1 INTRODUCTION

1.1 Background

Nauru Ocean Resources Inc. (NORI), a wholly owned subsidiary of The Metals Company Inc. (TMC), plans to carry out testing of a polymetallic nodule collector system in the NORI-D lease area (NORI-D) of the eastern Clarion Clipperton Zone (CCZ), north Pacific Ocean (Figure 1-1). The CCZ is a region of commercial interest due to the presence of polymetallic nodules, covering an area over 4.5-million-km^2 with a typical nodule concentration of 15 kg/m^2 (MIDAS, 2016a).

The nodules contain nickel, copper, and cobalt (around 2 - 3% of the nodule weight) as well as traces of other metals such as molybdenum, rare earth elements, and lithium, which are important to high-tech industries. The amount of copper contained in the CCZ nodules is estimated to be about 20% of that held in global land-based reserves (MIDAS, 2016a).

At the time of writing an Environmental and Social Impact Assessment (ESIA) is in process for the commercial mining of polymetallic nodules within NORI-D. The information gathered will inform a commercial Environmental Impact Statement (EIS) that will accompany NORI's application for a licence to operate commercially. The commercial EIS will include the information required by the International Seabed Authority (ISA) to make an informed decision on the feasibility of the application in terms of its social benefits and environmental impacts. Testing of the prototype collector vehicle (PCV), nodule processing system, the nodule riser system, and surface processing onboard the surface support vessel (SSV) (collectively referred to as The Collector Test) is considered an essential component of the commercial ESIA.

The ISA requires that an Environmental Impact Assessment (EIA) also be conducted for the Collector Test and an EIS (this document) submitted by the contractor to the Secretary-General no later than one year in advance of the activity taking place (ISBA/25/LTC/6/Rev.1/6B/B/34).

1.2 The Collector Test

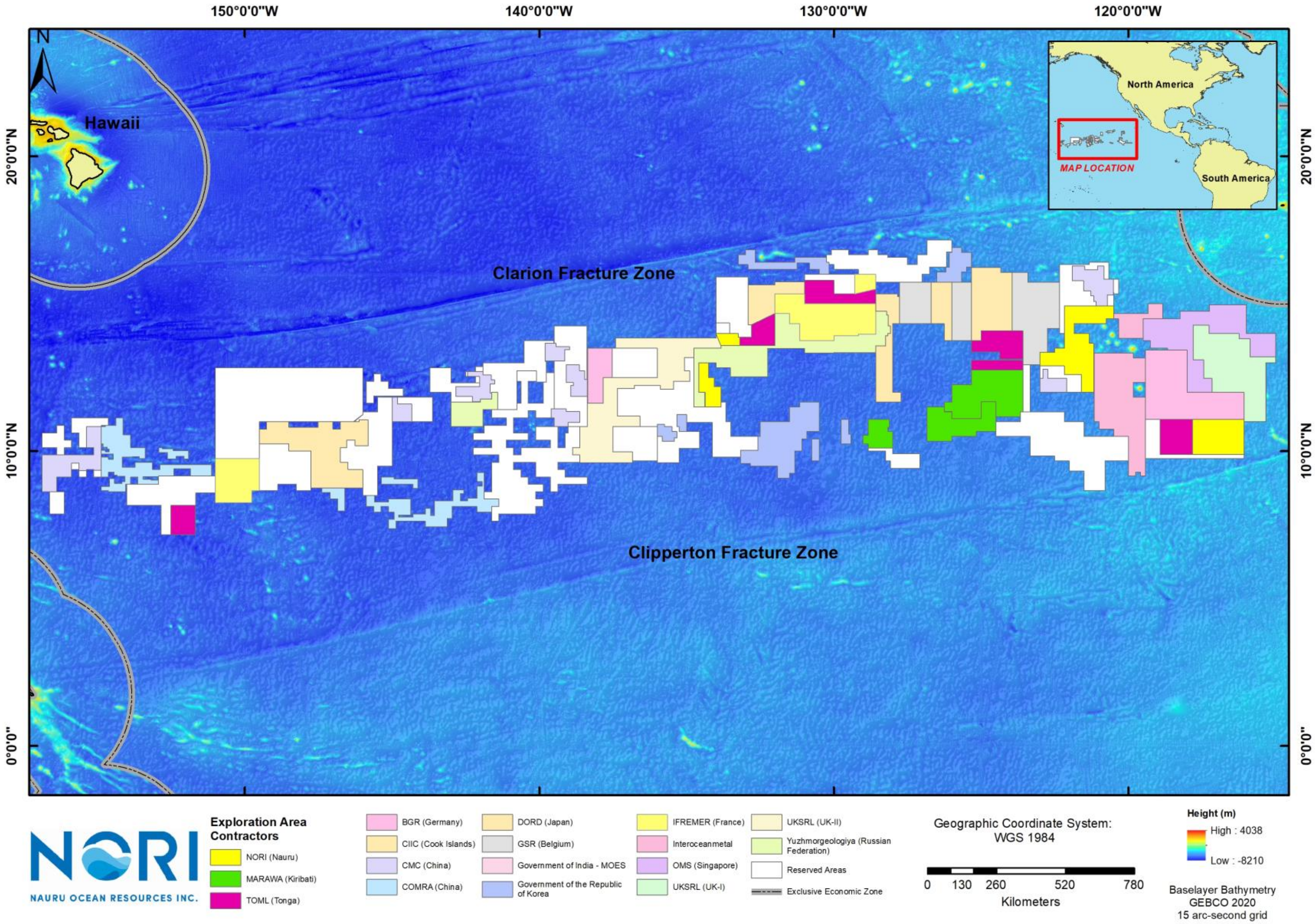
It is necessary to demonstrate the technical, economic, and environmental feasibility of operations proposed for the commercial mining of polymetallic nodules. The Collector Test is NORI's opportunity to demonstrate to the regulator that nodules can be successfully harvested from the seabed and transported to a surface vessel. It will also allow assumptions about the design of the PCV and riser system to be tested under field conditions. The results of the test will be used to inform and improve the design and environmental performance of the commercial system.

The Collector Test will be conducted in parallel with studies of the physicochemical and biological baseline of NORI-D; the combined results will provide critical data for the commercial ESIA.

The Collector Test will take place in international waters and will adhere to the latest ISA recommendations (ISBA/25/LTC/6/Rev.1; 30 March 2020).

This EIS has been informed by data collected from the eastern CCZ and NORI-D and outlines the potential environmental impacts associated with the Collector Test and serves to provide the basis for assessment of the proposed activities by the ISA.

Figure 1-1. CCZ location showing exploration areas.



1.3 Objectives

The key objectives of the Collector Test (the Project) are to:

- Test the PCV and riser system components to inform the design and operation of the full-scale commercial system.
- Develop sound procedures to assess environmental risks associated with polymetallic nodule collection.
- Study the environmental impacts of polymetallic nodule collection to inform monitoring and mitigation measures and the development of management plans for full-scale operations.

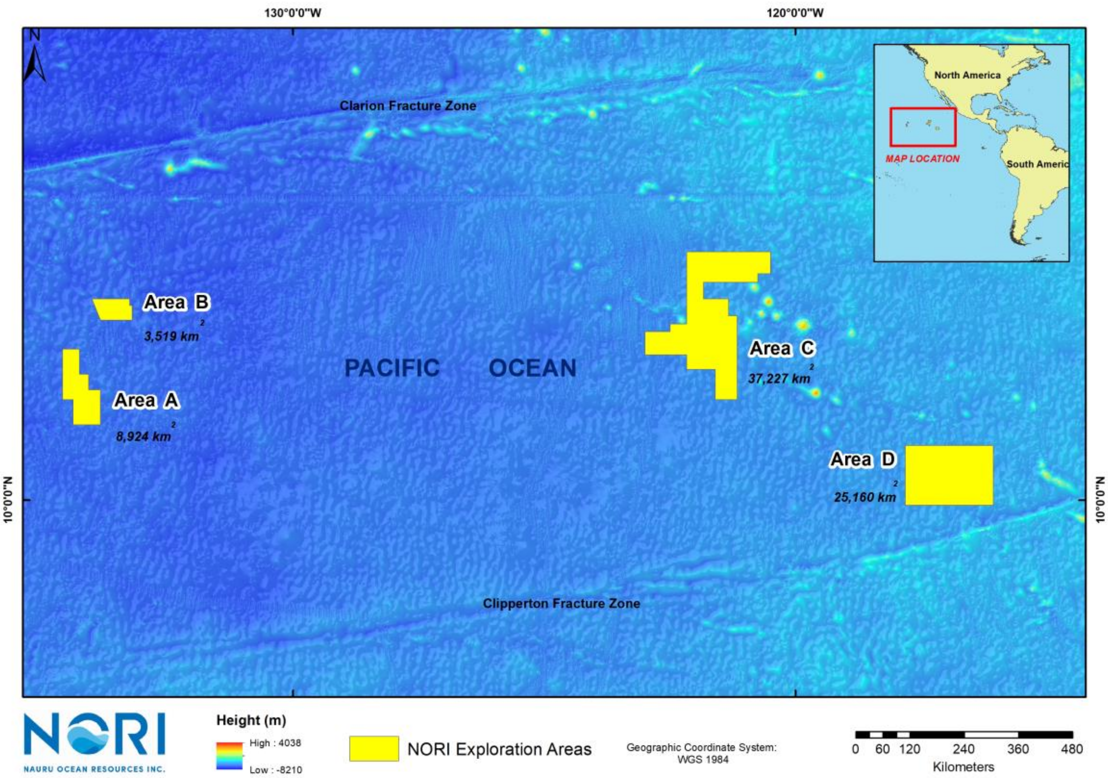
1.4 Project Proponent

The Project proponent is Nauru Ocean Resources Inc. (NORI), a wholly owned subsidiary of The Metals Company which holds interests in commercially exploring the seafloor for polymetallic nodule deposits that are rich in base and strategic metals. The Government of Nauru is the sponsor of NORI's exploration rights within the NORI exploration areas as shown in Figure 1-1 and Figure 1-2.

The Metals Company (TMC) is a publicly listed Canadian deep-sea mining company focused on producing clean base metals from polymetallic nodules. TMC has exploration rights issued by the ISA to three designated areas in the CCZ, sponsored by Nauru (NORI exploration areas), Tonga (TOML exploration area), and Kiribati (Marawa exploration area) (Figure 1-1).

In July 2011, NORI formally signed the agreement with the ISA for exploration tenements in the Pacific Ocean and became the first private sector organisation to be granted an exploration contract. The contract gives NORI exclusive rights to conduct polymetallic nodule exploration activities within the four NORI exploration areas in the CCZ. NORI has been granted 74,380 km^2 of exploration territory with their initial contract period maintained for 15 years.

Figure 1-2. NORI exploration areas



1.5 Offshore Campaigns

1.5.1 Completed Campaigns

Prior to NORI obtaining an exploration contract in 2011, exploration of the NORI-D site was conducted by three pioneer explorers, namely:

- The AMR group from the Federal Republic of Germany, which included Preussag (a German mining company).
- State Enterprise Yuzhmorgeologiya of the Russian Federation.
- Interoceanmetal Joint Organization (IOM), a consortium formed by Bulgaria, Cuba, the Czech Republic, Poland, the Russian Federation, and Slovakia.

The data collected by these early explorers has been used as the foundation for development of a program of works to develop an environmental baseline for NORI-D. Since 2011, NORI has conducted 16 research campaigns to NORI leases A, B, C and D, including:

- **Campaign 1** (2012) – Exploration of the polymetallic nodule resource in NORI-C and NORI-D aboard the RV Mt. Mitchell; including extensive multibeam geophysical surveying of the seafloor and bulk sampling. Approximately 4,500 kg of nodules were recovered from the seafloor as evidenced from video footage.
- **Campaign 2** (2013) – Exploration of the polymetallic nodule resource in NORI-A and NORI-B aboard the RV Mt. Mitchell; including extensive multibeam geophysical surveying of the seafloor along with recovery of approximately 270 kg of nodules by bulk sampling.
- **Campaign 3** (26/4 to 5/6/18) – Benthic sampling at NORI-D to support environmental studies and undertake geotechnical studies to inform PCV and riser system design, collected high-resolution imagery, including Autonomous Underwater Vehicle (AUV) geophysical and light geotechnical surveys. A total of 2,286 km of AUV geophysical data were collected that included high resolution multibeam. Camera traverses were completed at 3 km line spacing to investigate nodule abundance. Forty-five (45) box-cores were collected, with 35 used for environmental work. This resulted in the recovery of 239 nodule biota specimens, 62 megafauna (>20 mm) specimens, and macrofaunal infauna (>0.25 mm) samples sieved from sediment to depth of 100 mm. Sediments were also collected for geochemical analysis.
- **Campaign 6A** (19/8 to 1/10/19) – Box-core sampling of nodules and seafloor sediments at 100 locations within NORI-D for biological, geochemical, geotechnical and mineral assays.
- **Campaign 4A** (2/10 to 23/10/19) – Deployment of three oceanographic moorings within NORI-D from the Maersk Launcher to collect continuous metocean data. Water sampling and oceanographic profiling were also conducted.
- **Campaign 6B** (22/11 to 21/12/19) - Box-core sampling of nodules and seafloor sediments for biological, geochemical, geotechnical and mineral assays at 104 locations within NORI-D and 18 locations in the Marawa exploration area.
- **Campaign 4B** (6/1 to 4/02/20) – Bulk sampling of nodules from NORI-D for mineral assays using an epibenthic sled and first stage of benthic habitat disturbance studies.
- **Campaign 4C** (5/2 to 16/3/20) – Bulk sampling of nodules from NORI-D for mineral assays using an epibenthic sled and second stage of benthic habitat disturbance studies.
- **Ocean Infinity Campaign** (23/05 – 30/05/20) - The availability of the vessel Pacific Constructor, operated by Ocean Infinity provided the opportunity to commission ROV/AUV surveys of the collector site, the expected plume impact area, the PRZ, and intermediate control sites within NORI-D. This resulted in the acquisition of approximately 25K images of the sea floor acquired by an ROV mounted camera at an altitude of <3 m. This information will be used to characterize the megafaunal communities and survey planning for upcoming campaigns.
- **Campaign 4D** (16/6 – 15/7/20) – Serviced the oceanographic moorings deployed at NORI-D during Campaign 4A and undertook additional oceanographic profiling.

- **Campaign 5A** (16/10 – 30/11/20) - Collected data on the benthic biology, sediment geochemistry and surface biology of NORI-D using box-core, multicore and floating hydrophones.
- **Campaign 5B** (5/3 – 14/4/21) - Pelagic biology studies of NORI-D supported by ROV, CTDs, MOCNESS nets and rosette water quality samplers for trace metals.
- **Campaign 5D** – (27/4 – 12/6/21). Collected data on the benthic biology, sediment geochemistry and surface biology of NORI-D using box-core, multicore, lander deployments and floating hydrophones.
- **Campaign 4E –** (6/7-29/7/21). Scheduled annual servicing of moorings on NORI-D site.
- **Campaign 5C –** (21/9 – 2/11/21). Seasonal pelagic biology studies to compliment those conducted on Campaign 5B.
- **Campaign 5E -** (12/11 – 22/12/21). ROV pelagic and benthic transects and specimen collection, lander deployments.

1.5.2 Upcoming Campaigns

The forward work plan over the next two years will involve a further 4 offshore campaigns to NORI-D[1], including:

- **Pre/Mid- Collector Test** – (Q3/2022). Metocean, benthic and pelagic data will be collected both prior and during the Collector Test.
- **Post - Collector Test** – (Q3/2022). Disturbance studies during and after the Collector Test will be conducted.
- **Campaign 4F** – (Q2/2022). Scheduled annual servicing of moorings on NORI-D site.
- **Campaign 4G** – (Q2/2023). Scheduled annual servicing of moorings on NORI-D site.

The dataset collected by NORI for the commercial ESIA will be the most comprehensive single body of information on the nature of the seabed, sampling procedures, and potential environmental impacts of nodule collection in the CCZ.

NORI's scientific studies are designed to meet international best practice specifications and the standardized methodologies recommended by the ISA. This allows comparison with other CCZ technical studies, scientific publications and provides data that can be utilised by third parties. All data collected will be submitted to the ISA DeepData database making it available to other contractors and researchers.

1.6 Collector Test EIS

The ISA recommendations state that the Collector Test EIS should be submitted 12 months prior to the date of the test. The current schedule has the NORI-D Collector Test EIS being submitted Q3/2021, the Collector Test being conducted in Q3/2022.

1.7 Commercial ESIA

The objective of the commercial ESIA is to provide the ISA with sufficient information on the social and environmental impacts of the proposed polymetallic collection operations to make an informed assessment of NORI's application for a commercial licence for the NORI-D lease.

The commercial ESIA will include descriptions of the baseline conditions, project activities, impact assessment, proposed mitigation measures, and an Environmental Monitoring and Management Plan

[1] Schedules are subject to revision depending on COVID-19 situation

(EMMP). An outline of the topics that will be addressed by the environmental baseline studies is provided in Figure 1-3.

The ISA recommends that a Collector Test be conducted as part of the commercial ESIA to test assumptions about the collector system design, test hypotheses about impacts on the receiving environment, and to test the functionality of the collector system at a small scale prior to commercial scale operations (ISBA/25/LTC/6/Rev.1). The results of the Collector Test will be integral to the development of a full-scale system design and operational strategy that effectively minimises the environmental impacts of commercial operations.

1.8 This Report

1.8.1 Objective

The Collector Test EIS is intended to provide the ISA and stakeholders with a clear description of the Project, the potential environmental impacts, environmental risks and hazards, risk management measures and monitoring programs relating to the Collector Test.

As the Collector Test is a one-off activity of short duration limited to a small area of seafloor, socio-economic issues have not been included in the Collector Test EIS, however they will be addressed by the commercial ESIA for the full-scale operating system.

1.8.2 Source Documentation

The information relied upon to compile this EIS has been gathered from both primary and secondary sources. While it is the intention of NORI to ultimately share the findings of all investigations and studies through peer-reviewed publications, some data referred to in this EIS is still preliminary in nature and may currently reside only in internal reports and documents that are not publicly available. These source documents will be made available to the ISA/LTC on written request.

1.8.3 Report Structure

The structure of this report follows a logical sequence, and the individual sections follow the major headings listed in ISBA/25/LTC/6/Rev.1/Annex III, with the following additions: Section 4 - Impact Assessment Methods; Section 10 – Risk Prioritization; Section 11 – Cumulative & Transboundary Impacts; and Section 14 - Conclusions & Recommendations.

The report is structured as follows:

Preface

Executive Summary

1. Introduction
2. Legal & Regulatory Framework, Policy, Standards & Guidelines
3. Project Description
4. Impact Assessment Methods
5. Physicochemical Environment
6. Biological Environment
7. Physicochemical Environmental Impacts
8. Biological Environmental Impacts
9. Cumulative & Transboundary Impacts
10. Hazards, Mitigation & Emergency Response Plan
11. Risk Prioritization
12. Environmental Management, Monitoring & Reporting
13. Consultation & Review
14. Conclusions & Recommendation

Figure 1-3. Overview of environmental studies being conducted as part of the commercial ESIA

2 LEGAL & REGULATORY FRAMEWORK, POLICY, STANDARDS & GUIDELINES

2.1 Introduction

This section describes the main laws, regulations and policies applicable to the Collector Test at the time of writing, and good practice standards and guidelines that have informed the preparation of this document, namely:

- The 1982 United Nations Convention of the Law of the Sea (UNCLOS).
- Nauru legislation relevant to regulating the Project.
- The guidance that applies to the approvals and environmental permitting of the Project under the International Seabed Authority (ISA).
- Other international environmental and social conventions, standards and guidelines, which have informed the preparation of this Environmental Impact Statement (EIS).
- NORI's obligations relevant to the Project.

2.2 1982 United Nations Convention of the Law of the Sea

UNCLOS is an international treaty which was adopted and signed in 1982. It replaced the Geneva Conventions (1958) which addressed the territorial sea and the contiguous zone, the continental shelf, the high seas, fishing and conservation of living resources on the high seas. The convention created three new institutions being the International Seabed Authority (ISA), International Tribunal for the Law of the Sea and Commission on the Limits of the Continental Shelf. The convention has become the legal framework for marine and maritime activities.

Exploration for polymetallic nodules by NORI will be conducted in the 'Area' as defined by Article 1 of UNCLOS, that is, '…the seabed and ocean floor and subsoil thereof, beyond the limited of national jurisdiction'.

The ISA is an autonomous international organisation established under UNCLOS to organise, regulate and control activities in the Area, where activities are defined by Article 1 of UNCLOS as '…all activities of exploration for, and exploitation of, the resources of the Area' and resources are defined as '…all solid, liquid or gaseous mineral resources in situ in the Area at or beneath the seabed, including polymetallic nodules' (Article 133 of UNCLOS). The ISA has the duty to ensure the effective protection of the marine environment from harmful effects that may arise from deep-sea-related activities. The ISA comprises the European Union and 167 Member States, of which Nauru is a member state with permanent missions, becoming a party to UNCLOS on 23 January 1996, that is, State Party.

The Project is therefore governed by the ISA, UNCLOS and the agreement relating to the implementation of Part XI (The Area) of UNCLOS (1994 Implementation Agreement).

NORI's exploration contract is a contract area established in 2011 between NORI and the ISA (NORI Exploration Contract) covering an area of 74,830 km^2, that is, NORI Area A (Block 13), NORI Area B (Block 15), NORI Area C (Block 22) and NORI Area D (Block 25). NORI Area D (NORI-D) will be the location where the Collector Test will be conducted.

2.3 The ISA Mining Code

The ISA Mining Code is comprised of rules, regulations, and procedures to regulate prospecting, exploration, and exploitation of marine resources in the Area. These rules, regulations and procedures are issued within a general legal framework established by UNCLOS (for example, Part IX) and the 1994 Implementation Agreement (UN, 2016).

2.3.1 Recommendations

There are a number of recommendations that have been issued as part of the Draft Mining Code that once finalised will become regulations (see Section 2.3.2). The most relevant are the:

- Recommendations for the Guidance of Contractors for the Assessment of the Possible Environmental Impacts Arising from Exploration for Marine Minerals in the Area (30 March 2020; ISBA/25/LTC/6/Rev.1).

  This recommendation defines the activities that require environmental impact assessments (EIAs), the form and content of the EIAs, as well as guidance on baseline studies, monitoring and reporting, especially related to impacts on marine biodiversity. Annex III provides a template for the Environmental Impact Statement (EIS), although more detailed documentation on the requirement of an EIA is provided in draft regulations on exploitation of mineral resources in the Area (ISBA/25/C/WP.1) (see Section 2.3.2).

  Section VI(B)(33) states:

  33. The following activities require prior environmental impact assessment, as well as an environmental monitoring programme to be carried out during and after the specific activity, in accordance with the recommendations contained in paragraphs 33 and 38. It is important to note that baselines, monitoring and impact assessment studies are likely to be the primary inputs to the environmental impact assessment for commercial mining. The activities include:

  (a) Use of sediment disturbance systems that create artificial disturbances and plumes on the sea floor;

  (b) Testing of mining components;

  (c) Test-mining;

  (d) Testing of discharge systems and equipment;

  (e) Drilling activities using on-board drilling rigs;

  (f) Sampling with epibenthic sled, dredge or trawl, or similar technique, in nodule fields, that exceeds 10,000 m^2;

  (g) Taking of large samples to test land base processes.

Therefore, the Collector Test (to test the mining components, discharge systems and equipment) requires a prior EIA and an environmental monitoring program, as the activities proposed to be undertaken include:

- o The use of sediment disturbance systems that create plumes.
- o The testing of mining components.
- o The testing of discharge systems.
- o The collection of large samples.

The Collector Test EIS is to be submitted to the Secretary-General of the ISA no later than one year in advance of the activity taking place.

- Recommendations for the Guidance of Contractors for the Assessment of the Possible Environmental Impacts Arising from Exploration for Polymetallic Nodules in the Area (ISBA/16/LTC/7; 2 November 2020).

  This recommendation specifies baseline data collection requirements in detail and EIA requirements which are similar to those of ISBA/25/LTC/6/Rev.1 including the timing of submission. Section B(13) identifies activities requiring prior EIA:

  (a) Sampling with epibenthic sled, dredge or trawl, to collect nodules for on-land studies for mining and/or processing if the sampling area of any one sampling activity exceeds 10,000 m^2;

  (b) Use of specialized equipment to study the effect of artificial disturbances that may be created on the sea floor;

  (c) Testing of collection systems and equipment.

- ISBA/25/LTC/6/Rev.1 Section E. outlines the recommendations for stakeholder consultation. A stakeholder consultation process is required and while the Recommendations do not require that they be conducted by the Sponsoring State, the Secretary General may encourage the Sponsoring State to conduct them. To date three Collector Test EISs have been submitted and in all instances, the Sponsoring States hosted a consultation process.

2.3.2 Regulations

To date, the ISA has issued four regulations as part of the Mining Code, with those most relevant to the Project being:

- Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area (adopted 15 July 2013; (ISBA/16/A/12/Rev.1).

  Part 5 (Protection and Preservation of the Marine Environment) addresses:

  - Environmental baseline data and monitoring of environmental impacts of all its activities.
  - Reporting incidents caused by the contractor that might pose the risk of serious environmental harm and stopping activities if the risks warrant it.
  - Not undertaking any activities that might cause serious harm to coastal States.
  - Reporting on and preserving any potential historic or archaeological sites.

  Sections 5 to 7 of Annex IV (Standard Clauses for Exploration Contract) elaborate on these matters and specify:

  5.2 Prior to the commencement of exploration activities, the Contractor shall submit to the Authority:

  (a) An impact assessment of the potential effects on the marine environment of the proposed activities;

  (b) A proposal for a monitoring programme to determine the potential effect on the marine environment of the proposed activities; and

(c) Data that could be used to establish an environmental baseline against which to assess the effect of the proposed activities.

- Draft regulations on exploitation of mineral resources in the Area (March 2019; ISBA/25/C/WP.1). These regulations are expected to be finalised in 2021.

Part 4, Section 2 (Preparation of the Environmental Impact Statement and the Environmental Management and Monitoring Plan) outlines the purpose of, and requirements for, the EIS and environmental management and monitoring plan, including recommended formats to guide the content of the EIS.

The first set of draft standards and guidelines to support the Mining Code have been developed and were available for public consultation until 20 October 2020. These include three documents related to the preparation and assessment of an application for the approval of a commercial plan of work, the development and application of environmental management systems and the calculation of an environmental performance guarantee (noting that it is not permitted to quote or cite these documents).

These documents cover the obligations of NORI to the ISA with respect to exploration of the Area under contract. The EIS for activities associated with the Collector Test within NORI-D is consistent with the requirements described above.

2.4 Nauru Legislation

The Republic of Nauru *International Seabed Minerals Act 2015* governs Nauru's engagement in seabed mineral activities in the Area beyond national jurisdiction and the associated administrative functions of the republic. The Act defines exploration as:

> 'use and testing of recovery systems and equipment, processing facilities and transportation systems in the Area'

The Act recognises:

6 (d) the rules, regulations, procedures, codes and standards adopted by the ISA for the:

i. protection and preservation of the natural resources of the Area and the prevention of damage to the flora and fauna of the Marine Environment.

ii. preservation, reduction and control of pollution and other hazards to, and the interference with the ecological balance of the Marine Environment.

iii. exercise of control over activities in the Area as is necessary for the purpose of securing compliance with the UNCLOS and the Rules of the ISA by contractors carrying out activities in the Area.

Under the Act, to be eligible to perform seabed mineral activities, a Sponsorship Applicant must first:

(a) obtain a valid Sponsorship Certificate from the ISA; and

(b) obtain a valid contract from the ISA, pertaining to those seabed mineral activities.

A Sponsored Party is a person who holds a current Sponsorship Certificate issued under Part 3 of the Act, that person's representatives or officers, and any person or persons to whom the Sponsorship Certificate may lawfully have been assigned. The NORI Exploration Contract grants NORI tenure and the exclusive right to explore for polymetallic nodules in the NORI Areas for a period of 15 years. NORI will perform all exploration activities under this contract.

The following clauses within the Act provide guidance to Nauru in terms of their legal obligations:

7 Establishment of the Nauru Seabed Minerals Authority

(2) The Authority shall be a body corporate with perpetual succession and a common seal,

10 Objectives of the Authority

(c) ensure compliance by Sponsored Parties or any sub-contractors engaged by the State of Sponsored Parties in relation to Seabed Mineral Activities with relevant rules and internationally agreed standards;

(f) act in a way that is compatible with principles of best regulatory practice, including that regulatory activities should be proportionate, accountable, consistent, transparent and targeted only at cases where needed.

11 Functions of the Authority

The functions of the Authority are to:

(g) liaise with the ISA and any other relevant international organizations to facilitate a Sponsored Party's application to the ISA for a contract;

(i) assist the ISA in its work to establish, monitor, implement and secure compliance with the Rules of the ISA;

(j) undertake any advisory, supervisory or enforcement activities in relation to Seabed Mineral Activities or the protection of the Marine Environment, insofar as this is required in addition to the ISA's work in order for Nauru to meet its obligations under the UNCLOS as a Sponsoring State;

(n) seek expert advice on factual matters pertaining to the administration of this Act and concerning the management of Nauru's Seabed Mineral Activities including but not limited to advice on economic, legal, scientific, technical matters and the management and conservation of the Marine Environment, including from experts outside of the country.

17 Consultation

The Authority may at any time and in way that it sees fit, consult with persons of relevant expertise, interest groups, or the general public before taking a decision or action under this Act.

30 State Responsibilities

Where Nauru is sponsoring a Sponsored Party which holds a contract with the ISA to conduct Seabed Mineral Activities, Nauru via the Authority will:

(a) seek to ensure that its conduct in relation to the ISA, the Area and Seabed Mineral Activities adheres to the requirements and standards established by general principles of international law;

(b) take all appropriate means to exercise its effective control over Sponsored Parties or any relevant sub-contractors engaged by the State, seeking to ensure that any Seabed Mineral Activities are carried out in conformity with the UNCLOS, the Rules of the ISA and other requirements and standards established by general principles of international law;

(c) do all things reasonably necessary to give effect to its sponsorship of a Sponsored Party, including undertaking any communication with and providing any assistance, documentation, certificates and undertakings to the ISA or other relevant party required in respect of the Sponsorship;

31 Monitoring powers

(1) The Authority shall have the power to make such examinations, inspections and enquiries of Sponsored Parties and the conduct of Seabed Mineral Activities as are necessary to meet its responsibilities under international law, which may include the:

(a) sending of an observer to the site of the Seabed Mineral Activities and vessel or premises of the Sponsored Party.

2.5 Other International Conventions, Standards & Guidelines

The International Maritime Organisation (IMO) International Convention for the Prevention of Pollution from Ships (MARPOL), including the subsequent annexes I to VI (outlined below), is applicable to the operation of the vessel and the exploration activities.

- Annex I – Regulations for the Prevention of Pollution by Oil.
- Annex II – Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk.
- Annex III – Prevention of Pollution by Harmful Substances Carried in Sea in Packaged Form.
- Annex IV – Prevention of Pollution by Sewage from Ships.
- Annex V – Prevention of Pollution by Garbage from Ships.
- Annex VI – Prevention of Air Pollution from Ships.

Table 2-1 provides additional environmental conventions, protocols and codes that are applicable to the Project and its implementation.

Table 2-1. Relevant conventions, protocols and codes

CONVENTIONS, PROTOCOLS AND CODES	DESCRIPTION/IMPLICATIONS
Marine	
Convention for the Protection of the Natural Resources and Environment of the South Pacific Region (1986) Also known as the SPREP Convention or Noumea Convention.	Agreement for the protection, management and development of the marine and coastal environment of the South Pacific Region and represents the legal framework of the Action Plan for managing the Natural Resources and Environment of the South Pacific adopted in 1982.
Protocol for the Prevention of Pollution of the South Pacific Region by Dumping (1990) (Amendment) 2006	The objective of the protocol is to prevent, reduce and control pollution by dumping of wastes and other matter in the South Pacific.
International Convention for the Control and Management of Ships' Ballast Water and Sediments (2004)	Under the Convention, all ships in international traffic are required to manage their ballast water and sediments to a certain standard, according to a ship-specific ballast water management plan. The Convention requires all ships to implement a Ballast Water and Sediments Management Plan, and to carry a Ballast Water Record Book and are required to carry out ballast water management procedures to a given standard.
1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (as amended in 2006)	Article 1 Definitions Article 4.2 "Dumping" does not include: 4.3 The disposal or storage of wastes or other matter directly arising from, or related to the exploration, exploitation and associated offshore

CONVENTIONS, PROTOCOLS AND CODES	DESCRIPTION/IMPLICATIONS
	processing of seabed mineral resources is not covered by the provisions of this Protocol.
The International Marine Minerals Society's Code for Environmental Management of Marine Mining (2001)	The code anticipates and integrates environmental considerations for responsible marine mining. The Code seeks to complement national and international marine mining environmental regulations where they exist, and to provide environmental principles and guidelines where these are absent or could be improved.
Fauna and Flora	
Convention on Biological Diversity (1992)	The convention covers conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising from using genetic resources, including on the deep seabed.
Memorandum of Understanding for Cetaceans and their Habitats in the Pacific Island Region (2006)	To provide an awareness of international responsibilities to conserve cetacean populations of the Pacific Islands Region, in particular, pursuant to the Convention on Biological Diversity (CBD) for which the Convention on the Conservation of Migratory Species of Wild Animals (CMS) is the CBD lead partner in the global conservation of migratory species over their entire range.
UNCLOS (article 145 Part XII) Protection of the Marine Environment	To ensure the marine environment and all species related are protected and that no harm comes to flora or fauna during human activities.
Climate	
Vienna Convention for the Protection of the Ozone Layer (the Vienna Convention) (1993) and the Montreal Protocol on Substances that Deplete the Ozone Layer (1992)	To provide guidelines and protocols for the protection of the ozone layer on a global scale.
United Nations Framework Convention on Climate Change (1992)	An international environmental treaty providing guidelines and frameworks addressing climate change on a global scale.

3 PROJECT DESCRIPTION

3.1 Context

The ISA recommendations require that test-mining and testing of mining components be conducted as part of an EIA in support of an application for a commercial mining contract (ISBA/25/LTC/6/Rev.1.[I7]). NORI has scheduled testing of a collector system for Q3/2022. Testing of mining components will be conducted over approximately 60 days, in an area of 8 km^2 involving 860 hours of seafloor trials, of which approximately 259 hours will be full system test runs.

The creation of plumes, testing of mining components, test mining, and testing of discharge systems and equipment are identified as activities requiring an EIA and monitoring during and after testing (ISBA/25/LTC/6/Rev.1. [II.C11(c)]/[VIB33(a)(b)(c)(d)]).

Baseline data documenting natural conditions prior to test mining is required to monitor changes in the receiving environment resulting from these activities and to predict impacts of commercial scale mining (ISBA/25/LTC/6/Rev.1[III.B.15]).

3.2 Objectives

Testing of a prototype nodule collection system will be conducted in small area of NORI-D. The prototype system is currently under development by Allseas Group S.A. (Allseas) in the Netherlands; and will be a fully functioning 1/5 scale prototype of the commercial system.

Allseas and NORI will conduct a series of sea trials of the prototype system to assess its technical and environmental performance, and in doing so achieve the following objectives:

- Demonstrate the technical feasibility of the polymetallic nodule collection system.
- Assess the technical performance of the prototype collection system and incorporate learnings into the design of the full-scale commercial system.
- Assist in predicting potential environmental impacts associated with full-scale operations.

The prototype collector system will be put through the following sea trials:

- Deployment from the surface vessel to the seabed.
- Coupling of the riser pipe and umbilical with the prototype collector vehicle (PCV).
- Propulsion and manoeuvring of the PCV on the seabed.
- Collection of nodules.
- Transfer of nodules up the riser pipe to the surface vessel.
- Separation and retention of nodules from entrained water and sediment on the surface vessel.
- Release of entrained seawater and sediment through a return pipe at a depth of approximately 1,200 m.
- Recovery of riser pipe and PCV to the surface vessel.

3.3 Site Location

NORI-D is located in the eastern Pacific Ocean and is bounded by the Clarion Fracture Zone to the north and the Clipperton Fracture Zone to the south. Collectively the area is called the Clarion-Clipperton Zone

(CCZ). The CCZ spans 4.5-million-km^2 between Hawaii and Mexico; most of the polymetallic nodule exploration contracts issued by the ISA in the Pacific are in this region.

NORI-D is approximately 1,600 km offshore from the nearest landmass in the south-eastern part of the CCZ. It covers an area of 25,160 km^2 with water depths ranging between 3,000 and 4,600 m.

The centre of NORI-D is approximately 11°N and 117°W.

3.3.1 Collector Test Area

The testing will be conducted within the Collector Test Area (CTA) located in the southwest part of NORI-D. The CTA covers an area of 150 km^2 (10x15 km) and water depths are between 4,248 m and 4,336 m.

The location of the CTA was selected to be representative of target mining areas within NORI-D in terms of bathymetry, water depth, nodule type, nodule distribution, geoform, and slope. CTA selection is based on the following rationale:

- Located in the abyssal plain domain which constitutes the majority of NORI-D and is characterised by gentle slopes of 0˚ to 6˚ and nodules lying on soft sediment. Nodules are observed to be ubiquitous in this domain wherever surveyed and sampled. The abyssal plains are considered to be a highly prospective domain for nodules and constitute the majority of the target mining areas within NORI-D (AMC, 2020).

- NORI-D site is characterised by undulating seafloor topography with a mean slope of 2°; the mean slope of the CTA is <4° trending towards the mean for the site as a whole. (slope analysis is based on EM120 Bathymetric data collected by Williamson & Associates, 2012; in Darmawan, 2014) and is mapped at 50m resolution).

- Water depth across NORI-D ranges from 3,000 – 4,600 m, with a mean of 4,325 m.

- Three broad classes of nodule distribution at seafloor have been identified from NORI-D. Type 1 nodule distribution facies are typically characterised by >50% nodules (by area of coverage). Most of these nodules are medium-sized (1-10 cm) and closely packed, with many nodules in contact with their neighbours. Type 1 facies were the most dominant type observed on the site during the 2018 and 2019 campaigns and are well represented in the CTA. Type 1 facies are the prime mining target.

- Applying the "Clustering Large Applications" (CLARA) (Kaufman & Rousseeuw, 1990) algorithm to physical data collected for NORI-D resolved an eight-cluster geoform classification (including, seamounts, bathymetric highs, bathymetric lows, and flat plains). Within each geoform key compartments were identified (e.g., slopes associated with abyssal hills, depressions within bathymetric lows, seamount sub-features, etc). At this scale, biological communities are expected to be organised in response to abiotic type (Dunson *et al.* 1991).

- As Abyssal hills and seamounts have been shown to be higher in species richness and standing stock biomass compared to adjacent areas devoid of topographic variability (Clark *et al.*, 2009; Cuvelier *et al.*, 2020; Durden *et al.*, 2015, 2020; McClain, 2007; Ramirez-Llodra *et al.*, 2005; Rowden *et al.*, 2010), the CTA and TF have been purposely positioned in the 'Flatter area' geoform which is assumed to be less species rich and is the largest geoform type represented on NORI-D (8,553.70 km^2).

3.3.2 Test Field

Within the CTA, the testing will be conducted in a 2x4km Test Field (TF), this will be the only area of the seabed to be directly impacted by the PCV. Areas of the CTA outside of the TF may be indirectly impacted by sedimentation or deterioration of water quality.

The information used to select the CTA was also used to identify suitable TFs on which to conduct the Collector Test. A "Go/No-Go" map was prepared and used to determine the most suitable part of the CTA to conduct the Collector Test with the lowest potential for environmental impacts. The findings of the assessment are summarised below:

- Nine potentially suitable TFs (contiguous areas of adequate size, that is, 2x4km minimum) were identified using a maximum slope constraint of 4° (Figure 3-1).
- The identified fields differ in their location, size, orientation, and site conditions.
- The majority of potential TFs are typically 1.5 km - 2.5 km wide and 4km - 7km long.

Field No 6 was selected in view of its size (2x4 km), slope and topography (Figure 3-1). Bathymetry data acquired for the TF was gridded at 27cm (Figure 3-2).

3.3.3 Impact Reference Zone

ISA recommendations include the delineation of an Impact Reference Zone (IRZ) for the impact assessment of mining activities (ISBA/25/LTC/6/Rev.1.[VI7.C.38[o]). The IRZ should be a site where the mining activities and related direct impacts have previously occurred. It is intended that the TF and parts of the wider CTA are designated as IRZs after Collector Test activities are complete. A post-test long-term monitoring program for the IRZ will be included in the EMMP developed for submission with the application for the exploitation contract.

Figure 3-1. Test Field selection constraints analysis

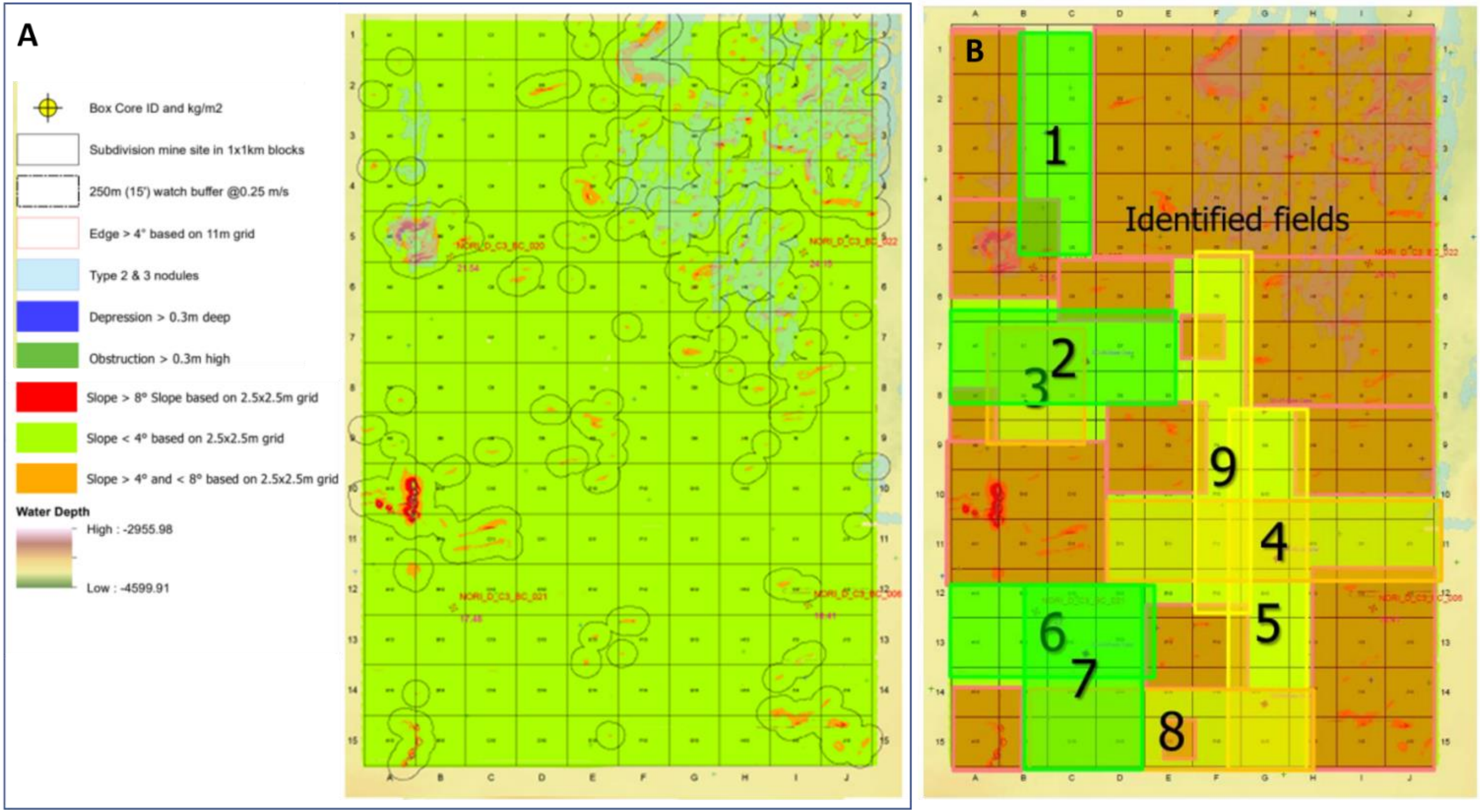
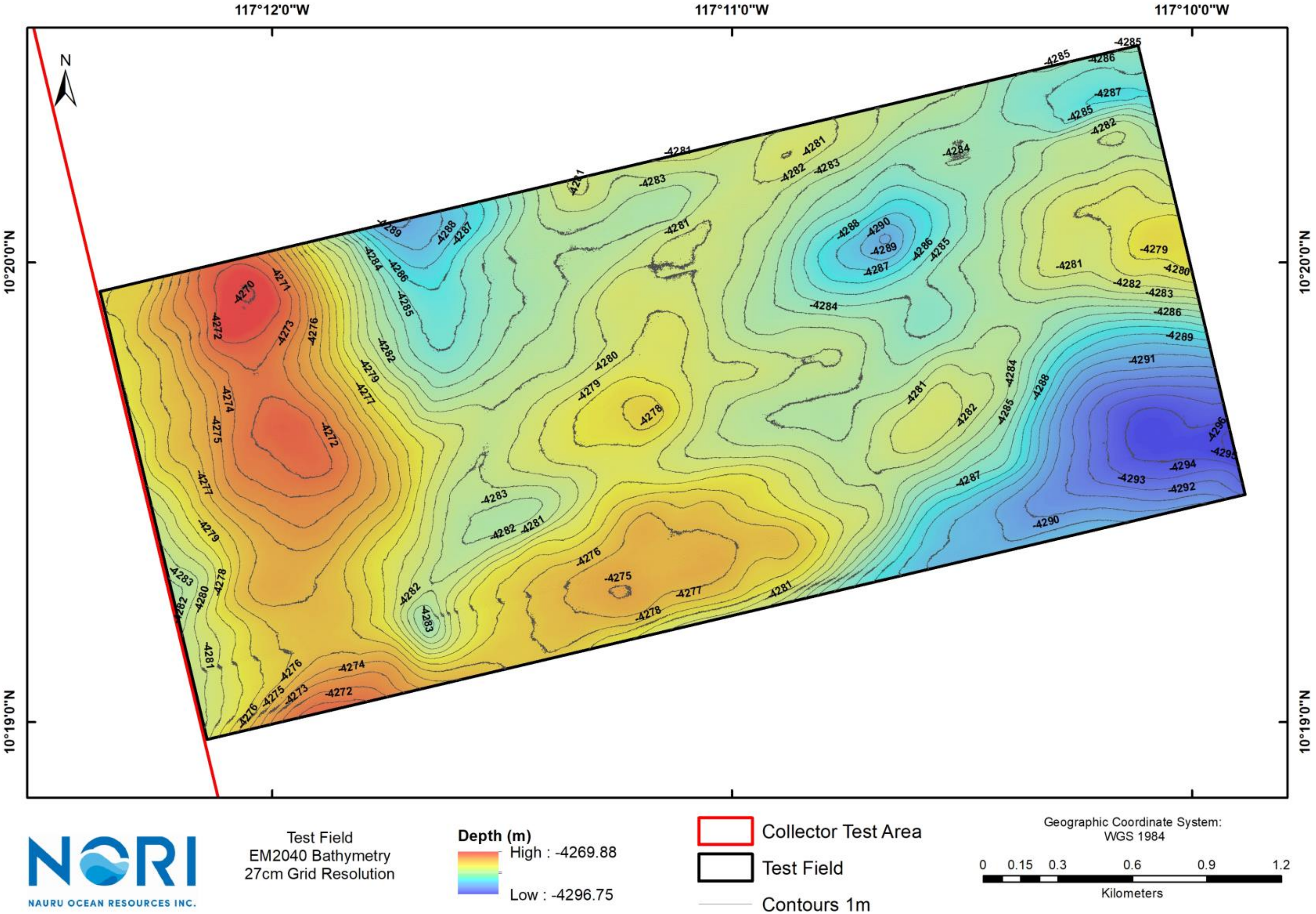


Figure 3-2. Test Field bathymetry (27cm grid)



3.3.4 Preservation Reference Zone & BACI Control Sites

ISBA/25/LTC/6/Rev.1 identifies Preservation Reference Zones (PRZs) as being important in identifying natural variations in environmental conditions against which the impacts of mining can be assessed.

The ISA recommends that a PRZ should be representative of the pre-mining condition so that impacts in mined areas can be benchmarked against it. Therefore, it is important that the composition and condition of the biotic and abiotic components of the PRZ are representative of those of the pre-mined IRZ, including comparable geochemistry and species composition. It has also been recommended that multiple control sites are desirable to detect disturbances that do not affect long-term mean abundances of a population, but, instead, alter the temporal pattern of variance of abundance (Jones *et.al.*, 2020).

To satisfy these recommendations both a PRZ and up to two control sites have been established on the NORI-D lease. The PRZ is in the NE corner of the lease covering an area of 750 km^2. The primary role of the PRZ is the long-term preservation of examples of the geoforms and associated habitats that may be directly or indirectly impacted by mining activities. The baseline condition of habitats in the PRZ has been established and they will be monitored for change as part of the long-term monitoring program developed for the lease.

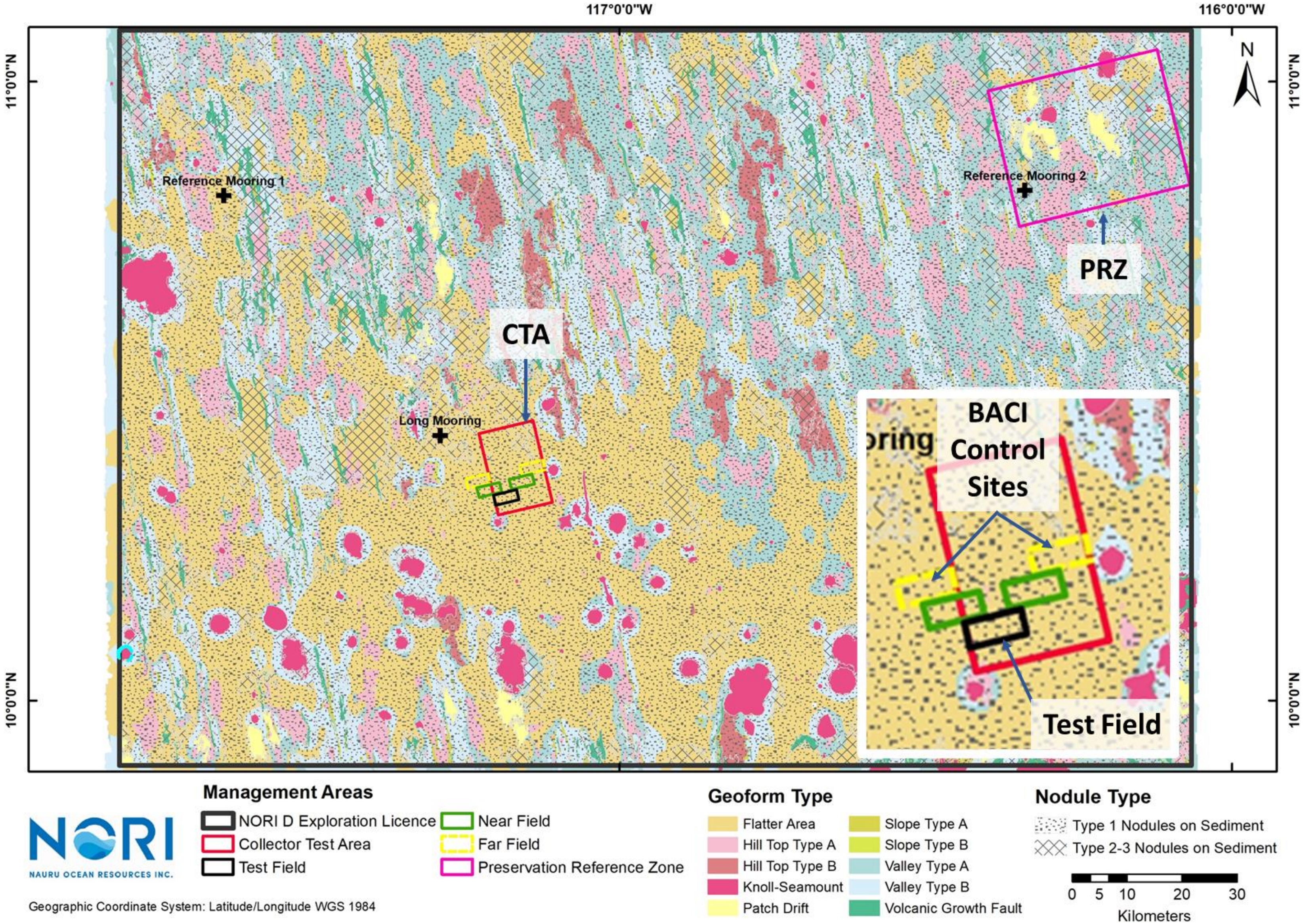
Specific to the Before-After-Control-Impact (BACI) studies to monitor recovery in the IRZ, two additional control sites have been established. These sites have been chosen specifically to be representative of the conditions at the IRZ only, rather than multiple habitats that will be impacted during commercial mining. The control sites are in the same geoform as the IRZ and as close as possible to it without being impacted by Collector Test activities (i.e., >10 km). Baseline studies demonstrate that the geochemistry and benthic species composition of the control sites are comparable to that of the TF (see Sections 5.13 and 6.3).

The 'Far Field' sites identified in Figure 3-3 have been designated as potential BACI control sites. Recently acquired data suggests that they are far enough away from the TF that impacts from Collector Test activities are unlikely for the following reasons:

- Modelled data from the RFP and also from Aleynik *et.al*., (2017) and from unpublished data from the JPI-Oceans project (Haeckel, 2021) suggest that the majority of the plume will settle out within a few hundred metres of the tracked regions.
- Sedimentation modelling indicates that sedimentation depths >0.1mm will be restricted to an approximate 5 km radius from the point of mobilization (see Section 7.2.1.4)

These assumptions will be tested during the Collector Test. Both the PRZ and the selected BACI control site will be monitored for the duration of the commercial contract.

Figure 3-3. Location of Before-After-Control-Impact Control sites



3.4 Collector Test Components

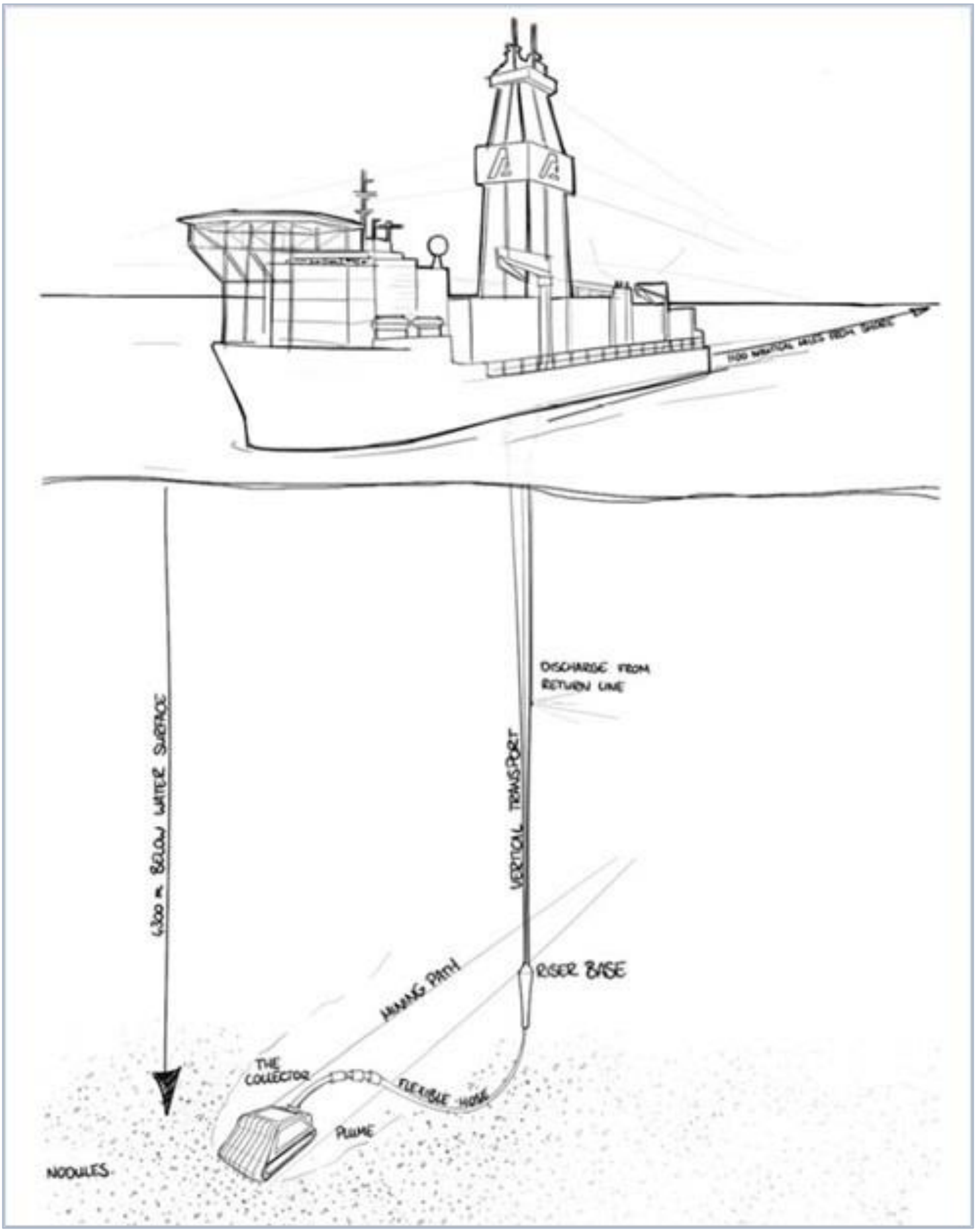
The equipment developed for Collector Test will leverage advances made in the offshore oil and gas, telecommunications, and dredging industries. Proven technology, such as the dynamically positioned surface vessel, ROVs, electric motors, pumps, riser pipes, hydraulic systems, and umbilical power cables, will be directly transferable to the collector system. The exception to this is the PCV which has been designed and built specifically for the collection of polymetallic nodules.

The main components of the test collector system are:

- **Surface Support Vessel (SSV)**. A dynamically positioned ship that will accommodate the PCV, ROV and associated launch and recovery systems. The riser system, dewatering plant, and nodule storage will also be housed on the SSV.
- **Prototype collector vehicle (PCV)**. The PCV will be a tracked vehicle that uses suction technology to collect nodules from the seafloor. It will be controlled from the surface vessel via an umbilical.
- **Riser and Return.** The riser system will transport nodules collected at the seabed to the SSV using an air lift system. A return pipe will discharge entrained water and sediment separated from nodules at the surface at a depth of -1,200 m.
- **Remotely Operated Vehicle (ROV)**. A support system used to conduct visual and sonar surveys, monitor the PCV, attach the riser system, and to provide assistance to the PCV as needed.
- **Umbilicals**. An umbilical will be used on both the PCV and the ROV to power and control the subsea equipment from the SSV. When the PCV and ROV are operating, the umbilical(s) will extend from the SSV to the seafloor.

Figure 3-4 shows how the SSV, riser, return pipe, and collector will be connected during system testing. Figure 3-5 shows the major collector system components at port in Rotterdam, Holland.

Figure 3-4. Nodule Collection System



Source: Allseas (2020)

Figure 3-5. Collector system components in port, Rotterdam, Holland.

Note: A - Hidden Gem; B - LARS system; C - LARS system and Prototype Collector Vehicle; D – Prototype Collector Vehicle
Source: Allseas, (2022).

3.4.1 Surface Support Vessel

The Surface Support Vessel (SSV) will be the converted drill ship *Hidden Gem* (Figure 3-6). The ship is single hulled with a carrying capacity of 61,042 t DWT. Current draught is reported to be 16 m, with an overall length of 228 m and a width of 42 m.

The vessel will be capable of supporting mining activities and launching and recovering all subsea equipment (e.g., the PCV, riser system, ROV) in conditions up to sea state 5 (where significant wave heights[2] can reach 3.5 m).

Dynamic positioning (DP) will enable the vessel to hold position and follow the PCV as it moves along the seafloor. Acoustic long baseline (LBL) transponders deployed on the seafloor will provide the SSV with information on the location of the PCV and ensure that all components of the system are within operational limits.

A dewatering plant will be fitted to the vessel that will separate nodules from seawater.

[2] The average height (trough to crest) of the one-third of the largest waves.

Figure 3-6 Mining Vessel Hidden Gem

3.4.2 Prototype Collector Vehicle

Polymetallic nodules will be collected from the seafloor using a PCV currently under development by Allseas Group S.A. based in Delft, Netherlands (www.allseas.com) (Figure 3-7).

Figure 3-7. Rendering of Prototype Collector Vehicle

The PCV has been designed to collect nodules from the seafloor and transfer them to the base of the riser system which transports them to the SSV. The PCV design has been structured around five core functions that the vehicle must be capable of executing in order to collect and transfer nodules:

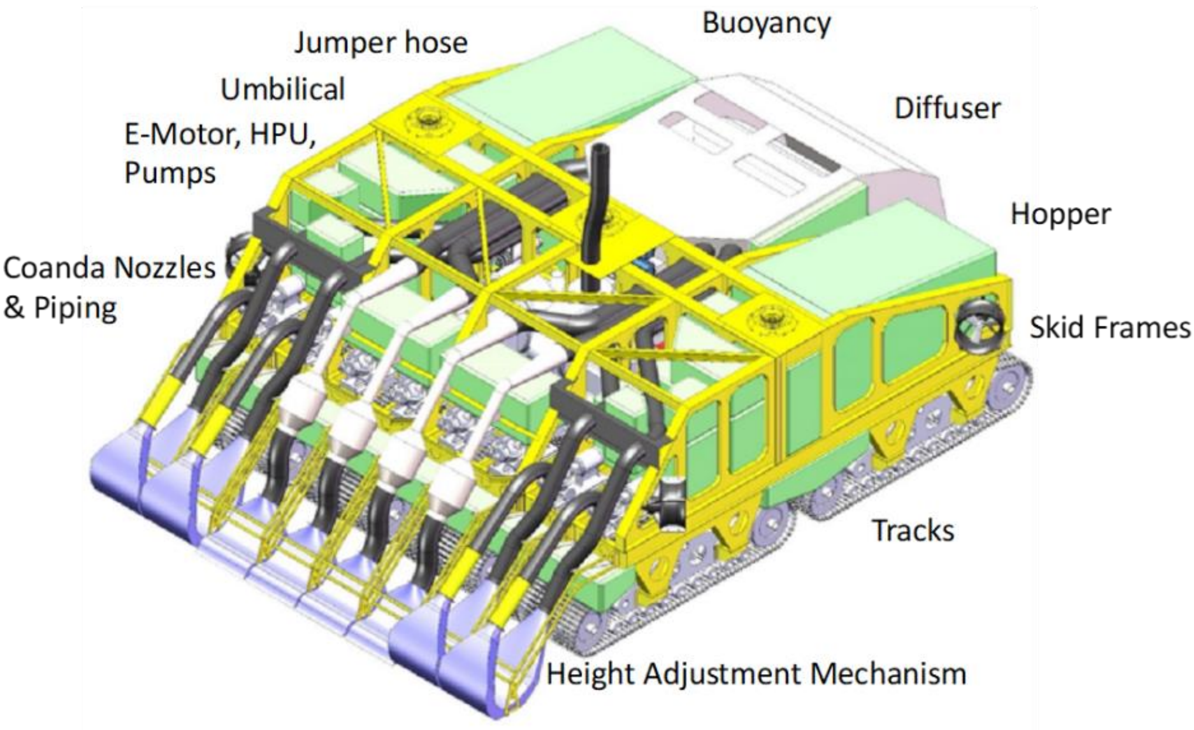
- Nodule pick-up
- Nodule processing system (at seabed)
- Nodule transfer to surface
- Propulsion
- Docking, launch and recovery.

These core functions are provided by the following systems and components:

- Nodule collection system
- Nodule sorting system
- Riser system
- Return water system
- Propulsion system
- Structural frames
- Control system
- Power distribution
- Electrical and instrumentation
- Hydraulic actuation
- Control and automation
- Navigation
- Slurry monitoring
- Deployment and recovery system
- Weight balance
- Weight and buoyancy

The main components of the PCV shown in Figure 3-8.

Figure 3-8 Main components of the Prototype Collector Vehicle



Source: Cellula Robotics Production Harvester Design Report, CRL-DCD15-RP-09 Rev R01

The dimensions of the PCV are:

- Length - 12 m
- Width - 6 m
- Height - 5 m
- Weight in air - 80 tonnes
- Weight on seabed - 14 tonnes

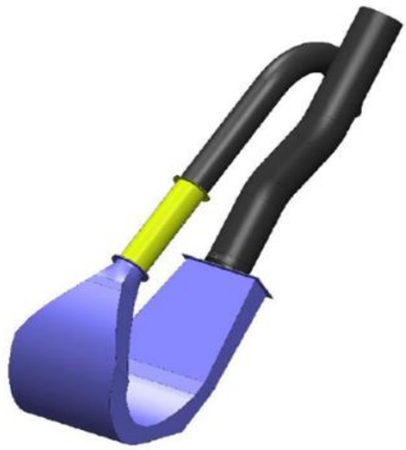
3.4.3 Nodule Collection System

The nodule collection system is comprised of the following components:

3.4.3.1 Pick-up Coandă Nozzle

The pick-up nozzles have been designed to utilize the Coandă effect – a tendency of a fluid jet to stay attached to a convex surface. The nozzle design utilizes a water jet and suction combination together with a convex nozzle head geometry to create lift from the Coandă effect (Figure 3-9). It is expected that this system will disturb the top 10-15 cm of sediment depending on the height of the nozzle above the seabed and the water jet and suction forces applied. An advantage of this design is that it minimises disturbance of the surface sediments, this will be verified during the Collector Test.

Figure 3-9. Coandă Nozzle



3.4.3.2 Height Adjustment System

The nodule collection system has been designed to be height adjustable. This allows distance between the nozzle head and the seabed to be varied in response to terrain and nodule size. Height adjustment also allows for fine tuning of the Coandă effect by changing the relative force of the water jet and suction combination on the seabed. The ability to fine tune in this manner will optimise the efficiency of nodule pick-up whilst minimising sediment disturbance.

The height adjustment system will consist of clearance arms mounted near the pick-up head (Figure 3-10), a hydraulic cylinder with stroke sensor, drag plate and encoder, ultrasonic altimeter, and overload protection system (cylinder pressure relief valve).

3.4.3.3 Pick-up Pumps

Multiple pick-up pumps powered by an electric motor will be used to create suction in the nozzle heads. The final design of the pump system will consist of either axial or radial flow pumps.

3.4.3.4 Nodule Processing System

The nodule processing system is designed to separate nodules from sediment inside the PCV. Special pump equipment is used for separating fines from the nodule flow stream, keeping as much sediment as possible at the seafloor. Figure 3-11 shows the general layout of the nodule processing system which will operate as follows:

- Seawater, sediment, and nodules are sucked into the PCV and pass through an 80 mm screen mesh. Any material that cannot pass through the screen mesh will be rejected and will remain on the seafloor. Finer nodules and sediment that pass through the screen will be pumped into a hopper.
- Inside the hopper, the bulk of sediment will be separated from the nodules and will be discharged behind the PCV via a diffuser system. This material will be discharged above the seafloor as a laminar flow.
- Nodules (and sediment that has not been separated) inside the hopper will settle into a buffer tank at the base of the hopper. Slurry material is then pumped up into a jumper hose for transfer to the riser pipe and the SSV.

Figure 3-10. Clearance Arms

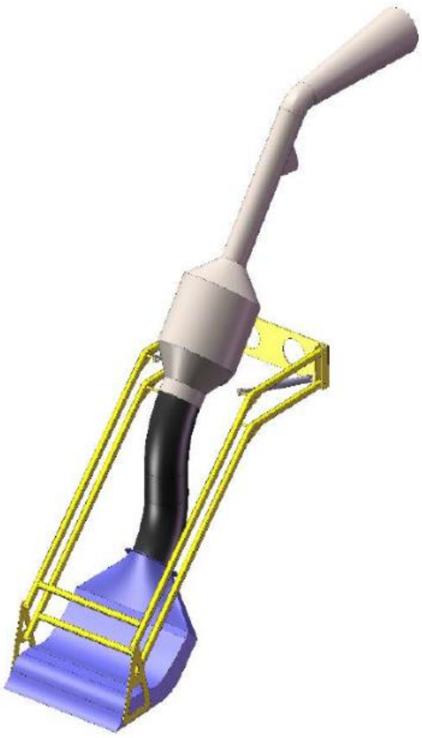
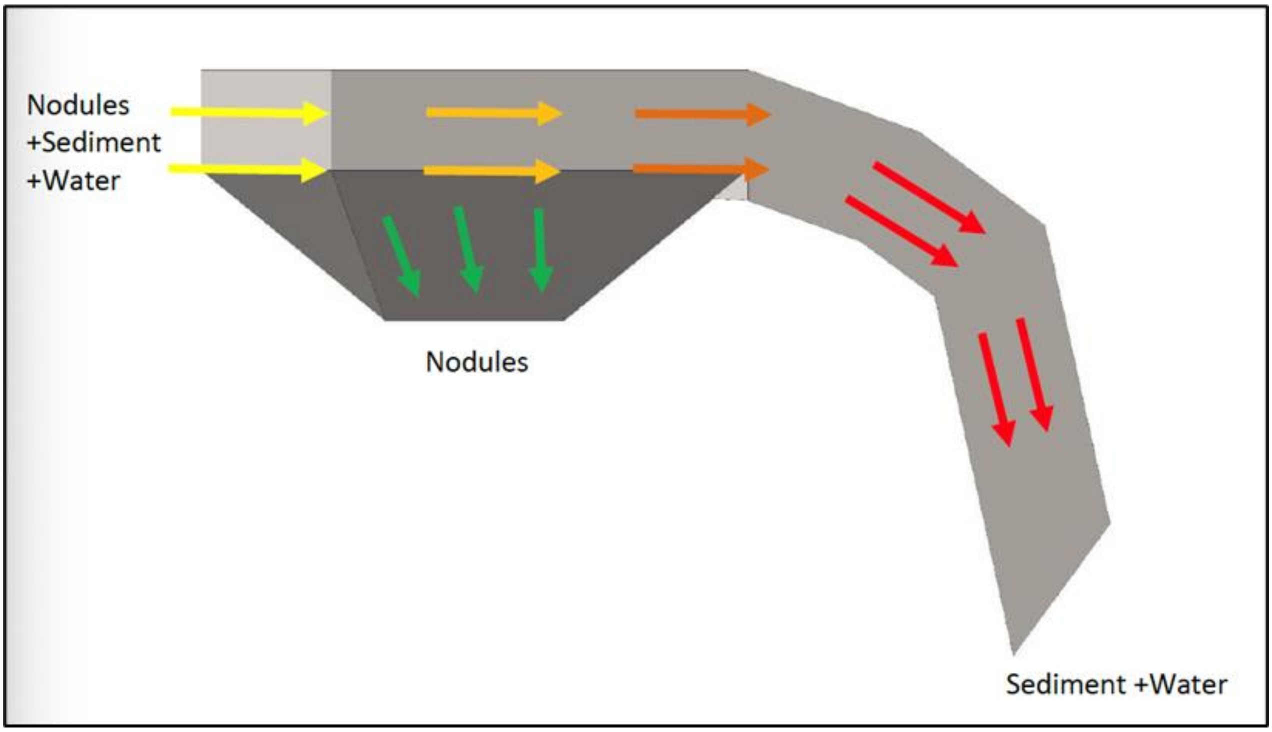


Figure 3-11. General layout of nodule processing system



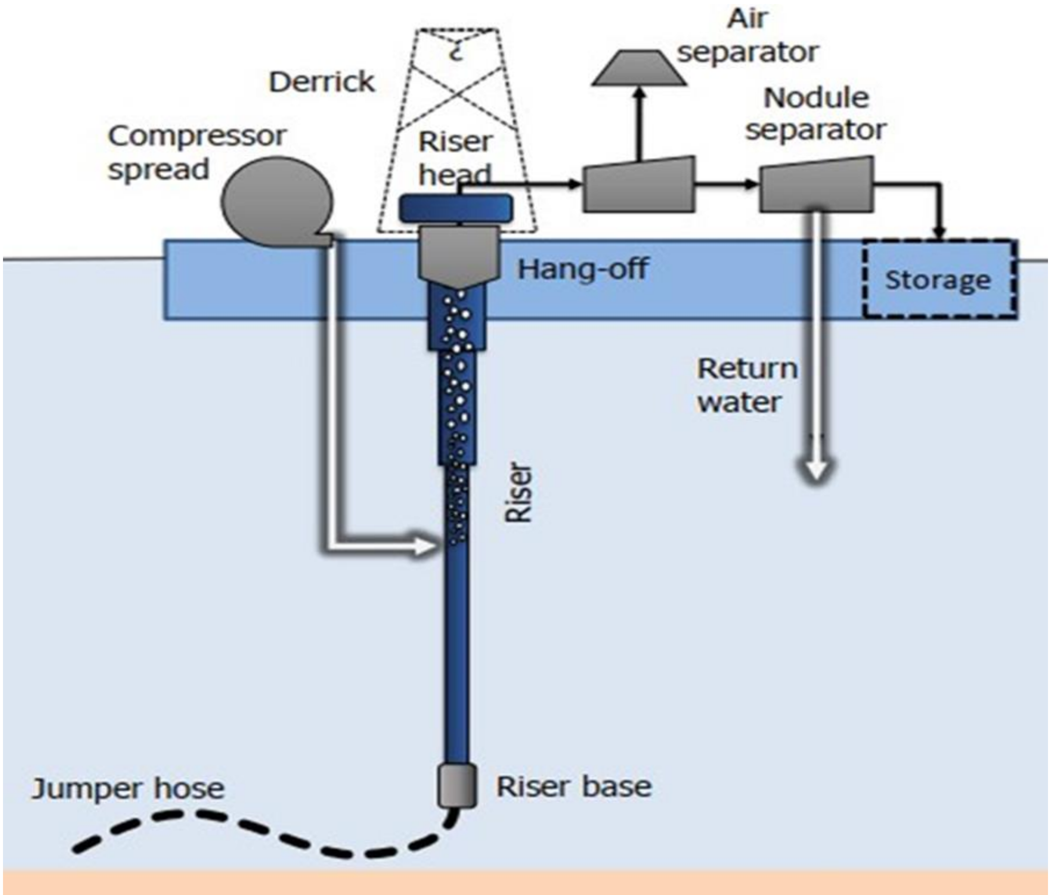
Source: Allseas (2020). Arrows represent direction of nodule/sediment/water flow and dispersal.

3.4.3.5 Riser System

The riser system will pump nodules from the sea floor to the SSV. Entrained water separated from nodules during the dewatering process will be returned to the water column via a return pipe and discharged at 1,200 m. The riser system consists of the following components:

- **Jumper hose**. The jumper hose will consist of a 500m long flexible hose, that will connect the PCV to the base of the riser pipe. The jumper will be fitted with buoyancy and weight elements to achieve a lazy-S configuration to accommodate changes in horizontal and vertical distance between the PCV and the riser pipe during operations. The jumper hose connector and pivot swivel are the point of contact between the riser pipe and the PCV. A wet connection will be made on the sea floor with the aid of an ROV and a buoyant pull-in wire.
- **Riser pipe**. The riser pipe will consist of 27.4m (90 ft.) long sections of steel pipe. The sections, similar to those used for subsea drilling activities in the oil and gas industry, will be hoisted into position with a derrick tower onboard the mining vessel. They will be joined together and sequentially lowered to the seafloor. The riser joints will be pre-fitted with the air injection line and return water pipe.
- **Air lift**. An air lift line will be fitted to the riser pipe and will be used to inject compressed air at up to 200 bar into the riser pipe at 2,500 m (Figure 3-12). Air bubbles in the riser pipe will lift the large particle slurry material consisting of nodules, sediment, and seawater to the SSV. Sensors at the air injection point on the riser pipe will measure slurry flow rates; based on these measurements, airflow in the riser will be adjusted to maintain flow velocities above settling velocities so nodules do not fall back down the riser pipe.

Figure 3-12. Air lift system



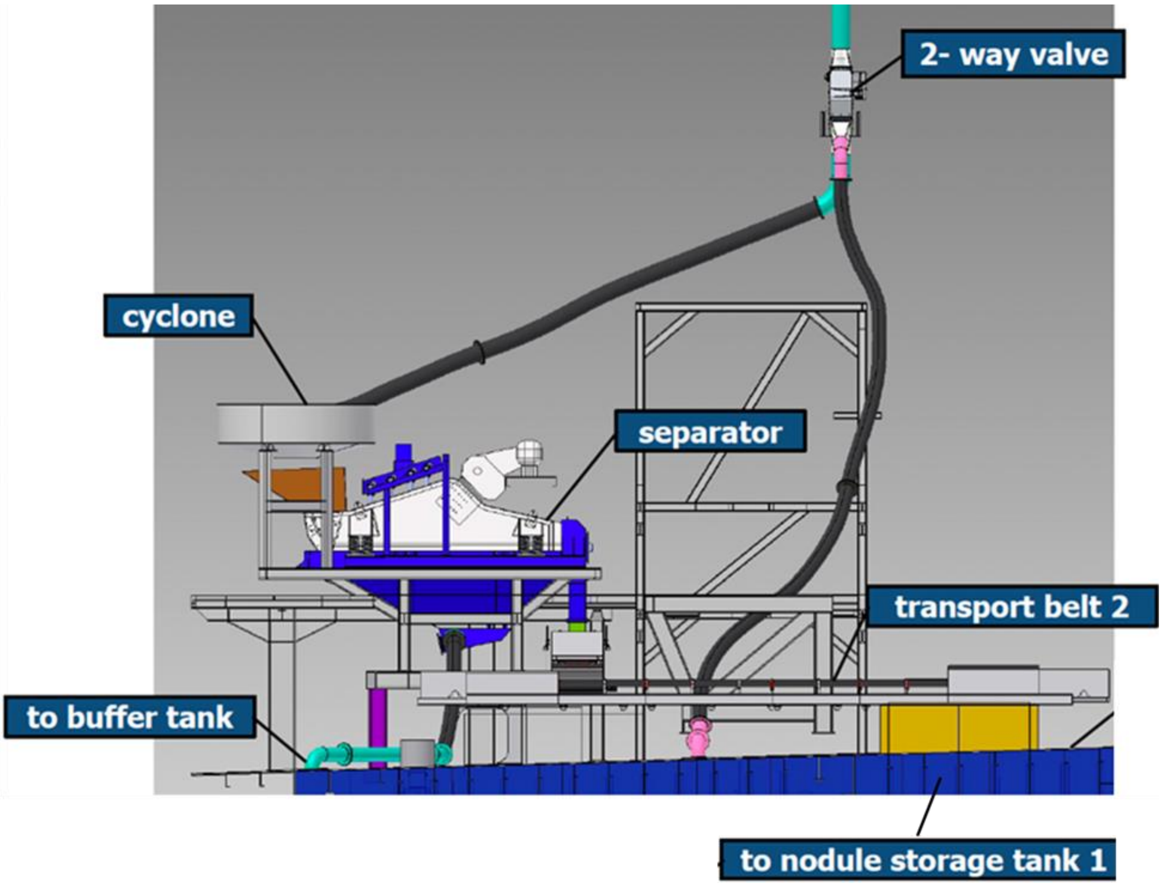
3.4.3.6 Nodule Surface Separator and Storage

Surface processing of the slurry will consist of the following steps:

- Upon arrival at the head of the riser pipe system the nodules slurry flow stream is slowed and passed through a 2-way valve diverter towards a separator system consisting of cyclone and shaker table equipment.
- The nodule slurry stream moves through the separator and then over a transport belt to enter the main nodule storage tank.
- Underflow (sediments, abraded fines and water) flow from separator to a buffer tank. The separator has been designed and sized such that the underflow properties are expected to be suitable for discharge as return water. Checks on the material properties will be performed at suitable located test stations.
- The buffer tank is drained with a cargo handling pump system and returned to return line.
- As a contingency the 2-way diverter valve can also send the slurry stream directly to the buffer tank. This provides a protection from sudden unexpected over-load.

The nodule surface separator and storage layout is shown in Figure 3-13.

Figure 3-13. Side view of surface process flow equipment



3.4.3.7 Return Water System

(a) Return Water Discharge

During test runs of the integrated system, sediment and deep-sea water will be entrained into the riser pipe from the ocean floor and transferred to the surface as by-product of nodule harvesting. All entrained sediment, deep-sea water, and small nodule fragments will be returned to the ocean via a return water discharge.

Collector Test operations generating return water discharge are necessary to provide the system engineers with important information relating to the optimum functional and environmental discharge depth for the fully operational system. Test operations generating a return water discharge will be of short duration (approx. 259 hours).

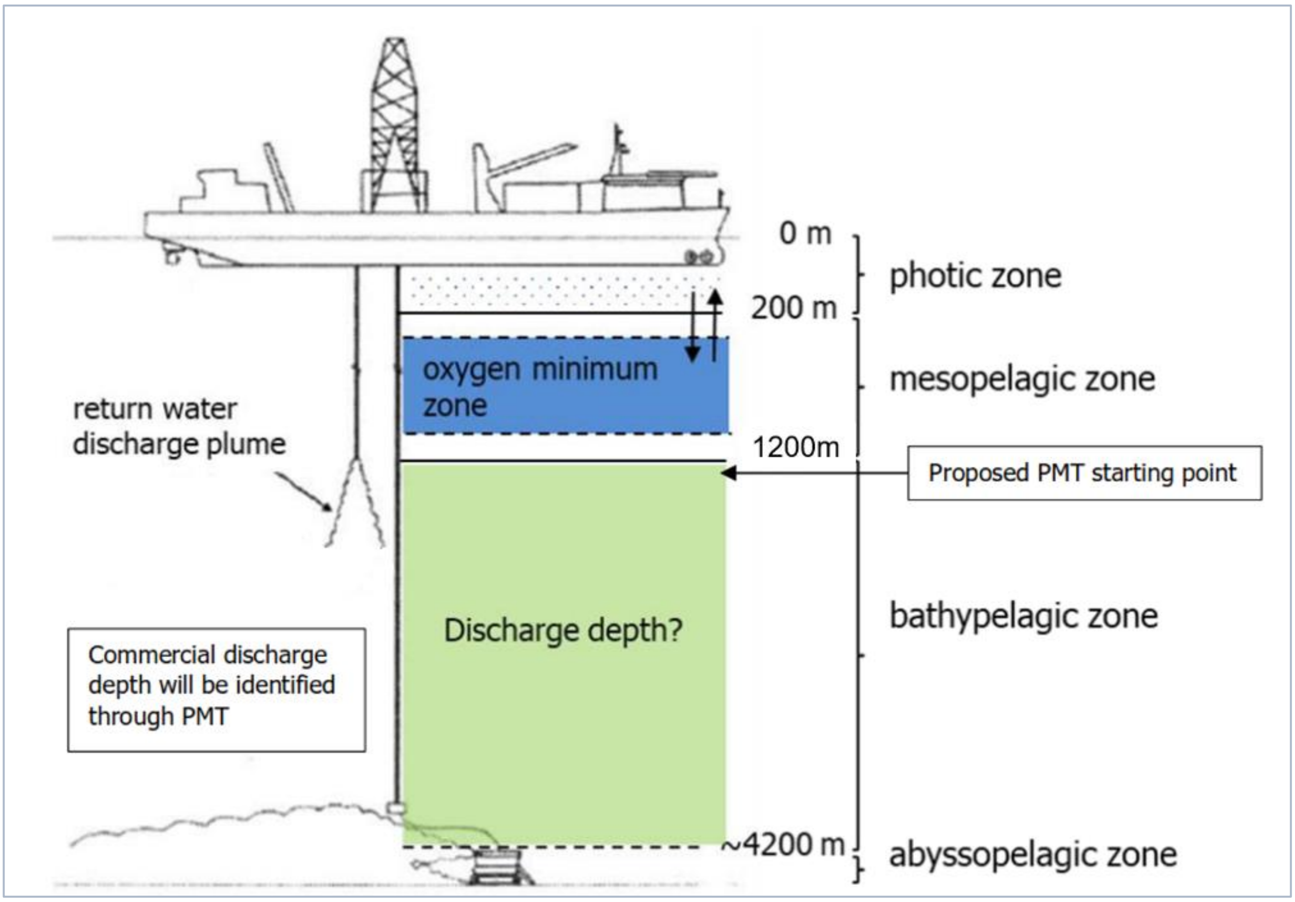
For the purposes of the Collector Test a 0.2 m (external) diameter return water pipe will be used to transport the discharge water to a depth of 1,200 m. The return water will be discharged vertically downwards at a rate of 0.0981 m^3/s.

It should be noted that the optimal depth for return water discharge and the design of the discharge nozzle (i.e., vertical or horizontal discharge) are yet to be determined and are not limited by engineering constraints. Mid-water/seabed and vertical/horizontal discharge options will be considered as part of the commercial ESIA. The optimal discharge depth and design will ultimately be decided based on an assessment of the engineering requirements and environmental impacts of the options under consideration.

(b) Return Water Discharge Depth

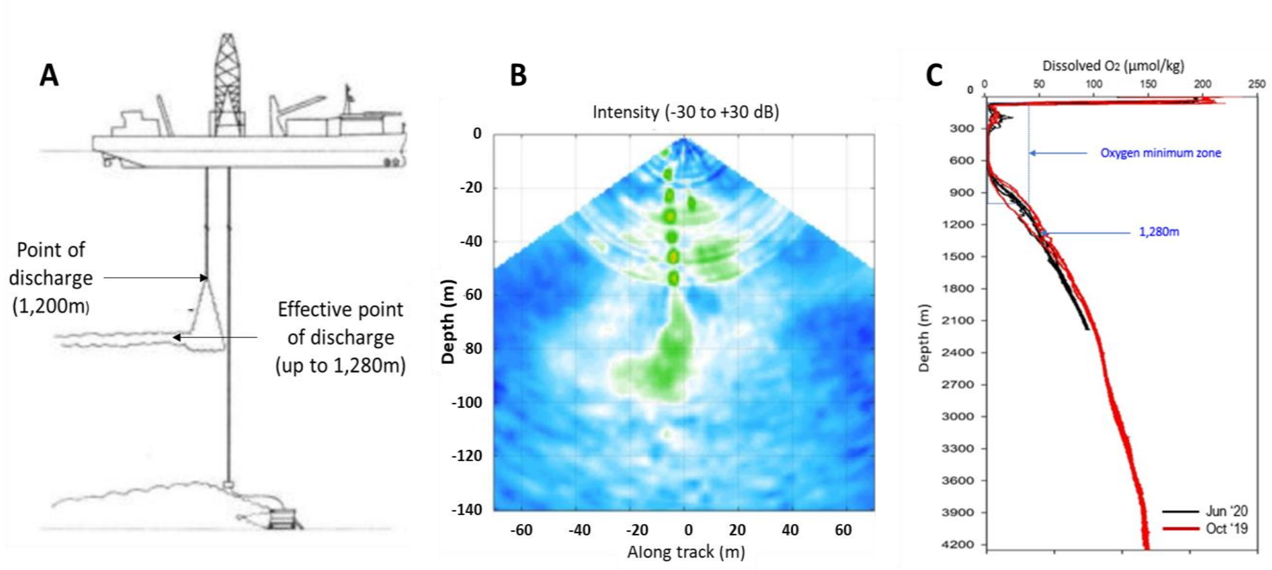
For the purpose of the Collector Test return water will be discharged outside the oxygen minimum zone (OMZ) (1000m; UOH, 2022) at a depth of 1,200 m (Figure 3-14). Further, plume dynamics modelling (Lavelle *et al*, 1982) indicates that when the plume leaves the outlet of the return pipe, the momentum and the negative buoyancy (particle load) result in the sinking of the particles up to 80m before being distributed laterally by ocean currents. This may extend the effective depth of the discharge up to 1,280m.

Figure 3-14. Proposed discharge depth for integrated system tests.



In the context of the Collector Test, placement of the return water discharge outlet at 1,200 m was based on the best information available at the time of design. The Collector Test will be used as an opportunity to accurately quantify depth of the neutrally buoyant plume and an adjustment to the discharge depth will be made for future operations, if required.

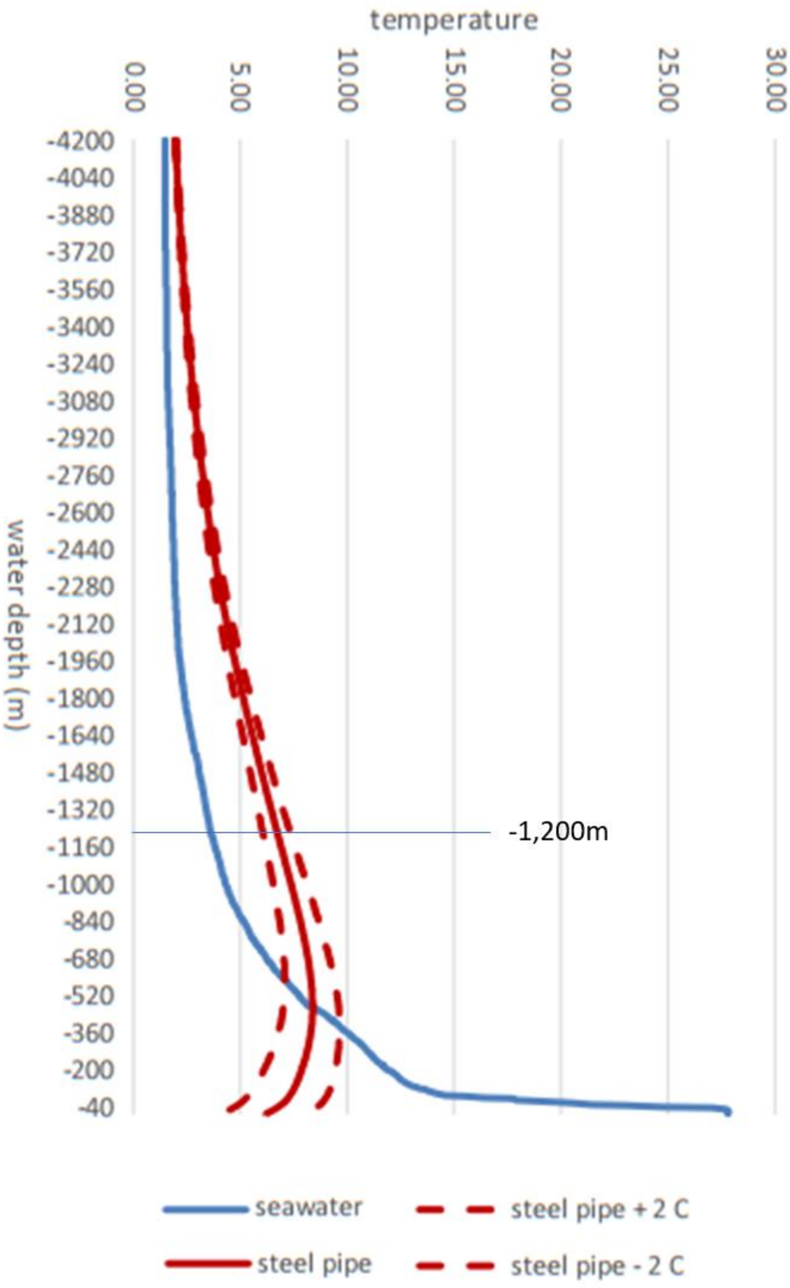
Figure 3-15. A - Effective point of discharge; B – PLUMEX modelling; C – Oxygen profile for NORI-D



(c) Return Water Characteristics

- As per current design of the return water hose (internal diameter of 0.16 m), the discharge speed is 3.9 m/s (Allseas, 2021).
- The mean volumetric sediment concentration in the return water is 21.3 g/l assuming the specific sediment density of 2,500 kg/m^3 (Allseas, 2021).
- A range of particle sizes in the return water is expected as per seabed grain size distribution at the Collector Test site. In addition, an unknown amount of nodule fines ≤3 mm (particle size rejection limit) may enter the return waterline. Degradation of nodules will likely occur during uplift in the airlift riser. Based on the dewatering plant recovery efficiency of 98%, as per base specifications, the sediment flow calculations assume a fraction of 2% by volume of uplifted nodule fines will be entrained in the return waterline (Allseas, 2021).
- The modelled temperature of discharge water within the return pipe between -5 m to -4,200 m is shown in Figure 3-16. At the buffer tank (after surface processing) the temperature is modelled to be 6.13°C including the cooling effect of isothermal expansion of air. As water passes down the steel return pipe it initially warms as passes through the upper layers of the water column then starts to cool with depth. Three scenarios are shown in Figure 3-16, the base case (solid red line) at which surface temperature of the water is 6.13°C and the return pipe material is steel, and the base case ±2°C (upper and lower red dotted lines) (Allseas, 2021).

Figure 3-16. Modelled return water temperature and ambient seawater temperature (°C) at depth (m)



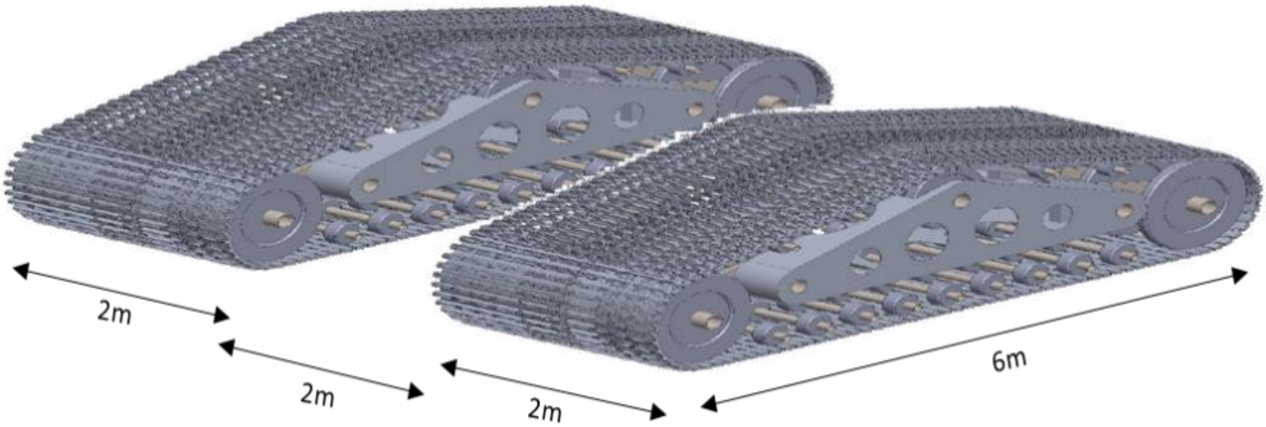
Source: Allseas, 2021

3.4.3.8 PCV Propulsion System

The PCV will move along the seafloor using a set of continuous tracks (Figure 3-17). The tracks will be 2 m wide, 6 m long at the base, and their outer edges will sit 6 m apart. The tracks will consist of a hydraulic motor, a gear box, a sprocket, and an encoder (speed sensor). A typical track design is shown in Figure 3-17.

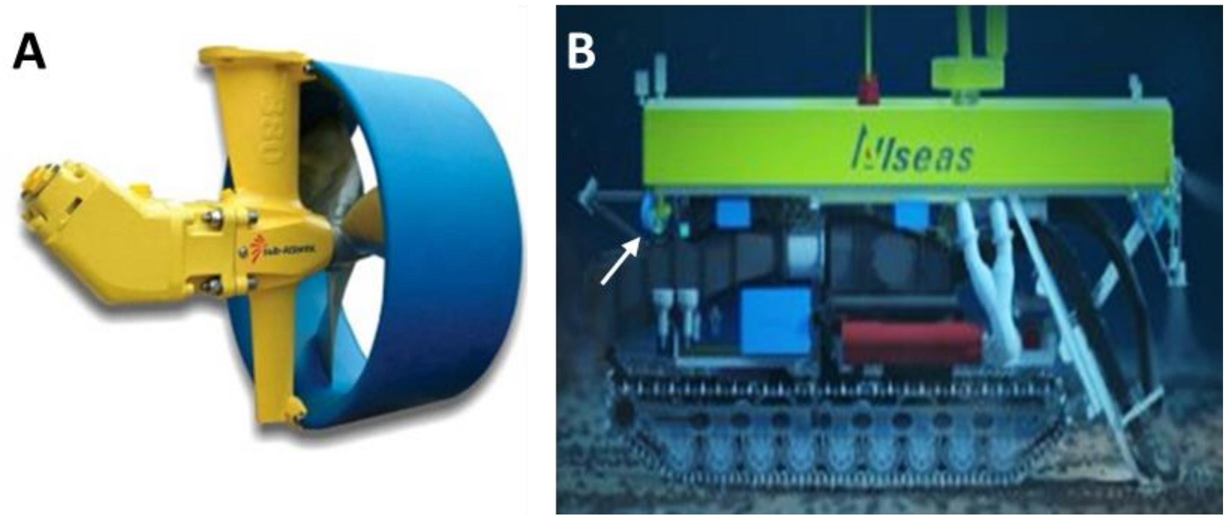
Tracks will be fitted with water jets, powered by a dedicated pump, which will clean sediment from the outer track surface and inner sprocket path prior to ascending to the surface.

Figure 3-17. PCV track system (A); 2 m wide, 6m apart (B); 6 m long at the base (C)



The PCV will also be equipped with thrusters powered by a hydraulic motor (Figure 3-18A). The thrusters will be positioned at each corner of the PCV (Figure 3-18B) which are designed to aid with positioning of the PCV when suspended in the water column during deployment and recovery.

Figure 3-18. Thruster unit (A) and position on the PCV (B - dotted red circles)



3.4.3.9 Structural Frame

The chassis of the PCV will consist of structural frames supporting the propulsion and nodule processing systems, connecting the articulated height adjustable frame supporting the nozzles, and the lifting interface which will provide a secure connection with the umbilical.

3.4.3.10 Electrical & Instrumentation

The PCV will be powered from the surface via an umbilical. It is expected that the onboard power system will consist of: 1x320kW hydraulic power unit; 1x200kW hydraulic power unit; 2x200kW electric motor pumps; and a 15kW control unit. The total power draw of the PCV will be approximately 1 MW.

A synthetic armoured umbilical will power and communicate with the PCV. The umbilical will consist of a combination of fibre optic, power conducting, strengthening, and armouring cables and sheaths.

3.4.3.11 Hydraulic Actuation

An onboard hydraulic system will be used to drive the tracks, thrusters, concentrator pump, rejector jet pump, track jet pump, collector height cylinders, collector rotation cylinder, and the diffuser pumps. The hydraulic system will consist of a hydraulic power unit, bellow compensators, valve pack and headers and piping to receiving components.

3.4.3.12 Control & Automation

The onboard automation system will control the various functions of the PCV, including:

- Process system power
- Collector head
- Nodule transport
- Thrust
- Tracks
- Track tension
- Track navigation controls

The information from the onboard automation system will be fed to a control van (Figure 3-19) onboard the surface vessel, similar to that used for an ROV setup. From here, the deployment, recovery, and operation of the PCV will be monitored and real time adjustments made in response to the data feedback.

Figure 3-19. PCV surface control van setup

Source: Cellula Robotics Production Harvester Design Report, CRL-DCD15-RP-09 Rev R01

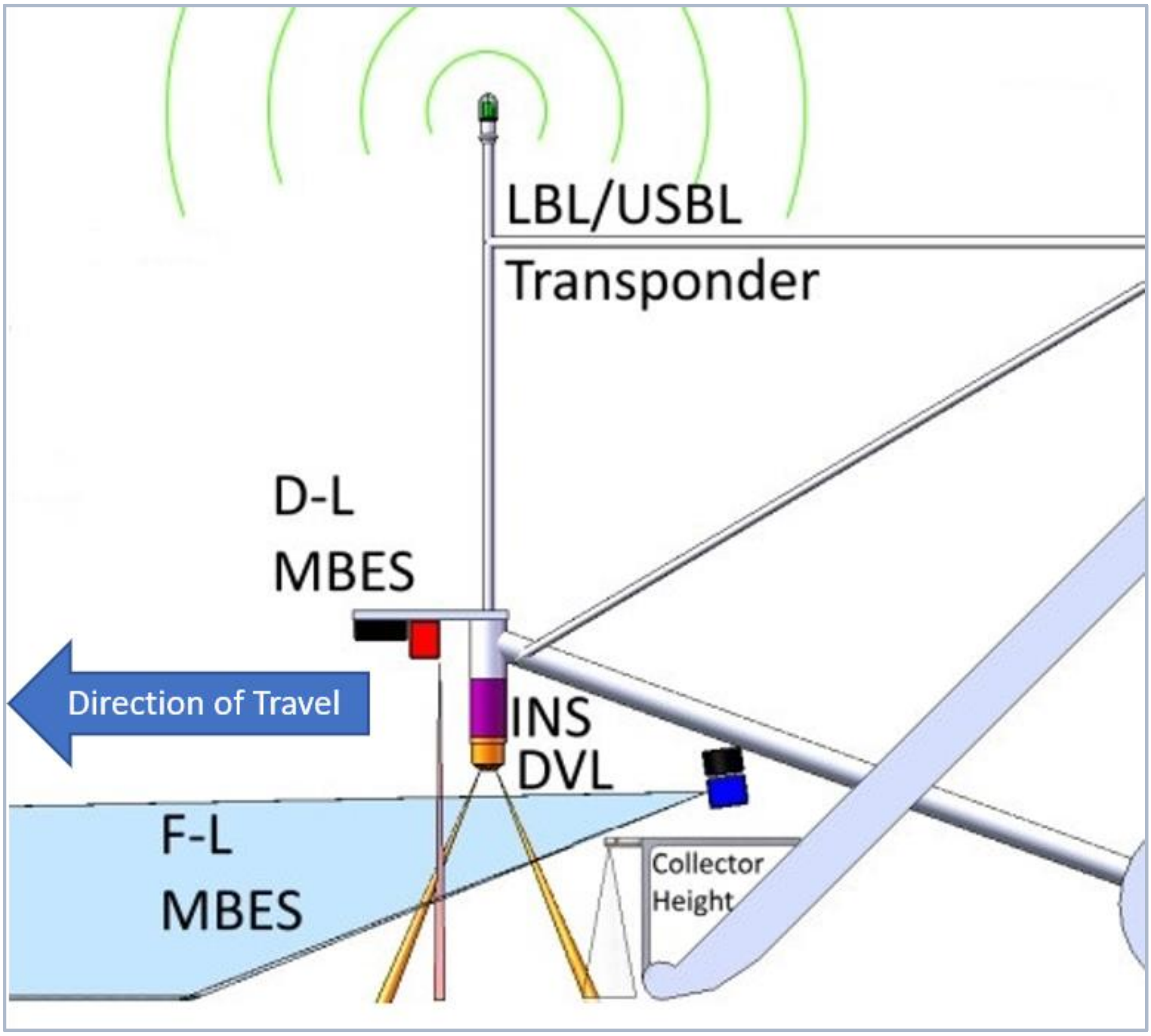
3.4.3.13 Navigation System

The PCV will orientate on the seabed using a multicomponent navigation system. This will be comprised of doppler velocity log (DVL), inertial navigation system (INS); front looking multibeam echosounder (F-L MBES); down looking multibeam echosounder (D-L MBES); long baseline (LBL) and ultrashort baseline (USBL) acoustic positioning system.

The F-L MBES will provide information on the terrain in front of the PCV.

The configuration of the navigation system components is shown in Figure 3-20.

Figure 3-20. PCV navigation system



3.4.3.14 Slurry Monitoring

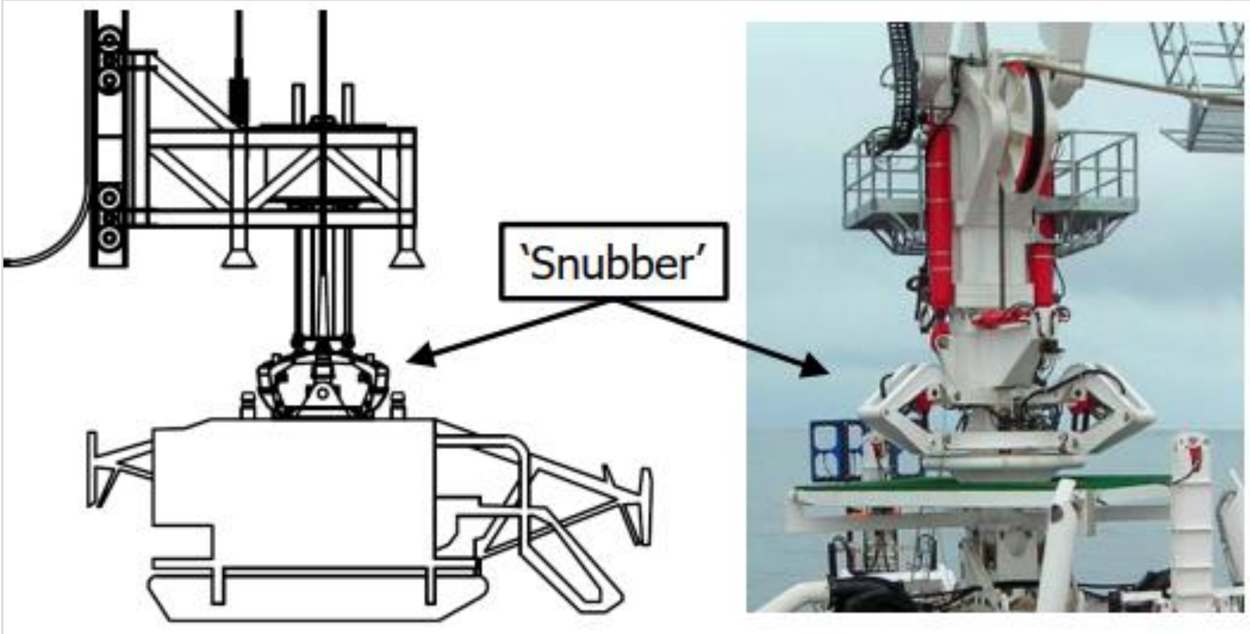
The slurry monitoring system will measure the large particle slurry at various points in the nodule processing system. The slurry monitoring system will consist of several meters including, an ultrasonic (volumetric) flow meter, an electrical impedance slurry density meter, and an ultrasound altimeter. The meters will receive and process information from various sensors, including pressure sensors, position sensors, flow sensors, filling level altimeter (in buffer), speed sensor, density sensor, and temperature sensor.

3.4.3.15 Docking Launch & Recovery System

The PCV will be launched and recovered from the surface vessel with the use of a deck/skid-mounted overside launch-and-recovery system (LARS) to enable the safe, precise handling of the PCV in all weather conditions and sea states.

An articulated and fully dampened snubber will used to provide increased load security and full load rotation (Figure 3-21).

Figure 3-21. Snubber configuration



3.5 Collector Test Program

3.5.1 Pre-Testing

Upon mobilisation for the Collector Test, the major components of the polymetallic nodule collector system will have been designed in full accordance with prevailing offshore engineering codes and standards as is normal for such major marine equipment. NORI's engineers and contractor Allseas respective teams have a vast experience of ultra-deep-water offshore equipment development.

As is customary, an extensive process of integration and functionality testing will have been performed. A series of design engineering checks and validations (where appropriate by third party experts) will have been undertaken including Failure Mode Effects Criticality Analyses (FMECA) for significant equipment designs, and Hazard Identification and Risk Assessments (HIRAs) for controlling operational hazards.

All pressure equipment (e.g., pipe structures, seals, gaskets, valves) including the compressor system for the air-lift pump will have been checked and certified in accordance with prevailing offshore codes, standards and regulations prior to mobilisation. A full system pressure test of the riser pipework is not planned.

The integration and functionality testing program will have followed the schedule detailed in Table 3-1.

Table 3-1. Collector system integration and functionality testing program

Description	Date	Location	Duration	Purpose
PCV (Collector Vehicle) Controls	Sep-21	Scheidam, Netherlands	2 weeks	Function testing of control software, telemetry, actuators and critical inter-locks.
Nodule handling shaker table and conveyor	Oct-21	Istanbul Turkey	2 days	Function testing of system.
Collector Flotation modules inspection	Oct-21	Aberdeen, UK	1 day	Quality Assurance (QA) inspection of the final batch of buoyancy modules
Collector Umbilical FAT*	Nov-21	Norway	7 days	Umbilical electrical FAT. Umbilical termination to Collector head strength test.
Riser tooling load tests	Feb-22	Whitburn, Scotland	2 days	Riser handling / running tools will be load tested. 20", 14", 10 3/4" and 8 5/8".
Riser FAT*	Feb-22	Whitburn, Scotland	3 days	Riser FAT will consist of make-up and break-out of the four different riser diameter sections.
Riser Spider FAT*	Feb-22	Whitburn, Scotland	3 days	FAT will include pressure easing of the hydraulic system and HPU functionality.
Harbour wet test	Feb-22	Rotterdam, Netherlands	10 days	Perform harbour wet test to check the functionality of the collector while submerged.
North Sea Drive test	Mar-22	North Sea Water depth 35m	10 days	Perform a vessel Dynamic Positioning (DP) trial and vehicle drive test to check on the mechanical, electrics, and corresponding control software and sensors functionality. Perform a driving test of the collector on the seabed.
Deepwater deployment test	Mar-22	Atlantic / Canary Islands	15 days	Check the passive heave functions of the LARS. Check the functionality of the system under high loads. Option: Further test collector vehicle drivability.
Riser and Jumper deployment test	May-22	Atlantic / Canary Islands	20 days	Perform various handling and running procedures to confirm operator familiarization with the equipment.

*Factory Acceptance Test

3.5.2 Collector Test Scope

The Collector Test in the CCZ will be conducted immediately following a Sea Acceptance Trial (SAT) and the Harbour Acceptance Trial (HAT) in the Atlantic (Canary Islands EEZ) to sea-trial the functionality of the system in shallow water before the deep-water commissioning test in the CCZ. This sequencing of shallow and deep-water tests provides opportunity for teething problems in the system to be addressed prior to deep-water testing.

The Collector Test program will consist of the following sequence of activities:

1. Transit to Collector Test Area
2. Offshore Inspection and Preparation
3. PCV Deployment
4. Jumper and Riser Deployment
5. Riser Commissioning

6. Subsea Connection of Jumper on PCV
7. System Testing
8. Emergency Shutdown Testing
9. Riser and PCV Recovery
10. Transit from Test Site

All test track positions, run durations and speeds have been selected by NORI's engineering team to ensure that a sufficiently thorough testing and verification of the major engineering components of the polymetallic nodule collector system can be undertaken. NORI's engineers were also required to develop a Collector Test Program which provides reasonably representative results in representative conditions, without creating undue impact to the test area environment.

3.5.2.1 Transit to Collector Test Area

The SSV (converted drill ship *Hidden Gem*) and an accompanying scientific research vessel (yet to be identified) will transit from the port of San Diego, USA. to NORI-D; approximately a five-day transit by sea. There is no access by helicopter to NORI-D. Once on site the vessel will position itself on the CTA.

3.5.2.2 Offshore Inspection & Preparation

The first task to be conducted on arrival at the CTA will be a field inspection and examination of the seafloor at the TF using the ROV to ensure the landing sites are suitable for the equipment. This will include:

- Arrive at TF
- Pre-dive checks and system verification
- Deployment of ROV/Basket to seabed - track beacon position
- Deployment of first sparse LBL array beacon and undertake subsea positioning verification
- Deployment of remaining LBL beacons and perform SLAM (simultaneous localisation and mapping) once array is installed
- ROV undertakes pre-survey whilst the PCV is being deployed.

Field inspection and preparation will require positioning equipment and the ROV. This task is expected to take 20 hours to complete.

3.5.2.3 PCV Deployment

The PCV will be deployed and recovered using a bespoke LARS designed to accommodate the 80 tonnes weight of the PCV. The system consists of rails that guide the PCV down the side of the vessel and through the splash zone before being released from the cursor frame prior to descent. This is a six-step process summarised in Figure 3-22.

i. Skidding in launch position (A)

ii. Lowering the collector with the cursor winch through the splash zone (B)

iii. Disconnect collector from the cursor frame (C)

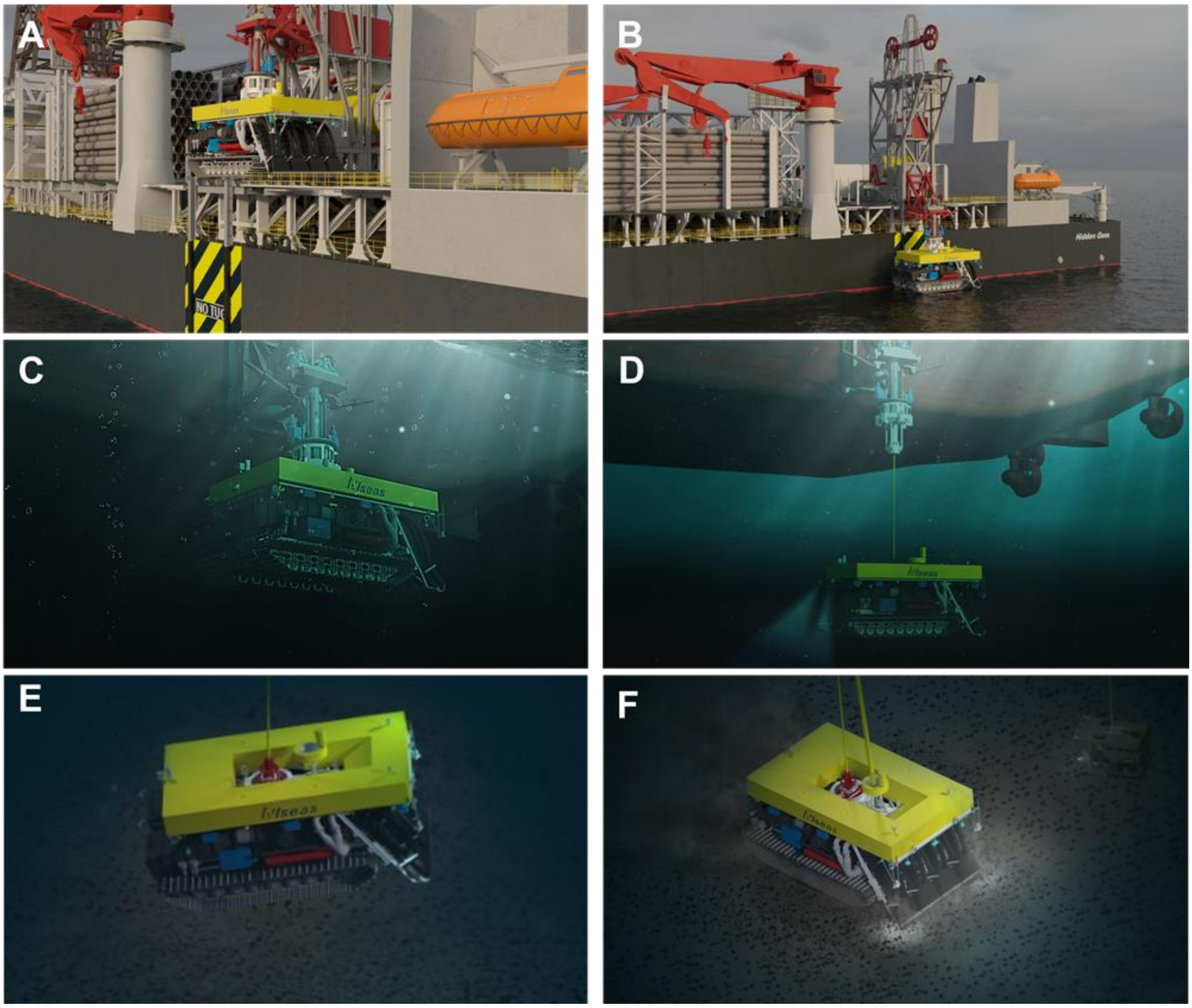
iv. Subsea lowering (D)

v. Collector touchdown (E)

vi. Collector on seabed (F)

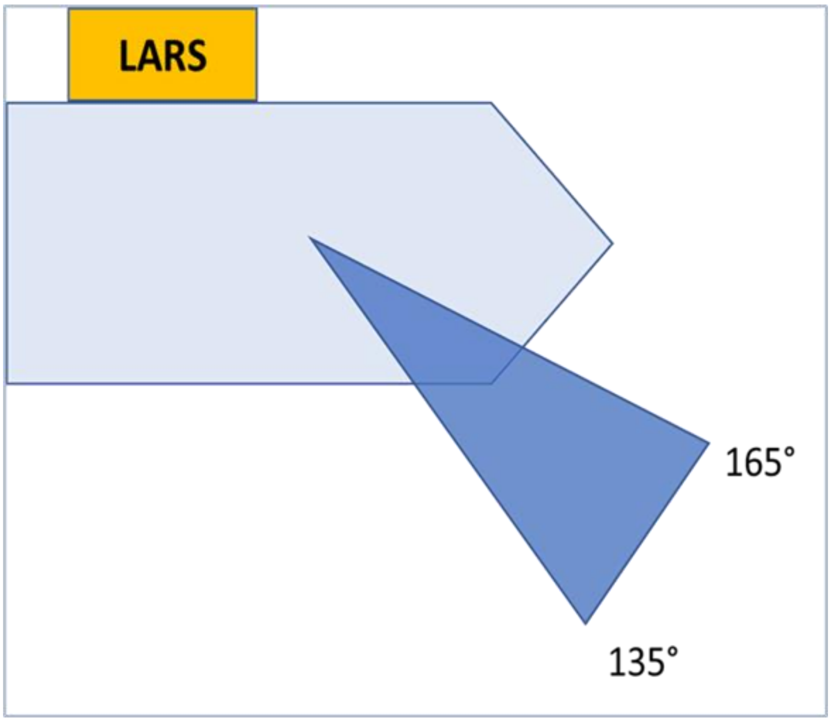
The steps for recovery are the same steps as for deployment but in reversed order.

Figure 3-22. PCV deployment & recovery sequence



When lowering the PCV through the splash zone, the vessel heading will be adjusted such that the LARS is on the lee side, and wave shielding is provided to the LARS. This is done to reduce the splash zone loads, as illustrated in Figure 3-23. When the PCV has passed through the splash zone, the heading will be adjusted to bow incoming waves again.

Figure 3-23. Design to provide wave shielding during lowering through the splash zone



3.5.2.4 Jumper & Riser Deployment

The riser deployment is conducted in two parts:

(a) Jumper hose deployment

(b) Riser deployment. Consisting of multiple riser joints (lengths) and connections (Figure 3-24). Some joints have special functionality, these are called the "riser specials", from bottom to top:

- Riser base
- Air injection piece
- Diameter transitions
- Stress joint
- Riser head

For deployment and recovery, the riser specials are not treated any differently than the riser joints. During riser deployment, the sensor line is attached to the riser. The sensor line connects the junction boxes on the riser specials to each other (daisy chained) and to the vessel. When the riser is deployed, the riser commissioning sub-task commences. This involves connection of the riser systems to the vessel systems and pre-operation checks are conducted.

(a) Jumper Hose Deployment

The jumper hose will consist of a 500 m flexible hose with a "lazy S" shape. The jumper hose will be installed from a reel over the side of the vessel. The upper part of the jumper will be lowered from the reel and keel-hauled through the moonpool and connected to the riser base. The riser and jumper will be lowered to reduce the risk of jumper damage. The lower part of the jumper will be lowered using a lift cable also mounted to the reel. The jumper will be pre-fitted with buoyancy and weight elements to achieve the "lazy-S" configuration when afloat.

To enable recovery, a messenger wire will be pre-mounted on the lower part of the jumper, the base case is to have assistance by ROV, although recovery can be done without an ROV if necessary.

(b) Riser Deployment

The riser joints (Figure 3-24) will be pre-assembled with the air injection line and the return line assembled to the load carrying production line, similar to a production riser used in the oil and gas drilling industry. The joints have a length of 27.4m (90 ft.) each.

Upending the riser joints is done with an established method used by the drilling industry. The equipment for this procedure is already installed on former drill ship Hidden Gem.

Figure 3-24. Riser joints

A riser joint is loaded on to trolley cradle and skate moved towards the moon pool. The riser is upended by hanging it from the riser running tool that is suspended from the top drive. The riser is lowered/pulled up with a winch. When the desired position is reached, the arms of the lifting tool are lowered to support the riser. The riser running tool is disconnected to pick up the next riser joint to be installed.

During running and pulling of the riser joints, a sensor line will be piggybacked on to the joints, the riser joints feature special clamps for this purpose. The purpose of the sensor line is to transmit the signals from the sensors on the riser specials to the controller station on the SSV.

3.5.2.5 Riser Commissioning

Riser commissioning involves the following steps:

1. The sensor line is routed over drill floor to the connector of the controller station and protected in a cable tray.
2. The air pressure hose is skidded/hoisted into place and connected to the hard piping on the vessel and to the stress joint (top joint of the riser) or to a point below the drill floor.

3. Leak testing and locking of the pressure hose. This is a safety precaution, as the pressure hose is 3–4-inch inner diameter and contains up to 200 bar compressed air.
4. The riser head is skidded/hoisted over the end of the riser and secured to the drill floor and end of the riser.
5. The hose to connect riser head to dewatering plant is skidded / hoisted in place and connected.

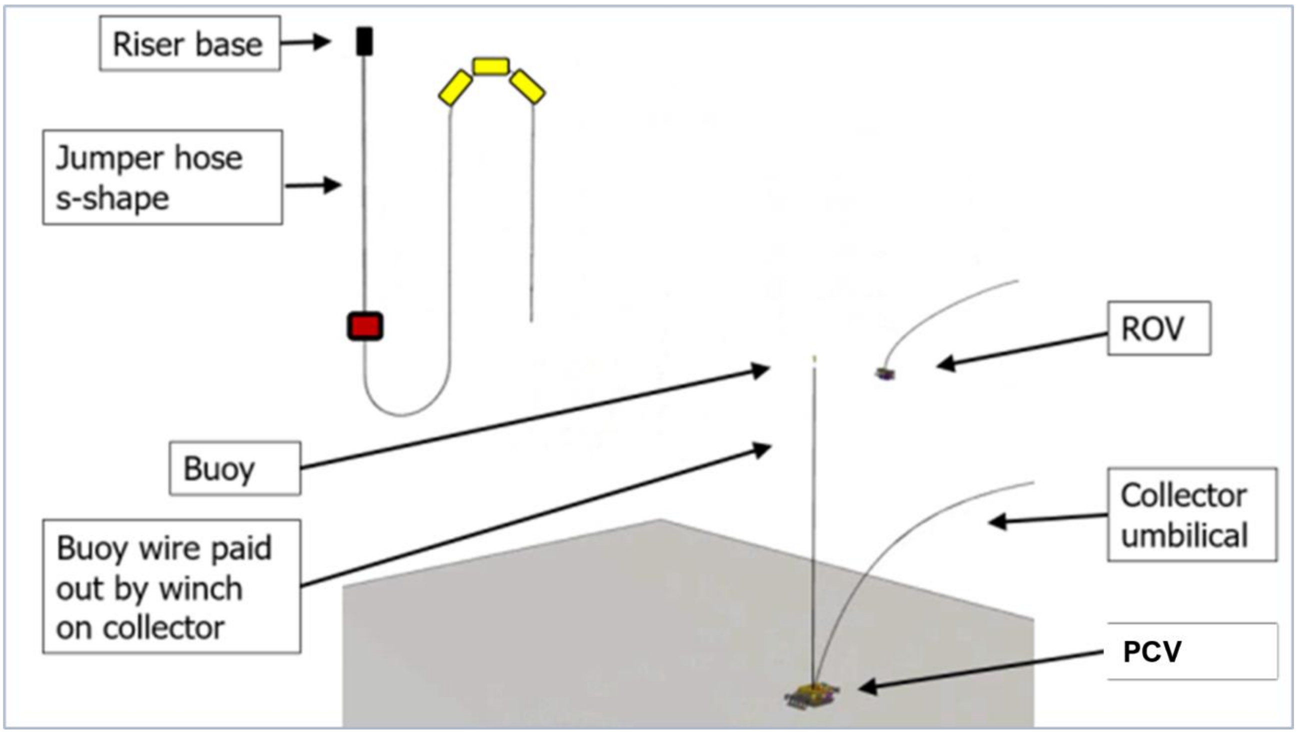
Riser and jumper hose are now in 'disconnect' state: suspended and ready for operation, but not connected with the PCV.

3.5.2.6 Subsea Connection of Jumper on PCV

The subsea connection procedure consists of the following tasks:

1. The PCV is positioned close to the jumper hose connector, based on the current, the SSV will adopt a heading and position such that:
    - The jumper S-shape is close to the PCV.
    - The PCV umbilical does not clash with the riser and the jumper hose.
2. ROV attaches pull-in wire on the jumper hose. The ROV is launched to make the connection, avoiding entanglement with the umbilical. The connection hook located on the top of the PCV is pulled up by means of releasing buoyancy and paying out with the winch. The pull-in wire is paid out until it reaches the approximate height of the connector on the jumper hose, which is floating in its neutral position (Figure 3-25). Next, the ROV connects the hook of the pull-in wire on the jumper hose. The wire is connected approximately 10 m above the hose connector, to allow some slack for final positioning.

Figure 3-25. Connection configuration



3. The jumper hose is pulled down to the PCV. The ROV guides the jumper connector on the hose in the horizontal plane, while the wire pulls in the hose.

4. Connection is made. The wire is routed via the buoyancy at the top of the pivot swivel. The pivot swivel on the PCV will therefore face in the direction of the hose connector. The jumper connector is kept in position (locked) with three cylinders. The conical shape allows for ~15 deg misalignment.
5. Jumper hose is disconnected by retracting the locking cylinders. For controlled ascent of the jumper hose (hose is buoyant at connected position) the cable will be used (inverse of connection procedure).

   For emergency disconnection, releasing pressure to the cylinders and pulling by the hose is expected to be enough to release the connection.

   In case of PCV black-out, a ROV operated valve can release the pressure to the locking cylinder.

   In case of jumper hose overloading, (unexpected) high pulling force, pressure relief valve is activated, and hose is disconnected as well.
6. Once the connection is fixed the pull-in wire is released by the ROV. After this the ROV can be recovered.

3.5.2.7 System Testing

Once field inspection and preparation are complete (estimated to take approximately 20 hours), the PCV will be lowered to the seafloor and manoeuvrability and pick-up tests will be conducted.

(a) Manoeuvrability Test Runs (HTR.1)

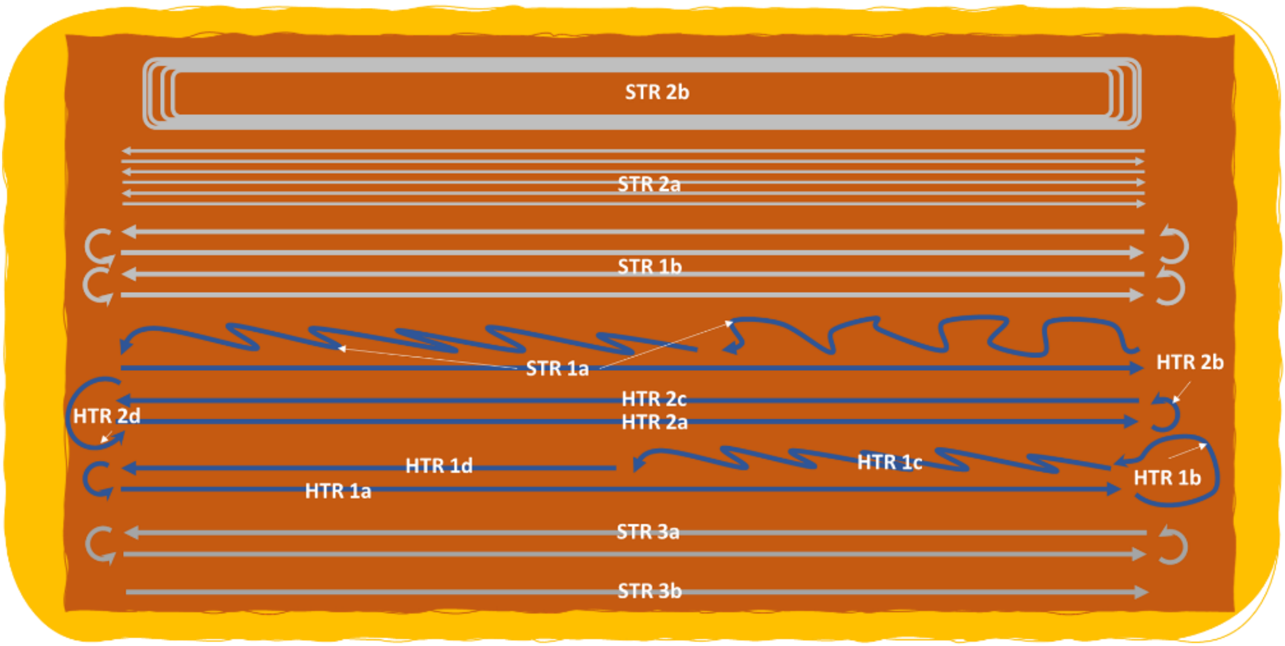
Manoeuvrability tests (without nodule collection) will be conducted to confirm the PCV can move across the seafloor as required and loads on the umbilical connecting the PCV to the mining vessel are within design specifications.

The following manoeuvrability tests will be conducted as shown in Figure 3-26:

- **Straight line test.** The PCV will be driven in a straight line at various speeds. A distance of approximately 3km will be travelled during this test,
- **Turning test.** The PCV turning capabilities will be tested over a distance of approximately 1km by turning the PCV as follows:
  - Manoeuvring the PCV through a 90°, 200 m radius turn at 0.1 m/s.
  - Manoeuvring the PCV through a 90°, 200 m radius turn at 0.3 m/s.
  - Manoeuvring the PCV through a 90°, 100 m radius turn at 0.1 m/s.
  - Manoeuvring the PCV through a 90°, 50 m radius turn at 0.05 m/s.
  - Manoeuvring the PCV through a 180°, 30 m radius turn at 0.05 m/s.
  - Manoeuvring the PCV through a 180°, 3 m radius turn at 0.05 m/s.
- **Obstacle avoidance test.** The PCV will be driven along a straight line and then around virtual test objects to test obstacle avoidance capability on the seafloor (e.g., rock outcrops) and then return to the straight line. A distance of less than 2km will be travelled during this test.
- **Lane tracking test.** The PCV will be driven along a straight line and then turned through 180° and driven along a parallel line to the initial line to test the PCV navigation and positioning system capabilities. During this test a distance of less than 2km will be travelled.

The manoeuvrability test runs are expected to take approximately 4 days to complete and the PCV will travel approximately **8 km**. During manoeuvrability tests, the PCV will not be collecting nodules and the riser system will not be deployed.

Figure 3-26. Test runs



Manoeuvrability Test Runs HTR.1a - Straight Line Test HTR.1b – Turning Test HTR. 1c – Obstacle Avoidance Test HTR. 1d – Lane Tracking Test	**Pick-up Test Runs** HTR.2a – First Pick-up Test HTR.2b – Pick-up Test During Turning HTR.2c – Pick-up Test Efficiency HTR.2d – Pick-up Performance Test With Turning
Commissioning Test STR.1a – Manoeuvrability test (no production) STR.1b – Production Ramp-up Test (production)	**Nominal Performance Test Runs** STR.2a – Straight Line Performance Test STR.2b – Contour Mining Test STR.3a – Straight Line Production testing STR.3b – Straight Line Production testing

Notes: Productive runs (nodules collected and transported to surface) – grey; non-productive runs (nodules not collected OR not transported to surface) – blue.
Source: After Allseas (2020)

(b) Pick-up Test Runs (HTR.2)

This component will test the ability of the PCV to collect nodules from the seafloor. The PCV will not be connected to the riser system and nodules and sediments that are collected will be discharged behind the vehicle and remain on the seafloor. (i.e., nodules will be displaced but no nodule production will take place)

The following pick-up test runs will be conducted:

- **First pick-up test.** The PCV will be driven in a straight line at various speeds. Pick-up nozzles will be raised off the seafloor and pumps and nozzle height adjustment systems will be tested. Approximately 3km will be travelled during this test.
- **Pick-up test during turning.** This will be a similar test as the first pick-up test but will include the PCV turning through a 180°. Several hundred meters will be travelled during this test.
- **Pick-up efficiency test.** The PCV will be driven in a straight line and nodules will be collected to measure and fine-tune pick-up efficiency. The test will then be repeated at a different speed.

Nodules and sediment collected during this test will be returned to the seafloor. Approximately 3km will be travelled during this test.

- **Pick-up performance test with turning.** The PCV will collect nodules as it is driven along a straight line, through a 180° turn and then back along a parallel like to test performance during turning. Approximately 3km will be travelled during this test.

The pick-up test runs are expected to take approximately 5.5 days to complete and the PCV will travel a total distance of approximately **10 km**.

(c) Riser Installation & Commissioning Test

After the riser system is installed, functional testing of the system will occur. Testing will include pumping seawater from approximately 4,200 m to the SSV and then pumping seawater via the return water pipe to 1,200 m where it will be discharged.

Riser installation and commissioning is estimated to take approximately 8 days to complete.

(d) System Integration Test

During the system integration test the jumper hose will be fitted to the PCV and the riser system. The SSV position and orientation relative to the PCV will then be changed to test the loads and performance of the umbilical, jumper hose and riser system under various operational conditions.

The system integration test is estimated to take approximately 1 day.

(e) System Test Runs

System test runs will take approximately 13.5 days to complete and will test the manoeuvrability and productivity of the full system, that is: the PCV, jumper hose, riser system and SSV all connected and operating. Commissioning test runs, nominal performance test runs, and advanced test runs will be undertaken, this phase of nodule production will last approximately 259 hours during which approximately 3,600 wet tons of nodules will be collected and pumped to the surface.

The system test runs shown in Figure 3-26 are described below.

i. Commissioning Test Runs (STR 1a and 1b)

- Manoeuvrability test with no nodule production. The PCV will be driven a total estimated distance of 6.5km along two lines as follows:
    - **Line 1.** The PCV will be driven along a straight line at various speeds. The SSV will be offset to avoid horizontal forces on the PCV or will be used to aid propulsion. This will test the ability of the PCV, jumper hose, riser system and SSV to move in a straight line as an integrated system.
    - **Line 2.** Turns and obstacle avoidance will be tested along this line to confirm the integrated system can manoeuvre over the seafloor.
- Nodule production ramp-up. The PCV will be driven along four straight lines, each one parallel to the previous line with a total estimated distanced travelled of 12.5km. Collection of nodules will increase with each line from minimum capacity (Line 1) through to low (Line 2), nominal (Line 3) and then full capacity (Line 4). During the Line 4 run, the PCV speed will be increased to a speed at which stable nodule production is achieved.

During commissioning test runs the PCV will travel approximately **19 km**.

ii. Nominal Performance Test Runs (STR 2a and 2b)

The following nominal performance test runs will be performed:

- **Straight line performance test.** Several straight lines will be run, followed by a 180° turn at each end. Line spacing between lines will gradually be decreased while nodule production is ramped up. During this test the PCV will travel an estimated distance of 9.5 km.
- **Contour mining test.** The collector system will be moved along pre-defined contour lines. The PCV turning radius will be increasing or decreasing to assess variable collection conditions. An estimated distance of 22.5km will be travelled during this test.

During nominal performance test runs the PCV will travel approximately **32 km**.

iii. Advanced Test Runs

The following advanced test runs will be conducted:

- 150% capacity test runs. The PCV will be driven along a series of straight lines while collection rate is continuously increased to a safe maximum of approximately 150%. This will test maximum capacity of the system. Approximately 6.5km will be travelled.
- Slope stability test runs. The PCV will be driven along a series of straight lines with inclined seafloor slopes exceeding 4° to test the system performance along uneven terrain. During this test an estimated distance of 7.0 km will be travelled.

During the advanced test runs the PCV will travel approximately 13.5km.

The PCV will travel a total linear distance of 82.5 km across the test field in completing all the trials described above. The tracks of the PCV are 6m across (see Section 3.4.3.8). The absolute location of each of the HTR's and STR's is not known and will be subject to TF bathymetry and prevailing operating conditions such as current direction; however, they will take place within the bounds of the TF. The cumulative direct disturbance footprint from these operations will be approximately 0.492km^2 (approx. 0.5km^2) representing 0.0019% of NORI-D.

3.5.2.8 Emergency Shutdown Testing

Controlled shutdown of the system will be performed to simulate an emergency shutdown. This will assist in understanding the procedures required for an emergency shutdown and the length of time such an actual event would take.

The emergency shutdown test will be performed over a period of 1 day.

3.5.2.9 Riser & PCV Recovery

When all tests are complete the jumper and riser will be disconnected from the PCV, the riser system will be dismantled and recovered to the mining vessel along with the PCV and all other seafloor components. The sequence of activities for recovery of the riser and PCV are as described for deployment in reverse.

Decommissioning and site closure are expected to take 63 hours.

3.5.2.10 Transit From Test Site

Following successful riser and PCV recovery the SSV will leave the CTA and return to San Diego.

3.6 Workforce

The Project will have a workforce of approximately 80 personnel, comprising vessel crew, system operators, scientists, contractors, NORI personnel, ISA and Nauru observers. The Project will operate 24 hrs/day split across two 12-hour shifts. Project Duration

The Project will commence with a transit from San Diego to NORI-D that will take approximately five days to reach site.

At the time of writing a tentative start date for the test is Q3/2022 for a duration of approximately 60 days. Figure 3-27 outlines the sequencing and duration of tasks, all timings are approximate and subject to change.

3.7 Alternatives Analysis

The objective of the Collector Test is to assess the technical performance of the prototype collector system and its potential environmental impacts in the NORI-D contract area. This section examines the technically feasible alternatives to the proposed project, outlining how it represents an optimised design that is technically feasible, achieves objectives and minimises the environmental impacts.

As recommended in the International Finance Corporation (IFC) Performance Standards Guidance Note 1: Assessment and Management of Environmental and Social Risks and Impacts (Ref. 4.3), this section is: "*An examination of technically and financially feasible alternatives to the source of such impacts, and documentation of the rationale for selecting the particular course of action proposed*."

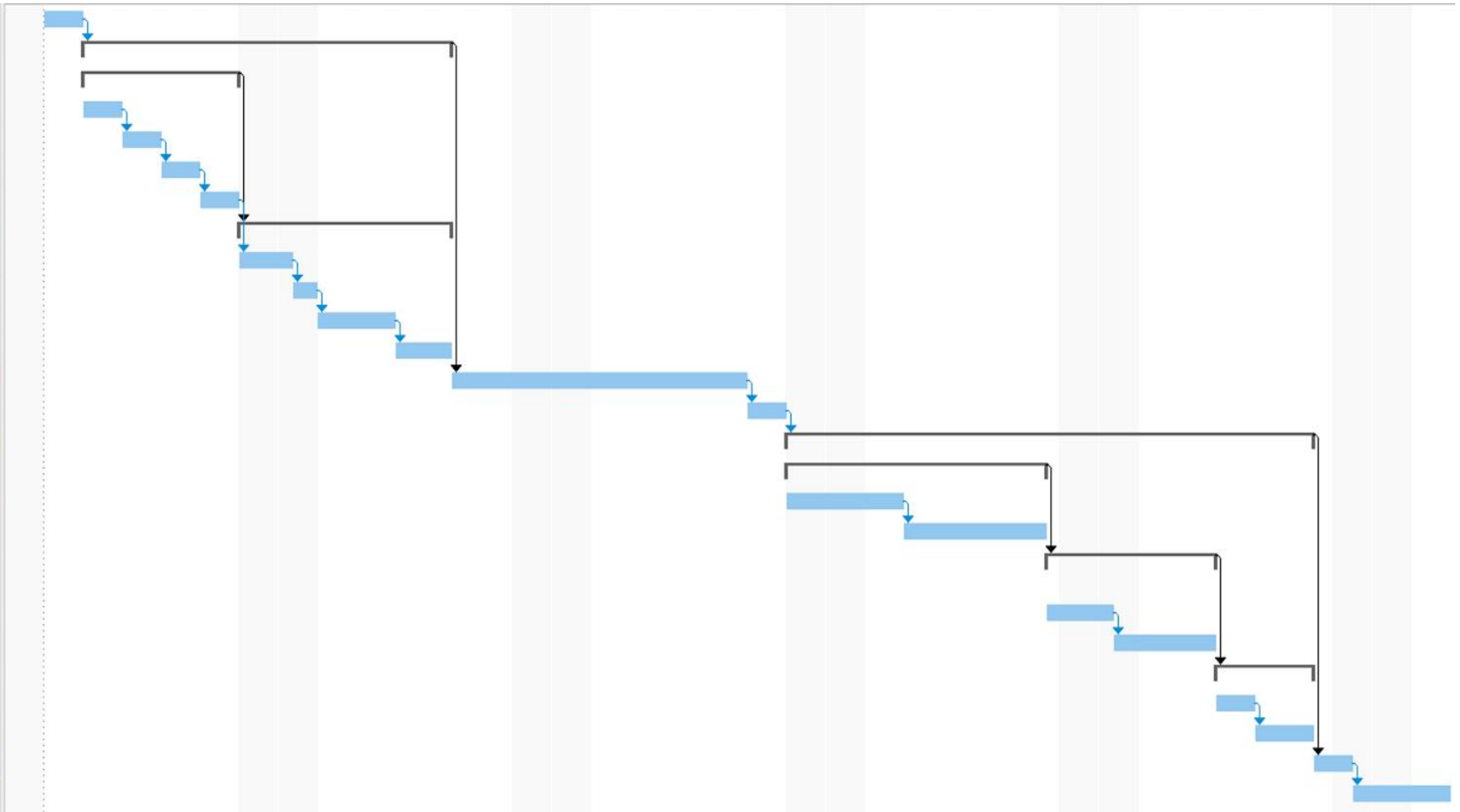
The Analysis of Alternatives described in this section is structured to follow a 'narrowing approach' involving a series of logical steps, starting with the high-level alternatives followed by description of more detailed alternatives considered as part of the Project. Using this commonly adopted narrowing approach, the Analysis of Alternatives considers alternatives in the following sequence:

- 'Zero' or 'No Project'
- Conduct the test be conducted in the 'CCZ' or 'elsewhere'
- Situate the CTA in the 'Flatter Area' or 'Other' geoform
- Situate TF in 'Area 6' or 'Other Area' alternative
- Situate BACI control site in 'PRZ' or 'Assign new control area'

The key decisions made in the development of the project description outlined in this section, and the rationale behind those decisions, are summarised in Table 3-2.

Figure 3-27. Sequencing and duration of Collector Test tasks

1	FIP – Field Inspection & Preparation	20 hrs
2	HTR – Harvester Test Runs (maneuvering & pick-up testing)	223 hrs
2.1	HTR.1: Manoeuvrability test runs (no production)	97 hrs
2.1.1	HTR.1a: Straight-line test	24 hrs
2.1.2	HTR.1b: Turning (radius) test	26 hrs
2.1.3	HTR.1c: Obstacle avoidance test	25 hrs
2.1.4	HTR.1d: Lane tracking test	22 hrs
2.2	HTR.2: Pick-up test runs (with production)	126 hrs
2.2.1	HTR.2a: First pick-up test	28 hrs
2.2.2	HTR.2b: Pick-up test during turning	20 hrs
2.2.3	HTR.2c: Pick-up efficiency test	41 hrs
2.2.4	HTR.2d: Pick-up performance test with turning	37 hrs
3	RIC – Riser Installation & Commissioning (circulation testing)	186 hrs
4	SIT – System Integration Test (functional testing)	24 hrs
5	STR – System Test Runs (commissioning & performance testing)	319 hrs
5.1	STR.1: Commissioning test runs	155 hrs
5.1.1	STR.1a: Maneuverability test (no production)	60 hrs
5.1.2	STR.1b: Production ramp-up test with 180°-turning	95 hrs
5.2	STR.2 Nominal performance test runs (demonstrate target production rates & efficiencies)	102 hrs
5.2.1	STR.2a: Straight-line performance test with 180°-turning	41 hrs
5.2.2	STR.2b: Contour mining (small-scale field test)	61 hrs
5.3	STR.3: Advanced test runs (outside test field No 6)	62 hrs
5.3.1	STR.3a: Capacity stress test runs	29 hrs
5.3.2	STR.3b: Slope ability test runs (>3°)	33 hrs
6	EST – Emergency Shutdown Test	24 hrs
7	DSC - Decomissioning & Site Closure	63 hrs



Source: AllSeas, 2020

Table 3-2. Alternatives analysis for key decisions

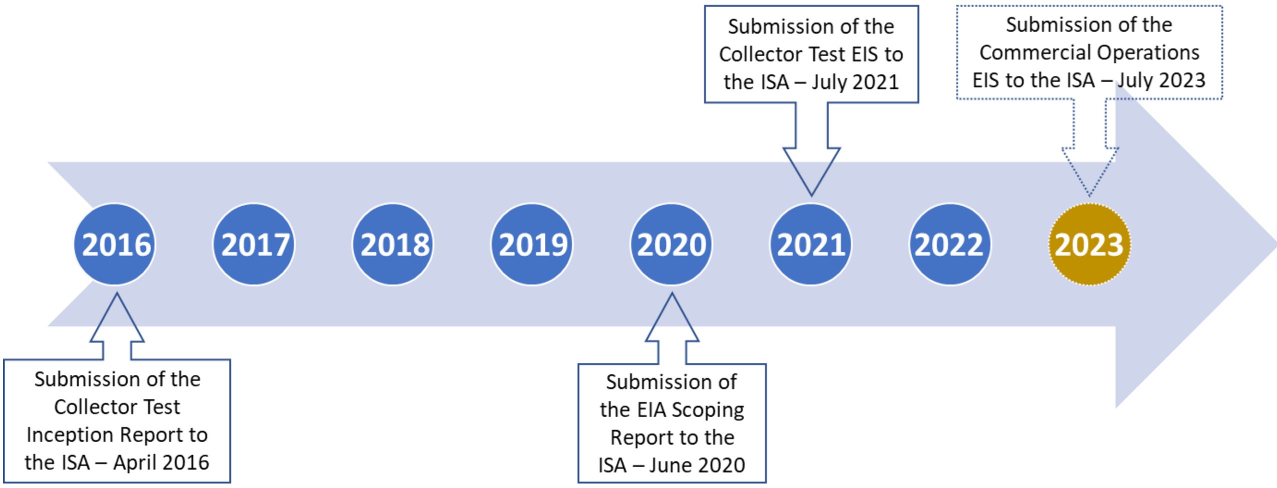
Alternatives	Decisions	Outcomes & Rationale
'Collector Test' or 'No Project'	**Option 1** Collector Test VS **Option 2** No Project	ISBA/25/LTC/6/Rev.1. Annex 1.66. Describes tests of mining components as «*an opportunity to determine the environmental implications of mining*». If the project does not proceed: • There will not be an optimal understanding of the environmental impacts of the mining components; • The Commercial EIS will be deficient of information required to make an informed decision. **The 'No Project' option was dismissed as this does not provide an optimal understanding of the environmental impacts of the mining components**
Conduct the test be conducted in the 'CCZ' or 'elsewhere'	**Option 3** Shallow water/ Lab based trials only VS **Option 4** Deep water trials in CCZ	Component testing in deep waters (>4000m) is considered essential to fully test the equipment under the operational conditions. The findings from the test will inform the design and operation of the full commercial system informing specifications that optimise resource recovery and environmental performance. **The 'Shallow water / Lab based trials only' as this does not provide understanding of the environmental impacts of the mining components**
Situate the CTA in the 'Flatter Area' or 'Other' geoform	**Option 5** CTA in 'Flatter Area' geoform VS **Option 6** CTA in other geoform	A benthic geoform analysis and mapping exercise was conducted (see Section 5.14). The findings of this analysis were ":*By limiting the disturbance caused by the collector test to the most abundant 'Flatter Area' geoform the potential for significant impact to abyssal hills and seamounts, which have been shown to be higher in species richness and biomass, is reduced.*" **The 'CTA in other geoform' option was dismissed as this does not minimise the potential for environmental impacts.**
Situate TF in 'Area 6' or 'Other Area'	**Option 7** TF in other area of CTA VS **Option 8** TF in Area 6 of CTA	Nine potential areas within the CTA were considered for the TF. Area 6 was selected based on it's location, size, orientation, slope and site conditions; the combination of which was considered optimal for safe PCV operation with minimised potential impacts to the environment (see Section 3.3.2) **The 'TF in other area of CTA' option was dismissed as this does not optimise the potential for safe PCV operation with minimised impacts to the environment.**
Situate BACI control site in 'PRZ' or 'Assign new control area'	**Option 9** PRZ VS **Option 10** Assign new control area	A PRZ representative of the pre-mining condition of multiple geofoms has been established in the NE corner of NORI-D. In addition a BACI specific control site has been established which is closer to the IRZ and potentially representative of the conditions at the IRZ. **The 'BACI Control Site in PRZ' option was dismissed as the new control site is likely a better representation of the conditions in the IRZ.**

4 ENVIRONMENTAL IMPACT ASSESSMENT METHODS

4.1 Introduction

The Collector Test EIS describes the findings from phase three of a four-phase EIA process to characterise the impacts from a commercial polymetallic nodule collection operation. The four-phases of the EIA process are outlined in Figure 4-1.

Figure 4-1. Four-phase Environmental Impact Assessment Process for NORI-D



The Collector Test EIA builds on the information supplied to the regulator in previous submissions.

The following sections describe the methods used to identify potential risks and significant impacts to the marine environment from the Collector Test. Impacts occur at the points of interaction between project related activities and the receiving environment. These points of interaction are termed 'Environmental Effects' defined in the draft Exploitation Regulations as "*any consequences in the Marine Environment arising from the conduct of Exploitation activities, whether positive, negative, direct, indirect, temporary, or permanent, or cumulative effect arising over time or in combination with other mining impacts*".

4.2 Significant Impacts

An environmental impact is defined as the effect a project related activity has on the receiving environment. The effect can be positive, negative, or neutral, and range from low-high in extent or duration. A 'significant impact' occurs if an environmental effect causes a change in the receiving environment that is deemed unacceptable by the regulating body or relevant authority. In the context of the ISA recommendations, a significant impact would have potential to cause 'serious harm' to the marine environment (ISBA/25/LTC/6/Rev.1(II)).

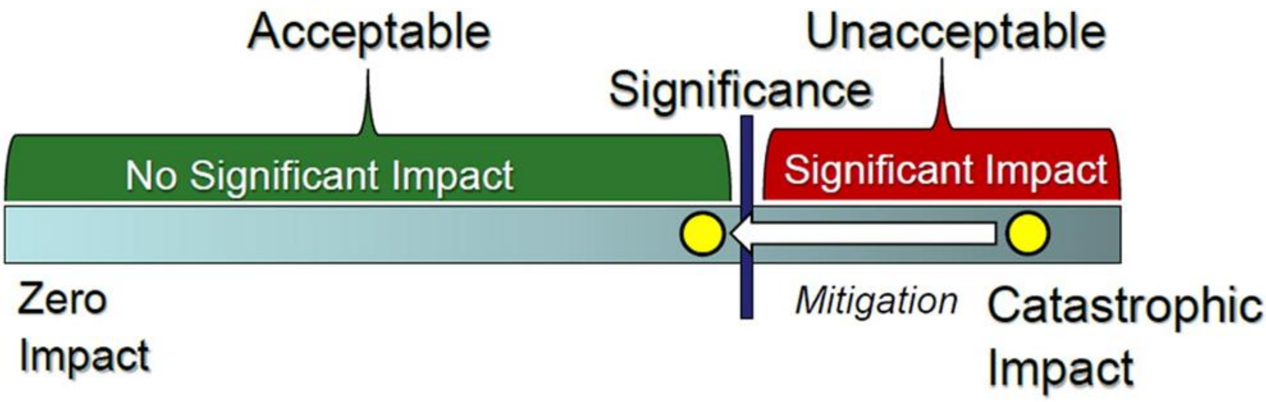
The question of whether or not the impacts of a proposed project are likely to be significant is key in many, if not all, EIA systems (European Commission, 2001; CEQ, 2005; World Bank, 2013). The United Nations Environment Programme states that 'particular attention is given in EIA practice to preventing, mitigating and offsetting the significant adverse effects of proposed undertakings' (Sadler et al. 2002, p. 103).

To determine significance, it must be decided where a predicted adverse impact is likely to fall on the Significance Spectrum (Figure 4-2); whether it falls on the side of acceptable (and therefore is not a significant impact) or on the side of unacceptable and is therefore a significant impact. An effective and efficient EIA will focus effort on evaluating potential impacts that fall to the right of the Significance Spectrum and should not focus on those that clearly fall to the left of the spectrum.

It can be argued, as some commentators have, that this is a subjective determination and that all potential impacts should undergo the same degree of scrutiny. NORI considers this approach inefficient and non-productive and has focussed the EIA on impacts with the potential to fall to the right of the spectrum.

A number of issues identified by commentator as not having been sufficiently addressed by the EIS, on inspection, would clearly fall to the left of the significance spectrum and have not been considered in depth by the assessment, including the impacts of light,

Figure 4-2. Significance spectrum (Ehrlich *et al*., 2015)



The concept of significance remains poorly undefined in the EIA literature and there is no international consensus on a single definition or process for assigning thresholds of significance (CEAA, 1992). For the purposes of this EIA the following process was applied to make an informed determination of significance:

1. Identification of activities associated with the project that may be sources of impact.
2. Identification and characterization of Valued Ecosystem Components (VECs) represented in the receiving environment.
3. Characterization of environmental effects, i.e., points of interaction between project related activities and VECs.
4. Assessment of environmental effects to determine if they are likely to result in significant impacts based on the anticipated magnitude of the impacting activity and the sensitivity of the impacted VEC.

For Step 4 an approach proposed by the Canadian Environmental Agency (1992) was used which assigns significance based on whether environmental impacts are *adverse*, *significant,* and *likely* as defined in Table 4-1.

Table 4-1. Approach used by Canadian Environmental Agency (1992) to determine if environmental impacts are adverse, significant, and likely.

STEP		CRITERIA
Step 1	Deciding whether the environmental effects are adverse	The quality of the existing environment is compared with the predicted quality of the environment once the project is in place.

STEP		CRITERIA
Step 2	Deciding whether the adverse environmental effects are significant	Criteria used are: • Magnitude • Geographic extent • Duration and frequency • Degree to which the adverse environmental effects are reversible or irreversible. • Ecological context
Step 3	Deciding whether the significant adverse environmental effects are likely	Criteria used are: • Probability of occurrence • Scientific uncertainty

The central question for the regulator when assessing the findings presented in this EIS is whether the any of the impacts associated with the collector can be considered **adverse, significant *and* likely**.

4.3 Project Related Activities

Based on the description of the Collector Test operations provided by Allseas (summarised in Chapter 3), the following project related activities have been identified as potential sources of impact:

- Transit to Collector Test Area
- Offshore inspection and preparation
    - Pre-dive checks and system verification
    - Deployment of ROV/basket to seabed
    - Deployment of first LBL array beacons subsea positioning verification
    - Deployment of remaining LBL beacons and SLAM
- PCV deployment
    - Parking position
    - Skidding in launch position
    - Lowering the PCV with the cursor winch through the splash zone
    - Disconnect PCV from the cursor frame
    - Subsea lowering
    - PCV touchdown
- Jumper and riser deployment
    - Jumper hose deployment
    - Riser deployment
- Riser commissioning
    - Sensor line routing over drill floor
    - Air pressure hose skidded/hoisted into place and connected
    - Leak testing and locking of the pressure hose
    - Hose to connect riser head to dewatering plant is skidded/hoisted/connected

    - Riser head is skidded/hoisted over the end of the riser
- Subsea connection of jumper on PCV
    - Collector placed close to the jumper hose
    - ROV attaches pull-in wire on jumper hose
    - Connector is pulled down
    - Connection is made
    - Pull-in wire is disconnected
    - Disconnect Jumper hose
- Operations
    - Manoeuvrability test runs
    - Pick-up test runs
    - Riser installation and commissioning test
    - System integration test
    - System test runs
- Emergency shutdown testing
- Riser and PCV recovery
    - Jumper hose recovery
    - Riser recovery
    - PCV recovery
- Transit from test site

The tasks associated with each activity are described in Section 3 (Project Description) and the potential impacts that the tasks may pose to the physicochemical and biological VECs of the receiving environment are described in detail in Section 6. An understanding of each task, the equipment used and how it will be operated, is necessary to accurately assess the extent, frequency and duration of potentially impacting activities.

4.4 Valued Ecosystem Components

Valued Ecosystem Components (VECs) are defined as any part of the receiving environment that is considered important by the proponent, public, scientists, and government (or regulator) involved in the assessment process. Importance may be determined on the basis of cultural values or scientific concern. (Hegmann *et al.*, 1999).

VECs can be identified once there is an understanding of: (i) the project works and activities; (ii) the environment likely to be affected; and (iii) the potential interactions between project works and activities and the environment (environmental effects).

The importance of VECs relevant to the Collector Test were identified by a review of the current literature on the risks of polymetallic mining activities. The 'at risk' VECs identified by the literature review are summarised in Table 4-2. The body of literature that was used in this analysis is provided as Appendix 1.

For the commercial EIA this list of VECs will be verified and supplemented as necessary, by workshopping the identification process with appropriate stakeholders.

Table 4-2. Outputs from VEC identification Literature Review

Source of Risk	CAUSES	IMPACTS	POTENTIAL CONSEQUENCES	REF*	VECs
Habitat alteration	Nodule collection	Loss of hard substrate	Local displacement of species leading to biodiversity losses	1,2,3, 4,5,6, 7,8,9, 10,11	Microbes Sediment biota Nodule biota Sediment habitat quality Nodule habitat quality
Habitat alteration	Nodule collection	Increased habitat homogeneity	Local displacement of species leading to biodiversity losses	6,19	Microbes Sediment biota Nodule biota Sediment habitat quality Nodule habitat quality
Habitat alteration	Vehicle disturbance of sediments	Organic enrichment of benthic surface	Increased biomass of species with a competitive advantage	6, 20	Microbes Sediment biota
Habitat alteration	Vehicle disturbance of sediments	Porewater alterations	Disturbance and degradation of organic matter at the sediment-water interface releases various elements (e.g., V, Cu, Mo, and DOC) to the pore water	6,8,17 ,21,29	Water quality Sediment geochemistry Sediment habitat quality Nodule habitat quality
Habitat alteration	Vehicle disturbance of sediments	Ecosystem function	Disruption of ecosystem function (total carbon cycling).	28	Microbes Sediment biota Nodule biota Sediment habitat quality Nodule habitat quality
Sediment compaction	Vehicle disturbance of sediments	Unknown	Benthic biota impacted by sediment compaction	4,8,11 ,12,14 ,15,16 ,17,18	Sediment biota Sediment habitat quality
Benthic plume generation	Vehicle disturbance of sediments	Organismal burial	Organismal stress, competitive disadvantage leading to reduced resilience and/or death	4,5,6, 8,10,1 1,14,1 5,16,2 7	Sediment biota Nodule biota
Benthic plume generation	Vehicle disturbance of sediments	Clogging of suspension feeding structures (benthic)	Organismal stress, competitive disadvantage leading to reduced resilience and/or death	9,11,1 2,14,1 5,27	Sediment biota Nodule biota

Source of Risk	CAUSES	IMPACTS	POTENTIAL CONSEQUENCES	REF*	VECs
Benthic plume generation	Vehicle disturbance of sediments	Alteration of deposit feeder behaviour (benthic)	Organismal stress, competitive disadvantage leading to reduced resilience and/or death	4,11,14,22	Sediment biota Nodule biota
Benthic plume generation	Vehicle disturbance of sediments	Plume toxicity (benthic)	Exposure to toxic levels of heavy metals possibly leading to competitive disadvantage, reduced resilience and/or death	9,11	Nekton Phytoplankton Zooplankton Sediment biota Nodule biota
Benthic plume generation	Vehicle disturbance of sediments	Alteration of water chemistry (benthic)	Exposure to toxic levels of pollutants heavy metals possibly leading to competitive disadvantage, reduced resilience and/or death	9,12	Nekton Phytoplankton Zooplankton Sediment biota Nodule biota
Physical disturbance of fauna	Vehicle operations	Increased light (benthic)	Masking of bioluminescence, competitive disadvantage leading to reduced resilience and/or death	11	Light Nekton Phytoplankton Zooplankton Sediment biota Nodule biota
Physical disturbance of fauna	Vehicle operations	Increased sound (benthic)	Local displacement, competitive disadvantage leading to reduced resilience and/or death	11	Acoustic quality (noise) Nekton Phytoplankton Zooplankton Sediment biota Nodule biota
Physical disturbance of fauna	Vehicle operations	Physical trauma to organisms entrained into the collection system	Organismal stress, competitive disadvantage leading to reduced resilience and/or death	27	Sediment biota Nodule biota
Mid-water plume generation	Return water discharge	Organismal burial	Organismal stress, competitive disadvantage leading to reduced resilience and/or death	5,6	Sediment biota Nodule biota
Mid-water plume generation	Return water discharge	Clogging of suspension feeding structures (pelagic)	Zooplankton stress, competitive disadvantage leading to reduced resilience and/or death	9,6,11, 27	Nekton Phytoplankton Zooplankton

Source of Risk	CAUSES	IMPACTS	POTENTIAL CONSEQUENCES	REF*	VECs
Mid-water plume generation	Return water discharge	Clogging of suspension feeding structures (pelagic)	Zooplankton stress, competitive disadvantage leading to reduced resilience and/or death	6,27	Nekton Zooplankton
Mid-water plume generation	Return water discharge	Clogging of suspension feeding structures (pelagic)	Zooplankton stress, competitive disadvantage leading to reduced resilience and/or death	6	Nekton Zooplankton
Mid-water plume generation	Return water discharge	Sunlight attenuation	Reduction in primary production	11,27	Phytoplankton
Mid-water plume generation	Return water discharge	Nutrient enrichment	Increase in primary production (algal blooms)	6,11,15,23,27	Phytoplankton
Mid-water plume generation	Return water discharge	Release of CO_2 in surface waters	Unknown	12	Phytoplankton
Mid-water plume generation	Return water discharge	Changes in deposition of Particulate Organic Carbon	Disruption to established trophic structure	11,27	Phytoplankton Nekton Zooplankton
Surface operations	Light, noise, vibration generation	Disturbance resulting in attraction or displacement	Behavioural patterns of cetaceans, fish, marine birds etc. may be disturbed	27	Air quality Acoustic quality Light Birds Cetaceans/turtles Fish
Cumulative impacts	Multiple anthropogenic stressors	Synergistic amplification of other stressors. Reduced availability of Ecosystem Services.	Unknown	26	Ecosystem function
Climate Change	Multiple anthropogenic stressors	Synergistic amplification of other stressors	Unknown	24,25	Ecosystem services (climate regulation)

*Numbering refers to the references provided in Appendix 1

Using the results of the literature review and the expertise of the EIA team the following physicochemical and biological VECs have been identified as having potential relevance for the Collector Test.

Physical

- Acoustic quality (noise)
- Vibration
- Air quality
- Water quality
- Light

Chemical

- Sediment geochemistry

Biological

- Birds
- Cetaceans/Turtles
- Fish
- Nekton
- Phytoplankton
- Zooplankton
- Microbes
- Sediment biota
- Nodule biota
- Sediment habitat quality
- Sediment geochemistry
- Nodule habitat quality

Functions

- Ecosystem function (as a result of cumulative impacts)
- Climate Regulation

4.5 Environmental Effects

Characterization of project related activities has identified 34 tasks as potential sources of impact, and 25 vulnerable VECs, distributed through the atmospheric, euphotic, mesopelagic, bathypelagic, and abyssal zones. In addition, ecosystem function and climate regulation have also been identified as VECs potentially vulnerable to cumulative impacts.

In total, 850 (34x25) potential interaction points were entered into a Leopold Matrix (Table 4-3), of which 103 were considered to be environmental effects with potential to cause significant impact. It should be noted that the Leopold Matrix has been used to identify interaction points only, the relative significance of impacts is addressed in subsequent sections

The environmental effects are distributed amongst the zones and activities at the frequencies shown in Table 4-4 and Table 4-5. This information demonstrates that the highest proportion of vulnerable VECs are in the abyssal and bathypelagic zones and most of the potential impacts are associated with System Testing. Table 4-6 describes the project activities, vulnerable VECs and potential impact pathways.

This information has been used to focus the EIA on the most relevant points of interaction. .

Table 4-3. Leopold Matrix

ACTIVITY →				Offshore Inspection & Preparation				PCV Deployment						Jumper & Riser Deployment		Riser Commissioning					Subsea Connection of Jumper on PCV						System Testing						Riser & PCV Recovery				←TOTAL NUMBER OF ENVIRONMENTAL EFFECTS
TASK →			Transit to Collector Test Area	Pre-dive checks and system verification	Deployment of ROV/Basket to seabed	Deployment of first Sparse LBL array beacons subsea positioning verification	Deployment of remaining LBL beacons and SLAM	Parking Position	Skidding in Launch Position	Lowering the PCV with the cursor winch through the splash zone	Disconnect PCV from the cursor frame	Subsea lowering	PHV touchdown	Jumper hose deployment	Riser deployment	Sensor line routed over drill floor	Air pressure hose is skidded / hoisted into place and connected	Leak testing and locking of the pressure hose	Hose to connect riser head to dewatering plant is skidded / hoisted / connected	Riser head is skidded / hoisted over the end of the riser	Collector placed close to the jumper hose	ROV attaches pull-in wire on jumper hose	Connector is pulled down	Connection is made	Pull-in wire is disconnected	Disconnect Jumper hose	Manoeuvrability Test Runs	Pick-up Test Runs	Riser Installation and Commissioning Test	System Integration Test	System Test Runs	Emergency Shutdown Testing	Jumper hose recovery	Riser recovery	PCV recovery	Transit From Collector Test Area	
Zone ↓	VEC ↓		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Atmospheric	Noise / Vibration / Light	1	●															●											●	●	●					●	8
	Air Quality / GHG Emissions	2	●																																	●	
Euphotic (0-200m)	Cetaceans / Turtles	3	●							●		●		●	●			●															●	●	●	●	23
	Nekton	4																											●								
	Phytoplankton	5																																			
	Zooplankton	6																																			
	Water Quality	7	●		●							●		●	●							●											●	●	●	●	
	Noise / Vibration	8																●											●								
Mesopelagic (200-1000m)	Cetaceans	9																																			11
	Nekton	10																											●								
	Zooplankton	11																																			
	Water Quality	12												●	●																		●	●	●	●	
	Noise / Vibration / Light	13																●											●	●	●						
Bathypelagic (1000-4000m)	Nekton	14																												●	●						17
	Zooplankton	15																												●	●						
	Water Quality	16			●							●										●								●	●		●	●	●	●	
	Noise / Vibration / Light	17																●											●	●	●						
Abyssal (4000-6000m)	Nekton	18																												●	●						44
	Zooplankton	19																												●	●						
	Microbes	20																									●	●			●						
	Water Quality	21			●							●		●	●							●					●	●		●	●		●	●	●	●	
	Noise / Vibration / Light	22			●																						●	●	●	●	●						
	Benthic Biota	23			●	●	●						●					●									●	●			●						
	Sediment Geochemistry	24																									●	●			●						
	Benthic Habitat Quality	25			●	●	●						●														●	●			●						
TOTAL NUMBER OF ENVIRONMENTAL EFFECTS→			4	10				7						8		6					3						43					0	15			7	103
																																					103

Table 4-4. Environmental effects per zone

ZONE	NUMBER OF ENVIRONMENTAL EFFECTS
Atmospheric	8
Euphotic (0-200 m)	23
Mesopelagic (200-1,000 m)	11
Bathypelagic (1,000-4,000 m), and	17
Abyssal (4,000-6,000 m; inc. benthos)	44
TOTAL	**103**

Table 4-5. Environmental effects per project related activity

ACTIVITY	NUMBER OF ENVIRONMENTAL EFFECTS
Transit to Collector Test Area	4
Offshore inspection and preparation	10
PCV Deployment	7
Jumper and riser deployment	8
Riser commissioning	6
Subsea connection of jumper on PCV	3
System Testing	43
Emergency shutdown testing	0
Riser and PCV recovery	15
Transit from test site	7
TOTAL	**103**

Table 4-6. Activities, valued ecosystem components, and impact pathways

ACTIVITY	VULNERABLE VECS	IMPACT PATHWAYS
Transit of the vessel from San Diego to the CCZ	Air quality/GHG	Vessel's diesel engines will emit fumes into the atmosphere reducing local air quality and contributing to GHG emissions.
	Noise/vibration/light	Vessel's diesel engines will generate noise and vibrations which could disturb birds, cetaceans, and turtles. Vessel will emit light.
	Cetaceans/turtles	Vessel strike on cetaceans or turtles
	Water quality	Intentional or accidental release of pollutants from the vessels could negatively impact water quality
Offshore Inspection and Preparation	Water quality	Leakage of hydraulic fluids, oil, or other substances from the ROV could negatively impact water quality throughout the water column during its descent to the seabed.
	Noise/vibration/light	Deployment of ROV top the seabed has potential to generate noise, vibration, and light.

ACTIVITY	VULNERABLE VECS	IMPACT PATHWAYS
	Benthic Biota (sediment, nodule, free swimming)	Deployment of the ROV and other equipment (inc. LBL network) to the seabed has the potential to physically disturb sediment and nodule dwelling animals.
	Benthic Habitat Quality	Deployment of other equipment (inc. LBL network) to the seabed will physically disturb benthic habitat by creating contours in the sediment.
PCV Deployment	Cetaceans/Turtles	Lowering the PCV through the splash zone could disturb or physically strike cetaceans or turtles that are in close proximity to the vessel.
	Water Quality	Leakage of hydraulic fluids, oil, or other substances from the PCV could negatively impact water quality throughout the water column during subsea lowering.
	Benthic Biota (sediment, nodule, free swimming)	Touchdown of the PCV on the seabed will physically disturb, displace or kill sediment and nodule dwelling animals.
	Benthic Habitat Quality	Touchdown of the PCV on the seabed will physically disturb the benthic habitat by creating contours in the sediment and/or moving or crushing nodules.
Jumper and Riser Deployment	Cetaceans/Turtles	Lowering the jumper and riser tubes through the splash zone has the potential to disturb or physically strike cetaceans or turtles that are in close proximity to the vessel.
	Water Quality	Leakage of hydraulic fluids, oil, or other substances from the ROV during manipulation of the jumper or riser could negatively impact water quality throughout the water column.
Riser Commissioning	Noise/Vibration	Surface and/or subsea noise or vibrations caused by pressure testing of the riser pipe could disturb birds, cetaceans, and turtles.
	Cetaceans/Turtles	Surface and/or subsea noise or vibrations caused by pressure testing of the riser pipe could disturb birds, cetaceans, and turtles
Subsea Connection of Jumper on PCV	Water Quality	Leakage of hydraulic fluids, oil, or other substances from the ROV during connection of the jumper on the PCV could negatively impact water quality throughout the water column.
System Testing	Cetaceans/Turtles	Riser installation and commissioning tests, system integration testing, and system test runs all have the potential to create noise and vibration disturbances at the surface and throughout the water column from use

ACTIVITY	VULNERABLE VECS	IMPACT PATHWAYS
		of the air lift and through pressure testing of the system which could disturb diving and foraging behaviour.
	Microbes	Manoeuvring the PCV on the seabed, pick-up test runs, and system test runs will physically disturb the sediments and nodules potentially disrupting the microbial community structure in the surface layers of the sediment, and seafloor metabolic activity
	Water Quality	Manoeuvring the PCV on the seabed, pick-up test runs, and system test runs will physically disturb the sediments and nodules creating a sediment plume and potentially mobilizing particle-bound nutrients and trace metals.
	Noise/Vibration/Light	Manoeuvring the PCV on the seabed and pick-up test runs will create noise and vibration which could disturb or displace motile large macrofauna. Riser installation and commissioning tests, system integration testing, and system test runs all have the potential to create noise and vibration disturbances at the surface and throughout the water column from use of the air lift and through pressure testing of the system. PCV will emit light.
	Benthic Biota (sediment, nodule, free swimming)	Manoeuvring the PCV on the seabed and pick-up test runs will create noise and vibration which could disturb or displace motile large macrofauna. Riser installation and commissioning tests, system integration testing, and system test runs all have the potential to create noise and vibration disturbances at the surface and throughout the water column from use of the air lift and through pressure testing of the system. PCV will emit light. Manoeuvring the PCV on the seabed and pick-up test runs will physically disturb or remove sediment and nodule dwelling animals. System test runs will create a benthic plume, as entrained sediment is ejected from the rear of the PCV; this plume will be denser than that formed during the manoeuvrability and pick-up test runs and will blanket and smother surrounding sessile biota.
	Sediment Geochemistry	Manoeuvring the PCV on the seabed, pick-up test runs, and system test runs will mix the surface layers of the sediment, disrupting oxygen concentration gradients in the surface layers and potentially mobilizing particle-bound nutrients and trace metals.
	Benthic Habitat Quality	Manoeuvring the PCV on the seabed and pick-up test runs will physically disturb the benthic habitat by

ACTIVITY	VULNERABLE VECS	IMPACT PATHWAYS
		creating contours in the sediment, disrupting surface layers of sediment, and/or moving or crushing nodules. System test runs will create a benthic plume, as entrained sediment is ejected from the rear of the PCV; this plume will be denser than that formed during the manoeuvrability and pick-up test runs and will blanket and smother surrounding sessile biota.
	Nekton	Nekton in the mesopelagic and bathypelagic zones could be impacted by noise and vibration from the air lift system and by suspended sediment and mobilized chemicals released from the return water pipe outlet at 1,200 m.
	Zooplankton	Zooplankton in the euphotic, pelagic and bathypelagic zones could be impacted by noise and vibration from the air lift system and by suspended sediment and mobilized chemicals released from the return water pipe outlet at 1,200 m.
	Water Quality	Water quality in the bathypelagic zone and below could be impacted by increased turbidity caused by suspended sediments and mobilized chemicals released from the return water pipe outlet at 1,200 m.
	Climate Regulation	Emissions of GHGs to the atmosphere through travel, operation of equipment or mobilization of sequestered C in benthic sediments.
Emergency Shutdown Testing	N/A	There are no environmental aspects anticipated to be associated with the emergency shutdown testing of the system.
Riser and PCV Recovery	Cetaceans / Turtles	Rising the jumper hose, riser pipe, and PCV through the splash zone could disturb or physically strike cetaceans or turtles that are in close proximity to the vessel.
	Water Quality	A ROV will be used for recovery, leakage of hydraulic fluids, oil, or other substances from the ROV could negatively impact water quality throughout the water column.
Transit of the vessel from the CCZ to San Diego	As for previous transit	As for previous transit
Cumulative Impacts	Ecosystem Function	Disruption of key ecosystem functions as a result of additive or synergistic impacts from project related activities.
	Ecosystem Services	Disruption of climate regulation capacity

4.6 Risk Assessment

The overarching objectives of the Environmental Risk Assessment (ERA) is to appropriately determine the potential impacts to VECs and to manage these impacts through the environmental management hierarchy of: avoid, minimise and mitigate/offset.

ERA requires and understanding of the consequence and likelihood of a potential impact.

4.6.1 Consequence

The consequence of a potential impact is a function of the sensitivity of the VEC and the magnitude of the potential impact

VEC sensitivity is assigned based on its intrinsic value as well as its susceptibility or vulnerability to threatening processes. Sensitivity has been estimated based on data collected during baseline studies to characterize key attributes such as existing condition, distribution, conservation status, rarity or uniqueness, replacement potential, and resilience to change.

Due to the small scale of the Collector Test a high level of control can be exerted over the magnitude (that is, extent, duration, or frequency) of impacting activities. The Collector Test has been designed to minimise the magnitude of impacts by:

- Restricting the TF to an area of just 8 km^2 within the CTA, minimising the likelihood that the Collector Test will result in significant impacts by making the disturbance footprint very small relative to the size of NORI-D.
- Locating the CTA and TF in the most abundant 'Flatter area' geoform which is assumed to be less species rich than the surrounding Abyssal hills and seamounts which have been shown to be higher in species richness and standing stock biomass compared to adjacent areas devoid of topographic variability (Clark *et al.*, 2009; Cuvelier *et al.*, 2020; Durden *et al.*, 2015, 2020; McClain, 2007; Ramirez-Llodra *et al.*, 2005; Rowden *et al.*, 2010).
- Locating the return pipe outlet at 1,200 m to avoid the productive mesopelagic zone and sensitive mesopelagic/bathypelagic interface which has been demonstrated to be located at approximately 1000m (see Section 5.11.3).
- Minimising system testing operations generating return water discharge to 259 hours.

The consequence of an impact has been assessed by considering the magnitude of an impact following the application of mitigation measures and the sensitivity of the VEC using the descriptors in Table 4-7 and Table 4-8.

Based on the anticipated magnitude of the impact and the sensitivity of the VEC, the consequence on a residual impact has been assessed using the criteria described in Table 4-9.

Table 4-7. Descriptions of impact magnitude

MAGNITUDE (M)	
1	**Negligible** - Impact is unlikely to occur, or the effect persists only for the duration of the impacting activity, **and/or** is restricted to the Test Field (including the overlying water column or atmosphere).
2	**Small** – Effect is temporary and persists for a short duration (weeks – months) after cessation of the impacting activity, **and/or** is mostly restricted to the CTA (including the overlying water column or atmosphere).
3	**Medium** - Effect is temporary and persists for a long duration (years) after cessation of the impacting activity, **and/or** is restricted to NORI-D (including the overlying water column or atmosphere).
4	**Large** - Effect is permanent and extends beyond NORI-D (including the overlying water column or atmosphere).

Table 4-8. Descriptions of VEC sensitivity

SENSITIVITY (S)	
1	**None** - High probability that the impacted VEC is well represented throughout the CCZ.
2	**Low** - High probability that the impacted VEC is well represented throughout NORI-D.
3	**Medium** - High probability that the impacted VEC found only in the CTA.
4	**High** - High probability that the impacted VEC is found only in the Test Field **OR** there is uncertainty around the status or distribution of the VEC or it's likely response to the impacting activity.

Table 4-9. Consequence

CONSEQUENCE (M*S)	
Negligible (1 – 4)	The residual risks pose no threat to the long-term viability of the VEC at a local or regional scale.
Low (5 – 8)	With the implementation of mitigation measures the residual risks pose negligible threat to the long-term viability of the VEC at a local or regional scale.
Moderate (9 – 12)	With the implementation of mitigation measures the residual risks may pose a threat to long-term viability of the VEC within NORI-D.
High (13 – 16)	With the implementation of mitigation measures the residual risks pose a threat to long-term viability of the VEC within NORI-D and regionally **OR** there is insufficient information available on the magnitude of the impact and sensitivity of the VEC to make an informed determination.

4.6.2 Likelihood

Likelihood refers to the chances of a potential impact occurring, assuming the effective implementation of the proposed mitigation measures. Likelihood is described semi-quantitatively in Table 4-10. There are five categories, ranging from rare (i.e., less than 1% chance of occurring over the life of the Project) to almost certain (i.e. greater than 90% probability of occurring).

Table 4-10. Likelihood definitions for potential impacts occurring over the life of the Project

DESCRIPTION	FREQUENCY
Rare	Highly unlikely to occur but theoretically possible during the life of the Project. Probability is less than 1% chance of occurring
Unlikely	Unlikely but not trivial. May occur during construction/life of the Project but probability well < 50%.
Possible	Less likely than not, but still considerable; probability of about 50% chance of occurring over the life of the Project.

DESCRIPTION	FREQUENCY
Likely	Likely to occur during life of the Project or during a 12-month timeframe; probability up to 90% chance of occurring.
Almost certain	Very likely and expected to occur during construction/life of the Project or during a 12-month timeframe; likely to occur multiple times during relevant period. Probability of 90% or greater chance of occurring.

4.6.3 Risk Assessment - Environment

Risk is the effect of uncertainty on objectives or desired/expected outcomes (e.g., uncertainty around the expected outcomes managing a potential impact). For this risk assessment, the uncertainty is the result of the lack of information relating to the understanding or knowledge of a potential impact, its consequence, or the likelihood of it occurring. The risk level of potential impacts is a product of the consequence of the potential impacts and the likelihood of their occurrence assuming the effective implementation of the proposed mitigation measures (refer Table 4-11 and Table 4-12).

Table 4-11. Risk matrix

LIKELIHOOD	CONSEQUENCE			
	Negligible	Low	Moderate	High
Rare	Negligible	Negligible	Medium	Medium
Unlikely	Negligible	Low	Medium	High
Possible	Negligible	Low	High	High
Likely	Negligible	Medium	High	Very High
Almost Certain	Low	Medium	Very High	Very High

Table 4-12. Risk category definitions

RISK	DEFINITION
Negligible Risk	No additional management required
Low Risk	Manageable by standard mitigation and similar operating procedures
Medium Risk	Issue may require project specific controls and operating procedures
High Risk	An issue requiring further detailed investigation and planning to manage and reduce risk; likely to result in a ‘significant’ impact.
Very High Risk	An issue requiring a change in Project scope and/or timing; almost certain to result in a ‘significant’ impact.

Using the criteria described above an assessment of the significance of the residual risks of the project on the physicochemical and biological VECs is provided in Sections 7.2 and 8.2 respectively.

4.7 Cumulative Impacts

The definition of cumulative impacts adopted for this assessment is consistent with the IFC *Good Practice Handbook for Cumulative Impact Assessment and Management* (IFC, 2013), which states:

"Cumulative impacts are those that result from the successive, incremental, and/or combined effects of an action, project, or activity when added to other existing, planned, and/or reasonably anticipated future ones."

Furthermore, the IFC (2013) considers that:

A cumulative impact assessment includes two components:

- *The anticipated future condition, which is the total effect of the other existing, and predictable future developments and external natural environmental and social drivers, and*
- *The contribution of the development under evaluation to the cumulative impacts.*

This definition considers the additive impact of the primary activity (that is, the current Project) and third-party activities. Cumulative impact assessment requires taking into account existing or other projects planned in the foreseeable future, it is intended to overcome the deficiencies associated with the limited scope of an individual project-based environmental impact assessment.

The contribution of the Collector Test to cumulative impacts has been considered in Chapter 9.

4.8 Major Hazards

A hazard is a situation with the potential for harm in terms of human injury or ill-health, damage to property, damage to the environment, or a combination of these. In the context of offshore projects hazards are often associated with chemical spills, fires, explosions and/or hazardous emissions.

While rare, such events may result in loss of life, environmental harm, asset loss and reputational damage. These are essentially unplanned events, to be anticipated as possibilities, for which preventative action and reactive responses are required. Potential major hazards and suggested management responses are described in Chapter 10.

4.8.1 Risk Assessment – Health Safety & Corporate

NORI has identified potential hazards associated with the Collector Test based on our knowledge of the activities, tasks, personnel and equipment required to implement the test and the receiving environment. Risk assessment is a three-step process:

1. Review of unplanned events that could impact on the environment.
2. Assessment of the potential hazards or threats that those activities might pose to the physical, biological or social/cultural environment.
3. Assessment of the risk posed by the hazards.

Potential unplanned impacts arising from Project related activities were assessed in terms of both likelihood and consequences. The risk assessment assumes the effective implementation of the proposed mitigation measures and best industry practice. It then examines the residual likelihood of an impact occurring as a result of an incident or hazard, and the severity of the potential consequences.

The principles of risk management described in the following documents were adopted in the risk assessment method:

- AS/NZS ISO 31000:2009 Risk management – principles and guidelines (Standards Australia, 2009).
- SA/SNZ HB 436:2013 Risk management guidelines companion to AS/NZS 31000:2009 (Standards Australia, 2013).
- HB 203:2012 Managing environmental-related risk (Standards Australia, 2012).

Table 4-13 and Table 4-14 describe qualitative criteria developed to rank the likelihood and consequence of potential hazards. Consequences are defined in terms of – environment, health and safety, business reputation and financial loss.

The level of risk is assessed by combining likelihood and consequence in a matrix as per Table 4-15.

Table 4-13. Qualitative criteria for likelihood

RATING	DESCRIPTION
Rare (A)	The impact may only occur in exceptional circumstances. Very rare occurrence (once per 1,000 years). Unlikely that it has occurred elsewhere and, if it has occurred, it is regarded as unique
Unlikely (B)	The impact could occur but is not expected. May be technically possible but extremely unusual. A rare occurrence (once per 100 years)
Possible (C)	The impact could occur, however has seldom occurred in similar operations. There is likely to be an impact on average every 5 to 20 years
Likely (D)	There is likely to be an impact on average every 1 to 5 years. Likely to have been a similar incident occurring in similar environments. The impact will probably occur in most circumstances
Almost certain (E)	The impact will occur, is of a continuous nature, or the likelihood is unknown. There is likely to be an impact at least once per year or more (up to 10 times per year). It often occurs in similar environments. The impact is expected to occur in most circumstances

Table 4-14 Qualitative criteria for consequence

RATING	HEALTH AND SAFETY	ENVIRONMENT	BUSINESS REPUTATION	FINANCIAL LOSS
None (0)	No injury or health effect	No impact	No impact	No loss
Negligible (1)	Minimal impact	Minimal impact	Minimal impact	Minor financial loss
Minor (2)	First-aid treatment	Minor local impact and/or regulatory notification required	Some impact	Financial loss <1 million US$
Moderate (3)	Medical treatment	Significant local environmental impact and/or regulatory intervention	Small to moderate impact	Financial loss 1 to 4 million US$
Major (4)	Extensive injury or hospitalisation	Significant ecological or cultural impact and/or regulatory intervention	Significant impact and/or national media exposure	Financial loss 4 to 40 million US$
Severe (5)	Fatality	Critical ecological or cultural impact and/or regulatory intervention	Critical impact and/or international media exposure	Financial loss >40 million US$

Table 4-15. Qualitative risk assessment matrix

			Likelihood				
			A	B	C	D	E
			Rare	Unlikely	Possible	Likely	Almost Certain
Consequence	0	None	Low	Low	Low	Low	Low
	1	Negligible	Low	Low	Low	Low	Low
	2	Minor	Low	Low	Low	Medium	Medium
	3	Moderate	Low	Low	Medium	Medium	High
	4	Major	Low	Medium	Medium	High	High
	5	Severe	Medium	Medium	High	High	High

Low risk outcomes are considered to have been reduced to low as reasonably practicable (ALARP) by the implementation of the prescribed management measures.

Medium risk outcomes are also considered to have been reduced to ALARP by the implementation of the prescribed management measures; however, a degree of unresolved uncertainty may exist or the consequences of a realised risk are high. Monitoring of these operations will be a priority and they may be modified or suspended if unanticipated outcomes are observed.

High risk outcomes, activity should not proceed without the development of additional focused mitigation measures.

Using the criteria described above a risk assessment of potential hazards arising from the Collector Test is provided in Section 10.

5 PHYSICOCHEMICAL ENVIRONMENT

5.1 General Setting

The Clarion-Clipperton Zone (CCZ) is a 4.5-million-km^2 region in the northern part of the Central Pacific Ocean (Figure 5-1). This region is situated between the Clarion Fracture Zone to the north, the Clipperton Fracture Zone to the south, the Mathematician Ridge to the east and the Line Islands Ridge to the west, with the closest populated land mass being Manzanillo, Mexico, approximately 1,700 km to the northeast.

The vast areas of the CCZ are comprised of muddy-clay abyssal plains, punctuated by discrete deep-sea features such as seamounts. Water depths range from 4,000 m in the east to 6,500 m in the west (ISA, 2010).

5.2 NORI-D

The study area, NORI-D, is in the southeast sector of the CCZ and has an approximate area of 25,160 km^2.

Isolated seamounts occur in the southern half of NORI-D, becoming larger and more prominent towards the southeast. The flanks of the seamounts are the steepest slopes encountered in NORI-D, ranging from 8° to near vertical in places. These geomorphologic structures are thought to be directly related to seafloor spreading from the East Pacific Rise (ISA, 2010a). Sedimentation and particulate organic carbon (POC) flux in the area is influenced by change in gradients and water depth, and potentially have an important controlling function on abundance and diversity of species (Golder Associates, 2018).

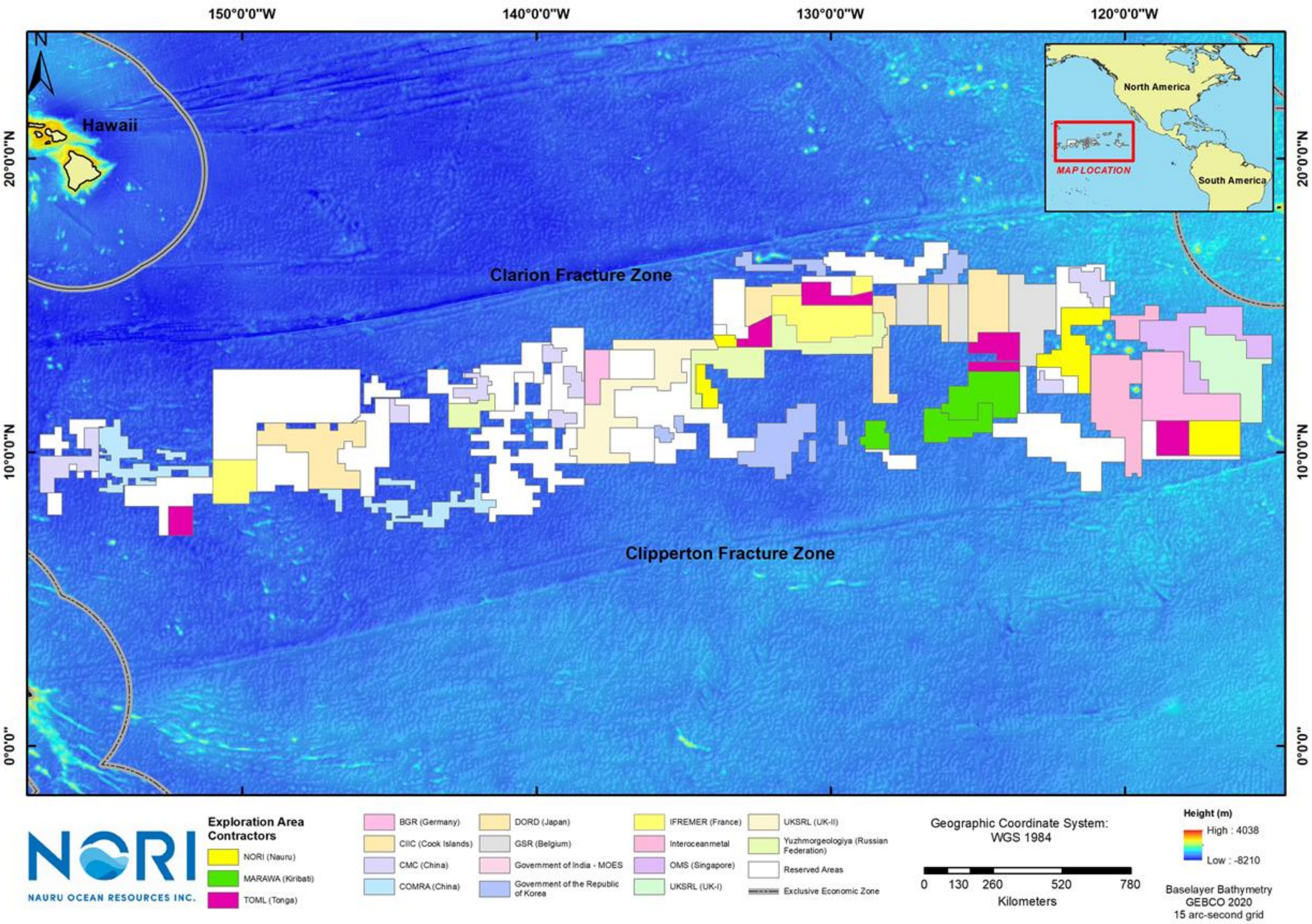
Water depths within NORI-D range from approximately 3,000 to 4,600 m, with a mean of 3,800 m. Water depths increase to the west of the area, with a range of 3,000 to 4,250 m in the east and 4,000 to 4,600 m in the west (Golder Associates, 2018).

5.3 Climate & Meteorology

NORI-D is located in the southern part of the subtropical sea pressure ridge of the North Pacific High and just north of the sea level pressure trough associated with the Intertropical Convergence Zone (ITCZ) (Golder Associates, 2018).

The climate is dominated by north-easterly trade winds from April to November. Seasonal discrepancies of sea level pressure, surface winds and rainfall reflect the seasonal change of the ITCZ and fluctuations of the Subtropical High. NORI-D is dominated by high sea level atmospheric pressure and low precipitation in the northern hemisphere spring, when the influence of the ITCZ is weakest due to it being close to the equator. In winter, the ITCZ is 10 degrees of latitude further north, and sea level atmospheric pressure is lower. Precipitation and cloud cover are sporadic, with winds persistently changing direction (Golder Associates, 2018). Sea surface temperatures are lowest during February and highest in August with average temperatures of 20 and 32ºC, respectively (BGR, 2019). The hurricane season starts in May with approximately one tropical storm event occurring per month. Storm counts subside in October, but storms can occur as late as November.

Figure 5-1. Location of the Clarion-Clipperton Zone



5.4 Ambient Air Quality

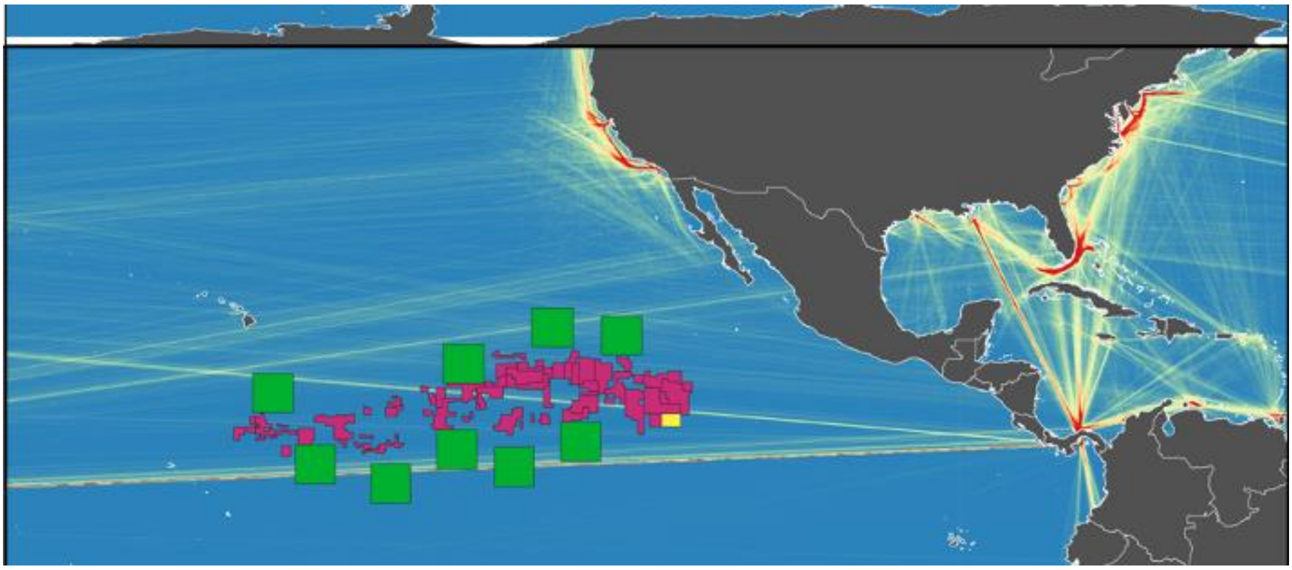
There is no known ambient air quality data available for NORI-D. Given the site is extremely remote, with the nearest land being over 1,700 km northeast (Manzanillo, Mexico), ambient air quality is assumed to be near pristine.

Ambient air quality pollutant measurements (e.g., carbon monoxide, nitrogen dioxide, sulphur dioxide, particulate matter) will be collected as part of the ongoing baseline studies.

5.5 Noise

The background noise profile for NORI-D will comprise of a combination of natural and anthropogenically derived sounds. Naturally occurring background noises will be generated by wave action, weather (e.g., rain), geologic movements (e.g., earthquakes) and animal vocalisations. Anthropogenic generated noise will mainly be from passing shipping; however, it is anticipated that shipping movements through NORI-D will be relatively few in comparison to other global shipping routes (Figure 5-2).

Figure 5-2. Shipping routes around the CCZ and NORI-D.



Source: Flynn and Donnelly (2020). NORI-D represented by yellow rectangle, green squares represent areas of particular environmental interest, and pink polygons are contract areas.

The data collection efforts implemented to date to develop a noise profile for NORI-D are described below.

5.5.1 Data collection activities

Baseline noise data is generated from three primary sources in NORI-D:

- Long-term moored hydrophones attached to the long moorings deployed by CSA (CSA, 2022).
- Ocean Instruments SoundTrap ST600HF hydrophone was added to the long mooring at a depth of 450 m in July 2021; and
- Drifting hydrophone deployed on Campaigns 5A, 5B, 5C and 5D

5.5.1.1 Long-term Moored Hydrophones

CSA deployed two SNAP hydrophones on the long mooring in NORI-D, located at depths of 520 m (HTI-96-MIN hydrophone) and 4,295 m (HTI-90-U hydrophone). The hydrophones are tuned to detect mid to low frequency sounds that characterise the background soundscape and capable of detecting the vocalisations of baleen whales, and the clicks of large-toothed whales and whistles of dolphins.

To date three hydrophone deployments have been completed:

- Deployment Period 1: 14 October 2019 to 27 June 2020.
- Deployment Period 2: 28 June 2020 to 19 July 2021.
- Deployment Period 3: 20 July 2020 to 18 July 21.

5.5.1.2 Moored SoundTrap ST600HF Hydrophone

The SNAP hydrophones are not capable of detecting the high frequency clicks of beaked whales that are known to occur in the region and that are deep-diving and therefore are purported to be a species of relevance to potential deep-sea mining impacts. To address this potential data gap, in July 2021 an additional Ocean Instruments SoundTrap ST600HF hydrophone was added to the mooring at a depth of 450 m. (Note: This data will be available for the Commercial EIS and is not discussed further in this report).

5.5.1.3 Drifting Hydrophone

A drifting hydrophone array was deployed on Campaigns 5A, 5B, 5C and 5D with the aim to increase detectability of high frequency beaked whale vocalisations. The drifting hydrophone array consists of a SoundTrap ST500HF hydrophone deployed at a depth of 450 m on a rope with surface floats and bungee lines to suppress hydrodynamic noise. A SoFar Ocean Spotter v2 float was used to track the array in real time. The drifting array was deployed throughout NORI-D for several days per deployment.

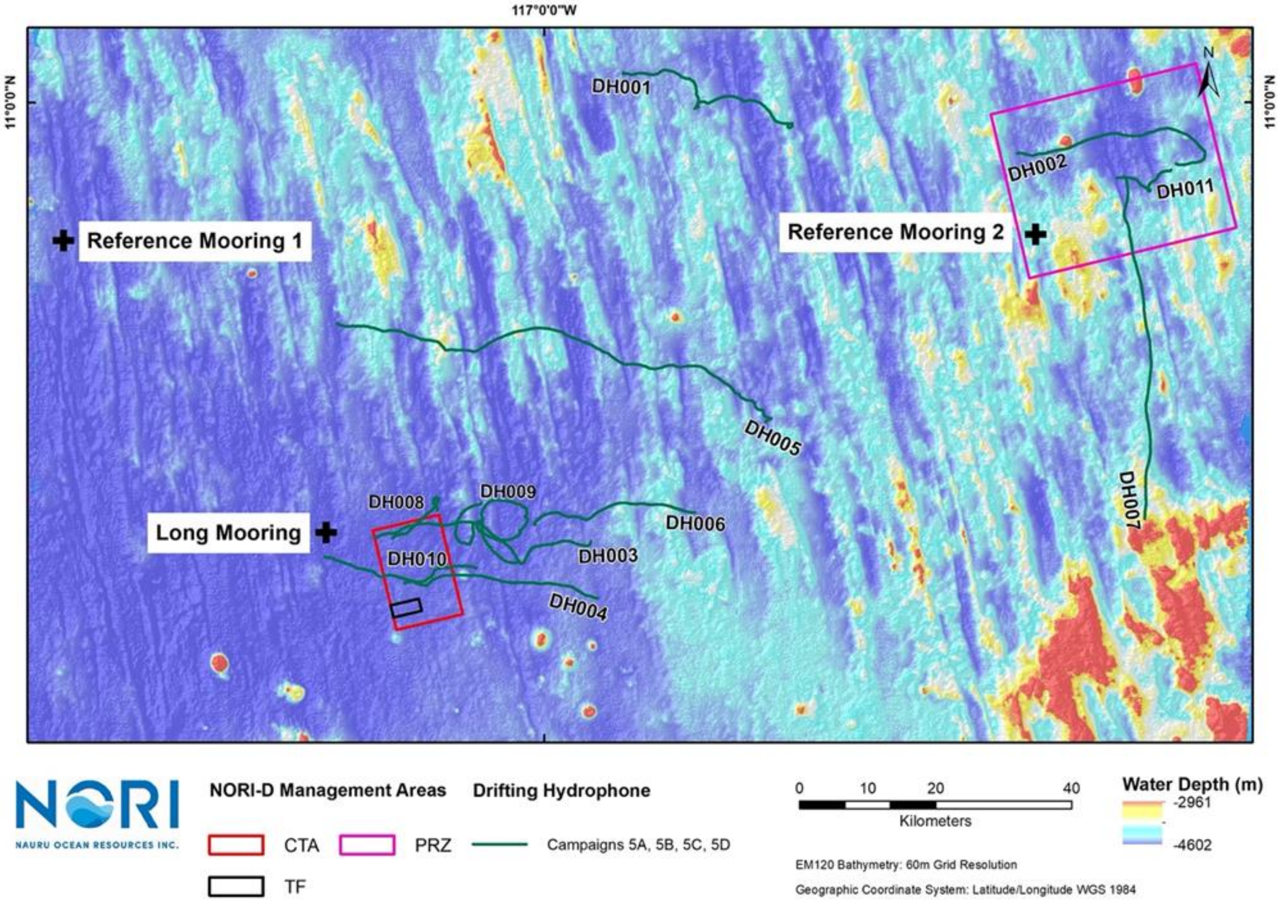
Details of the mooring configurations and hydrophone deployments can be found in the appropriate source reports (i.e., CSA, 2022; Fathom Pacific, 2021).

5.5.2 Sample Sites

The long mooring housing the two SNAP hydrophones and the additional SoundTrap ST600HF hydrophone is located at 10°25’43.9461”(N)/117°17’34.2620”(w), just NW of the CTA (Figure 5-3).

The drifting array was deployed throughout NORI-D for several days per deployment. At the time of writing, data were available for 10 deployments. Analysis has been completed for deployments DH_002 to DH_010 in Figure 5-3.

Figure 5-3. Long mooring location and tracks of the hydrophone drifting array from campaigns 5A, 5B and 5D[3]



5.5.3 Results

5.5.3.1 Long-term Moored Hydrophones

(a) Sound Pressure Level Analysis

Figure 5-4 and Figure 5-5 show the broadband Sound Pressure Level (SPL) and zero-to-peak sound pressure level (PK) for the shallow and deep SAR, respectively. The plots are presented as the daily averaged sound levels (for each metric) for the recorded period. The shallow SAR generally had higher sound levels for both the SPL and PK metric, but the variability among sound levels was relatively consistent between SARs, with a variance between minimum and maximum SPL of 23 and PK of 17 at both the shallow and deep SAR. The minimum, mean, and maximum sound pressure levels for both metrics and both SARs are summarized in Table 5-1.

[3] Deployments DH_002 to DH_010 analysed for this report.

Figure 5-4. Daily averaged broadband root-mean-square sound pressure level (SPL) and zero-to-peak sound pressure level (PK) for the shallow static acoustic recorder.

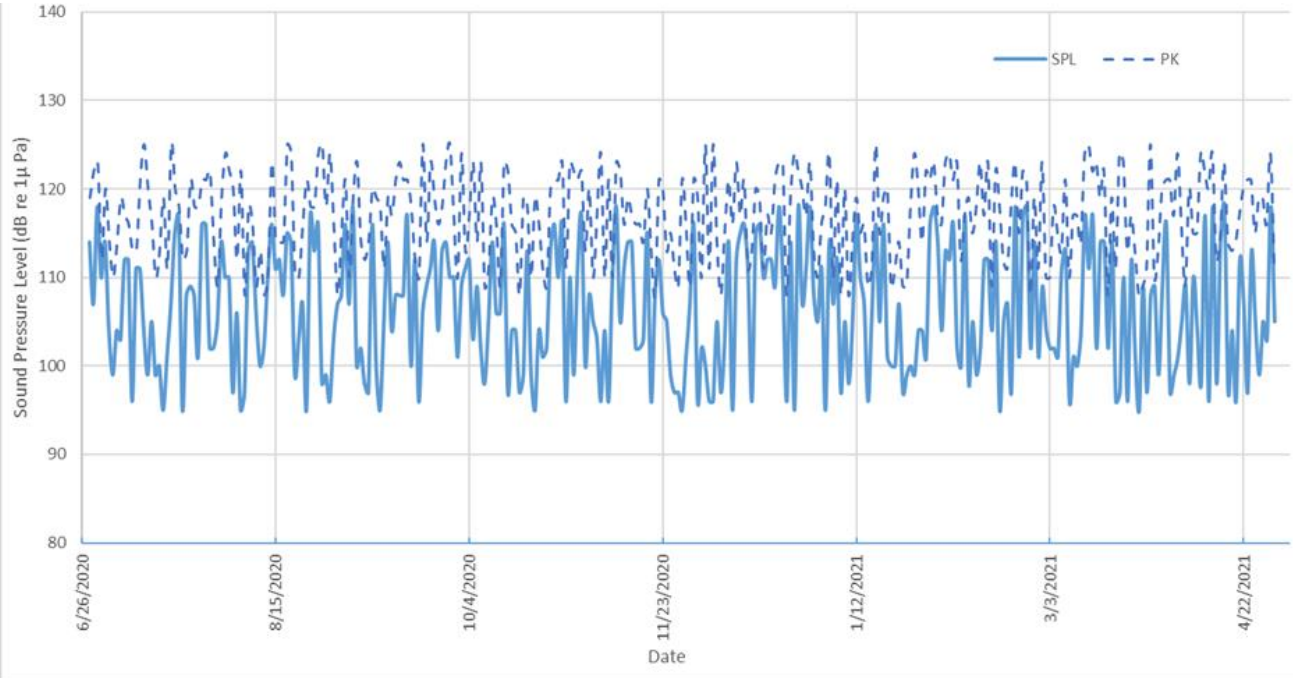


Figure 5-5. Daily averaged broadband root-mean-square sound pressure level (SPL) and zero-to-peak sound pressure level (PK) for the deep static acoustic recorder.

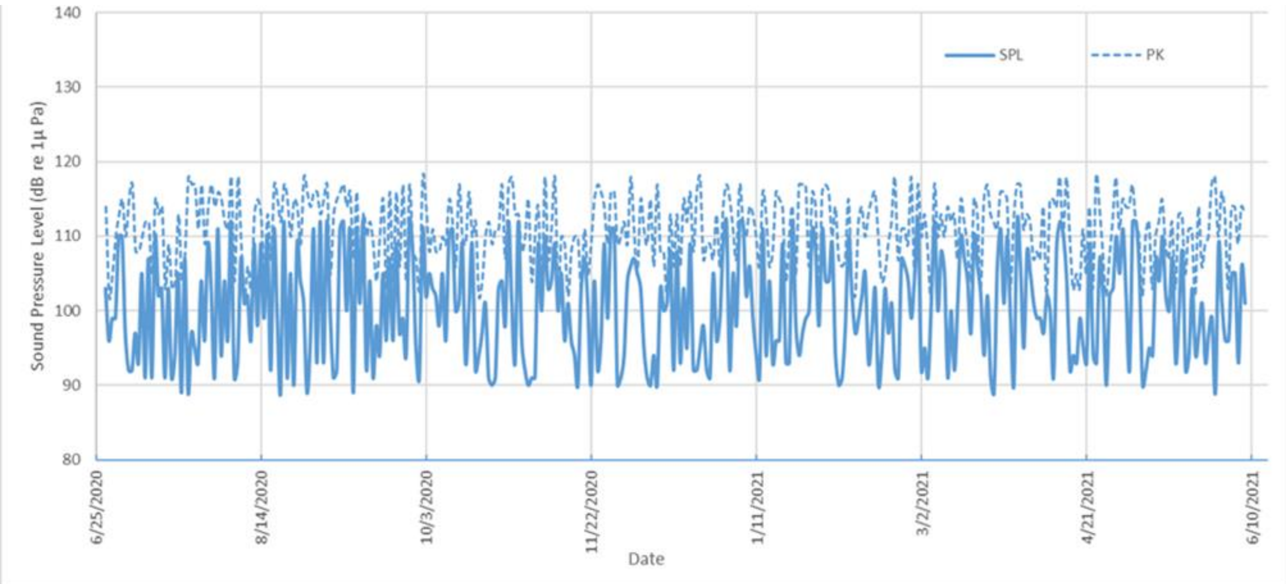


Table 5-1. Minimum, mean, and maximum root-mean-square sound pressure level (SPL) and zero-to-peak sound pressure level (PK) calculated for each day of recording on the shallow and deep static acoustic recorders (SAR).

Value	Shallow SAR		Deep SAR	
	SPL (dB re 1 µPa)	PK (dB re 1 µPa)	SPL (dB re 1 µPa)	PK (dB re 1 µPa)
Minimum	95	108	89	102
Mean	106	117	100	111
Maximum	118	125	112	118

µPa = micropascal; dB = decibel; re = referenced to.

(b) Spectral Analysis

The one-third octave Power Spectral Density (PSD) plot shows the sound pressure contained in the one-third octave frequency bands centred between 3 and 40,000 Hz for the shallow SAR, and between 3 and 20,000 Hz for the deep SAR. The sound pressure in each one-third octave band was averaged and plotted for each full month of data collection to analyse differences in spectral content throughout the year. However, for the purposes of readability in this report, the yearly average was calculated for each one-third octave band and plotted for each SAR in Figure 5-6 and Figure 5-7.

Data indicate that sound levels varied throughout the one-third octave bands and no one dominant frequency band was identified at either SAR (Figure 5-6 and Figure 5-7). Analysis of monthly PSDs showed no discernible trend among frequency bands. Analysis of the data showed numerous broadband events throughout the recording period with acoustic events spanning frequency bands from 0 Hz to 48 kHz (shallow SAR) and 0 to 24 kHz (deep SAR) within a single event. Upper frequency bands above approximately 10 kHz were dominated by marine mammal vocalizations such as odontocete clicks and whistles, and low frequency bands were dominated by anthropogenic sounds such as vessels or equipment operations, and weather events (see Section 6.4.9 for more details).

Figure 5-6. Power spectral density plot of the monthly averaged one-third octave spectrum from the shallow static acoustic recorder (SAR).

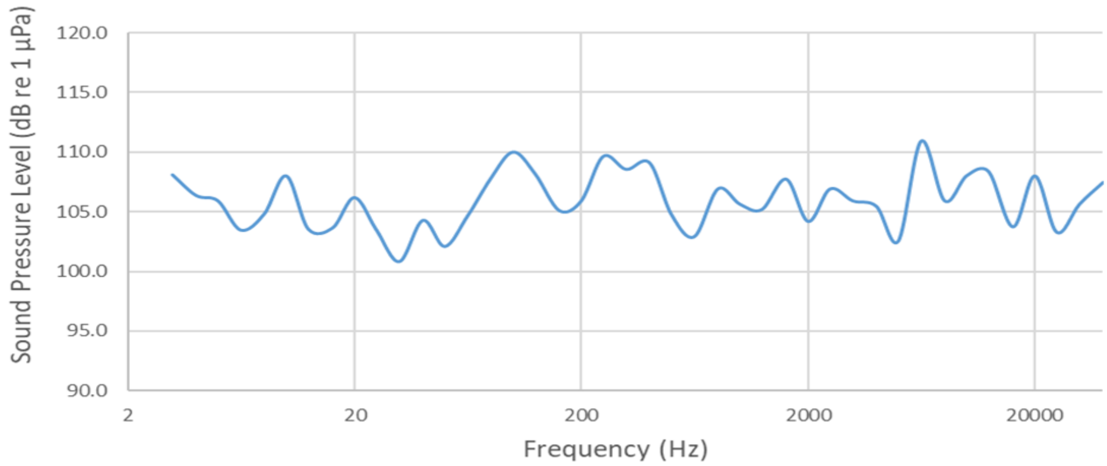
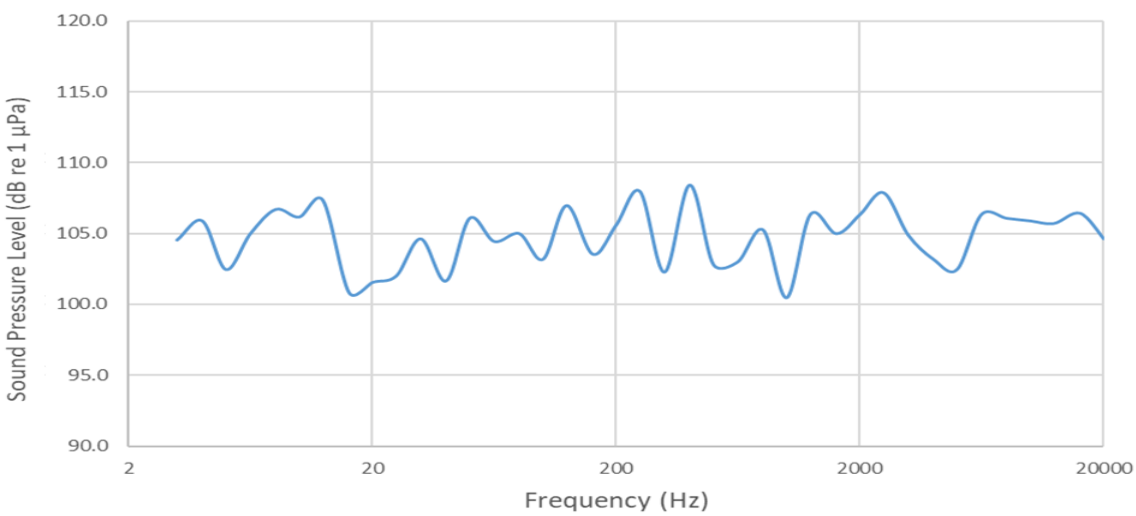


Figure 5-7. Power spectral density plot of the monthly averaged one-third octave spectrum from the shallow static acoustic recorder (SAR).



5.5.3.2 Drifting Hydrophone Deployments

These results are discussed further in the context of the biological baseline in Section 6.4.9.

5.6 Anthropogenic Light

NORI-D is located some 1,700 km from the nearest inhabited land mass, and the occurrence of artificial lighting within the upper water column is assumed to be absent, with the exception of occasional passing vessels.

Ambient light levels from SSVs will be measured as part of the ongoing baseline studies.

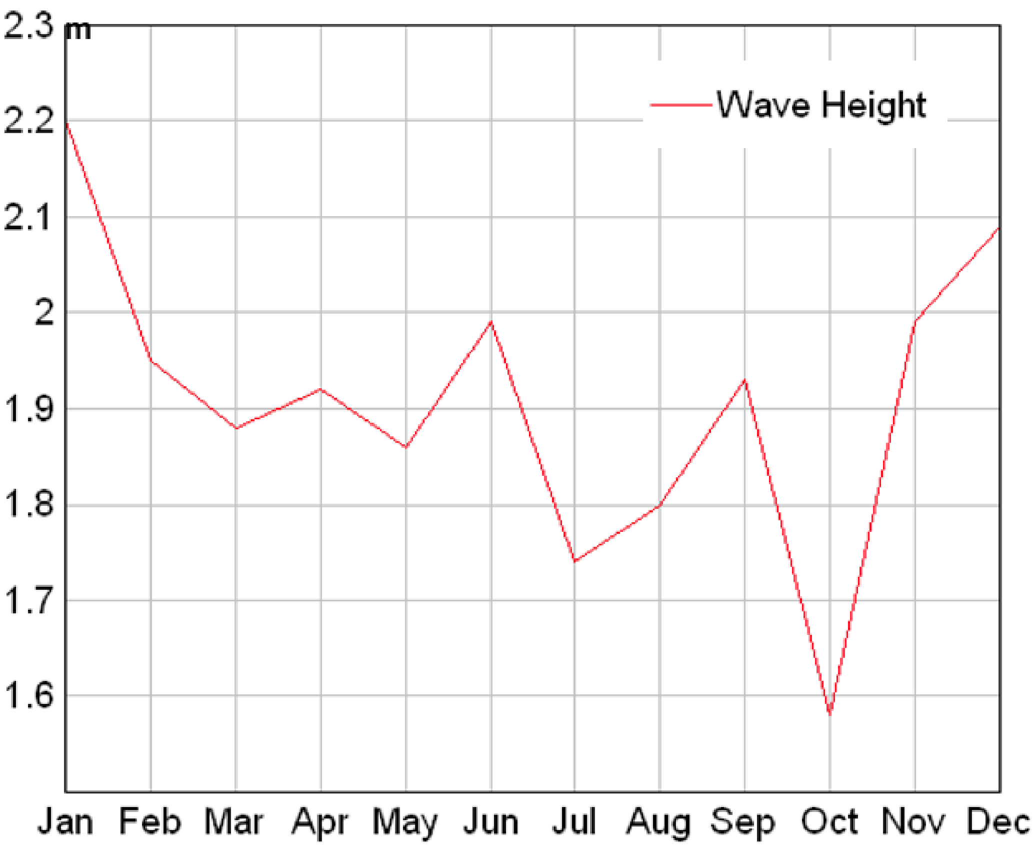
5.7 Waves

The CCZ is subject to South Pacific swells from winter storms. These storms produce swells from the south with long periods (14 to 22 s) and low amplitudes (approximately 1m) (BGR, 2019).

The region is dominated by northerly swells from November to March with largest amplitudes occurring in February. Smaller easterly and south-easterly swells occur from May. Waves generated by the north-eastern trade winds typically have periods of 5 s to 8 s with heights of 1m to 4m. Wave patterns tend to approach from the northeast, east or southeast (Dee *et al*, 2011).

Figure 5-8 shows the average monthly wave heights in the region. Highest waves occur in December and January, decreasing to lowest heights in October.

Figure 5-8. Average monthly wave heights in the CCZ



Source: Dee *et al.* (2011)

Six SOFAR spotter metocean buoys were deployed at NORI-D during Campaign 4A (2 - 23 October 2019) and two more were deployed during Campaign 4D (16 June – 15 July 2020) (Figure 5-9). These floating, free-drifting instruments recorded wind, wave and temperature data. Wind speeds of between 3.0 to 19 knots and wave heights from 1.3 to 2.8 m were recorded.

5.8 Tides

Tides in the CCZ are mixed semi-diurnal, that is, there are two uneven tidal cycles per day (Aleynik, 2017).

5.9 Ocean Currents

Upper ocean circulation within the CCZ is affected by trade winds and a system of large-scale currents (Demidova *et al.*, 1993). Wind-driven upper ocean circulation in the central Pacific Ocean undergoes substantial variation in response to the shifting of the major wind systems. The six SOFAR surface drifters deployed during Campaign 4A all initially drifted south-eastward to eastward across NORI-D, with times of calm periods (circular drifting) until late-October 2019 when they left the block boundary and drifted north-westward, with a net westerly displacement towards the central Pacific Ocean (Figure 5-9).

Collection of current information will continue through the deployment of additional SOFAR drifters as part of the ongoing baseline studies.

The eastern CCZ is influenced by the North Equatorial Current, with westward surface current speeds sometimes exceeding 20 cm/s. In boreal summers, surface currents weaken when the ITCZ and associated weak winds are further north.

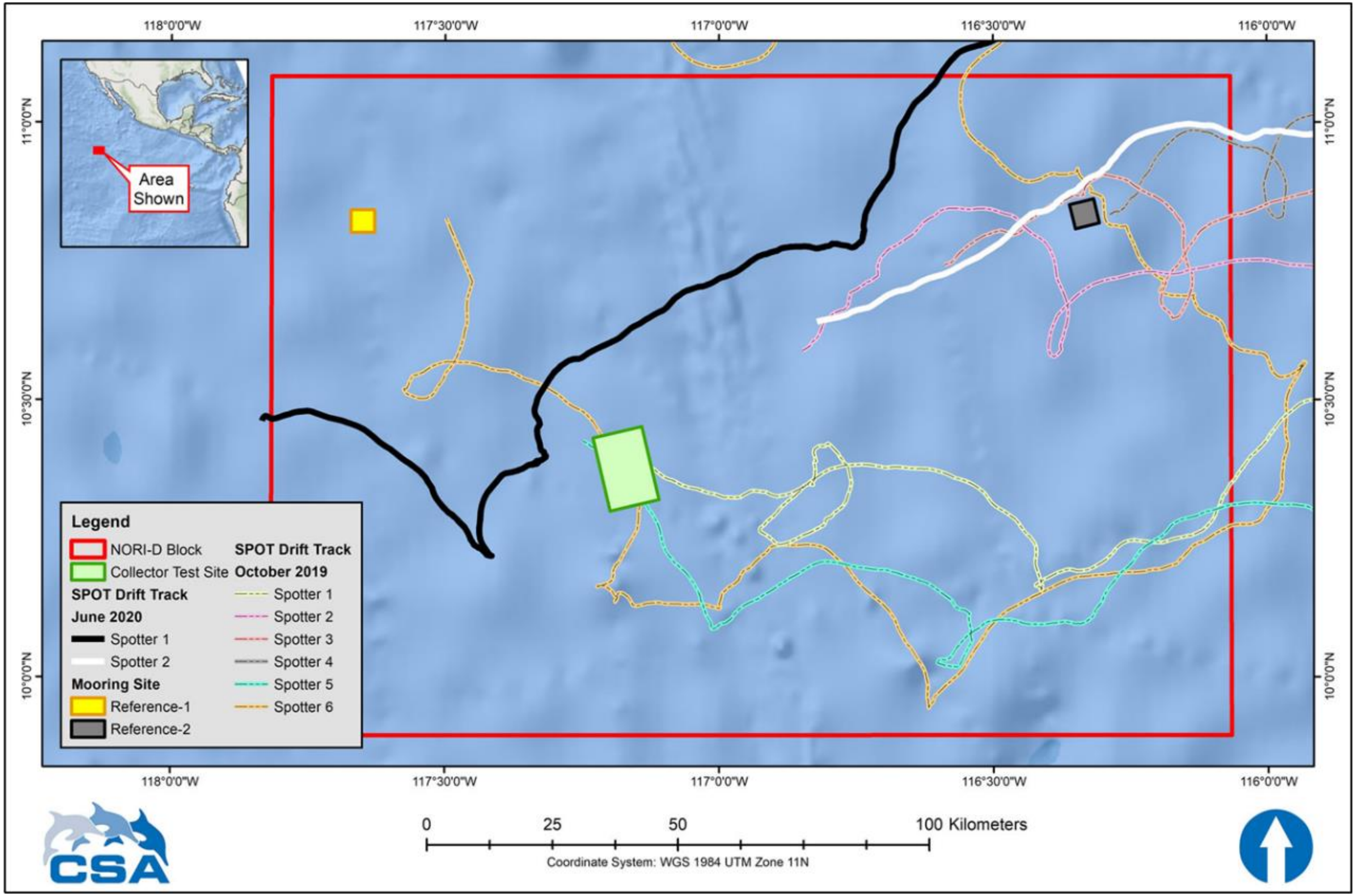
Currents in the mesopelagic zone continue the westward flow but slow their speed considerably in May and October. In the bathypelagic zone currents are reversed, flowing eastward from February to June and westward for the remainder of the year (BGR, 2019).

Morgan *et al.* (1999) collated benthic current data from several studies in the CCZ and describes the following three benthic current regimes occurring in the region:

- Calm periods, characterised by minimal current speeds (0 to 3 cm/s), moderate to low variance, and low tidal activity with time intervals lasting about 11 days.
- Intermediate, mostly inertial-tidal periods characterised by the alteration of current speed (0 to 5 or 6 cm/s) with a corresponding increase in the variance of data.
- Active periods, associated with an initial sharp increase in current speed, which can maintain relatively stable speeds to produce 24-hour means up to 8 cm/s and 1-hour means between 13 and 15 cm/s. These events are termed ‘benthic storms’, which are regular (but not periodic) increases in current speed lasting from about one or two weeks to five or six weeks.

Current data specific to NORI-D was collected with a mooring mounted Acoustic Doppler Current Profiler (ADCP) and Doppler Velocity Sensor (DVS). These data are discussed below.

Figure 5-9. Drift tracks of the SOFAR spotters deployed during Campaign 4A (October 2019) and Campaign 4D (June 2020) in NORI-D



5.10 Hydrographic Profiles

Baseline hydrographic profiles for NORI-D have been developed with data collected from the following sources:

- Three permanent oceanographic moorings deployed in the NORI-D lease since 2019. These were designed and equipped according to ISA guidelines and incorporated instrumentation capable of the in-situ measurement and recording of currents, hydrographic conditions, sound, and particle flux at multiple points throughout the water column.
- In situ hydrographic and current profiles and water quality sampling conducted by CSA at discrete depths within the water column at five sample sites on Campaigns 4A and 4E.
- In situ hydrographic profiles and water quality sampling conducted by UOH and TA&M at 11 sites distributed between the CTA and PRZ on Campaign 5B.

A summary of the techniques, methods and instrumentation used for each data collection effort is provided below. Details can be found in the appropriate source reports (CSA, 2019; 2020; 2022 and UOH, 2022).

5.10.1 Oceanographic Moorings

Three oceanographic moorings were deployed in NORI-D in October 2019, at the locations shown in Figure 5-3. The placement of the moorings was based upon the following criteria:

- Consideration of bathymetric features within NORI-D to ensure that the mooring design depth for scientific data collection is in accordance with ISA recommendations[4].
- Establish representative baseline conditions of the water column in proximity to the Collector Test site with minimal disturbance to the test site.
- Establish baseline conditions for reference areas within NORI-D to provide a comparative assessment of potential impacts to the water column by activities conducted at the Collector Test site.

Scientific instrumentation attached to the moorings included:

- Conductivity-temperature-depth (CTD), turbidity, transmissivity, and dissolved oxygen sensors.
- Acoustic Doppler Current Profilers (ADCP) and Doppler velocity samplers (DVS).
- Acoustic hydrophone (SAR).
- Sediment traps.
- Seafloor camera system.

Mooring instrumentation is detailed in Table 5-2.

[4] The type and placement of scientific instrumentation on the moorings is based upon, and compliant with, ISA recommendations for the assessment of the possible environmental impacts arising from exploration for polymetallic nodules (ISBA/16/LTC/7, ISBA/19/LTC/8).

Table 5-2. Mooring depths and equipment

ZONE	MOORING INSTRUMENTATION		
	LONG MOORING	REFERENCE 1	REFERENCE 2
Oceanic Layer	• (4,070-m-long mooring)	• (32-m-long mooring)	• (552-m-long mooring)
Epipelagic Zone (0 to 200 m depth)	• None	• None	• None
Mesopelagic Zone (200 to 1,000 m depth)	• RBR CTD • 2 x 75 kHz ADCP • SAR • SBE CTD	• None	• None
Bathypelagic Zone (1,000 to 4,000 m depth)	• 2 x 300 kHz ADCP • 2 x Sediment trap • 2 x DVS current meter • 2 x SBE CTD	• None	• Sediment trap
Abyssopelagic Zone to Seafloor (4,000 to 4,320 m depth)	• 150 kHz ADCP • 300 kHz ADCP • SAR • 2 x SBE CTD • 600 kHz ADCP • DVS Current Meter	• 150 kHz ADCP • 300 kHz ADCP • Sediment Trap • 2 x Turbidity sensor • 600 kHz ADCP • SBE CTD • Baited camera	• 150 kHz ADCP • 150 kHz ADCP • 300 kHz ADCP • 2 x Turbidity sensor • 600 kHz ADCP • SBE CTD • Baited camera

Source: CSA, 2022. ADCP = Acoustic Doppler Current Drofiler; CTD = conductivity-temperature-depth; DVS = Doppler velocity sensor; SAR = static acoustic recorder; SBE = Sea-Bird Electronics.

Mooring instruments were positioned to capture data throughout the water column, and with a focus on the following:

- Upper water column, where most marine mammals and marine traffic will occur.
- Mid-water zone, where discharge return water will occur.
- Near-seafloor zone, where collection activities will occur.

Sediment traps were positioned in accordance with ISA recommendations at depths >1,000 m and 500 m above the seafloor, and with an additional sediment trap attached to one mooring at a height of 17 m above the seafloor.

At the time of writing the following continuous mooring deployment periods have been conducted:

To date, there have been four deployments:

- Deployment Period 1: 14 October 2019 to 27 June 2020.
- Deployment Period 2: 28 June 2020 to 19 July 2021.
- Deployment Period 3: 20 July 2020 to 18 July 21.
- Deployment Period 4: 29 July 21 to Q2 2022

Details of mooring specifications can be found in the source reports (CSA, 2019; 2020; 2022)

5.10.2 In situ Sampling by CSA - Campaigns 4A, 4D and 4E

Water sample collection and Lowered Acoustic Doppler Current Profiling (LADCP) was conducted at four stations to develop hydrographic and current profiles. The profiling stations were located within the

Collector Test site, 20 km west of the Collector Test site, and at reference locations within the northeast and northwest corners of the block. Profiles were collected to a water depth of 4,000 m.

During Campaigns 4A and 4E water sample profiles were conducted at 16 depth intervals in the water column from 30 to 4,150 m. Water samples were tested for nutrients (TN; TP; PO_4; SiO_2), carbon (particulate and total inorganic), and suspended solids.

5.10.3 In situ Sampling by UOH & TA&M - Campaign 5B & 5D

Hydrographic profiles of temperature, salinity, dissolved oxygen, fluorescence and pH were measured with a regular CTD at 11 sample sites distributed between the CTA and PRZ during Campaigns 5B and 5D (Figure 5-10). Seawater samples collected using trace metal clean procedures established by the International GEOTRACES Program (Cutter & Bruland, 2012) were analysed for biologically-active elements such as oxygen, inorganic nutrients (nitrate, nitrite, phosphate, silicate), dissolved inorganic carbon (DIC), total alkalinity (TA), dissolved organic carbon (DOC), and the biologically essential trace elements in including iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nickel (Ni), and cobalt (Co).

5.11 Physical Oceanography

5.11.1 Oceanographic Moorings

The following section is a summary of the results from near-continuous long-term monitoring of hydrographic parameters as recorded by the CTDs mounted on the Long Mooring, and two reference moorings positioned within NORI-D. Measurements were continuously recorded from 14 October 2019 through 21 July 2021, with an approximately 1-to-2-day break between each campaign for mooring servicing. Values recoded from CTDs placed at a water depth of 1,999 m represent conditions at the that would be impacted by a return pipe discharge situated at 1,200m with a downward facing nozzle. Values recoded from CTDs at water depths greater than 4,195 m represent conditions less than 3.5 m above the seafloor.

5.11.1.1 Temperature

A near-continuous long-term record of temperatures recorded from the three moorings located within the NORI-D block is provided in Figure 5-11. Short-term temperature variations (i.e., days) were observed in records collected within water depths of 284 m (~0.5°C variation; Figure 5-11A) and 1,999 m (0.1°C variation; Figure 5-11B). Short-term temperature variations were not as apparent in deeper waters, with near-seafloor temperatures consistently stable at approximately 1.5°C (Figure 5-11D to F; Figure 5-12).

Evidence of seasonal temperature variation was observed within records collected within the upper half of the water column. At 1,999 m, the temperature decreased by 0.3°C between May and November in 2020, and a similar trend seems evident in the shorter-term 2019 and 2021 records (Figure 5-13).

5.11.1.2 Salinity

A near-continuous long-term record of salinities recorded from the three moorings located within NORI-D is provided in Figure 5-14. Salinity at all recorded depths throughout the deployment period remained steady at approximately 34.7 PSU. These results indicate uniformity and consistency in salinity values across NORI-D regardless of depth or location.

Figure 5-10. In situ sampling sites - UOH and TA&M during Campaigns 5B and 5D

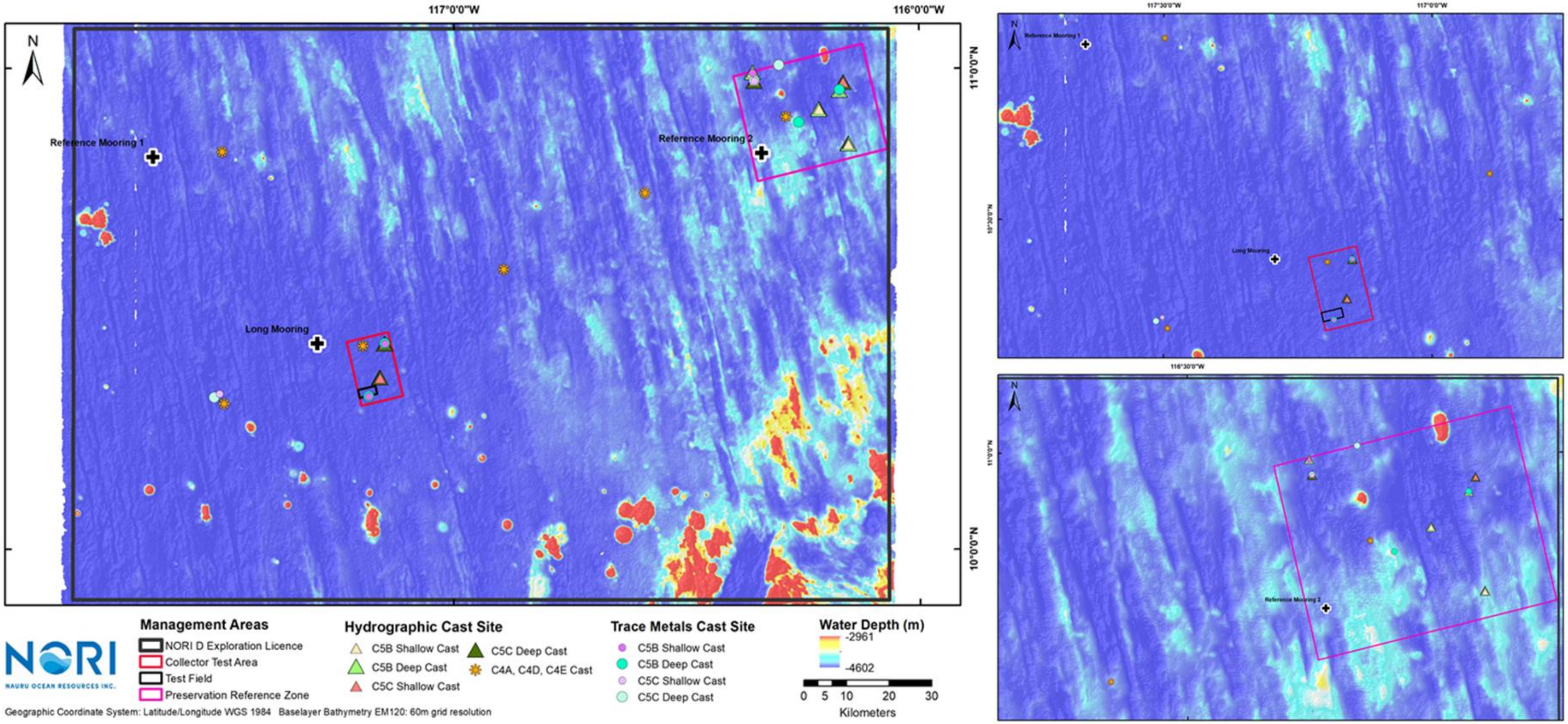


Figure 5-11. Near-continuous temperatures values (°C) at selected Long (A to D) and Reference (E to F) mooring conductivity-temperature-depth (CTD) instrumentation depths in the NORI-D block from October 2019 through July 2021. Note the difference in y-axis scales.

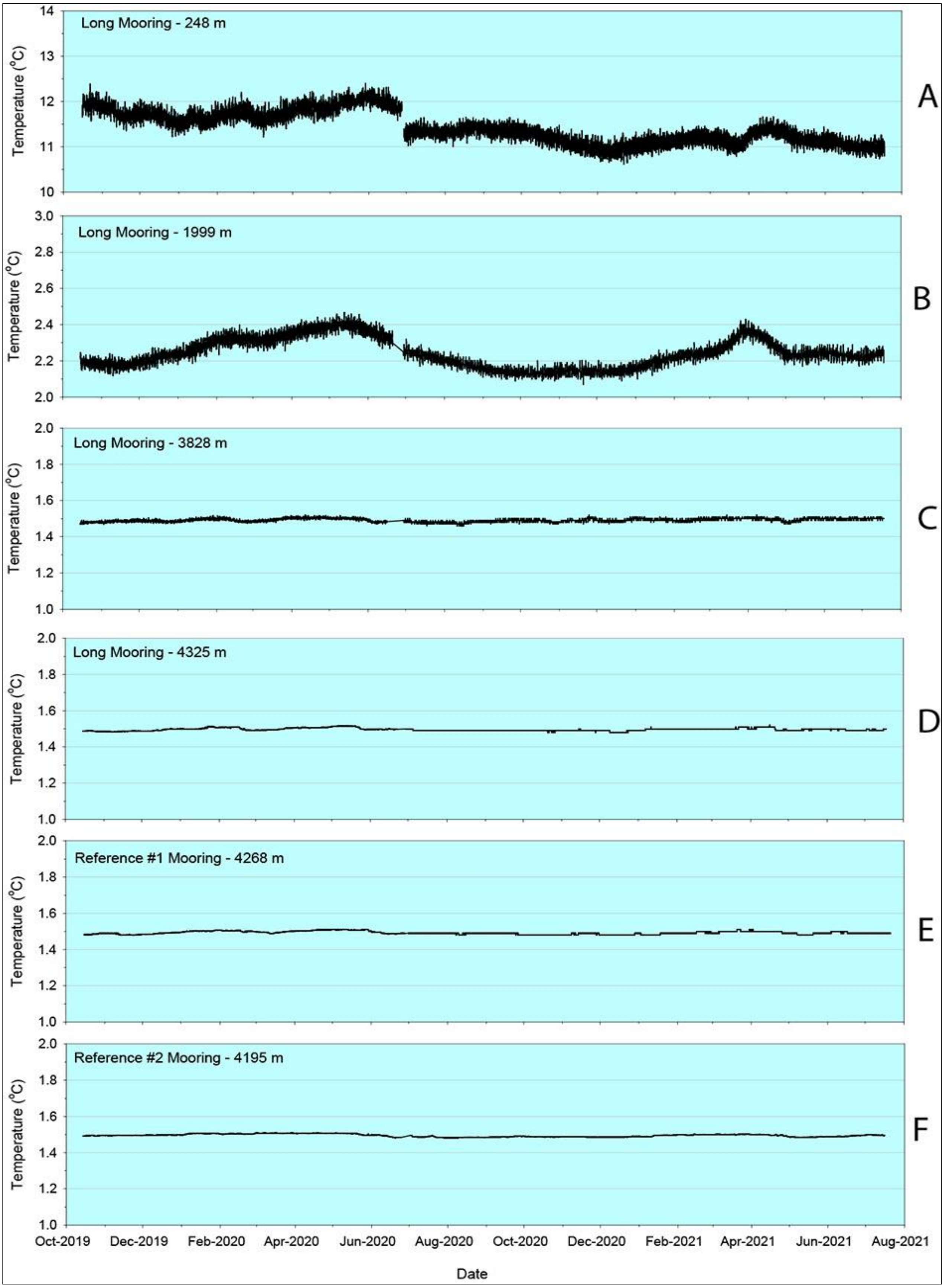


Figure 5-12. Near-continuous temperatures values (°C) near-seafloor (i.e., <3.5 m above seafloor) at the Long (red) and Reference (orange and brown) mooring stations from October 2019 through July 2021.

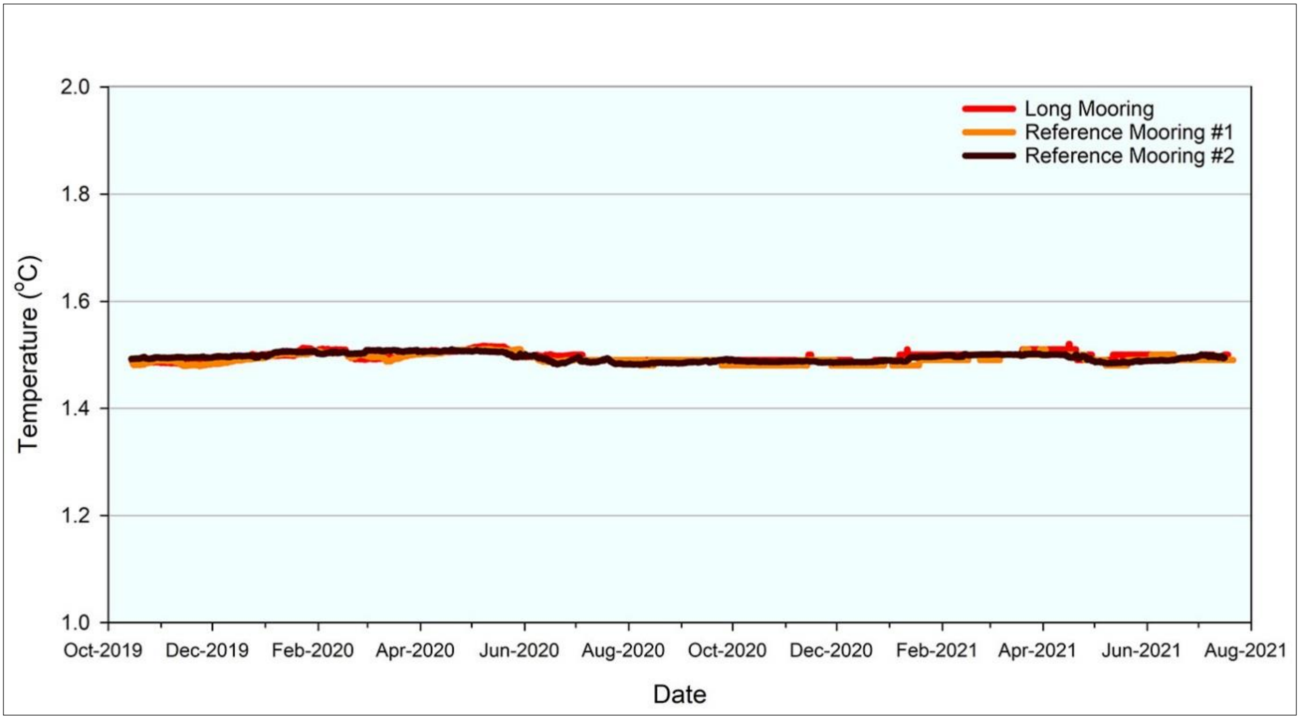


Figure 5-13. Running average of temperatures values (°C) by month at 2,000 m at the Long Mooring Site in the NORI-D block from October 2019 through July 2021.

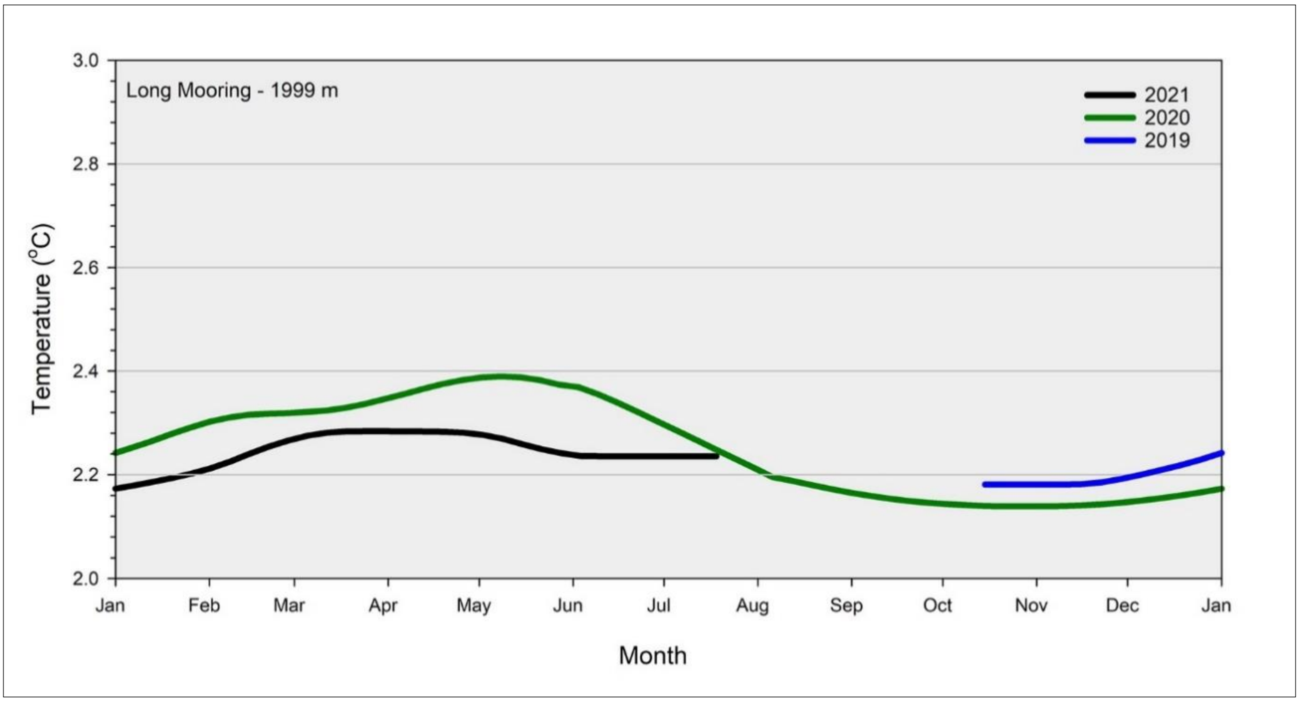
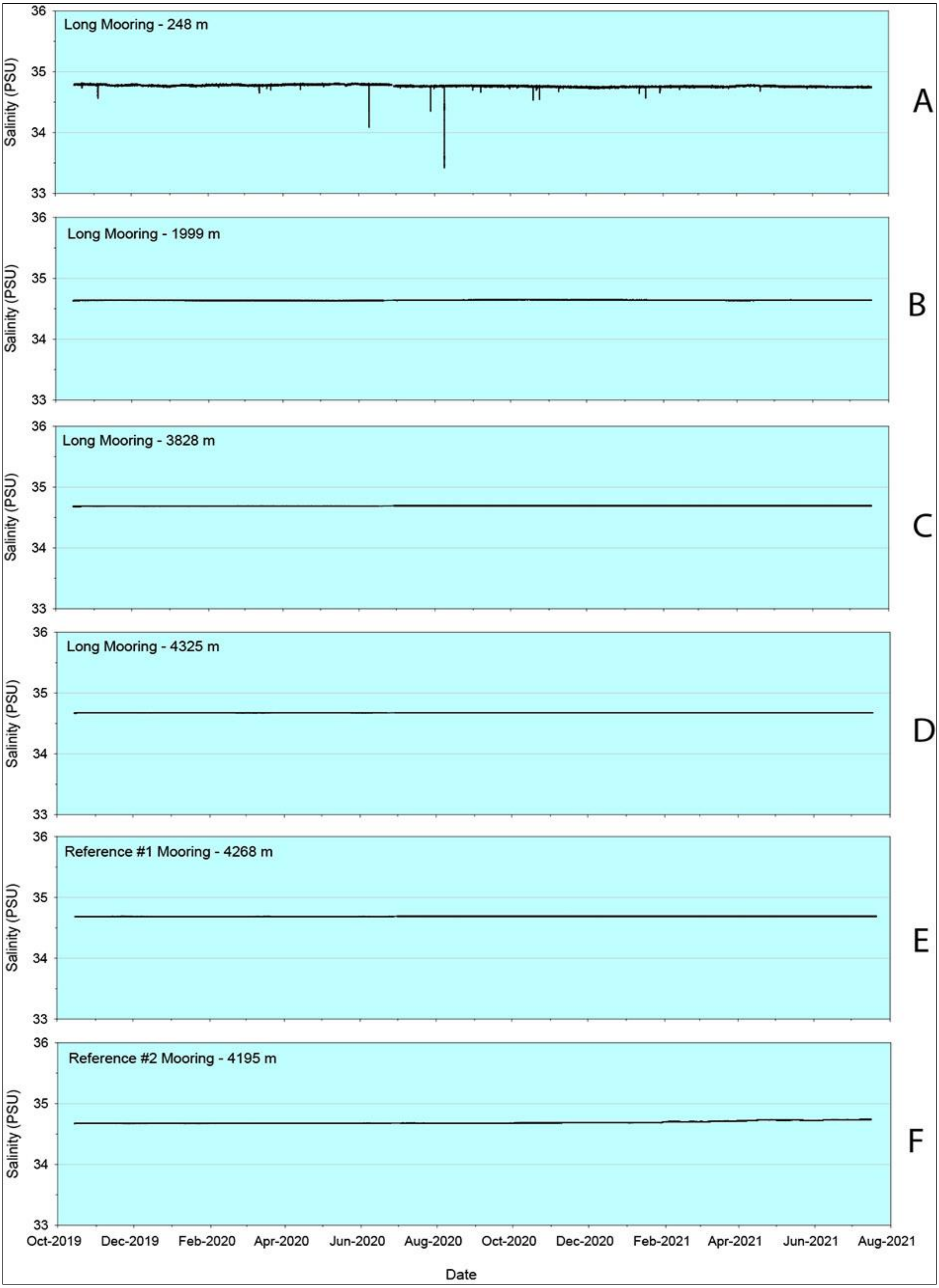


Figure 5-14. Near-continuous salinity values (PSU) at selected Long (A to D) and Reference (E to F) mooring conductivity-temperature-depth (CTD) instrumentation depths in the NORI-D block from October 2019 through July 2021.



5.11.1.3 Dissolved Oxygen

A near-continuous long-term record of dissolved oxygen concentrations recorded from the three moorings located within NORI-D is provided in Figure 5-15. The CTD located at a water depth of 516 m was firmly within the oxygen minimum zone, where dissolved oxygen concentrations did not exceed 0.2 mg L-1 (Figure 5-15). Dissolved oxygen concentrations at 1,999m ranged from 2.3 to 3.1 mg L-1 and typically had short-term (i.e., daily) variations of 0.1 mg L-1, with the exception of between November 2020 and March 2021 where the short-term variation increased to approximately 0.5 mg L-1 (Figure 5-15 B). Near-seafloor dissolved oxygen concentrations were consistently between 4.7 and 5.0 mg L-1 at all mooring locations (Figure 5-15D to F; Figure 5-16). It should be noted that in water depths >2,000 m it took the dissolved oxygen probe approximately 10 to 15 days to fully equalize to ambient concentrations after deployment of the moorings, as denoted by the sharp decrease in recorded dissolved oxygen concentrations during these periods (Figure 5-15D to F; Figure 5-16).

A pattern of long-term variability (i.e., seasonal) in dissolved oxygen concentrations at 1,999 m is not readily apparent (Figure 5-17). The 2020 data seems to indicate some seasonal trend of increasing dissolved oxygen concentrations between May and September, although this difference is only 0.3 mg L-1 and may be attributable to slight temperature changes at this water depth.

5.11.1.4 Turbidity

A near-continuous long-term record of turbidity values recorded from the three moorings located within NORI-D is provided in Figure 5-18. Turbidity through most of the water column rarely exceeded 0.2 NTU (i.e., 0.2 to 1 mg/L; using 1:1 to 1:5 conversion ratios (DOER, 2000)) (Figure 5-18A to C). Turbidity recorded near the seafloor was highly variable, with singular very short-term peaks (i.e., hours) exceeding 10 NTU (i.e., 10 – 50mg/L) near the seafloor at all mooring locations (Figure 5-18 D to F; Figure 5-19). A running median of turbidity values near the seafloor indicates median values generally ranged from 0.1 to 0.5 NTU (0.1 to 2.5 mg/L) for the majority of the deployment period (Figure 5-20). Increased turbidity values at the near seafloor during the short-term peaks are likely due to the occasional resuspension of sediments.

The mean turbidity values are in the order of 0.17NTU (0.2 to 0.9 mg/L) across the 3 instruments, with a standard deviation of 0.13NTU (0.1 to 0.6 mg/L). With an observed relatively high standard deviation in the Turbidity data, it is reasonable to conclude that the biological receptors are unlikely to be sensitive to incremental concentrations less than 0.1mg/l.

Figure 5-15. Near-continuous dissolved oxygen values (mg L-1) at selected Long (A to D) and Reference (E to F) mooring conductivity-temperature-depth (CTD) instrumentation depths in the NORI D block from October 2019 through July 2021. Note the difference in y-axis scales.

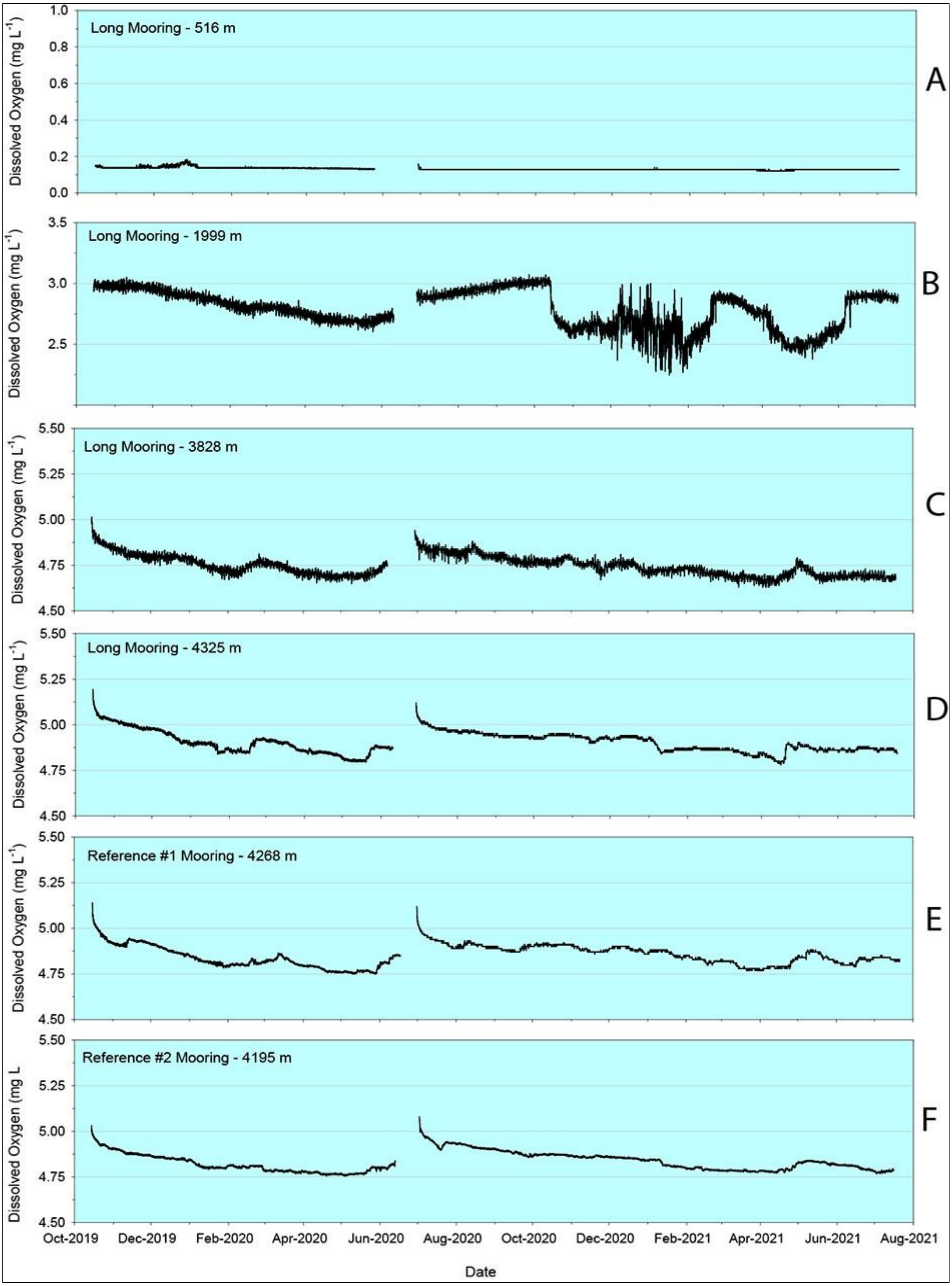


Figure 5-16. Near-continuous dissolved oxygen values (mg L-1) near-seafloor (i.e., <3.5 m above seafloor) at the Long (red) and Reference (orange and brown) mooring stations from October 2019 through July 2021.

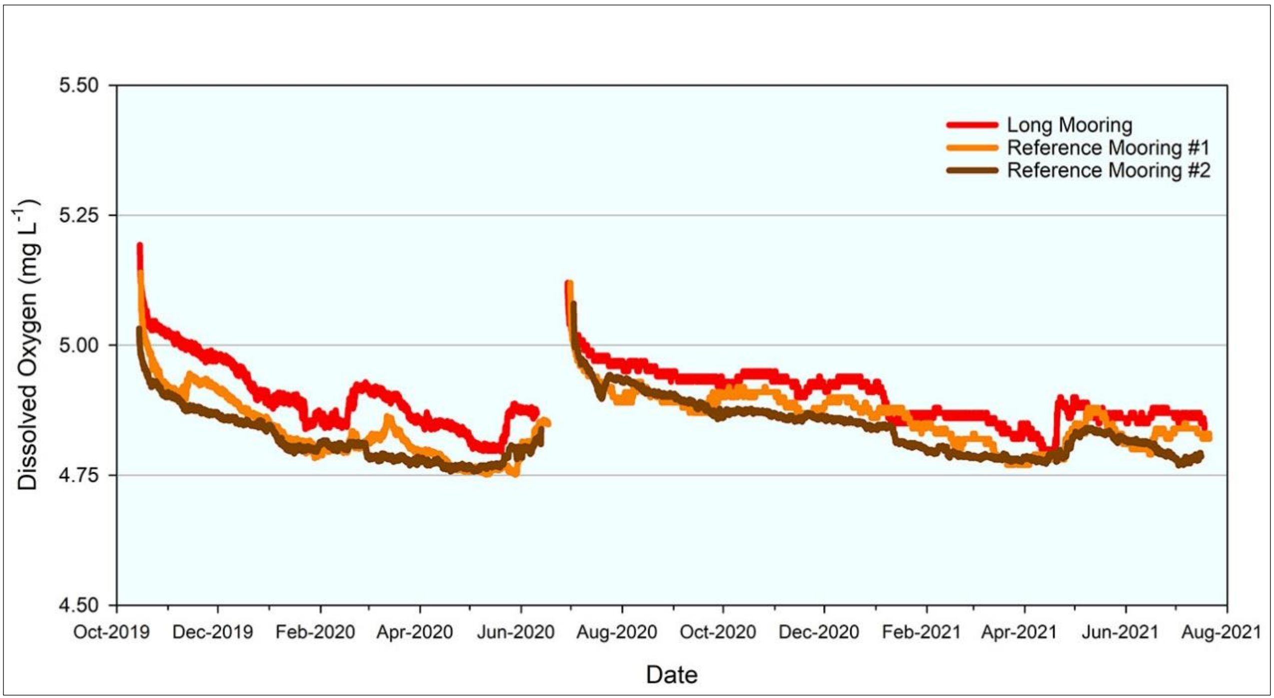


Figure 5-17. Running average of dissolved oxygen concentration values (mg L-1) by month at the proposed discharge water depth (~2,000 m) at the Long Mooring Site in the NORI-D block from October 2019 through July 2021.

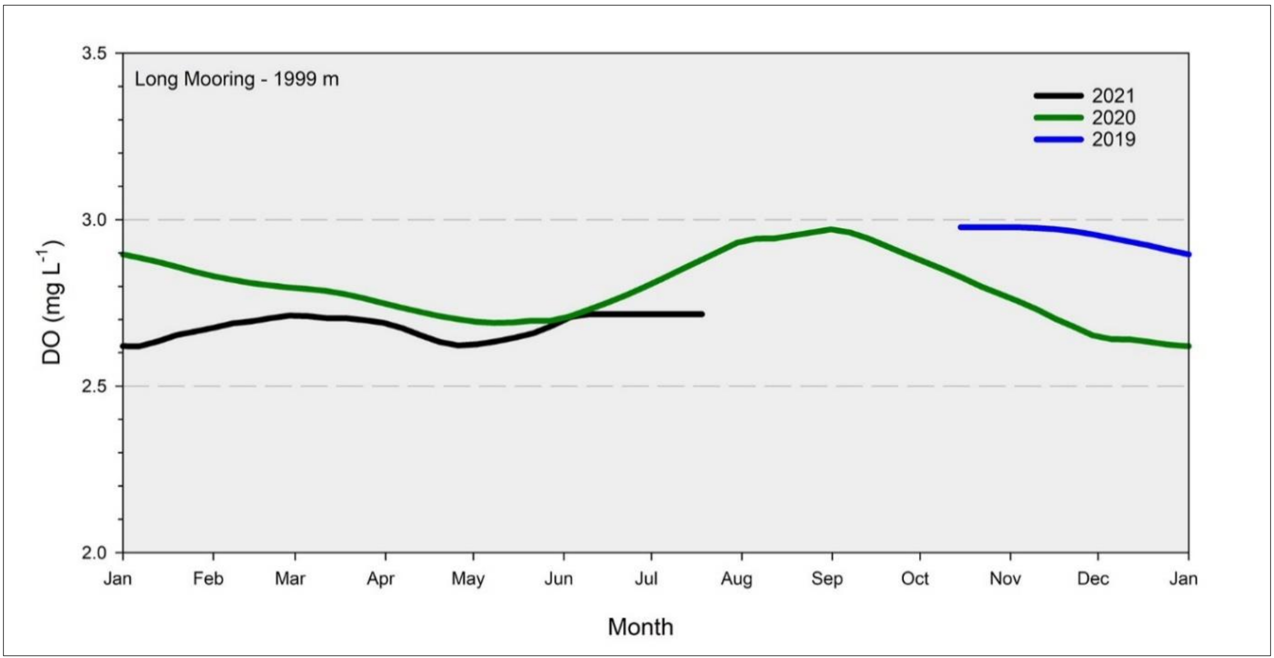


Figure 5-18. Near-continuous turbidity values (NTU) at selected Long (A to D) and Reference (E to F) mooring conductivity-temperature-depth (CTD) instrumentation depths in the NORI-D block from October 2019 through July 2021.

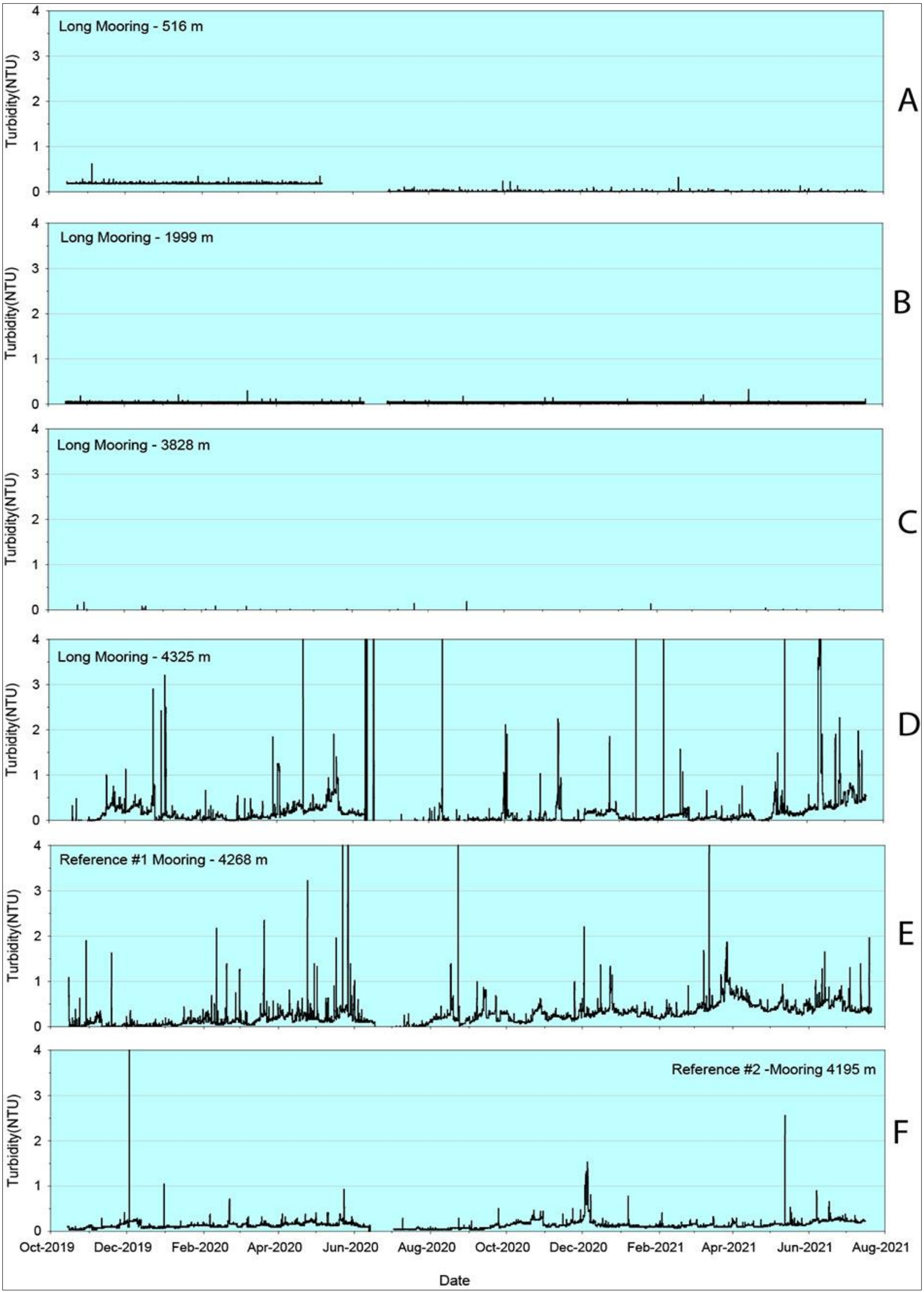


Figure 5-19. Near-continuous turbidity values (NTU) near-seafloor (i.e., <3.5 m above seafloor) with y axis showing the maximum values at the Long (red) and Reference (orange and brown) mooring stations from October 2019 through July 2021.

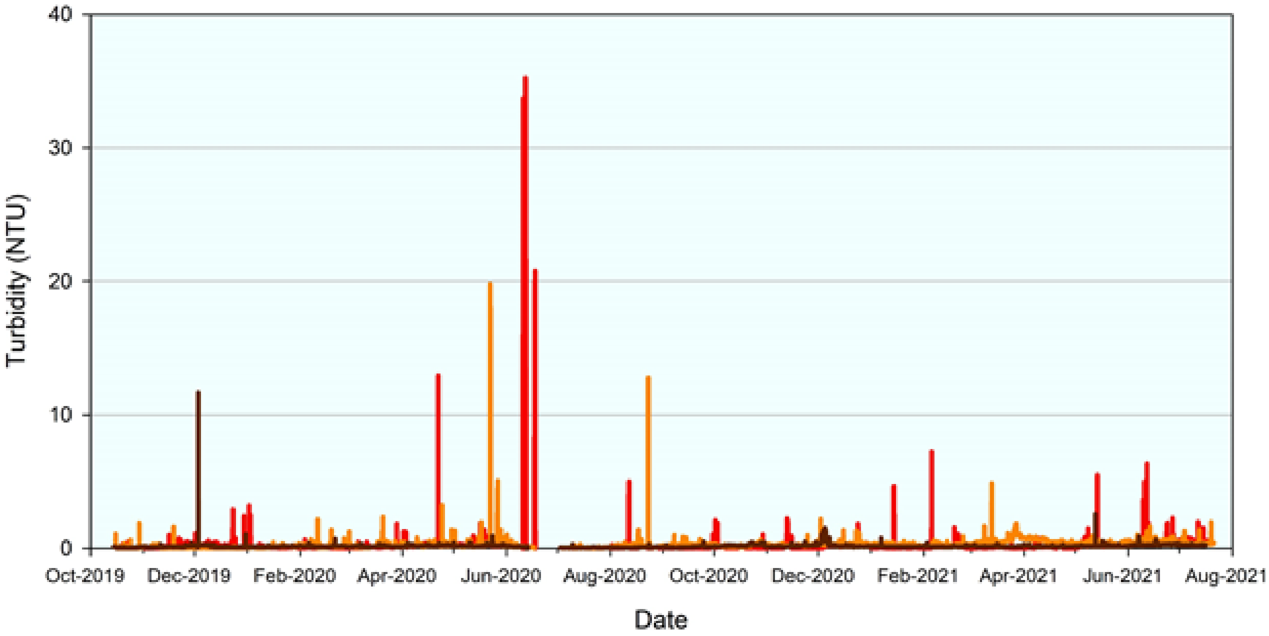
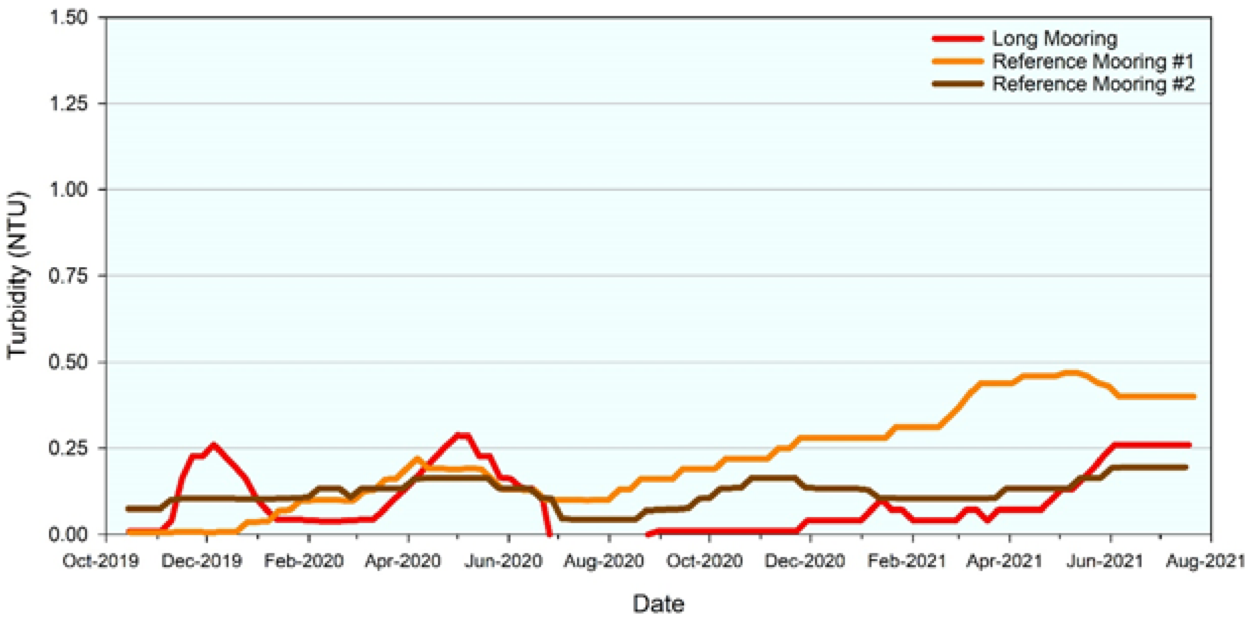


Figure 5-20. Running median of near-seafloor (i.e., <3.5 m above seafloor) turbidity values (NTU) at the Long (red) and Reference (orange and brown) mooring stations from October 2019 through July 2021.



5.11.1.5 Long-Term Acoustic Doppler Current Profiler Parameters

The following sections summarize the results from near-continuous long-term monitoring of current parameters as recorded by the ADCPs mounted on the Long Mooring positioned near the test collector site. Results from ADCPs located at 1,999m and near the seafloor are provided. Measurements were continuously recorded between initial deployment during Campaign 4A through recovery during Campaign 4E.

(a) Current speed and direction at 2,000 m

The data from bin #4 of the 300 kHz upward-looking ADCP, representing a water depth of approximately 2000 m, was assessed for current speed and direction over the duration of the Long Mooring deployment between 15 October 2019 and 2 June 2021. Over the course of the full mooring deployment, current speeds at the proposed discharge depth averaged 2.6 ± 1.4 cm s-1. The highest average current speeds were recorded in July (3.6 ± 1.9 cm s-1) and the lowest average current speeds (~2.3 cm s-1) were recorded from September through November (Figure 5-21).

Average current speeds were frequently higher in July, where 30% of recordings measured current speeds between 3.6 and 5.7 cm s-1 (Figure 5-22). Conversely, average current speeds were frequently lower in October, where 47% of recordings measured current speeds between 0.0 and 2.1 cm s-1.

Current direction at 2,000m generally flowed towards the southwest over the course of the full mooring deployment (Figure 5-23). However current direction did vary monthly, sometimes trending northwest (January) or northeast (March) (Figure 5-24).

Figure 5-21. Average (± standard deviation) current speeds (cm s-1) recorded at 2,000m depth from bin #4 of the upward-looking acoustic Doppler current profiler (ADCP) (300 kHz) on the Long Mooring between 15 October 2019 and 2 June 2021.

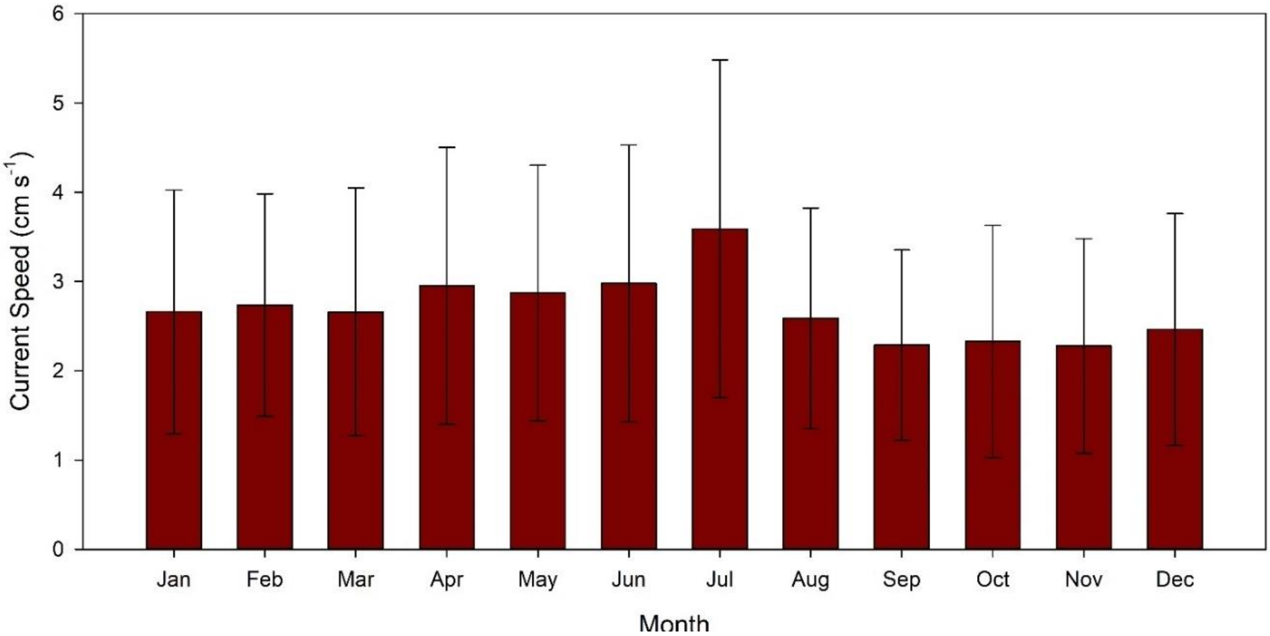


Figure 5-22. Average frequency (%) by current speed class (cm s-1) recorded from bin #4 of the upward-looking acoustic Doppler current profiler (ADCP) (300 kHz) on the Long Mooring between 15 October 2019 and 2 June 2021.

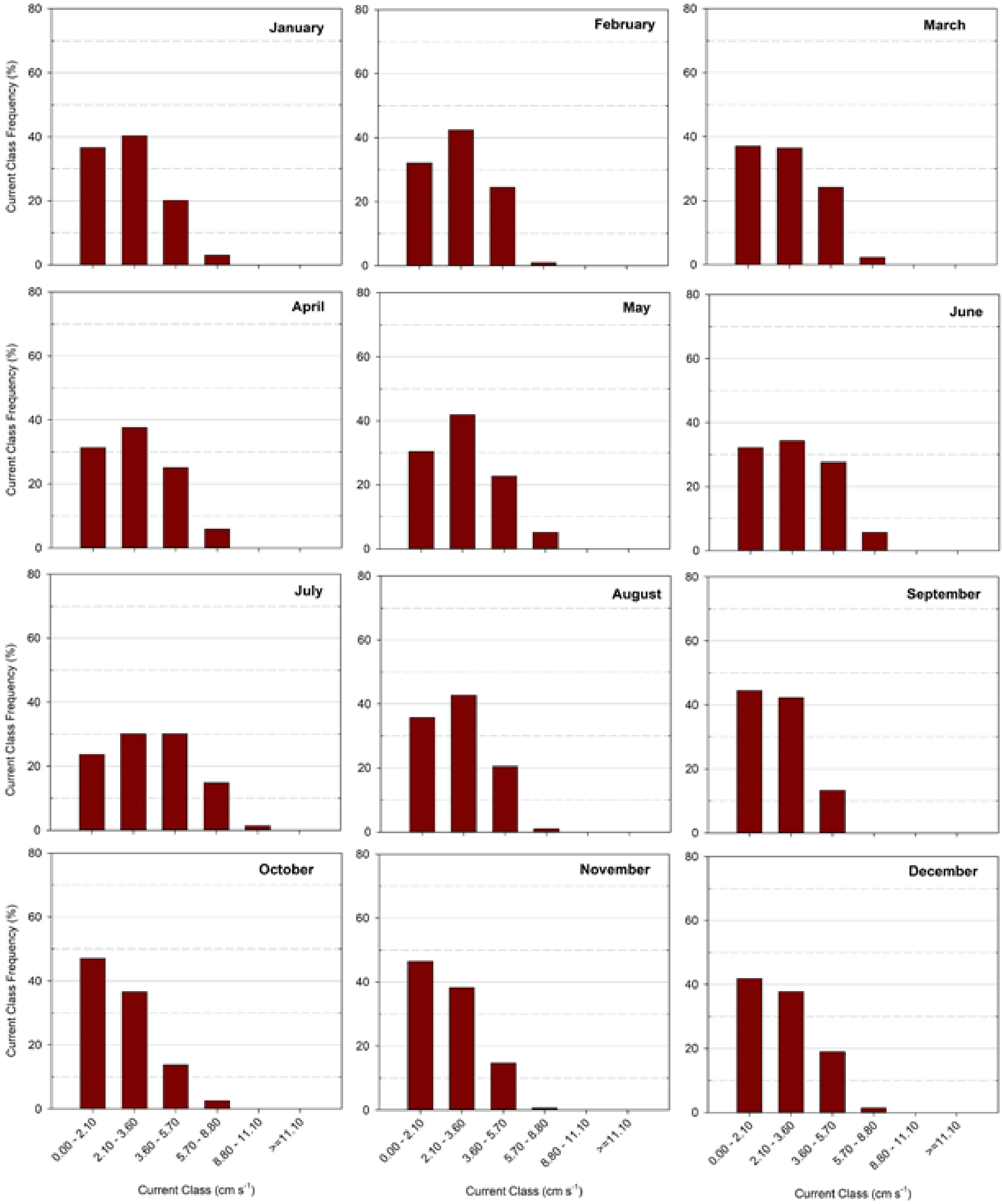


Figure 5-23. Near-continuous record of current speeds (cm s-1) and direction (flowing towards) recorded from bin #4 of upward-looking acoustic Doppler current profiler (ADCP) (300 kHz) at 2,000 m on the Long Mooring between 15 October 2019 and 2 June 2021.

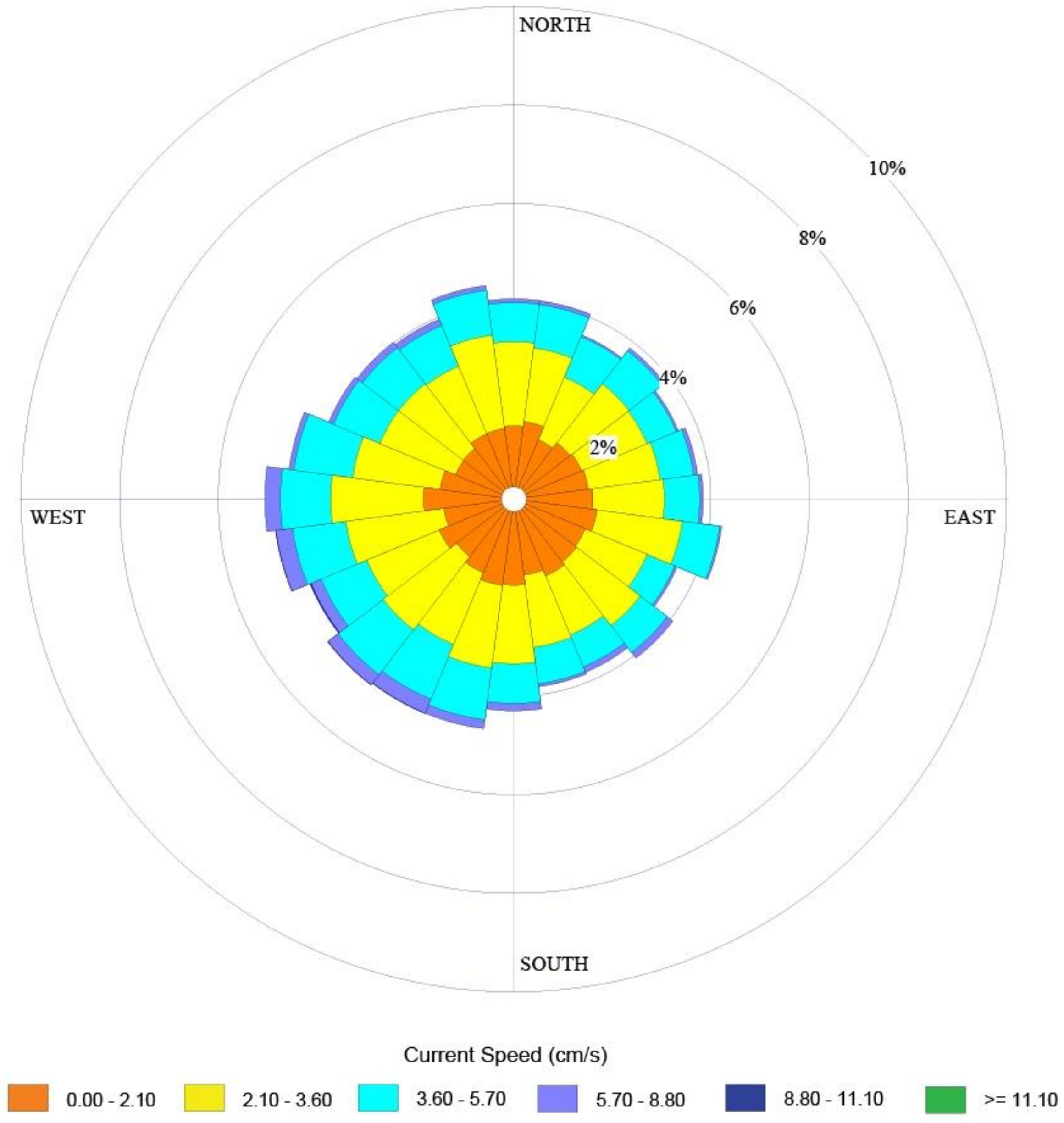


Figure 5-24. Monthly current rose direction (flowing towards) and speed (cm s-1) plot recorded from bin #4 of upward-looking acoustic Doppler current profiler (ADCP) (300 kHz) at 2,000 m on the Long Mooring between 15 October 2019 and 2 June 2021.

(b) Current speed and direction near seafloor (4,321 m water depth/5 m above seafloor)

The data from bin #4 of the 600 kHz downward-looking ADCP, representing a water depth of 4,321 m, was assessed for current speed and direction over the duration of the Long Mooring deployment between 15 October 2019 and 24 April 2021. The results from this water depth summarize current parameters at approximately 5 m off the seafloor. Over the course of the full mooring deployment, current speeds near the seafloor averaged 2.6 ± 1.6 cm s-1. The highest average current speeds were recorded in June (3.8 ± 1.6 cm s-1) and the lowest average current speeds were recorded in October (2.5 ± 1.3 cm s-1) (Figure 5-25).

Average current speeds were frequently higher in June where 41% of recordings measured current speeds between 3.6 and 5.7 cm s-1 (Figure 5-26). Conversely, average current speeds were frequently lower in April where 41% of recordings measured current speeds between 0.0 and 2.1 cm s-1.

Current direction at the near seafloor generally flowed towards the northwest over the course of the full mooring deployment (Figure 5-28). However current direction did vary monthly, sometimes trending northeast (March) or south (June) (Figure 5-28).

Figure 5-25. Average (± standard deviation) current speeds (cm s-1) recorded from bin #4 of the downward-looking acoustic Doppler current profiler (ADCP) (600 kHz) at 4,321 m water depth (i.e., 5 m above the seafloor) on the Long Mooring between 15 October 2019 and 24 April 2021.

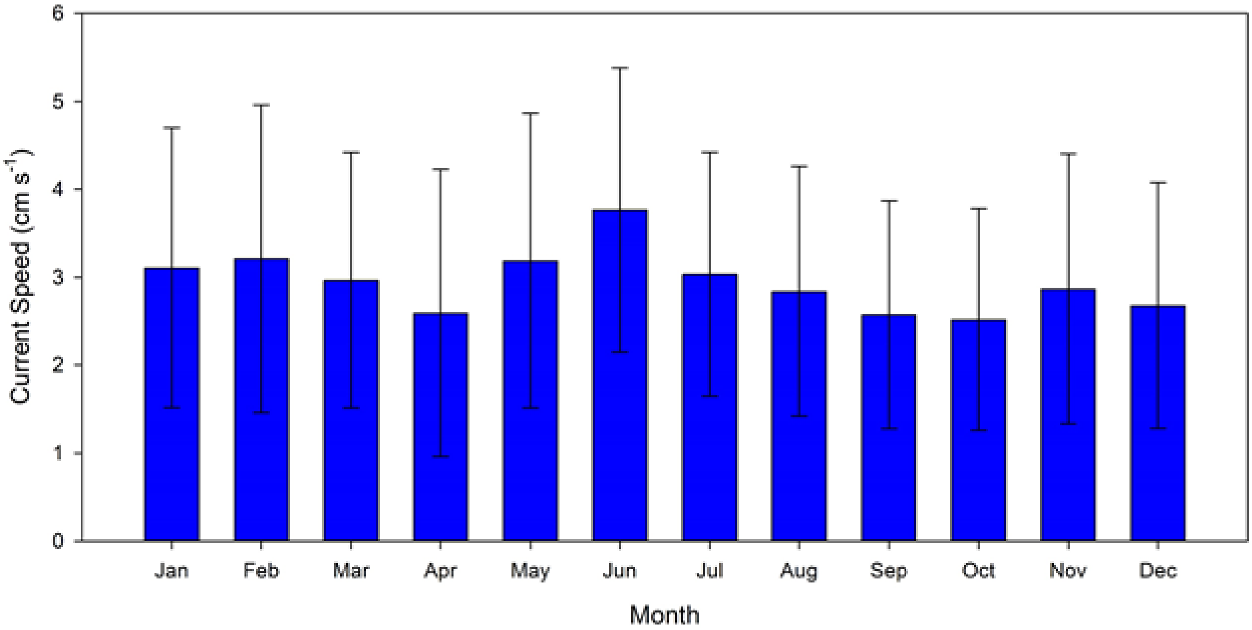


Figure 5-26. Average frequency (%) by current speed class (cm s-1) recorded from bin #4 of the downward-looking acoustic Doppler current profiler (ADCP) (600 kHz) at 4,321 m water depth (i.e., 5 m above the seafloor) on the Long Mooring between 15 October 2019 and 24 April 2021.

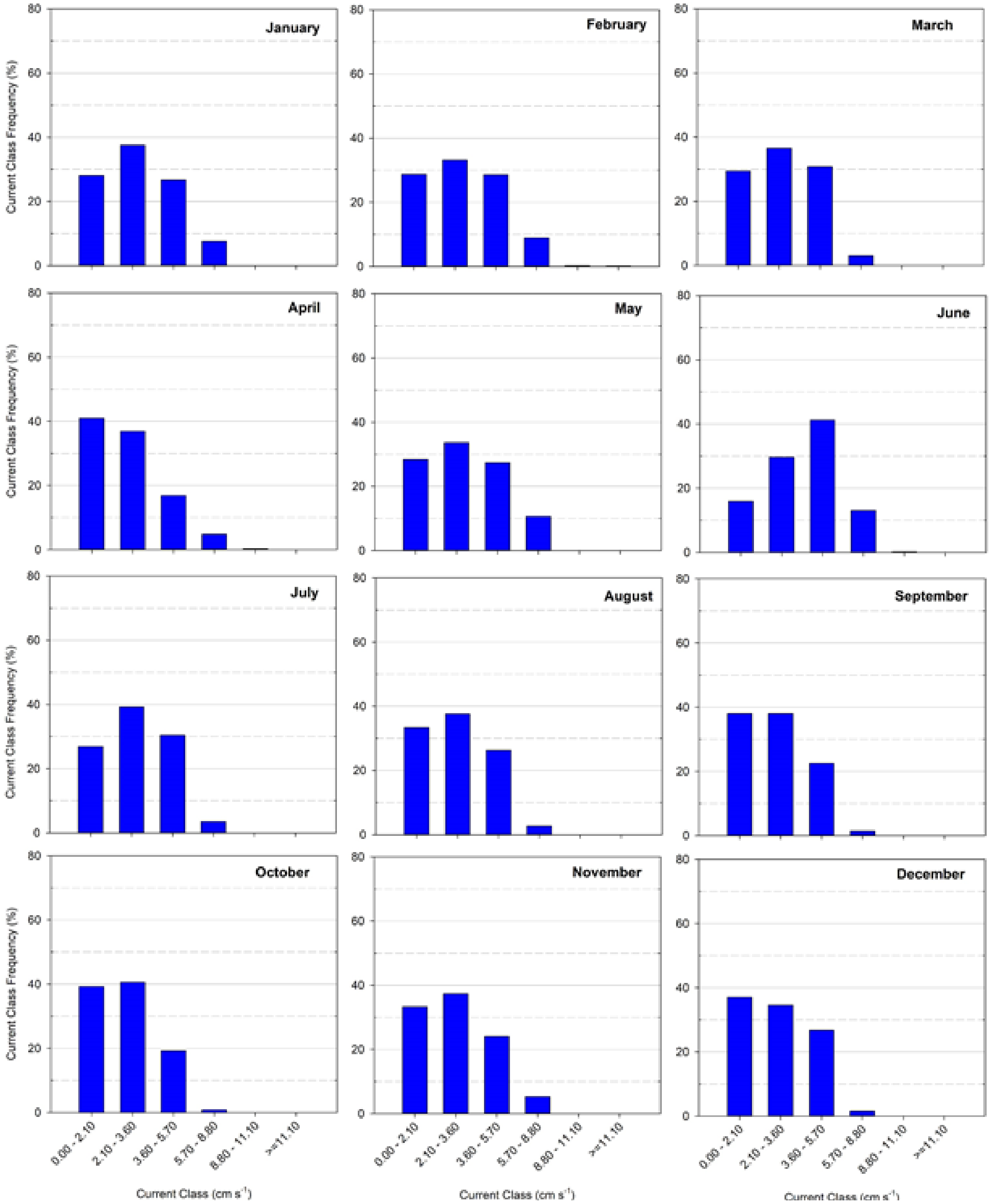


Figure 5-27. Near-continuous record of current speeds (cm s-1) and direction (flowing towards) recorded from bin #4 of the downward looking Acoustic Doppler Current Profiler (ADCP) (600 kHz) at 4,321 m water depth (i.e., 5 m above the seafloor) on the Long Mooring.

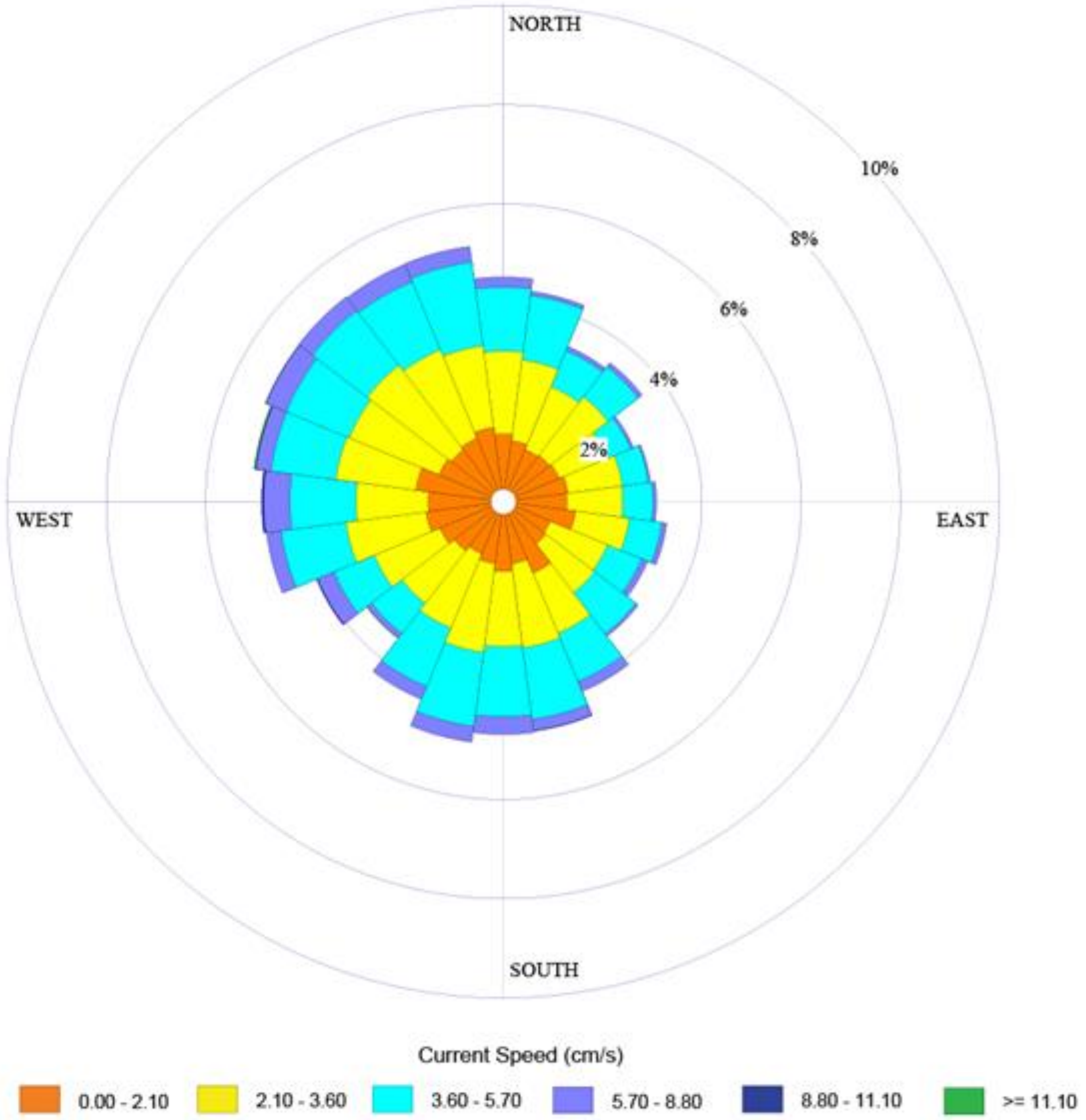
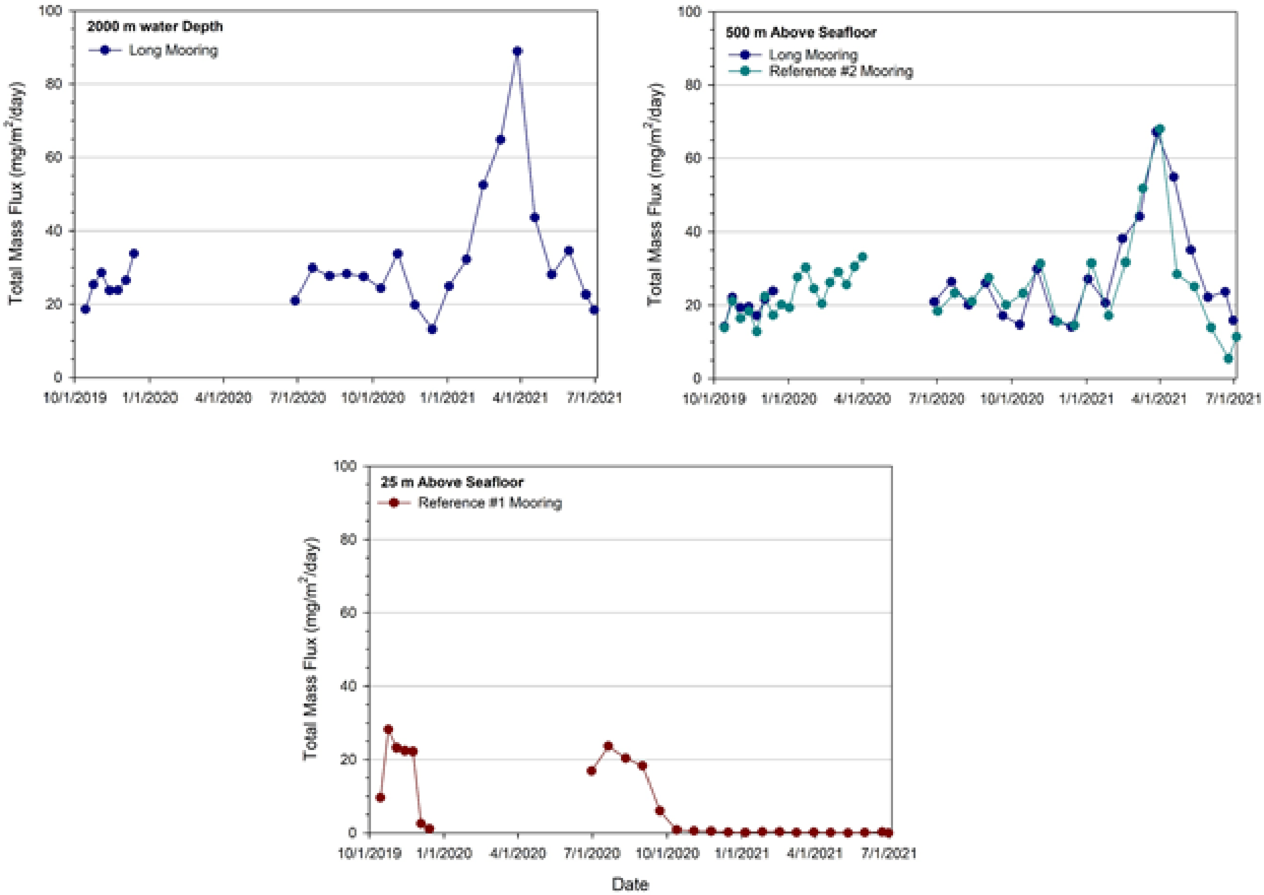


Figure 5-28. Monthly current rose direction (flowing towards) and speed (cm s-1) plot recorded from bin #4 of the downward-looking Acoustic Doppler Current Profiler (ADCP) (600 kHz) at 4,321 m water depth. (i.e., 5 m above the seafloor) on the Long Mooring between 15 October 2019 and 24 April 2021.

5.11.1.6 Sediment Traps

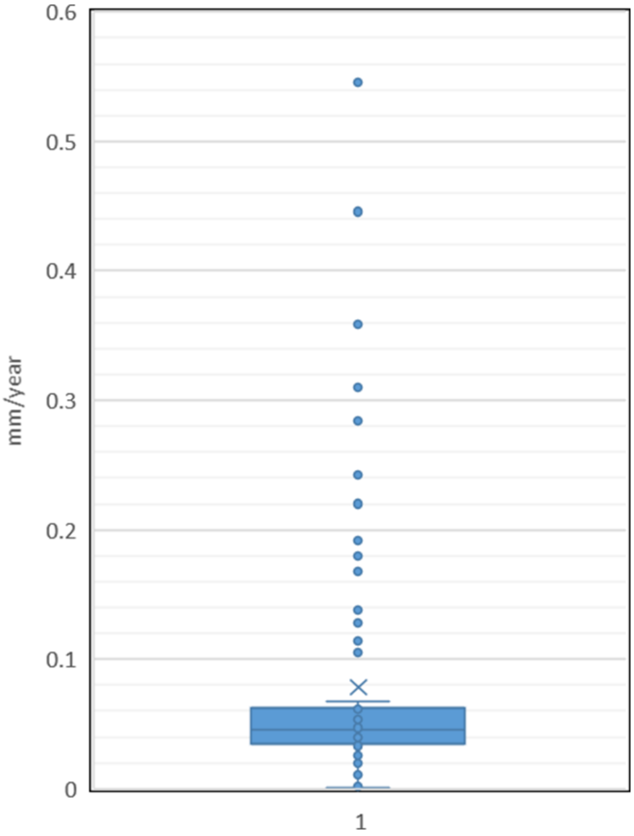
Total mass flux values and trends were similar among the sediment traps located in a water depth of 2,000 m at the Long Mooring Site and those located 500 m above the seafloor (~3,800 m water depth) at both the Long Mooring and Reference #2 Mooring Sites (Figure 5-29). Maximum flux values were recorded in late-March/early-April 2021 (Figure 5-29). Total mass flux values were variable at the sediment trap located 25 m above the seafloor at the Reference #1 Mooring site. At this location the highest values were recorded for up to 2 months after mooring deployment and negligible values recorded for the rest of the deployment period (Figure 5-29 bottom).

Figure 5-29. Total mass flux (mg m-2 day-1) at sediment traps located in a water depth of 2,000 m (top), 500 m above the seafloor (middle), and 25 m above the seafloor (bottom) at the Long Mooring, Reference Mooring #2, and Reference Mooring #1 Sites within the NORI-D.



77 valid sediment trap data sets are available from the near bed zone over the period October 2019 to June 2022 from which a deposition density of 180kg/m^3 is estimated. This yields background sedimentation rates with mean of 0.08mm/year with a standard deviation of 0.09mm/year. The full data set is presented in Figure 5-30. It is apparent from Figure 5-30 that the sedimentation rate is characterised by persistent low sedimentation rates with a median in the order of 0.05mm/year, but with a number of high sedimentation events, with the highest event 5 standard deviations above the mean.

Figure 5-30. Near bed sediment trap data from NORI-D area, October 2019 to June 2021 converted to sedimentation rate based on a density of 180kg/m^3



The measured mean background sedimentation rate from sediment traps from NORI-D of 0.08mm/year should be compared to literature values in the CCFZ (Volza *et al.* 2018) in the order of 0.2 and 1.15cm/k-year (0.002 to 0.011mm/year) based upon radioisotope analysis techniques. At face value the radioisotope analysis techniques indicate a natural sedimentation rate an order of magnitude lower than predicted from the sediment trap data. However, it is noted that the sampling presented in Volza *et al* 2018 commences from a core depth of 7.5cm and as such should not be considered representative of fresh deposits, rather deposits after several 1000 years of consolidation. Further, based upon the variability in the Turbidity data presented in Section 5.11.1.4, there is indication of re-suspension events in the NORI-D area. Consequently, although long-term sedimentation may be in the order of 0.1mm/year or lower (DHI, 2022), short term sedimentation and thereby adaptation of the biological system is most likely best described by the sediment trap data from the NORI-D area.

5.11.2 In situ Sampling by CSA - Campaigns 4A, 4D and 4E

Hydrographic profiles developed from the analysis of samples collected to a water depth of 4,200 m during Campaign 4A – Oct'19, Campaign 4D – Jun'20, and Campaign 4E – Jul'21 are discussed below.

5.11.2.1 Temperature

Seawater temperatures were typical of conditions for deep water systems in the tropical Pacific Ocean. Surface waters were warm (~29°C) but dropped sharply (~15°C) through the first 100 m of the water column. Seawater temperatures gradually decreased from 15°C to 2°C through the next 2,000 m, and then remained relatively stable and cold (1.5°C to 2°C) through the remainder of the measured water column (Figure 5-31A). Temperatures throughout the water column were similar among the October 2019, June 2020, and July 2021 surveys (Figure 5-31A).

5.11.2.2 Salinity

Salinity within the water column ranged from approximately 33.5 psu in surface waters to 34.5 psu at the seafloor, with a halocline occurring within the top 100 m of the water column. The maximum salinity (~35.2 psu) occurred at approximately 100 m and then generally decreased and stabilized through the remainder of the measured water column (Figure 5-31B). Salinities throughout the water column were similar among the October 2019, June 2020, and July 2021 surveys (Figure 5-31B).

5.11.2.3 Dissolved Oxygen

Dissolved oxygen concentrations were highest in the surface waters and then decreased rapidly through the first 100 m of the water column. Dissolved oxygen concentrations are less than 2 mg L-1 within water depths between 80 and 1,500 m. Within the oxygen minimum zone oxygen concentrations are extremely low (i.e., 0.0 to 0.5 mg L-1) between water depths of 300 to 700 m. Below water depths of 1,500 m, the dissolved oxygen concentration gradually increases to approximately 4.5 mg L-1 to near the seafloor (Figure 5-32A). Dissolved oxygen concentrations throughout the water column were similar among the October 2019, June 2020, and July 2021 surveys (Figure 5-32A). The oxygen reduction potential is generally uniform through the water column within the Nori-D block with slight variation between surveys (Figure 5-32B).

5.11.2.4 Turbidity

Turbidity (Figure 5-33A) and transmissivity (Figure 5-33B) were fairly constant through the water column from the surface to the seafloor during all surveys. Turbidity values were slightly higher in the upper 200 m of the water column in June 2020 when compared to measurements conducted in October 2019 and July 2021 (Figure 5-33A). Both measurements indicate that there is little particle suspension within the water column, which is typical for open ocean systems far from terrigenous inputs or upwelling regions.

5.11.2.5 Fluorescence

Fluorescence measurements across the NORI-D block indicate that the deep chlorophyll maximum is found at a water depth of between 40 and 50 m (Figure 5-34A), which coincides with a photosynthetically active radiation transmittance of between 4% to 5% and the border of the oxygen minimum zone within the region (Figure 5-35A). Fluorescence measurements ranged from 0.1 to 0.8 mg m-3 in surface waters, then rapidly decreased with depth to 0.1 mg m-3 just below 125 m through the remainder of the water column due to light attenuation (Figure 5-34B). Percent of photosynthetically active radiation transmitted through the water column decreases quickly and approaches 0% at a water depth of approximately 140 m during all surveys (Figure 5-35B).

5.11.2.6 Current

Current profiles were collected throughout the entire water column at each station sampled within the NORI-D block during the July 2021. Current velocity measured throughout the water column in July 2021 ranged from 2 to 17 cm s-1 (Figure 5-36A). The fastest current velocities were found in the upper 100 m of the water column (maximum of 17 cm s-1). Current velocities throughout the water column were generally similar among surveys (Figure 5-36A). At 2,000 m current velocities averaged between 3 and 5 cm s-1 during each survey. Near the seafloor current velocities averaged between 2 and 8 cm s-1 during each survey.

Current direction was variable throughout the water column at each station, but generally trended north to north-northwest in the surface (Figure 5-36B), southwest to south-southwest at 2000m (Figure 5-36), and southwest near the seafloor during Campaign 4e (Figure 5-36D).

Figure 5-31. Average temperature and salinity profiles among Campaign 4A – Oct’19, Campaign 4D – Jun’20, and Campaign 4E – Jul’21.

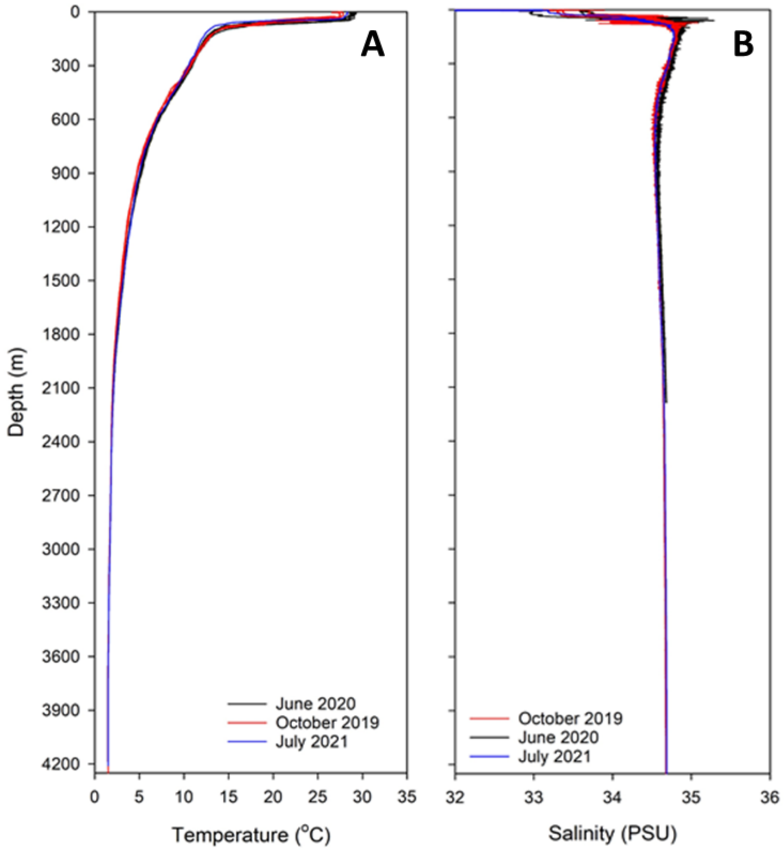


Figure 5-32. Average dissolved oxygen profiles among Campaign 4A – Oct’19, Campaign 4D – Jun’20, and Campaign 4E – Jul’21. Average oxygen reduction profiles among Campaign 4A – Oct’19 and Campaign 4E – Jul’21

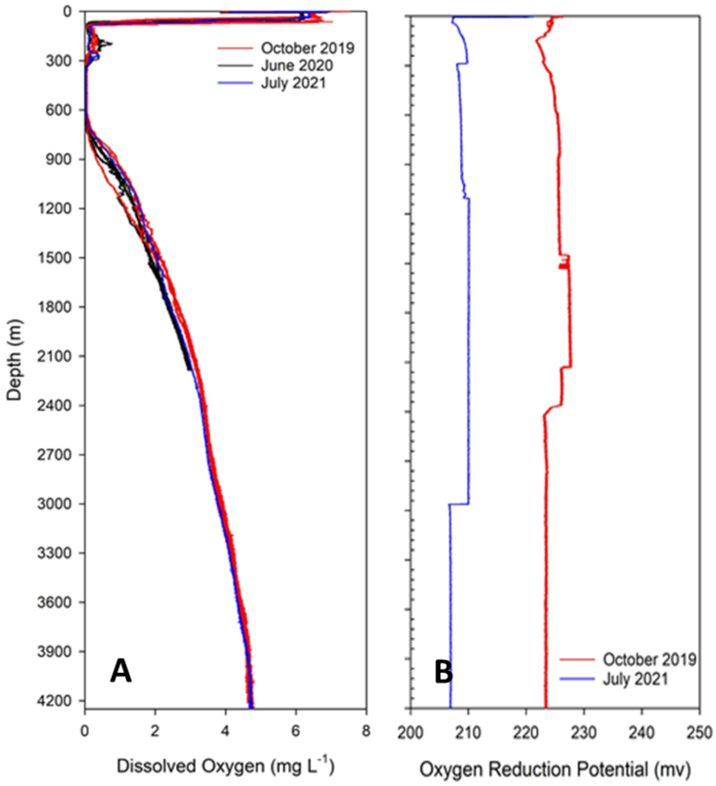


Figure 5-33. Average turbidity and transmissivity profiles among Campaign 4A – Oct’19, Campaign 4D – Jun’20, and Campaign 4E – Jul’21

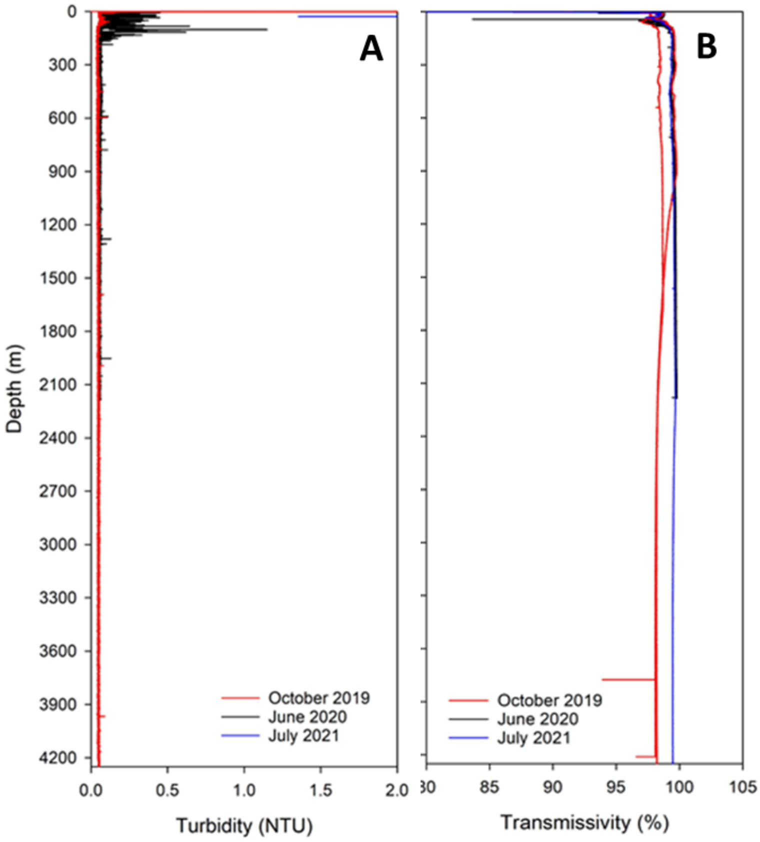


Figure 5-34. Average fluorescence and % photosynthetically active radiation (PAR) profiles among Campaign 4A – Oct’19, Campaign 4D – Jun’20, and Campaign 4E – Jul’21

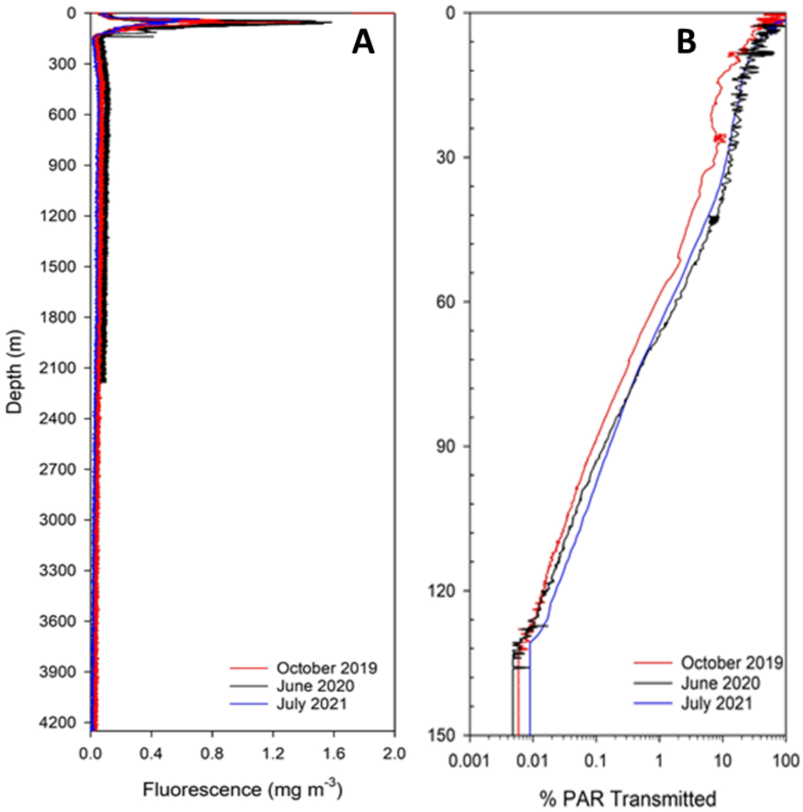


Figure 5-35. Representative % photosynthetically active radiation (PAR) transmitted through the water column vs. fluorescence (mg m-3) and dissolved oxygen (mg L-1) vs fluorescence (mg m-3) profile in the top 150 m of the water column at sampling Station ND|001 during Campaign 4E – Jul'21.

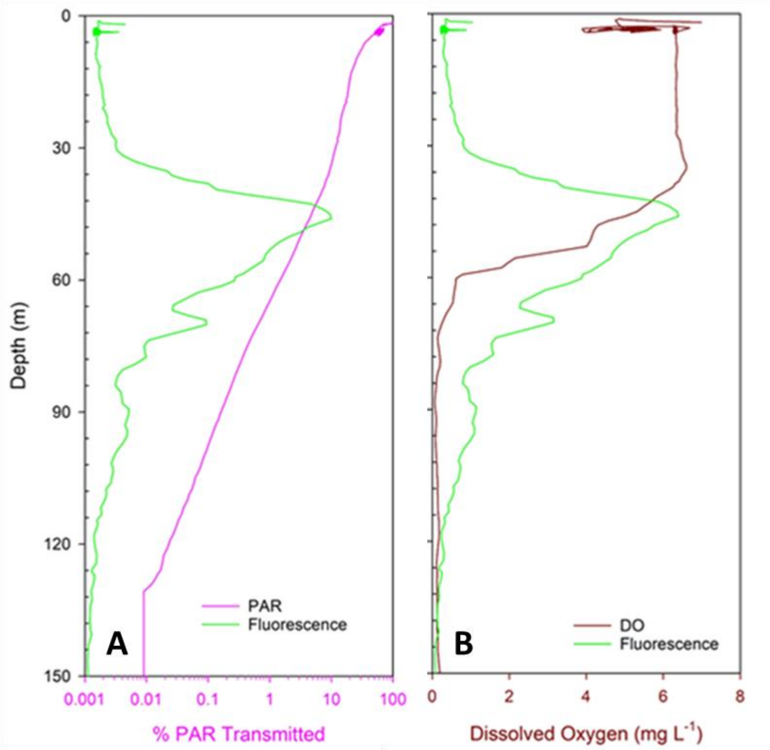
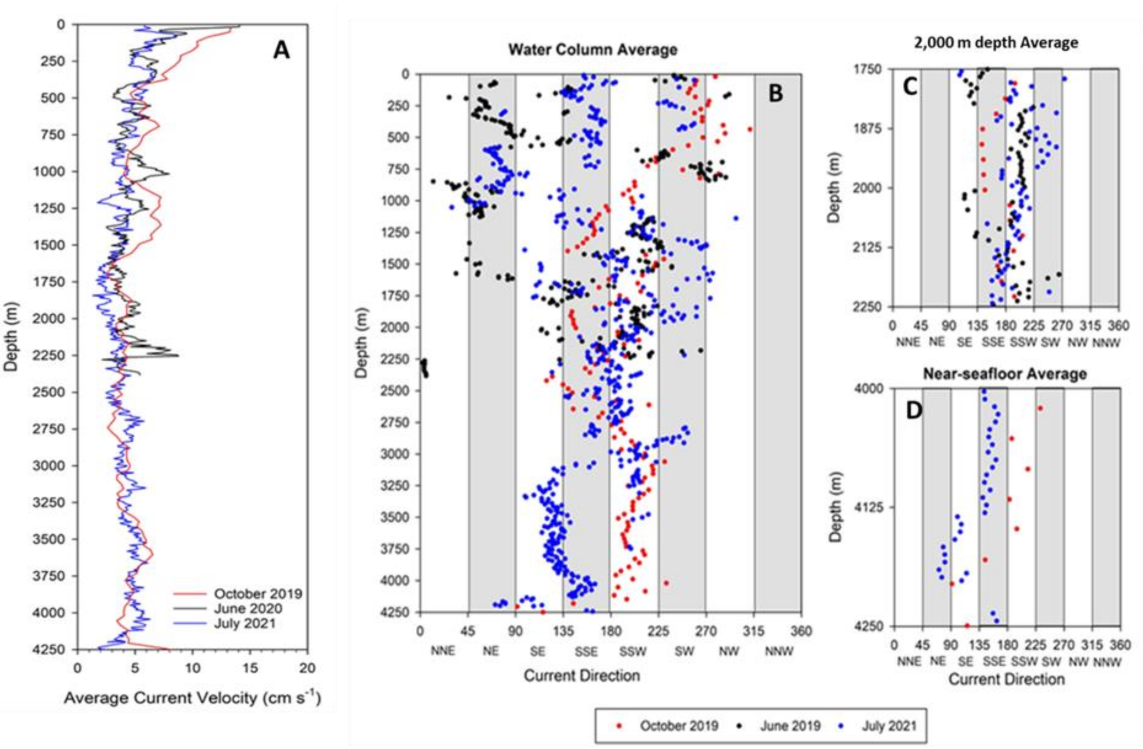


Figure 5-36. A - Average current velocity profiles; B - Comparison of average current velocity; C - Average current direction profiles at 2,000 m profiles; among Campaign 4A – Oct'19, Campaign 4D – Jun'20, and Campaign 4E – Jul'21; D - Average current direction profiles near the seafloor among Campaign 4A – Oct'19 and Campaign 4E – Jul'21 only.



5.11.2.7 Total suspended solids

Total suspended solids concentrations collected during Campaign 4A ranged between 1.5 and 4.5 mg L-1 throughout the water column. There is little in the literature that reference ambient TSS concentrations in the middle of the Pacific Ocean to compare against; however, the values obtained during Campaign 4A appeared to be higher than would be expected for a highly oligotrophic and remote region such as NORI-D. NORI requested that CSA review the data from Campaign 4A upon which it was determined that the higher-than-expected values were likely due to salts that were not rinsed thoroughly from the filters during the rinsing step of the filtration process. Therefore, the Campaign 4A TSS, as reported in the original version of the Collector Test EIS are considered null and void.

During Campaign 4E, all filters were rinsed with deionized water until the filtrate was composed entirely of fresh water. Total suspended solids concentrations collected during Campaign 4E are provided in Table 5-3. The pooled mean TSS concentrations at depths that could be exposed to the mid-water discharge (i.e., 950 – 1500m) ranged from 0.76 to 0.90 mg L^{-1}; whereas concentrations closet to the seafloor (i.e., B200 – B050m) ranged from 0.84 to 1.17 mg L^{-1}.

A temporal TSS data set is still being collected, from the available data it is reasonable to conclude that the average background concentration is in the order of 1 mg L^{-1} or slightly lower (pooled mean 0.93), with a relatively high standard deviation in the order of 0.4mg L^{-1} (pooled mean 0.42). Adopting a results presentation limit of 0.1mg/l (i.e., 10% of background concentrations) for short term effects from the PCV, thus seems appropriate given that the natural variability appears to be several times this limit.

Table 5-3. Average (± standard deviation) seawater total suspended solids concentrations (mg L-1) by water depth within the NORI-D block during Campaign 4E (Jul '21).

Water Depth (m)	Total Suspended Solids (mg L^{-1})				Mean	S.d.
	ND|001	ND|002	ND|005	ND|006		
950 m	1.00	0.57	0.53	1.10	0.80	0.29
1150 m	1.30	0.57	0.60	0.57	0.76	0.36
1250 m	1.20	1.00	0.90	1.10	1.05	0.13
1500 m	1.80	0.70	0.60	0.57	0.92	0.59
B200m	0.70	1.10	1.00	0.57	0.84	0.25
B150m	1.50	1.10	0.57	1.50	1.17	0.44
B100m	0.90	2.30	0.59	0.57	1.09	0.827
B050m	1.00	0.70	0.56	1.10	0.84	0.25
				Pooled Mean	**0.93**	**0.42**

5.11.3 In situ Sampling by UOH and TA&M - Campaign 5B

5.11.3.1 Temperature, Salinity, Dissolved Oxygen and Fluorescence

The physical properties of the water column including temperature, salinity, oxygen concentration and fluorescence, were measured using a regular CTD on Campaign 5B (Mar/Apr'21) and Campaign 5D (Oct/Nov'21) across the PRZ and the CTA at the sites shown in Figure 5-10 (UOH, 2022). Averaged results from Campaign 5B are presented in Figure 5-37 to Figure 5-40 for the entire water column and the euphotic zone (i.e., top 200m).

Figure 5-37. Vertical profiles of temperature, salinity, dissolved oxygen, and fluorescence measured with the regular CTD at the PRZ site during Campaign 5B.

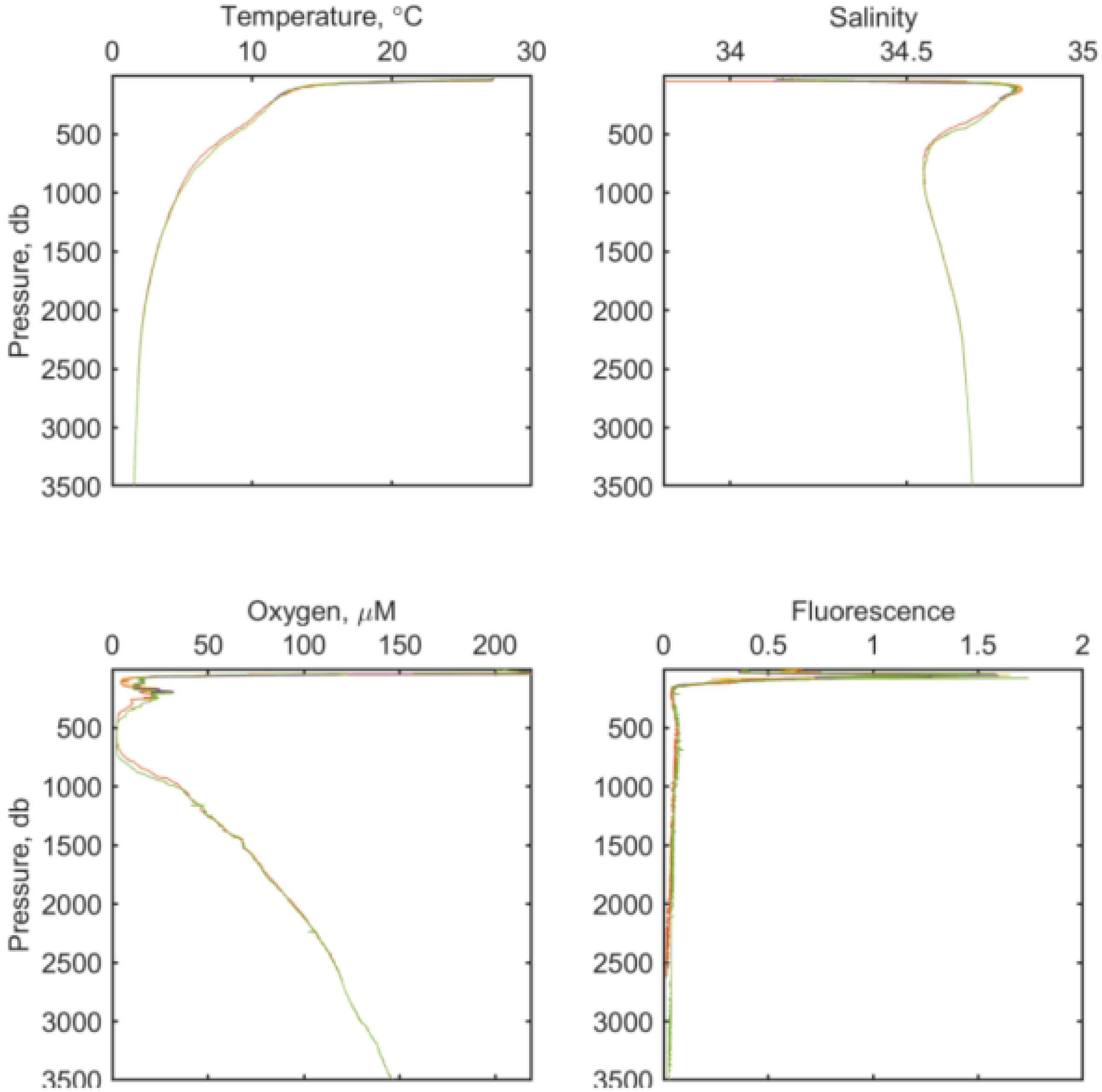


Figure 5-38. Vertical profiles of temperature, salinity, dissolved oxygen, and fluorescence in the upper 200 m of the water column at the PRZ site during Campaign 5B.

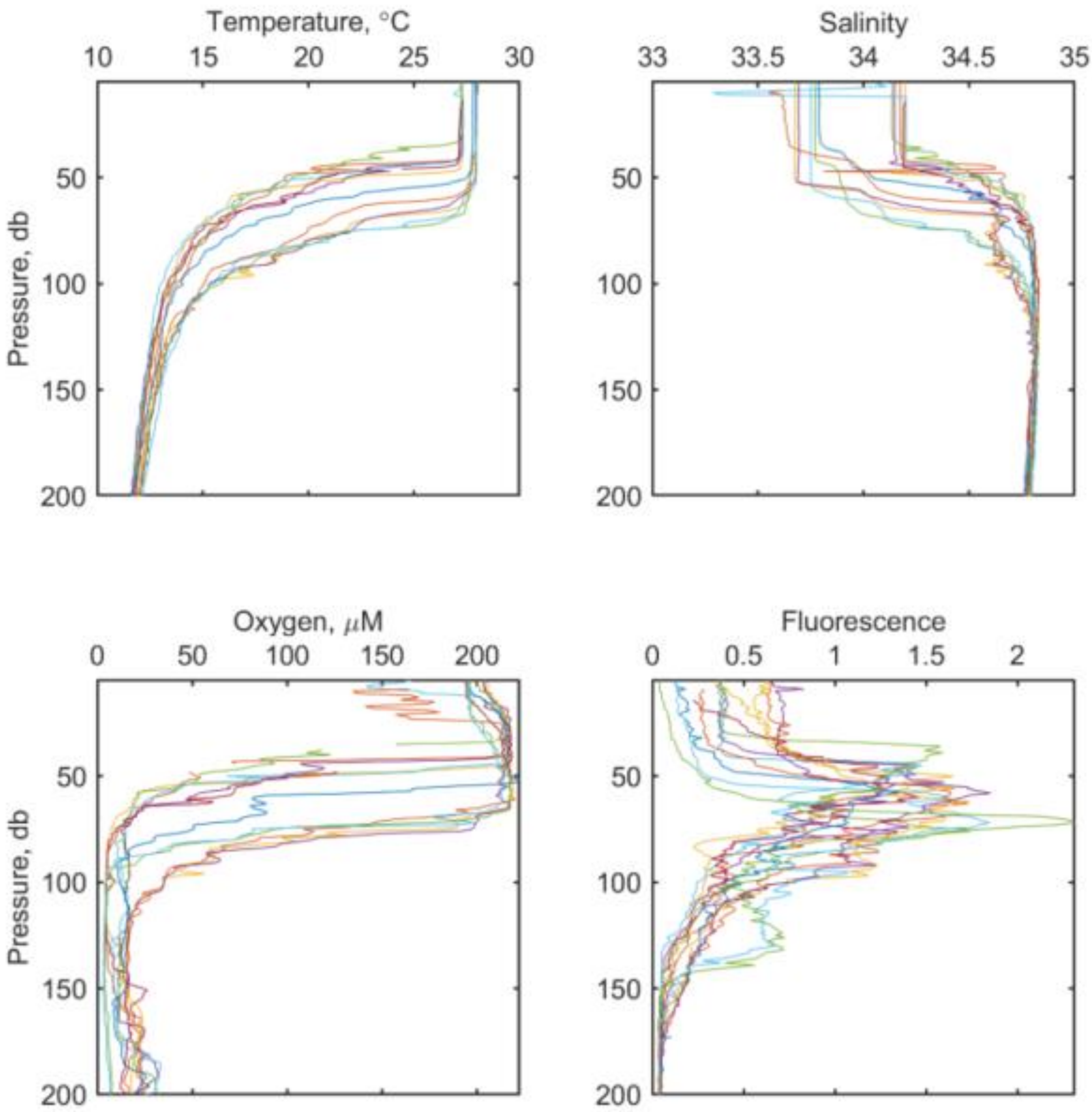


Figure 5-39. Vertical profiles of temperature, salinity, dissolved oxygen, and fluorescence measured with the regular CTD at the CTA site during campaign 5B.

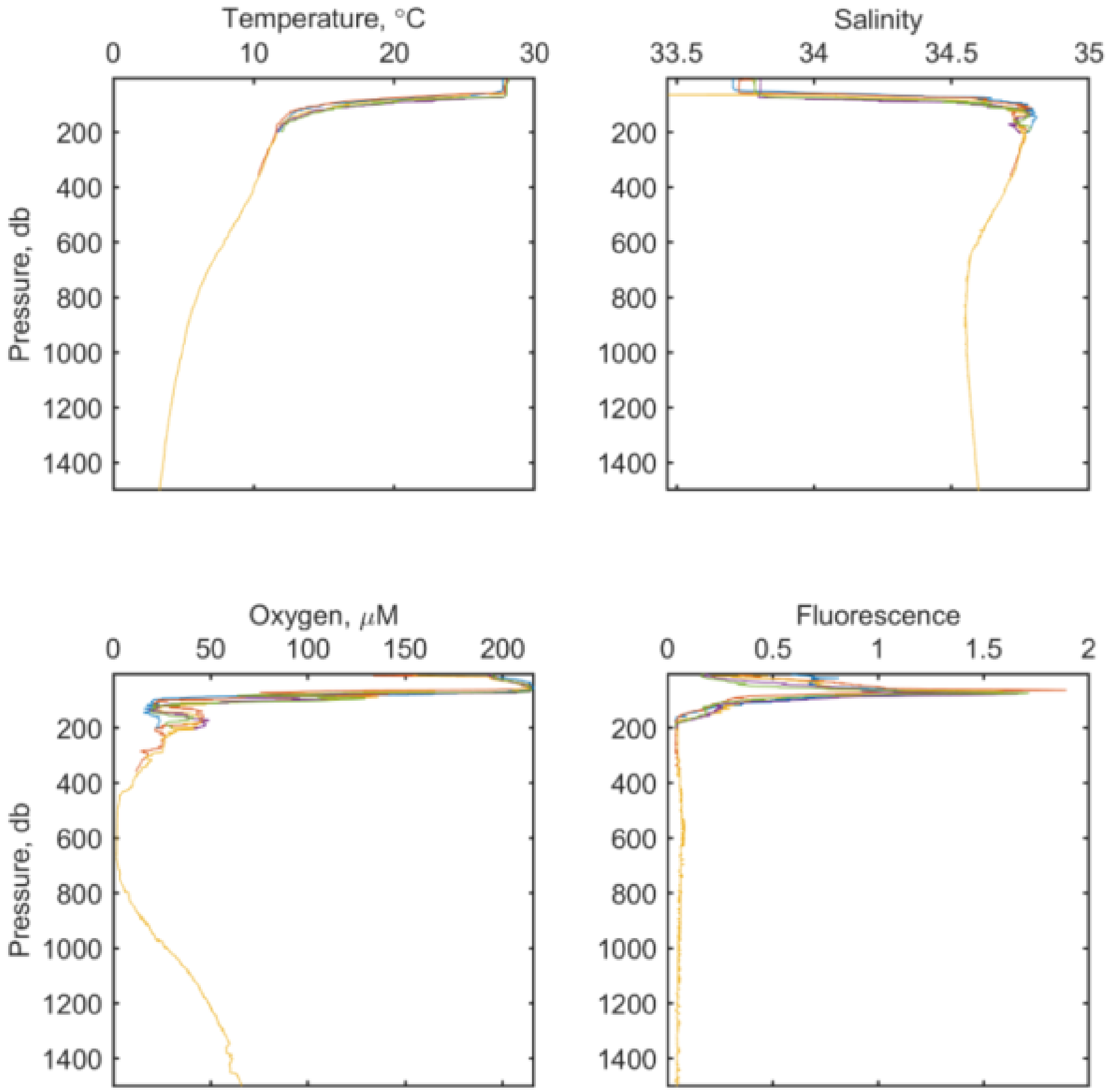
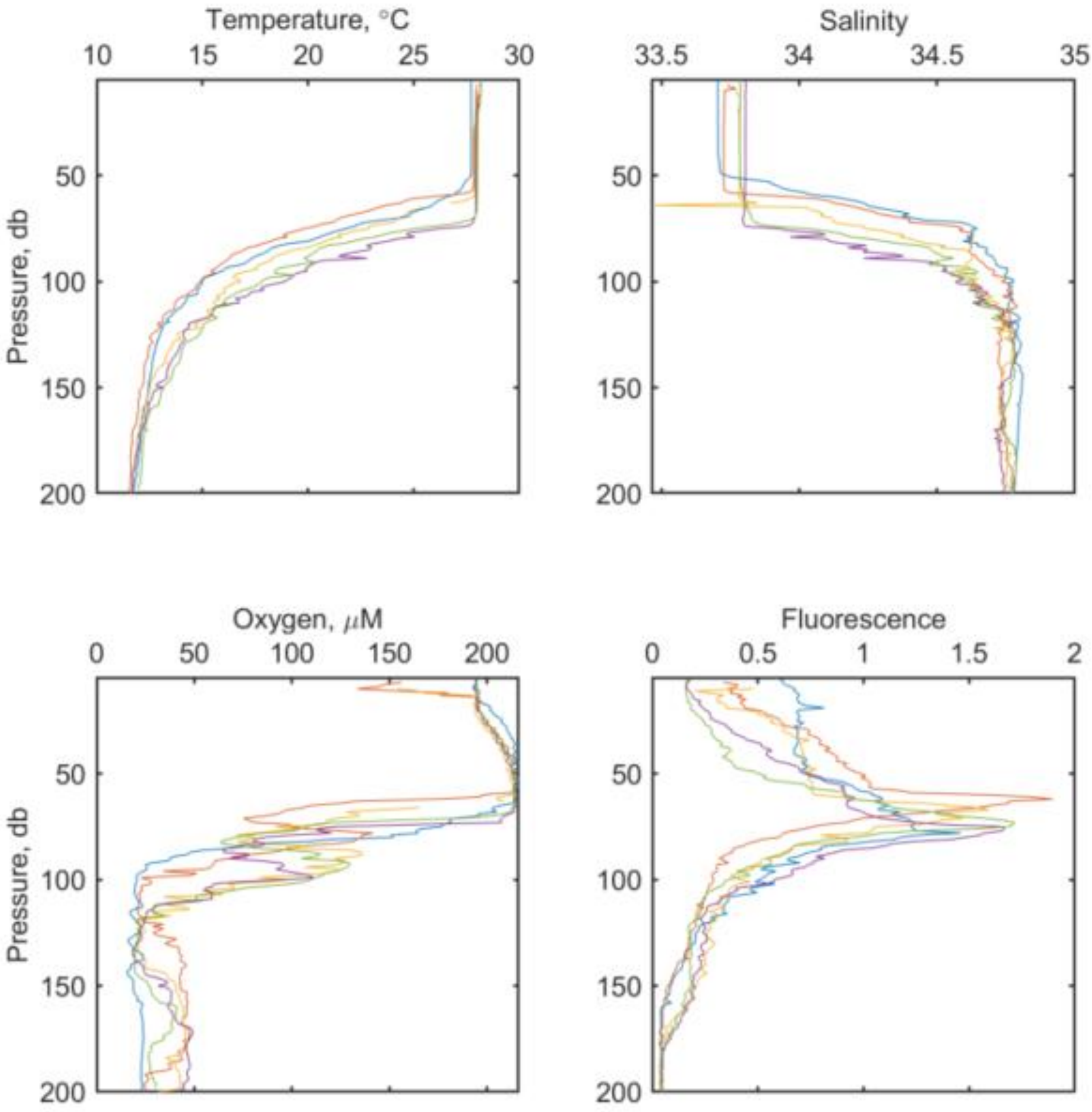


Figure 5-40. Vertical profiles of temperature, salinity, dissolved oxygen, and fluorescence in the upper 200 m of the water column at the CTA site during Campaign 5B.



5.11.3.2 Particle Size

The LISST was deployed on several 'pump' casts where it made continuous measurements at depths well below the euphotic zone where particle concentrations are at or below detection limits set by the clean water (zscat) calibrations. A single test cast was conducted in a near-shore station off Mexico and 4 profiles were collected in NORI-D (3 in the CTA and 1 in the PRZ). Evaluation of scattering spectra showed values within 5 counts of the factory calibrations in all size bins; the mean of these casts was used as a blank correction. The reproducibility of these spectra between casts was excellent suggesting that the mesopelagic area potentially impacted by deep sea mining is of high clarity and low turbidity.

The higher the slope of the particle size spectrum, the more predominant smaller particles are in the water column; the lower the absolute value of the slope the higher the volume of larger particles. There were clear depth distributions in the particle size distribution (PSD) slope with mid-water scattering layers having higher contributions in the large particle sizes, presumably indicative of sedimenting particles with a mode of ~ 6 µm as opposed to the mode of the PSD in surface waters of 4 µm (Figure 5-41). Total particle concentration (#/L) tracked the beam transmission profiles well (Figure 5-42).

Figure 5-41. Particle size distribution in surface (65-75 m, red) and deeper (449-550 m, black) waters.

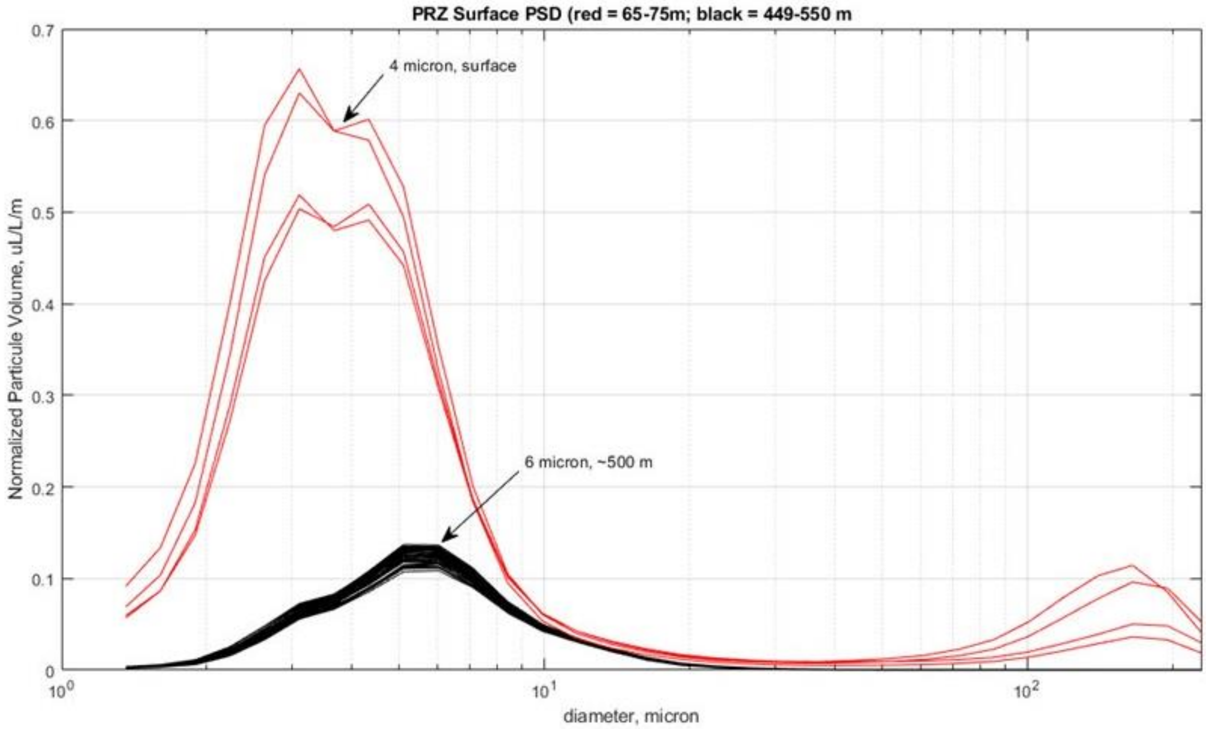
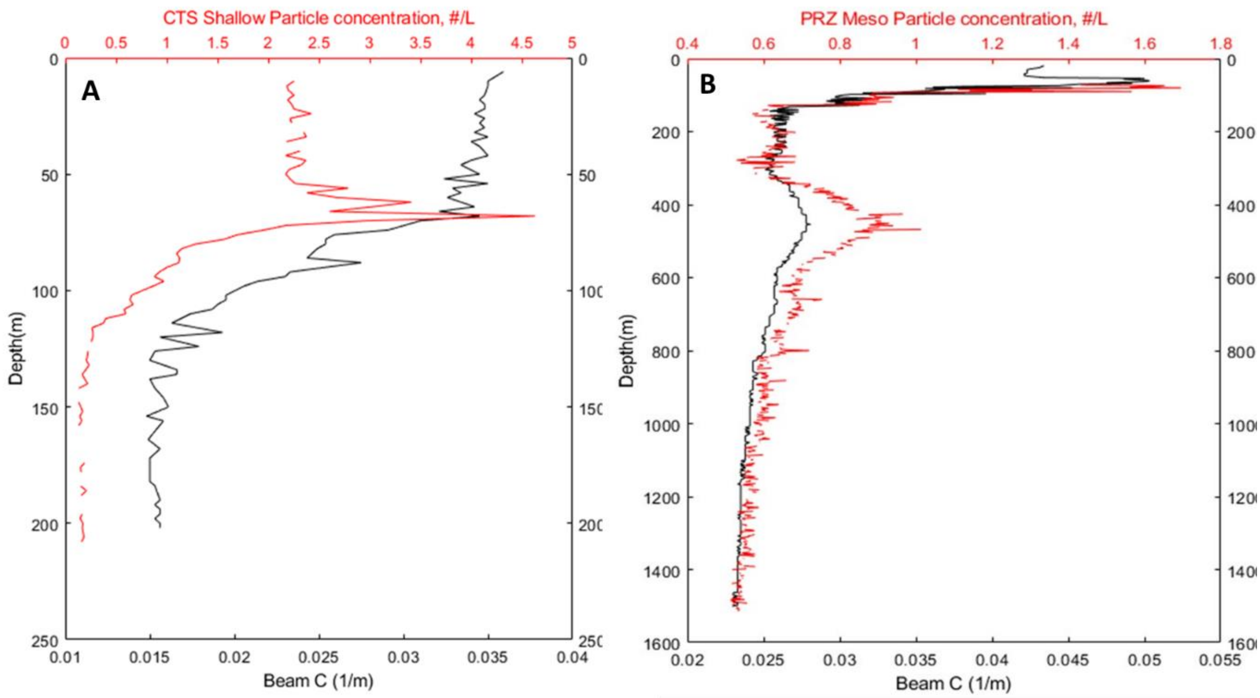


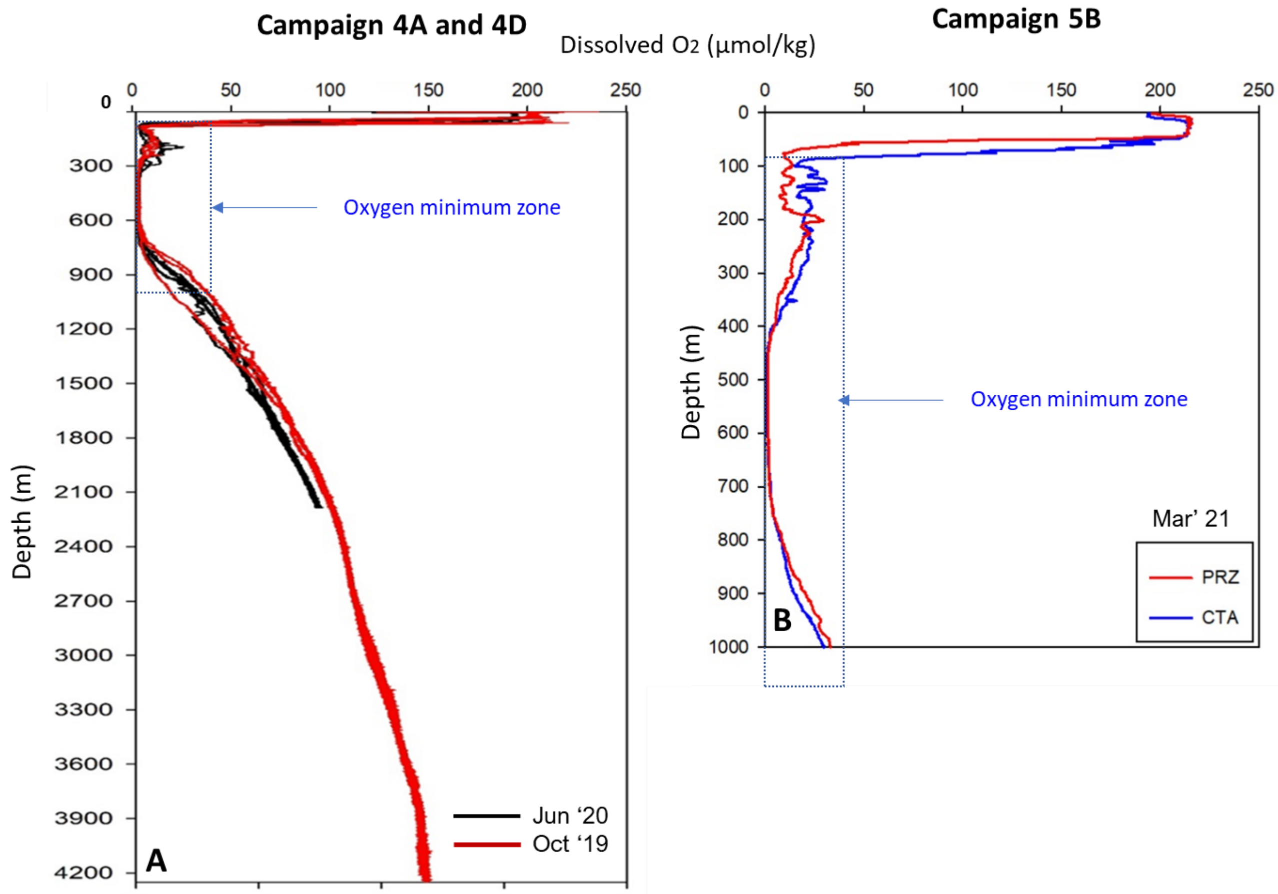
Figure 5-42. Vertical profiles of particle concentration (red) and beam transmission (black) at the CTA (A) and the PRZ (B)



5.11.3.3 Dissolved Oxygen

Dissolved oxygen was measured in the water column during Campaigns 4A and 4D at five sites across NORI-D by CSA and by UOH during Campaigns 5B and 5D at 11 sites across the CTA and the PRZ. A comparison of results from Campaigns 4A, 4D and 5B are shown in Figure 5-43.

Figure 5-43. A - Dissolved Oxygen profiles measured on Campaigns 4A, 4D; B - Dissolved Oxygen profiles measured on Campaign 5B.



Although there is no agreed threshold in oxygen that defines the oxygen minimum zone (OMZ), the global boundaries of an oxygen minimum zone (OMZ) can be defined by dissolved oxygen concentrations of about 45 µmol/kg (Karstensen *et al.* 2008). Using this definition, the oxygen OMZ in NORI-D extends from about 100 to just below 1000 m during Campaigns 4A, 4D and 5B (Figure 5-43). Within the proposed depth range of the return water discharge for the Collector Test (1500-1000m), dissolved oxygen concentrations at the PRZ site range from 33 to 68 µmol/kg (average 51 µmol/kg) and at the CTA site range from 29 to 67 µmol/kg (average 51 µmol/kg) (UOH, 2022). Based on these findings the depth of the return water discharge point for the Collector Test has been set at 1200m where the average dissolved oxygen concentrations would be expected to be >50 µmol/kg outside of the bounds of the 45 µmol/kg (Karstensen *et al.* 2008). As discussed previously, the effective discharge point could be up to 1,280m (see Section 3.4.3.7).

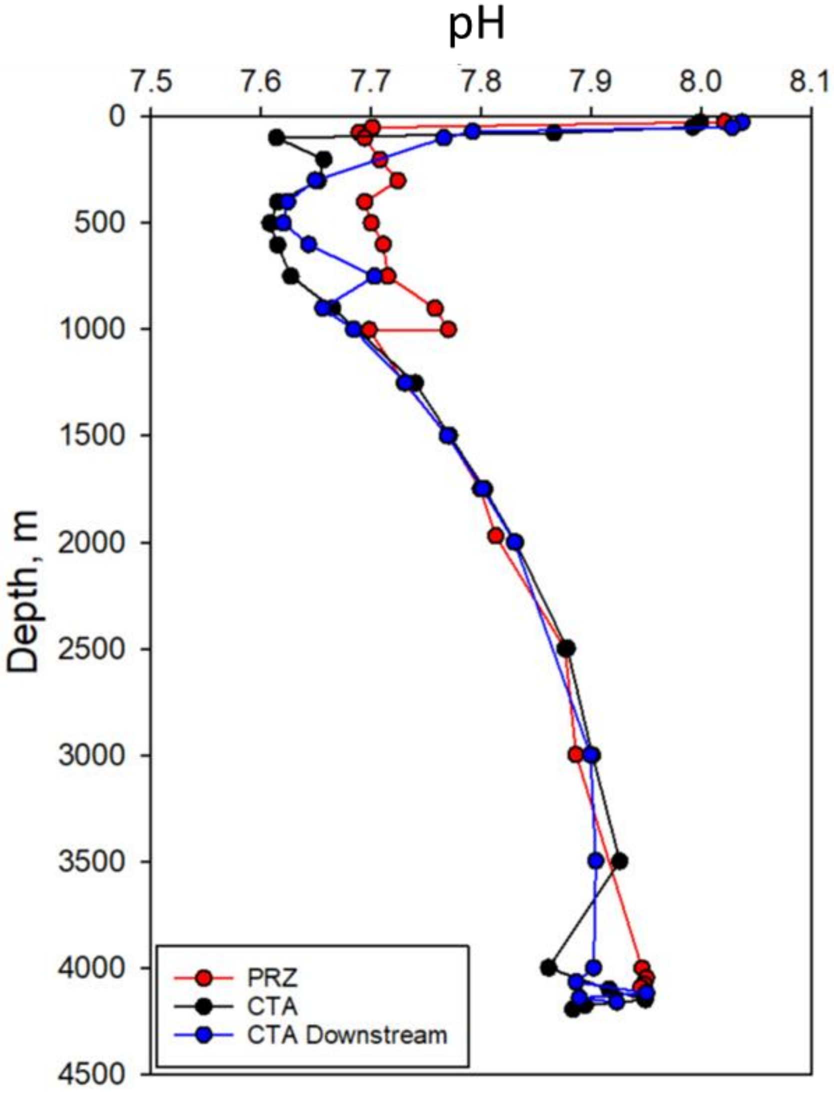
It is acknowledged that the range of dissolved oxygen concentrations at 1500 - 1000 m is well below that found in surface water, so if deep waters carrying seafloor sediments equilibrates with atmospheric oxygen while on the collector ship, then dissolved oxygen concentrations of seawater released between 1500-1000 m from mining activities could be substantially higher than in situ concentrations (UOH, 2022). This will be investigated during the Collector Test and the results considered when considering the optimal depth for the mid-water outlet during commercial operations.

5.11.3.4 pH

Measuring seawater pH provides a means of monitoring for changes in mid-water pH at the point of mid-water discharge. ISBA/25/LTC/6/Rev.1; (30 March 2020) recommends measurement of pH and other components of the carbonate system where appropriate (e.g., carbon dioxide, alkalinity) Section III, B, 15, b, iv.

During Campaign 5B 68 valid samples were collected to characterize pH variations in the water column from 25 m to ~5 m above the seafloor. The results are shown in Figure 5-44.

Figure 5-44. Plot of mean pH with depth for three sites sampled during Campaign 5B



The pH at all sites ranged from 7.61 in the OMZ to 8.04 in the surface mixed layer (Figure 5-44). The variation in pH in the upper 60 m at similar depths at each station is greater than measured reproducibility at 1000 m and represents environmental changes in pH with depth. These differences between stations can be attributed to depth of sample collection, which was different at each site as well as differences in the balance between photosynthesis and respiration at each site. Variation in pH within the OMZ (~100-1000 m) shows differences between sites that is most likely related to intensity of suboxic and anoxic respiratory processes. Variation in pH in the deepest samples within the benthic boundary layer (~5-10 m above the seafloor), ranges from 7.88 to 7.95 (average 7.93) and most likely results from the release of CO2 from respiration from abyssal deposit feeders and benthic infauna, which can be very patchy on the seafloor (UOH, 2020).

5.12 Chemical Oceanography

5.12.1 In situ Sampling by CSA - Campaigns 4A, 4D and 4E

5.12.1.1 Nutrients

Average nutrient concentrations for nitrogen, phosphorous, and silica compounds measured within the NORI-D are in Figure 5-45. Analytical laboratory data sheets are provided in the source report (CSA, 2022). All nutrient concentrations were lowest within the surficial mixed layer at the 30 m sampling depth, and most nutrients were highest at the lower boundary of the oxygen minimum zone at water sampling depth of between 950 and 1,500 m. The highest average silicon dioxide concentration was located at a sampling depth of 2,500 m.

Nutrient concentrations measured during Campaign 4A and 4E were generally similar at all depths examined (Figure 5-45 A-D), implying temporal stability of seawater nutrient concentrations within the NORI-D block. Nutrient concentrations measured during both campaigns were also very similar to vertical profiling trends reported elsewhere within the generalized deep-water Pacific Ocean (MBARI, 2021).

5.12.1.2 Metals & Metalloids

Seawater samples collected on Campaign 4A were analysed for average concentrations of selected metals and metalloids, the results of which are shown in Figure 5-46. It should be noted that the methods used to collect seawater samples on this campaign were not compliant with the International GEOTRACES Program (Cutter & Bruland, 2012), unlike the samples collected on Campaigns 5B and 5D. Concentrations of aluminium, antimony, bismuth, cobalt, gold, iron, manganese, selenium and tellurium were below their respective laboratory limits of detection (i.e., 5.01 µg/L, 0.4 µg/L, 6.0 µg/L, 0.01 µg/L, 2.0 µg/L, 8.03 µg/L, 0.81 µg/L, 0.4 µg/L and 1.29 µg/L, respectively) and are not included in Figure 5-46.

Trace metal concentrations were generally comparable to other reported values for the Pacific Ocean (Nameroff *et al.*,2002). Copper, molybdenum, uranium and vanadium showed variability at certain water depths which was generally due to elevated concentrations at one particular, but varying, sampling station.

While concentrations of zinc, lead and silver were highly variable, this was attributed to results being close to the laboratory detection limits (CSA, 2020).

Figure 5-45. (A) - Average nitrogen (NO2 + NO3-), (B) - orthophosphate (PO4), (C) - total phosphorous, and (D) - silicon dioxide (SiO2) concentrations within the NORI-D block during Campaigns 4A conducted in October 2019 (grey) and 4E conducted in July 2021 (black). Standard deviation bars are provided only for Campaign 4E. Blue symbols indicate general Pacific Ocean reference concentrations for orthophosphate from MBARI (2021).

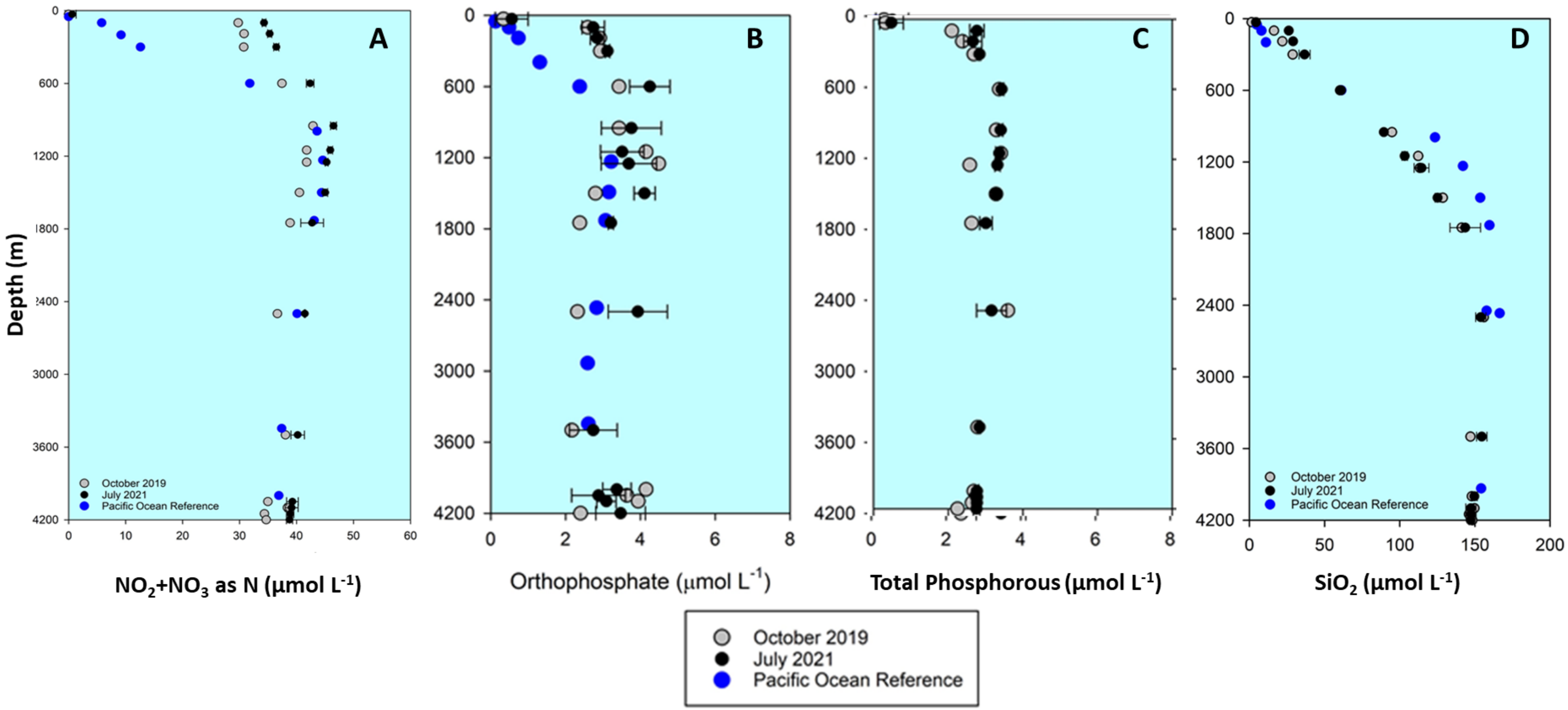
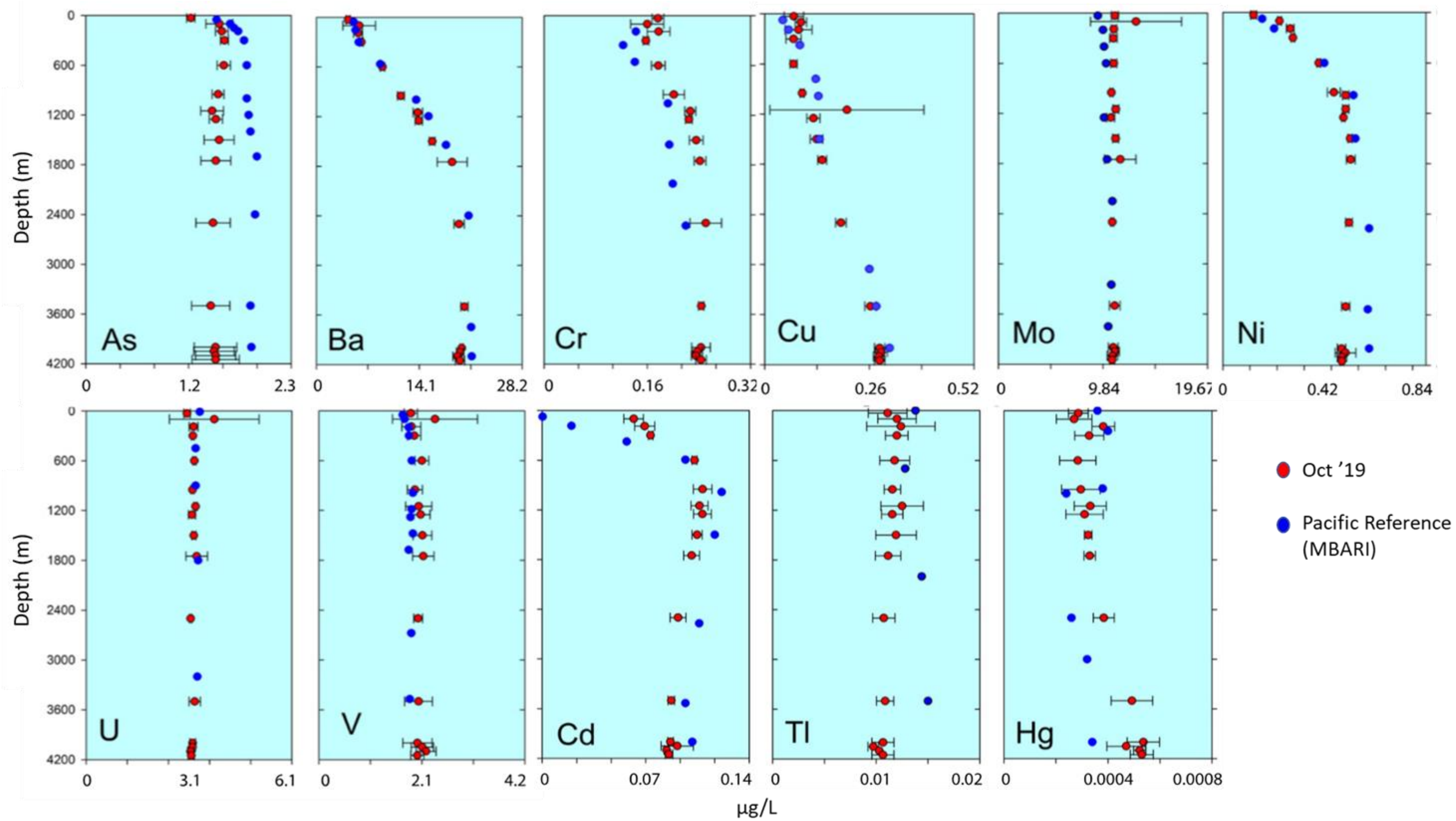


Figure 5-46. Concentrations of metals and metalloids from seawater samples collected on Campaign 4A (note: not GEOTRACES compliant)



5.12.2 In situ Sampling by UOH & TA&M - Campaign 5B

5.12.2.1 Nutrients

The vertical distribution of major nutrients (phosphate, nitrate plus nitrite, and silicate) was measured by UOH during Campaigns 5B at 11 sites across the CTA and the PRZ.

Comparison traces for the full water column depth shows similar patterns across the PRZ and CTA (Figure 5-47; row 1). The 0-200m profiles (Figure 5-47; row 2) show consistently low concentrations at the surface (<50 m) and a transition to nutrient-rich waters between 50 to 100 m. The top of the nutricline roughly coincides with the deep chlorophyll maximum (Figure 5-40 and Figure 5-47); this was also demonstrated in the CSA data which shows the chlorophyll maximum to be between 40 and 50 m (Figure 5-34A). Both the nutricline and the deep chlorophyll maximum are shallower than at the NPSG time-series site, Station ALOHA (Karl *et al.*, 2021), but distributions of nutrients are otherwise consistent with historical data at this subtropical time-series site.

5.12.2.2 Trace Elements

During Campaign 5B and 5D seawater samples were collected using trace metal clean procedures established by the International GEOTRACES Program (Cutter & Bruland, 2012). A trace metal clean CTD rosette mounted with GO-Flo bottles was provided by the UOH (Measures *et al.*, 2008a); this rosette has been proven to be clean for trace metal analysis in past CLIVAR sampling programs (Measures *et al.*, 2008b; Grand *et al.*, 2015). Three areas were sampled on Campaign 5B and 5D: CTA; PRZ and a third area downstream of the CTA (Figure 5-10). Each area was sampled for a shallow cast to 1000m and a deep cast to the seafloor.

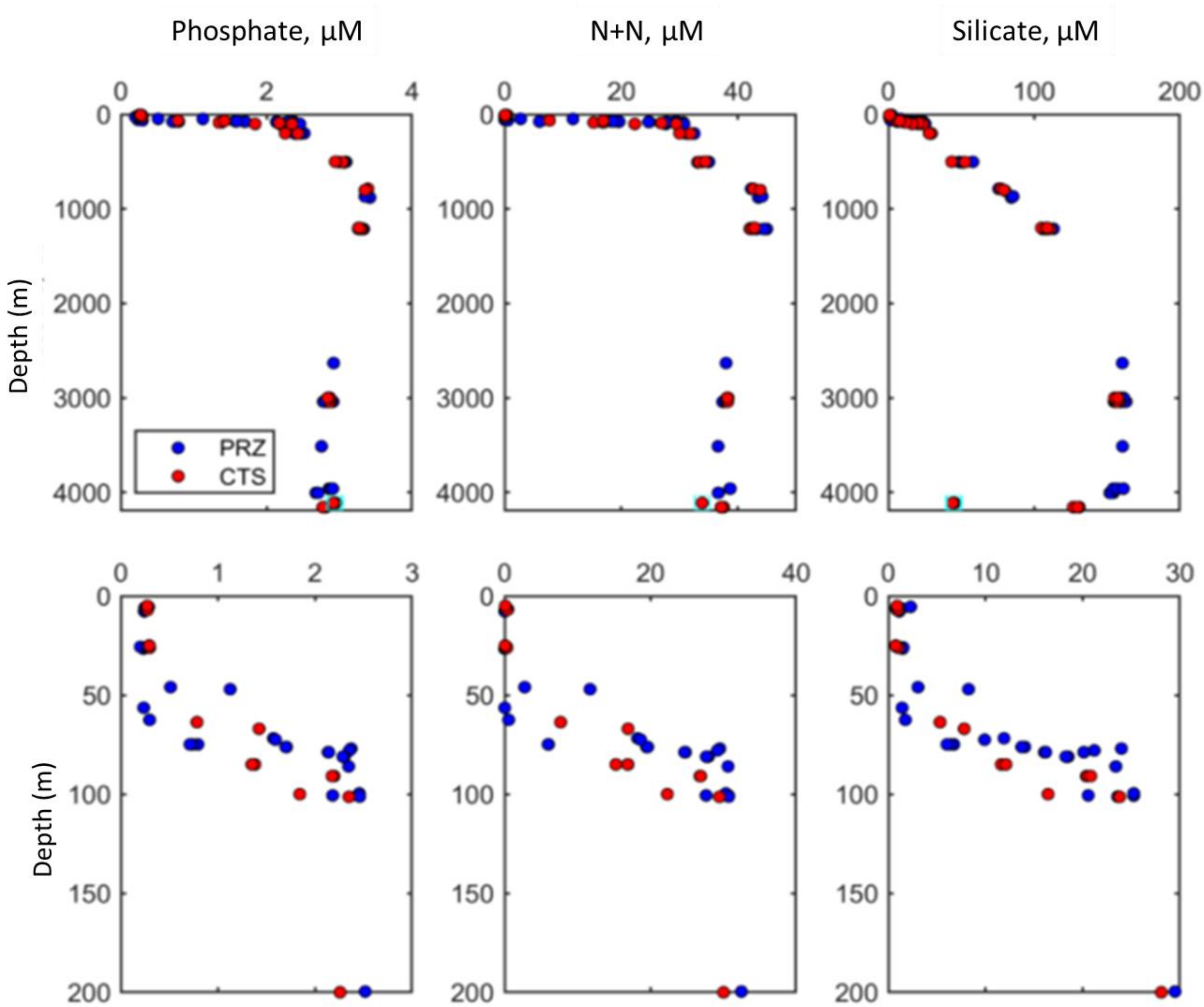
The results for concentrations of total dissolved mercury (THg), dissolved lead (dPb), dissolved zinc (dZn), dissolved nickel (dNi), dissolved cadmium (dCd), dissolved manganese (dMn), labile cobalt (Co), dissolved iron (dFe) and dissolved copper (dCu) from Campaign 5B are summarised in Figure 5-48.

Total dissolved mercury (THg) and dissolved lead (dPb) were both at concentrations far below toxic drinking water levels, which is typical for open ocean seawater. At all areas sampled, THg was <1 pM in surface waters and increased to a maximum >1 pM in 13°C Water near 100m depth. In the OMZ, concentrations were variable, with a minimum in the heart of the OMZ at the CTA but maxima in the OMZ at the other two sites. Concentrations steadily increased with depth, showing excellent agreement across the 3 sites at intermediate depths.

Dissolved Pb, in contrast, showed a more typical “scavenging-type” profile shape (Boyle *et al.*, 2014) with low surface concentrations, a maximum at 100m in the 13°C Water, and then decreasing concentrations with depth. The PRZ showed higher dPb concentrations than the other two sites in the 13°C Water, which could be a spatial difference (pending QA/QC). Similarly, dPb concentrations were elevated at the bottom of the CTA (these data are not final).

The dissolved Zn, Ni, and Cd profiles showed classic nutrient-like profile shapes that emulated the macronutrients. While several datapoints are still undergoing QA/QC, there was overall little spatial variability observed across the three sites for Zn, Ni, or Cd. One depth range that deserves special interest is the deepest depths near the seafloor, which showed concurrent variability in these micronutrients and the macronutrients above; it is possible that there was a GO-Flo bottle tripping issue that needs special attention at these depths.

Figure 5-47. Vertical profiles of phosphate, nitrate plus nitrite (N+N) and silicate concentrations at across NORI-D collected on Campaign 4A and 5B



Note: *Top row shows full profiles from 11 sites distributed between the CTA and PRZ collected by UOH during Campaign 5B. Bottom row shows the 200m of the water column only from the Campaign 5B data.*

In contrast, dissolved Mn and labile Co are redox-sensitive elements that typically have hybrid-type profiles: between nutrient-type and scavenging-type. While their datasets are not yet complete at the CTA, Mn demonstrated a surface maximum, as is typical when particulate Mn(IV) is photo-reduced to dissolved Mn(II) in sunlit waters. Mn can also receive dust inputs (Shiller, 1997) and does have a higher surface concentration at Station 3, like dAl, than at the PRZ. Dissolved Mn concentrations then typically decrease with depth, except here there is a secondary dMn maximum coincident with the OMZ between 500-700m depth. This secondary Mn maximum was larger at Station 3 than at the PRZ.

Dissolved Al data showed profile shapes consistent with the rest of the global ocean, with a surface maximum decreasing to low concentrations at depth due to scavenging onto sinking particles (Figure 5-49A(. Surface dissolved Al is often reflective of an atmospheric input (dust), and it is notable that there was a marked increase in surface dAl at Station 3, which could have arisen from a local dust input or might have been advected into the region during sampling (such as with a mesoscale eddy feature). Otherwise, little spatial variability was observed across the 3 sites sampled.

Finally, dissolved Fe concentrations showed classic nutrient-type profile shape (Figure 5-49). Surface concentrations were depleted, suggesting strong nutrient uptake/recycling, especially since even Station 3 did not show the surface dFe maximum indicative of recent dust inputs. In fact, the dFe profiles at all three trace metal stations were very similar, suggesting that spatial variability was negligible. Subsurface, dissolved Fe concentrations increased to 0.6-0.7 nmol/kg within the OMZ and in intermediate waters below, and then deeper they jumped even higher to ~0.8 nmol/kg between 2000-3000m. These are depths coincident with the known Northern East Pacific Rise hydrothermal plume, based on 3He distributions (Lupton, 1998). A concomitant hydrothermal input of dissolved Mn, Al, or Zn (Resing *et al.*, 2015; Roshan *et al.*, 2016) was not observed in the NORI-D lease.

To examine whether the baseline data collected from NORI-D is oceanographically consistent it has been compared with available historical data from other areas.

The physical properties and nutrient data described have been compared with historical data from the WOCE, CLIVAR, and GO-SHIP programs (cchdo.ucsd.edu) (Figure 5-50). The data from NORI-D has excellent comparison to the historical datasets. Nitrate+nitrite and phosphate were slightly lower from the trace metal casts on Campaign 5B than the nearest historical data (in yellow), but the other analytes are nearly indistinguishable. This indicates our high level of data quality. Note that the nitrite+nitrate and phosphate datasets have the most variability across the historical intercomparison, indicating that they suffer the most temporal variability, which may be expected for major macronutrients that are biologically cycled.

Comparison of trace elements was a little more challenging and the Pacific historical datasets were scoured for the nearest profiles to NORI-D with which to compare results. These data comparisons are plotted in Figure 5-51. Note that many of these profiles come from hundreds-thousands of kilometres away from NORI-D, though attempts were made to keep the ~10°N latitude constant.

Importantly, all the dissolved metals studied on Campaign 5B showed profiles similar to their literature values for the tropical/subtropical Pacific (Figure 5-51), with some exceptions that may in fact relate true spatial variability (since the historic data are from locations quite far from NORI-D). For example, the OMZ depths showed higher concentrations of dMn and labile Co than at similar latitudes farther west that have a less intense OMZ. Additionally, dissolved Fe concentrations were higher in NORI-D compared to farther west in the Central Pacific, as is often true for margin-derived metal such as Fe. Finally, the dAl values that we obtained during Campaign 5B are slightly higher at the PRZ throughout the water column (except the mid depths) but other stations are very similar to historic values.

Figure 5-48.	Dissolved concentrations of mercury, lead, zinc, nickel, cadmium, manganese, labile cobalt, iron and copper at PRZ, CTA and downstream CTA (pending QA/QC)

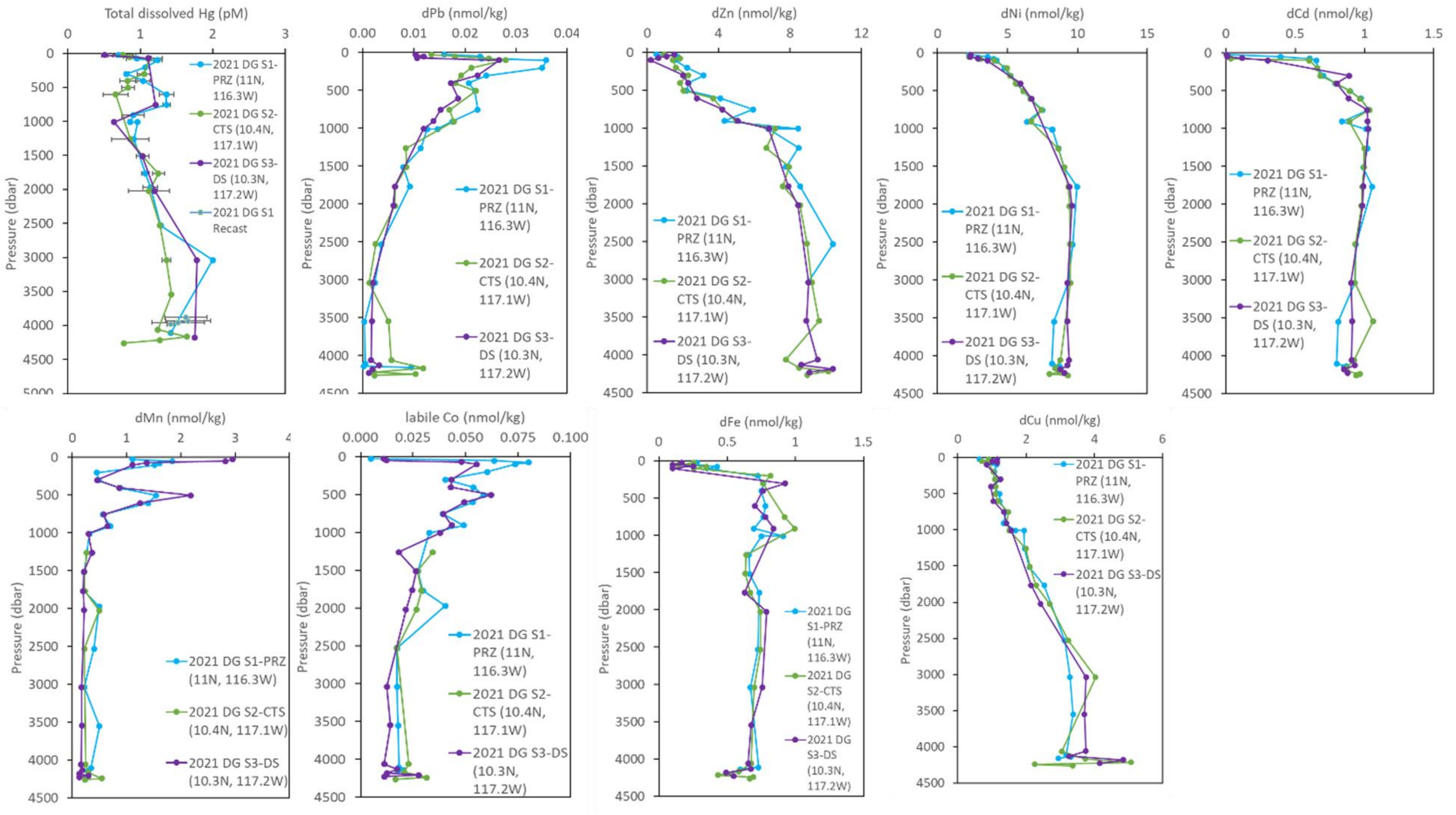


Figure 5-49. Vertical profiles for FIA-based dissolved Al and Fe during Campaign 5B. PRZ (red circle), CTS (blue circle), and downstream (green circle) were shown together with previous GEOTRACES GP15 station (samples were collected at 11°N, 152°W on 2018 November 1st during the GP15-PMT cruise). These data are unpublished and should be considered preliminary.

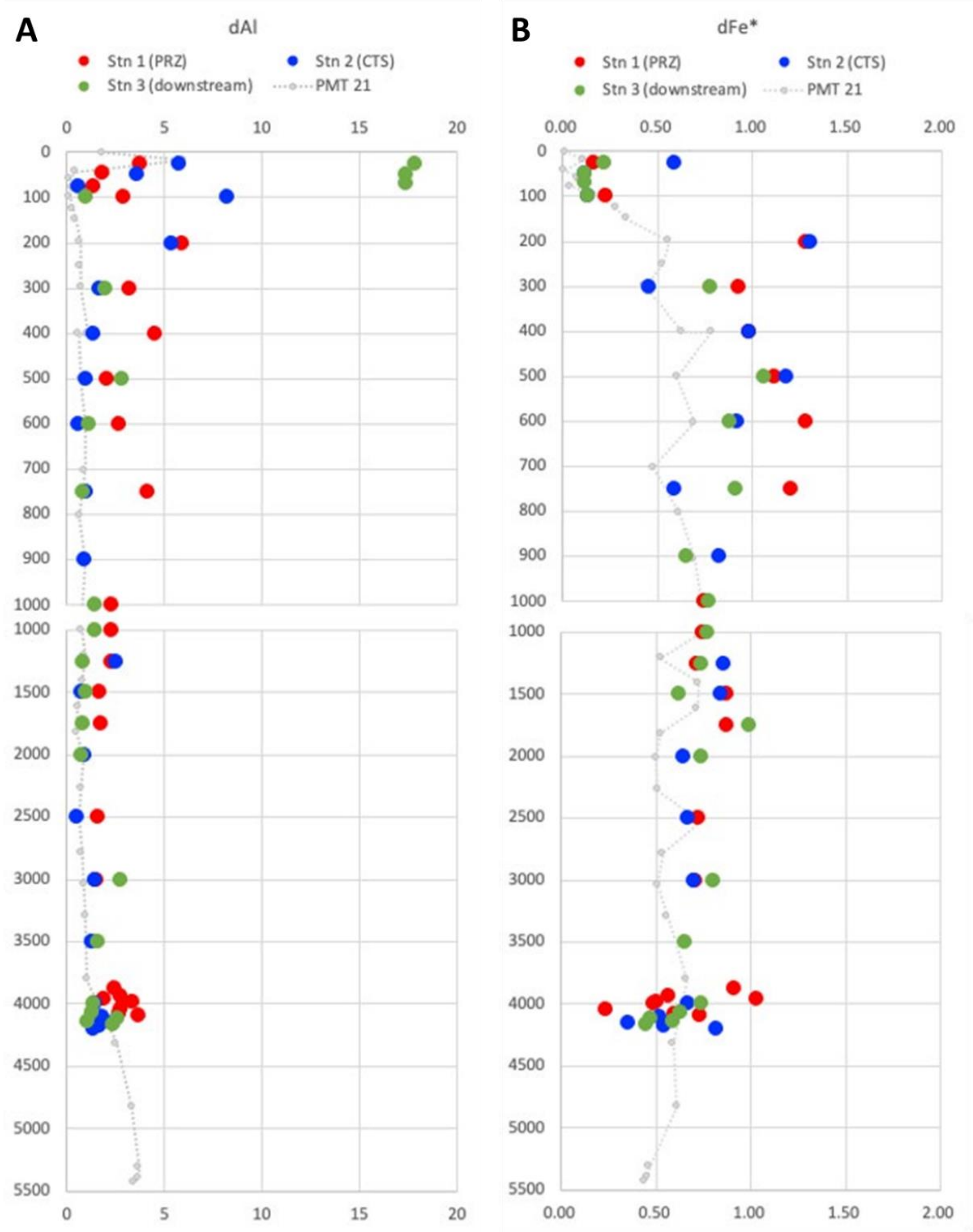


Figure 5-50. Full profiles of hydrographic data and nutrients in colour, atop historical data from the WOCE, CLIVAR, and GO-SHIP programs (cchdo.ucsd.edu). Historical data is shown in gray, except for the station nearest the NORI-D region, which is shown in yellow (but may have been sampled decades ago). All latitude/longitude data and the years of sampling are shown in the legends.

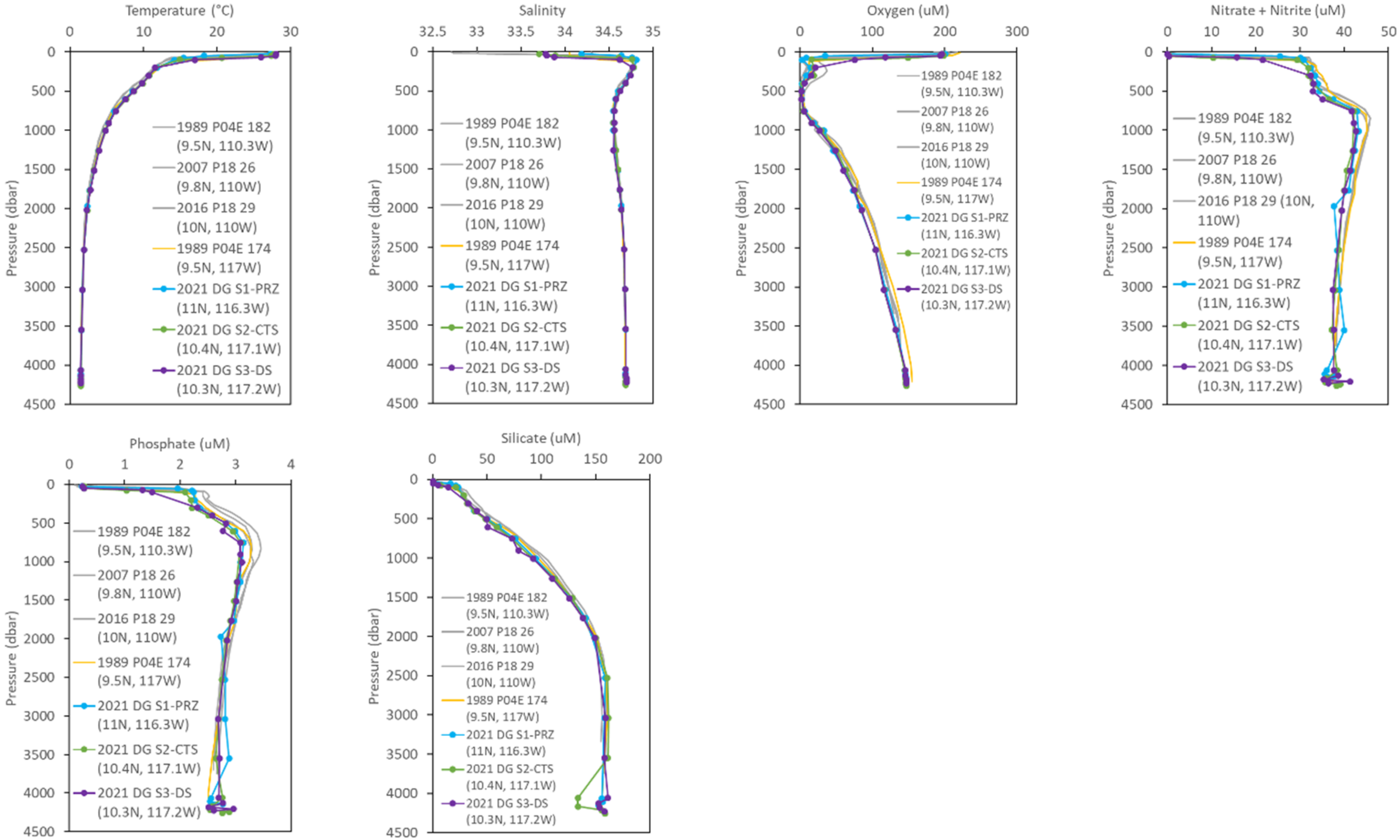
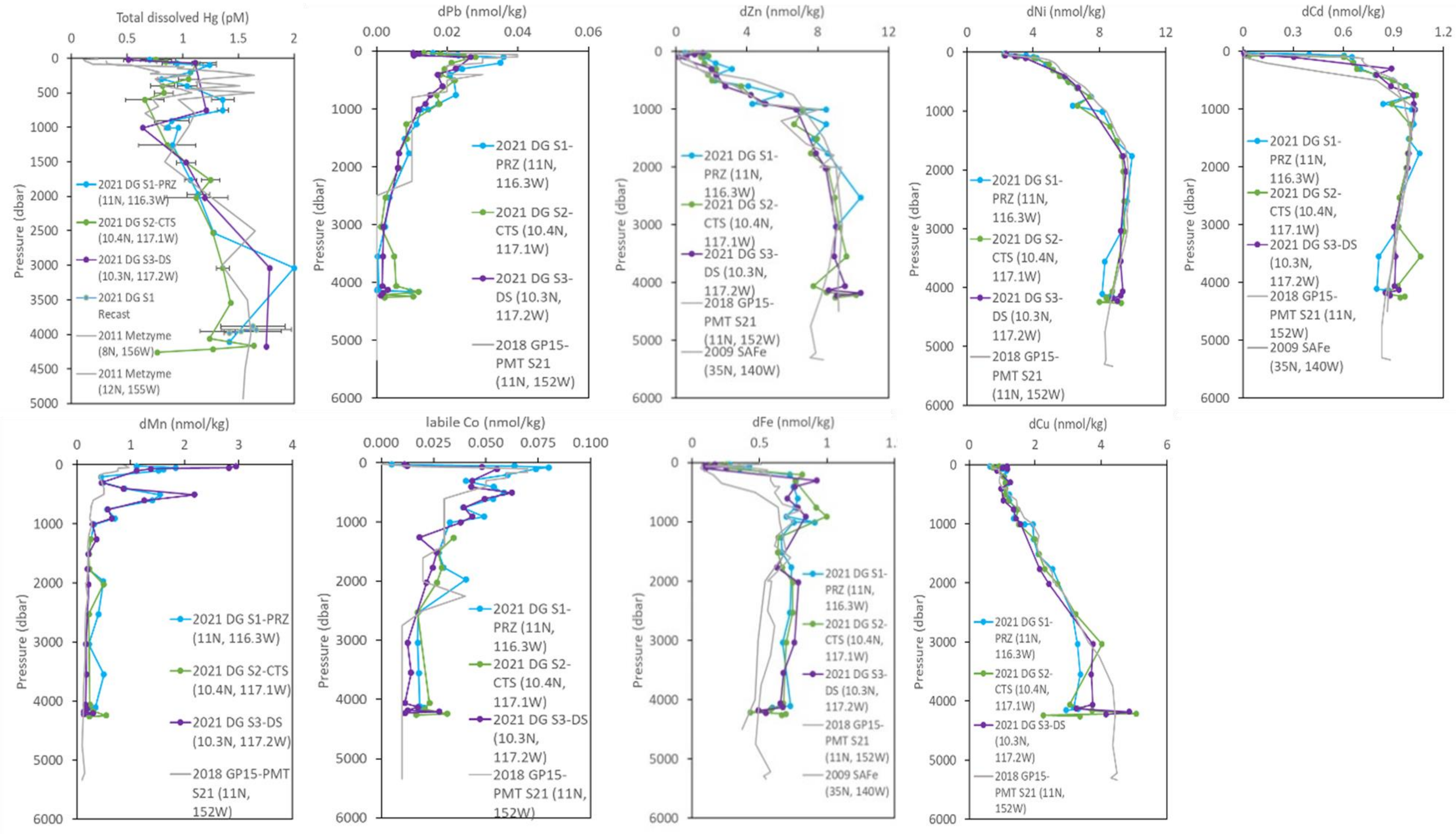


Figure 5-51. Full profiles dissolved metals and total dissolved Hg from Campaign 5B, atop historical data from other sites in the tropical/subtropical Pacific from the literature. Historical data is shown in gray. All latitude/longitude data and the years of sampling are shown in the legends. The literature total dissolved Hg data come from Munson *et al.* (2015), and some dissolved Fe, Zn, and Cd data come from Conway and John (2015). The rest of the dissolved metals data is unpublished from the GEOTRACES GP15-PMT cruise (Fitzsimmons, unpublished) and should be considered preliminary.



5.13 Geological Properties

5.13.1 Sediments

Sediment characteristics have been investigated from 235 sites across the whole of NORI-D as part of the resource definition efforts (i.e., Campaigns 3, 6A and 6B); and at 14 sites across the CTA and PRZ as part of the environmental investigations (i.e., Campaigns 5A and 5D). Results from both sources are presented as together they provide a more complete assessment sediment quality not only in the CTA and PRZ, but across the wider NORI-D lease. In this context, it is acknowledged that some of the sampling techniques employed as part of the resource definition efforts are not consistent with the direction in ISBA/25/LTC/6/Rev.1. Resource data is presented as a compliment to that collected during the environmental investigations and not as a substitute.

5.13.2 Resource Definition Campaigns 3, 6A and 6B

During Campaigns 3, 6A and 6B seafloor sediment chemistry samples were collected from 235 sites across NORI-D as shown in Figure 5-52. The following section describes the data gathered during these campaigns that is relevant to the physicochemical baseline of NORI-D in the context of the Collector Test. Details on the activities and methods employed on each campaign can be found in the relative source documents (Fugro, 2018; ERIAS, 2020).

5.13.2.1 Sediment Particle Size

Fugro (2018) reports the percent passing by weight for sieve size 32 µm ranged from about 73% to 99%[5], while 100% of samples passed 250 µm. All samples were classified as clay or calcareous clay. Hydrometer results showed that the <2 µm fraction ranged from 13% to 88%. By comparison, Halbach and Abram (2013) found the particle size of 88.6% of surface sediments in the eastern part of the CCZ (west of the current sampling area) was less than 4 µm, thereby classifying the bulk of the sediment in that area as clay or silty clay.

Sediments were generally described by Fugro (2018) as:

> *a thin veneer (about 6-cm thick) of surficial very soft dark brown semi-liquid clay generally grades into very soft, dark brown clay to core penetration depths between 0.27 to 0.50 m bsf (below sea floor). At about 0.15 m bsf, typically, a colour change from dark brown to light brown occurs. Evidence of bioturbation of the light brown layer is indicated by mottling with dark brown and brown clays.*

Particle size distribution (PSD) data will continue to be collected as part of the ongoing baseline studies.

5.13.2.2 Metals

(a) Vertical Variability

Analyses of metals were undertaken on the 0 to 1 cm, 1 to 5 cm and 5 to 10 cm sections of cores collected on Campaign 3 (26/4 to 5/6/18) and 0 to 10 cm core sections collected during Campaign 6A (19/8 to 1/10/19) and Campaign 6B (22/11 to 21/12/19). The results show few consistent trends across sites in terms of metal concentrations with depth ERIAS (2020), although the following observations are noted:

- A number of sites have maximum metal concentrations (aluminium (Al), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), nickel (Ni), vanadium (V) and zinc (Zn))

[5] Fine sand = 75 to 425 µm, silt = 2 to 75 µm, clay <2 µm (Fugro, 2018).

in the surface 0 to 1 cm section, while at other sites the maximum metal concentrations occur in the 1 to 5 cm or 5 to 10 cm sections.

- Some metals exhibit virtually no change in concentration with increasing depth.

To allow comparison with the Campaign 6A and 6B sites, where samples represented a single depth (i.e., 0 to 10 cm), the results from Campaign 3 were combined to calculate a weighted average for the entire 0 to 10 cm core depth, that is, the results were integrated to present a single value for each site rather than three individual values. These results are presented in detail in the source report (ERIAS, 2020), a summary is provided below.

There are no universally accepted guidelines for deep-sea sediment quality. In the absence of standards relevant to highly mineralised areas, such as the CCZ, assessment of the laboratory data was undertaken based initially on screening quick reference tables (SQuiRTs) published by NOAA. Comparison of total metal concentrations has been made with the SQuiRT “Effects Range-Low” ERL and “Effects Range-Medium” ERM guidelines. This comparison shows the following:

- All Ni results exceeded the SQuiRT ERM (51.6 mg/kg) with the maximum being more than ten times that value (950 mg/kg) and the minimum two to three times the ERM (130 mg/kg). The median value was 224 mg/kg.

- All cadmium (Cd) results were below the SQuiRT ERM (9.6 mg/kg), with five of the results being higher than the SQuiRT ERL (1.2 mg/kg).

- The majority of mercury (Hg) results were equal to or less than the SQuiRT ERL (0.15 mg/kg), with three values lying between the ERL and ERM values (including one value that was reported as <0.16 mg/kg). One value exceeded the ERM (0.71 mg/kg).

- Most Zn results were less than the ERL (150 mg/kg); however, around a quarter of values were between the ERL and the ERM (410 mg/kg). The median value was 138 mg/kg (that is, below the ERL).

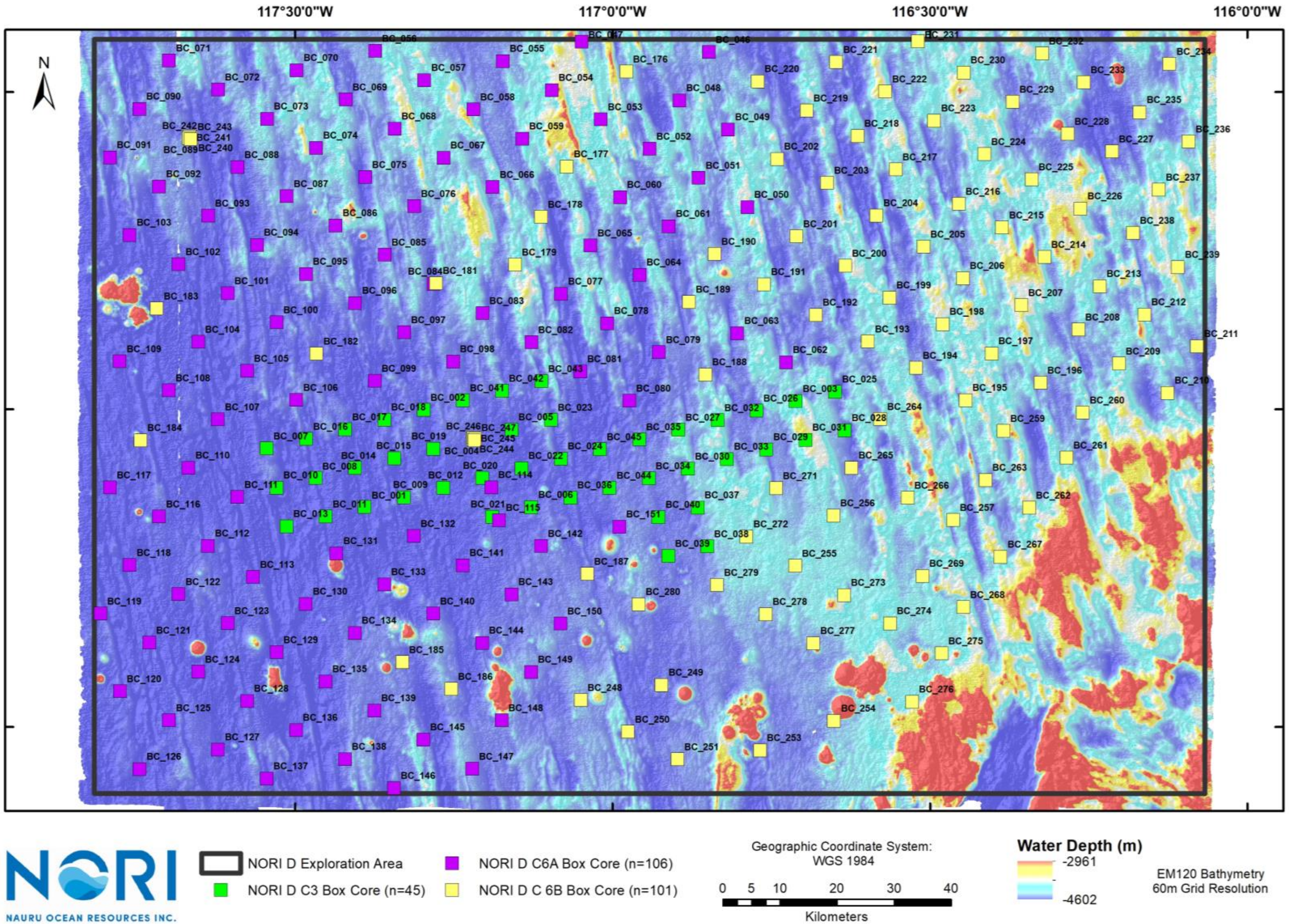
- All Cr results were lower than the SQuiRT ERL (81 mg/kg), with the highest value (including calculated weighted averages of sectioned cores) being 31 mg/kg. Results for Cr(VI) were no more than 50% of the total Cr values.

- All Pb results above the limit of reporting were less than the SQuiRT ERL (46.7 mg/kg), with the exception of two results, with the highest value (including weighted averages where appropriate) being 61.1 mg/kg.

- Most Cu results exceeded the SQuiRT ERM (270 mg/kg), with the maximum being 1,260 mg/kg. Only one result was between the ERL and ERM, and no results were less than the ERL (34 mg/kg). The median value was 442 mg/kg.

- The concentrations of a number of metals/metalloids were lower than the limits of reporting for all samples, with varying reporting limits due to different dilution requirements to address matrix effects. These include antimony (Sb) <100 to <150 mg/kg, arsenic (As) <34 to <110 mg/kg, boron (B) <69 to <110 mg/kg, selenium (Se) <34 to <110 mg/kg, silver (Ag) <3.4 to <5.0 mg/kg, thallium (Tl) <68 to <110 mg/kg and uranium (U) <0.63 to <1.1 mg/kg. Of these metals/metalloids, SQuiRT guideline values are available for As and Ag. The reporting limits achieved for As and Ag in most samples were higher than SQuiRT ERM and ERL guideline values, therefore assessment of compliance with these guidelines is not possible.

Figure 5-52. NORI-D seafloor sediment sampling locations



(b) Horizontal Variability

Horizontal variability in metal concentrations across NORI-D for selected metals is shown in Figure 5-53, with results presented as 'heat maps' that show changes in concentrations over the sampling area. Higher concentrations are shown in red and lower concentrations green. Points of note include:

- The spatial distribution of Ni and Cu values is very similar, with a number of higher values evident in the north-western, southern and central/eastern part of the sample area. A similar distribution is observed for the Zn values.
- The highest Cr values tend to be in the central part of the sample area trending towards the north.
- The highest Pb values are located in the northwest with a band of higher values also occurring in the central part of the area where Cr values are also high.

The mean metal concentrations in sediments determined from the NORI sampling campaigns are generally similar to these reported by Halbach and Abram (2013) for surficial sediments in the CCZ in an area west of NORI-D. Concentrations are also generally similar to typical values reported in the literature for deep-sea clays (Salomons & Förstner, 1984), apart from Al, Cr and Fe (which are two to four times lower in the NORI-D samples).

In terms of possible adverse ecological impacts, the results show that the naturally occurring Ni and Cu were significantly elevated at levels that are generally associated with adverse benthic impacts. Some Zn and Hg results also fall into this category. Other metals such as Cr and Pb were present at relatively low concentrations.

Sediment metals concentration data will continue to be collected as part of the ongoing NORI-D baseline studies.

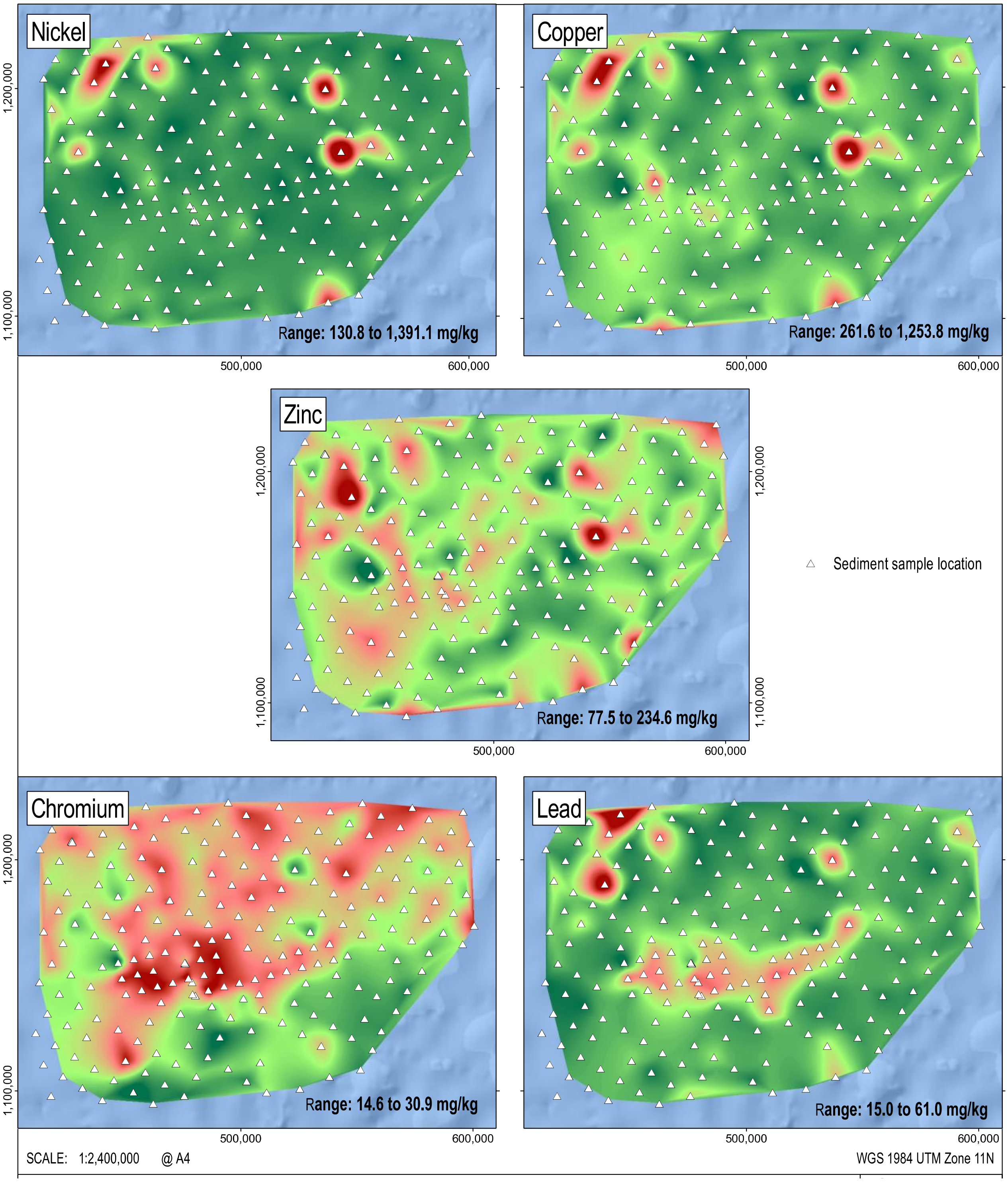
5.13.2.3 Carbon

Sediment samples collected during Campaign 3 showed no consistent trend in total carbon (TC) concentrations with depth, with some sites showing lower concentrations with increasing depth and others showing higher concentrations with depth. In contrast, a consistent trend was evident for total organic carbon (TOC) with concentrations increasing with depth in all samples (ERIAS, 2020).

Comparison of TC, TOC and total inorganic carbon (TIC) results obtained during Campaigns 3, 6A and 6B indicate the following:

- TOC values were consistent across samples from all three campaigns, with an average value of 0.47%.
- Average TIC values were slightly higher in samples from Campaign 6A and 6B conducted in 2019, than for those from Campaign 3 conducted in 2018.
- In terms of spatial variation, TC and TIC showed considerable variability between sampling sites; however, there was little variation in TOC between sites.

Figure 5-53. Relative variability of selected metal concentrations across NORI-D



5.13.2.4 Nutrients and Chlorophyll-a

Results for Total Phosphorus from sediment samples collected during Campaign 3 showed either no change in concentration between 0 to 1 cm and 5 to 10 cm or a notable increase, with all values then generally decreasing in the 5 to 10 cm samples. Not surprisingly, the highest values were obtained in the 0 to 1 cm sample at all sites, that is, at the sediment/water interface (ERIAS, 2020).

Total phosphorus concentrations for all sample sites ranged from 570 mg/kg to 2,310 mg/kg, which is within the range reported in the literature for open ocean sediments (i.e., 216 to 9,500 mg/kg; Filippelli, 1997). Little spatial variation was evident in total phosphorus concentrations, apart from a few elevated values, and one noticeably low value, with most samples having concentrations around 1,000 mg/kg.

Concentrations of nitrate and nitrite in all samples were below the limits of reporting.

Chlorophyll-a values were spatially highly variable, with concentrations ranging from non-detectable to 132.7 mg/kg.

5.13.3 Environmental Campaigns 5A & 5D

Benthic sediment samples suitable for biogeochemical baseline analysis have been successfully collected during Campaigns 5A and 5D from the CTA and PRZ; with additional pre- and post-disturbance sampling efforts scheduled in conjunction with the Collector Test. The objective of the study is to characterize the biogeochemistry of the benthic sediments seasonally, spatially and pre- and post-disturbance.

The techniques used to analyse the samples have been successfully implemented during the ABYSSLINE programme (e.g., Shulse *et al.* 2017). This includes a) bioturbation rates and mixed-layer depths estimated from excess 210Pb profiles of core replicates; b) sediment porewater analysed for nutrients, metals and alkalinity; C) sediments analysed for Total C, N, total organic carbon (TOC) and total inorganic carbon (TIC); analysis of the physical properties of the sediment i.e., specific gravity, bulk density, porosity, grain size and shear strength.

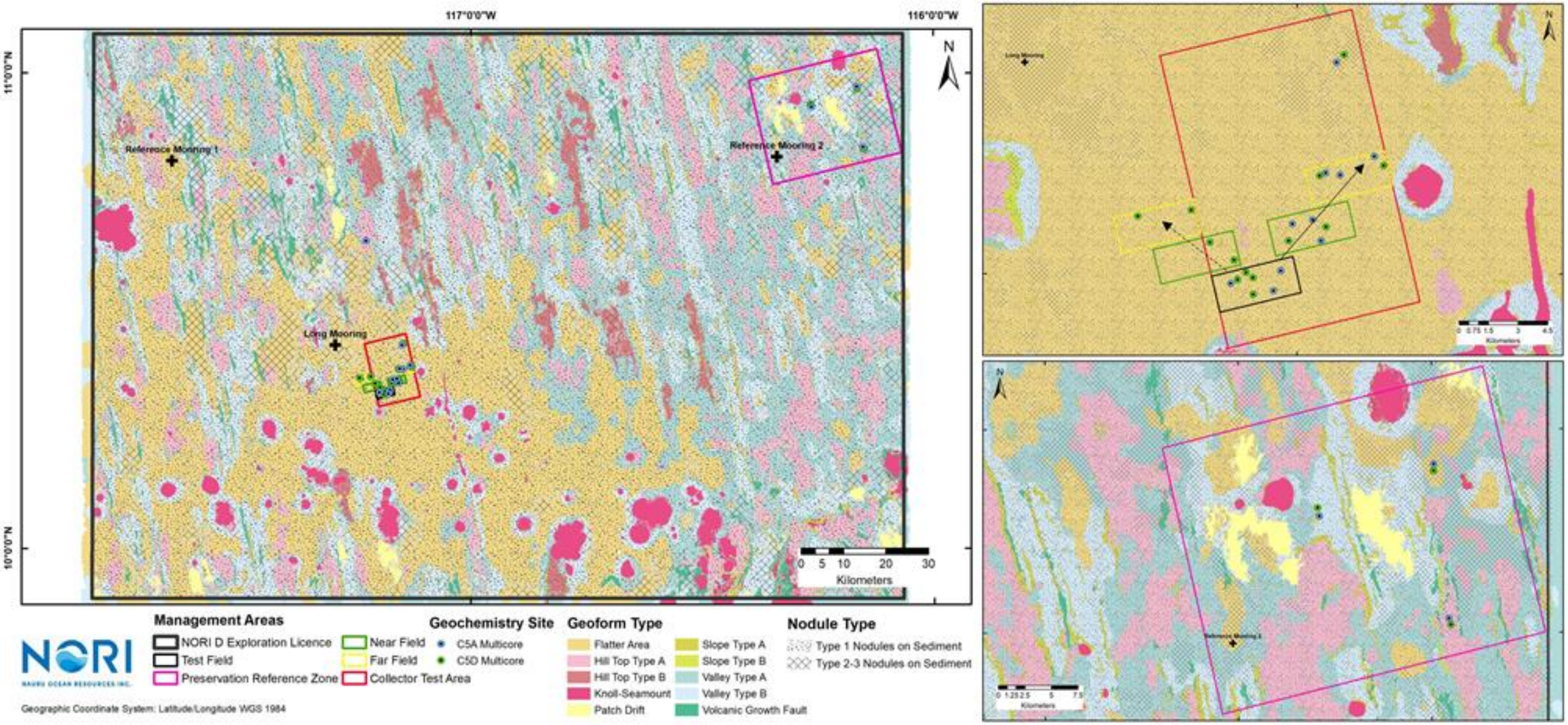
Further details of how sediment samples were collected, processed and analysed can be found in the source reports (i.e., TMC, 2020; 2021b; UOL, 2021).

5.13.3.1 Sample sites

On Campaign 5A 14 sites were sampled (Figure 5-54A), 3 in the Test Field (TF), 7 in the wider Collector Test Area (CTA), 1 northwest of the CTA (Figure 5-54B); 3 sites were also sampled in the Preservation Reference Zone (PRZ; Figure 5-54C).

On Campaign 5B the 14 sites sampled on Campaign 5A were resampled with two additional sites being added to the northeast of the TF (Figure 5-54B), for a total of 16 sites. The two additional sites were added opportunistically to expand the sample footprint to the northeast of the TF and increase pre-disturbance sample coverage.

Figure 5-54. Sediment geochemistry sample sites - Campaign 5A and 5D



5.13.3.2 Sample analysis

Analytical methods appropriate for the anticipated sample concentrations were used and the quality of analysis controlled by monitoring the reproducibility of standards measured alongside samples, and the reproducibility of repeat sample measurements. Accuracy was assessed by comparing measured standard values to certified reference values supplied by the manufacturer where available.

The following analyses were conducted on the sediment samples:

- Porewater Nutrients (SiO_2; PO_4; NO_3; NO_2; NH_4)
- Ex-situ porewater oxygen profiling and alkalinity
- Physical properties (porosity, dry bulk density and grain size)
- Inorganic Carbon (IC), Total Organic Carbon (TOC), Total bulk Nitrogen and associated stable isotopes
- Metal concentration and iron mineral extractions
- Radio-isotopes (^{210}Pb)

Full methodology for all the analyses performed is provided in the source document (Woulds *et.al.*, 2021).

5.13.3.3 Porewater nutrients

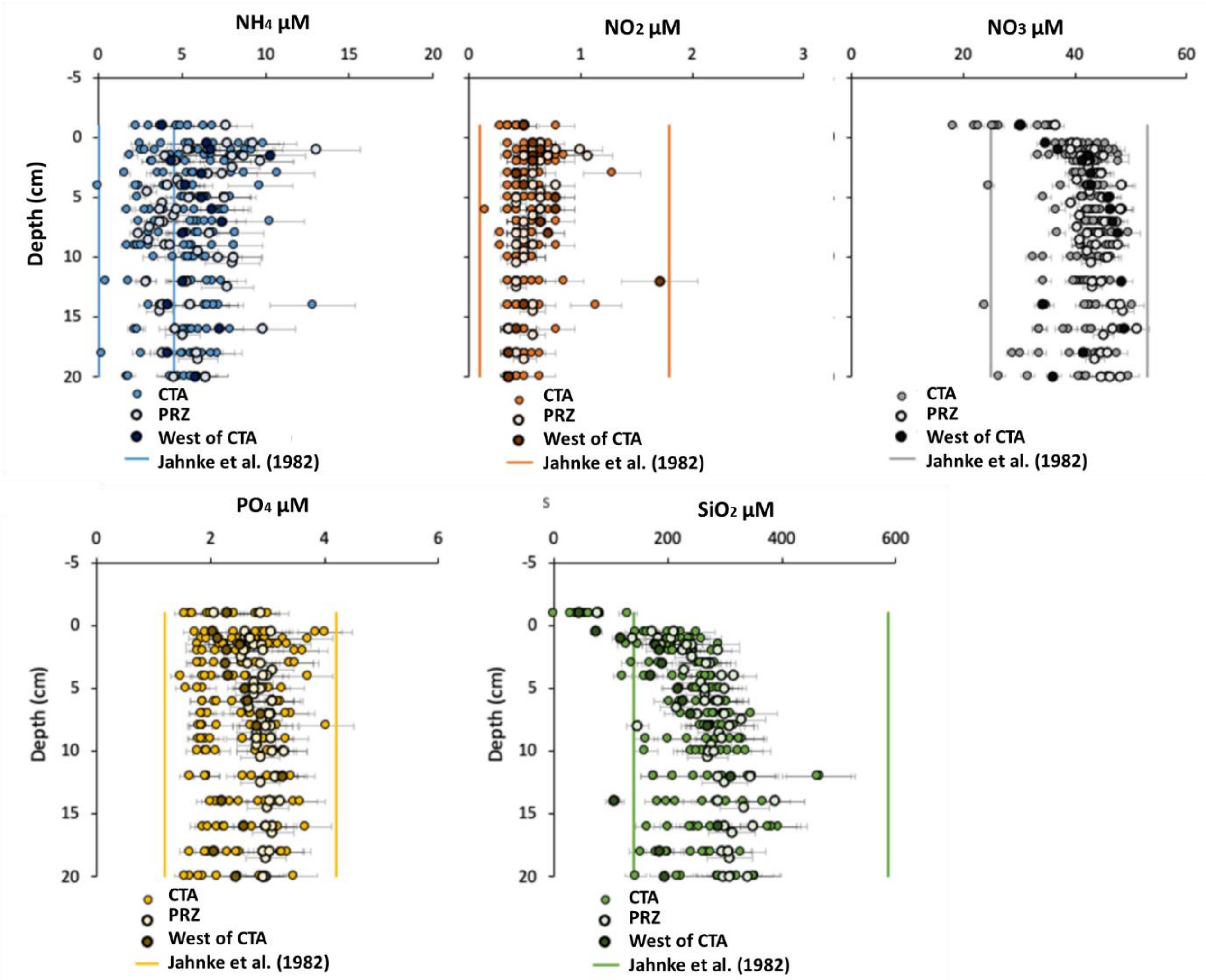
Analysis of samples from 5A have been completed for the following porewater nutrients: silicate (SiO_2), phosphate (PO_4), nitrate (NO_3), nitrite (NO_2), ammonia (NH_4), alkalinity, and ex-situ dissolved oxygen (O_2). Concentrations of all analytes were broadly within the range of values published previously for the closest CCZ sediments to the NORI-D block (Jahnke *et al.*, 1982).

Preliminary results from 5A indicate no discernible difference in the linear spatial trend of nutrient concentrations either at a local scale (i.e., between sites) or between the CTA and the PRZ (Figure 5-55).

Individual sites do exhibit concentration variability with profile depth that is in the range of expected concentrations. There was also a difference in nutrient concentrations between bottom waters (i.e., <0 depth) and porewaters (i.e., >0 depth) with lower nutrient concentrations observed in bottom waters.

For most nutrient species there were no discernible downcore trends observed, with concentrations remaining relatively constant with depth. This is consistent with low organic C concentrations and slow organic matter remineralisation. In the case of nitrate and nitrite profiles it is also consistent with oxic conditions throughout the depth studied, and the lack of nitrate or nitrite reduction processes. Silicate did show an increase in concentration with depth in the sediment, consistent with ongoing silica dissolution with time.

Figure 5-55. Porewater concentrations of nutrients colour coded for sample area.

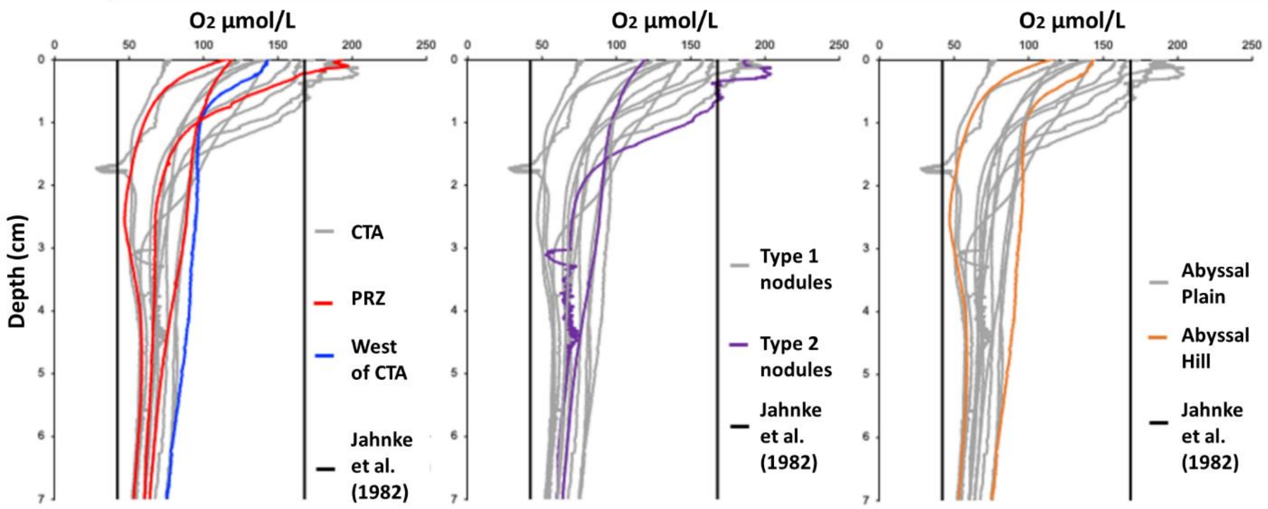


5.13.3.4 Porewater Oxygen (ex-situ) and Alkalinity

O_2 profiles measured during 5A decrease relative to bottom waters within the first 1-2 cm of sediment as is oxygen is consumed by microbial oxic respiration (Figure 5-56). O_2 concentrations then remain relatively constant from a depth of 2-10 cm at 75 ± 15 µM due to a balance between O_2 supply from bottom waters diffusing down into the sediment and O_2 consumption by respiring microbes. The fact that O_2 did not decrease to zero within 22 cm depth is an expected but notable feature of CCZ sediments. It should be noted that whilst the shape of O_2 profiles will reflect the balance between O_2 diffusion and consumption, exposure to atmosphere once cores are recovered on deck will inevitably lead to a change in O_2 concentrations. This was minimised to the extent possible.

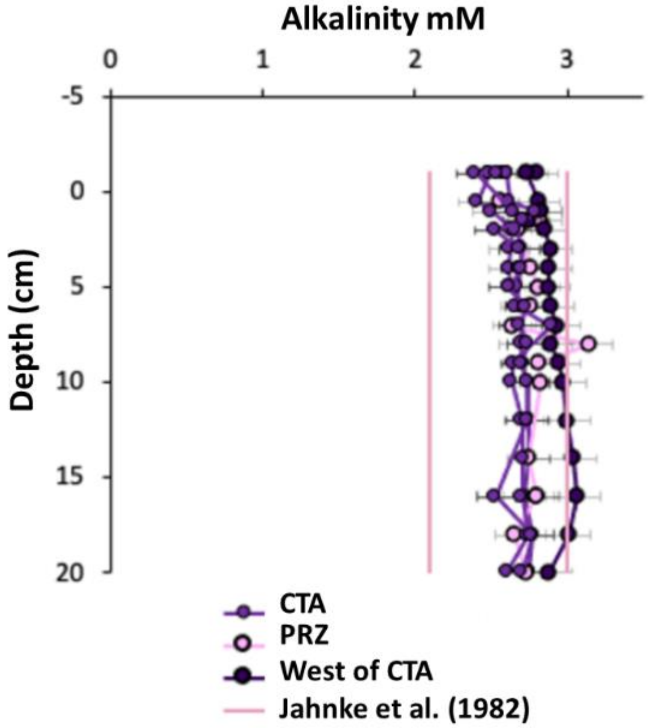
The sediment O_2 concentrations recorded are consistent with those reported by Jahnke *et al.*, (1982). And there was no clear evidence of sediment O_2 concentrations differing discernibly either spatially (i.e., CTA vs PRZ), with nodule type (i.e., Type 1 vs Type 2), or with geoform (i.e., Abyssal Plain vs Abyssal Hill). Figure 5-56. Ex-situ oxygen profiles colour coded for sample region, nodule type and geofrom (left to right).

Figure 5-56. Ex-situ oxygen profiles colour coded for sample region, nodule type and geofrom (left to right).



Alkalinity concentrations were constant across all sites at 2.8 ± 0.2 mM to a maximum depth of 22 cm, suggesting negligible change in carbonate chemistry across the sediment water interface and with depth (Figure 5-57).

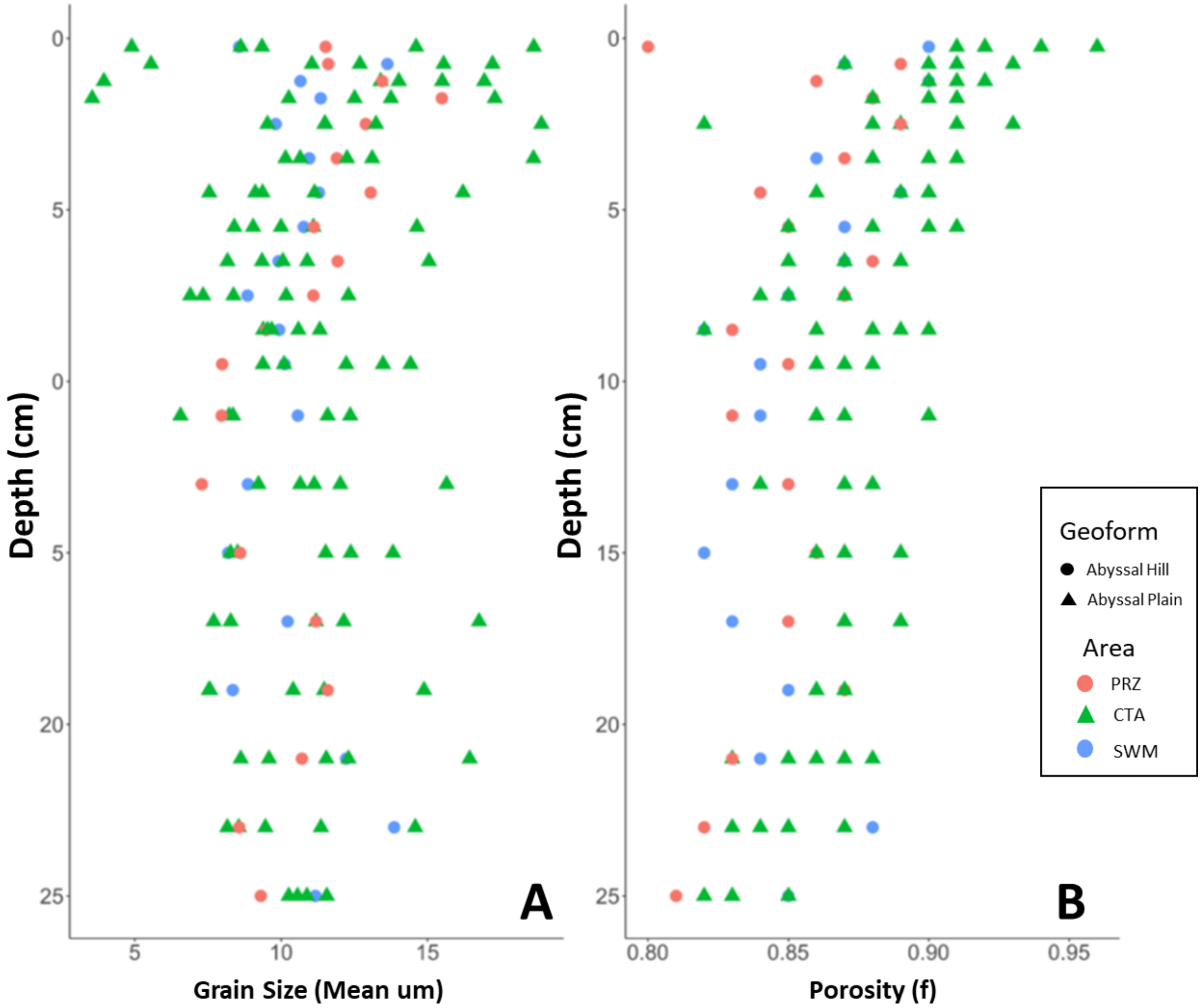
Figure 5-57. Porewater alkalinity results colour coded for sampling region.



5.13.3.5 Physical Properties

There are no notable differences in the grain size or porosity of sediment between local sample sites or between the CTA and PRZ (Figure 5-58). The average grain size was 11 ± 3 µm (n = 139) and average porosity was 0.87 ± 0.03 which is to be expected for deep sea pelagic clay rich sediment. Grain size appears to be finer than the only other published data for the CCZ (Mewes *et al.*, 2014). This is likely due to a difference in methods used as Mewes *et al.* (2014) sieved their samples and did not have a particle analyser capable of measuring particles <2 µm whereas the particle analyser used in this study can detect particles as small as 0.001 µm.

Figure 5-58. Mean grain size (A) and porosity (B) of sediment samples. Colours indicate sample region, shapes indicate geoform



5.13.3.6 Sediment TOC, IC, Bulk N and associated stable isotope analysis

The concentration profile of TOC with depth across all 5A sediment cores is similar (

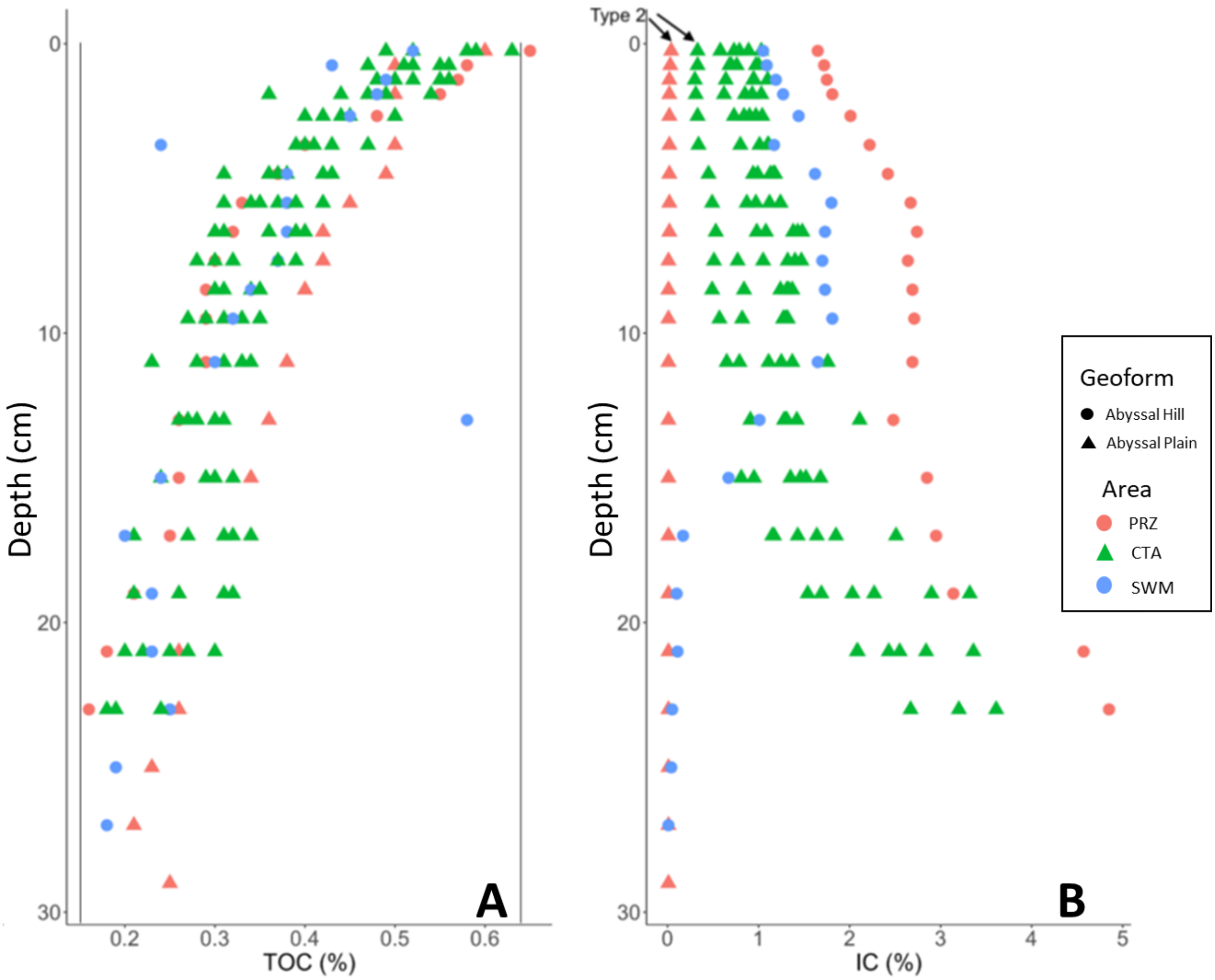
Figure 5-59A) with low TOC content typical of deep-sea sediments and within the range of previously measured TOC values in the CCZ (0.2-0.7 wt %). Profiles show the highest concentrations of TOC in surface sediment decreasing with depth typical of deposition of organic matter in surface sediments which is degraded by microbial respiration with burial in the sediment. The highest TOC concentrations in the NORI-D claim area are ~0.6 % which is the same as the adjacent BGR claim area (Volz *et al.*, 2018).

Depth profiles of IC generally increased with depth except for two sites (

Figure 5-59B). Whilst IC values and the profile shape appear to be similar within the CTA, 2 sites from outside the trial mining area had the highest IC concentrations in the top 10 cm and the sites with the lowest concentration were those with type 2 nodules. This variability could be related to the abundance of calcifying forams at different sites and/or the depth of the sediment surface relative to the calcite compensation depth (CCD) of the water column. The CCD is the depth at which temperature, pressure and water column chemistry result in the dissolution of solid phase inorganic carbon minerals such as calcite. In the Pacific the CCD is at a depth of 4200-4500 m below sea level which is similar to the depth of the sampling sites.

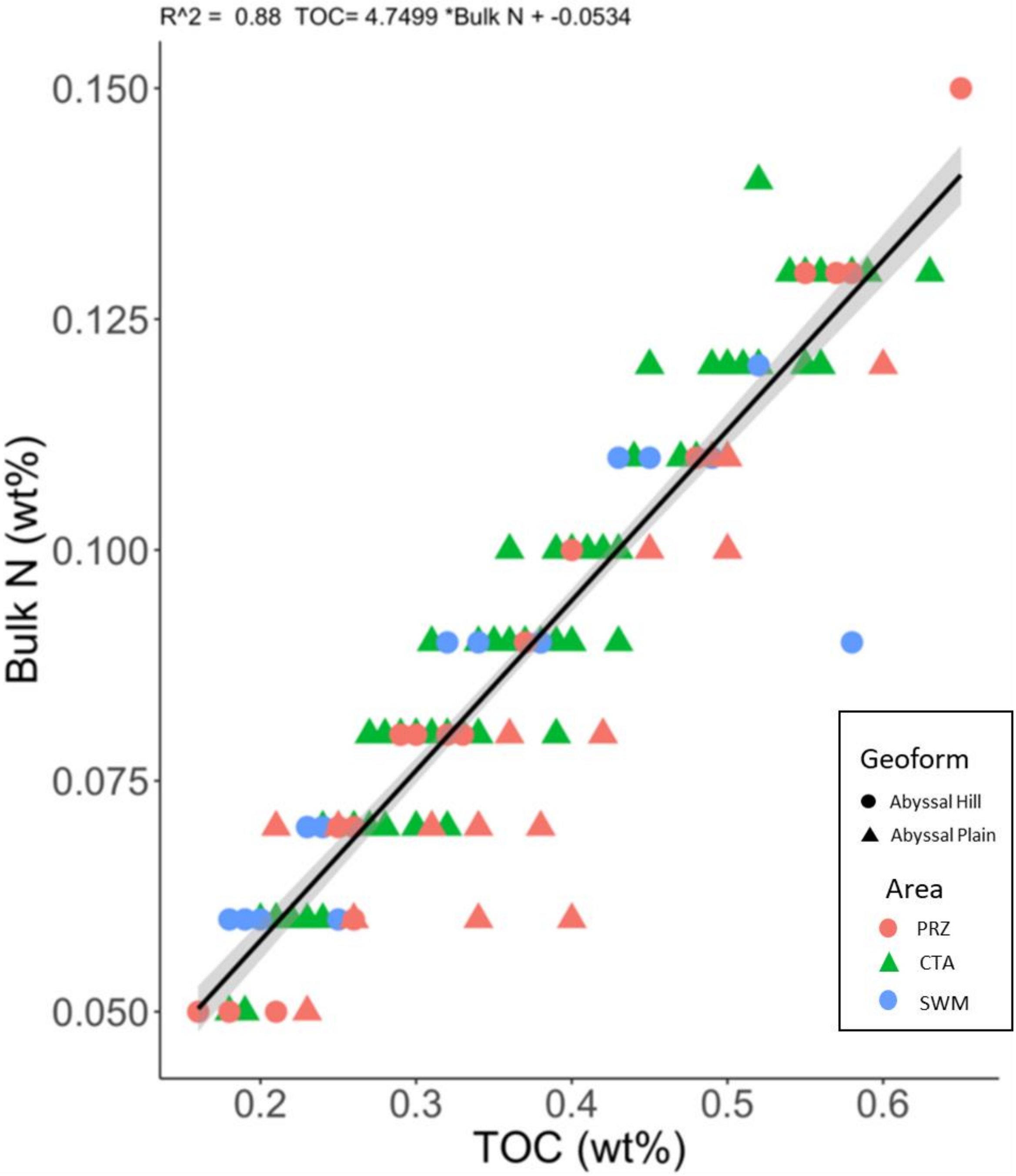
IC data can also be compared with sample site elevation to further test whether site depth relative to the CCD impacts IC concentrations.

Figure 5-59. Inorganic carbon (wt %) and total organic carbon (wt %) in sediments. Colours represent different sampling region and shapes indicate geoform.



There is no notable difference in bulk N content of sediment between different sample regions or nodule types. There is, however, a strong correlation (r2 = 0.88) between bulk N and TOC. This indicates that the vast majority of N in sediments is associated with organic matter in the sediments. Stable isotope data also showed no notable differences between the CTA and PRZ (Figure 5-60).

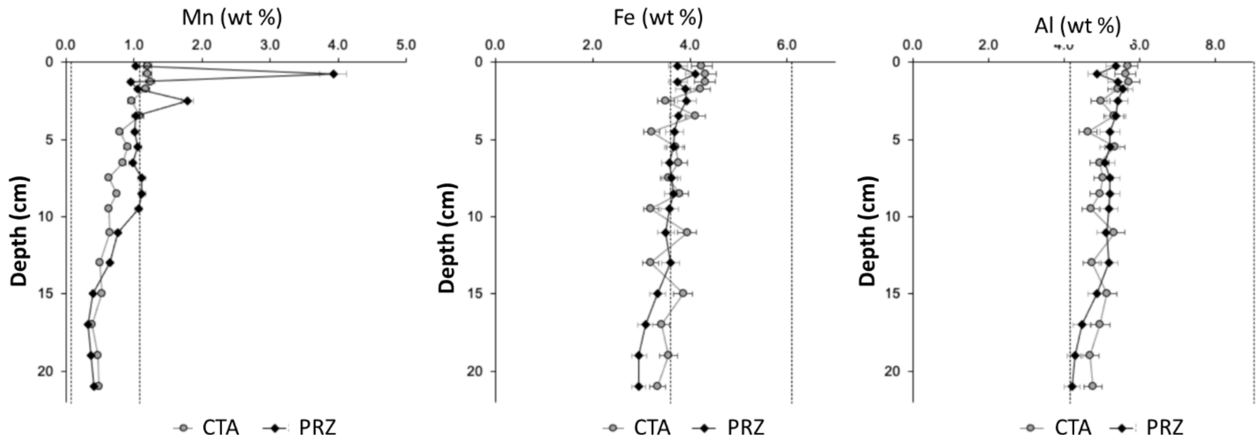
Figure 5-60. Bulk N content of sediment is correlated with TOC content.



5.13.3.7 Sediment total metals and Fe mineral extractions

Total metals data from Campaign 5A samples indicate negligible differences in metal content of sediments between the CTA and PRZ. This data set will be added to as samples from Campaign 5D are analysed. Key mineral forming metals (Mn, Fe, Al) show a gradual decrease with depth at both sites (Figure 5-61). This agrees with published Mn data and NORI-D Mn concentrations appear similar to that measured in other areas of the CCZ (0.05-1.09 wt % (Volz *et al.*, 2020)). Elevated Mn concentrations (4 wt %) were observed at one site at the same depth as sub-surface nodules were collected from the core. Indicating either that nodule fragments had broken off during sediment sampling or the presence of increased Mn minerals which may have contributed to nodule growth. Both Al and Fe concentrations were at the lower end of the range previously reported for CCZ sediments (3.7-6.1 wt % Fe and 5.9-9.8 wt % Al (Volz *et al.*, 2020b)).

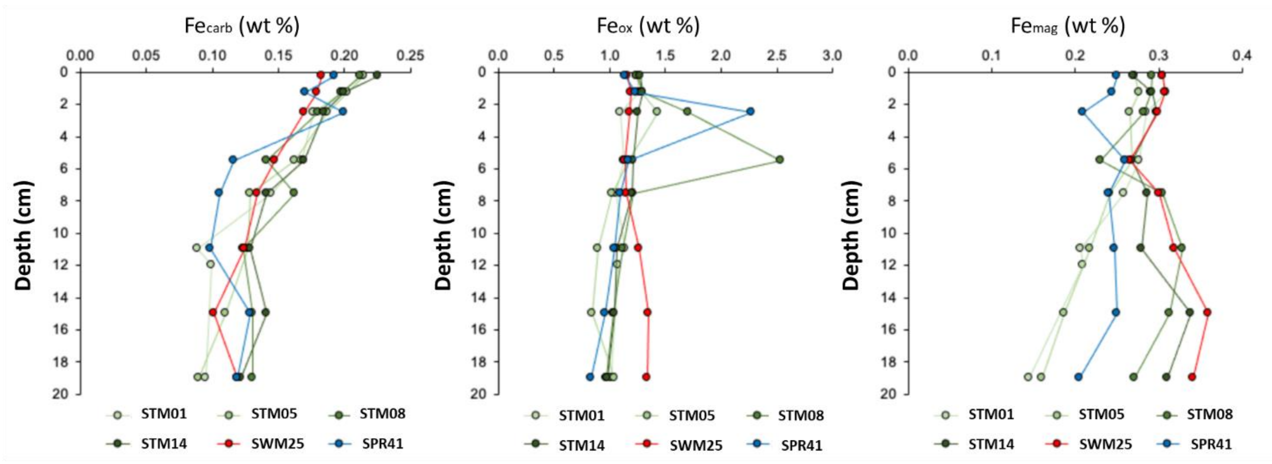
Figure 5-61. Preliminary data of on-going total metal analysis.



Note: Data still requires a minor correction for residual salt content. Dashed lines represent range observed in the CCZ in scientific literature (Volz *et al.*, 2018).

The majority of Fe was associated with the Fe_{mag} fraction suggesting most of the Fe in sediments are present as Fe minerals with a mixed oxidation state (Fe^{2+}/Fe^{3+}) (Figure 5-62). Variability in Fe_{mag} increased with depth and this could reflect variability in Fe mineral content between sites. Fe_{carb} and Fe_{ox} were similar between sites. Fe_{ox} concentrations show negligible change with depth except two subsurface peaks in concentration which could be related to sub-surface nodules. Fe_{carb} decreased with depth indicating that the Fe associated with this fraction is either lost to porewaters or other mineral phases during sediment diagenesis.

Figure 5-62. Fe mineral extractions from selected sites

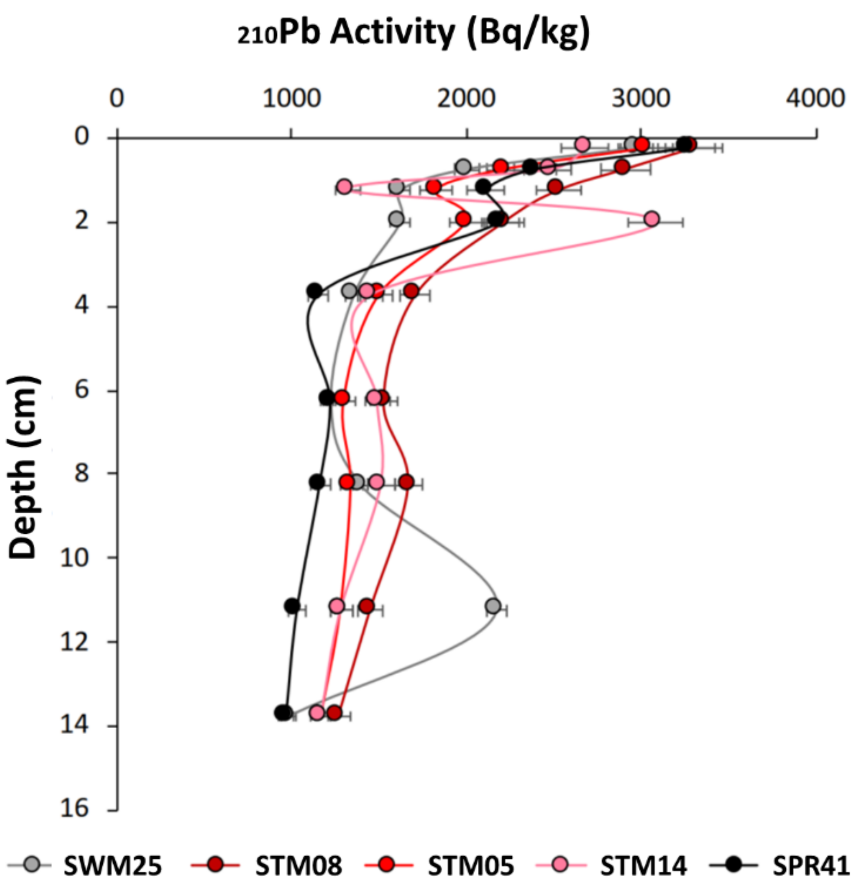


5.13.3.8 Radioisotopes (^{210}Pb)

Secular equilibrium was observed between ^{228}Ra, ^{228}Th and ^{208}Tl (considering the 35.9% branch of ^{208}Tl). ^{227}Th and ^{231}Pa are at secular equilibrium. ^{227}Th may thus be considered as an estimate of the ^{231}Pa activity (with a lower uncertainty). There is significant excess of ^{210}Pb, ^{231}Pa and ^{230}Th in comparison to the mother nuclides ^{226}Ra, ^{235}U and ^{238}U, respectively. Note that we do not report any significant ^{238}U activities (that can usually be determined by gamma spectrometry from the daughter nuclide ^{234}Th), despite presence of 235U.

Generally, ^{210}Pb activities decreased with depth as expected with younger surface sediment having higher activity than older sediment at depth. Higher ^{210}Pb activities were observed at 2 cm depth at STM14 and 11 cm depth at SWM25. Pre-disturbance bioturbation rates will be assessed by calculating $xs^{210}Pb$ this will be compared with post-disturbance rates calculated from data collected post-Collector Test.

Figure 5-63. 210Pb activities measured at key sites



5.13.3.9 Observations

Across almost all parameters analysed so far, no notable differences have been observed between the CTA and PRZ regions or between regions with different nodule types or geoforms. The only parameter that showed notable variability between sites was inorganic carbon and this may be related to changes in the abundance of calcifying benthic forams between sites.

With regard to the recommendations from the international seabed authority legal and technical commission. Of the 14 measurements recommended in Annex I, section 28 of the international seabed authority 2020 technical committee review (ISBA/25/LTC/6/Rev.1) all parameters were sampled for during Campaign 5A, with additional data from 5D to be added once the laboratory analysis has been completed. The only analysis recommended by the ISA that has not yet been completed is the complete analysis of dissolved metal species, which has been due to delays with lab infrastructure development caused by COVID-19.

All cores met the required minimum sampling depth of 20 cm. The ISA recommends measuring the change in redox profile depth which can be detected from changes in O_2 profiles but in the CCZ this change occurs several meters below the sediment surface, well below the minimum sampling depth of

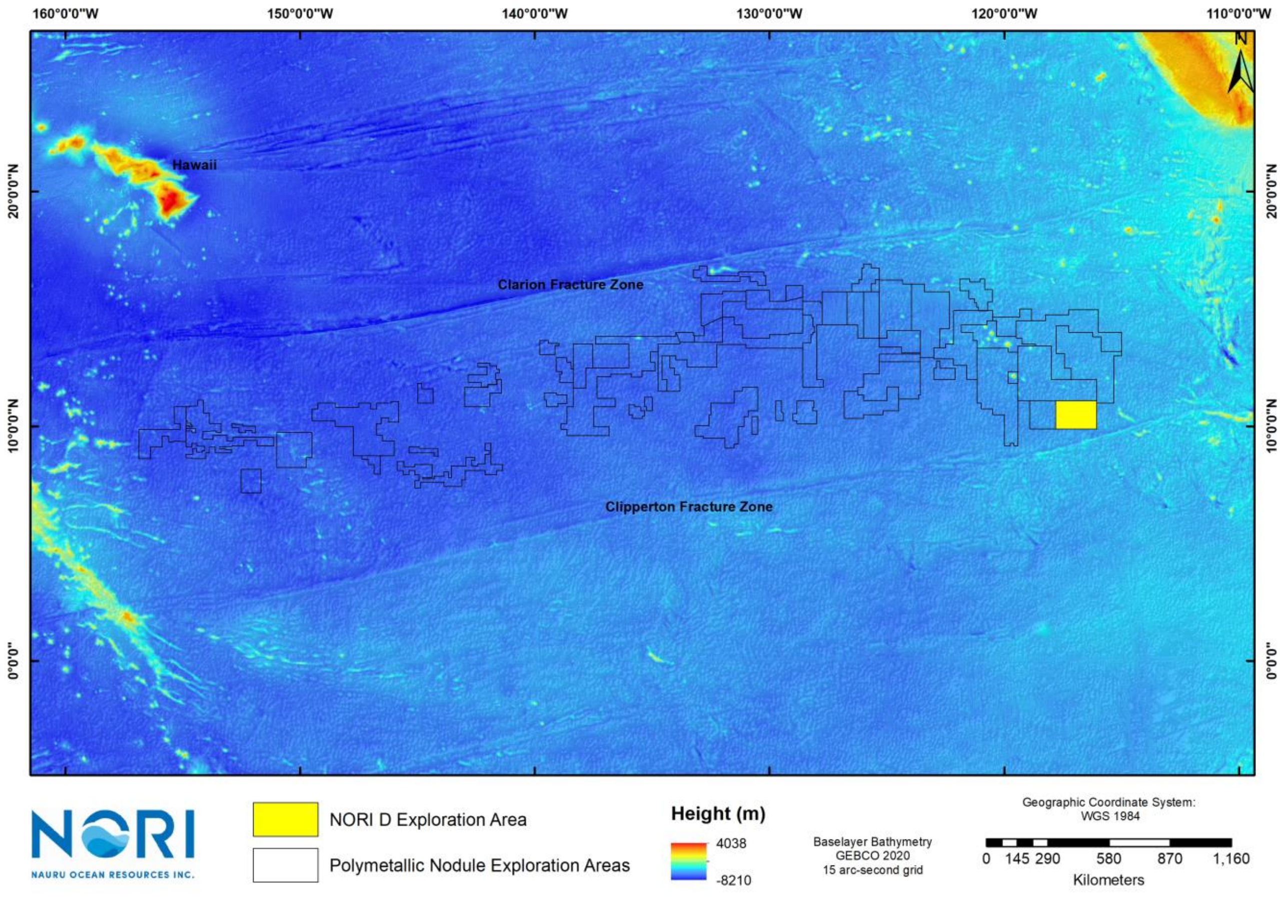
20 cm specified by the ISA. We therefore did not detect changes in redox profile associated with the onset of sub/anoxic conditions.

To assess bioturbation rates the ISA recommends sampling at least 6 depths from a core (0–0.5 and 0.5–1.0 cm; 1–2 and 2–3 cm; and 3–5, 5–7 and 7–9 cm) for 4 cores per site (e.g., tubes from separate multi-core drops. Analysis has been performed on 5 cores from 5A analysing all recommended depths plus 2 additional depths. Baseline rates and depths of bioturbation will be assessed by standard advection or direct diffusion-reaction models as recommended and compared with post-disturbance bioturbation rates after the Collector Test.

5.14 Bathymetry

The seafloor of the CCZ lies mostly between 4,000 and 6,000 m water depth and is characterized by numerous seamounts, some of which reach depths of less than 3,000 m. The widespread seafloor, oriented approximately orthogonal to the trend of the bounding fracture zones, provides a large number of flat-floored valleys, separated by irregular, often discontinuous ridges a few hundred metres high, as shown in Figure 5-64.

Figure 5-64. Bathymetric overview of the CCZ



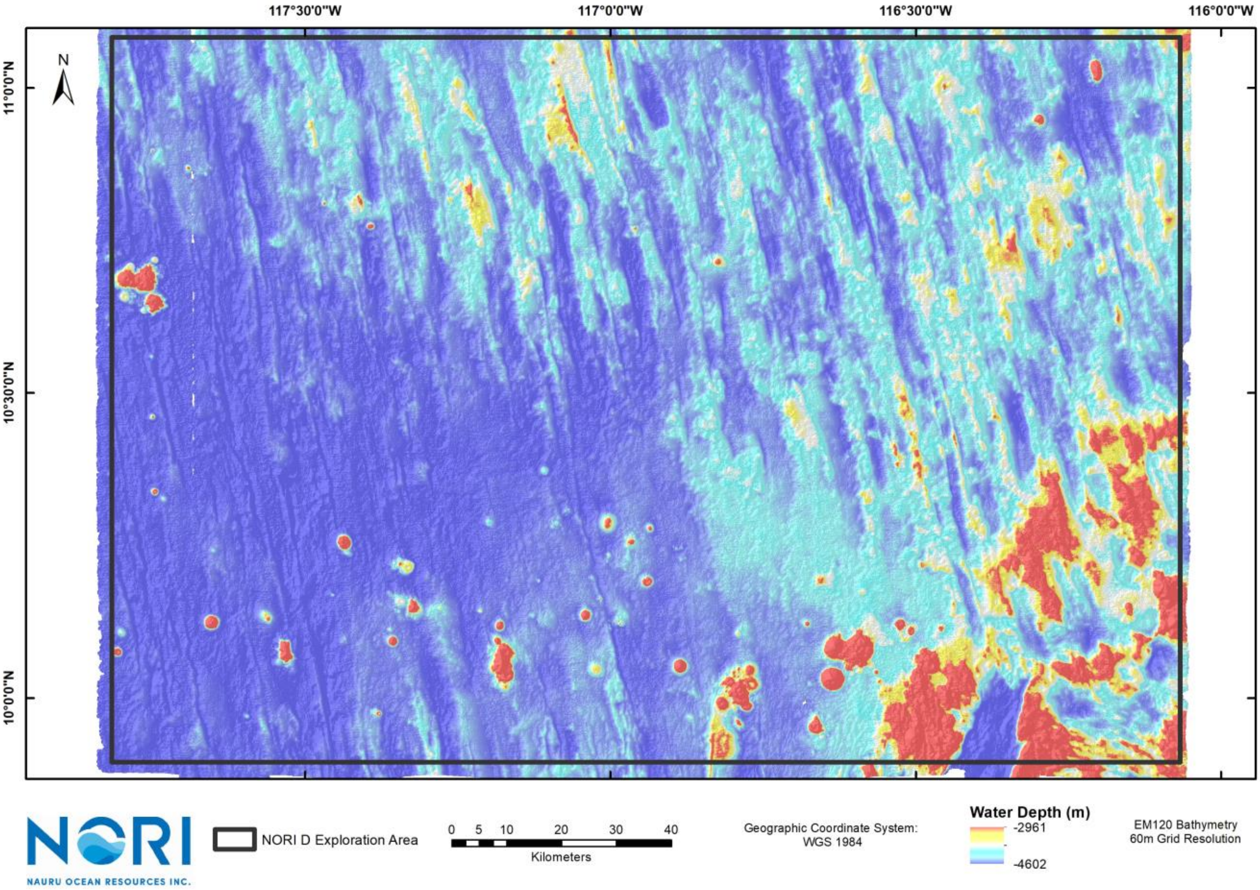
NORI-D shown as yellow box; other exploration areas outlined.

Bathymetric data from NORI-D was collected during Campaign 1 using a hull-mounted Kongsberg Simrad EM120 12 kHz, full-ocean depth multibeam system, with 25,720 km^2 of seafloor mapped. This multibeam bathymetry data was combined with backscatter data to locate areas of high nodule densities for targeted dredge sampling (Golder Associates, 2018).

Figure 5-65 shows several seamounts in the south of NORI-D, particularly in the southeast sector, and deeper waters towards the west. NORI-D is characterised by undulating seafloor topography with a mean slope of 2º but greater than 8º along ridges. Linear ridges are dominant across the northwest and southeast, with the most defined ridges found in the north.

The various seamounts in the area are all of submarine volcanic origin. Their formation is related to the seafloor spreading of the East Pacific Rise 18 to 22 million years ago (Barckhausen *et al.*, 2013). The East Pacific Rise is located to the west southwest of the area and is characterised as having the most volcanic activity in the CCZ (Vithana *et al.*,2019).

Figure 5-65. Bathymetry of NORI-D



5.15 Seafloor Characteristics

Two sediment types have been identified in the eastern CCZ, namely carbonate sediment (e.g., carbonate silts, clays and oozes) found predominantly in the southwest, and siliceous sediments (e.g., red clays, siliceous silts, clays and oozes) found predominantly in the west-northwest (BGR, 2019).

The occurrence of siliceous sediments in the western part of the CCZ is thought to be due to the greater water depths in this area, with increased solubility of carbonate minerals with increasing hydrostatic pressure (BGR, 2019).

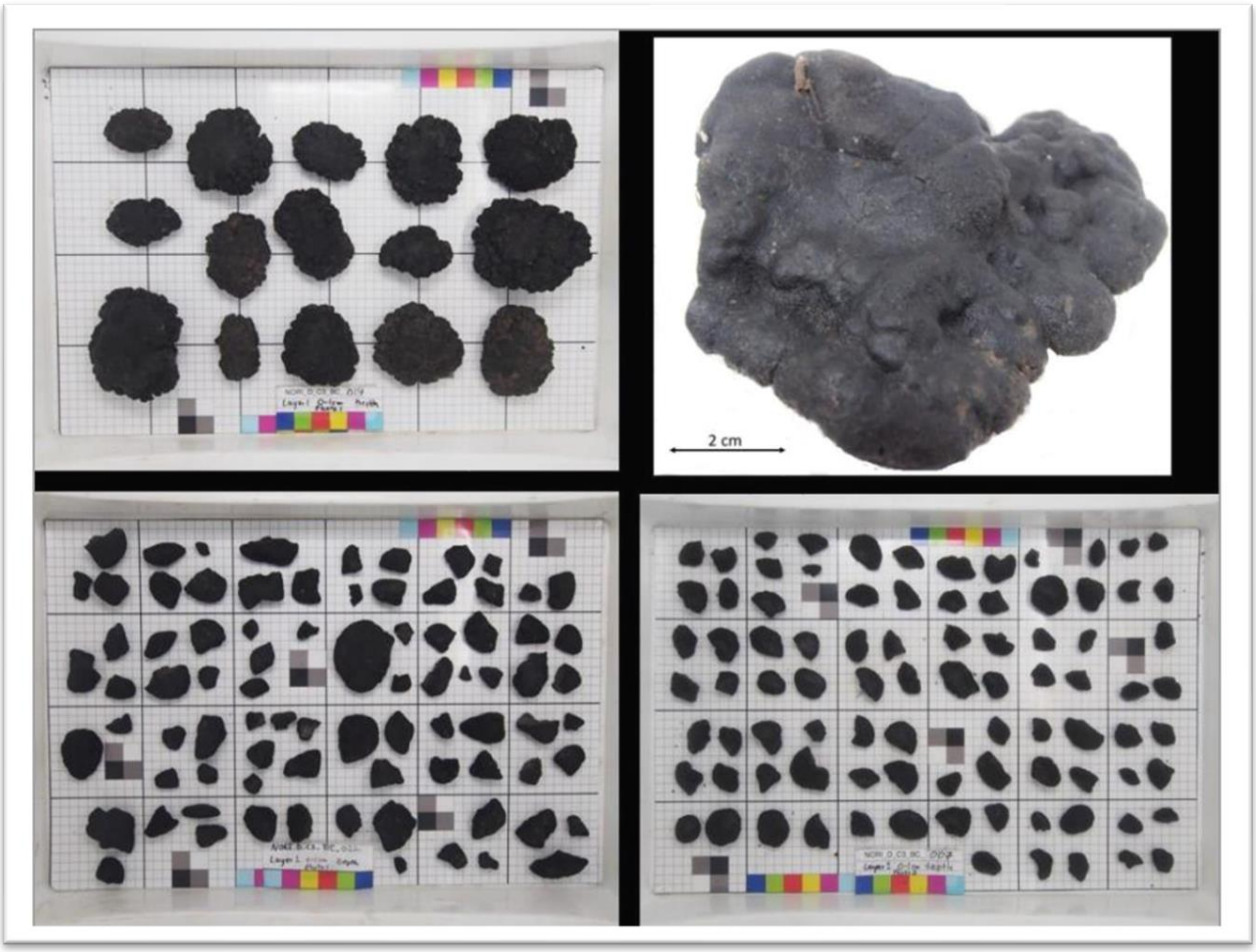
Results from field tests conducted on Campaign 3 (26/4 to 5/6/18) indicated that in NORI-D the shallow soil stratigraphy consists of a veneer (about 6 cm thick) of surficial, dark brown, very soft semi-liquid clay overlying very soft, dark brown clay to a maximum core penetration depth of about 0.5 m. At about 0.15 m depth, typically, a colour change from dark brown to light brown occurs. Evidence of bioturbation of the light brown layer is indicated by mottling with dark brown and brown clays (Figure 5-66). It was noted on the high-resolution geophysical survey data that a reflector at about 15 cm to 20 cm depth was consistently present across all the box-core sites sampled. This depth corresponds with the top of the light brown clay. Qualitative carbonate content testing typically indicates no reaction with dilute hydrochloric acid (10% concentration) (AMC, 2020).

Figure 5-66. Sediment cores from NORI-D showing sediment colour changes and mottling.

5.16 Nodules

Polymetallic nodules are black, potato-shaped concretions made up of multiple layers of hydroxides around a core and can contain metals of economic interest. Box-core sampling within NORI-D shows nodules in vary in size, with some nodules smaller than 4 cm in diameter while others are over 20 cm. Samples of nodule sizes collected are shown in Figure 5-67; more than half the nodules found in NORI-D are medium-sized (i.e., 8 to 12 cm diameter).

Figure 5-67. NORI-D nodule collection showing ranges of sizes



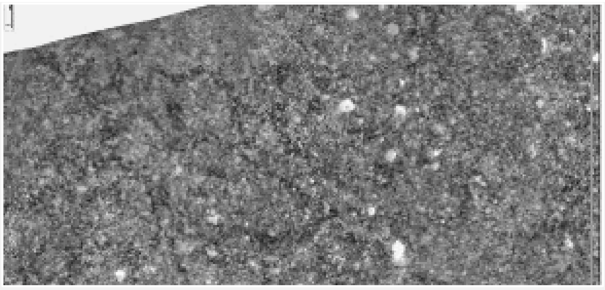
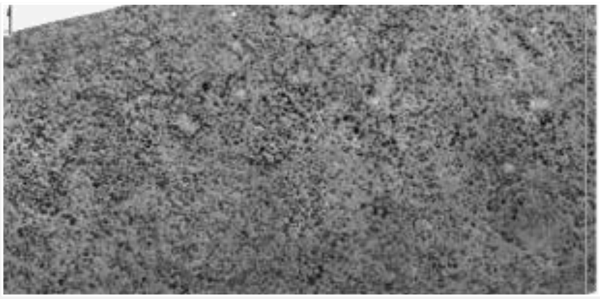
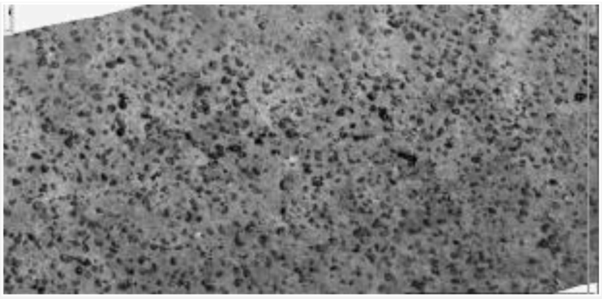
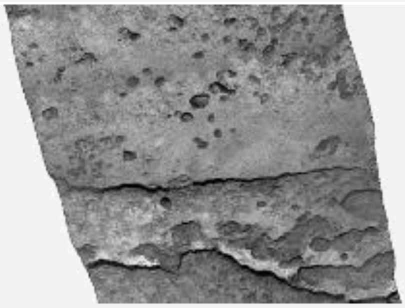
Notes: Upper left – example of large nodules with rough texture. Top right – close up of medium nodule.
Source: AMC (2019).

The following three classes of nodule distribution have been identified in NORI-D based on camera imagery.

- Type 1 is typically characterised by medium-sized (1 to 10 cm) and densely packed nodules. Many nodules are in contact with their neighbours and over 50% of the seafloor is occupied by nodules.
- Type 2 is characterised by lower nodule abundance, larger nodules (5 to 20 cm) and noticeable sediment gaps between individual nodules. Between 20 and 40% of the seafloor is occupied by nodules.
- Type 3 has sparser nodule abundance, nodules between 5 to 20 cm in size and increased sediment gaps between individual nodules. Between 10 and 20% of the seafloor is occupied by nodules.

Further description and photographic examples of nodule types is provided in Table 5-4.

Table 5-4. Nodule facies types

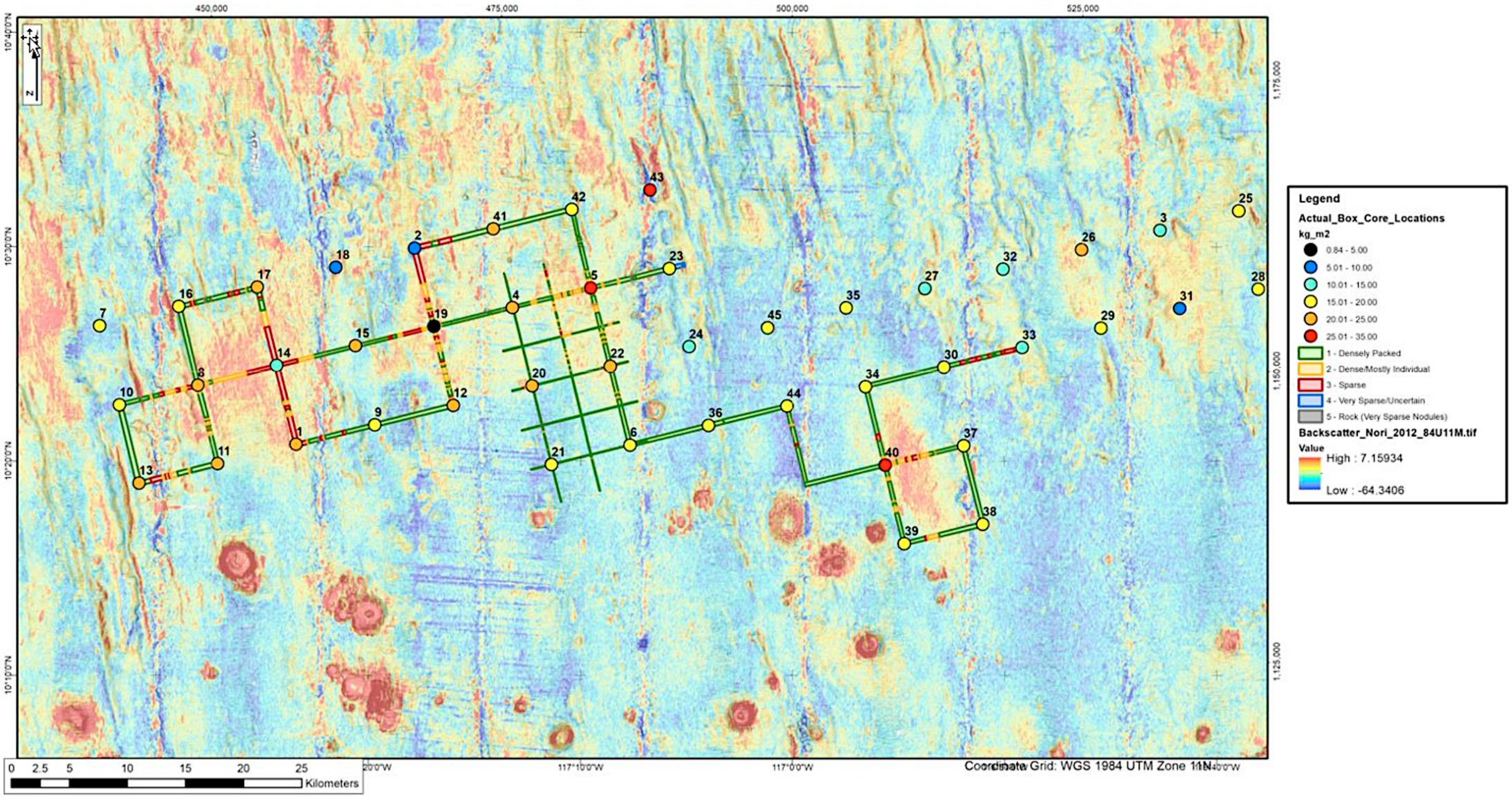
NODULE FACIES TYPE	DESCRIPTION	PHOTOGRAPHIC EXAMPLE
Type 1 – Densely packed and interconnected	More than 50% nodules are type 1. ~1 to 10 cm width. Low to moderate confidence in camera imagery to resolve individual nodules	
Type 2 – Mostly individual and locally interconnected	~20 to 40% nodules. ~5 to 20 cm width. Moderate to high confidence in camera imagery to resolve individual nodules	
Type 3 – Mostly individual and sparse	10 to 20% nodules. ~5 to 20 cm width. Moderate to high confidence in camera imagery to resolve individual nodules	
Other	Volcanic outcrop-associated with NW-SE ridges	

Source: AMC (2019).

Type 1 nodule facies are the most common, this trend is also found within the neighbouring German contract area and all four NORI contract areas (NORI, 2019). Type 2 and 3 nodule facies typically correlate with higher amplitude acoustic backscatter survey data. These correlations are shown in Figure 5-68 , which shows nodule classification according to AUV (coloured ribbon-track: Type1 (green), Type 2 (yellow), Type 3 (red)) against a background of acoustic backscatter data.

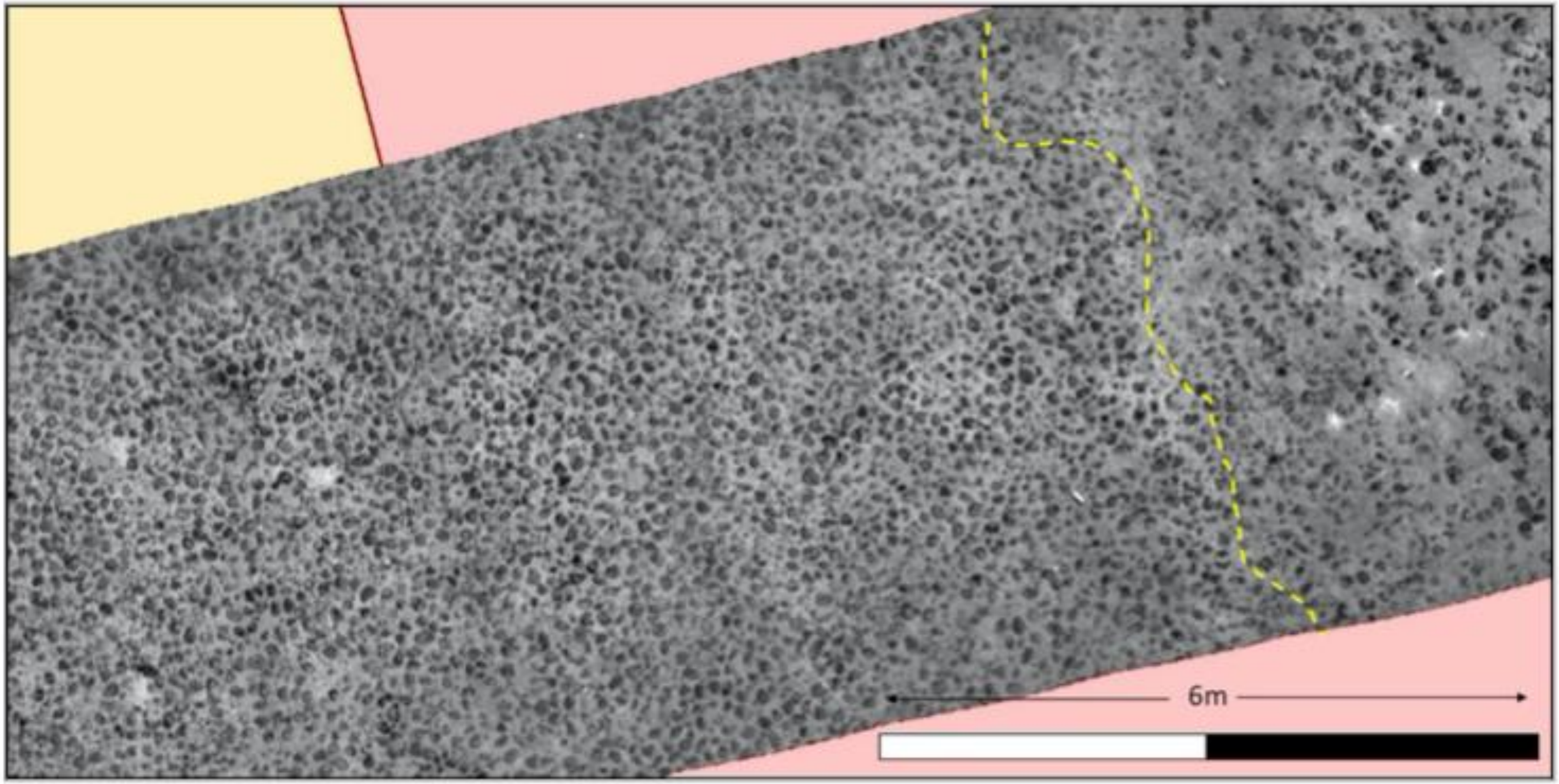
The backscatter responses are coloured by amplitude; high amplitude areas associated with Type 2 and 3 nodule facies are shown in warmer colours, with Type 1 represented by colder colours. Facies boundaries are often well-defined and variable over short distances (less than 100 m), as shown in Figure 5-69.

Figure 5-68. Nodule classification in NORI-D



Source: AMC (2019).

Figure 5-69. NORI-D camera imagery showing change from Type 2 (left) to Type 3 (right)



Source: AMC (2019).

5.17 Benthic Geoforms

5.17.1 Geoforms

Habitats are comprised of three primary components: geoforms, substrates, and biota. Habitat mapping requires an initial consideration of the abiotic components (geoforms and substrates) as the first spatial indicators or surrogates of the biotic component. Therefore, depiction of habitats, and progressive improvement of knowledge by later inclusion of biological data, which is typically more challenging to collect than abiotic data, is considered central to environmental management at the regional (1,000s km) and contract (100s km) scales (Fejer & Flynn, 2021).

Geoform mapping requires the development of a terrain classification for NORI-D using the same topographic variables used by McQuaid *et al.* (2020) as follows:

- GEBCO 2014 Bathymetry scaled down from native 30 arc-seconds grid to 2,000 × 2,000 m grid, reprojected to EPSG:3832.
- Fine-scale Topographic Positioning Index (TPI) on the GEBCO 2014 down-scaled grid: Inner radius 1, outer radius 5, with a scale factor of 10 km.
- Broad-scale TPI on the GEBCO 2014 down-scaled grid: Inner radius 1, outer radius 50, with a scale factor of 100 km.
- Slope calculated from the GEBCO 2014 down-scaled grid.

5.17.2 Geoform Classification

To calculate the preliminary geoform classification, cluster analysis was performed on a multidimensional raster matrix (raster stack). The raster stack consisted of the following:

- NORI-D bathymetry, collected by DeepGreen during a seabed mapping campaign in 2012–2013, down-scaled from a native 50-m grid to a 200-m grid.
- TPI calculated from the 200-m bathymetry grid.
- Terrain Ruggedness Index (TRI) calculated from the 200-m bathymetry grid.
- Slope calculated from the 200-m bathymetry grid.

Detailed methods for the application of the multivariate raster-based clustering algorithm known as “Clustering Large Applications” (CLARA) (Kaufman & Rouysseuw, 1990) can be found in (Fejer and Flynn, 2021).

5.17.3 Substrate Classification

Margin (2020) mapped substrates in NORI-D by segmenting and classifying the multibeam backscatter using the ISO Cluster algorithm in ArcGIS. Substrate classes were confirmed by analyzing a subset of boxcore data and imagery from cameras installed on the boxcorer and from an autonomous underwater vehicle (AUV) survey. Detailed methods for substrate mapping can be found in (Fejer and Flynn, 2021).

5.17.4 Mapping

The areal coverage of each geoform and substrate class within the final geoform and substrate maps was calculated as shown in Table 5-5 and Table 5-6.

Table 5-5. NORI-D geoform classification scheme

Level 1	Level 2	Level 3	Geoform Area (km^2)
CCZ abyssal plain	Abyssal hill	Hill Top Type A	3,644.90
-	-	Hill Top Type B	690.7
-	-	Valley Type A	5,534.30
-	-	Valley Type B	5,338.50
-	-	Slope Type A	1,641.40
-	-	Slope Type B	67.5
-	-	Volcanic growth fault	417.5
-	Flatter area	-	8,534.70
-	Knoll-seamount chain	Knoll-seamount	906.7
-	Sediment Drift	Patch Drift	262.2

Table 5-6. NORI-D substrate classification scheme.

Level 1	Level 2	Level 3	Substrate Area (km^2)
CCZ nodule-sediment veneer	Nodule-sediment veneer	Type 1 nodules on sediment	19,620.20
-	-	Type 2–3 nodules on sediment	4,253
CCZ bare sediment bed	Sediment drift	Patch drift	262.2
CCZ rock	Volcanic rock	Knoll volcanic rock	700.2
-	-	Growth fault volcanic rock	417.5

Figure 5-70. CCZ Level 1 classes of tectonic setting, geomorphology and algorithmic terrain classification.

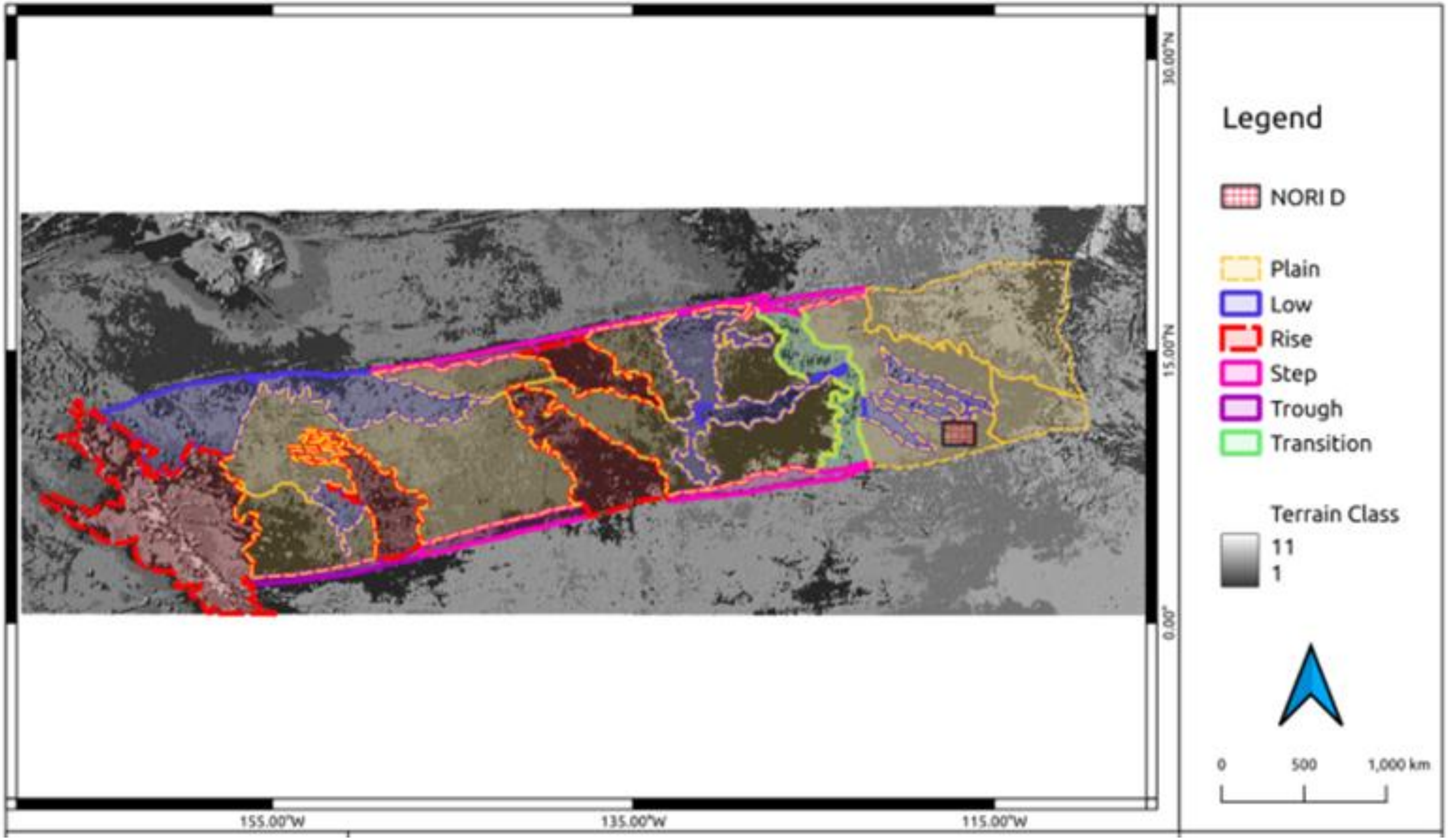


Figure 5-71. NORI-D Level 2 geoforms and Level 2 substrates

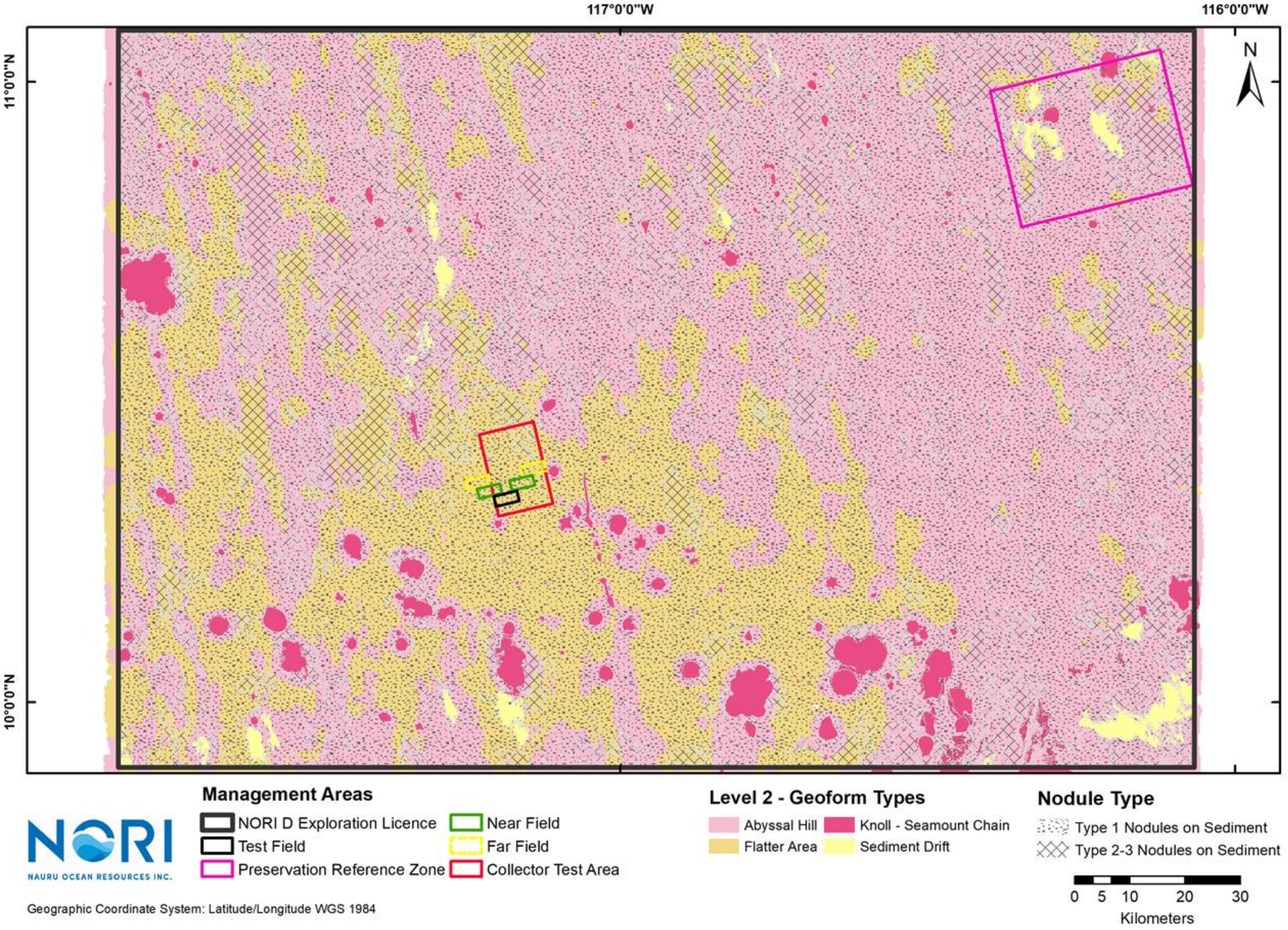
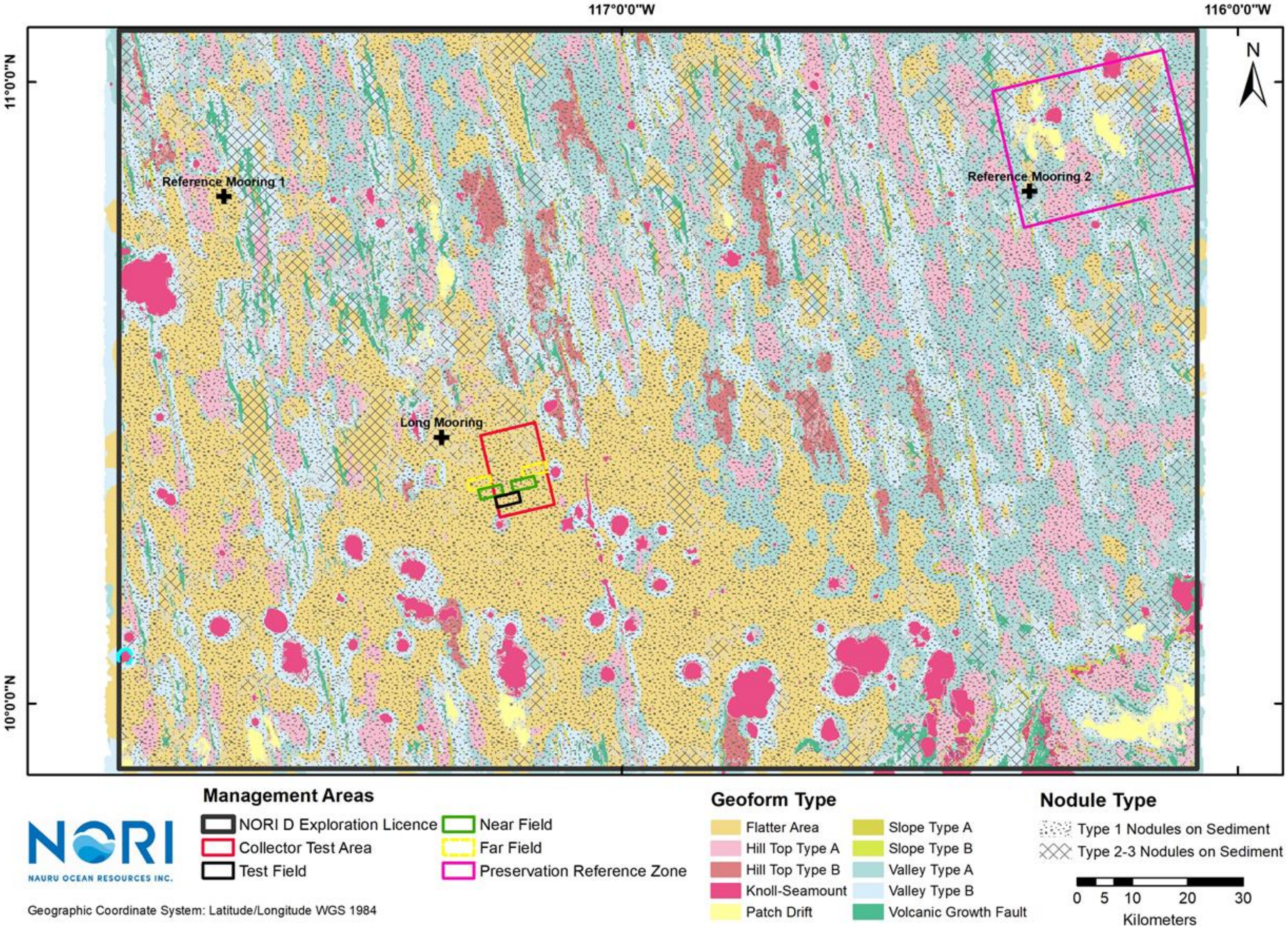


Figure 5-72. NORI-D Level 3 geoforms and Level 3 substrates



NORI-D is situated within an abyssal plain tectonic setting, thus the adoption of CCZ Abyssal Plain as the Level 1 class of the geoform classification scheme (Table 5-5; Figure 5-70).

In addition, the consolidated geoform classification established four Level 2 geoforms and nine Level 3 geoforms within NORI-D (Table 5-6; Figure 5-71 and Figure 5-72). ‘Flatter areas’ represent the largest geoform by area. Abyssal hills and seamounts have been shown to be higher in species richness and standing stock biomass compared to adjacent areas devoid of topographic variability (Clark *et al.*, 2009; Cuvelier *et al.*, 2020; Durden *et al.*, 2015, 2020; McClain, 2007; Ramirez-Llodra *et al.*, 2005; Rowden *et al.*, 2010). For this reason, the CTA has been located in the Level 2/3 ‘Flatter area’ rather than a Level 2 geoform- ‘Abyssal Hills’ to minimise the potential impacts to biodiversity.

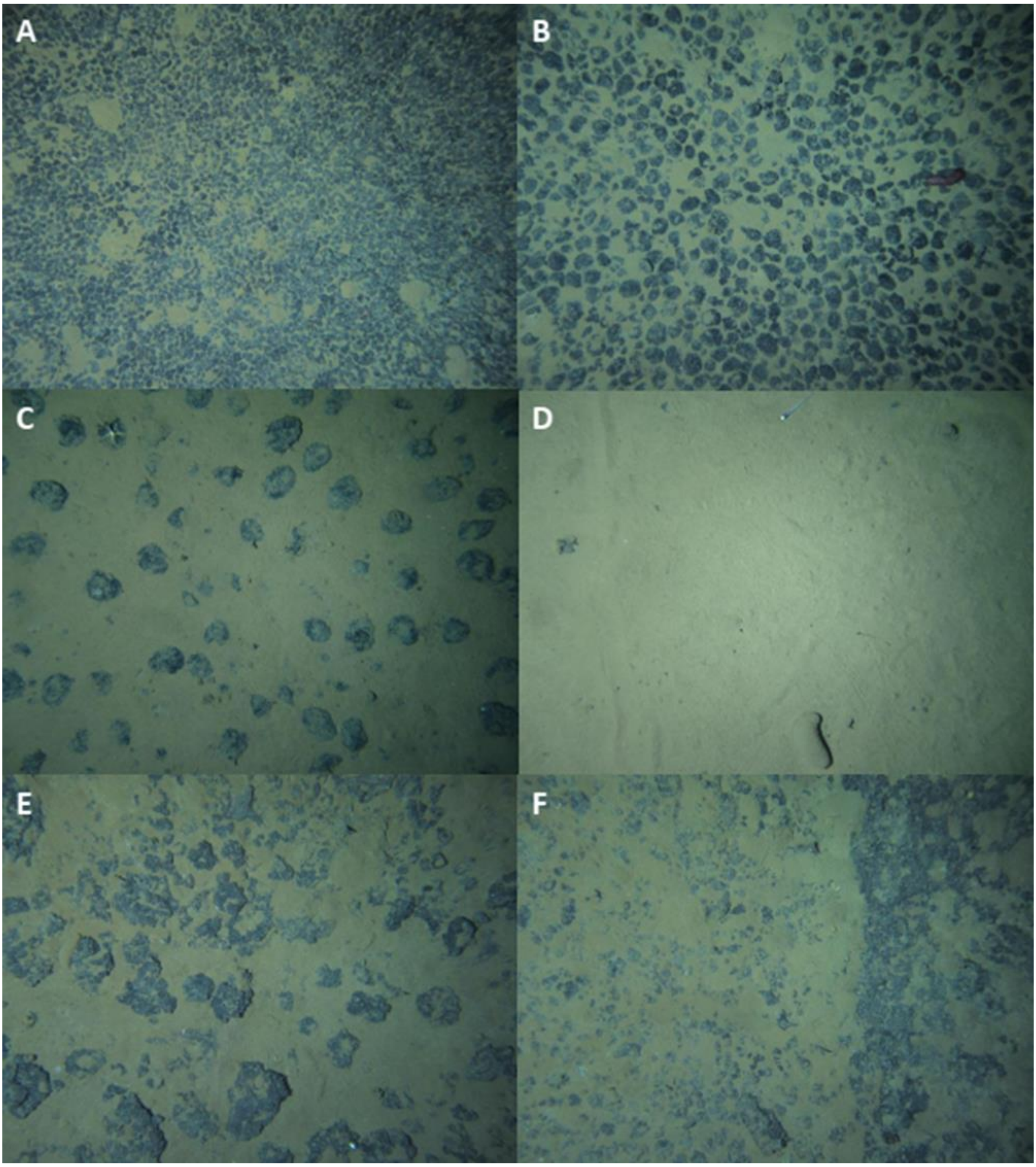
Biological studies are currently underway in accordance with the ISA recommendations, stratified by multiple spatial scales and depth, and based on geoform and substrate classes. The results from some of these studies are presented in Section 6. As these studies progress, they will provide answers to key questions such as the existence of gradients in biodiversity and ecological function between abyssal hill tops, slopes, valleys, and flatter areas or between contrasting nodule types and abundances, the existence of underlying biogeographic gradients within NORI-D, and representativeness PRZs are critical to Ecosystem Based Management.

In the context of the Collector Test geoform mapping has been used to inform decision making on the optimal location for the TF and IRZ. By limiting the disturbance caused by the Collector Test to the most abundant Level 3 ‘Flatter Area’ geoform, the potential for significant impact to abyssal hills and seamounts, which have been shown to be higher in species richness and biomass, is reduced.

5.17.5 Verification

Mapping outputs were field verified by visual assessment of seabed composition across the different study areas within NORI-D. A total of 26,916 images (collected during the OI campaign) were visualised and classified by seabed typology into 6 categories. These were: Type I nodule facies (73%), Type II nodule facies (12%), Type III nodule facies (13%), nodule-free areas (%), and areas with either exposed basalt bedrock or covered with rock fragments (e.g., > 20 cm) (1%) (Figure 5-73). Figure 5-74 shows the correspondence between the predicted distributions of seabed typologies and those observed in image data, which was remarkably comparable (NOC, 2022).

Figure 5-73. Different seabed types observed in seabed imagery collected across NORI-D.



Note: A) Nodules: Type I.B) Nodules: Type II. C) Nodules: Type III. D) Nodule-free. E and F: Exposed rock: E) Fragments; F) Bedrock

Figure 5-74. Comparison between predicted distribution of different seabed typologies (background, Fathom Pacific 2020) and observations obtained from in image data (lines, ROV surveys 2020)