SFG3660

PALAU FSM CONNECTIVITY PROJECT
(Project No. P130592)

Pohnpei Cable Landing

Addendum to IEE document
(*World Bank Project Number P130592*)

Report prepared by
Argo Environmental Ltd

FINAL

September 2017

argoenvironmental
ENVIRONMENTAL CONSULTANTS

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1. Introduction

1.1 Background

In 2014 the World Bank (WB) approved the Palau - FSM Connectivity Project (P130592) providing FSM with IDA17 grant funding in the amount of $47.5 million. The Project Development Objective is to reduce the cost and increase the availability of Internet Communication Technology (ICT) services needed to support social and economic development in the Recipient's territory.

Major elements of the development program include:

- A national ICT and telecommunications policy (September 2012), providing for market opening and the establishment of an independent sector regulator;
- The adoption of new legislation, the Telecommunications Act of 2014, to give effect to the ICT policy;
- Restructuring the incumbent telecommunications service provider, the FSM Telecommunications Corporation (FSMTC);
- International connectivity infrastructure investments in the FSM States of Chuuk, Kosrae, and Yap;
- Issuance of licenses for new operators and service providers to enter the market.

The project funding for FSM is allocated to the construction of a new cable system for FSM to connect Chuuk State to Pohnpei via the Pohnpei – Hantru Segment which has been in service for the past seven years.

In March 2016, FSM signed a supply contract with NEC for a 781 km cable system (Chuuk – Pohnpei Cable System) linking Chuuk to Pohnpei. The Chuuk – Pohnpei Cable System is planned to be landed adjacent to Chuuk Airport and to be interconnected with Pohnpei through a Pre-Laid Shore End (PLSE) cable landing into an existing Beach Manhole. Once completed, Chuuk and Pohnpei will have access to up to multiple 100Gbps wavelengths of bandwidth between Chuuk and Pohnpei, with the ability to forward traffic to Guam and the rest of the world.

NEC Corporation of Japan (NEC), the system supplier, is responsible for the installation of the wet works in both Chuuk and Pohnpei.

1.2 Rationale

The original intent of the Palau FSM Connectivity Project was to connect the deep ocean portion of the Chuuk cable to the existing HANTRU-1 cable using an installed branching unit (BU) located about 10 Km offshore from Pohnpei.

Due to recent advancements in consideration of the technical and commercial aspects of the Project, it is now proposed to land cable directly into Pohnpei via the existing BMH site for HANTRU-1 and along the existing easement to the CLS at FSMTC premises.

International connectivity would then be facilitated from Chuuk to Pohnpei with traffic forwarding on the Pohnpei – Hantru Cable Segment of HANTRU-1 with termination in Guam (Figure 1).

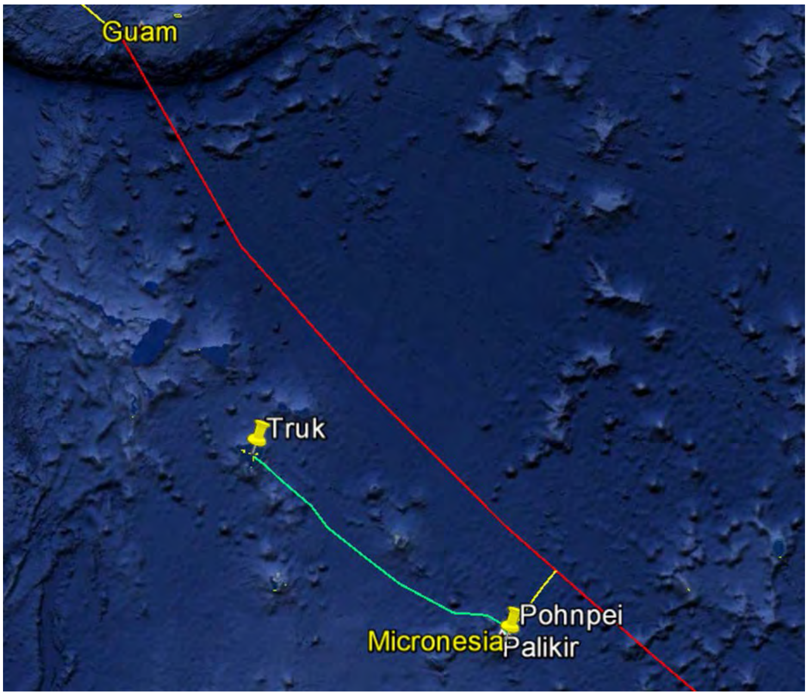

Figure 1: Chuuk - Pohnpei Cable System

An Initial Environmental Examination (IEE)[1] and Environmental and Social Management Plan (ESMP) have already been prepared addressing the impacts of the proposed Palau FSM Connectivity Project. The IEE report provides: the policy, legal and administrative framework; a comprehensive description of the overall Project; baseline information on the physical, ecological and socio-economic environment; an analysis of alternatives; anticipated impacts and mitigation measures; a grievance redress mechanism; description of public consultation; and an ESMP and Environmental Code of Practice (ECOP).

This documentation previously provided will apply to this variation in Project scope.

1.3 This Report

This addendum, addressing the new Pohnpei connection only, has been prepared in accordance with WB Policy 4.01 to provide information on the following:

1. A description of the works.
2. A description of the environmental and social screening.
3. Land due diligence assessment (confirmation of agreement of land owners).
4. Local permitting requirements from Pohnpei EPA (if any) and approvals process.
5. Changes to the ESMP and Codes of Practice (if any).
6. Summary of public consultation.

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[1] IEE 2016. Palau FSM Connectivity Project. Environmental and Social Impact Assessment Document. An Initial Environemtal Examination. Project No. P130592. March 2016.

2. Project Description

2.1 Pre-Laid Shore End Installation

The PLSE multi-fiber subsea optical transmission will be laid terminating in the existing Beach Manhole (BMH) for the Pohnpei – Hantru Segment 4 where the transition is made to terrestrial cable. The PLSE is constructed from SC500 Double Armor Cable (Figure 2) having an outer diameter of approximately 36 mm.

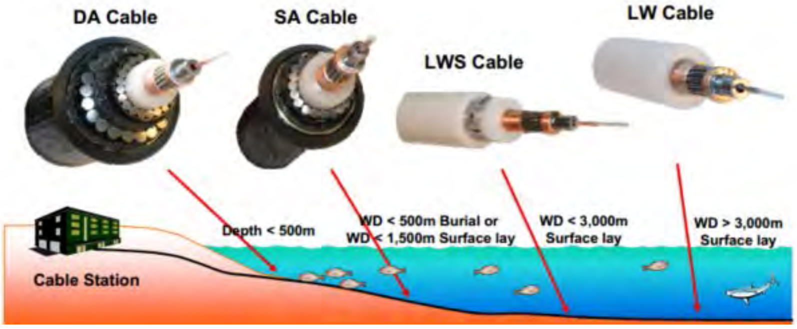

Figure 2: NEC Double Armor Cable for PLSE (located far left)

The Chuuk–Pohnpei PLSE will be laid along the same route and in close proximity to the existing PLSE for the Pohnpei–Hantru Segment 4. The planned PLSE lay for the Chuuk – Pohnpei PLSE is expected to be very similar. Figure 3 shows the Pohnpei – Hantru Segment 4 PLSE installation.

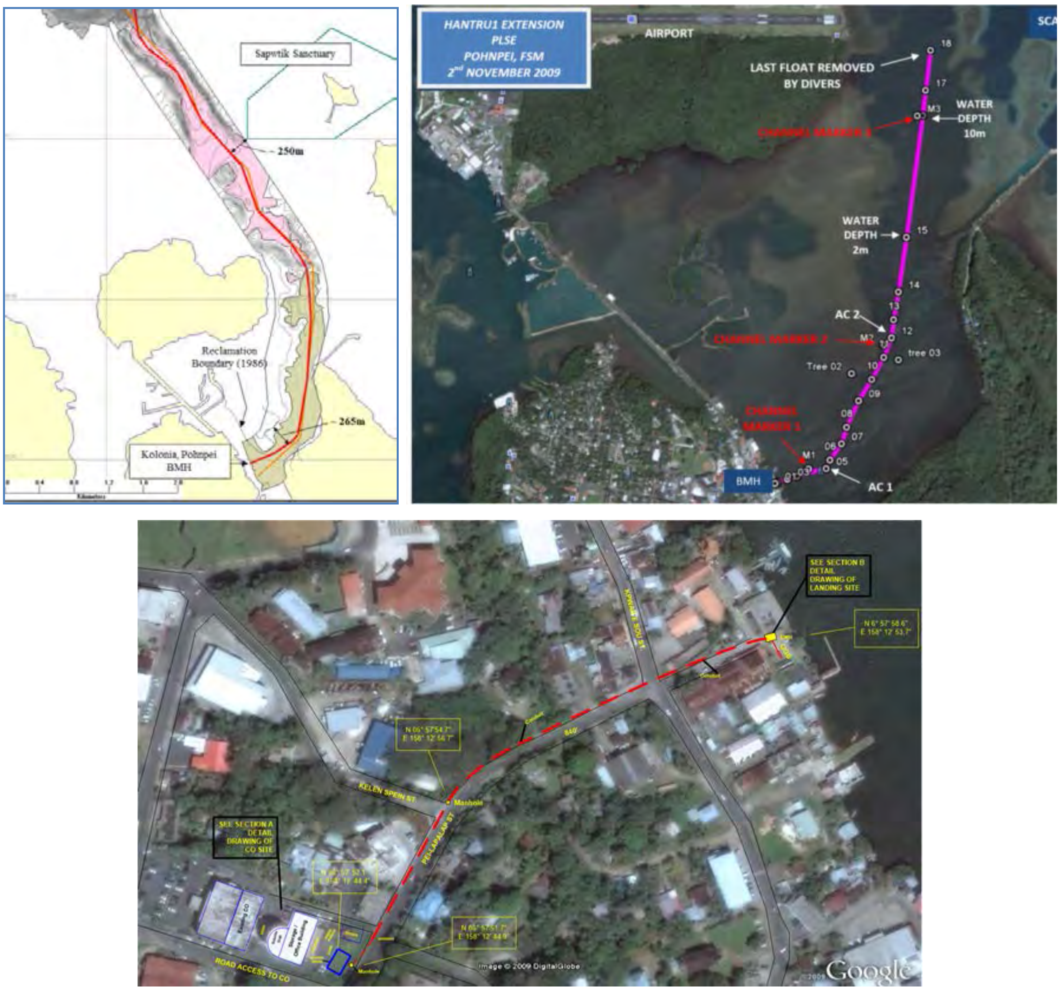

Figure 3: Existing Pohnpei – Hantru marine and terrestrial cable route

2.2 Pre-Laid Shore End Lay

The proposed PLSE will be laid in close proximity to the existing PLSE. In some regions of the Pohnpei channel the entire channel width is very narrow, so proximity of the two cables cannot be avoided.

The PLSE lay will be undertaken by a small ship that has Dynamic Positioning capability and is expected to take approximately 1 to 2 days. It is proposed to undertake this work between 17 – 24th September 2017.

The lay will begin at the existing BMH. The BMH has spare seaward ducts; one of which will be accessed to pull the cable into the BMH. No earthworks are anticipated for the landing or to make modifications to the existing BMH. However in order to facilitate access to the spare duct there will be a requirement to remove a small volume of built up sediment using an excavator. Figure 4 shows plan and elevation views of the exisiting seawall and ducts.

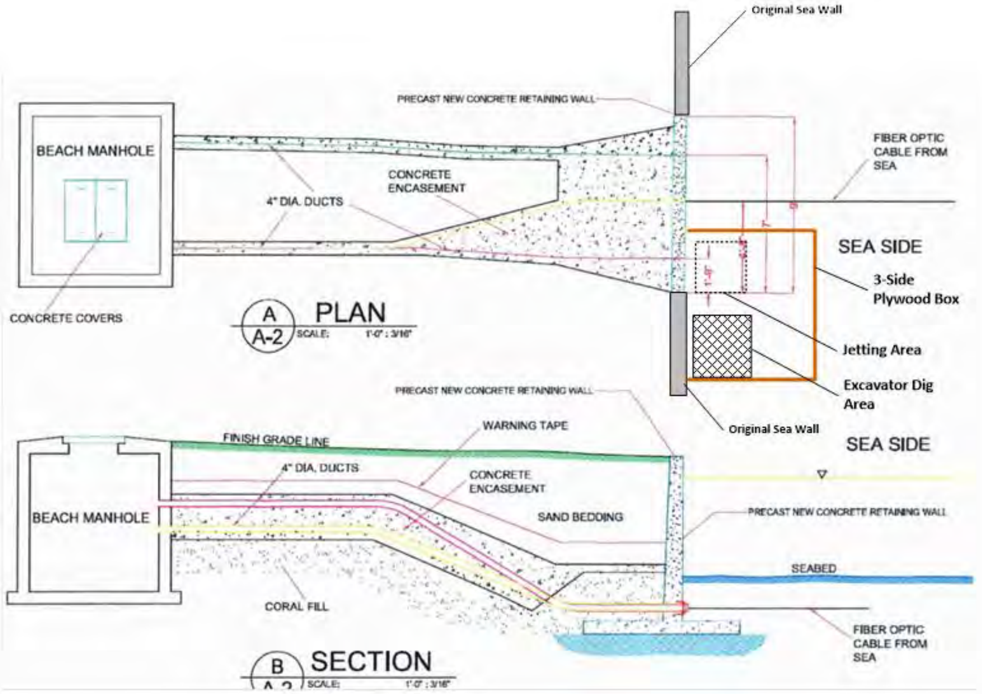

Figure 4: Pohnpei BMH and ducting based on as built prepared by Tyco Engineering

The proposed methodology is as follows:

1. Construct a 3-sided plywood box 8ft x 8ft x 8ft tall enough to protrude above the water surface at the BMH location.
2. Place the box on the sea floor with the open side against the seawall affixed to the seawall using timber restraints (note no stakes or supporting posts are proposed due to the potential for damge to the existing cable). The purpose of the box is to contain any sediment or silt plumes within the confines of the box. To ensure there is no impact on the HANTRU cable as a result of box installation, one wall of the box will be placed between the conduit containing the HANTRU cable (which is encased in cast iron articulated pipe) and the spare conduit to ensure the HANTRU cable is located outside the work area. A cable locator tool will also be used to locate the vable prior to works being undertaken.
3. Using an excavator scoop out soil / sediment from the area within the installed box (ensuring no potential for disruption to the conduit containing the HANTRU cable) and

place this soil on dry land. A tarp will be used to ensure that the sediment removed from the sea bottom is not mixed with terrestrial soil. It is expected that the required hole will be about 2ft deep and approximately 3ft x 3ft in area.

4. Using a water jetting tool loosen the soil/gravel in the area above the spare duct and allow this soil to be swept into the excavated hole. The waterjetter will be a medium duty pressure washer with a maximum psi of between 2900 and 3000 psi which can be adjusted downward by increasing the diameter of the spray. The use of this tool will not be an issue for the HANTRU Cable as: the area of the spray is very confined; the Hantru cable duct is separated from the pressure washing area by both distance and a physical barrier of the Plywood; and the Hantru cable is encased in cast iron articulated pipe, and is, itself, of double armor cable construction.
5. Continue to do 4. until the spare duct is uncovered. This may require using the excavator to re-establish the original hole.
6. Allow the sediment in the water to settle prior to removing the box from the water.
7. After the spare duct is occupied by the Chuuk – Pohnpei Cable and articulated pipe placed on the cable, replace the 3 sided box into its original position.
8. Return the removed soil into the box and allow the sediment to settle prior to removing the box for the final time.

Once the PLSE is secured in the BMH (Figure 4), the installation vessel will proceed seaward deploying the PLSE cable on the sea bottom along a predetermined route.

Close to the BMH, articulated piping will be applied for approximately 50m onto the PLSE to provide extra protection for the cable (Figure 5).

Figure 4: Securing the PLSE within the Beach Manhole

Figure 5: Articulated Pipe

After deployment, a diver survey will be conducted to ensure that the cable was not caught on or hung up on any rocks or coral outcrops causing a suspension. Should the cable be caught up, remedial actions will be taken to ensure that the cable is free and anchored to the bottom.

The procedures discussed above were successfully utilized during the installation of the Pohnpei – Hantru Segment 4 PLSE.

2.3 Connection to the Cable Landing Station

The existing land cable used by the Pohnpei – Hantru Segment 4 cable system contains several pairs of unused fibers. It is the intent to access these fibers to provide connectivity back to the Cable Landing Station (CLS) located on the FSMTC Facility grounds.

Consequently, no earthworks are required to install duct works from the BMH to the CLS.

3. Background Information / Data

3.1 Marine Ecological Resources

The results of the near shore marine surve from the Pohnpei–Hantru Segment 4 Survey prepared by Fugro (2006) are presented in Appendix 1. It is considered highly unlikely that the exisiting habitat will have changed significantly since the time of the survey.

In summary, the route (Figure 6) consists of the following:

- Hard bottom with rock outcrops and coralline patch reefs.
- Soft bottom consisting primarily of silt
- Featureless bottom consisting of a combination of silt, limestone reef, cobbles and sand.

Overall, no habitat or species of particular ecological and conservation significance were identified along the cable route. NEC will also be undertaking a marine survey of the cable route in mid-September 2017 to confirm the location of the exisiting PLSE.

3.2 Landownership

The BMH is owned by FSM TC (see Appendix 2). The State of Pohnpei lease the land to FSM TC.

3.3 Permitting Requirements

The EPA has indicated there are no issues with providing permission to install and land the cable at the exisiting BMH. The EPA approval letter (see Appendix 2) contains a number of conditions which will need to be complied with.

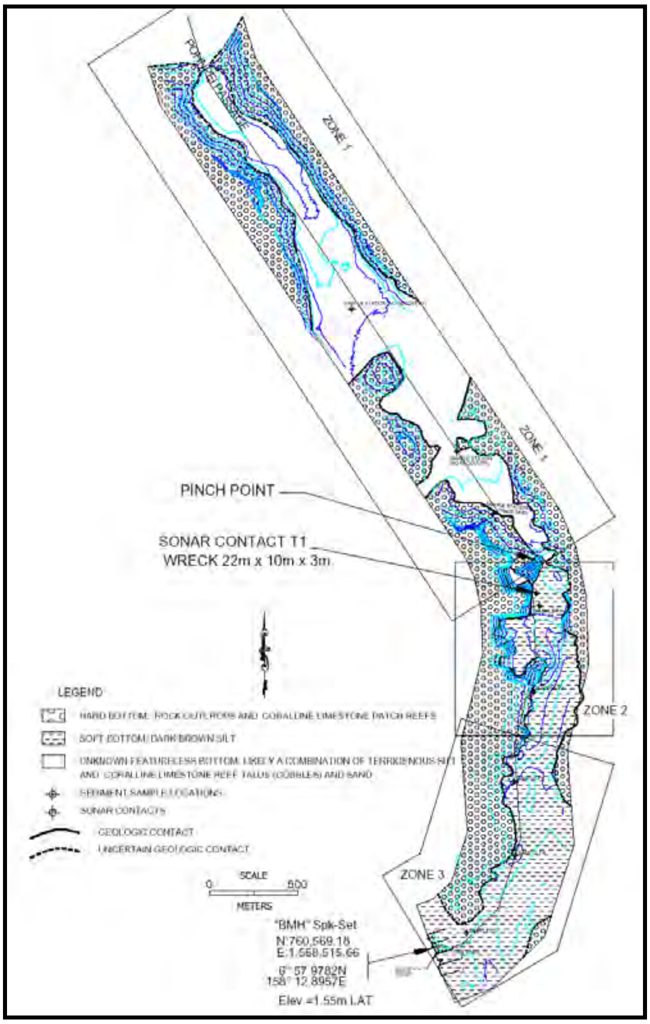

Figure 6: Pohnpei survey near shore marine area

4. Anticipated Impacts & Mitigation Measures

4.1 Introduction

The Project has the potential to create a variety of impacts which can be either positive, negative or negligible or neutral depending on the receptors involved. The impact of the Project on the physical, ecological and social environment has been assessed.

An impact is defined as "any change to the physical, biological or social environment, whether adverse or beneficial, wholly or partially resulting from an organisation's activities, products or services".

4.2 Coastal Marine & Terrestrial Ecology

No adverse effects on the exising are anticipated on account of the following:

- No ecological resources of significance are present along the cable route.
- The proposed method to contain silt generated during the process to access the cable duct will minimise offsite movement of suspended material potentially affecting offsite benthic and fish communities.
- The PLSE is to be laid in close proximity to the existing PLSE.

- No adverse effects were identified or arose as a result of installation of the existing PLSE.
- There will be no landside works undertaken that has the potential to affect terrestrial ecological resources.

4.3 Land-ownership

As the land where the BMH is located and cable is buried is leased by FSM TC from the State of Pohnpei and FSM TC don't have any objection in principle to the landing of the new cable withing the BMH, no adverse impacts are anticipated.

5. Consultation, Participation & Information Disclosure

5.1 Consultation

Consultation with key stakeholders and local community has been undertaken by way of email and phone calls with the following: FSMTC; DTC&I; Public Works; Marine Resources Department; Port Authority; EPA; Fisheries Department; Pohnpei Governor; and Local Community Groups.

The key issues raised are summarised as follows:

EPA

- Assume the mitigation and monitoring requirements identified in the Palau FSM Project IEE apply for the Pohnpei Cable Project.
- Requested a copy of the vessel air quality certificate (which have been provided) and request notification in the event of violation of emission standards and provision of report detailing corrections implemented and verification of corrections.
- Requested a copy of specifications of vessel fuel and lubricant management equipment and storage, cerificates that installations comply with MARPOL specifications, Contingency Plan to address spills and groundings, and sewage treatment and discharge system specifications. All of this material has been provided.
- In the unlikely event of a fuel spill or grounding, EPA request they are notified and measures are implemented as outlined in the Contingency Plan.
- Development of a Plan to minimise spread of siltation during removal of silt covering the manhole caps.
- Provision of post deployment cable video.
- Participation in planning of remedial works (if required).

FSMTC

- Please provide more details such as the distance of the box and expected digging area from the occupied conduit and the PSI of the water jet.
- How would you place the box in such a way to ensure it holds up in water?

- Will it be installed 3 feet deep into the sea-bed? If so, how can you be sure it will not be placed on the existing cable?

- Please arrange to have a cable locator tool to accurately locate the existing cable before any placement of the box or any attempts to excavate/jet.

These issues raised by FSM TC have been addressed as decribed in Section 2.2 of this Report.

5.2 Disclosure

This Appendum will be publicly disclosed on FSMs DTC&I and the World Bank website.

A public notice will advise stakeholders when the document is available to view.

6. Environmental & Social Management Plan

An Environmental & Social Management Plan (ESMP) is presented in the IEE. The IEE also outlines mitigation measures and monitoring actions that the Implementing Agency has committed to implement, from the planning through to the operating period of the project, which are summarised in the environmental mitigation table (ESMiT) and monitoring table (ESMoT). The ESMP also outlines:

- Chance Find Procedures
- Environmental Code of Practice (ECOP)
- The process of land acquisition.

No changes are required to the exisiting ESMP for the variation in Project scope as described in this Addendum.

7. Conclusions & Recommendations

Overall, the proposed Pohnpei PLSE Project will requires no newland-based infrastructure, will have minimal marine-based impacts which are limited in scale and extent and can be fully mitigated, and will require no involuntary land acquisition.

The new cable will be laid adjacent to the exisiting cable potentially impacting a corridor no more than 1-2 m wide. The cable route has been surveyed previously and there is no habitat or species of particular ecological and conservation significance present.

Given the small-scale of the work, and the fact that nearly all of the work takes place on board a vessel at sea with specially trained crew, no negative social impacts are anticipated during any stage of the project.

The ESMP provided with the 2016 IEE defines a full set of working area boundaries, work restrictions and timing limits which will be in the updated contract specifications which NEC will have to comply with. Compliance will be monitored by a safeguards advisor.

The Approval letter provided by the EPA has a number of conditions that will also need to be complied with.

Appendices

Appendix 1 Marine Survey

Kwajalein Cable System
Route Survey

Optional Segments 4 & 5

VOLUME 1of 1
Preliminary Report

Report No: 0504J001a

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FUGRO

02 March 2006

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Issue No.	Date	Description	Checked	Approved
0	02 Mar 2006	Preliminary Report	JO	CD

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1. INTRODUCTION

Tyco Telecommunications (Tyco) contracted Fugro Seafloor Surveys, Inc. (FSSI), part of the worldwide Fugro Group, to undertake a geophysical route survey for the Kwajalein Cable System (KCS).

This report presents the following two optional segments of the KCS project:

- **Segment 4**: From Pohnpei, Federated States of Micronesia to BU1 offshore Pohnpei
- **Segment 5:** From the BU2 offshore Kwajalein to Majuro, Republic of Marshal Islands

The contract included a small boat survey to a water depth of 20 meters, as well as a diver and beach topographic survey for each landing. It also included a nearshore geophysical survey to a depth of 1,000 meters off each landing, and a deepsea survey performed to full ocean depth along the remainder of the cable route, and at the BU locations.

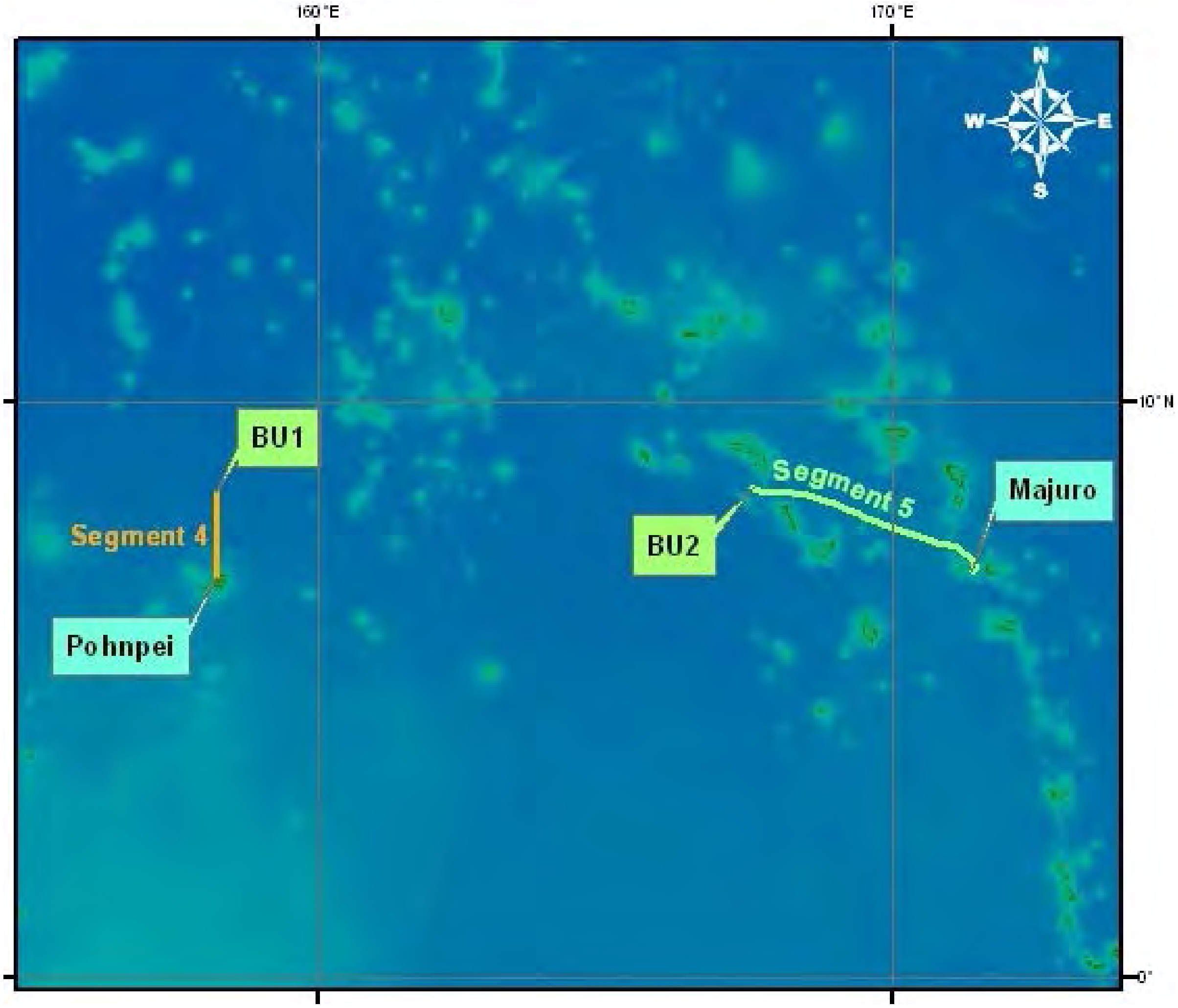

Figure 1.1.1: Overview of the Kwajalein Cable System Optional Routes

The nearshore and deepsea portions of the geophysical survey, nominally in water depths greater than 20 meters, were conducted by FSSI between 18 Jan and 11 Feb 06, aboard the M/V Trinity Explorer. The beach topographic, diver and small boat survey operations were subcontracted by FSSI to Sea Engineering, Inc. (SEI) and were conducted between 03 Dec 05 and 24 Jan 06. No cable burial is planned for either optional route of the KCS project.

These surveys provide information necessary for the engineering, construction, installation, and subsequent maintenance of the cable system. Survey data collected for the KCS project are analyzed in this survey report to yield information on bathymetry and seabed geology along the surveyed route, and to highlight any potential hazards and obstructions (natural or man-made, either existing or foreseeable) at or close to the seabed.

During the nearshore, deepsea and BU surveys, all data processing, geological interpretation and charting of the data were performed onboard the survey vessel to allow in-field evaluation of the survey route. In this regard, the Client Representative and the FSSI Geologists worked closely to determine route acceptability. Data from the topographic, diver and small boat surveys were incorporated into the report in FSSI's Seattle office upon completion of survey operations.

All elements of the survey were intended to accomplish the survey objectives at the highest level of quality, in conformance with industry-standard in the most efficient and economical manner.

1.1 Project Organization

1.2 Contacts

The principal parties in the project are:

Client:	**Tyco Telecommunications (US), Inc.** Patriot's Plaza 60 Columbia Road Morristown, NJ 07960
TYCO Project Manager / Point-of-Contact:	Lisa Morrow
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Contract Holder and Project Operations Coordination:	**Fugro Seafloor Surveys, Inc. (FSSI)** 2727 Alaskan Way – Pier 69 Seattle, WA 98121-1107
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Mobile:	(206) 618-0382
Email:	micronesia@seafloor.com

1.3 Geodesy

Spheroid	WGS84
Datum	WGS84
Semi-major Axis	6,378,137.000 meters
Semi-minor Axis	6,356,752.314 meters
Inverse Flattening	298.2572235630
Eccentricity^2	0.006694380
Projection	Mercator
Latitude of True Scale	10°N
Longitude of Origin	144°E
False Easting	0 meters
False Northing	0 meters

1.4 Vertical Control

Elevations and depths shallower than 1,000 meters water depth will be tidally reduced to the Lowest Astronomical Tide (LAT), in agreement with the local nautical charts for the area. All such reductions will use predicted tidal information published in the Admiralty Tide Tables ATT Vol.4, NP204, 2006.

1.5 List of Acronyms

BMH	Beach manhole
DGPS	Differential global positioning system
DS	Diver or Dredge sample
EEZ	Exclusive Economic Zone
GC	Gravity core
GS	Grab sample
KP	Kilometer post
LAT	Lowest astronomical tide
MC	Magnetometer contact
MLLW	Mean Low Low Water (NOAA tidal datum)
MRU	Motion reference unit (magnetic compass)
M/V	Motor vessel
N/A	Not applicable
NOAA	National Oceanic and Atmospheric Administration (U.S.)
QA, QC	Quality assurance, quality control
RPL	Route position list
SBP	Subbottom profiler
SC	Sonar contact
SVP	Sound velocity probe/profile

USBL	Ultra-short baseline (towfish positioning)
UTC	Universal time coordinated
WGS84	World Geodetic System, 1984
XBT	Expendable Bathy Thermograph (temperature profiler)

1.6 Glossary of Geologic Terms

Coral	A group of radially symmetrical aquatic animals with calcareous external walls. These may be either solitary or colonial, forming reefs.
Escarpment	A long, more or less continuous cliff or relatively steep slope facing in one general direction, separating two level or gently sloping surfaces.
Fault	A fracture or fracture zone along which there has been displacement of the sides relative to one another parallel to the fracture.
Normal Fault	A fault caused by extension, in which the hanging wall appears to have moved downward relative to the footwall.
Shoaling	To become shallow.

2. SCOPE OF WORK

This section describes each portion of the survey work completed for the KCS project. It should be noted that:

- Deviations from the Scope of Work are detailed in Section 4.1.2.
- During the nearshore and deepsea survey operations, areas along the route that showed potential difficulties for cable installation were brought to the attention of the onboard Client Representative. On-line decisions were made regarding the necessity of survey development work to ensure that an appropriate route was identified. The work development allowance was 10% of the total route kilometers.
- At the time of the nearshore and deepsea survey operations, survey data processing and quality control (QC) were conducted on board the M/V Trinity Explorer in order to assess immediately the suitability of the route. Preliminary electronic charts (.pdf) were produced as a walk-off product and provided to the Client Representative at the end of the survey program.
- For the topographic, diver and small boat surveys, only QC of the data was conducted during the field operations to determine route suitability, i.e. no report or charts were provided as a walk-off product. All charting was performed by FSSI following the completion of these operations.

The survey RPLs, as provided by Tyco at the end of the survey operations are given in Appendix A. They include Segment 4 and 5 routes.

2.1 Beach Topographic Survey

The specifications for the beach landing topographic surveys required a survey corridor of 250 meters from the BMH to 0 meters (LAT). The BMH and landing sites were positioned using differential GPS. Two reference points were also established. The topographic surveys were conducted using standard land survey techniques. Bar probing was conducted between the BMH and the water line at an interval of 50 meters to assess seabed conditions.

2.2 Diver Swim Survey

A diver swim survey was conducted along five survey lines from 0 meters (LAT) to approximately 3 meters water depth, or to overlap with the small boat survey, within a 250-meter corridor. The survey was conducted using a line with 20-meter graduations positioned along the route. Bathymetry and probing were conducted every 20 meters. Two tie lines were performed.

2.3 Small Boat Survey

A small boat survey was conducted within a 500-meter corridor in water depths less than 20 meters, with minimum seven primary survey lines and cross-lines at ten times the primary line spacing. The inshore surveys were conducted from vessels of opportunity obtained at each of the landing sites. Due to the steep offshore bathymetry, the limit of the inshore surveys was extended to the 100-meter water depth to provide adequate overlap with the deepwater survey vessel. The small boat survey included single beam bathymetry and side-scan sonar, and sampling every 500 meters along the proposed route.

2.4 Nearshore Survey

From the main survey launch, M/V Trinity Explorer, the nearshore survey was performed along each segment of the KCS route from the offshore limit of the small boat survey (nominally 20 meters water depth) to the 1,000-meter water depth contour. As explained in Section 2.3 above, the minimum depth requirement for the main launch was amended because the extremely steep terrain off the landing sites made navigation of the M/V Trinity Explorer unsafe. For the same reason, the minimum 500-meter overlap required by contract between the small boat and main launch surveys could not be achieved off the landings (see Section 4.1.2 for details). However, a minimum 1-kilometer overlap was achieved around the 1,000-meter water depth contour, as per original contract specifications (see Section 2.5 below).

The nearshore included a geophysical survey and a seabed-sampling program. The survey consisted of a minimum of three survey lines centered along the proposed route, with a 20% bathymetric swath data overlap. Swath bathymetry and side-scan sonar intensity were acquired simultaneously using FSSI’s Sys100D towfish. It should be noted that the acquisition of sub-bottom profiler (SBP) data, although inherent to the Sys100D system, was not a contract requirement for the KCS project. Although SBP data interpretation was not required, the geologists used the SBP information as needed for interpretation only.

The sampling program was to include core or dredge samples (depending on the seabed type) along the route, collected at a 5-kilometer interval from 20 to 1,000 meters water depth. Upon review of the side-scan and SBP data at both landings, the on-board geologists and Client Representative agreed that the seabed was not suitable for gravity coring, so only dredge samples were collected. A maximum of two dredge attempts were made to recover a suitable sample. All samples were photographed (in color) with an identification number and scale in centimeters. The precise location of all samples was recorded, reported and charted on the survey charts along with a physical description. Samples were discarded following complete analysis and photography.

The magnetometer was only to be deployed where the position of existing cables could not be clearly identified from side-scan sonar or other geophysical records. Where necessary, and in water depths of less than 200 meters, the magnetometer was to be used to locate existing **in-service cables** only, or as required by the Client Representative, by running three lines over any cable or target.

Temperatures through the water column were measured on a daily basis, or more if required, using expendable probes (XBTs). Water Column Temperature Graphs are provided along with probe type and geodetic position in Appendix B.

Survey resources utilized for the nearshore and deepsea geophysical survey consisted of:

- The fully equipped primary survey vessel “M/V Trinity Explorer” inclusive of fuel, lubes, water, accommodation, food, communications for 24-hour operations,
- All ancillary mob/demob services in New Iberia, Louisiana and Guam, such as welding, craneage, local ground transport, and dockside nav/positioning calibrations as required,
- FSSI’s proprietary Sys100D towfish, inclusive of winch and tow cable, for simultaneous acquisition of swath bathymetry, side-scan sonar intensity and

subbottom profiler data (not a contract requirement) in water depths between 20 and 1,000 meters,

- All acoustic towfish tracking, such as USBL, heave/motion sensors, and XBT probe,
- All navigation equipment such as DGPS, gyrocompasses, hardware and software,
- 2-meter long gravity corer and dredge, with appropriate supplies, and
- A G880 cesium marine magnetometer.

Detailed equipment specifications are provided in Appendix C.

2.5 Deepsea Survey

The deepsea survey was conducted along each segment of the KCS route from the limit of the nearshore survey, i.e. in water depths greater than 1,000 meters, and near the BU offshore Pohnpei and Kwajalein (see Section 2.6). A 1-kilometer overlap was planned between the nearshore and the deepsea surveys around the 1,000-meter bathymetric contour.

Deepsea survey operations were conducted on a 24-hour per day basis utilizing the Sys09 towed system to simultaneously acquire swath bathymetry and side-scan sonar intensity to full ocean water depth. It should be noted that the acquisition of side-scan sonar data, although inherent to the Sys09 system, was not a contract requirement for the KCS project.

A single survey line centered on the proposed cable route was run to provide a total survey corridor of two times the water depth to a maximum of 10 kilometers. A 10% route development allowance (based on the proposal RPLs) was provided to enable optimum cable routing.

The deepsea survey did not include any sampling program.

2.6 Branching Unit Survey

Additional bathymetric surveys were conducted in the areas of the two planned BUs offshore Pohnpei and Kwajalein. No side-scan or SBP data acquisition, and no magnetometer or seabed sampling programs were required.

Each BU survey consisted of two or more survey lines (20% overlap) covering an area of at least five times the water depth, centered on the BU location. The area around BU2 off Kwajalein was increased at Client request in order to fine a suitable and safe location for the BU.

Survey data for the area surrounding the BUs were incorporated into the standard survey data presentation, with data processing and presentation parameters appropriate for the water depth at the BU locations.

3. SURVEY RESULTS

3.1 Segment 4 – Pohnpei to BU1 offshore Pohnpei

3.1.1 Route Summary

The route proceeds east from the BMH out across a shallow, relatively flat shoreline for about 175 meters then turns north to follow the inner reaches of a deepwater channel, the Pohnpei Passage that leads out through the barrier reef (KCS.S4.RS.NU.BATHY-001 / KCS.S4.RS.NU.GEO-001). The inner part of the route is about 1.3 kilometers in length and is characterized by shallow water less than 3 meters in depth. The channel is wider than deeper sections, with shoals occurring mostly on the north and west side of the route. The shoals in this area appear to be formed from small boulders and cobbles, probably transported by fluvial processes, rather than the patch reefs common along other portions of the route. The high island relief and abundant rainfall apparently produce high sedimentation rates in this area (KCS.S4.RS.NU.BATHY-002 / KCS.S4.RS.NU.GEO-002).

At approximately 06°58.86’N, the route undulates between 5 and 10 meters water depth for about 600 meters then drops steeply from 10 down to 50 meters depth through a steep-sided canyon (KCS.S4.RS.NU.BATHY-003 / KCS.S4.RS.NU.GEO-003). The route continues to head northwest through the passage that slowly deepens to 120 meters at the top of the shelf break. The seabed shoals abruptly on either side of the channel and the shoreline is almost entirely lined with mangroves (KCS.S4.RS.NU.BATHY-004 / KCS.S4.RS.NU.GEO-004).

The route then proceeds north down the very steep (localized gradients up to 50°) rocky upper slope of Pohnpei Island. The upper slopes are composed of roughly weathered, corrugated rock (probably coral reef rock/limestone) with patchy accumulations of loose reef rock rubble and gravel occasionally overlying the rock. After reaching 350 meters water depth, gradients along the route decrease to around 20° to 25°. Numerous isolated areas of rock (probably ancient coral heads) stand up to 5 meters above the seabed to the west and northeast of the route. They vary in diameter from approximately 10 to 50 meters (KCS.S4.RS.NU.BATHY-004 / KCS.S4.RS.NU.GEO-004).

The route continues north down the rocky, undulating, main island slope to about 3,000 meters depth. Typical gradients are 5° to 10°. From here, the seabed slopes gently down to 4,500 meters (KCS.S4.RS.NU.BATHY-005). The route skirts west of a 1,500-meter high seamount centered at 07°35.877’N – 158°14.967’E, across a rockier, undulating and deepening seabed, passing approximately 4,000 meters from the westerly base slopes (KCS.S4.RS.NU.BATHY-006) and then continues north across flat, featureless, sediment-covered seabed to BU1 offshore Pohnpei at 4,950 meters water depth (KCS.S4.RS.NU.BATHY-008).

3.1.2 Landing, Diver and Inshore Survey – Pohnpei

Pohnpei is a high island in the Eastern Caroline Islands group. It is surrounded by a barrier reef and lagoon system, yet has abundant rainfall and river flow. The barrier reef is breached by deepwater passes that were likely cut during lower sea level stands. Regional marine geology is a product of carbonate reef morphology compounded by high siltation due to abundant terrigenous input from the island river systems.

The project route is on the northwest section of the island. The route begins at the BMH in the waterfront town of Kolonia (Figure 3.1.1) and meanders north across an essentially flat, shallow shelf to a deepwater channel known as the Pohnpei Passage that leads out to the barrier reef. The inshore portion of the route is characterized by abrupt shoals that rise steeply on either side of the channel for almost the entire length of the route.

The beach manhole was located on-site by a representative of FSM Telecom, and positioned using C-Nav DGPS. As per instructions from the client, the route centerline was adjusted to be 50 meters distant from the BMH location to ensure survey coverage of an alternate landing site. Figure 3.1.2 is from the beach topographic drawing showing the locations of the BMH and the FSM Telecom tie-in.

The BMH position is: 06°57.9782'N – 158°12.8957'E

The waterfront area near the landing point is dense with buildings – both private and commercial. Buildings in the immediate area of the BMH include the Conservation Society of Pohnpei field office, a Yamaha automobile and outboard motor repair shop, and a public fish market. However, the BMH position is located in a clear area that provides easy access (86 meters line-of-sight) to the tie-in provided by FSM Telecom (Figures 3.1.2 through 3.1.4). Figure 3.1.5 shows the general area of an alternate landing site. The shoreline is protected by vertical seawalls along most of the project reach. Several small pier and floating dock structures are present in the immediate vicinity to service the small local fishing and tourist boat operations.

Water depths at the shoreline are on the order of 1 meter LAT. Water levels between peak high and low tides are normally between 0.5 and 1 meter. The highest tide during the month of January was 1.52 meters. The elevation of the BMH is 1.55 meters, so this area can be expected to flood during extreme high tides, or high tides combined with surge conditions. The highest tide observed during the survey was 1.2 meters on 19 Jan 06, and water levels appeared close to overtopping the banks along some portions of the shoreline in the vicinity.

The survey route is 5.8 kilometers in length from the shoreline at Kolonia to 100 meters water depth outside Pohnpei Passage (Figure 3.1.1). There are three distinct zones along the route, characterized by water depth.

The inner part of the route, Zone 3 is about 1.3 kilometers long and is characterized by shallow water less than 3 meters in depth. Sediment samples taken in this zone are composed of organic rich, dark, brown silt (Figure 3.1.6). The channel here is wider than the deeper sections, and shoals mostly on the north and west side of the route. The shoals appear to be formed from small boulders and cobbles, probably transported by fluvial processes, rather than the patch reefs common along other portions of the route.

Diver swim surveys show the silt thickness near the shoreline is greater than 1.5 meters.

Zone 2 is a transition zone about 1 kilometer long between the inner and outer passage. The water depth in the channel is about 3 meters at the inner end of this zone. At the outer end, the seabed drops rapidly from 20 to about 50 meters. The zone is characterized at the outer end by a pinch point in the channel with hard bottom at both sides, and a narrow (25-meter) pass that appears to be soft sediment (Figures 3.1.1 and 3.1.7). Sediment samples show the bottom in this zone to be composed of dark brown (organic-rich) silt, similar to those collected in Zone 3.

The high island relief and abundant rainfall apparently produce high sedimentation rates in this area. The seabed shoals abruptly on either side of the channel and the shoreline is almost entirely lined with mangroves.

The only sonar target found during the survey is in Zone 2 in 15 meters water depth. Target PO-SC-001 is probably a shipwreck. (See also Section 3.1.6.2.) According to the small boat survey boat operator, at one time a fishing boat was stranded on the shallow coral reef and then disappeared – likely slipping off the reef edge into deeper water.

The deeper zone, Zone 1, is about 3.5 kilometers long comprising the outer passage from the barrier reef pass to a distinct bend in the route near AC5. Channel depths in this zone are typically greater than 50 meters, although patch reefs rise to the surface on either side of the channel for most of the distance. The seabed along the route appears mostly smooth in side-scan sonar records, although some high relief rocky areas were mapped. No major sonar targets indicative of obstructions were found in this zone. Bottom sampling was not successful except for traces of mud found on the sampler toward the landward end of the zone. Due to the presence of coralline limestone patch reefs, the bottom can be speculated to contain a mix of coral sand and cobbles (reef talus), as well as terrigenous silt derived from fluvial processes.

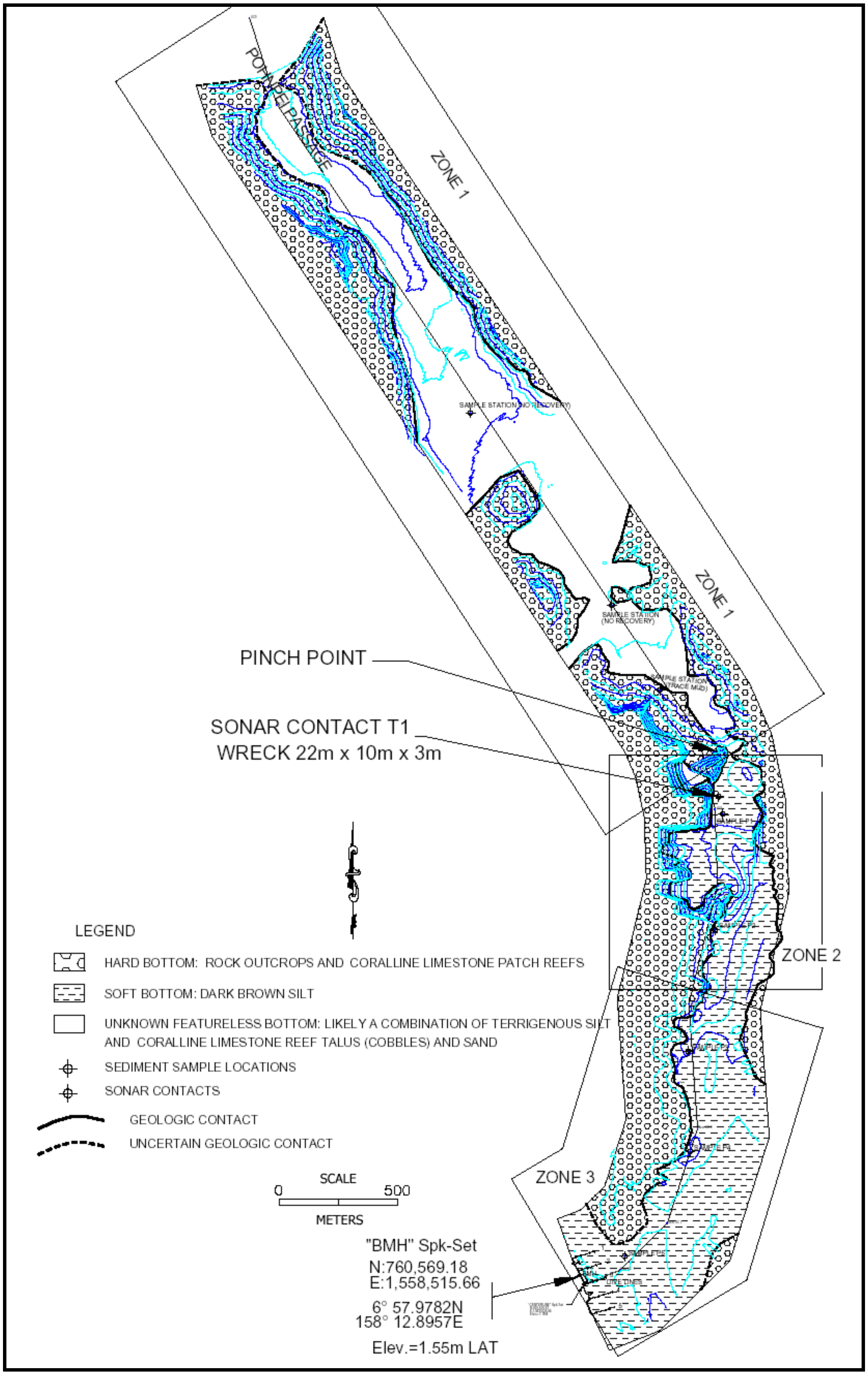
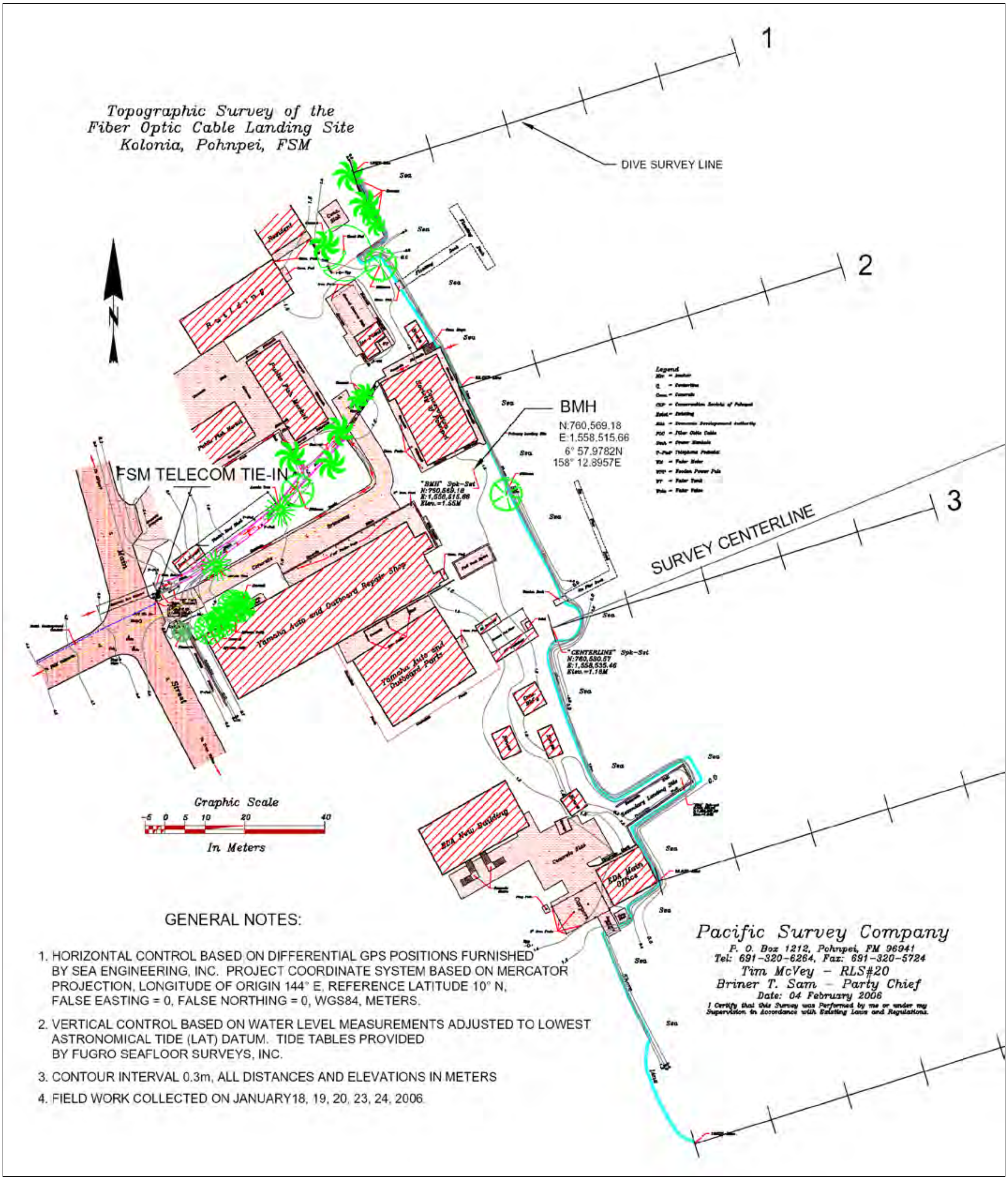


Figure 3.1.1: Pohnpei survey area with interpretation



Topographic Survey of the
Fiber Optic Cable Landing Site
Kolonia, Pohnpei, FSM

GENERAL NOTES:

1. HORIZONTAL CONTROL BASED ON DIFFERENTIAL GPS POSITIONS FURNISHED BY SEA ENGINEERING, INC. PROJECT COORDINATE SYSTEM BASED ON MERCATOR PROJECTION, LONGITUDE OF ORIGIN 144° E, REFERENCE LATITUDE 10° N, FALSE EASTING = 0, FALSE NORTHING = 0, WGS84, METERS.
2. VERTICAL CONTROL BASED ON WATER LEVEL MEASUREMENTS ADJUSTED TO LOWEST ASTRONOMICAL TIDE (LAT) DATUM. TIDE TABLES PROVIDED BY FUGRO SEAFLOOR SURVEYS, INC.
3. CONTOUR INTERVAL 0.3m, ALL DISTANCES AND ELEVATIONS IN METERS
4. FIELD WORK COLLECTED ON JANUARY18, 19, 20, 23, 24, 2006

Pacific Survey Company
P. O. Box 1212, Pohnpei, FM 96941
Tel: 691-320-6264, Fax: 691-320-5724
Tim McVey – RLS#20
Briner T. Sam – Party Chief
Date: 04 February 2006
I Certify that this Survey was Performed by me or under my Supervision in Accordance with Existing Laws and Regulations.

Figure 3.1.2: Pohnpei beach topographic survey

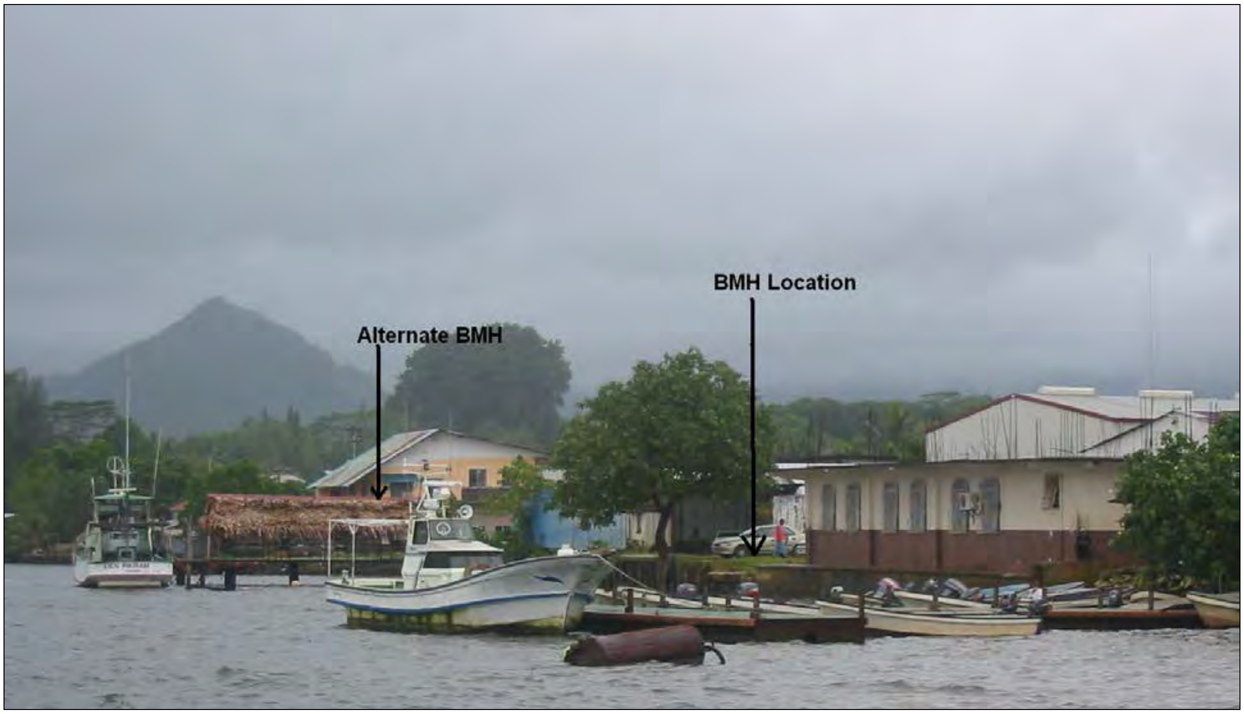


Figure 3.1.3: BMH location

Figure 3.1.4: Pohnpei BMH with tie-in location

Figure 3.1.5: Alternate landing site

Figure 3.1.6: Typical sediment sample

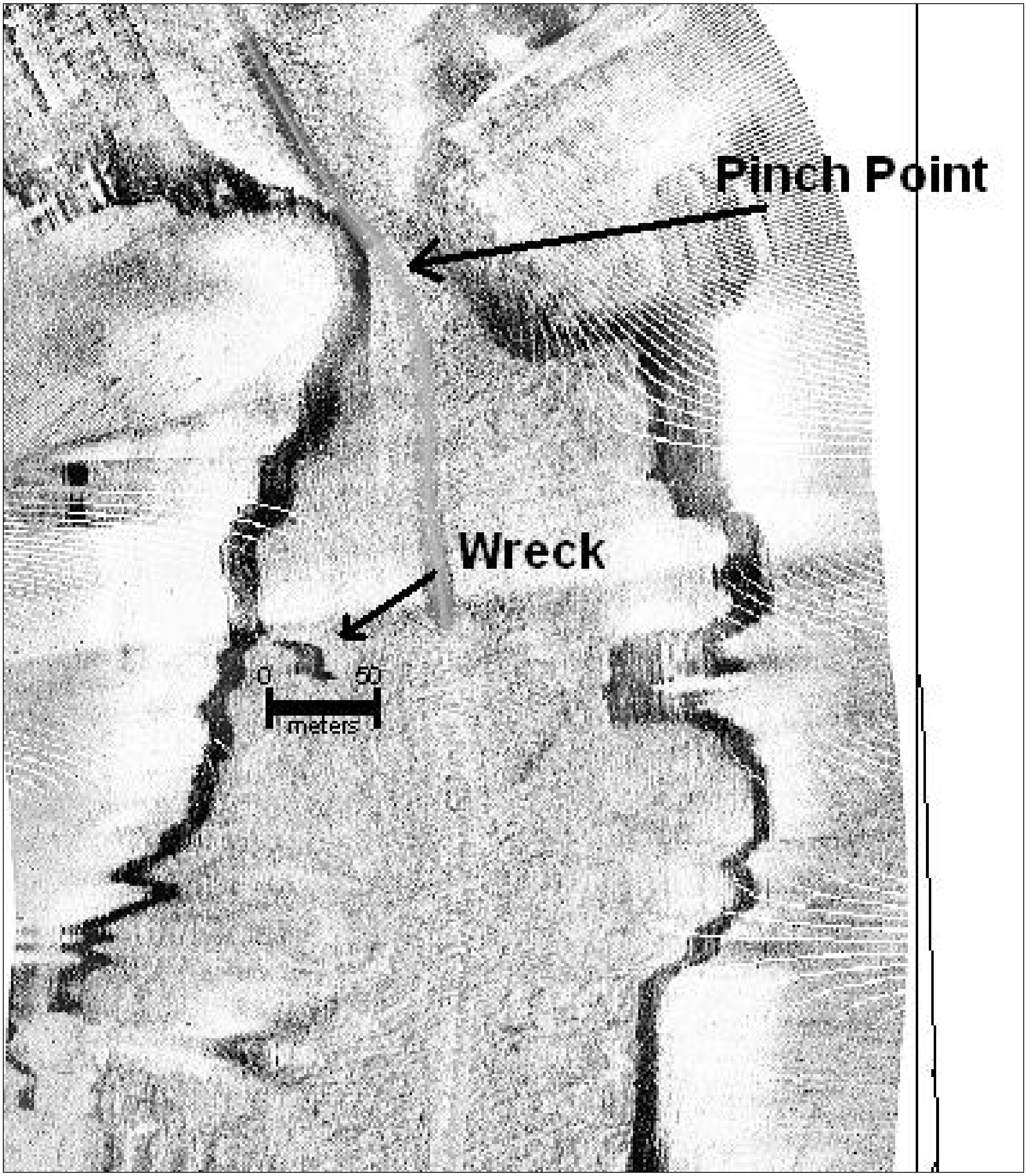


Figure 3.1.7: Side-scan Sonar record (125 kHz, 200m range) showing wreck and pinch point

3.1.3 Chart Descriptions

In this section, the Bathymetric Charts are described first, followed by the Geological chart descriptions.

Chart Description **Segment 4 – Pohnpei to BU1**

Chart Number	KCS.S4.RS.NU.BATHY-001
Scale	1:1,000
Chart Location	Pohnpei Approach

Seafloor Topography

Minimum depth along route:	-1.5 meters
Maximum depth along route:	<3 meters
Minimum depth within chart:	-4.5 meters
Maximum depth within chart:	<3 meters
Maximum gradient along route:	<1°

From the BMH at 1.55 meters LAT the route heads east for about 175 meters then turns northeast to head out the Pohnpei Passage. This section of the channel is characterized by shallow water less than 3 meters in depth. The seabed shoals to the north and west of the route, likely formed from small boulders and cobbles transported by fluvial processes, rather than the patch reefs common along other portions of the route. Seabed sample PO-GS-005 was taken in this area.

Cable Engineering Considerations

The final alignment of the cable should account for the hazardous reef areas bordering the channel. The present route runs across non-navigable shallow water reefs. The channel is not well marked, and the generally poor water clarity makes the reef areas difficult to anticipate. It would be prudent to enlist local navigation assistance during cable laying operations.

Chart Description

Segment 4 – Pohnpei to BU1

Chart Number	KCS.S4.RS.NU.BATHY-002
Scale	1:2,500
Chart Location	Pohnpei Approach

Seafloor Topography

Minimum depth along route:	-1.5 meters
Maximum depth along route:	5 meters
Minimum depth within chart:	-4.5 meters
Maximum depth within chart:	10 meters
Maximum gradient along route:	<1°

From the BMH at 1.55 meters LAT the route heads east for about 175 meters then turns northeast to head out the Pohnpei Passage. This section of the channel is characterized by shallow water less than 3 meters in depth. The seabed shoals to the north and west of the route, likely formed from small boulders and cobbles transported by fluvial processes rather than the patch reefs common along other portions of the route.

Cable Engineering Considerations

The final alignment of the cable should account for the hazardous reef areas bordering the channel. The present route runs across non-navigable shallow water reefs. The channel is not well marked, and the generally poor water clarity makes the reef areas difficult to anticipate. It would be prudent to enlist local navigation assistance during cable laying operations.

Chart Description **Segment 4 – Pohnpei to BU1**

Chart Number	KCS.S4.RS.NU.BATHY-003
Scale	1:5,000
Chart Location	Pohnpei Approach

Seafloor Topography

Minimum depth along route:	-1.5 meters
Maximum depth along route:	60 meters
Minimum depth within chart:	-4.5 meters
Maximum depth within chart:	65 meters
Maximum gradient along route:	12°

From the BMH at 1.55 meters LAT the route heads east for about 175 meters then turns northeast to head out the Pohnpei Passage. This section of the channel is characterized by shallow water less than 3 meters in depth. The seabed shoals to the north and west of the route, likely formed from small boulders and cobbles transported by fluvial processes rather than the patch reefs common along other portions of the route. The route turns towards the north, following the passage. At approximately 15 meters water depth the channel drops rapidly to 50 meters with steep hard bottom at both sides. The route turns northwest following the channel. Patch reefs rise to the surface on either side of the channel for most of the distance.

Cable Engineering Considerations

One sonar target, PO-SC-001, was located with both the single beam and side-scan sonar, and is thought to be a wreck lying in about 15 meters of water. See Section 3.1.6.2 for details.

The final alignment of the cable should account for the hazardous reef areas bordering the channel. The present route runs across non-navigable shallow water reefs. The channel is not well marked, and the generally poor water clarity makes the reef areas difficult to anticipate. It would be prudent to enlist local navigation assistance during cable laying operations.

Chart Description

Segment 4 – Pohnpei to BU1

Chart Number	KCS.S4.RS.NU.BATHY-004
Scale	1:10,000
Chart Location	Pohnpei Approach

Seafloor Topography

Minimum depth along route:	10 meters
Maximum depth along route:	1,520 meters
Minimum depth within chart:	0 meters
Maximum depth within chart:	2,280 meters
Maximum gradient along route:	54°

From the southern limit of the chart (5 meters water depth), the route gently descends across dead coral pan through the navigable channel to around 100 meters water depth. The route then drops off a very steep scarp with gradients in excess of 50°, and then descends down the main Pohnpei volcanic island slope with typical gradients of 20° to the northern limit of the chart (1,520 meters water depth)

Cable Engineering Considerations

Very steep gradients at the top of the main island slope.

One sonar target, PO-SC-001, was located with both the single beam and side-scan sonar, and is thought to be a wreck lying in about 15 meters of water. See Section 3.1.6.2 for details.

The final alignment of the cable should account for the hazardous reef areas bordering the channel. The present route runs across non-navigable shallow water reefs. The channel is not well marked, and the generally poor water clarity makes the reef areas difficult to anticipate. It would be prudent to enlist local navigation assistance during cable laying operations.

Chart Description **Segment 4 – Pohnpei to BU1**

Chart Number	KCS.S4.RS.NU.BATHY-005
Scale	1:100,000
Chart Location	Pohnpei Approach

Seafloor Topography

Minimum depth along route:	-1 meters
Maximum depth along route:	4,650 meters
Minimum depth within chart:	-4.5 meters
Maximum depth within chart:	4,700 meters
Maximum gradient along route:	54°

From the Pohnpei landing site, the route descends gently across dead coral pan across the navigable channel to around 100 meters water depth. The route then drops off a very steep scarp with gradients in excess of 50° down to the main Pohnpei Volcanic Island Slope where gradients are closer to 20° to a water depth of around 1,000 meters. The route continues down the northwest-oriented base slopes on typical gradients around 10°, down to approximately 3,000 meters water depth. The route continues at a gentle descent, skirting west of a 1,500-meter high seamount, passing approximately 4,000 meters from the westerly base slopes, to the northern limit of the chart (4,650 meters water depth).

Cable Engineering Considerations
Very steep gradients at the top of the main island slope.

One sonar target, PO-SC-001, was located with both the single beam and side-scan sonar, and is thought to be a wreck lying in about 15 meters of water. See Section 3.1.6.2 for details.

The final alignment of the cable should account for the hazardous reef areas bordering the channel. The present route runs across non-navigable shallow water reefs. The channel is not well marked, and the generally poor water clarity makes the reef areas difficult to anticipate. It would be prudent to enlist local navigation assistance during cable laying operations.

Chart Description

Segment 4 – Pohnpei to BU1

Chart Number	KCS.S4.RS.NU.BATHY-006
Scale	1:100,000
Chart Location	Pohnpei approach

Seafloor Topography

Minimum depth along route:	4,500 meters
Maximum depth along route:	4,900 meters
Minimum depth within chart:	3,200 meters
Maximum depth within chart:	4,900 meters
Maximum gradient along route:	2°

From the southern limit of the chart (4,500 meters water depth), the route gently deepens and skirts west of a 1,500-meter high seamount, passing approximately 4,000 meters from the westerly base slopes. The route heads north across very gently undulating seabed to the northern limit of the chart (4,900 meters water depth).

Cable Engineering Considerations

None

Chart Description

Segment 4 – Pohnpei to BU1

Chart Number	KCS.S4.RS.NU.BATHY-007
Scale	1:100,000
Chart Location	Federated States of Micronesia north of Pohnpei

Seafloor Topography

Minimum depth along route:	4,900 meters
Maximum depth along route:	4,950 meters
Minimum depth within chart:	4,900 meters
Maximum depth within chart:	4,950 meters
Maximum gradient along route:	<1°

From the southern limit of the chart (4,900 meters water depth), the route heads north across a very gently undulating seabed to the BU1 (4,950 meters water depth).

Cable Engineering Considerations

None

Chart Description

Segment 4 – Pohnpei to BU1

Chart Number	KCS.S4.RS.NU.BATHY-008
Scale	1:25,000
Chart Location	BU1, Federated States of Micronesia north of Pohnpei

Seafloor Topography

Minimum depth along route:	4,950 meters
Maximum depth along route:	4,950 meters
Minimum depth within chart:	4,950 meters
Maximum depth within chart:	4,950 meters
Maximum gradient along route:	1°

From the southern limit of the chart (4,950 meters water depth) the route crosses a flat and featureless seabed to the BU1 (4,950 meters water depth).

Cable Engineering Considerations

None

Chart Description

Segment 4 – Pohnpei to BU1

Chart Number	KCS.S4.RS.NU.GEO-001
Scale	1:1,000
Chart Location	Pohnpei Approach

Seabed Features

The inner part of the route is characterized by shallow water less than 3 meters in depth. A sediment sample (PO-GS-005) taken in this zone was composed of organic rich dark brown silt. Although more shallow, the channel is wider than towards the outer passage, and shoals mostly on the north and west side of the route. The shoals appear to be formed from small boulders and cobbles transported by fluvial processes, rather than the patch reefs common along other portions of the route.

Cable Engineering Considerations

The final alignment of the cable should account for the hazardous reef areas bordering the channel. The present route runs across non-navigable shallow water reefs. The channel is not well marked, and the generally poor water clarity makes the reef areas difficult to anticipate. It would be prudent to enlist local navigation assistance during cable laying operations.

Chart Description

Segment 4 – Pohnpei to BU1

Chart Number	KCS.S4.RS.NU.GEO-002
Scale	1:2,500
Chart Location	Pohnpei Approach

Seabed Features

The inner part of the route is characterized by shallow water less than 3 meters in depth. A sediment sample (PO-GS-005) taken in this zone was composed of organic rich dark brown silt. Although more shallow, the channel is wider than towards the outer passage, and shoals mostly on the north and west side of the route. The shoals appear to be formed from small boulders and cobbles transported by fluvial processes, rather than the patch reefs common along other portions of the route.

Cable Engineering Considerations

The final alignment of the cable should account for the hazardous reef areas bordering the channel. The present route runs across non-navigable shallow water reefs. The channel is not well marked, and the generally poor water clarity makes the reef areas difficult to anticipate. It would be prudent to enlist local navigation assistance during cable laying operations.

Chart Description **Segment 4 – Pohnpei to BU1**

Chart Number	KCS.S4.RS.NU.GEO-003
Scale	1:5,000
Chart Location	Pohnpei Approach

Seabed Features

The inner part of the route is characterized by shallow water less than 3 meters in depth. A sediment sample (PO-GS-005) taken in this zone was composed of organic rich dark brown silt. Although more shallow, the channel is wider than towards the outer passage, and shoals mostly on the north and west side of the route. The shoals appear to be formed from small boulders and cobbles transported by fluvial processes, rather than the patch reefs common along other portions of the route. As the route approaches the outer passage coralline limestone patch reefs appear, although terrigenous silt is also still present.

The route continues to follow the channel, turning north and then northwest. The high island relief and abundant rainfall apparently produce high sedimentation rates in this area, resulting in the high organic content in the sediment samples.

Cable Engineering Considerations

One sonar target, PO-SC-001, was located with both the single beam and side-scan sonar, and is thought to be a wreck lying in about 15 meters of water. Refer to Section 3.1.6.2 for details.

The final alignment of the cable should account for the hazardous reef areas bordering the channel. The present route runs across non-navigable shallow water reefs. The channel is not well marked, and the generally poor water clarity makes the reef areas difficult to anticipate. It would be prudent to enlist local navigation assistance during cable laying operations.

Chart Description **Segment 4 – Pohnpei to BU1**

Chart Number	KCS.S4.RS.NU.GEO-004
Scale	1:10,000
Chart Location	Pohnpei Approach

Seabed Features

The route comes in from the south across a transition zone between the inner and outer sections of Pohnpei Passage. The water depth in the channel drops rapidly from about 20 to 50 meters at the outer end of this zone. The area is characterized at the outer end by a pinch point in the channel with hard bottom at both sides, and a narrow (25-meter) pass that appears to be soft sediment. The only sonar target found during the survey (PO-SC-001) is in 15 meters of water and is probably a shipwreck. A sediment sample (PO-GS-001) shows the bottom in this area to be composed of dark brown (organic-rich) silt. The high island relief and abundant rainfall apparently produce high sedimentation rates in this area. The seabed shoals abruptly on either side of the channel and the shoreline is almost entirely lined with mangroves.

The route heads through the outer passage towards the barrier reef. The seabed along most of this section of the route appears mostly smooth in side-scan sonar records, although some high relief rocky areas were mapped. No major sonar targets indicative of obstructions were found in this zone. Bottom sampling was not successful except for traces of mud found on the sampler toward the landward end of the zone. Due to the presence of coralline limestone patch reefs, the seafloor can be expected to contain a mix of coral sand and cobbles (reef talus), as well as terrigenous silt derived from fluvial processes.

Once past the barrier reef, side-scan sonar data (100kHz) indicate the upper slopes of the Pohnpei Seamount is comprised of roughly weathered, corrugated rock (probably coral reef rock/limestone) with patchy accumulations of loose reef rock rubble and gravel occasionally overlying the rock. Numerous, isolated areas of rock (probably ancient coral heads) stand up to 5 meters above the seabed to the west and northeast of the route. They vary in diameter from approximately 10 to 50 meters.

Cable Engineering Considerations

Very steep gradients at the top of the main island slope.

One sonar target, PO-SC-001, was located with both the single beam and side-scan sonar, and is thought to be a wreck lying in about 15 meters of water. Refer to Section 3.1.6.2 for details.

The final alignment of the cable should account for the hazardous reef areas bordering the channel. The present route runs across non-navigable shallow water reefs. The channel is not well marked, and the generally poor water clarity makes the reef areas difficult to anticipate. It would be prudent to enlist local navigation assistance during cable laying operations.

3.1.4 Seabed Sampling

Seabed sampling was required in survey areas of less than 1,000 meters water depth. Side-scan sonar and SBP data indicated a seafloor of roughly weathered, corrugated rock (probably coral reef rock/limestone) with patchy accumulations of loose reef rock rubble and gravel occasionally overlying the rock so gravity coring was not attempted. Instead, two seabed dredge samples were attempted but recovery was only successful on one occasion (TE-DS-004). The dredge bucket was pulled across the seafloor for approximately 200 meters. This sample was considered representative of loose coral rubble distributed across the upper island slopes in the survey area.

During the small boat operations, seabed sample stations were positioned at 500-meter intervals along the survey centerline. A *Ponar* grab sampler was used for all sample collection. The first two stations, in deep water areas of Zone 1, yielded no recovery despite numerous attempts. The third station, also in Zone 1 but closer to the shoreline, had a trace of yellow green mud with some *halimeda* (coralline green algae) fragments. The sample was nevertheless too small for recovery. Five samples, labeled P1 through P5, were recovered in Zones 2 and 3. The samples were all similar, consisting of organic-rich dark brown silt. A photograph of a typical sample (P5) is shown in Figure 3.1.6.

Seabed sampling results for Segment 4 are presented in Table 3.1.1, on Chart Nos. KCS.S4.RS.NU.GEO-001 through KCS.S4.RS.NU.GEO-004, and details can be found in Appendix D.

Table 3.1.1: Seabed Samples – Segment 4

Seabed Sample ID	**Position**		**Water depth** (m)	**Description**
	Latitude (N)	Longitude (E)		
TE-DS-004	07°01.3790’	158°11.6470’	775	One 9cm piece of reef-rock coral, several pieces (1-2cm) of coral/sand conglomerate and basalt, two shells (1cm)
TE-DS-005	07°01.1695’	158°12.1715’	N/A	No recovery (2 attempts)
PO-GS-001	06°59.0504’	158°13.2283’	13.9	Very fine SILT, dark brown to black homogeneous sediment, no calcareous fragments.
PO-GS-002	06°58.7807’	158°13.2106’	5.6	Very fine SILT, dark brown to black homogeneous sediment, no calcareous shell fragments
PO-GS-003	06°58.4987’	158°13.1483’	3.7	Very fine SILT, dark brown to black homogeneous sediment, with small fibrous material and other organic particles. No calcareous shell fragments.
PO-GS-004	06°58.2660’	158°13.1530’	4.3	Very fine SILT, dark brown to black homogeneous sediment, with sand size calcareous shell fragments and large organic debris.
PO-GS-005	06°58.0225’	158°13.0013’	2.2	Very fine SILT, dark brown to black homogeneous sediment, with sand size calcareous shell fragments.

Please note: Seabed samples TE-DS-002, TE-DS-003, TE-DS-006, TE-DS-007, TE-DS-007a, collected by the M/V Trinity Explorer, are presented in a separate volume of the report, Kwajalein Submarine Cable System Route Survey.

3.1.5 Magnetometer Results

Magnetometer surveys were not conducted.

3.1.6 Areas of Concern

3.1.6.1 Existing and Planned Cables

This segment of the route crosses no existing or planned cables.

3.1.6.2 Hazards and Obstructions

The cable may become exposed on reef and tidal flat during times of low tide.

Dredging of the navigable Pohnpei Passage channel would create an issue.

Steep gradients are located along the top of the island slope at the reef-break offshore Pohnpei. Localized vertical ledges that are not resolved on the bathymetry data due to the overall steep slopes may occur across the corrugated rocky terrain at the top of the island slope.

Strong surf pounds the reef-break along the seaward side of the offshore island reef.

The final alignment of the cable should account for the hazardous reef areas bordering the channel. The present route runs across non-navigable shallow water reefs. The channel is not well marked, and the generally poor water clarity makes the reef areas difficult to anticipate. It would be prudent to enlist local navigation assistance during cable laying operations.

One sonar target (see Figure 3.1.7) was located with both the single beam and side-scan sonar, and is thought to be a wreck lying in about 15 meters of water depth. It is large (L22 x W10 x H3 meters) and should be avoided. North of the wreck location is a bathymetric and geologic “pinch point”, where hard bottom approaches from both sides of the channel and forms a narrow 25-meter corridor of soft bottom. These features are shown in Figure 3.1.7, an image produced from the side-scan sonar data, as well as Figure 3.1.1.

3.1.6.3 Fishing and Shipping

The Pohnpei Passage has restricted maneuverability and is therefore not used by large-tonnage vessels. Large vessels were observed using Sokehs Passage, located about 4 kilometers to the southwest. However, smaller fishing boats use the dock facilities at Kolonia and actively fish both inside and outside the passage.

Table 3.1.2: Bottom Obstruction Report
Kwajalein Cable System
Segment 4
FROM POHNPEI TO BU1

Date Updated:
Engineer:

Obstruction	Description	Position		KP	Offset (m)	Water Depth (m)	Chart #
		Latitude (N)	Longitude (E)				
PO-SC-001	Sonar Target - shipwreck, 22m x 10m x 3m	06 59.0899'	158 13.2192'	2.32	27mE	13	KCS.S4.RS.NU.GEO-003-004

3.2 Segment 5 - BU Kwajalein to Majuro, Republic of Marshall Islands

3.2.1 Route Summary

From the Kwajalein BU (4,360 meters water depth) the route gently shoals and undulates over rocky terrain to a depth of 3,950 meters (KCS.S5.RS.NU.BATHY-001). From here, the route crosses a 12-kilometer stretch of flat, featureless seabed where there may be some sediment cover, before crossing the southern tip of the volcanic slopes of the Kwajalein Seamount. The route begins ascending the western slope of a volcanic ridge at 167°40.2'E with gradients of approximately 15°, crests the ridge at a depth of 3,100 meters, then descends the easterly slopes to a depth of 4,150 meters on gradients of approximately 23° (KCS.S5.RS.NU.BATHY-002). The route then continues to gently undulate across a predominantly flat and featureless seabed, possibly becoming rockier after 170°32'E as the route approaches the north-south orientated volcanic saddle connecting Majuro and Aur Atoll belonging to the Ratak Island Chain (KCS.S5.RS.NU.BATHY-005). The route ascends the rocky western slopes with maximum gradients of approximately 20° and crests the saddle at a depth of 2,660 meters at 171°02.7'E before descending in an easterly direction on localized maximum gradients of approximately 16°, to approximately 4,000 meters (KCS.S5.RS.NU.BATHY-006). From here, the route gently undulates and shoals for approximately 42 kilometers before beginning to ascend the northerly facing volcanic slopes of the Majuro Seamount at a depth of approximately 3,650 meters (KCS.S5.RS.NU.BATHY-006). The route ascends the rocky slopes with typical gradients of 10° to 15° until 07°07.89'N – 171°25.55'E at which point the slopes begin to turn eastward and gradients become steeper reaching a localized maximum of approximately 60° at around 600 meters depth (KCS.S5.RS.NU.BATHY-007 / KCS.S5.RS.NU.BATHY-008). The route finally crests the upper island slopes comprised of rough rock and intermittent coralline sand pockets with accumulated dead coral, at approximately 07°05.60'N – 171°23.27'E where a paleo-reef-break forms a steep scarp of approximately 62° (KCS.S5.RS.NU.BATHY-009 / KCS.S5.RS.NU.GEO-009). The route then crosses a very gently shoaling rocky hard-pan for approximately 250 meters before rising onto the current reef break and continuing across a hard-pan of relatively flat reef rock to a small beach berm where the BMH is located (KCS.S5.RS.NU.BATHY-010 / KCS.S5.RS.NU.GEO-010).

3.2.2 Landing, Diver and Inshore Survey

Majuro Atoll is a string of 64 small and low islands enclosing a lagoon 295 square kilometers in area. The project site is near the eastern-most edge of the atoll on the main island of Delap (Figure 3.2.1). The project location is directly exposed to steady and persistent trade winds and trade wind generated waves from the northeast. The configuration of the bathymetry at the project site is typical for mid-Pacific atolls, as it rises steeply from deep water to a narrow limestone reef platform. Exposed land areas consist of fossil reef limestone and beach sediments. The average elevation is about 2.1 meters above mean sea level.

Seabed features for the Majuro landing are shown in Figure 3.2.2, and land topographic features are shown in Figure 3.2.3. A steep 33° rise characterizes the survey route from the survey limit at 100 meters water depth to about 15 meters water depth. A moderate slope continues from 10 to 3 meters water depth, and ends on a reef flat with an elevation change of less than 1 meter over a distance of 150 meters.

The offshore area was inspected during one diver swim. Only one swim was attempted as the steep waves breaking in shallow water was considered hazardous. The diver swim ended at the 15-meter drop-off where the bathymetry plunges (Figure 3.2.4). The offshore area was homogenous, with 100% low relief live coral coverage. Individual coral head size increased gradually from the breaking zone to the drop-off (Figure 3.2.5).

The wave-breaking zone is about 50 meters wide at low tide (i.e. waves break across the entire reef flat during high tide conditions). Surge channels (spur and groove structures) that are incised up to 2.5 meters into the limestone substrate characterize the seabed morphology. The top of the channels, or spur features, rise above the water surface at lower tide elevations, and have the appearance of large boulders in the surf zone (Figure 3.2.6). Figure 3.2.7 is a photograph taken from offshore that shows the emergent spur features at low tide, as well as the BMH location.

The reef flat is composed of very dense, crystalline limestone. It is flat, with a nominal elevation of 1 meter LAT (rising from about 0.5 to 1.2 meters over a distance of 150 meters), with little or no pockets of sediment. Portions of the reef flat have been excavated for building material, and a large pool (less than a meter deep) has formed north of the survey route. Figure 3.2.8 shows the reef flat at high tide, while low tide conditions are exhibited in Figures 3.2.9 and 3.2.10. The excavated area can also be seen in Figure 3.2.9.

The shoreline is a 2.5-meter escarpment of sand, coral cobbles, and limestone boulders. The land area behind the escarpment slopes gently down from the shoreline escarpment.

Abandoned pieces of heavy equipment are scattered on the landward edge of the reef flat, at the base of the shoreline escarpment. One group lies close to the proposed alignment of the cable (Figure 3.2.11).

The landing site is a densely populated area with many small houses. The BMH is as located in the desktop study (Appendix E) and is situated to provide access to the Marshall Islands National Telecommunications Authority (MINTA) facilities. At present, vegetation and an abandoned vehicle block the path to the MINTA facilities.

The BMH was located from the desktop study, and positioned with decimeter accuracy.

The BMH position is: 07°05.5697’N – 171°23.0072’E

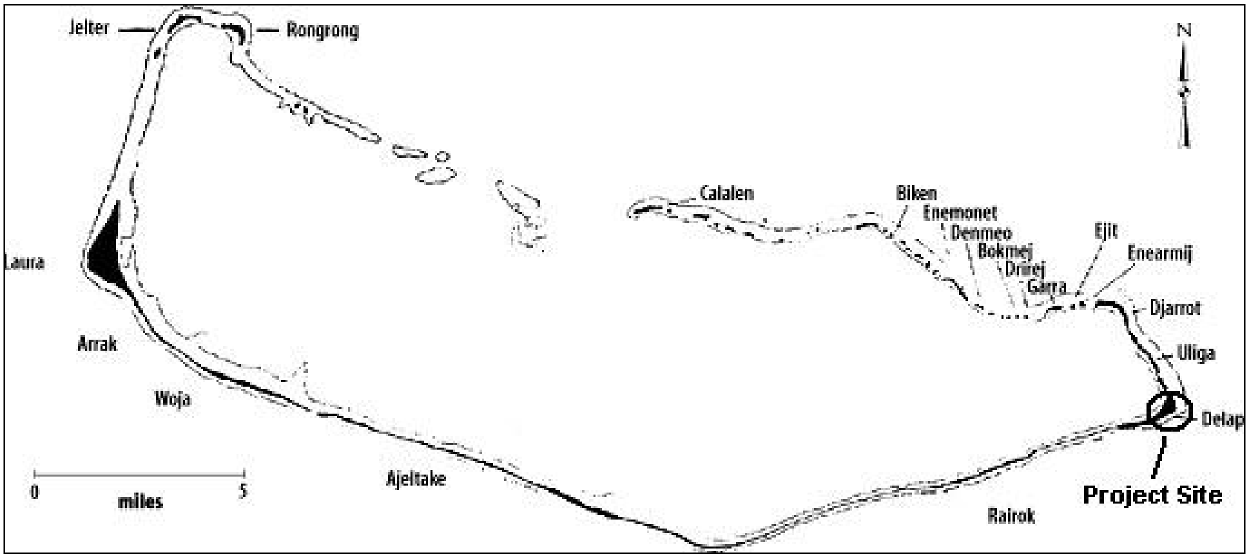
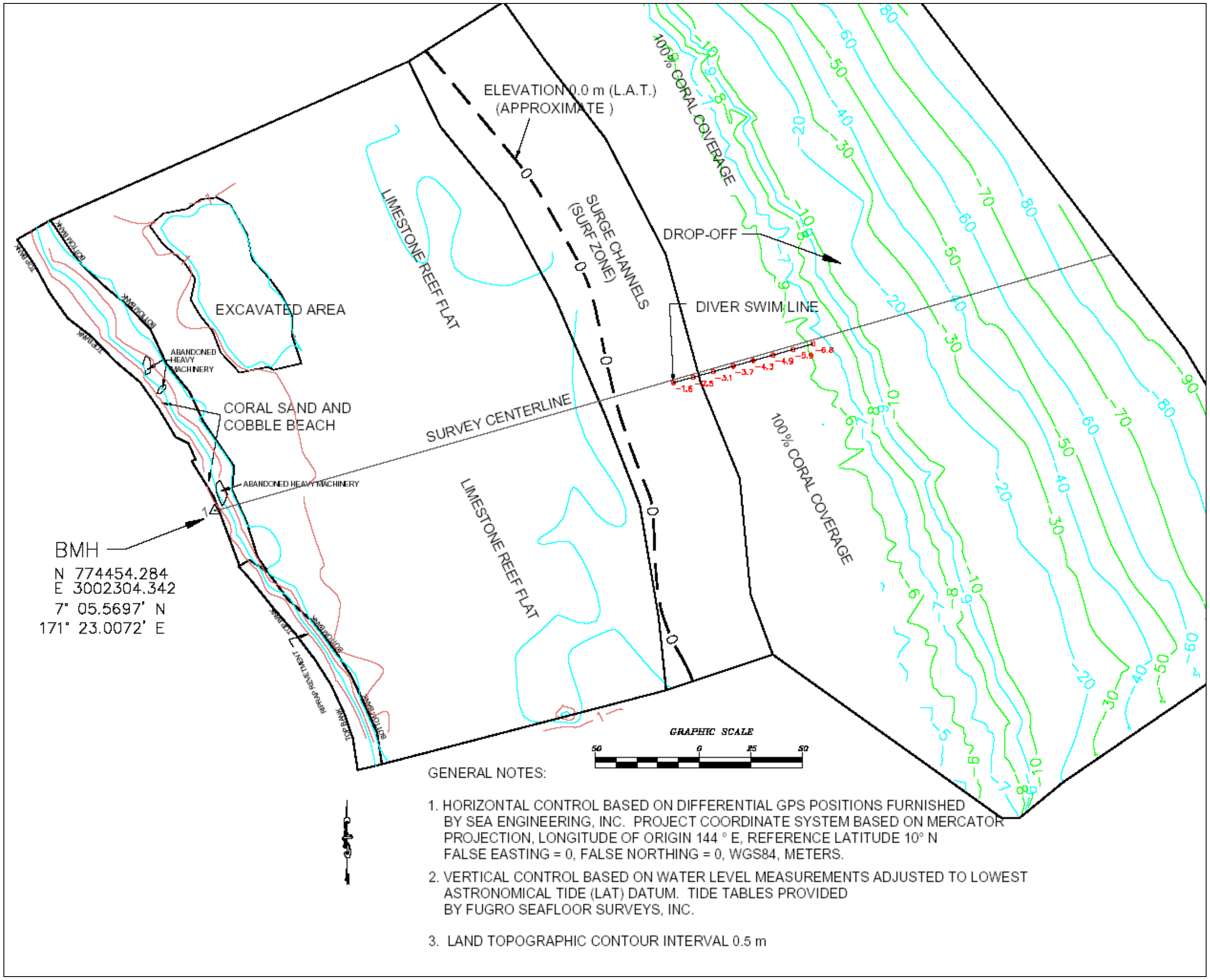


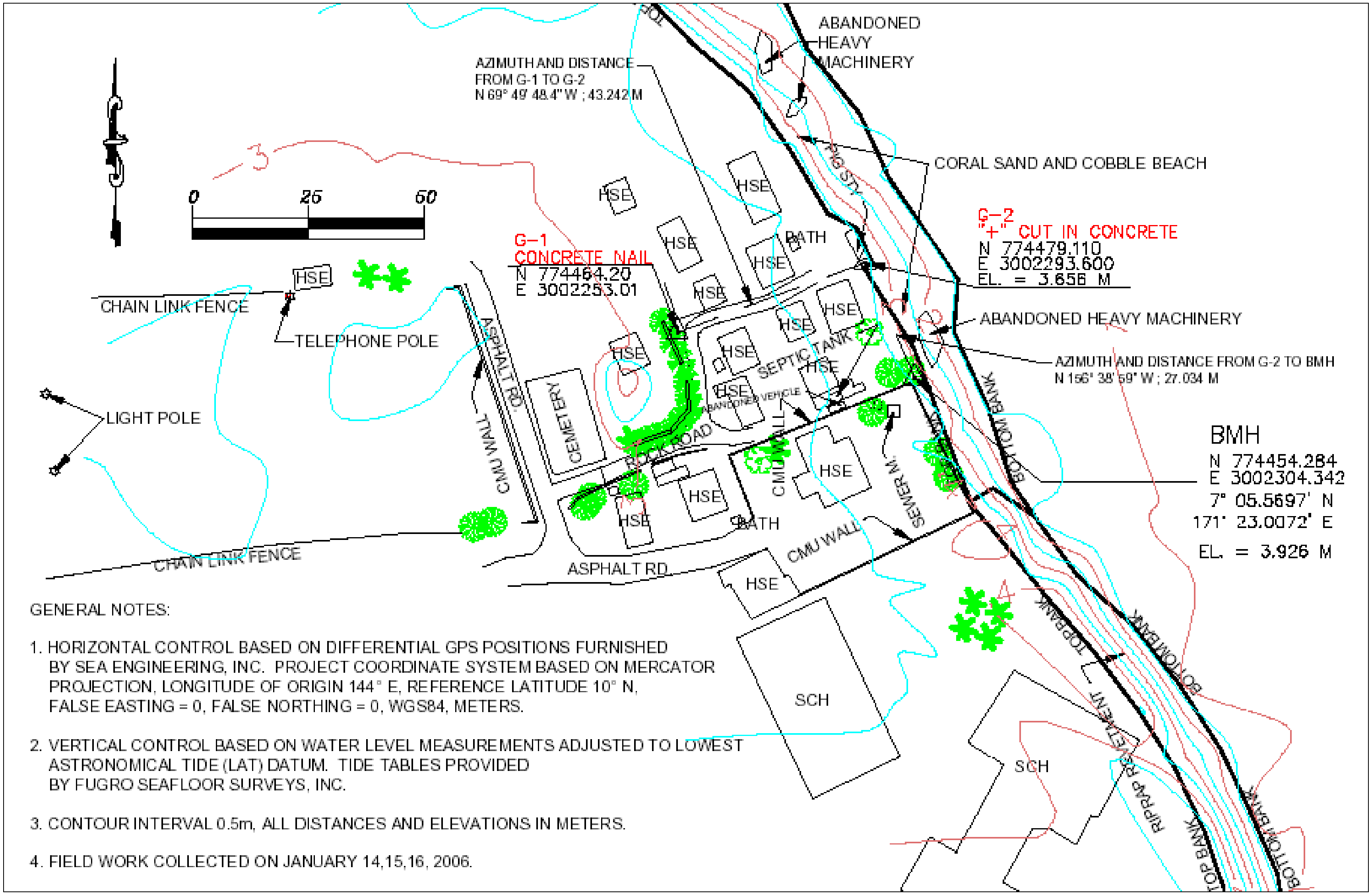
Figure 3.2.1: Project site, Majuro Atoll



GENERAL NOTES:

1. HORIZONTAL CONTROL BASED ON DIFFERENTIAL GPS POSITIONS FURNISHED BY SEA ENGINEERING, INC. PROJECT COORDINATE SYSTEM BASED ON MERCATOR PROJECTION, LONGITUDE OF ORIGIN 144 ° E, REFERENCE LATITUDE 10° N FALSE EASTING = 0, FALSE NORTHING = 0, WGS84, METERS.
2. VERTICAL CONTROL BASED ON WATER LEVEL MEASUREMENTS ADJUSTED TO LOWEST ASTRONOMICAL TIDE (LAT) DATUM. TIDE TABLES PROVIDED BY FUGRO SEAFLOOR SURVEYS, INC.
3. LAND TOPOGRAPHIC CONTOUR INTERVAL 0.5 m

Figure 3.2.2: Seabed features at the Majuro landing site



GENERAL NOTES:

1. HORIZONTAL CONTROL BASED ON DIFFERENTIAL GPS POSITIONS FURNISHED BY SEA ENGINEERING, INC. PROJECT COORDINATE SYSTEM BASED ON MERCATOR PROJECTION, LONGITUDE OF ORIGIN 144° E, REFERENCE LATITUDE 10° N, FALSE EASTING = 0, FALSE NORTHING = 0, WGS84, METERS.

2. VERTICAL CONTROL BASED ON WATER LEVEL MEASUREMENTS ADJUSTED TO LOWEST ASTRONOMICAL TIDE (LAT) DATUM. TIDE TABLES PROVIDED BY FUGRO SEAFLOOR SURVEYS, INC.

3. CONTOUR INTERVAL 0.5m, ALL DISTANCES AND ELEVATIONS IN METERS.

4. FIELD WORK COLLECTED ON JANUARY 14,15,16, 2006.

Figure 3.2.3: Topographic features at Majuro landing site

Figure 3.2.4: Bathymetric drop-off at 15m

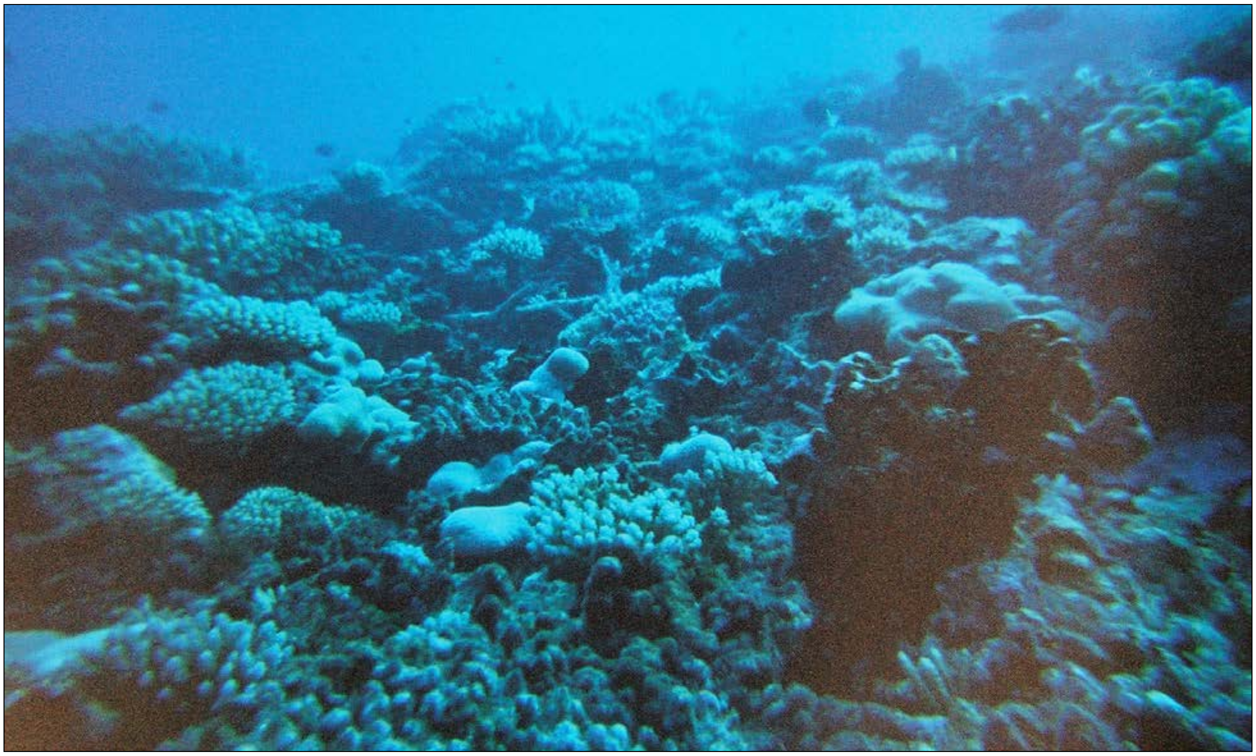


Figure 3.2.5: Typical bottom conditions near the drop-off

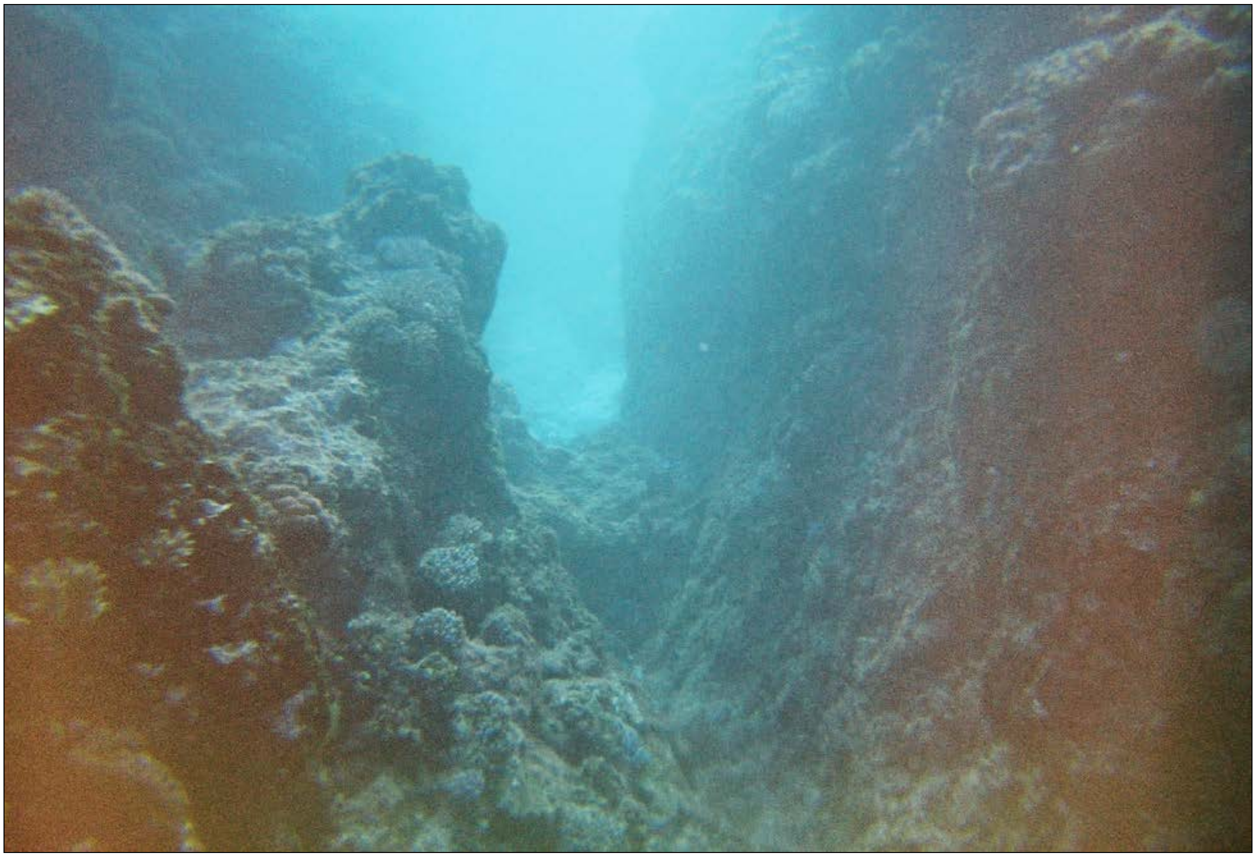


Figure 3.2.6: Surge channel in the wave breaker impact zone

Figure 3.2.7: BMH location and emergent spur features in wave breaking zone

Figure 3.2.8: Reef flat at high tide

Figure 3.2.9: Reef flat at low tide (1)

Figure 3.2.10: Reef flat at low tide (2)

Figure 3.2.11: Abandoned heavy equipment near BMH

3.2.3 Chart Descriptions

In this section, the Bathymetric Charts are described first, followed by the Geological chart descriptions.

Chart Description **Segment 5 – BU2 to Majuro**

Chart Number	KCS.S5.RS.NU.BATHY-001
Scale	1:25,000
Chart Location	BU2

Seafloor Topography

Minimum depth along route:	3,900 meters
Maximum depth along route:	4,360 meters
Minimum depth within chart:	3,150 meters
Maximum depth within chart:	4,600 meters
Maximum gradient along route:	5°

From BU2 (4,360 meters water depth), the route gently ascends to approximately 3,900 meters as it crosses the southern tip of the Kwajalein Seamount to the eastern limit of the chart.

Cable Engineering Considerations

None

Chart Description

Segment 5 – BU2 to Majuro

Chart Number	KCS.S5.RS.NU.BATHY-002
Scale	1:100,000
Chart Location	BU2

Seafloor Topography

Minimum depth along route:	2,960 meters
Maximum depth along route:	4,250 meters
Minimum depth within chart:	0 meters
Maximum depth within chart:	4,600 meters
Maximum gradient along route:	<23°

From BU2 (4,360 meters water depth), the route gently undulates across the southern tip of the Kwajalein Seamount with gradients not exceeding 23°. It ascends to approximately 2,960 meters before descending to around 4,250 meters water depth where the route gently undulates to the eastern limit of the chart.

Between 167°40.22’E and 167°45.00’E the route crosses the southern tip of the extinct paleo-volcano that formed Kwajalein Atoll. Survey development was conducted south of the original route at this location but was unsuccessful in locating a route that would completely avoid this feature.

Cable Engineering Considerations

None

Chart Description

Segment 5 – BU2 to Majuro

Chart Number	KCS.S5.RS.NU.BATHY-003
Scale	1:100,000
Chart Location	North of Namu Atoll and Jabwot Atoll

Seafloor Topography

Minimum depth along route:	4,250 meters
Maximum depth along route:	4,350 meters
Minimum depth within chart:	4,250 meters
Maximum depth within chart:	4,350 meters
Maximum gradient along route:	<1°

From the western limit of the chart (4,250 meters water depth), the route crosses a gently undulating seabed with negligible gradients to the eastern limit of the chart (4,350 meters water depth).

Cable Engineering Considerations

None

Chart Description

Segment 5 – BU2 to Majuro

Chart Number	KCS.S5.RS.NU.BATHY-004
Scale	1:100,000
Chart Location	Between Jabwot Atoll and Erikub Atoll

Seafloor Topography

Minimum depth along route:	4,150 meters
Maximum depth along route:	4,400 meters
Minimum depth within chart:	4,000 meters
Maximum depth within chart:	4,400 meters
Maximum gradient along route:	<5°

From the western limit of the chart (4,300 meters water depth), the route crosses a relatively flat, featureless seabed with negligible gradients, to the eastern limit of the chart (4,050 meters water depth).

Cable Engineering Considerations

None

Chart Description — Segment 5 – BU2 to Majuro

Chart Number	KCS.S5.RS.NU.BATHY-005
Scale	1:100,000
Chart Location	South of Erikub Atoll

Seafloor Topography

Minimum depth along route:	4,050 meters
Maximum depth along route:	4,150 meters
Minimum depth within chart:	4,000 meters
Maximum depth within chart:	4,200 meters
Maximum gradient along route:	<5°

From the western limit of the chart (4,150 meters water depth), the route crosses a relatively flat, featureless seabed with negligible gradients, to the eastern limit of the chart (4,050 meters water depth).

Cable Engineering Considerations

None

Chart Description — Segment 5 – BU2 to Majuro

Chart Number	KCS.S5.RS.NU.BATHY-006
Scale	1:100,000
Chart Location	Majuro approach

Seafloor Topography

Minimum depth along route:	-3.9 meters
Maximum depth along route:	4,050 meters
Minimum depth within chart:	-4 meters
Maximum depth within chart:	4,050 meters
Maximum gradient along route:	60°

From the western limit of the chart (4,050 meters water depth), the route crosses a relatively flat, featureless seabed with negligible gradients. Between approximately 170°E and 171°06.70’E, the route crosses the Ratak Island Chain between Majuro Atoll and Aur Atoll, reaching a minimum depth of 2,680 meters. Maximum slope gradients along the route across this saddle are approximately 11° on the upslope and 26° on the downslope face.

The route then again traverses a relatively flat and featureless seabed with negligible gradients before it begins to ascend the northeastern slope of the Majuro Atoll at approximately 171°24.48’E. The slope at the base of the seamount is steep and irregular, with slopes up to 20°. At a water depth of approximately 1,800 meters, the seabed steepens further, becoming very steep and irregular towards the top of the slope with gradients up to 60° along the route.

At 10 to 15 meters water depth the seabed gradient becomes less steep as the route comes onto reef terrace. The route proceeds west across the terrace for about 50 meters, shoaling over the moderate gradient of approximately 5° to 3 meters water depth. The seabed morphology in this zone is characterized by surge channels (spur and groove structures) that are incised up to 2.5 meters into the limestone substrate. The top of the channels, or spur features, rise above the water surface at lower tide elevations, and have the appearance of large boulders in the surf zone. The route then crosses the reef flat, which is approximately 150 meters wide and is relatively flat, with a nominal elevation of 1 meter LAT. Portions of the reef flat have been excavated for building material, and a large pool (less than a meter deep) has been formed north of the survey route.

The shoreline is a 2.5-meter escarpment of sand, coral cobbles, and limestone boulders. The land area behind the escarpment slopes gently down to the BMH.

Cable Engineering Considerations

Very steep gradients and rocky, rough terrain occur across the upper slopes of the Majuro Seamount.

The surf zone can be extremely hazardous, with steep plunging waves breaking in shallow water. Installation of the cable in these conditions will be difficult.

The breaking wave zone is characterized by deep surge channels. There are many channels adjacent to each other. The cable can be expected to stay within one of these channels once located. However, some channels have steep headwalls on the landward side that could force a bend in the cable beyond tolerances. As such, a suitable channel should be located prior to cable installation.

Strong eastward moving currents on the order of 1 to 2 knots (est.) were observed. This may affect cable-laying operations.

Chart Description

Segment 5 – BU2 to Majuro

Chart Number	KCS.S5.RS.NU.BATHY-007
Scale	1:10,000
Chart Location	Majuro Approach

Seafloor Topography

Minimum depth along route:	-3.9 meters
Maximum depth along route:	2,040 meters
Minimum depth within chart:	-4 meters
Maximum depth within chart:	2,060 meters
Maximum gradient along route:	62°

From the northeastern corner of the chart, the route ascends the very steep and irregular northeastern slope of the Majuro Atoll, with gradients up to 20°. Gradients become very steep toward the top of the slope between water depths of 1,000 and 500 meters. The route finally crests the upper island slopes at approximately 50 meters water depth (07°05.60'N – 171°23.27'E) where a paleo-reef-break forms a steep scarp of approximately 62°.

At 10 to 15 meters water depth the seabed gradient becomes less steep as the route comes onto reef terrace. The route proceeds west across the terrace for about 50 meters, shoaling over the moderate gradient of approximately 5° to 3 meters water depth. The bottom morphology in this zone is characterized by surge channels (spur and groove structures) that are incised up to 2.5 meters into the limestone substrate. The top of the channels, or spur features, rise above the water surface at lower tide elevations, and have the appearance of large boulders in the surf zone. The route then crosses the reef flat, which is approximately 150 meters wide and is relatively level, with a nominal elevation of 1 meter LAT. Portions of the reef flat have been excavated for building material, and a large pool (less than 1 meter deep) has been formed north of the survey route.

The shoreline is a 2.5-meter escarpment of sand, coral cobbles, and limestone boulders. The land area behind the escarpment slopes gently down to the BMH.

Cable Engineering Considerations

Very steep gradients and rocky, rough terrain occur across the upper slopes of the Majuro seamount.

The surf zone can be extremely hazardous, with steep plunging waves breaking in shallow water. Installation of the cable in these conditions will be difficult.

The breaking wave zone is characterized by deep surge channels. There are many channels virtually adjacent to each other. The cable can be expected to stay within one of these channels once located. However, some channels have steep headwalls on the landward side that could force a bend in the cable beyond tolerances. As such, a suitable channel should be located prior to cable installation.

Strong eastward moving currents on the order of 1 to 2 knots (est.) were observed offshore. This may affect cable-laying operations.

Chart Description — Segment 5 – BU2 to Majuro

Chart Number	KCS.S5.RS.NU.BATHY-008
Scale	1:5,000
Chart Location	Majuro Approach

Seafloor Topography

Minimum depth along route:	-3.9 meters
Maximum depth along route:	1,680 meters
Minimum depth within chart:	-4 meters
Maximum depth within chart:	1,720 meters
Maximum gradient along route:	62°

From the northeastern corner of the chart, the route ascends the very steep and irregular northeasterly facing slopes of the Majuro Seamount. Gradients become very steep towards the top of the slope between water depths of 1,000 and 500 meters. The route finally crests the upper island slopes at approximately 50 meters water depth (07°05.60'N – 171°23.27'E) where a paleo-reef-break forms a steep scarp of approximately 62°.

At 10 to 15 meters water depth the seabed gradient becomes less steep as the route comes onto reef terrace. The route proceeds west across the terrace for about 50 meters, shoaling over the moderate gradient of approximately 5° to 3 meters water depth. The bottom morphology in this zone is characterized by surge channels (spur and groove structures) that are incised up to 2.5 meters into the limestone substrate. The top of the channels, or spur features, rise above the water surface at lower tide elevations, and have the appearance of large boulders in the surf zone. The route then crosses the reef flat, which is approximately 150 meters wide and is relatively flat, with a nominal elevation of 1 meter LAT. Portions of the reef flat have been excavated for building material, and a large pool (less than 1 meter deep) has been formed north of the survey route.

The shoreline is a 2.5-meter escarpment of sand, coral cobbles, and limestone boulders. The land area behind the escarpment slopes gently down to the BMH.

Cable Engineering Considerations

Localized vertical ledges, not resolved on the bathymetry data due to the overall very steep slopes may occur across the corrugated rocky terrain at the top of the island slope.

The surf zone can be extremely hazardous, with steep plunging waves breaking in shallow water. Installation of the cable in these conditions will be difficult.

The breaking wave zone is characterized by deep surge channels. There are many channels virtually adjacent to each other. The cable can be expected to stay within one of these channels once located. However, some channels have steep headwalls on the landward side that could force a bend in the cable beyond tolerances. As such, a suitable channel should be located prior to cable installation.

Strong eastward moving currents on the order of 1 to 2 knots (est.) were observed. This may affect cable-laying operations.

Chart Description

Segment 5 – BU2 to Majuro

Chart Number	KCS.S5.RS.NU.BATHY-009
Scale	1:2,500
Chart Location	Majuro Landing

Seafloor Topography

Minimum depth along route:	-3.9 meters
Maximum depth along route:	565 meters
Minimum depth within chart:	-4 meters
Maximum depth within chart:	775 meters
Maximum gradient along route:	62°

From the eastern limit of the chart, the route ascends the very steep and irregular slopes of the Majuro Seamount. The route finally crests the upper island slopes at approximately 50 meters water depth (07°05.60'N – 171°23.27'E) where a paleo-reef-break forms a steep scarp of approximately 62°.

At 10 to 15 meters water depth the seabed gradient becomes less steep as the route comes onto reef terrace. The route proceeds west across the terrace for about 50 meters, shoaling over the moderate gradient of approximately 5° to 3 meters water depth. The bottom morphology in this zone is characterized by surge channels (spur and groove structures) that are incised up to 2.5 meters into the limestone substrate. The top of the channels, or spur features, rise above the water surface at lower tide elevations, and have the appearance of large boulders in the surf zone. The route then crosses the reef flat, which is approximately 150 meters wide and is relatively flat, with a nominal elevation of 1 meter LAT. Portions of the reef flat have been excavated for building material, and a large pool (less than 1 meter deep) has been formed north of the survey route.

The shoreline is a 2.5-meter escarpment of sand, coral cobbles, and limestone boulders. The land area behind the escarpment slopes gently down to the BMH.

Cable Engineering Considerations

Localized vertical ledges, not resolved on the bathymetry data due to the overall very steep slopes may occur across the corrugated rocky terrain at the top of the island slope.

The surf zone can be extremely hazardous, with steep plunging waves breaking in shallow water. Installation of the cable in these conditions will be difficult.

The breaking wave zone is characterized by deep surge channels. There are many channels virtually adjacent to each other. The cable can be expected to stay within one of these channels once located. However, some channels have steep headwalls on the landward side that could force a bend in the cable beyond tolerances, so that a suitable channel should be located prior to cable installation.

Strong eastward moving currents on the order of 1 to 2 knots (est.) were observed. This may affect cable-laying operations.

Chart Description

Segment 5 – BU2 to Majuro

Chart Number	KCS.S5.RS.NU.BATHY-010
Scale	1:1,000
Chart Location	Majuro Landing

Seafloor Topography

Minimum depth along route:	-3.9 meters
Maximum depth along route:	385 meters
Minimum depth within chart:	-4 meters
Maximum depth within chart:	430 meters
Maximum gradient along route:	62°

From the eastern limit of the chart, the route ascends the very steep and irregular slopes of the Majuro Seamount. The route finally crests the upper island slopes at approximately 50 meters water depth (07°05.60'N – 171°23.27'E) where a paleo-reef-break forms a steep scarp of approximately 62°.

At 10 to 15 meters water depth the seabed gradient becomes less steep as the route comes onto reef terrace. The route proceeds west across the terrace for about 50 meters, shoaling over the moderate gradient of approximately 5° to 3 meters water depth. The bottom morphology in this zone is characterized by surge channels (spur and groove structures) that are incised up to 2.5 meters into the limestone substrate. The top of the channels, or spur features, rise above the water surface at lower tide elevations, and have the appearance of large boulders in the surf zone. The route then crosses the reef flat, which is approximately 150 meters wide and is relatively flat, with a nominal elevation of 1 meter LAT. Portions of the reef flat have been excavated for building material, and a large pool (less than 1 meter deep) has been formed north of the survey route.

The shoreline is a 2.5-meter escarpment of sand, coral cobbles, and limestone boulders. The land area behind the escarpment slopes gently down to the BMH.

Cable Engineering Considerations

Localized vertical ledges, not resolved on the bathymetry data due to the overall very steep slopes may occur across the corrugated rocky terrain at the top of the island slope.

The surf zone can be extremely hazardous, with steep plunging waves breaking in shallow water. Installation of the cable in these conditions will be difficult.

The breaking wave zone is characterized by deep surge channels. There are many channels virtually adjacent to each other. The cable can be expected to stay within one of these channels once located. However, some channels have steep headwalls on the landward side that could force a bend in the cable beyond tolerances, so that a suitable channel should be located prior to cable installation.

Strong eastward moving currents on the order of 1 to 2 knots (est.) were observed. This may affect cable-laying operations.

Chart Description

Segment 5 – BU2 to Majuro

Chart Number	KCS.S5.RS.NU.GEO-007
Scale	1:10,000
Chart Location	Majuro Approach

Seabed Features

The side-scan sonar data indicate the seabed shallower than 1,000 meters water depth is composed of a rough, often corrugated, rocky surface with an irregular patchy sediment veneer. Dredge sample (TE-DS-001), obtained on the slope, confirmed the veneer to comprise a loose mix of fine-medium coralline sand (50% broken coral) with occasional pieces of dead, broken coral up to 6centimeters. To the north of the route at the top of the slope, several isolated lumps of rock (probably ancient coral heads) stand less than 5 meters above the seabed.

At the top of the slope, in less than 100 meters water depth, the route crosses through abundant low-relief live coral. Individual coral heads were larger in the deeper areas, becoming smaller as the route reaches the wave-breaking zone on the reef terrace. The reef terrace bottom morphology is characterized by surge channels (spur and groove structures) that are incised up to 2.5 meters into the limestone substrate. The top of the channels, or spur features, rise above the water surface at lower tide elevations, and have the appearance of large boulders in the surf zone. The reef flat is composed of very dense, crystalline limestone, with little or no pockets of sediment.

The route proceeds west to the shoreline and BMH over a 2.5-meter escarpment of sand, coral cobbles and limestone boulders.

Cable Engineering Considerations

Very steep gradients and rocky, rough terrain occur across the upper slopes of the Majuro Seamount.

The surf zone can be extremely hazardous, with steep plunging waves breaking in shallow water. Installation of the cable in these conditions will be difficult.

The breaking wave zone is characterized by deep surge channels. There are many channels virtually adjacent to each other. The cable can be expected to stay within one of these channels once located. However, some channels have steep headwalls on the landward side that could force a bend in the cable beyond tolerances, so that a suitable channel should be located prior to cable installation.

Strong eastward moving currents on the order of 1 to 2 knots (est.) were observed. This may affect cable-laying operations.

Chart Description

Segment 5 – BU2 to Majuro

Chart Number	KCS.S5.RS.NU.GEO-008
Scale	1:5,000
Chart Location	Majuro Approach

Seabed Features

The side-scan sonar data indicate the seabed shallower than 1,000 meters water depth is composed of rough, often corrugated, rock, often overlain by intermittent, coralline sandy pockets with accumulated coral rubble. Dredge sample (TE-DS-001), obtained on the slope, confirmed the veneer to comprise a loose mix of fine-medium coralline sand (50% broken coral) with occasional pieces of dead, broken coral up to 6 centimeters. To the north of the route, several isolated lumps of rock (probably ancient coral heads) stand less than 5 meters above the seabed.

At the top of the slope, in less than 100 meters water depth, the route crosses through abundant low-relief live coral. Individual coral heads were larger in the deeper areas, becoming smaller as the route reaches the wave-breaking zone on the reef terrace. The reef terrace bottom morphology is characterized by surge channels (spur and groove structures) that are incised up to 2.5 meters into the limestone substrate. The top of the channels, or spur features, rise above the water surface at lower tide elevations, and have the appearance of large boulders in the surf zone. The reef flat is composed of very dense, crystalline limestone, with little or no pockets of sediment.

The route proceeds west to the shoreline and BMH over a 2.5-meter escarpment of sand, coral cobbles and limestone boulders.

Cable Engineering Considerations

Localized vertical ledges, not resolved on the bathymetry data due to the overall very steep slopes may occur across the corrugated rocky terrain at the top of the island slope.

The surf zone can be extremely hazardous, with steep plunging waves breaking in shallow water. Installation of the cable in these conditions will be difficult.

The breaking wave zone is characterized by deep surge channels. There are many channels virtually adjacent to each other. The cable can be expected to stay within one of these channels once located. However, some channels have steep headwalls on the landward side that could force a bend in the cable beyond tolerances, so that a suitable channel should be located prior to cable installation.

Strong eastward moving currents on the order of 1 to 2 knots (est.) were observed. This may affect cable-laying operations.

Chart Description **Segment 5 – BU2 to Majuro**

Chart Number	KCS.S5.RS.NU.GEO-009
Scale	1:2,500
Chart Location	Majuro Landing

Seabed Features

The side-scan sonar data indicate the seabed shallower than 1,000 meters water depth is composed of rough, often corrugated, rock, often overlain by intermittent, coralline sandy pockets with accumulated coral rubble. Dredge sample (TE-DS-001), obtained on the slope, confirmed the veneer to comprise a loose mix of fine-medium coralline sand (50% broken coral) with occasional pieces of dead, broken coral up to 6cm in size.

At the top of the slope, in less than 100 meters water depth, the route crosses through abundant low-relief live coral. Individual coral heads were larger in the deeper areas, becoming smaller as the route reaches the wave-breaking zone on the reef terrace. The reef terrace bottom morphology is characterized by surge channels (spur and groove structures) that are incised up to 2.5 meters into the limestone substrate. The top of the channels, or spur features, rise above the water surface at lower tide elevations, and have the appearance of large boulders in the surf zone. The reef flat is composed of very dense, crystalline limestone, with little or no pockets of sediment.

The route proceeds west to the shoreline and BMH over a 2.5-meter escarpment of sand, coral cobbles and limestone boulders.

Cable Engineering Considerations

Localized vertical ledges, not resolved on the bathymetry data due to the overall very steep slopes may occur across the corrugated rocky terrain at the top of the island slope.

The surf zone can be extremely hazardous, with steep plunging waves breaking in shallow water. Installation of the cable in these conditions will be difficult.

The breaking wave zone is characterized by deep surge channels. There are many channels virtually adjacent to each other. The cable can be expected to stay within one of these channels once located. However, some channels have steep headwalls on the landward side that could force a bend in the cable beyond tolerances, so that a suitable channel should be located prior to cable installation.

Strong eastward moving currents on the order of 1 to 2 knots (est.) were observed. This may affect cable-laying operations.

Chart Description **Segment 5 – BU2 to Majuro**

Chart Number	KCS.S5.RS.NU.GEO-010
Scale	1:1,000
Chart Location	Majuro Landing

Seabed Features
The side-scan sonar data indicate the seabed shallower than 1,000 meters water depth is composed of rough, often corrugated, rock, often overlain by intermittent, coralline sandy pockets with accumulated coral rubble. Several isolated lumps of rock (probably ancient coral heads) stand less than 5 meters above the seabed to the north of the route.

At the top of the slope, in less than 100 meters water depth, the route crosses through abundant low-relief live coral. Individual coral heads were larger in the deeper areas, becoming smaller as the route reaches the wave-breaking zone on the reef terrace. The reef terrace bottom morphology is characterized by surge channels (spur and groove structures) that are incised up to 2.5 meters into the limestone substrate. The top of the channels, or spur features, rise above the water surface at lower tide elevations, and have the appearance of large boulders in the surf zone. The reef flat is composed of very dense, crystalline limestone, with little or no pockets of sediment.

The route proceeds west to the shoreline and BMH over a 2.5-meter escarpment of sand, coral cobbles and limestone boulders.

Cable Engineering Considerations
Localized vertical ledges, not resolved on the bathymetry data due to the overall very steep slopes may occur across the corrugated rocky terrain at the top of the island slope.

The surf zone can be extremely hazardous, with steep plunging waves breaking in shallow water. Installation of the cable in these conditions will be difficult.

The breaking wave zone is characterized by deep surge channels. There are many channels virtually adjacent to each other. The cable can be expected to stay within one of these channels once located. However, some channels have steep headwalls on the landward side that could force a bend in the cable beyond tolerances, so that a suitable channel should be located prior to cable installation.

Strong eastward moving currents on the order of 1 to 2 knots (est.) were observed. This may affect cable-laying operations.

3.2.4 Seabed Sampling

Seabed sampling was required in survey areas of less than 1,000 meters water depth. The only area along this segment of the route within this depth was the upper slopes of the Majuro Seamount close to the landing site. Here, side-scan sonar and SBP data indicated a seafloor of rough, possibly corrugated, reef rock with intermittent, thin sediment pocket accumulations, so gravity coring was not attempted. Instead, a seabed dredge sample was obtained (TE-DS-001) from the Majuro Island Slope. The dredge bucket was pulled across the seafloor for approximately 200 meters, which resulted in a recovery of a half-bucket full of sample, considered representative of the sporadic sediment/dead coral accumulations across the upper island slopes in the survey area.

No seabed samples were taken in the inshore area, hard bottom occurs along the entire route.

Seabed sampling results for Segment 5 are presented in Table 3.2.1, in Chart Nos. KCS.S5.RS.NU.GEO-007 through KCS.S5.RS.NU.GEO-010 and details can be found in Appendix D.

Table 3.2.1: Seabed Samples – Segment 5

Seabed Sample ID	**Position**		**Water depth** (m)	**Description**
	Latitude (N)	Longitude (E)		
TE-DS-001	07°05.7146'	171°23.7269'	556	Fine to medium coralline SAND (50% broken coral) with occasional dead coral pieces up to 6cm

Please note: Seabed samples TE-DS-002, TE-DS-003, TE-DS-006, TE-DS-007, TE-DS-007a, collected by the M/V Trinity Explorer, are presented in a separate volume of the report, Kwajalein Submarine Cable System Route Survey.

3.2.5 Magnetometer Results

A magnetometer survey was not conducted.

3.2.6 Areas of Concern

3.2.6.1 Existing and Planned Cables

No cables presently exist at the project site.

3.2.6.2 Hazards and Obstructions

Very steep gradients occur across the upper slopes of the Majuro Seamount and localized vertical ledges that are not resolved on the bathymetry data due to the overall steep slopes may occur across the corrugated rocky terrain at the top of the island slope.

The cable route alignment is on an open coastline exposed to strong and steady trade winds and trade wind generated waves. The surf zone can be extremely hazardous, with steep plunging waves breaking in shallow water. Installation of the cable in these conditions would be difficult. The winds and waves exhibit a seasonal pattern, being strongest in the winter months. The lowest average wind speeds in the region occur during the months of August through October, and this period should be targeted for cable installation.

The wave-breaking zone is characterized by deep surge channels. There are many channels placed virtually adjacent to each other. The cable can be expected to stay within one of these channels once located. However, some channels have steep headwalls on the landward side that could force a bend in the cable beyond tolerances, so that a suitable channel should be located prior to cable installation.

The steep drop-off at 15 meters water depth will likely require suitable engineering for stable cable installation.

Strong eastward moving currents on the order of 1 to 2 knots (est.) were observed offshore of the route alignment. This may affect cable-laying operations.

3.2.6.3 Fishing and Shipping

Fishing is a major source of livelihood in the Marshall Islands. However, fishing activities should have no effect on cable installation or service.

4. METHODOLOGY

4.1 Survey Operations

4.1.1 Equipment and Personnel

The technical specifications of all survey equipment used for the KCS project are provided in Appendix C. Details regarding the personnel involved with the surveys are given in Appendix F.

The below listed equipment were provided for the landing, diver and inshore surveys:

- Cmax CM-800 Side scan sonar (fish and processor)
- C&C Technologies C-Nav 2000 DGPS
- Odom Hydrotrak single beam echo sounder (9° transducer)
- Dell laptop computer
- Wildco Petite Ponar Grab Sampler
- TOPCON GTS-201D Total Station w/ HP48 Data Collector

4.1.1.1 Beach Topographic Survey

Pacific International, Inc. conducted the beach and topographic surveys in Majuro, while the Pacific Survey Company conducted the beach and topographic surveys in Pohnpei.

4.1.1.2 Diver Swim Survey

Ikaika Kincaid and Miles Driscoll of SEI conducted the diver swim surveys in both locations.

4.1.1.3 Small Boat Survey

Jim Barry of SEI conducted the small boat survey in Pohnpei and Majuro.

4.1.1.4 Nearshore and Deepsea Survey

The following FSSI personnel conducted the nearshore and deepsea surveys aboard the M/V Trinity Explorer on a 24-hour per day, 12-hour per shift basis from 22 Jan to 11 Feb 06:

Name	Position
Jared Fedor	FSSI Party Chief
Joanna O'Neill	Geologist
Andy Davidson	Geologist
Mike Walsh	Engineer
A.J. Davis	Engineer
Kurt Eckelmeyer	Marine Technician
Tom Olsen	Marine Technician
Chris Henry	IT Engineer
Heather McGrath	Data Analyst
Dorsey Wanless	Data Analyst
Lynn Collier	Data Analyst
Gina Peery	Data Analyst
Shannon Frame	Surveyor
Jason Schafer	Surveyor

FSSI geophysical survey equipment included:

Quantity	**Description**
1	Primary survey vessel “M/V TRINITY EXPLORER” inclusive of fuel, lubes, water, accommodation, food, communications for 24-hour operations.
1	FSSI’s proprietary Sys100D towfish, inclusive of winch and tow cable, for simultaneous acquisition of swath bathymetry, side-scan sonar intensity and sub-bottom profiler data in water depths of 20 to 1,000 meters. The system will include a complete shipboard data acquisition/processing suite, peripherals, consumables and system spares.
1	FSSI’s proprietary Sys09 towfish, inclusive of launch and recovery system and tow cable, for simultaneous acquisition of swath bathymetry and side-scan sonar intensity data in water depths greater than 1,000 meters. The system will include a Surface Electronics Package, complete with shipboard data acquisition/processing suites, peripherals, consumables and system spares.
1	Sonardyne mid-frequency USBL system for towfish tracking, including 3 Supersub mini-beacons and 2 MKIV Compatts beacons.
2	Fugro SeaStar 3000L DGPS receivers utilizing independent differential corrections from the AP and POR satellite.
2	IXSEA Octans Fiber Optic Gyrocompass (1 + spare).
2	On-line navigation system including Fugro's own Starfix.Seis software and two complete additional PC systems (1 offline and 1 spare).
1	Sippican Expendable bathy-thermograph (enough for one shot/day with extras).
1	Applied Microsystems SVPlus Velocimeter (as spare to XBT).
1	Geometrics 880 cesium vapor magnetometer.
1	2-meter long gravity corer / coring winch spread with 3-inch diameter core barrels, plastic liners, core catchers, trigger arm release and weights, system spares.
1	Seabed dredge (backup to gravity corer).

Diagrams of the Sys100D and Sys09 systems configuration are given in Figures 4.1.1 and 4.1.2. Details regarding the systems specifications are given in the Appendix C.

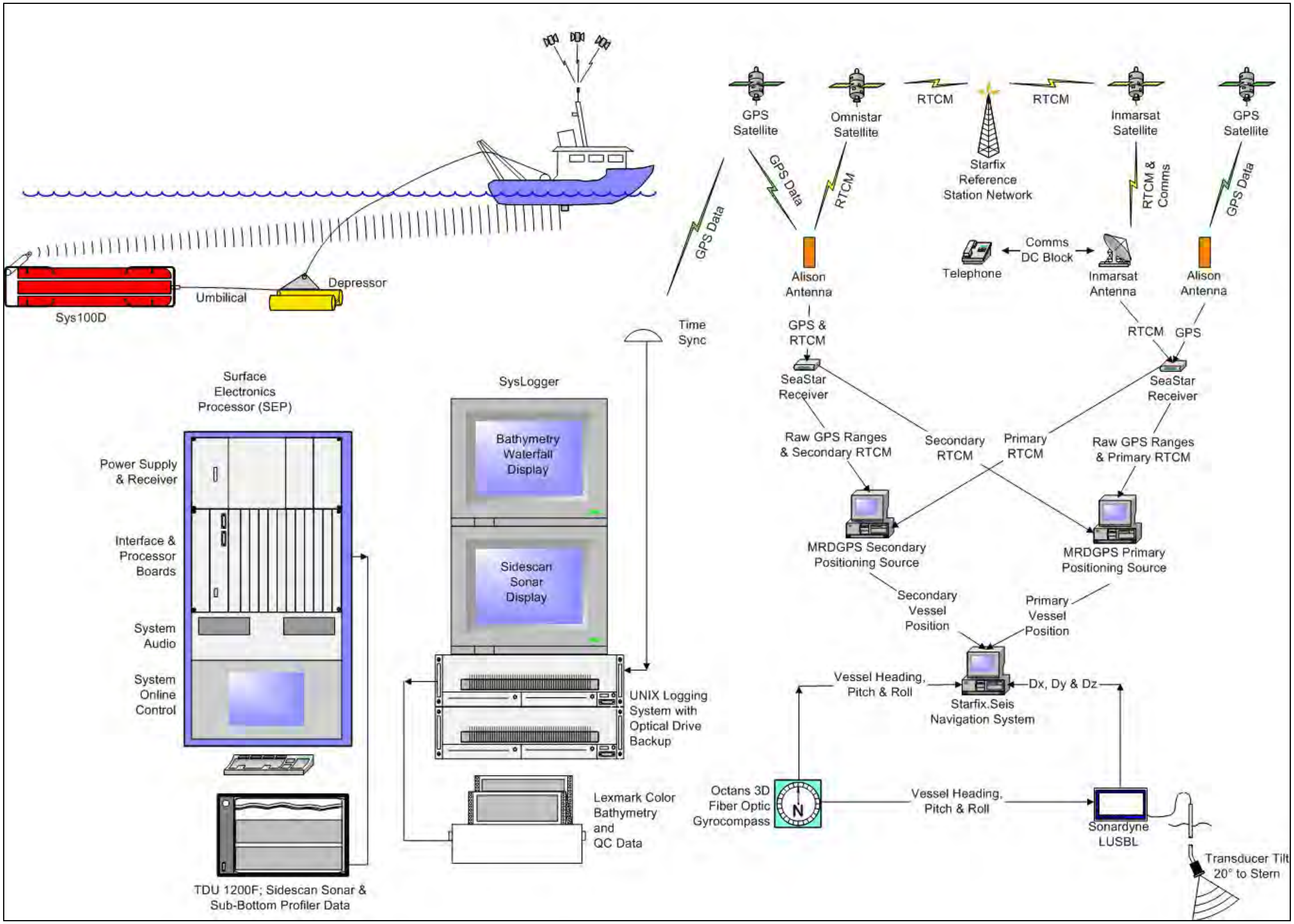


Figure 4.1.1: Sys100D equipment configuration and data logging flow diagram

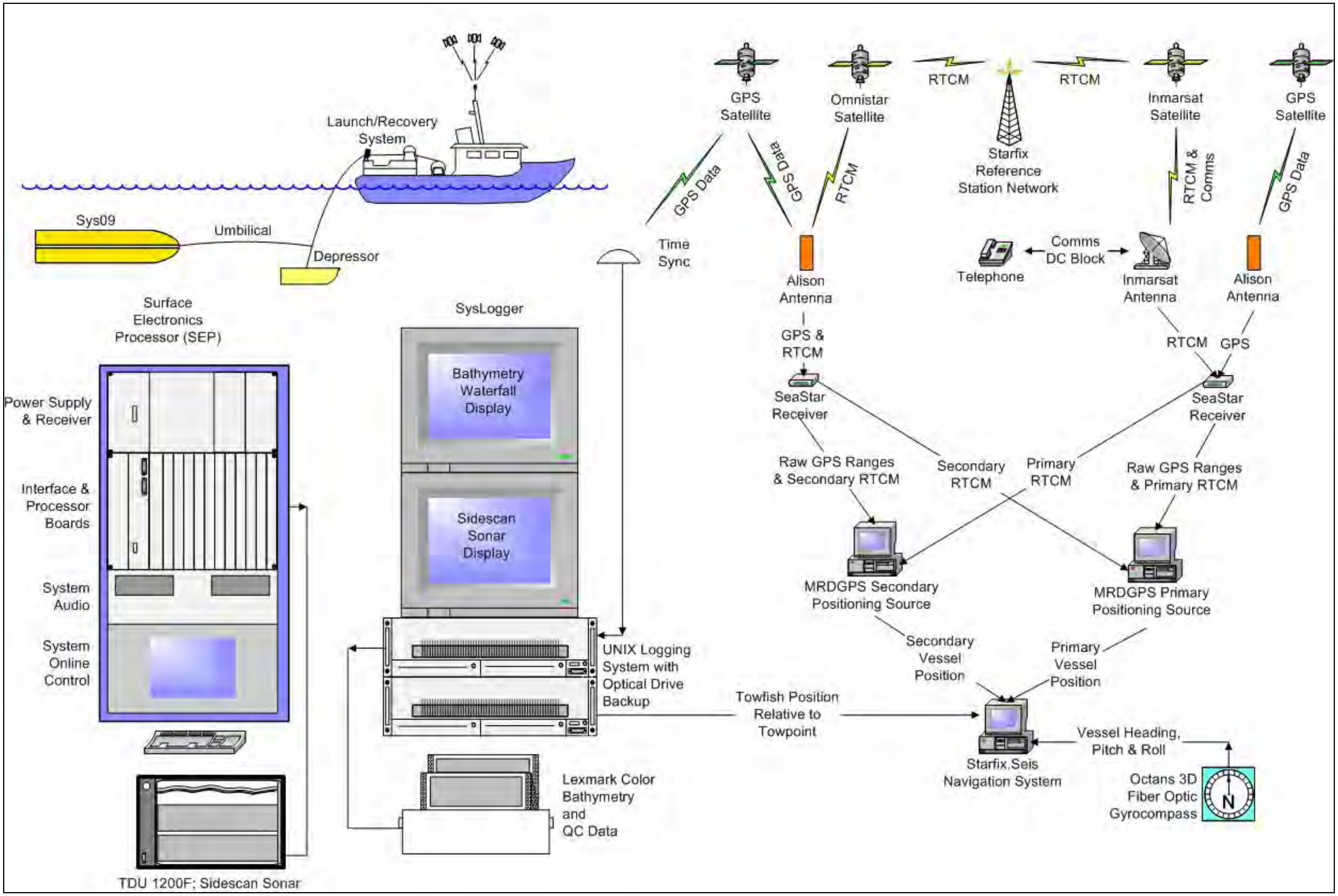


Figure 4.1.2: Sys09 equipment configuration and data logging flow diagram

4.1.2 Operations Summary

4.1.2.1 Beach Topographic Survey

14-16 Jan 06: The Majuro beach topographic survey was conducted by Pacific International, Inc. under sub-contract to SEI. Ikaika Kincaid and Myles Driscoll of SEI assisted.

18-20 and 23-24 Jan 06: Pohnpei beach topographic survey was conducted by Pacific Survey Company, as subcontractors to SEI. SEI provided differential GPS positions for the existing BMH, and three other reference points.

4.1.2.2 Diver Swim Survey

14-15 Jan 06: The Majuro diver swim survey was conducted by Ikaika Kincaid, Myles Driscoll, and Jim Barry of SEI. Due to hazardous surf conditions, the diver swim survey consisted of a single centerline, which began at the seaward edge of the reef flat, 220 meters from shore. Underwater video was not taken because of the hazardous surf; instead, underwater still photographs were taken.

18 Jan 06: The Pohnpei diver survey was conducted by Ikaika Kincaid and Myles Driscoll of SEI. As the small boat survey was able to survey close to the shoreline, the diver swim surveys were set at 100-meter lengths. There was no diver visibility because of the fine silt substrate.

4.1.2.3 Small Boat Survey

14-15 Jan 06: The Majuro small boat survey was conducted by Jim Barry of SEI. The ocean conditions were poor during the survey, with 15 to 20 knot winds and seas over 2 meters in height.

18-19 Jan 06: The Pohnpei small boat survey was conducted by Jim Barry and Ikaika Kincaid of SEI. The survey consisted of single beam bathymetry and side-scan sonar. Weather was generally poor and a significant factor in the surveys. Operational details are provided in the Daily Operation Reports (DOR) included in Appendix G.

4.1.2.4 Nearshore and Deepsea Survey

All times are UTC unless otherwise stated.

With all survey crew personnel and Client Representative aboard, the M/V Trinity Explorer departed Majuro at 1900 on 10 Jan 06 and transited to the calibration site. The USBL calibration began at 2100 and continued through to 0000 on 12 Jan.

The survey vessel then transited to the Majuro nearshore survey area to begin Sys100 operations arriving at 0500. While approaching the start of line, acquisition lost contact with the Sys100. After bringing the Sys100 back on board it was found that the electrical connection had been damaged during launch. After repairing the connection, it was discovered that the USBL system wasn't working properly. Working through the night with repeated calls to the manufacturer for technical support, it was concluded that the USBL head was inoperable and required replacement. At 1800 on 12 Jan, the vessel began transiting back to Majuro.

At 0500 on 13 Jan, the new USBL head was aboard and the vessel departed for the USBL calibration site. At 1800, it was determined that the replacement head was malfunctioning and the vessel returned to Majuro at 2400.

On 17 Jan at 0300, a new USBL head arrived aboard from the US. After transiting to the calibration site, the calibration commenced at 0800 and was successfully complete at 1900. At 2200, the vessel transited to the start of line to begin the Sys100 Majuro nearshore landing survey.

At 0000, 19 Jan the Sys100 was recovered and the dredge was deployed to begin bottom sampling. Upon completion of the bottom sampling, the Sys09 was deployed at 0400 and the deepsea survey to BU2 commenced and continued along Segment 5 until finishing at 1300 on 21 Jan.

After running Segment 5 development, the BU2 survey began at 1600 on 23 Jan and continued through to 1330 the next day.

The Segment 4 Sys09 survey began at 0830 on 30 Jan and continued through the remainder of the day, at which time the vessel transited to Pohnpei, arriving alongside at 0130 on 31 Jan. After delays with clearing customs and immigration, loading of provisions and supplies began at 0345.

The vessel departed Pohnpei for the Segment 4 Sys100 survey at 0030, 01 Feb, and began surveying at 0230. The Sys100 survey continued until 0040 on Feb 2, when bottom sampling commenced. Upon completion of sampling and Segment 4 development work, the BU1 survey commenced at 2230. The BU1 survey was uneventful and was complete on 3 Feb at 1423.

4.1.3 Surface Positioning

4.1.3.1 Beach Topographic Survey

SEI provided differential GPS positions for BMH locations, and additional reference points. These points were occupied by the land surveyors and traditional land survey instrumentation – total stations and prism rods – were used to complete the land surveys. Elevation was established by measuring water level and adjusting to LAT datum using tidal data provided by FSSI. A stilling well was used where possible for greater accuracy.

4.1.3.2 Diver Swim Survey

Along the diver swim lines a narrow gauge wire rope marked at 10-meter intervals was laid for positioning. Line start points and lineups for setting the line azimuths were positioned by the land survey crews. Water depths were measured from the surface using either a survey rod or diver depth gauge. Two tie lines were also surveyed.

4.1.3.3 Small Boat Survey

C&C Technologies C-Nav 2000 DGPS was integrated with Hypack Max for navigation.

4.1.3.4 Nearshore and Deepsea Survey

The Fugro SeaStar Differential GPS system with L-Band AP-Sat differential corrections was used for primary positioning throughout the survey.

Using Starfix MRDGPS, a health check was performed alongside the Delap dock in Majuro. Using Fugro's Seastar worldwide differential station network, health statistics were monitored for stability and repeatability. Absolute GPS positions were logged and scatter plots were produced to give a visual indication of the fix distribution of both the primary and secondary DGPS antenna (see Appendix B).

The following parameters were used for the SeaStar unit position calculation:

Elevation Mask	= 10.0°
HDOP Mask	= 4.0
VDOP Mask	= 6.0
Primary GPS Antenna offset	= 7.8m starboard and 11.6m forward vessel CRP
Secondary GPS Antenna offset	= 6.1m starboard and 11.6m forward of vessel CRP

The SeaStar unit was run in Virtual Base Station (VBS) mode. This utilizes a multi-reference base station solution. The stations used during the verifications were as provided in Appendix B.

4.1.4 Acoustic Positioning

The Sonardyne ultra short baseline (USBL) acoustic tracking system was calibrated on 17 Jan 06 offshore Majuro.

A MF Compatt MK4 transponder with flotation collar was deployed in 1,044 meters water depth at position 07°11.2131'N – 171°10.8392'E. The compatt transducer was 10 meters above the seabed. Surface and USBL data were collected using CASIUS software via the Windows Terminal program at an update rate of two seconds.

An SVP measurement was made prior to commencing the calibration. The results were:

Measured Date:	10 Jan 06
Maximum Depth:	1150.0m
Avg. Sound Vel.:	1496.68 m/s

The average velocity was entered into the USBL system and used through the duration of the calibration.

The transponder position and calibration coefficients were determined by collecting data in a "box" pattern around the Compatt at a range of 500 meters and a length of 1,000 meters. Parallel lines were run in opposite directions. An "X" pattern was also run over the Compatt from the corners of the "box". The two lines were run twice in opposite directions. A constant vessel speed of 3.5kts was maintained during data collection. This resulted in eight minutes of data per line.

With corrections entered into the Sonardyne USBL, the vessel then proceeded to run two check lines over the Compatt in opposite directions to confirm the results.

Values Prior to Calibration:

	Easting (UTM 59)	Northing (UTM 59)	Depth
TSP Centre	519945.3E	794413.10N	1043.7m

	Pitch	**Roll**	**Alignment**	**Scale**
USBL Corrections	20.51°	0.75°	0°	1.0

Calibration Results:

	Easting (UTM 59)	**Northing (UTM 59)**	**Depth**
TSP Centre	519945.0E	794412.3N	1044.4m

	Pitch	Roll	Alignment	Scale
USBL Corrections	19.43°	2.03°	2.05°	1.0

Note the USBL alignment correction of 2.05° does not include gyro error - it is the pure shaft orientation correction.

4.1.5 Survey Operations

4.1.5.1 Beach Topographic Survey

Majuro

Pacific International, Inc. under sub-contract to SEI, conducted the beach topographic survey from 14 to 26 Jan 06. Ikaika Kincaid and Myles Driscoll of SEI assisted. The topographic survey was conducted using standard land survey techniques. The BMH and control points were positioned with C-Nav decimeter accuracy DGPS. The surveyors used the control points to establish the survey in the project coordinate system. Elevations were corrected to the LAT datum using predicted tide tables furnished by FSSI and stilled water levels measured on-site.

Pohnpei

Pacific Survey Company under sub-contract to SEI, conducted the beach topographic survey from 18 to 24 Jan 06. SEI provided differential GPS positions for the existing beach manhole, and three other reference points. These points were occupied by the land surveyors, and traditional land survey instrumentation – total stations and prism rods – was used to complete the land survey. The topographic survey was conducted along a 250-meter swath centered 50 meters south of the BMH, and covered the area between the shoreline and the cable tie-in location. Elevations were corrected to the LAT datum using predicted tide tables furnished by FSSI and stilled water levels measured on-site.

4.1.5.2 Diver Swim Survey

Majuro

SEI's Ikaika Kincaid, Myles Driscoll, and Jim Barry conducted the diver swim survey on 14 to 15 Jan 06. Land based topographic shots were taken across the reef flat at low tide. Due to hazardous surf conditions, the diver swim survey consisted of a single centerline, which began at the seaward edge of the reef flat, 220 meters from shore. The centerline diver swim survey was conducted at high tide to maximize water depth in the surf zone. A 300-meter tag line, marked at 10-meter intervals, was anchored at the BMH position and laid offshore along the route. Depths and observations were taken seaward of the surf zone. The bathymetric drop-off at 15 meters water depth was located approximately 50 meters past the end of the survey tag line. Underwater video was not taken because of the hazardous surf; instead, underwater still photographs were taken.

Pohnpei

Ikaika Kincaid and Myles Driscoll of SEI conducted the diver surveys on 18 Jan 06. Diver swim survey lines were located at 62.5-meter intervals along the shoreline. As the small boat survey was able to survey close to the shoreline, the diver swim surveys were set at 100-meter lengths. A tag-line cable, marked at 10-meter intervals, was set from the shore using a compass and lineups for azimuth positioning. All sediment probes were pushed the full probe distance (1.5 meters) into the substrate with no hard material encountered. There was no diver visibility because of the fine silt substrate. The video of the diver swim survey is of poor quality due to the lack of visibility.

4.1.5.3 Small Boat Survey

Majuro

The small boat survey was conducted by Jim Barry (SEI) on 14 to 15 Jan 06. The ocean conditions were poor during the survey, with 15 to 20 knot winds, and seas over 2 meters. The survey instrumentation consisted of single beam echo sounder and side-scan sonar. Because of the steep bottom characteristics, the side-scan sonar was towed parallel to the shoreline.

Pohnpei

Jim Barry and Ikaika Kincaid of SEI conducted the small boat survey on 18 and 19 Jan 06. The survey consisted of single beam bathymetry and side-scan sonar. Weather was generally poor and a significant factor in the surveys. Rainsqualls with high winds caused periodic interruptions of the topographic and small boat surveys. The small boat surveys were expanded from the original scope of work to include the entire distance out to the reef pass. Portions of the survey corridor in Zones 2 and 3 could be surveyed only during peak high tide conditions because of the shallow water. Side-scan sonar data were obtained with difficulty due to the extremely shallow and variable water depth conditions in Zones 2 and 3, and deep water in Zone 1. Side scan sonar was run at 75 meters range in Zones 2 and 3, and at 200 meters range in Zone 1 due to the increased water depth.

4.1.5.4 Sys100D Operations

For the KCS route survey, FSSI's high resolution Sys100D was used to simultaneously acquire co-registered bathymetric, side-scan sonar and sub-bottom profiler data in water depths between 20 and 1,000 meters.

The deep-towed Sys100D integrated swath bathymetry and side-scan sonar system provided an acoustic intensity seafloor image in fixed swath widths and simultaneously mapped highly accurate bathymetry in a swath that was about three times as wide as the water depth beneath the transducer array. The Sys100D also provided "Chirp" sub-bottom profiler data. It should be noted that the acquisition of SBP data, although inherent to the Sys100D system, was not a contract requirement for the KCS project. While no "proper" SBP data interpretation and charting were required, the geologists utilized the sub-bottom profiler data as needed for their own interpretation.

All bathymetry measurements were corrected for towfish attitude using an internally mounted, six-component motion reference unit (MRU). These devices were calibrated for pitch and roll on the pier before the survey operations (see Appendix B). Array Calibration Table (ACT) tie lines were run for the Sys100D, as required during the survey. Additionally, during the Sys100D survey, multiple, adjacent, survey lines were run to complete the survey corridor. These lines were also used to confirm the accuracy of the ACTs during bathymetric post-processing.

Bathymetric, intensity and SBP data were logged to optical disc for storage. Realtime paper records of pre-processed, time-stamped, and corrected (for slant range and ship's speed) side-scan data and color-coded swath bathymetry were produced on the vessel during the survey. These were immediately available for data quality analysis and any on-site decisions that may have been needed to adjust the survey plan. Because of the high resolution of the Sys100D, even relatively small man-made objects could be identified on the seafloor.

4.1.5.5 Sys09 Operations

The Sys09 deepwater towfish was used for the deepsea survey, generally in water depths greater than 1,000 meters. Co-registered bathymetry and side-scan sonar data were acquired using the Sys09 system along a single survey line, except in areas of route development where additional survey lines were required.

All bathymetry measurements were corrected for towfish attitude using an internally mounted, six-component MRU. This device was calibrated for pitch and roll on the pier before the survey operations (see Appendix B). All Sys09 data were logged to optical disc and all monitor records were "read-after-write", that is to say that the data were written to disk and then read back off for quality verification during acquisition. Real time paper copies of the preprocessed, time stamped, data were archived daily.

The Sys09 is a towed 9 kHz /10 kHz vector side-scan sonar system that simultaneously provides an acoustic intensity image in fixed swath widths and maps highly accurate bathymetry. Bathymetric data are acquired by measuring the angle of incidence of seafloor reflections on the towed array using a phase measurement technique. The Sys09 produces a robust bathymetry swath to an accuracy of better than 1% of water depth, with a width that is more than three times the water depth – up to 10 kilometers wide in deep water. Detailed Sys09 system specifications are included in Appendix C.

Real-time monitor records of the Sys09 side-scan sonar and bathymetric data were immediately available on the survey vessel for quality control and adjustment of the survey plan to meet changing route conditions. The side-scan images of the seafloor can be used to delineate zones of the seafloor that are sediment-covered and areas of exposed rock, essential for proper routing of the cable.

It should be noted that the acquisition of side-scan sonar data, although inherent to the Sys09 system, was not a contract requirement for the KCS project. Therefore, no “proper” intensity data interpretation or charting was required.

4.1.6 Sound Velocity Profiles

Sound velocities throughout the water column were measured on a daily basis for the Sys100D operations using a Sippican Oceanographic Data Acquisition System and Expendable Bathythermograph (XBT) disposable probes. Two types of XBT probes were used: T7 in water depths up to 760 meters, and T5 in water depths up to 1,830 meters. Measured sound velocity graphs are provided in Appendix B.

4.1.7 Magnetometer Operations

A Geometrics G880 cesium marine magnetometer was carried aboard the M/V Trinity Explorer to be used to locate in-service cables along the nearshore portions of the route where the position of existing cables could not be clearly identified from side-scan sonar records and in water depths less than 200 meters.

The operating principle of the G880 is a self-oscillating split-beam cesium vapor, which allows greater sensitivity and sampling rate compared to conventional marine proton magnetometers. The sensitivity is quoted as 0.01 nanoTesla (nT) at a 1-second cycle rate. The unit's components were manually adjusted to account for the local inclination of the Earth's magnetic field in the area.

4.1.8 Seabed Sampling

4.1.8.1 Beach Topographic Survey

Bottom composition of the beach landing area was noted and recorded during the beach topographic survey. Probes were conducted every 50 meters along the proposed route centerline.

4.1.8.2 Diver Swim Survey

Bottom composition, water depth and probe penetration were noted every 20 meters along the diver swim lines.

4.1.8.3 Small Boat Survey

Majuro
No samples were collected. The seafloor is coralline reef throughout the entire survey corridor.

Pohnpei
Seabed sample stations were positioned at 500-meter intervals along the survey centerline. A Ponar grab sampler was used for all sample collection.

4.1.8.4 Nearshore and Deepsea

The survey vessel was equipped with a gravity corer and a bucket dredge for seabed sampling. The geologists and Client Representative determined seabed sample locations using available survey data.

Side-scan sonar and sub-bottom data at all landing locations indicated a seafloor of rough reef rock with intermittent, thin sediment patches, so gravity coring was not attempted. However, two dredge attempts were made. The dredge bucket was pulled across the seafloor for approximately 200 meters at each location.

Dredge samples were described and photographed by the onboard geologists. After verification of the quality and clarity of the sample photographs, the samples were disposed of at sea. The location of all samples was recorded, reported and charted on the survey charts along with a physical description, which can be found in Appendix E.

4.2 Data Processing

4.2.1 Beach Topographic Survey

The beach topographic survey data was reduced to LAT elevation datum using LAT tidal data provided by FSSI, and field measurements of water level. A stilling well was used where possible for greater accuracy. Survey data was processed using standard land survey processing methods, and survey plan maps were produced in AutoCad.

4.2.2 Diver Swim Survey

A narrow gauge wire rope marked at 20-meter intervals was laid on the seafloor for positioning. Starting line positions and line azimuths were measured by the land survey crew using land survey instrumentation. The diver lines were plotted in Terramodel DTM software and points were created at each 20-meter interval along the survey lines. Depth, bottom type, notes and coordinate positions for each point were tabulated in an Excel spreadsheet.

4.2.3 Small Boat Survey

The following data processing steps were involved in producing the charts and report:

Data editing: The bathymetry and navigation data were reviewed and edited line by line using Hypack software to remove spurious data points. A bathymetry data file was generated that contains east and north coordinates and tide-corrected depths. Side-scan navigation data files were generated that contain east and north coordinates and time.

Tide Reduction: The vertical datum for the bathymetry was LAT. The applied corrections were provided by FSSI.

Chart Production: A bathymetry contour chart was generated using Terramodel digital terrain software. The navigation data files were used to produce side-scan track line plots. The track line maps correlated the charted time and position with time on the survey records. The time stamps were at one-minute intervals with intervening marks at 0.1-minute (6-second) intervals. The track lines were superimposed on the bathymetry contours to facilitate interpretation.

Geophysical interpretation: The side-scan data were analyzed and interpreted. Seafloor features were mapped using the track line map. The diver video and probe data were used to verify interpretations.

Bathymetric and geomorphologic chart: All data collected during the surveys were synthesized on a chart. The chart mapped bathymetric features, bottom types, sediment features, and any other information pertinent to the cable routes.

4.2.4 Towfish Positioning

The Starfix.Seis navigation suite was used to derive realtime towfish position from the vessel antenna position, heading information, fixed offsets related to them and USBL data (Appendix B). These data were then processed using Fugro's Starfix.Proc software. Raw GPS, gyro and USBL data was de-spiked removing any erroneous points and the data merged together to form an edited towfish position file. Edited files were converted to "satfix" format and passed on to the FSSI data processors for swath processing.

4.2.5 Bathymetry

All Sys100D bathymetry was corrected for variations in sound speed through the water column. Acoustic positioning ranges were also corrected for the speed of sound and any refraction that exists in the data. The Sys09 bathymetry was corrected using published sound speed tables from the digital NGDC World Ocean Atlas.

The vertical datum for all bathymetric measurements was LAT. Raw sonar data were logged to 2.4 Gigabyte magneto-optical disks, then converted and processed offline on SUN workstations.

Navigation data were processed to remove erroneous fixes. The final fish positions were offset from the ship's antenna position, using either layback information or USBL logged data. The final navigation data were reviewed in Microstation to confirm the validity of fish position versus ship position, and to aid in the correlation between navigation data and chart location.
The first significant step in processing bathymetry data required FSSI proprietary software, G3Mosaic. The G3Mosaic software allowed the user to specify towfish navigation files, geodetic parameters, and bathymetric parameters and filters. Towfish position data (heading offsets, depth offsets, and pitch and roll compensation) were applied. Additional bathymetry corrections were applied where required, including tide and water column sound speed corrections. However, the majority of bathymetry processing required in G3Mosaic revolved around two concerns:

- Mapping electrical (phase) to geometric angles using ACTs, and
- Forcing the range of measured phase angles (from the transducer array spacing, signal wavelength) to be unique for each towfish altitude (referred to as "unwrap" in processing jargon).

G3Mosaic output bathymetry as a binary, irregular-array, XYZ file in a Fugro proprietary format (.stb) and a color-contoured, geo-referenced, digital mosaic image (.tif/.tfw). Data were assembled, gridded and contoured using the proprietary Fugro Starfix suite of programs (Starfix Assemble, DTM and Surface). Starfix.Assemble assembles a user-specified set of irregular array XYZ data files into a larger file for use in the gridding process. Starfix.DTM grids the data into a regular array of XYZ points. The program requires user-specified parameters for grid cell size, which is often Client-specified, or based on swath width, ping rate and complexity of the seafloor. Gridded XYZ-data is output in a Fugro proprietary format (.gri) for use in downstream contouring and profiling steps.

Starfix.Surface was used by FSSI to contour the gridded data. The package requires user-specified contouring parameters, including contour interval and index contour interval. Final output was a geo-referenced contour file in Microstation (.dgn) format. A rigorous quality check included comparing the G3Mosaic output bathymetry mosaic against the contours produced after filtering, gridding and contouring in the downstream processing steps. The contours must closely agree with the color-coded bathymetry mosaic, or else the data were reprocessed. Grid files and final contour files were built with overlap at file boundaries to ensure continuity across chart boundaries.

The final stage of bathymetry processing is the chart production in Microstation. Prior to the survey, existing data were compiled to create the basemap information. These data included existing cables, man-made hazards, coastlines, and all other pertinent information that were digitized from nautical charts. The final bathymetry, along with the geologic interpretation, was set into the appropriate chart with a grid and legend. After the chart was reviewed, a final plot file was created and archived in a plots directory, ready to be plotted at any time. See Figure 4.2.1 for detailed data processing flow.

4.2.6 Seabed Imagery

All side-scan sonar intensity image processing was done using G3Mosaic software. A unique intensity mosaic was created for each survey chart. The co-registered, side-scan mosaic was simultaneously processed in the same G3-workspace as the bathymetry. The majority of the image processing revolved around setting contrast and stack order for the multiple tracks, with the values set to achieve maximum contrast for the whole (survey) dataset. Side-scan intensity mosaic images were output from G3Mosaic as geo-referenced tiff files (.tif/.tfw) for reference into the charts in Microstation. See Figure 4.2.1 for detailed data processing flow.

The project Geologist reviewed each intensity mosaic, along with sub-bottom and side-scan sonar paper records, and created a seabed features interpretation for the nearshore survey areas (nominally less than 1,000 meters water depth). The interpretation was then digitized into a Microstation file by a data processor. It should be noted that because the interpretation was conducted using the original paper records, some features posted on the seabed feature charts might not be visible in the side-scan intensity mosaics. This most often occurs with features that are already faint and/or small on the real-time records.

4.2.7 Sub-bottom Profiler

The SBP data represent time sections on which the vertical axis corresponds to the two-way travel time (in milliseconds) from the source to the various reflecting surfaces and back to the receiving transducer or hydrophone array. Sub-bottom features were mapped onto the track line charts using time to correlate position. Sediment thickness was derived assuming a sediment sound speed of 1,500 meters/second.

It should be noted that the acquisition of SBP data, although inherent to the Sys100D system, is not a contract requirement for the KCS project. Therefore, no “proper” SBP data interpretation was required although the geologists utilized the SBP information as needed for interpretation.

4.2.8 Seabed Sampling

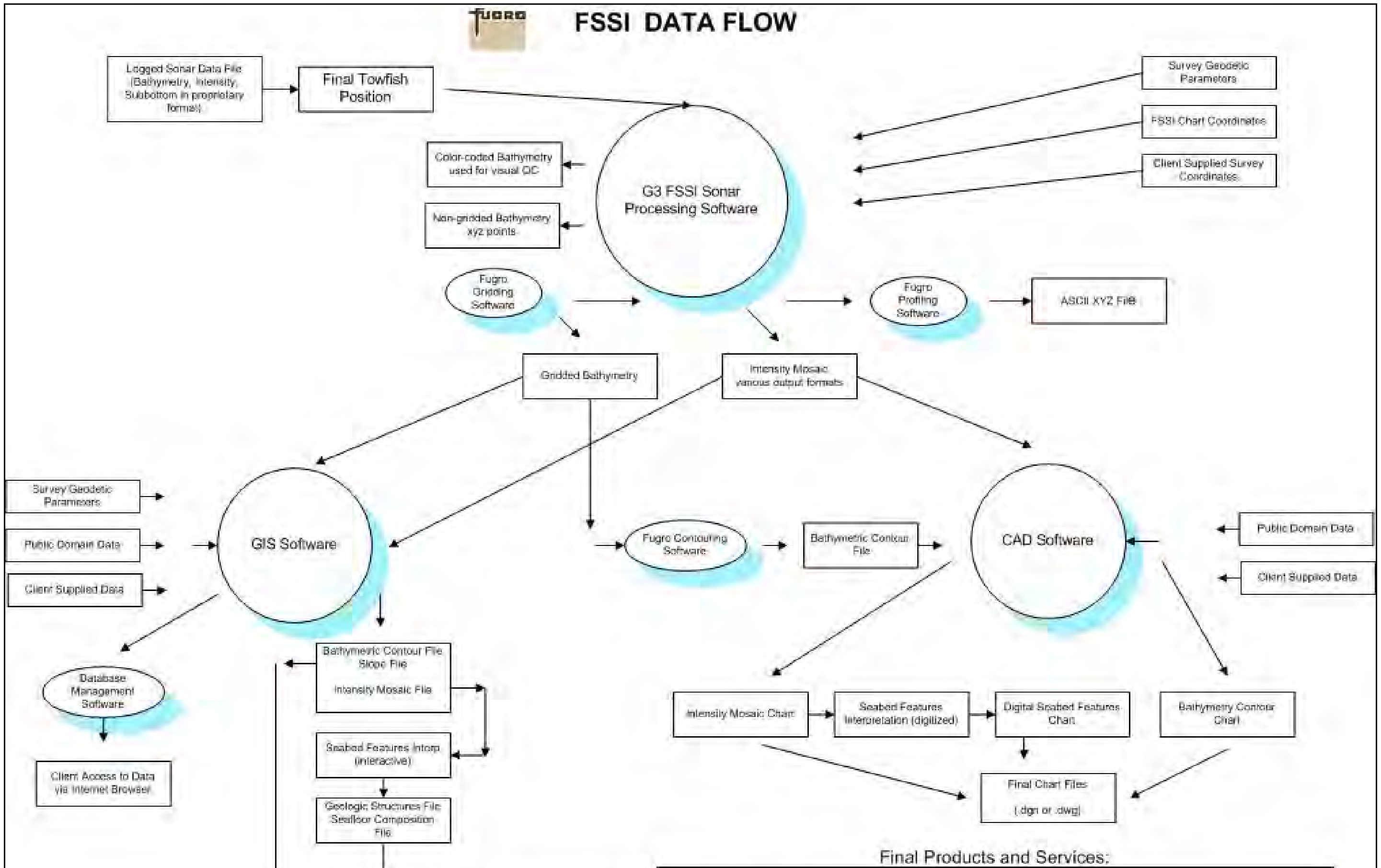
Samples were logged and photographed by the onboard geologists. After verification of the quality and clarity of the sample photographs, the samples were disposed of at sea. The precise location of all samples was recorded, reported and charted on the survey charts along with a physical description.

All samples were named and numbered according to the convention specified below. Grab samples collected during the small boat survey contain a prefix to denote the landing site from which the sample was taken (i.e. GM=Guam, KW=Kwajalein):

Dredge Sample	TE-DS-001
Grab Sample	GM-GS-001

4.2.9 Magnetometer

No magnetometer surveys were performed for the KCS project.



Final Products and Services:

Printed charts in Client specified layouts

Digital charts in Client specified formats

Digital data in Client specified formats including .dgn, .dwg, and ESRI GIS formats

Provision of a Client database with data management tools and services using an Internet browser

Figure 4.2.1: Sys100D/09 Sonar Data Processing Flow

4.3 Data Quality

4.3.1 Beach Topographic Survey

Data quality was good on all beach topographic surveys.

4.3.2 Diver Swim Survey

Majuro

Land based topographic shots were taken across the reef flat at low tide. Due to hazardous surf conditions, the diver swim survey consisted of a single centerline, which began at the seaward edge of the reef flat, 220 meters from shore. Underwater video was not taken because of the hazardous surf; instead, underwater still photographs were taken.

Pohnpei

The quality of the diver video was poor due to turbid water conditions.

4.3.3 Small Boat Survey

Majuro

Bathymetry and side-scan data quality were adequate; some data degradation occurred because of extremely rough sea conditions and extremely steep slopes.

Pohnpei

Small boat survey data quality was good. In some nearshore areas, side-scan data quality was degraded because of extreme shallow water and steep reef shoals.

4.3.4 Nearshore and Deepsea

The geophysical data (bathymetry, side-scan sonar imagery and sub-bottom profiler data) acquired in the nearshore survey area is of good to excellent quality. The deepsea survey data were of very good quality.

4.4 Safety

All FSSI employees who may be working offshore receive basic safety instructions and/or training. Prior to an employee's first survey (or within the first year of employment) the employee attends three safety certification courses: Emergency First Aid, Deck and Crane Safety, and Survival at Sea.

The Party Chief reviewed offshore safety rules and emergency procedures with all personnel before vessel departure. The Party Chief also arranged with the vessel's Master to conduct weekly fire and safety drills and to outline procedures for abandoning ship.

The Party Chief had emergency contact information for coastline medical facilities nearest the offshore survey location in the project quality manual. Additionally, medical emergency phone numbers were posted near the satellite and cell phones on board. Twenty-four hour physician advice and shipment of medical supplies are contracted through Maritime Health Services of AEA International USA, Inc. Whenever possible there was an individual on the boat qualified in first aid and cardiopulmonary resuscitation (CPR).

5. SERVICE WARRANTY

A. This report and the geophysical interpretation and assessment carried out in connection with the report (together the “Services”) were compiled and carried out by Fugro in accordance with the Scope of Work and terms of a contract between Fugro and Tyco Telecommunications (the ‘Client’). Fugro performed the Services with all due skill and care as ordinarily exercised by a reasonable geophysical survey contractor, at the time the Services were performed. Further, and in particular, the Services were performed by Fugro taking into account the Scope of Work limitations as specified by the Client, time scale involved, and the resources, including both financial and manpower, agreed upon between Fugro and the Client.

B. Other than that expressly contained in Paragraph 1 above, Fugro provides no other representation or warranty, whether express or implied, in relation to the Services.

C. Fugro performed the Services exclusively for the purposes of the Client. Fugro is not aware of any interest of or reliance by any party other than the Client in or on the Services. Unless stated in the contract or report for the Services or expressly provided in writing, Fugro does not authorize, consent or condone any party other than the Client relying upon the services. Should this report or any part of this report, or otherwise details of the Services or any part of the services be made known to any such party and such party relies thereon that party does so wholly at its own and sole risk and Fugro disclaims any liability to such parties. Any such party would be well advised to seek independent advice from a competent geophysical survey contractor/consultant and/or lawyer.

D. It is Fugro’s understanding that this report is to be used for the purpose described in Section 1 - “Introduction” of the report. That purpose was a significant factor in determining the scope and level of the Services. Should the purpose for which the report is used, or the Client’s proposed development or activity change, this report may no longer be valid and any further use of or reliance upon the report in those circumstances by the Client without Fugro’s review and advice shall be at the Client’s sole and own risk. Should Fugro be requested to review the report after the date hereof, Fugro shall be entitled to additional payment at the then existing rates or such other terms as agreed upon between Fugro and the Client.

E. The passage of time may result in man-made and/or natural changes in site conditions and changes in regulatory or other legal provisions, technology or economic conditions, which could render the report inaccurate or unreliable. The information and conclusions contained in this report should not be relied upon if any such changes have taken place, and in any event, after a period not greater than two years (or six months in the case of seabed features information) from the date of this report or as stated in the report without the written advice of Fugro. In the absence of such written advice from Fugro, reliance on the report after the specified time period shall be at the Client’s own and sole risk. Should Fugro be asked to review the report after the specified time period, Fugro shall be entitled to additional payment terms as agreed upon between Fugro and the Client.

F. The observations and conclusions described in this report are based solely upon the Services, which were provided pursuant to the agreement between the Client and Fugro. Fugro has not performed any observations, investigations, studies or testing not specifically set out or required by the contract between the Client and Fugro. Fugro is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the Services.

G. All information provided within the Route Position Lists (RPLs) are supplied by the Client. Fugro is in no way responsible for information pertaining to cable type, slack values, the positioning of beginning of burial (BOB), end of burial (EOB), and transitions between cables types and repeater location.

H. Recommendations for cable engineering and installation in this report are based solely on the results of the Desktop Study and Geophysical Route Survey. In essence, the instruments used to collect data during the Geophysical Survey do so by remote sensing. Interpretation of physical seabed characteristics and underlying sediment structure were confirmed, to the extent possible, by ground truthing representative regions of the seafloor. To fully investigate the mechanical properties of the soil within burial areas, a proper Burial Assessment Survey is recommended to evaluate plowability and expected burial conditions along the proposed route.

I. Some information in this report was obtained from third parties; this information has been accepted in good faith and is, to the best of Fugro's knowledge, accurate. Such data sources are listed in the report. However, Fugro accepts no liability for issues arising from the reliance on information supplied by third parties.

Appendix A
Route Position Lists

Appendix B
Calibration Report

Appendix C
Equipment Specifications

To be included in Final Report

Appendix D
Seabed Samples

Appendix E
Desktop Study

To be included in Final Report

Appendix F
Personnel

Appendix G
Daily Operation Reports

To be included in Final Report

Appendix 2 Correspondence

Government of the Federated States of Micronesia
Department of Transportation, Communication & Infrastructure
Division of Communication
P.O. Box PS-2 Palikir, Pohnpei State, FM 96941
E-mail address: communications@tci.gov.fm

September 1, 2017

Luke Gowing
Environmental Safeguards Monitor
FSM Connectivity Project
lgowing@argoenv.com

Re: IEE Addendum Section 3.2 Landownership at Pohnpei Landing Site

Dear Luke,

This is in reference to Gerald Tourgee email of 28 August 2017 regarding above subject matter. Accordingly, this is to verify that FSMTC owned the BMH and Pohnpei State owned the property surrounding the BMH and lease the property to FSMTC-this is the open space.

We will be required to get prior permission from FSMTC to access the BMH and the ducts as well as permission from EPA to conduct any excavation or digging around the BMH and the ducts. While we would not require a permit, EPA may have to issue permission by an official letter.

This then is what we have so far but we will continue to work with EPA Office regarding their requirement.

Sincerely,

Mark DeOrio

Copy: Gerald Tourgee, PMU

Pohnpei Environmental Protection Agency

Mail Box: Governor's Mail Box
Tel: 691-320-1780/1210
Email: pohnpeiepa@gmail.com
Site: pohnpeiepa.wix.com/epaoffice

September 18, 2017

Mr. Lukner B. Weilbacher
Dept. of TC&I
FSM National Government
Palikir, FSM 96941

Dear Mr. Weilbacher:

Thank you for your letter of September 15, 2017, regarding the Proposed Chuuk-Pohnpei Fiber Optic Cable System Project., providing us with the Shipboard Oil Pollution Emergency Plan, and the plan to uncover the spare duct at the manhole.

Based on the information provided, we hereby approve the project to lay and connect the optic cable from Chuuk to Pohnpei, with the following conditions:

1. Pohnpei EPA shall be immediately notified of any violation of the International Oil Pollution Prevention Certificate, International Sewage Pollution Prevention Certificate, International Air Pollution Prevention Certificate and the actions taken to prevent environmental impacts from such incidents.
2. The proposed plan to expose the manhole cap is approved. The height of the plywood box should be sufficient to prevent spillage over the top from high tides and boat wakes. The excavated material should be disposed of at the Dekehtik dump site, unless it is necessary to re-bury the cap once the cable has been connected.
3. No relocation or anchoring of the cable on the Pohnpei lagoon seabed shall be done until Pohnpei EPA has been assured that such actions will not impact any living coral.

Please let us know if you have any comments or questions on the above.

Thank you.

Sincerely,

Henry Susaia
Executive Officer

cc: Mark DeOrio (mark.deorio@gmail.com)

Gerald Tourgee (gtourgee@tourgeeconsulting.com)
Luke Gowing (lgowing@argoenv.com)