to a wider range of stakeholders to gather additional guidance on how to implement the studies and foster collaboration. Both engagements provided input and rationale for a comprehensive research initiative to generate the scientific and technical knowledge to evaluate DSTP. The Consortium has obtained feedback from a wide range of stakeholders and will use this guidance to develop a path forward.

Moving forward, the Consortium will collaborate with leading scientists to develop and carry out the research program and all subprograms identified during the workshops. Simply put, the intent of the research is to address the following areas pertinent to DSTP:

1. Characterize the mine tailings
2. Characterize the disposal site and surrounding areas
3. Assess the potential impacts
4. Conduct a comparative risk assessment of DSTP and land disposal

In addition the Consortium will maintain a strong engagement with all stakeholders. Ongoing communication and regular engagement is essential to building stakeholder trust and establishing the evaluation as a credible and unbiased effort.

The Consortium remains committed to the vision — "To generate the information and scientific and technological knowledge needed to evaluate a sustainable deep sea tailing placement, ensuring their viability from the human health, social, and environmental perspectives" — and is aware that the results of the research may not support a decision to use DSTP. It will keep stakeholders informed of the initiative's progress and maintain full transparency while the research is carried out. DSTP will not be an alternative to tailing dams unless it can be shown to be viable from the human health, social, and environmental perspectives.

Developing valid scientific and technical knowledge is an important step. However, even if the research results demonstrate the viability of DSTP, its implementation as an alternative for mining tailings placement in Central Chile will still require governmental, regulatory, and social acceptance and agreement. The Consortium hopes that the DSTP Initiative and its outreach efforts provide the necessary information and build the necessary level of trust to enable a productive and unbiased discussion across all stakeholders.

This page intentionally left blank

Appendix A: Participant List

Participants' Name	University / Institute / Company	Specialty / Position	Group
Samuel Hormazábal	Universidad Católica de Valparaiso	(Dr) Physic Oceanography	National Scientific
Juan Díaz Naveas	Universidad Católica de Valparaiso	(Dr) Natural Science (Geophysics Marine)	National Scientific
Juan Carlos Castilla	Pontificia Universidad Católica	(Dr) Marine Ecology and Science	National Scientific
Stefan Gelcich	Pontificia Universidad Católica	(Dr) Marine Biology	National Scientific
Miriam Fernandez	Pontificia Universidad Católica	(Dr) Marine Ecology and Science	National Scientific
Hugo Arancibia	Universidad de Concepción	(Dr) Natural Science (Fishing Resource Economy)	National Scientific
Marco Salamanca	Universidad de Concepción	(Dr) Chemistry Oceanography	National Scientific
Ruben Escribano	Universidad de Concepción	(Dr) Oceanography	National Scientific
Giovanni Daneri	Centro de Investigación en Ecosistemas de la Patagonia (CIEP)	(Dr) Oceanography	National Scientific
Yolanda Sanchez	Pontificia Universidad Católica	Oceanography / Coordinator Center for Marine Conservation	National Scientific
Jorina Waworuntu	Newmont Nusa Tenggara	(PhD) Oceanography / Technical Environmental Advisor	International Experts
Stuart Simpson	CSIRO Australia	(PhD) Chemistry-Ecotoxicology / Senior Principal Research Scientist	International Experts
Jens Skei	Skei Mining Consultant (SMC)	(PhD) Marine Geochemistry / Independent Advisor	International Experts
Tracy Shimmield	Scottish Association for Marine Science	(MSc., PhD) Geochemistry	International Experts
Craig Vogt	Craig Vogt inc	(BSc) Environmental Engineering	International Experts
Enrique Vargas	DIRINMAR	Captain / Head of Aquatic Environment	National Government
Eugenia Valdebenito	DIRECTEMAR	Marine Biologist / Environment Section	National Government
Gresel Arancibia	CONA - Comité Oceanográfico Nacional	Oceanography / Scientific Technical Advisory	National Government
Maria de la Luz V.	Mining Ministry	Chemistry / Head Environmental Unit	National Government
Jaime Rovira	Environmental Ministry	Agronomy Engineer / Chief Section Biodiversity	National Government

Participants' Name	University / Institute / Company	Specialty / Position	Group
Jorge Dálbora	Fishing Sub secretary	Fishery and aquaculture Engineer / Fishery Management Division	National Government
Juan Pablo Belmar Palacios	Fishing Sub secretary	Oceanographer / Fishery Management Division	National Government
Flor Uribe Ruiz	Fishing Sub secretary	Marine Biologist / Fishery Management Division	National Government
Patricio Bernal	International Union for Conservation of Nature	(PhD) Oceanography marine Biology / Coordinator Global Ocean Biodiversity	NGO
Carlos Rodriguez	Universidad del Desarrollo	(PhD) Economy	National Consultant
Ricardo Katz	Gestion Ambiental Consultores	Environmental Advisor	National Consultant
Ernesto Escobar	Publico Comunicaciones	Journalist / CEO	National Consultant
Christian Ihle	Advanced Mining Technology Center - Universidad de Chile	(PhD) Civil Engineer / Researcher	National Academic
Patricio Rodriguez	Universidad Adolfo Ibañez	(Dr) Science / Science Researcher	National Academic
Gustavo Lagos	Pontificia Universidad Católica	(PhD) Electroquimic, Mining Engineer / Researcher	National Academic
Patricio Meller	Universidad de Chile	Civil Engineer / Researcher & Director CIEPLAN	National Academic
Miguel Herrera Marchant	Universidad Adolfo Ibañez	(PhD) In Engineering / Researcher	National Academic
Sofia Moreno	Consejo Minero	Lawyer / International Affairs Manager	Mining Institutions
Carlos Gajardo	SONAMI	Lawyer / Environmental Manager	Mining Institutions
Gustavo Possel	Antofagasta Minerals	Environmental Manager	Mining Companies
Gustavo Tapia	Antofagasta Minerals	Innovation and Process Manager	Mining Companies
Marcela Angulo	Anglo American	Environmental Manager	Mining Companies
Juan Somavia	Anglo American	Governmental Relations Manager	Mining Companies
Fidel Baez	Codelco	Innovation Manager	Mining Companies
Pamela Chavez	Aquamarina	(PhD) Microbiology Molecular y Biotechnology / CEO	National Expert

Host & Facilitator' Name	University / Institute / Company	Specialty / Position	Group
Francisco Veloso	Antofagasta Minerals Group	Vice President Corporate Affairs	Host
Rodrigo Moya	Antofagasta Minerals Group	Special Project Manager	Host
Christian Brea	Antofagasta Minerals Group	Special Project Senior Engineer	Host
Marcela Bocchetto	Anglo American	Environmental Manager	Host
Nelson Sanchez	Anglo American	Project Manager	Host
Martin Rodriguez	Feedback Comunicaciones	Director	Host
Federico Torres	Feedback Comunicaciones	Account Director	Host
Leonel Sierralta	Consortium	Scientific Director	Host
Fred Hansen	Energetics Inc	Consultant	Facilitators
Mauricio Justiniano	Energetics Inc	Consultant	Facilitators

Appendix B: Small Groups

Group 1

Oceanographic Characterization

Gresel Arancibia
Miriam Fernandez
Juan Pablo Belmar Palacios
Enrique Vargas
Jens Skei
Ruben Escribano
Craig Vogt

Group 2

Food Chain Analysis

Patricio Bernal
Jorina Waworuntu
Samuel Hormazábal Frirz
Jaime Rovira
Jorge D'Albora
Hugo Arancibia

Group 3

Ecological Characterization

Gustavo Possel
Euginia Valdebenito
Flor Uribe Ruiz
Marcela Angula
Juan Carlos Castilla
Giovanni Daneri

Group 4

Tailing Characterization/Conditioning

Fidel Baez
Tracy Shimmield
Marco Salamanca
Stuart Simpson
Miguel Herrera Marchant
Patricio Rodriguez
Maria de la Luz V.

Group 5

Study of Solids Behavior, Modeling of Tailings, and Tailing Transport Study

Gustavo Tapia
Pamela Chavez
Juan Diaz Naveas
Christian Ihle
Ricardo Katz'Gustavo Lagos

Group 6

Social Issues

Juan Somavia
Stefan Gelcich
Carlos Rodriguez
Sofia Moreno
Carlos Gajardo
Leonel Sierralta
Ernesto Escobar
Patricio Meller

Appendix C: Glossary of Terms and Acronyms

Acute toxicity: Effects resulting from exposure (usually short-term) over a small part of the organism's life span e.g. mortality, enzyme inhibition.

Aquatic ecosystem: Any water environment from small to large, from pond to ocean, in which plants and animals interact with the chemical and physical features of the environment.

Bathymetry/bathymetric: The study of underwater depth (e.g. of ocean floors). Bathymetric charts are typically produced from bathymetric studies.

Benthic: Referring to organisms living in or on the sediments of aquatic habitats.

Bioaccumulation: A general term describing a process by which chemical substances are accumulated by aquatic organisms (total body concentration) from water directly or through consumption of food containing the chemicals.

Bioassay: A test used to evaluate the relative potency of a chemical by measuring its effect on a living organism relative to a control.

Bioavailable: Bioavailability can be defined as the fraction of contaminants that are available for uptake by an organism of interest, and is therefore organism specific. The bioavailable fraction of the contaminants is directly responsible for observed biological effects. This is related to the chemical behaviour of the contaminant (diffusion, sorption, and partitioning) and is closely linked to activity, fugacity, the freely dissolved concentration, and also the uptake kinetics of contaminants associated with ingested solids (dietary exposure).

Bioaccessible: The term bioaccessibility is commonly used in soil science and refers to the accessible quantity of a contaminant that can become available for, for example, biodegradation and accumulation (McLaughlin and Lannoz, 2000). Bioaccessibility can be determined with mild extraction schemes or depletive sampling techniques (see Section X).

Biodiversity: The variety and variability of living organisms and the ecological complexes in which they occur.

Biomagnification: The result of the processes of bioaccumulation by which tissue concentrations of bioaccumulated chemicals increase as the chemical passes up through two or more trophic levels. The term implies an efficient transfer of chemicals from food to consumer so that the residue concentrations increase systematically from one trophic level to the next.

Box core: A specialised device for obtaining a sediment sample collected and retaining its vertical profile.

Chronic toxicity: Effects over a significant portion of the organism's life span e.g. effects on growth and reproduction.

Community: Assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another.

Community composition: All the types of taxa present in a community.

Concentration: The quantifiable amount of a substance in water, food or sediment.

Contaminants: Biological or chemical substances or entities, not normally present in a system, capable of producing an adverse effect in a biological system, seriously injuring structure or function.

Contaminated sediment: A sediment containing chemical substances at concentrations above background concentrations and above the ANZECC/ ARMCANZ guideline values.

Core: A sediment sample collected to obtain a vertical profile using a variety of instruments.

DSTP: Deep Sea Tailing Placement is a method whereby the tailing slurry is deposited by the force of gravity from a submerged pipeline into a depth that not allows a resuspension of elements.

DO: Dissolved oxygen.

DOC: Dissolved organic carbon.

Ecogenomics: The examination of genetic (eDNA) materials in environmental samples for the purpose of identifying the organisms present.

Ecotoxicology: The science dealing with the adverse effects of chemicals, physical agents and natural products on populations and communities of living organisms.

Elutriate: An aqueous solution obtained after adding water to a solid substance or loose material (e.g., sediment, tailings, drilling mud, dredge spoil), shaking the mixture, then centrifuging or filtering it or decanting the supernatant.

Guideline: Numerical concentration limit or narrative statement to support and maintain a designated water use.

Invertebrates: Animals lacking a dorsal column of vertebrae or a notochord.

KD: Sediment/water partition coefficient.

Level of protection: The acceptable level of change from a defined reference condition.

Measurement parameter: Any parameter or variable that is measured to find something out about an ecosystem.

Mesocosm: A mesocosm is an experimental tool that brings a small part of the natural environment under controlled conditions. (In this way mesocosms provide a link between observational field studies that take place in natural environments, but without replication, and controlled laboratory experiments that may take place under somewhat unnatural conditions.)

Organism: Any living animal or plant; anything capable of carrying on life processes.

Overlying water: The water above the sediment at a collection site or in a test chamber.

Oxidation: The combination of oxygen with a substance, or the removal of hydrogen from it, or, more generally, any reaction in which an atom loses electrons.

pH: The intensity of the acidic or basic character of a solution, defined as the negative logarithm of the hydrogen ion concentration of a solution.

Piston core: A specialised device for obtaining a sediment sample collected and retaining its vertical profile.

Pore water: The water that occupies the space between and surrounds individual sediment particles in an aquatic sediment (often called interstitial water).

Plankton: Plants, usually microscopic, floating in aquatic systems.

QA/QC: Quality assurance/quality control.

Quality assurance (QA): The implementation of checks on the success of quality control (e.g. replicate samples, analysis of samples of known concentration).

Quality control (QC): The implementation of procedures to maximise the integrity of monitoring data (e.g. cleaning procedures, contamination avoidance, sample preservation methods).

Redox: Simultaneous (chemical) reduction and oxidation; reduction is the transfer of electrons to an atom or molecule, whereas oxidation is the removal of electrons from an atom or molecule.

Redox potential: A measure of the oxidation-reduction potential (ORP) of sediments. The redox potential is often reported as Eh (versus the normal hydrogen electrode).

Risk: A statistical concept defined as the expected frequency or probability of undesirable effects resulting from a specified exposure to known or potential environmental concentrations of a material, organism or condition. A material is considered safe if the risks associated with its exposure are judged to be acceptable. Estimates of risk may be expressed in absolute or relative terms. Absolute risk is the excess risk due to exposure. Relative risk is the ratio of the risk in the exposed population to the risk in the unexposed population.

Rheology: The study of the flow of matter, primarily in the liquid state, but also for fine particulates (supsended solids).

ROV: Remotely operated vehicle (often used for working in deep waters).

Salinity: The presence of soluble salts in water or soils.

Sediment: Unconsolidated mineral and organic particulate material that has settled to the bottom of aquatic environments.

Sedimentation: The process of depositing sediments.

Shallow Tailings Disposal (STD): Involves tailing disposal through a pipe into shallow waters.

Shoreline Disposal: Involves coastal disposal of tailings.

Speciation: Measurement of different chemical forms or species of an element in a solution or solid.

Species: Generally regarded as a group of organisms that resemble each other to a greater degree than members of other groups and that form a reproductively isolated group that will not normally breed with members of another group. (Chemical species are differing compounds of an element.)

SQG: Sediment quality guideline.

Stressors: The physical, chemical or biological factors that can cause an adverse effect on an aquatic ecosystem as measured by the condition indicators.

Sub lethal: Involving a stimulus effect below the level that causes death.

Taxon/toxanomy (taxa): Any group of organisms considered sufficiently distinct from other such groups to be treated as a separate unit (e.g. species, genera, families). Taxonomy is the study taxa.

TOC: Total organic carbon.

Trace metals: Concentrations of metals and metalloids in very low concentrations (often parts per trillion to billion (sub-µg/L)).

Trophic transfer: Transfer of accumulated contaminants from on level of the food chain to the next higher level.

Toxicant: A chemical capable of producing an adverse response (effect) in a biological system, seriously injuring structure or function or producing death.

Toxicity: The inherent potential or capacity of a material to cause adverse effects in a living organism.

Toxicity test: The means by which the toxicity of a chemical or other test material is determined. A toxicity test is used to measure the degree of response produced by exposure to a specific level of stimulus (or concentration of chemical).

Trophic level: A notional stage in the `food chain' that transfers matter and energy through a community; primary producers, herbivores, carnivores and decomposers each occupy a different trophic level.

Uptake: A process by which materials are absorbed and incorporated into a living organism.

WQG: Water quality guideline.