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# Talisman-Saber 2009 Remote Sensing Experiment

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**14. ABSTRACT**

This report describes the data collected during one of a series of NRL remote sensing and calibration and validation (Cal/Val) campaigns, providing data and information for the development of models of coast types and their associated environmental factors for use in rapidly processing hyperspectral imagery (HSI) and generating shallow water bathymetric charts and trafficability maps. This report documents data that was collected during a remote sensing campaign that was conducted from May 18 to 29, 2009 at the Shoalwater Bay Training Area (SWBTA) located in Australia along a tropical stretch of the Queensland coast. Airborne collections from the HyMap™ sensor were used to build shallow water bathymetric charts and trafficability maps that were provided to military planners during Exercise Talisman-Saber 2009, which was conducted primarily in Australia and surrounding waters from July 13 to 16, 2009. This report details both the airborne HyMap imagery collected as well as the ground and water spectral and geotechnical data collected to calibrate and validate the products developed in support of the exercise.

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ADF | Australian Defence Force |
| AFRL | Air Force Research Laboratory |
| ARTEMIS | Advanced Responsive Tactically Effective Military Imaging Spectrometer |
| ASD | Analytical Spectral Devices |
| Cal/Val | Calibration/Validation |
| CBR | California Bearing Ratio |
| DCP | Dynamic Cone Pentrometer |
| ESRI | Environmental Systems Research Institute |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| GSD | Ground Sample Distance |
| HSI | Hyperspectral Imagery |
| HyMAP | Hyperspectral Mapper |
| in | inches |
| JPEG | Joint Photographic Experts Group |
| km | kilometer |
| LPA | Littoral Penetration Area |
| LPP | Littoral Penetration Point |
| LPS | Littoral Penetration Site |
| LWD | Light Weight Deflectometer |
| m | meter |
| μm | micrometer (micron) |
| MARFORPAC | Marine Corps Forces Pacific |
| MCIA | Marine Corps Intelligence Activity |
| MEC | MARFORPAC Experimentation Center |
| MEU | Marine Expeditionary Unit |
| NGA | National Geospatial Intelligence Agency |
| NRL | Naval Research Laboratory |
| nm | nanometers, nautical miles |
| ONR | Office of Naval Research |
| ORS | Operationally Responsive Space office |
| PACOM | Pacific Command |
| TACSAT | Tactical Satellite |

# EXECUTIVE SUMMARY

The Naval Research Laboratory (NRL) in collaboration with a number of other institutions (e.g., Office of Naval Research, National Oceanic and Atmospheric Administration, Australia Defence Force, HyVista Corporation Pty Ltd, and Marine Information Resources Corporation) has developed look up tables for estimating trafficability in littoral regions and the remote retrieval of bathymetry from hyperspectral imagery (HSI). Key instrumentation to collect requireddata for analysis includes airborne and space borne spectrometers, dynamic cone penetrometers, lightweight deflectometers, sediment corers, field spectrometers, underwater spectrometers, and handheld sonar. It should be noted that expeditionary airfield technicians of Marine Wing Support Squadrons use dynamic cone penetrometers to determine whether or not terrain is favorable for installation of landing pads and arresting gear.

To date the NRL-led trafficability research has been conducted at barrier island coasts found in the vicinity of Cape Charles, Virginia, along the Pearl River in Mississippi, and coral coasts along Kaneohe Bay on Oahu, Hawaii. The first of these experiments, held at the Virginia Coast Reserve Long Term Ecological Research (VCR LTER) site in 2007, provided the first demonstrations of the trafficability and shallow water bathymetry products (Bachmann, Nichols, et al, 2008; Bachmann, Montes, et al., 2008; Bachmann, Montes et al, 2010; Bachmann, Nichols et al, in press) and formed the basis of the analysis and products developed in the present study undertaken in Queensland, Australia.

This report documents data that was collected during a remote sensing campaign that was conducted from 18 – 29 May 2009 at the Shoalwater Bay Training Area (SWBTA) located in Australia along a tropical stretch of the Queensland coast, south of the Burdekin River and north of the Fitzroy River. This coast is somewhat protected from swell waves by the Great Barrier Reef, but is subject to approximately three tropical cyclones per year. Semidiurnal tidal ranges reach a maximum of more than nine meters in Broad Sound, but diminish to two meters in southern Queensland and three meters near Townsville to the north. Tidal ranges also decrease rapidly seaward and are on the order of six meters over the Great Barrier Reef. A number of the islands have fringing reefs. Saltpan, salt marsh, cheniers and mangroves are commonly found in this coastal region. Sandy beaches are attributed to sediment load from rivers.

Shoalwater Bay and surrounding lands are managed by the Australian Defence Force, for the purpose of military training exercises. Remotely sensed and cal/val data were collected in order to generate remote sensing products to support Exercise TALISMAN SABER 2009 (TS'09), one of Australia's largest multilateral military training exercises. The joint military exercise, undertaken biannually by the U.S. and Australia, included approximately 20 scientific experiments that improve crisis-action planning and contingency response, enhancing both nations' military capabilities to deal with regional contingencies and the Global War on Terrorism. Algorithms from this airborne remote sensing campaign can also be applied to space-borne sensors such asTactical Satellite-3/Advanced Responsive Tactically Effective Military Imaging Spectrometer (TACSAT-3/ARTEMIS), which was launched from Wallops Island, VA on May 19, 2009. Hallenborg and Nichols (2009) provided an assessment of the military utility of HSI, evaluating the utility of the NRL-led products derived from airborne HSI, during TS'09 to the Office of Operationally Responsive Space (ORS).

Airborne collections from the HyMap$^{TM}$ sensor were used to build shallow water bathymetric charts and trafficability maps that were provided to military planners duringTS'09, which was conducted primarily in Australia and surrounding waters from 13-26 July 2009. The primary focus of TS'09 was to improve coalition force capabilities and the Joint Task Force certification of the III Marine Expeditionary Force (MEF) as a war fighting task organization under the United States Pacific Command (USPACOM). Researchers from NRL established an HSI exploitation cell at Camp Smith, Hawaii in order to interface with USPACOM. A liaison officer (LNO) representing NRL worked with militaryplanners from 31$^{st}$ Marine Expeditionary Unit (MEU) aboard the USS ESSEX. Researchers working in Hawaii and at-sea were provided with an opportunity to employ and validate hyperspectral imagery products such as trafficability maps with operational organizations such as III MEF and 31$^{st}$ MEU. Imagery and geotechnical collections from SWBTA were also used by a student from the Naval Post Graduate School to complete a thesis entitled, "Littoral Trafficability Prediction by Hyperspectral Imagers."

# 1 Introduction

This data report presents airborne hyperspectral imagery (HSI) and sea and ground truth observations made at the Shoalwater Bay Training Area (SWBTA) in central Queensland, Australia during May 2009 as part of Exercise TALISMAN SABER 2009 (TS'09). Goals and planning for TS'09 were defined in a science plan (see Bachmann Montes, et al., 2008, Bachmann, Nichols, et al, 2008; Bachmann, Montes, et al., 2010; Bachmann, Nichols, et al., in press). In summary, the Remote Sensing Division of the Naval Research Laboratory (NRL) participated in TS'09 to investigate the feasibility of supporting military planners by extracting shallow water bathymetry and characterizing bearing strength and shear of the foreshore from HSI. This data report highlights elements of the science plan and presents a description of the field program, instrumentation, and data collections. It is an overview of the various data types collected during the experiment, through summary plots and statistics, spectra, and imagery. This data report is intended to help transition partners from organizations such as the Naval Oceanographic Office (NAVOCEANO) and Marine Corps Intelligence Activity (MCIA) understand archived data and information as well as the TS'09 geodatabase. Example summary plots and statistics will also facilitate browsing the geodatabase. A formal NRL technical report describing remote sensing products developed by the NRL team will build upon this NRL Memorandum Report describing TS'09 collected data.

Numerous authors (Bachmann, Montes et al., 2008, Bachmann, Nichols, et al., 2008; Bachmann, Montes et al., 2010; Bachmann, Nichols, et al., in press; Mobley 1994; and Mobley et al., 2005) have discussed the use of HSI for the classification of coastal types and the estimation of shallow water depths. NRL's approach to coastal classification is an adaptation of Francis Shepard's work (see Nichols and Williams, 2008), where coastal subdivisions occur according to which specific agent, terrestrial or marine, has the greatest influence on coastal development. Coastal geodatabase development at NRL directly benefits the development of algorithms for processing HSI. Most importantly, the geodatabases facilitate the study of diverse coast types. Research efforts are currently focused on fine-tuning the measured relationships between spectra and environmental factors such as bearing capacity or water depth in order to support military decision-making. This work supports operational organizations such as the NAVOCEANO, MCIA, Marine Corps Forces Pacific, and U.S. Pacific Command, who have expressed interest in trafficability maps and shallow water bathymetry. TS'09 results are therefore being adapted to support the Marine Corps Planning Process. Imagery derived products will aid military planners to report factors such as shallow water bathymetry and trafficability. This information will improve the manner in which amphibious planners determine the capability of vehicles to transit the beach and pass through beach exits. Innovative new products developed by NRL, e.g., those demonstrated during the execution phase of TS'09, may also be added to the geodatabase by users.

Leading up to TS'09, several white papers, proposals, programmatic presentations and results from a remote sensing campaign in Hawaii were provided to various Navy and Marine Corps proponents regarding the Naval Research Laboratory's research thrusts and methodologies that advance the science behind coastal classifications. The final planning brief for TS'09 to MARFORPAC staff and selected others from the PACOM staff occurred on February 6, 2009 at Camp Smith. TS'09 exercise planners decided that NRL would provide a HSI exploitation cell to Camp Smith and would have a liaison officer aboard the USS ESSEX to help integrate HSI as a tool to support military decision making. During the execution phase of TS'09, airborne HSI

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from HyMAP (www.hyvista.com) was used to develop trafficability and shallow water bathymetry products, and these products were delivered to operational staff involved in amphibious planning during the execution phase of TS'09. Following the execution phase of TS'09, NRL's research activities in estimating shallow water bathymetry and developing trafficability maps are continuing with ARTEMIS imagery, since it was not readily available during the execution phase of TS'09 in July 2009.

## 2 Field Experiment

The calibration and validation (Cal/Val) phase for TS'09 was carried out from 18-29 May at SWBTA in central Queensland, Australia and consisted of an airborne survey and the collection of ground and sea-truth data. The field Cal/Val team used laboratory space at Sam Hill for sample processing at SWBTA. Data collections included meteorological measurements in order to improve atmospheric correction of the measured spectral radiance. Atmospheric correction is the removal of effects that result from scattering and absorption in the atmosphere. Equipment failures such as a malfunctioning underwater spectrometer resulted in reduced data collection than what was originally planned in the science plan; however a large body of data was collected relating *in situ* geotechnical and oceanographic measurements to spectral reflectance above the water column and on land from substrates and vegetation. This calibration and validation data was later used to retrieve products from hyperspectral imagery and assess accuracy.

The geography of the SWBTA is provided in Figure 1. This area is used for Combined Joint Task Force Exercises, which combines blue water naval forces with air and land capabilities. The area has been well studied by environmental support scientists employed by the Australian Defence Force (ADF) to maintain and protect the SWBTA environment from degradation. Electronic resources, where complementary information for TS'09 can be found, are provided in Appendix A. Principal study sites at SWBTA included data collection efforts at Sabina Point and Freshwater Beach. The littorals around Shoalwater Bay are somewhat unusual with large parabolic sand dunes and scattered perched lakes and peat swamps. Spectral reflectance data representative of some of the vegetation found at SWBTA was also collected at the Lyon Arboretum and Foster Botanical Gardens in Hawaii in January and February 2009 and on site at SWBTA during the cal/val effort; this were primarily leaf optical reflectance measurement, and in some cases, a few representative canopy level reflectance spectra were measured, notably in mangrove regions of Shoalwater Bay.

### 2.1 Airborne Survey

Imagery was collected using the HyMap™ (www.hyvista.com) spectrometer mounted aboard a twin-engine aircraft during the period from 21-23 May 2009. HyMap provides 128 bands across the reflective solar wavelength region of 0.45 – 2.5 μm with contiguous spectral coverage (except in the atmospheric water vapor bands) and bandwidths between 15 – 20 nm. The spectral configuration of the HyMap sensor is depicted in Table 1.

**Table 1. Spectral configuration of HyMap.** Each of the spectral modules contains 32 bands for a total of 128 spectral bands

| Module | Spectral Range | Bandwidth across module | Average spectral sampling interval |
|---|---|---|---|
| VIS | 0.45 – 0.89 μm | 15 – 16 nm | 15 nm |
| NIR | 0.89 – 1.35 μm | 15 – 16 nm | 15 nm |
| SWIR1 | 1.40 – 1.80 μm | 15 – 16 nm | 13 nm |
| SWIR2 | 1.95 – 2.48 μm | 18 – 20 nm | 17 nm |
| Additional details on the HyMap sensor may be accessed online at URL: http://www.hyvista.com. | | | |

Flight lines (provided in Appendix B) were planned so that adjacent strips overlap, ensuring that complete ground cover was achieved over the TS'09 study area. Flight lines covered the study boxes that are provided in Figure 2. Since these boxes included areas that are covered by water, data was only collected when solar zenith angles were between 35-60$^{\circ}$ in order to minimize glint and flight paths were chosen such that the airborne platform flew into and out of the direction of the solar azimuth to further minimize glint from the water. Imagery was also acquired near both low and high tidal states since one objective was to verify bathymetry retrievals in the very shallow water limit of the inter-tidal zone. To validate bathymetry retrievals from the hyperspectral imagery acquired at high tide, post-processed kinematic GPS survey data was acquired in the inter-tidal zone. In addition, fathometer soundings were conducted throughout the shallow water areas to provide validation data beyond the inter-tidal zone. A water-level gauge was deployed during each day of field calibration and validation activities. This gauge, the GPS base station established by the team on site, and the rover post-processed kinematic GPS units provided the basis for direct comparison of depth retrievals against reference depths.

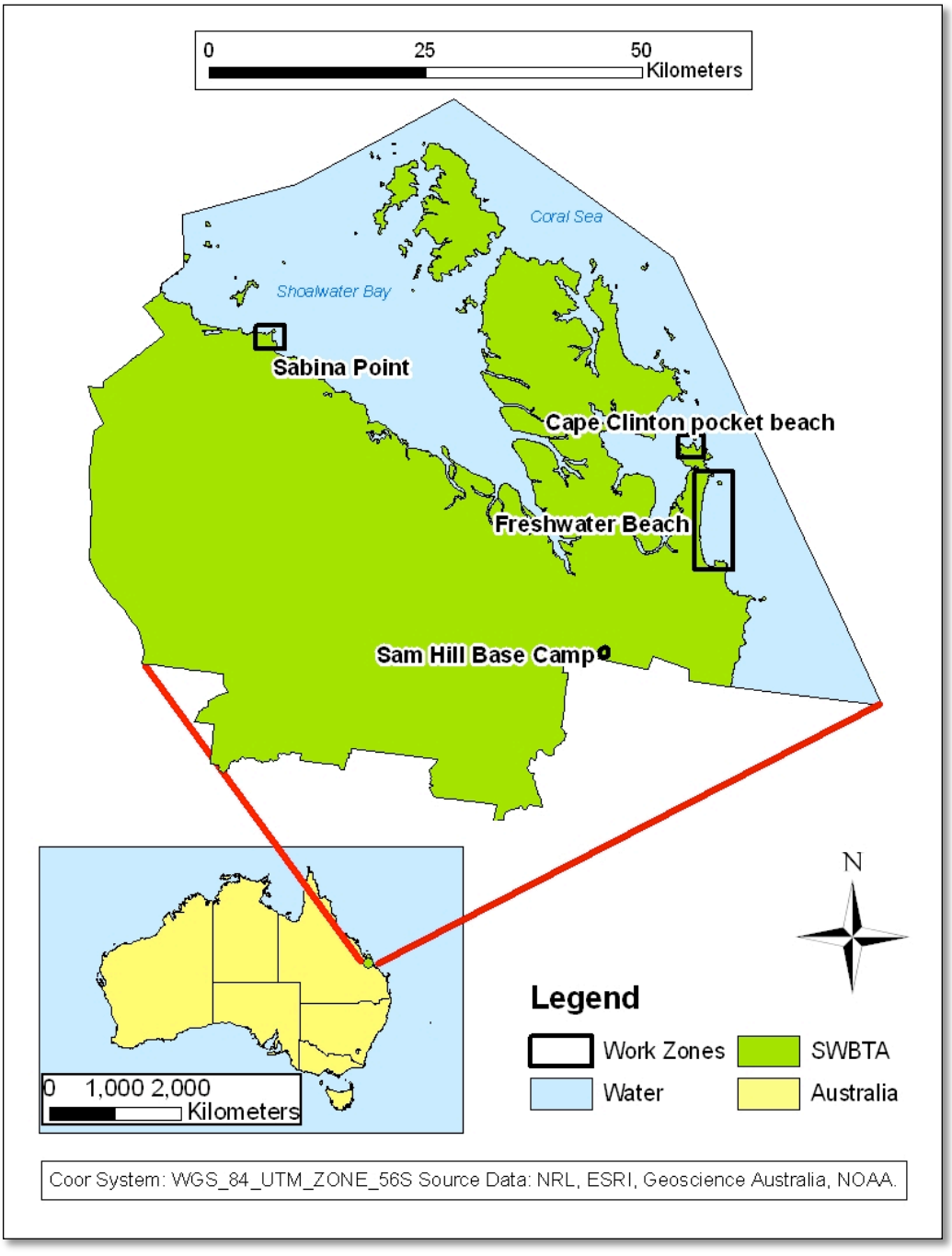



**Figure 1. Geography of SWBTA.** This coastal zone is dominated by various wetland types and includes fringing coral reefs, shallow open water with sea grass beds, rocky marine shores, beaches and sandbars, intertidal mudflats and sand flats, mangrove forests and melaleuca woodland, freshwater lagoons, and swamps and streams on elevated sand plains. The tidal flats and mangrove forests are particularly well developed owing to the macro-tidal range (i.e., 4m at Freshwater Beach and 7m at Sabina Point).

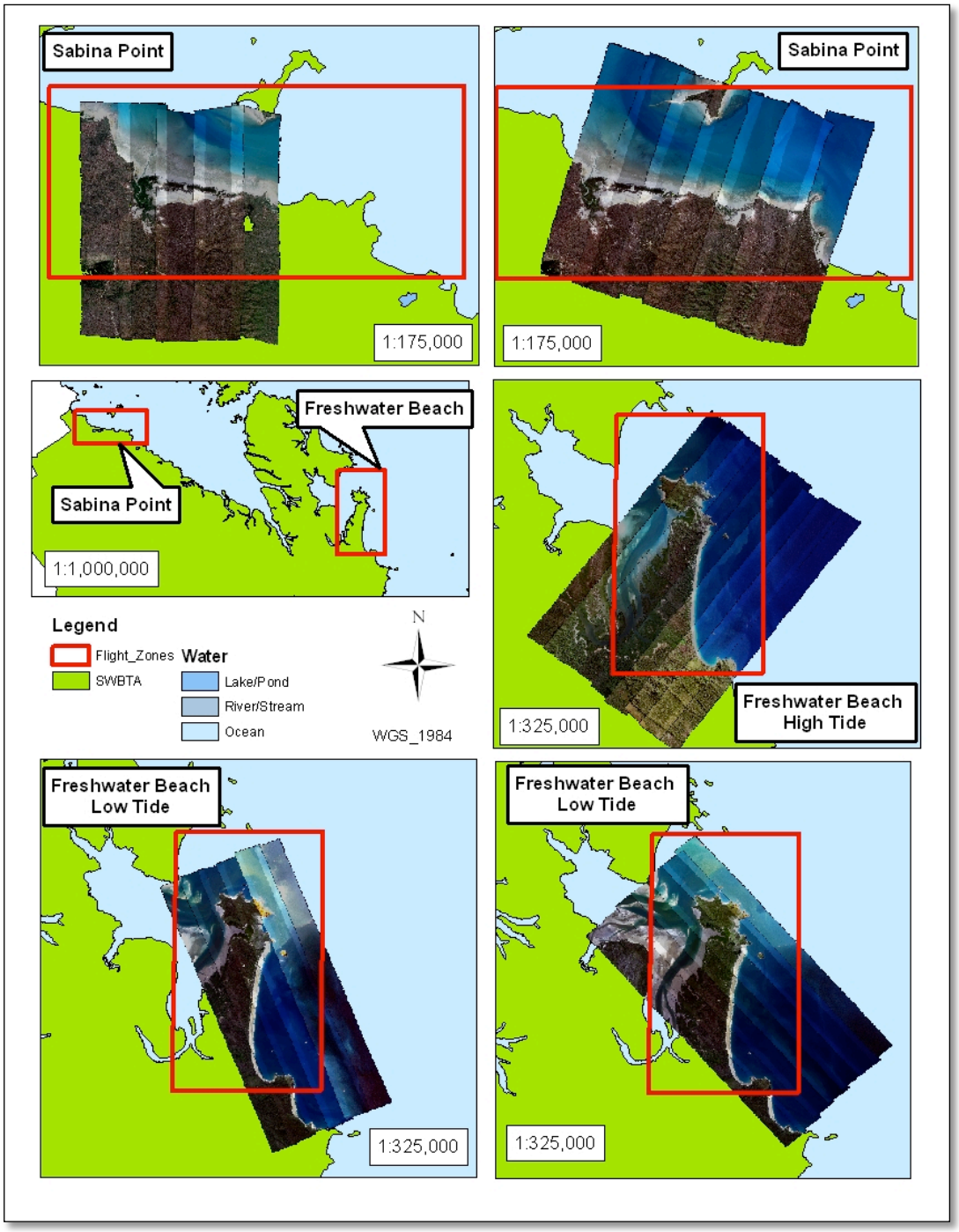



**Figure 2. TS'09 Study Boxes.** These views of SWBTA illustrate the location of primary and secondary study boxes as well as "quicklooks" of data acquired during the campaign. The northern box encompasses Sabina Point and surrounding beaches and inland tropical forest regions. The southern box includes Freshwater Beach, the main landing beach for amphibious exercises. Imagery was acquired at different stages of the tidal cycle, with particularly good coverage (low and high tide) at Freshwater Beach.

Each imagery strip is composed of successive scan lines acquired by the scanner along the flight line. The HyMap™ survey captured images of SWBTA in narrow contiguous wavelength channels or spectral bands, to create a data cube from which diagnostic spectra can be obtained from each pixel in the image. An example cube for the main landing beach is provided in Figure 3.

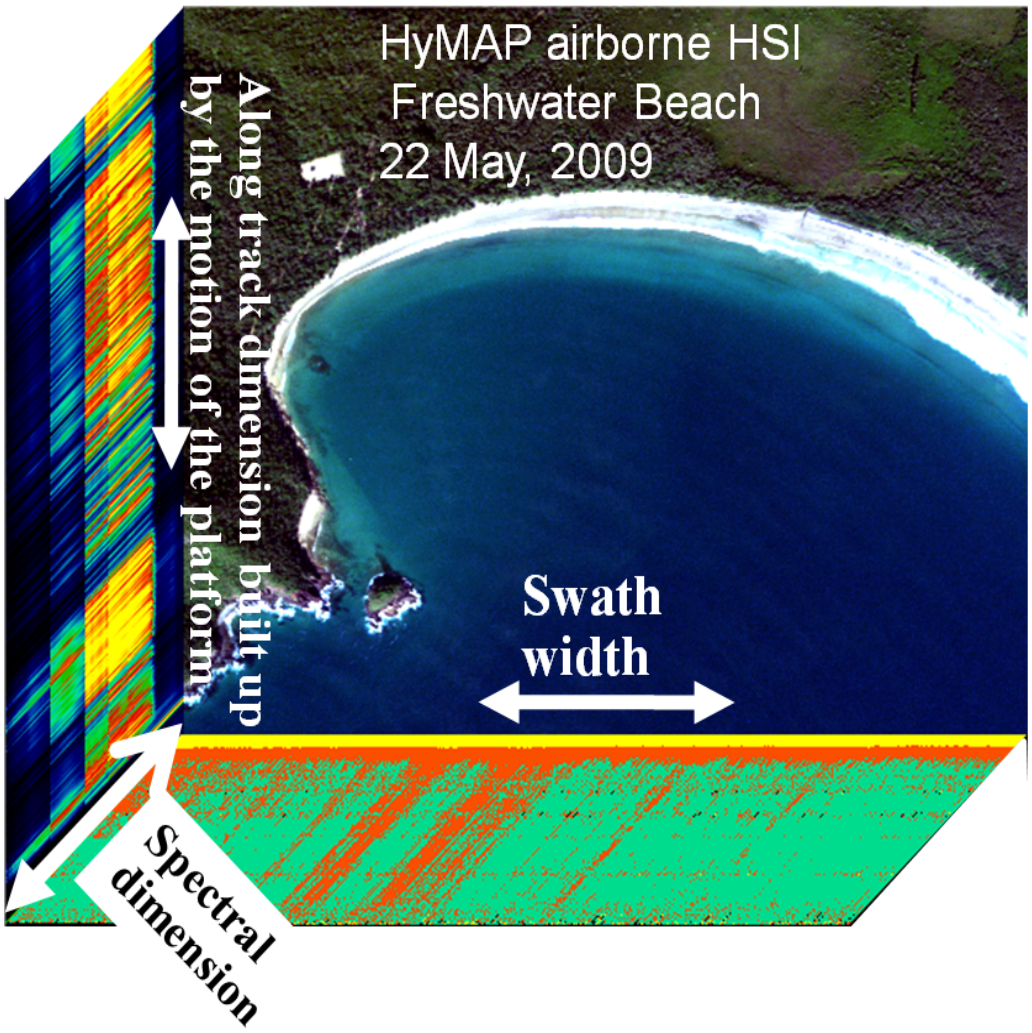



**Figure 3. Hyperspectral Imagery Cube.** Information from this imagery cube for Freshwater Beach was used to make trafficability maps and to retrieve bathymetry during TS'09. Cal/Val data were collected inland and along the coast to help characterize the Case 2 water areas.

Radiance values from each pixel are measured at many narrow, contiguous wavelength intervals. Such an image provides detailed spectral signatures for every pixel. These signatures often provide enough information to identify and quantify materials, even within a particular pixel. By removing atmospheric effects (atmospheric correction), data are then converted to images of the reflectance from the surface of the land or water across this large number of wavelengths. NRL uses collected hyperspectral images to locate and quantify different types of

vegetation, beach composition, soil moisture, and estimate bearing strength and depths in the near-shore region that are present within possible littoral penetration areas.

Meteorological and oceanographic data were collected to support tasks relevant to atmospheric correction and modeling the transfer of radiant energy across the air-sea interface. Since radiative transfer across wind-blown water surfaces is more complex and difficult to describe quantitatively than transfer within the water column, these environmental observations are imperative for follow-on numerical modeling tasks. Meteorological values displayed in Table 2 were used in TAFKAA (Montes, Gao, and Davis, 2004) and HYDROLIGHT (Mobley and Sundman, 2000). Refinement in imagery processing results in improved bathymetric retrievals and estimates of soil properties such as bearing strength. A complete listing of available imagery and weather data from Sam Hill at SWBTA is provided in Appendix C.

**Table 2. Selected meterological values.** Parameters such as air temperature, wind speed (ff), wind direction (dd) were collected for tasks such as atmospheric correction and modeling radiative transfer.

| Day | Temp (ºC) | | Max Wind Gust (m/s) | | | 0900 | | | | 1500 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | min | Max | dd | ff | time | Temp (ºC) | Wind (m/s) | | Pres (mb) | Temp (ºC) | Wind (m/s) | | Pres (mb) |
| | | | | | | | dd | ff | | | dd | ff | |
| 21 | 9.6 | 25.1 | WSW | 6.1 | 1908 | 17.9 | SSW | 1.1 | 1010 | 23.7 | WNW | 1.7 | 1007 |
| 22 | 8.6 | 24.2 | SE | 5.6 | 1210 | 17.5 | W | 2.5 | 1011 | 22 | S | 1.9 | 1007 |
| 23 | 7.9 | 25.4 | W | 6.7 | 1430 | 17.5 | SSE | 1.7 | 1012 | 25.1 | SW | 3.6 | 1008 |
| Daily Weather Observations for Station 033308 sited at Samuel Hill, Queensland for May 2009. | | | | | | | | | | | | | |

## 2.2 Calibration/Validation Data

Primary instrumentation to collect data required for trafficability analysis includes spectrometers, lightweight deflectometers, dynamic cone penetrometers, soil core samplers, drying oven, and sieves. The portable field spectrometers were used to collect field spectra in support of remote sensing image analysis from hyperspectral imaging sensors. The lightweight deflectometer (LWD) was used to measure the dynamic deflection modulus of the substrate, which provides an estimate of bearing strength. The LWD imparts a pulse by dropping a weight onto an accelerometer embedded in a base plate, which simulates the response of the surface to passage of vehicle traffic. The dynamic cone penetrometer (DCP) determines shear strength by measuring the kinetic energy required to push a probe through the soil. Soil sampling was also conducted and analyzed at a field station to determine soil moisture content as well as grain size

profile. Post-processed kinematic beach surveys in the intertidal zone and soundings in the near shore waters (with accompanying differential GPS positioning) were also undertaken as described above. The use of geotechnical instruments fostered the accurate characterization of SWBTA's sand and muddy littoral environments. NRL found the SWBTA littoral region was very different from previously studied coasts composed of coralline sands, plastic clays, combinations of clayey gravels and sands of lesser plasticity, and lean clays and silts.

### 2.3 Site Characterization

Shoalwater Bay is located on the central coast of Queensland, Australia, which is approximately 100 km north of the coastal town of Yeppoon and 628 km north northwest of the state capital, Brisbane. Shoalwater Bay is a closely studied environmental area that is habitat for endangered species such as dugong (*Dugong dugon*) and is part of the Great Barrier Reef Marine Park. The dugong is heavily dependent on sea grasses for subsistence and is thus restricted to habitats such as Shoalwater Bay and associated mangrove swamps. Sea grasses such as eelgrass (*Zostera capricorni*), strapweed (*Posidonia australis*), and paddleweed (*Halophila ovalis*) have varying spectral response, especially in the reflectance of these sea grasses growing in varying wetlands. Example sea grasses that may be found in Shoalwater Bay are listed in Table 3. This region, which includes the Warginburra Peninsula, is one of Queensland's tropical rainforests. It includes a narrow, coastal, high rainfall belt fringed and dissected by a range of eucalypt forests and woodlands, mangroves, and *Melaleuca* swamp communities.

**Table 3. Shoalwater Bay sea grasses.** Field-based spectral reflectance studies have been important in generating baseline data that optimizes the mapping of submerged aquatic vegetation (SAV), and has laid the groundwork for the monitoring of the physiological condition of SAV meadows by hyperspectral remote sensing.

| Scientific Name | Common Name | Latitude | Longitude | Comment |
|---|---|---|---|---|
| *Caulerpa mexicana* | fern algae | 22° 27.39 S | 150° 34.52 E | Eastern Shoalwater Bay |
| *Cymodocea serrulata* | serrated ribbon sea grass | 22° 25.2 S | 150° 19.65 E | Sabina Point |
| | | 22° 14.09 S | 150° 18.52 E | Collins Island |
| *Halodule pinifolia* | needle sea grass | 22° 12.05 S | 150° 5.85 E | Shoalwater Bay (NW) |
| *Halophila decipiens* | paddleweed | 22° 34.91 S | 150° 32.60 E | Georges Creek |
| | | 22° 32.07 S | 150° 30.38 E | Island Head Creek |
| | | 22° 25.1 S | 150° 19.65 E | South Sabina Point |
| | | 22° 12.05 S | 150° 5.85 E | Between Stannage Bay and Broome Head |
| *Halophila ovalis* | paddleweed | 22° 36.29 S | 150° 36.36 E | Head Creek |
| | | 22° 34.43 S | 150° 35.28 E | Head Creek |

| | | | | |
|---|---|---|---|---|
| | | 22° 23.84 S | 150° 17.27 E | North of Sabina Point |
| | | 22° 20.97 S | 150° 19.73 E | Conner Island |
| | | 22° 15.16 S | 150° 23.41 E | North of Sabina Point |
| | | 22° 26 S | 150° 43 E | Pearl Bay |
| *Halophila sp.* | paddleweed | 22° 19.43 S | 150° 11.44 E | McDonald Point to Sabina Pt. |
| | | 22° 12.05 S | 150° 5.85 E | Between Stannage Bay and Broome Head |
| | | 22° 12.05 S | 150° 5.85 E | Shoalwater Bay |
| | | 22° 12 S | 150° 6 E | Stannage Bay |
| | | 22° 11.96 S | 150° 5.916 E | Bald Hill |
| | | 22° 10.5 S | 150° 5 E | Stannage Bay |
| *Halophila spinulosa* | fern seagrass | 22° 33.43 S | 150° 35.34 E | Head Creek |
| | | 22° 31.48 S | 150° 31.71 E | Middle Shoal |
| | | 22° 15.1 S | 150° 19.65 E | South of Sabina Point |
| *Halodule uninervis* | narrow leaf seagrass | 22° 23.27 S | 150° 15.94 E | North of Sabina Point |
| | | 22° 26.6 S | 150° 43.98 E | Pearl Bay |
| | | 22° 12.05 S | 150° 5.85 E | Shoalwater Bay |
| *Zostera capricorni* | Eelgrass | 22° 31.93 S | 150° 30.64 E | Western Shoalwater Bay |
| | | 22° 30.01 S | 150° 33.44 E | East Creek |
| | | 22° 23.84 S | 150° 17.27 E | Shoalwater Bay (West) |
| | | 22° 22.60 S | 150° 30.54 E | Triangular Round Rock |
| | | 22° 15.1 S | 150° 19.65 E | Sabina Point |
| | | 22° 12 S | 150° 6 E | South of Stannage Bay |
| Information adapted from Seagrass-Watch (see URL: http://www.seagrasswatch.org). | | | | |

Since 1966, the land surrounding Shoalwater Bay has been under the ownership of the Australian Defence Force, for the purpose of military training exercises. The SWBTA encompasses approximately 454,500 hectares (4,545 km²), which includes the Warginburra

Peninsula, the Torilla Peninsula east of the Stannage Bay Road, Townshend and Leicester Islands, and a sizable chunk of the Shoalwater Bay hinterland north of the village of Byfield. Townshend Island, which is located at the mouth of Shoalwater Bay, includes a target range and landing beach. On land, military access to SWBTA is through Raspberry Creek and Rossmoya Roads. Access through Stannage Bay Road has been closed to general military traffic since 1999. Access to SWBTA from the Coral Sea is usually via Freshwater Bay and Sea Hound Hard that is on the south arm of Port Clinton. Other nearby beaches include One Mile Beach, Nine Mile Beach, and Five Rocks Beach. There are some massive parabolic sand dunes found along the coast such as the "Orange Bowl" dunes at Nine Mile Beach. The southern half of Five Rocks Beach is adjacent to Byfield National Park and the northern half of the beach is adjacent to the SWBTA. The tidal range is high and approaches seven meters at the mouth of Shoalwater Bay and is in excess of five meters at Port Clinton, a natural harbor. These large tidal ranges have contributed to the development of extensive mud and sand flats and mangrove forests. The times of high and low water as well as predicted tidal amplitudes from 21 to 23 May 2009 at Port Clinton are provided in Table 4.

**Table 4. Tide predictions for Port Clinton.** Tide heights (Ht) are in meters above lowest astronomical tide**,** ***red for low water*** and **blue for high water.** Times stated are Australian Eastern Standard Time (24 hour clock).

| 21 May 09 | | 22 May 09 | | 23 May 09 | |
|---|---|---|---|---|---|
| Time | Ht | Time | Ht | Time | Ht |
| 0058 | *1.27* | 0149 | *1.06* | 0238 | *0.87* |
| 0657 | 3.52 | 0747 | 3.54 | 0834 | 3.54 |
| 1307 | *0.81* | 1359 | *0.67* | 1441 | *0.58* |
| 1936 | 3.92 | 2009 | 4.17 | 2104 | 4.35 |
| Adapted from Australian Bureau of Meteorology. Available online at URL: http://www.bom.gov.au. | | | | | |

Data collected during this survey focused on Sabina Point and Freshwater Beach. Sabina Point is characterized by a low swampy mangrove shore, intersected by several salt-water creeks, and sandy beaches that are fronted by extensive mud flats, which are inundated at about half flood, and extend offshore from approximately 500 m to 3 km. Freshwater Beach is a gently sloping 10 km long beach with a well developed fore-dune ridge. Beach sands tend to be composed of mainly well-sorted pale brown quartz sand. Wind-deposited sands have developed the fore-dune ridges, which consist of pale brown fine quartz sands with little if any soil development. Fore-dune ridges tend to be exposed to the prevailing southeast winds and are subject to erosion and blowout development during cyclones.

## 3. Project Archive

### 3.1 General Information

Remote sensing campaigns at NRL are of great importance since they are being conducted at various coastal sites and allow the collection of large scale (1:5,000) data. The archived datasets are crucial to generating useful relationships among California Bearing Ratio (CBR), a standard index of soil shear strength, and other fundamental material properties for soils, especially in selecting favorable littoral penetration points. CBR is derived from penetration tests that measure the pressure required to penetrate the soil. The USMC uses CBR to determine the load-bearing capacity of soils used for building roads and expeditionary airfields. Harder surfaces will have higher CBR ratings. In general, a CBR of 3 equates to tilled farmland, a CBR of 4.75 equates to turf or moist clay, while moist sand may have a CBR of 10. High quality crushed rock has a CBR over 80. Archiving this type of data from NRL's remote sensing campaigns complements existing databasing efforts such as the small scale (1:5,000,000) United Nations Food and Agriculture Organization's world soils map (see FAO-UNESCO 1974) and the medium scale (1:250,000) Soil and Terrain Database (see ISRIC 2004), and relating this and other associated geotechnical data to *in situ* spectral measurements and remote sensing data is the basis of NRL's approach to remote retrieval of soil bearing properties

### 3.2 Geodatabase

When developing a geographic database or "geodatabase" to archive the results of feature classification, it is important to include, at a minimum, the imagery that each feature was based on, and the associated feature class or vector file. Figure 4 explains how the

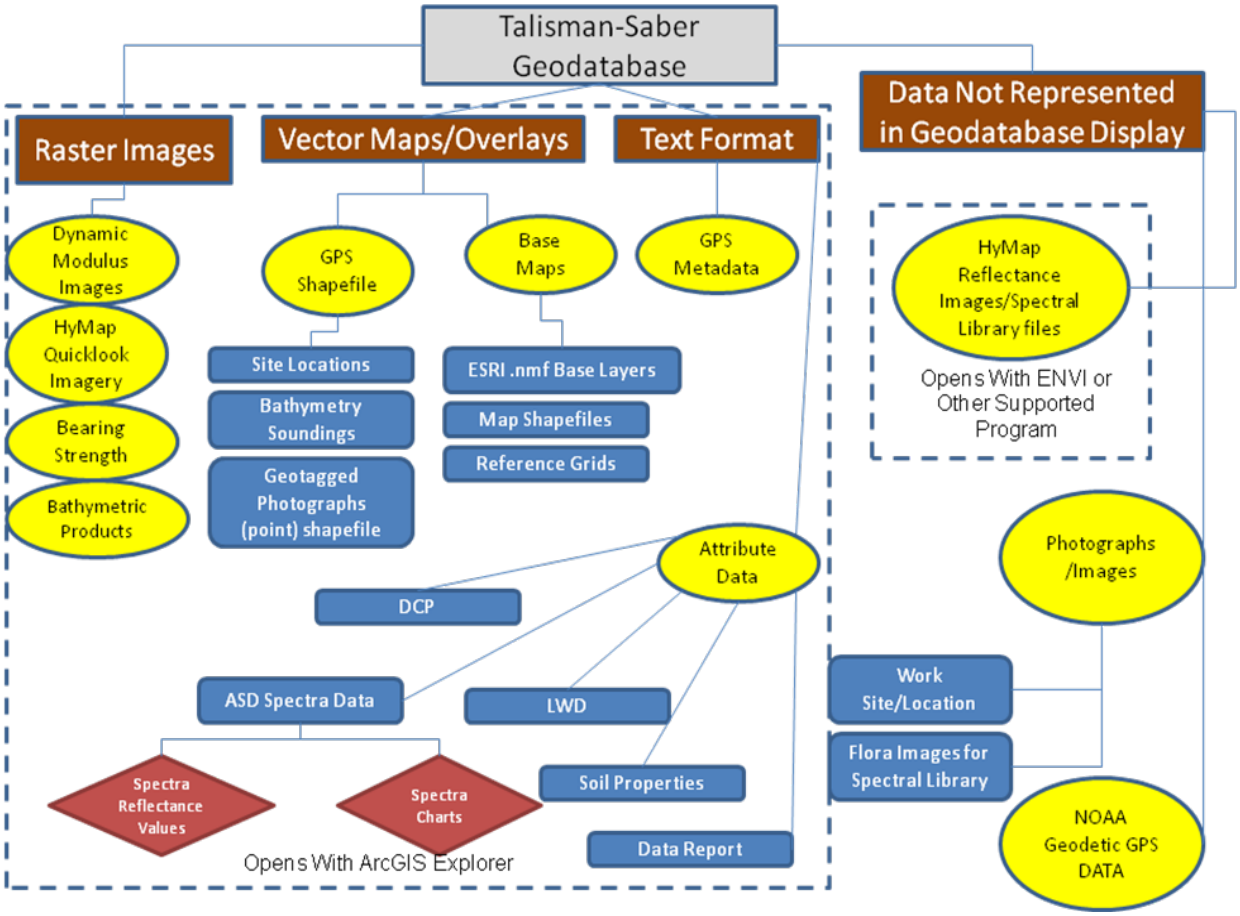



**Figure 4. TS'09 geodatabase development framework.** HyMap quicklooks and GPS Datasets are opened with ArcGIS Explorer. Attribute data is stored in Microsoft Excel files, Microsoft Word document files, or as JPEG Images. HyMAP reflectance images need to be opened with ITT's ENVI or another supported program.

Features and images of this project were organized into a file geodatabase, which was provided to users aboard the USS ESSEX during the execution phase of TALISMAN SABER'09 and has also been provided to NAVOCEANO on an external hard disk. When developing these geodatabases, we include selected intermediate files. Showing all the imagery analyses involved in creating the final result is helpful to those who want to repeat the same process for similar projects. Regardless of the number of files included, metadata is provided for each feature so others can understand how a particular file was produced and the proper way it should be interpreted.

The software packages used in the development of NRL CODE 7232 geodatabases are ESRI's ArcGIS Explorer and ESRI's ArcGIS suite. Both can be used to view the geodatabase,

but there are organizational differences in data structure between the two viewers. The primary software package to view the geodatabase would be ArcGIS, as it allows for analysis and interpretation capabilities much greater than ArcGIS Explorer. ArcGIS Explorer is a free Geographic Information System (GIS) software package based on ESRI's commercial ArcGIS product series. The software package facilitates the input of local data as well as data from ESRI. Shapefiles made in ArcGIS can be brought into the ArcGIS Explorer. ArcGIS users may find some compatibility issues with the ArcGIS Explorer, but in general, data created in ArcGIS can be brought into ArcGIS Explorer. Keyhole markup language (.kml) and keyhole markup language-zipped (.kmz) files made in Google Earth can be imported into ArcGIS Explorer.

ESRI's ArcGIS Explorer allows this GIS database to be applied by others that do not have access to ArcGIS. This allows for geodatabase developers at NRL to present data findings to potential operators in the field who do not have access to imagery analysis software. For example, the ArcGIS Explorer database was used aboard the USS ESSEX by a scientist from Space and Naval Warfare (SPAWAR) Systems Center – Pacific during TS'09. There are some limitations to ArcGIS Explorer, but, this software package allows for the development of databases with the use of Microsoft® Excel as the spreadsheet database. This software package is available for download (ESRI, 2009).

ArcGIS, which is a commercial product, allows for much better analysis of shapefiles than the freeware ArcGIS Explorer, as it enables selecting and differentiating attribute data and presenting the data through symbology. ArcGIS has the ability to gain much more information through the attribute data of shapefiles such as setting important regions with different colors. In ArcGIS Explorer, differentiating regions of a shapefile through analysis of the attribute table data is not possible. If a shapefile's attribute data is given symbological levels of different colors in ArcGIS, it can be exported as a kml file and imported in ArcGIS Explorer, but the resultant image will appear as a raster in the viewer and each polygon does not produce attribute data. Collected attribute data in ArcGIS is stored in spreadsheet and document form and can be accessed by using the identify tool and hyperlinking to the data.

Specific types of data (raster, vector, and text) included in the TS'09 geodatabase are as follows:

- **Imagery** - HyMap imagery was added into both GIS programs as well as the GPS shapefiles. HyMap reflectance files cannot be opened within the ArcGIS Explorer software. These files, which provide reflectance values at each wavelength, can be analyzed to relate the spectra that comprise the data to a variety of environmental types over the study area. Geotagged photographs for Sabina Point and Freshwater Beach are also included in the geodatabase.
- **Survey data** - Each of the Trimble differential GPS locations was processed and exported as a shapefile, depicting the point where data was captured.
- **Cal/Val data** - The GPS shapefiles highlight the location on the Earth's surface where instrument data were taken. The instrument data are stored as Microsoft Excel spreadsheets, JPEG images, or Word documents with information about the data capture. These data sources are accessed via hyperlinking in the GIS programs.
- **Metadata** - Digital photographs and field notes are provided that help explain the

data.

These types of data have been analyzed by NRL to develop innovative new products such as very shallow water bathymetric retrievals and trafficability maps. Operators without ArcGIS (or the Topographic Production Capability for U.S. Marines) will be able to view geospatial information with ArcGIS Explorer. Additional products derived by the HSI exploitation cell to support TS'09 can be added to the geodatabase.

### 3.3 Digital Data Files

Geodatabase files described in this report are from the TS'09 remote sensing campaign. Example files from the geodatabase are included as tables, appendices, and figures for this data report. Most of the map data and their metadata files, and a number of ArcGIS Explorer and ArcGIS projects are also included. Most of the data table files are tab-delimited text files, usable in spreadsheet and database software. The imagery and map data are in several formats for use in digital mapping software. Table 5 is a listing of primary paper maps and charts used during TS'09.

**Table 5. Maps and charts of the study area.**

| Title/Series | Scale | Sheet/Edition | Date |
|---|---|---|---|
| Shoalwater Bay/Special | 1:100 000 | AUSSPEC0155/7-DTA | 2000 |
| Shoalwater Bay/Special | 1:50 000 | AUSSPE0349/1-DIGO | 2008 |
| Plans in Shoalwater Bay | 1:25 000 | Aus 261 | 2005 |
| Port Clinton/1501(Air) | 1:250 000 | SF 56-9/3 | 1996 |
| Port Clinton | 1:25 000 | Aus 248 | 3 Sept 2004 |
| Mount Flinders/R733 | 1:50 000 | 9052 1/4-AAS | 1996 |
| Mount Flinders/Special | 1:50 000 | AUSPEC0345/1-DIGO | 2008 |
| Several of the nautical charts depict unsurveyed areas close to the shore within the approach to concave landing areas, i.e., pocket beaches. | | | |

The types of data present in the TS'09 campaign can be broken down into data archived in geographical form (which are presented through ArcGIS Explorer or ArcGIS) and data that are not archived in geographical form. Appendix D describes access of attribute data within both geographic viewers. Attribute data can be accessed via either GIS program by linking to the "TS09_ALL_DATA.xlsx" spreadsheet. Types of data available on the geodatabase drive but not accessed through ArcGIS Explorer or ArcGIS are listed in Table 6.

**Table 6. TS'09 data files.** There are numerous TS'09 data types, including data tables, GIS files, spectra, and plot files. This table summarizes data that is not rendered through ArcGIS or ArcGIS explorer, but does appear on the geodatabase disk. These data are rendered through alternative means such as the operating system browser tools or packages such as ITT's ENVI**.**

| Path | Folder | File Types/Notes |
|---|---|---|
| \TS09_GD\Attribute_Data\Multimedia | Pictures\ | Work site photos. Photos of flora for ASD control. Soil experiment photos. Miscellaneous survey photos. |
| \TS09_GD\Attribute_Data\ | ASD\ | ASD_SUMMARY spreadsheet. Contains all site spectra, graphs, and comments about spectra. |
| \TS09_GD\Attribute_Data\ | Backup\ | Backup data. Raw data, intermediary files, .rfl files. |
| \TS09_GD\Attribute_Data\ | RAW_ASD_DATA\ | Raw rad files. |
| \TS09_GD\Attribute_Data\ | Reflectance_files\ | .rfl files containing average reflectance spectra for each site. |
| \TS09_GD\Attribute_Data\ | Scripts\ | Numerous IDL scripts for use in processing spectra. |
| \TS09_GD\Attribute_Data\ | SpectralLibraries\ | Spectral library files in spreadsheet and .sli (opens in ENVI) format |
| \TS09_GD\Attribute_Data\ | HyMap…\ | Folders contain headers, geocorrection files, georeferenced images, and quicklooks. Intermediary files are broken down by date and azimuth. |

## 4. Visualization/Analysis

Trafficability is the ability of the terrain to support the movement of vehicles and people. Some of the important factors are vegetation density, bearing capacity, and shear strength of the soil. Analysis was conducted to classify HSI of SWBTA's littoral penetration area's trafficability as excellent, good, fair, poor, or bad.

### 4.1 Spectra Collection



**Figure 5. FieldSpec ® 3 Spectroradiometer.** Portable spectrometers are used to collect spectra (see ASD INC., Available online. URL: http://www.asdi.com/products-fs3.asp).

Researchers collected reflectance data from field spectrometers and from airborne spectrometers in order to study specific beaches. The ASD, Inc. FieldSpec®3 Spectroradiometer that is depicted in Figure 5 was one of four instruments of this or similar type used during TS'09. Vegetation density, grain sizes, beach composition, and soil moisture may be derived from the spectra, and from these, trafficability parameters can be estimated. Spectra collected during HI-TS'09 are provided in Appendix E.

### 4.2 Light Weight Deflectometer

Dynamic deflection modulus, measured in $MN/m^2$ (units are a measure of pressure), was determined by using a lightweight deflectometer (LWD). The Zorn ZFG 2000 LWD is depicted in Figure 6. Some of the factors upon which soil modulus depends, and which are pertinent for TS'09 are soil composition, soil moisture content, soil stress level, stress history, and age of the soil. Records of dynamic deflection modulus are provided in Appendix F.



**Figure 6. Lightweight deflectometer being used to determine dynamic deflection modulus.** It is a non-destructive test device most often used in civil engineering to measure pavement deflections by applying a dynamic load to the pavement surface.

### 4.3 Dynamic Cone Penetrometer

A Kessler Dynamic Cone Penetrometer (DCP) was used in accordance with ASTM D 6951-03 in order to measure soil shear strength. It functions by striking a cone tipped rod with a freefalling weight, thereby driving the cone into the soil. The distance the cone penetrates is measured and the process is repeated until the desired depth is achieved. The recorded data is most commonly plotted as the number of blows divided by the penetration of the cone. For TS'09 the CBR was determined using the Kessler DCP that is illustrated in Figure 7. Appendix G summarizes DCP testing done during TS'09.



**Figure 7. Dynamic Cone Penetrometers being used to determine material shear strength.** The left panel depicts the DCP and magnetic ruler. The right panel illustrates the typical use of the DCP. The number of blows and depth of penetration are used to compute CBR.

### 4.4 Soil Property Determination

Some of the oldest rocks and sediments in the region have come from offshore volcanic island chains such as the *Calliope Island Arc*, which extends along the east coast from central Queensland to the border of New South Wales. Others are believed to have come from deep-sea sediments that were smeared up onto the shelf by plate tectonics. Soil samples were collected with a corer. Soil moisture was determined by weighing a portion of the soil sample while wet and again after drying using a microwave oven. After sieving, the samples were described based on particle size (see Figures 8, 9, and 10). This allowed determination of the proportions of coarse, medium and fine sands, silt, and clay in a soil sample. A picture of a stack of sieves sitting in one of the shakers used to sort grain sizes is provided in Figure 11. Appendix H summarizes soil analysis testing done during TS'09.

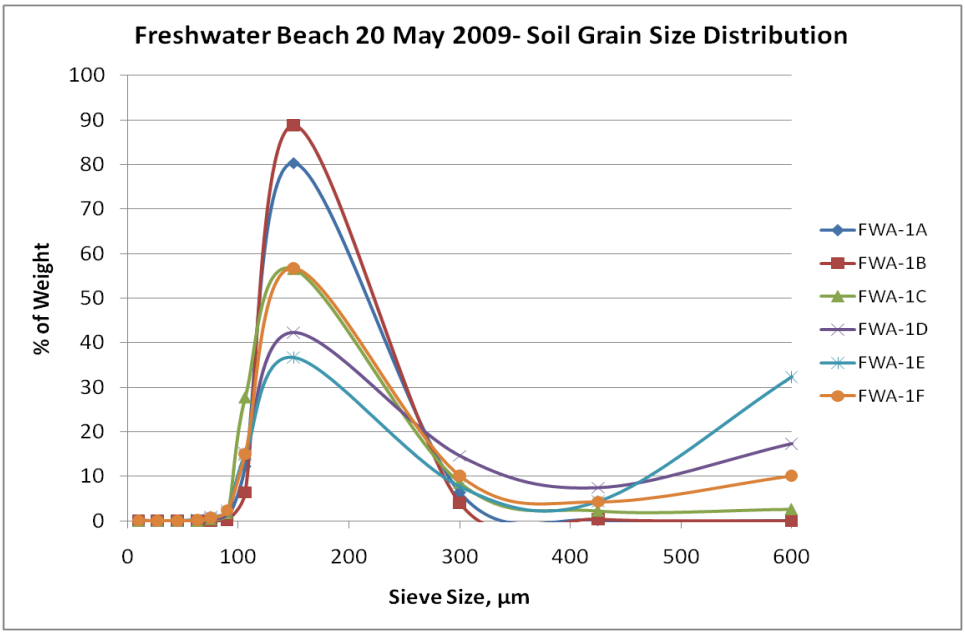



**Figure 8. Grain size distribution along Freshwater Beach transect.**

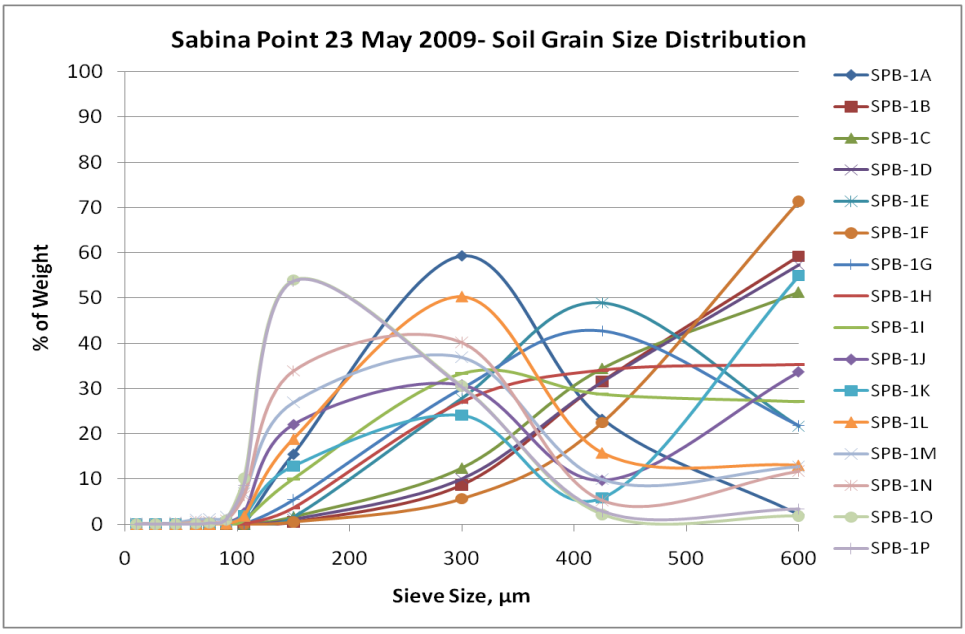



**Figure 9.Grain size distribution along Sabina Point transect.**

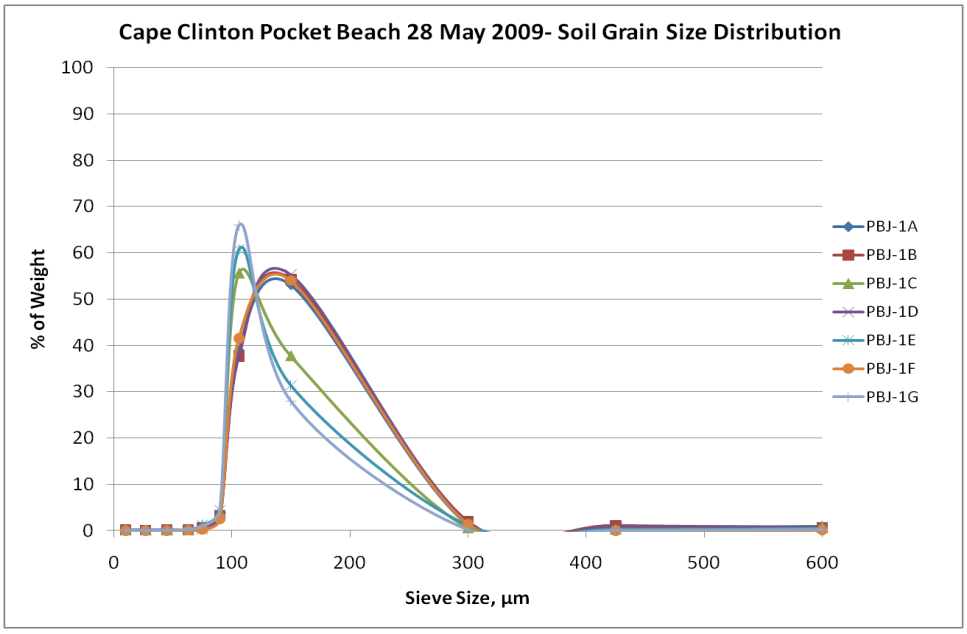



**Figure 10. Grain size distribution along Cape Clinton pocket beach transect.**



**Figure 11. Sieves and shaker used to determine grain size distributions.** .Two Humboldt H4325 sieve shakers were used to determine grain size distributions (see LABEQUIP LTD. Available online. URL: www.labequip.com).

### 4.5 Geotagged Photographs

A camera with a GPS component was used to take pictures of Freshwater Beach and Sabina Point. These photographs were taken from a vehicle at Freshwater beach on 19 May 2009 and 29 May 2009 and from a boat at Sabina Point on 23 May 2009. Views of the landing area at Freshwater Beach and Sabina Point are provided in each photograph. The photographs also provide information on submerged features, especially at Sabina Point. Display of these images can be done via both versions of the geodatabase. In both versions of the geodatabase, a point shapefile presents the point at which the photograph was captured. By clicking on the point, a pop-up screen displays the photograph. A map of photograph locations and spreadsheet of photograph information appears in Appendix I.

### 4.6 Water Level Data

A buoy constructed by participating NOAA team members was used to measure water levels at various sites within the study area during the cal/val effort. The buoy, as shown in Figure 12, utilized an Ashtech® Z-Xtreme™ dual-frequency GPS receiver to measure water level fluctuations with centimeter scale accuracies. It was constructed with a frame of PVC piping filled with floatation material and a wooden base for positioning of the kinematic GPS unit. The GPS computer unit was located inside a watertight plastic container while the receiver was positioned on top of a wooden base above the container. Figure 13 highlights locations where the water level buoy was deployed in order to record water level height. The buoy was deployed from 20 to 22 May 2009 and on 27 May 2009 at Freshwater Beach, at Sabina Point on 23 May 2009, in South Arm estuary near Seahound boat ramp on 25 May 2009, and at the pocket beach study at the northern point of Cape Clinton on 28 May 2009. Buoy water level time series are provided in Appendix J.



**Figure 12. NOAA water level buoy shown with Danforth anchor and rope.** This water level buoy, containing a kinematic GPS, was manually deployed from a boat during the cal/val campaign and was used to accurately determine water levels at the time of HyMap imagery acquisition.

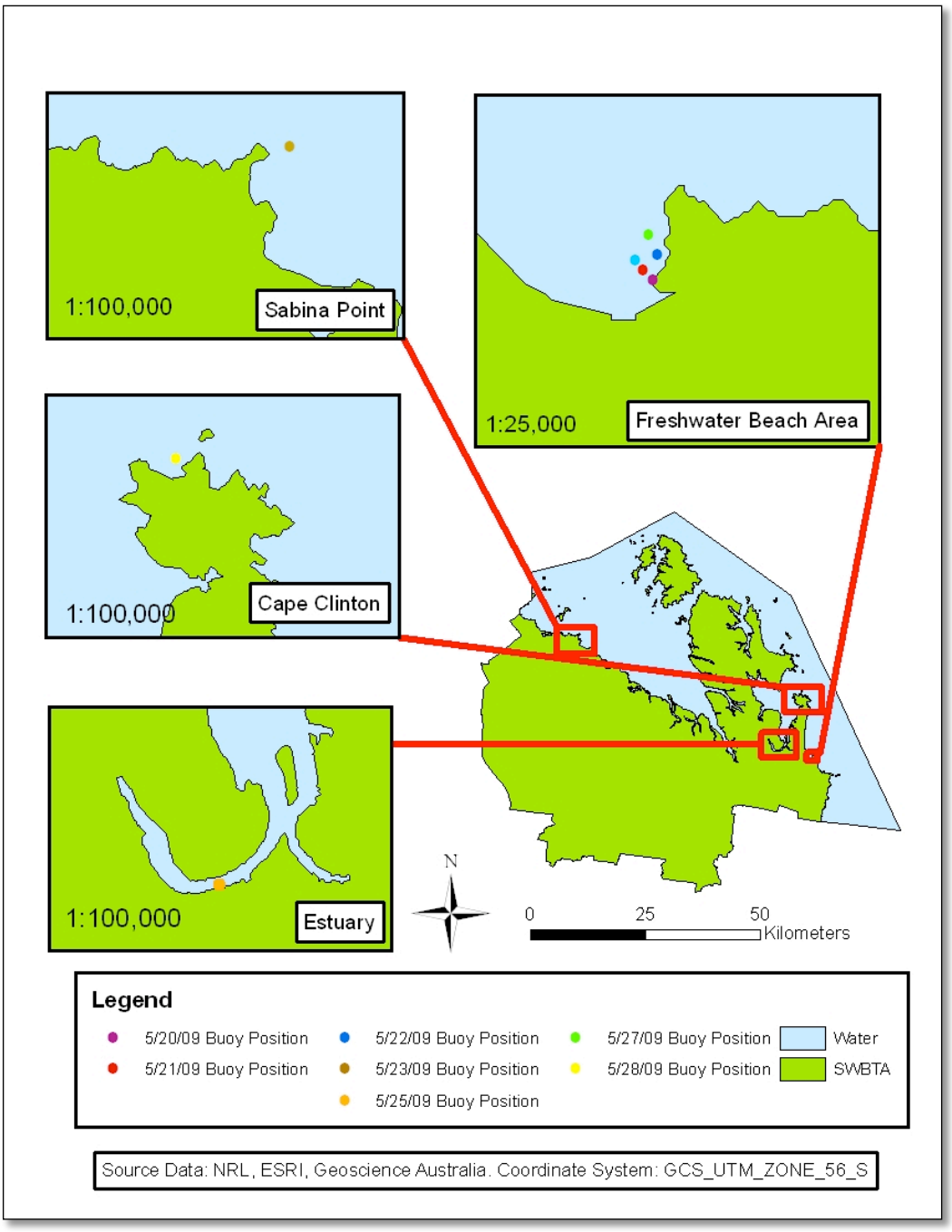



**Figure 13. NOAA water level buoy positions during TS'09.** Areas located on the map indicate where the buoy was collecting water level height data.

### 4.7 Kinematic GPS Data

Survey data collected by team members from NOAA were of sufficient resolution to help calibrate and evaluate the accuracy of the HyMap airborne imagery. The GPS data was also instrumental in bringing topographic data, such as beach profiles measured with a kinematic GPS, into a common reference frame. Figure 14 highlights the distribution of elevation measurements along Freshwater Beach and Sabina Point at SWBTA from the kinematic GPS. A picture of the fixed base station is provided in Figure 15. The base allows differential corrections to be made with the "kinematic" or mobile GPS receiver.

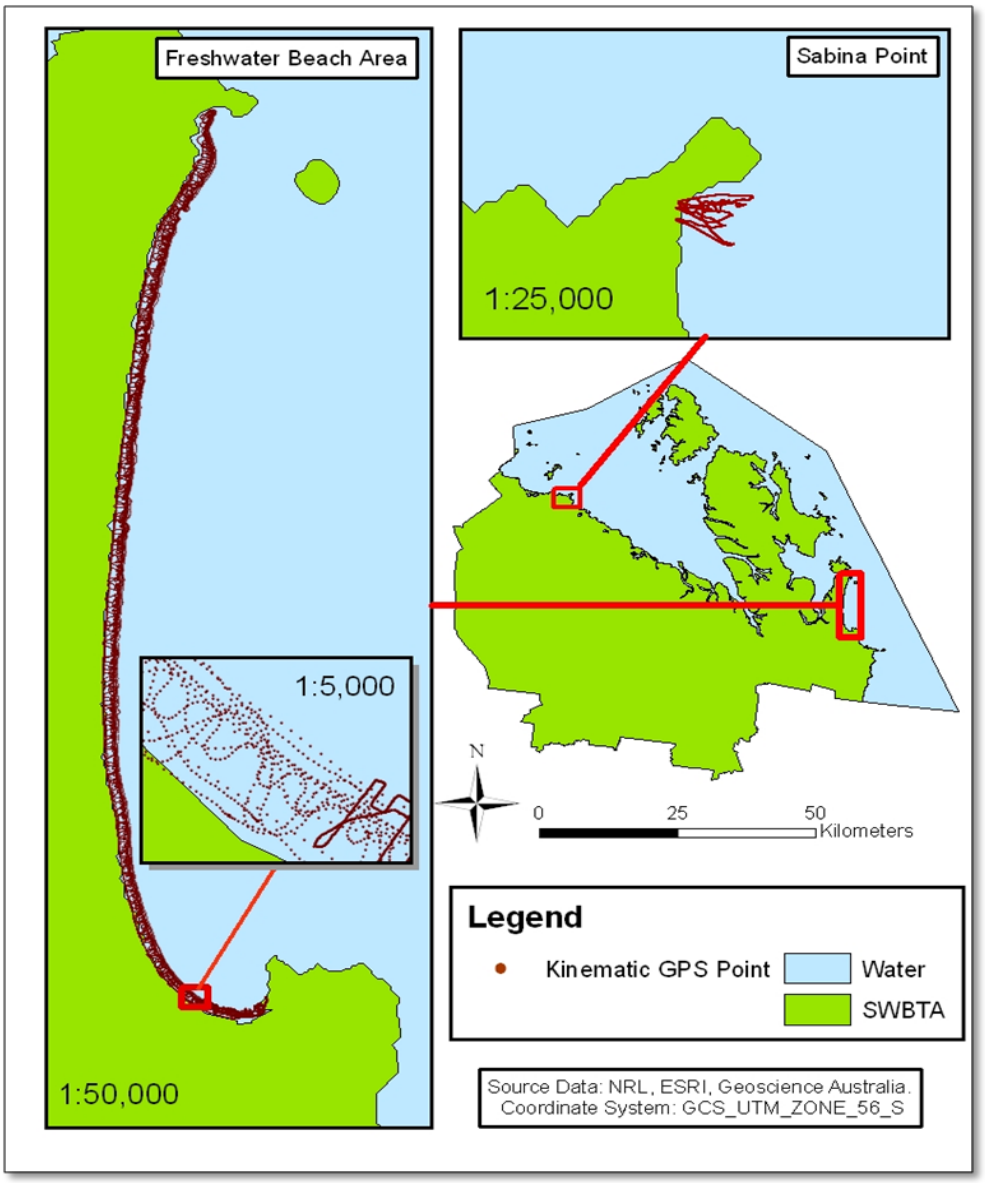



**Figure 14. Kinematic GPS positions during TS'09.**



**Figure 15. NOAA GPS base station at Freshwater Beach.** This base station was used to finely tune the positioning of rover units used to record beach profiles in the intertidal zone**.**

### 4.8 Ground Control Points

The utility of using hyperspectral data from HyMap or ARTEMIS lies in the ability to detect and identify scene materials based on their spectral signature characteristics. For this reason, calibration panels were deployed near Freshwater Beach. They were used to produce calibration data suitable for converting radiance data from hyperspectral sensors to units of apparent reflectance. In addition, blue tarps were surveyed in and are helpful in determining edge response, imagery resolution, and geo-referencing. These ground control points are shown in Figure 16. These survey data are provided in Appendix J.

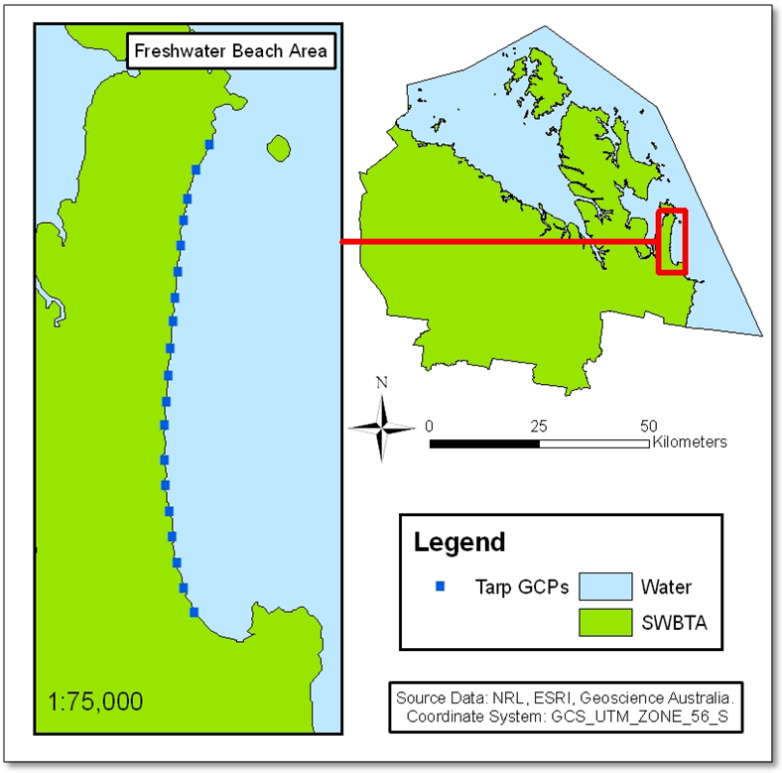



**Figure 16. Blue tarp GCPs (ground control points).**

## 5 Acknowledgments

This fieldwork was a collective effort that involved a wide network of individuals and institutions beyond those that actually collected data, provided analyses, and wrote reports. Dr. Charles Bachmann was the principal investigator and was greatly aided by the efforts and insights of Mr. Gordon Mattis, the Science Advisor at Marine Corps Forces Pacific. This compilation of data represents the work of many individuals throughout the Naval Research Laboratory, Naval Postgraduate School, National Oceanic and Atmospheric Administration, and Australian Defence Force. We are specifically grateful to the support and assistance from Warrant Officer Class 2 David Renton, our coxswain, Majors Bill Wattam and Bob Kebby, our LNOs, and LtCOL Greg Thompson, the lead planner for TS'09 experiments.

The TS'09 remote sensing campaign was funded by the Office of Naval Research. Of particular importance was support from Dr. Larry Schuette and Mr. Jim Blessé from SwampWorks who were particularly interested in exploring how airborne hyperspectral imagery and ARTEMIS might advance the capabilities of Navy and Marine Corps war fighters. Additional funding was provided by Dr. Chung Hye Read of NGA Innovision at the conclusion of the exercise to support analysis and reporting related to the data collected and processed during TS'09.

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# APPENDIX A

## Web Resources

## Introduction

There is considerable information relevant to TS09 and the exploitation of hyperspectral imagery stored on the World Wide Web. Therefore, the following list of Uniform Resource Locators (URLs) is provided since they complement this data report.

**Aerosol Optical Depth, Earth Observatory, NASA, Available online. URL: http://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MODAL2_M_AER_OD#, Accessed on June 24, 2009.**

Global scale maps show average monthly aerosol amounts around the world based on observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. Satellite measurements of aerosols, called *aerosol optical thickness,* are based on the fact that the particles change the way the atmosphere reflects and absorbs visible and infrared light. An optical thickness of less than 0.1 (palest yellow) indicates a crystal clear sky with maximum visibility, whereas a value of 1 (reddish brown) indicates very hazy conditions.

**Asia-Pacific Area Network (APAN). Available online. URL: http://www1.apan-info.net/ts. Accessed on September 17, 2008.**

APAN is a web portal offering information resources on exercises such as TALISMAN SABER and a collaborative planning environment. APAN tools include Training Objective Matrix (TOW), Joint Training Information Management System (JTIMS), Joint Master Scenario Events List (JMSEL), Enterprise Platform for Information Collaboration (EPIC), and a Lessons Learned Tool. APAN is hosted by the Commander, U.S. Pacific Command, Camp Smith, Hawaii.

**Australian Quarantine and Inspection Service. Available online. URL: http://www.daffa.gov.au/aqis/avm/military/talisman-saber-2009. Accessed on November 17, 2008.**

The Australian Quarantine and Inspection Service (AQIS) which is part of the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) provides inspections for all equipment coming into Australia for TS09. An advance party from the Naval Research Laboratory traveled to Brisbane, Australia to ensure all equipment was ready for AQIS from 7-13 May 2009. Once inspected by AQIS, equipment was then shipped to Shoalwater Bay Training Area (SWBTA) near Byfield, Australia. At the Australian Defence Force facility in Rockhampton, Australia, all rental vehicles were cleaned and inspected prior to being operated in the SWBTA.

**Bureau of Meteorology, Australian Government. Available online. URL: http://www.bom.gov.au/. Accessed on May 1, 2009.**

An official site to access weather forecasts and tide predictions. Weather observations were made at Samuel Hill, Station Number 033308, at the SWBTA. A reference station is located at Gladstone and the closest secondary station is Port Clinton. Tide predictions at Port Clinton are 34 minutes after Gladstone. These secondary station predictions are calculated by

applying an adjustment to the time and height of tide for the reference station.

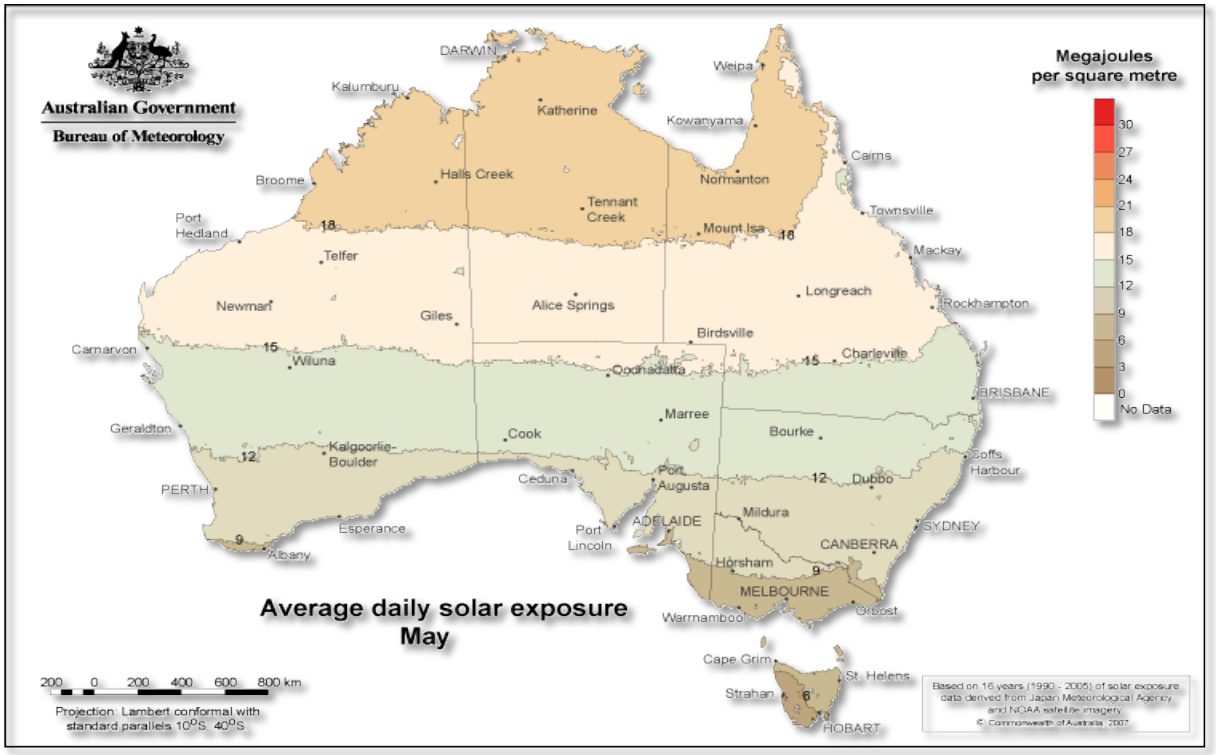



**Figure 1.Average daily solar exposure for May.** Typical values for daily global solar exposure range from 1 to 35 MJ/m$^2$ (megajoules per square metre). For mid-latitudes, the values are usually highest in clear sun conditions during the summer, and lowest during winter or very cloudy days.

**Honolulu Botanical Gardens. Available online. URL: http://www.co.honolulu.hi.us/parks/hbg/index1.htm. Accessed on January 7, 2008.**

During the Mid Planning Conference for Talisman Saber'09 and during HI-HARES'09, research scientists visited the approximately 0.1 km$^2$ Foster Botanical Garden to obtain spectra of vegetation indigenous to Oahu and from several specialty gardens, spectra of plants common to Australia. On November 19, 2008, Dr. Charles Bachmann, Mr. Gordon Mattis and Mr. Reid Nichols, and USMC Capt Chris Jones were aided by Ms. Naomi Hoffman, a botanist, in the collection of data on species listed in Table 1. Field spectra were collected from selected leaf samples.

**Table 1. Plant species studied at Foster Botanical Garden on November 19, 2008.**

| Scientific Name | Common Name | Remarks |
|---|---|---|
| *Acacia koa* | Koa | Endemic to Hawaiia. |
| *Aleurites moluccana* | Kukui | Distributed throughout tropical regions. |
| *Chamaesyce degeneri* | Akoko | Endemic to Hawaiia. |
| *Coix lacryma-jobi* | Job's tear | Common along streams and ditches in Hawaii. |
| *Colocasia esculenta* | taro | Native to tropical Polynesia and southeastern Asia. |
| *Cordia sebestena* | Kou haole | Found worldwide, mostly in warmer regions. |
| *Cordyline fruticosa* | Ti plant | It is native to tropical Asia, Australia, the Indian Ocean, and parts of Polynesia. |
| *Curculigo capitalata* | palm grass | Arching palm-like leaves, evergreen in protected areas, small yellow flowers in summer |
| *Gossypium tomeutosum* | Ma'o | A shrub found in Hawaii that grows in dry, rocky, or clay coastal plains. |
| *Hibiscus brackenridgei* | Ma'o Hau Hele | Found in dry forests and Hawaiian tropical low shrublands. |
| *Hyophorbe verschaffeltii* | spindle palm | Found in tropical coastal savannas and hilly forests worldwide due to cultivation. |
| *Macrozamia miquelii* | Zamia bush | Found in Queensland Australia. |
| *Myoporum sandwicense* | Naio | Endemic to Hawaii. |
| *Ophiopogon japonicus* | mondo grass | Ground cover found in temperate and tropical Asia. |
| *Pandanus tectorius* | Hala | Found on Pacific islands, in Micronesia, in Melanesia, and as far west as northern Australia. |
| *Pittosporum undulatum* | mock orange | Native to the coastal belt and mountains of south-eastern Australia. |
| *Pritchardia remota*[1] | Loulu | Palm tree found in Hawaii and being cultivated in botanical gardens. |
| *Terminalia catappa* | tropical almond | Widespread in subtropical and tropical zones of Indian and Pacific Oceans; planted extensively throughout the tropics. |
| *Thespesia populnea* | Milo | Tropical and subtropical distribution. |
| *Veitchia montgomeryana* | Montgomery palm | Native to Vanuatu. |
| For specifics on Hawaiian plants see Eileen Herring, Thesis Project: Hawaiian Native Plant Propagation Database, Available online. URL: http://pdcs.ctahr.hawaii.edu:591/hawnprop/default.htm, Accessed November 17, 2008. | | |

***Supplementary Environmental Report Talisman Saber 05*, Australian Defence Force, EPBC Act Referral. Available online. URL: http://www.maunsell.com/media/4418.pdf. Accessed on June 24, 2009.**

A summary report prepared by Maunsell Australia Pty Ltd describing the environment and Australian Defence Force activities taking place at the Shoalwater Bay Training Area. This report also explains safeguards which mitigate the impact of military activities on the

[1] Several *Pritchardia* species are listed as endangered under the US Endangered Species Act and are only found in cultivation in botanical gardens.

environment. Additionally, a detailed risk assessment planning process that is conducted by exercise planners is fully explained.

***SWBTA State of the Environment Report 2008*. Estate Policy and Environment Branch, Department of Defence, CANBERRA ACT 2600. Available online. URL: http://www.defence.gov.au/environment/swbta_report.htm. Accessed on June 24, 2009.**

A descriptive report which synthesizes information from many sources, both internal and external to the Australian Department of Defence. This report describes many of the environmental factors which impact military operations. In reporting the environmental attributes of SWBTA and their condition, this report seeks to compare environmental performance of the Area with adjacent landscapes and protected areas.

***Shoalwater Bay Seagrasses*, Great Barrier Reef Marine Park Authority, Australian Government. Available online. URL: http://www.gbrmpa.gov.au/__data/assets/pdf_file/0013/2722/rp44_intro_methods_analy.pdf. Accessed on June 24, 2009.**

A descriptive report which highlights the distribution and abundance of submerged aquatic vegetation (SAV) by seasons. Bottom types are described and maps are provided to locate SAV beds.

**Tunstall, B., Marks, A., Reece, P., 1998. Vegetation and Soil Mapping Shoalwater Bay Training Area, CSIRO Land and Water Technical Report 9/98, Available online. URL: http://www.clw.csiro.au/publications/technical98/tr9-98.pdf. Accessed on June 24, 2009.**

A summary of vegetation and soil mapping at the SWBTA. New methods are described and GIS coverage maps are presented.

**U.S. Geological Survey, Global Visualization Viewer. Available online. URL: http://glovis.usgs.gov/. Accessed on June 24, 2009.**

The USGS Global Visualization Viewer or GloVis provides Landsat and EO-1 ALI and Hyperion datasets for download at no charge. The Earth Observing 1 (EO-1) satellite has three imaging sensors: the multispectral Advanced Land Imager (ALI), the hyperspectral Hyperion sensor, and the Atmospheric Corrector. Hyperion is a high-resolution hyperspectral imager capable of resolving 220 spectral bands (from 0.4 to 2.5 micron) with a 30 m resolution. The instrument images a 7.5 km by 100 km surface area. Prior to the launch of TACSAT-3/ARTEMIS, Hyperion was the only source of spaceborne hyperspectral imaging data.

**U.S. Marine Corps Forces Pacific. Available online. URL: http://www.mfp.usmc.mil. Accessed on January 7, 2008.**

A PME was conducted at MARFORPAC by NRL and AFRL scientists during January 2008 on hyperspectral Imagery and the TACSAT-3/ARTEMIS experiment. The Chief of Staff directed the Science Advisor to include ARTEMIS as an experiment during TS09. Primary sponsors for Talisman Saber were the Science Advisor, AC/S G-2, representatives from the

MARFORPAC Experimentation Center (MEC), and exercise planners from the PACOM J-8. Exercise proposals and presentations were delivered to the MEC and PACOM J-8. Data collected during HI-HARES was planned to be made available to various military planning personnel from 31st MEU, MARFORPAC, MCIA, and NAVOCEANO during the TS09 Staff Exercise.

**Wetland Info, Department of Environment and Resource Management, Queensland Governement, Australia. Available online. URL: http://www.epa.qld.gov.au/wetlandinfo/site/index.html, Accessed on June 24, 2009.**

A web site which characterizes a variety of wetlands that are found in Queensland. Information that is provided includes data on wetland soils, water quality, flora and fauna. In addition, Wetland Info provides maps and data that are used in management, planning, assessment, research and rehabilitation projects.

# APPENDIX B

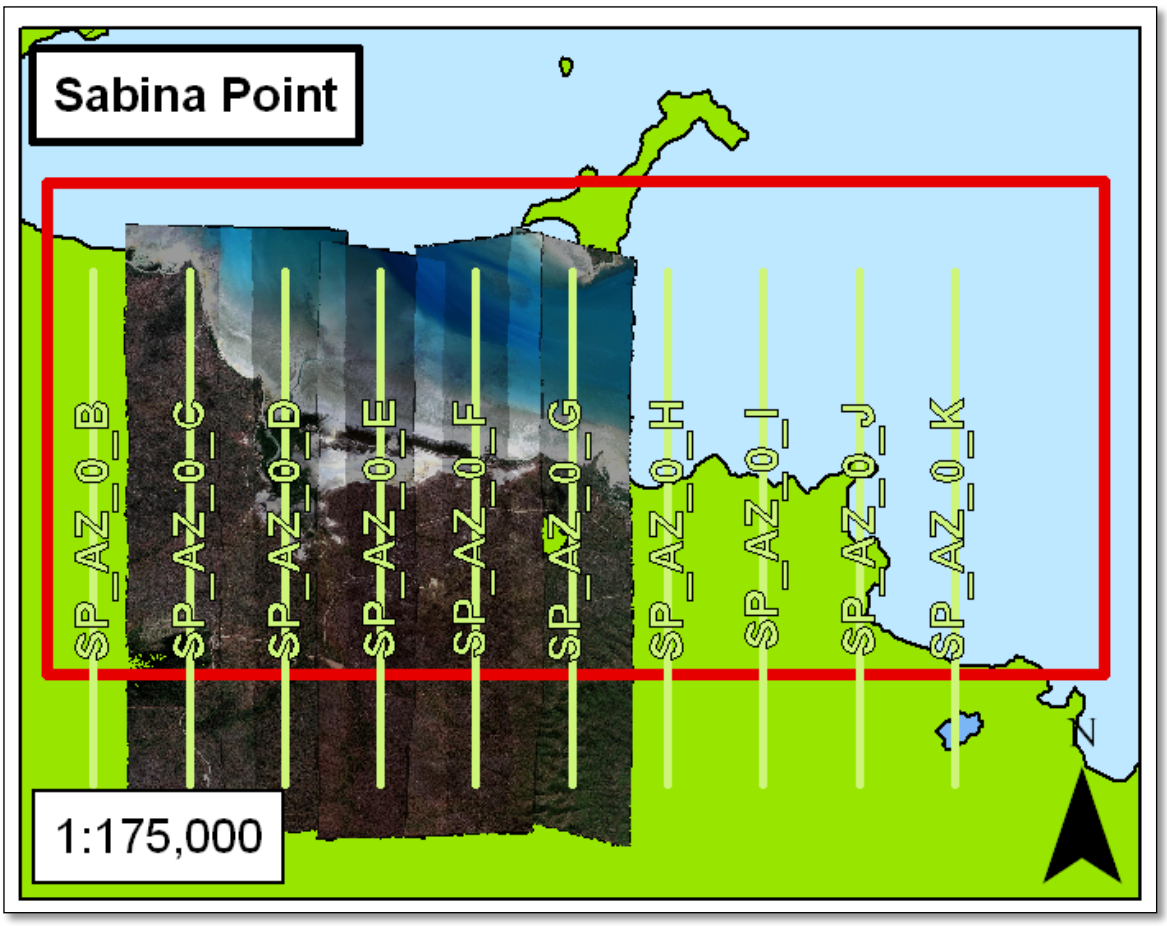
## Flight Lines

## 1. Introduction

Talisman-Saber 2009 flight lines were planned to achieve a nominal ground sample distance (GSD) of about 3m with an approximate swath of about 1.8 km. An overlap of approximately 20% (which is about 300 m) between adjacent flight lines was achieved in order to prevent any data gaps from small variations in the planned flight-lines. To minimize glint from the water, flights were flown when solar zenith angles were between 30-60°. In addition, flights were flown into and out of the sun to further minimize glint as illustrated in the following solar azimuth heading figures. Section 2 displays the flight lines that were flown by the aircraft.

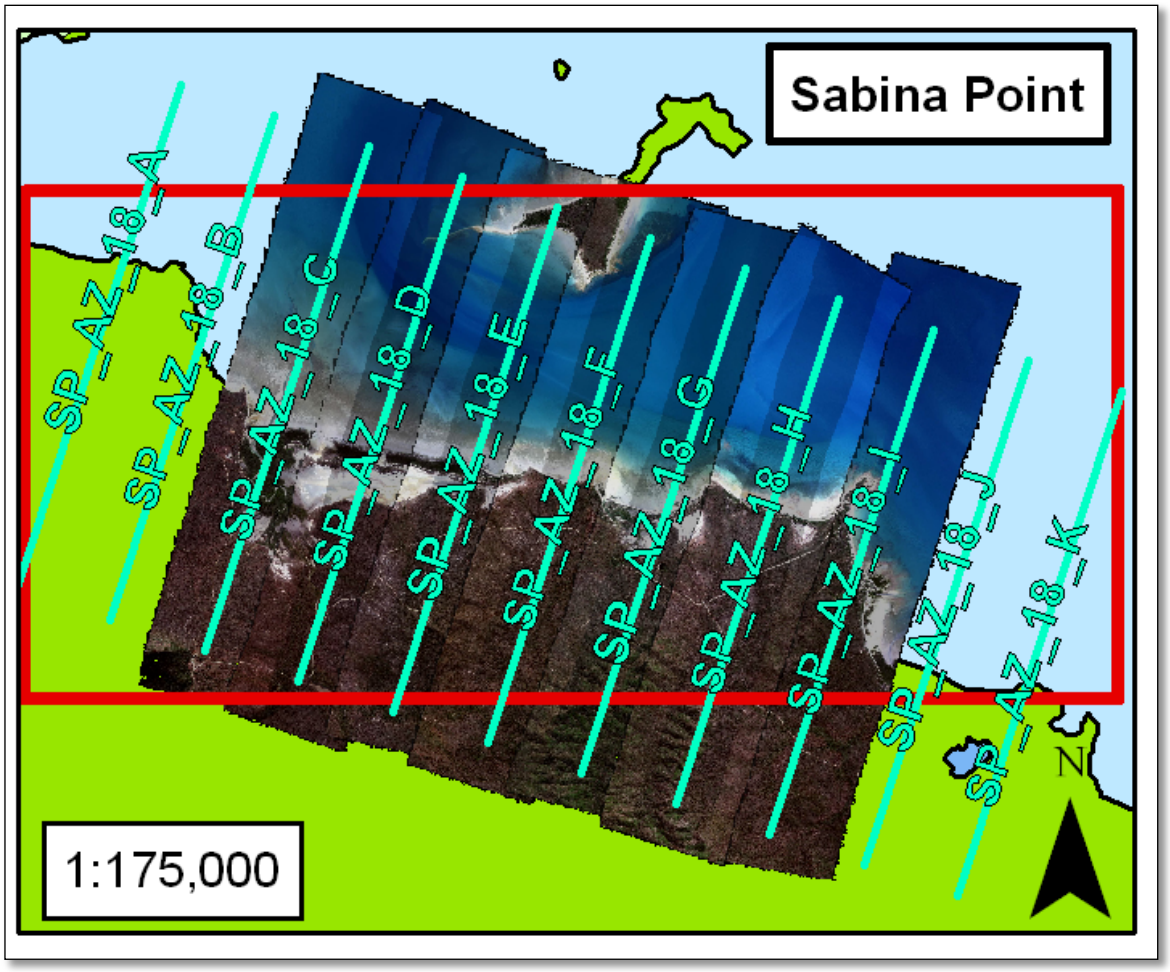
## 2. Flight Lines

### 2.1 Sabina Point- Azimuth 0 Flight Lines



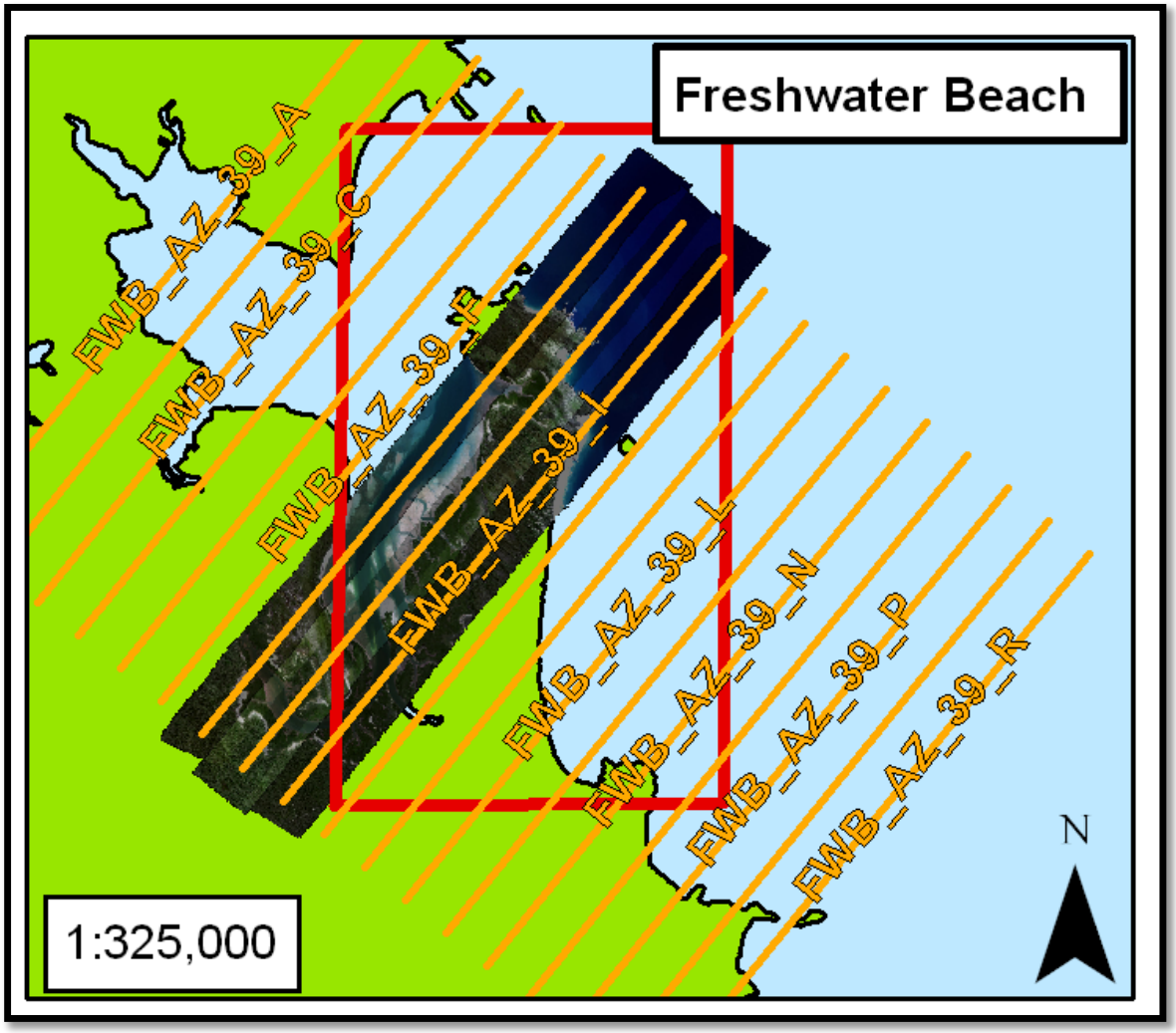

Flight-line boxes with heading along 0 degrees solar azimuth, allowing flights approximately into and out of the sun in order to minimize glint. The HyMap quicklooks can be seen below the name of the flight line. The line appears in the middle of each quicklook image. These flight lines were flown on May 21, 2009. Flight lines not associated with an image were not flown.

## 2.2. Sabina Point-Azimuth 18 Flight Lines



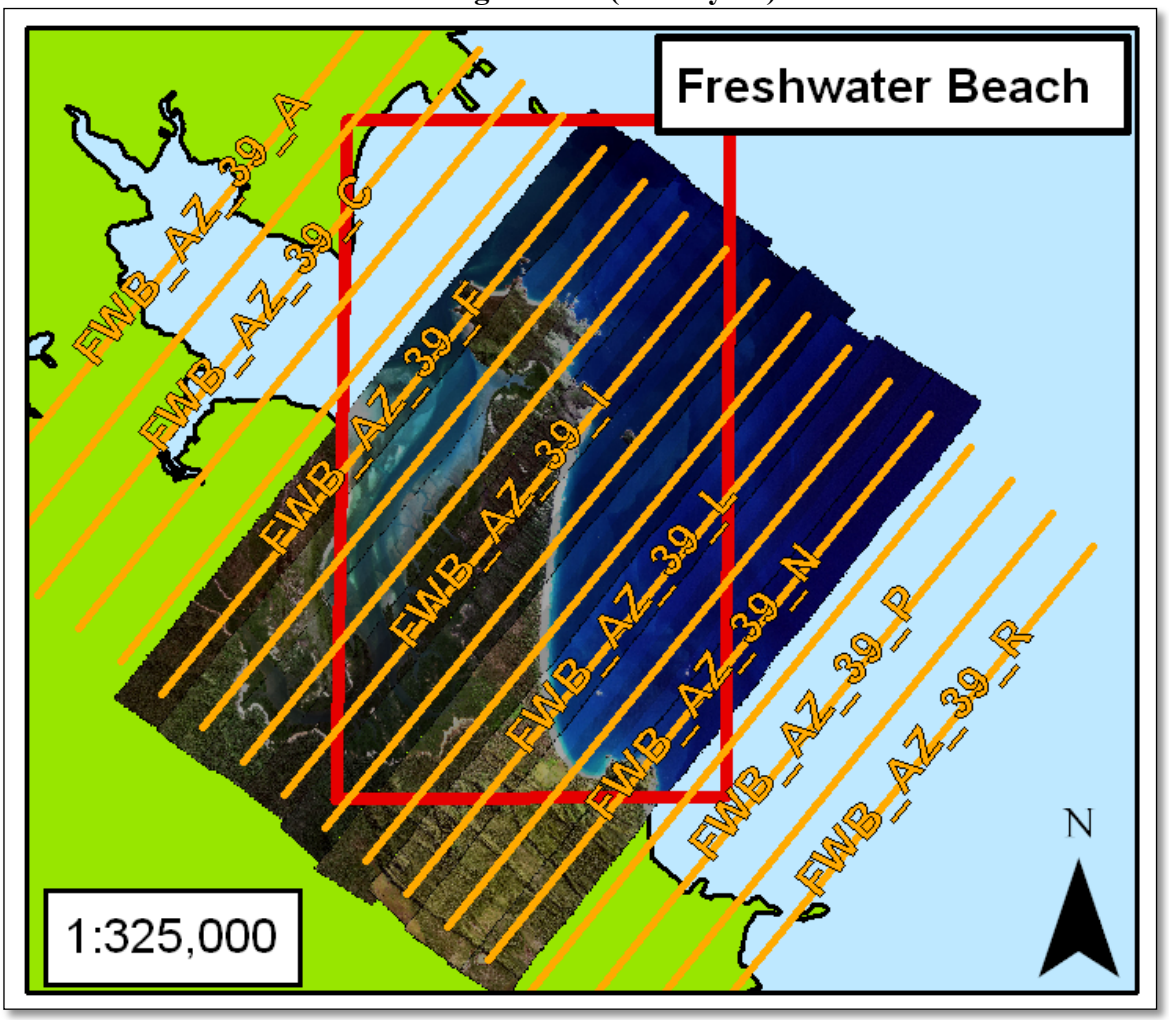

Flight-line boxes with heading along 18 degrees solar azimuth, allowing flights approximately into and out of the sun in order to minimize glint. The HyMap quicklooks can be seen below the name of the flight line. The line appears in the middle of each quicklook image. These flight lines were flown on May 21, 2009. Flight lines not associated with an image were not flown.

### 2.3 Freshwater Beach- Azimuth 39 Flight Lines (21-May-2009)



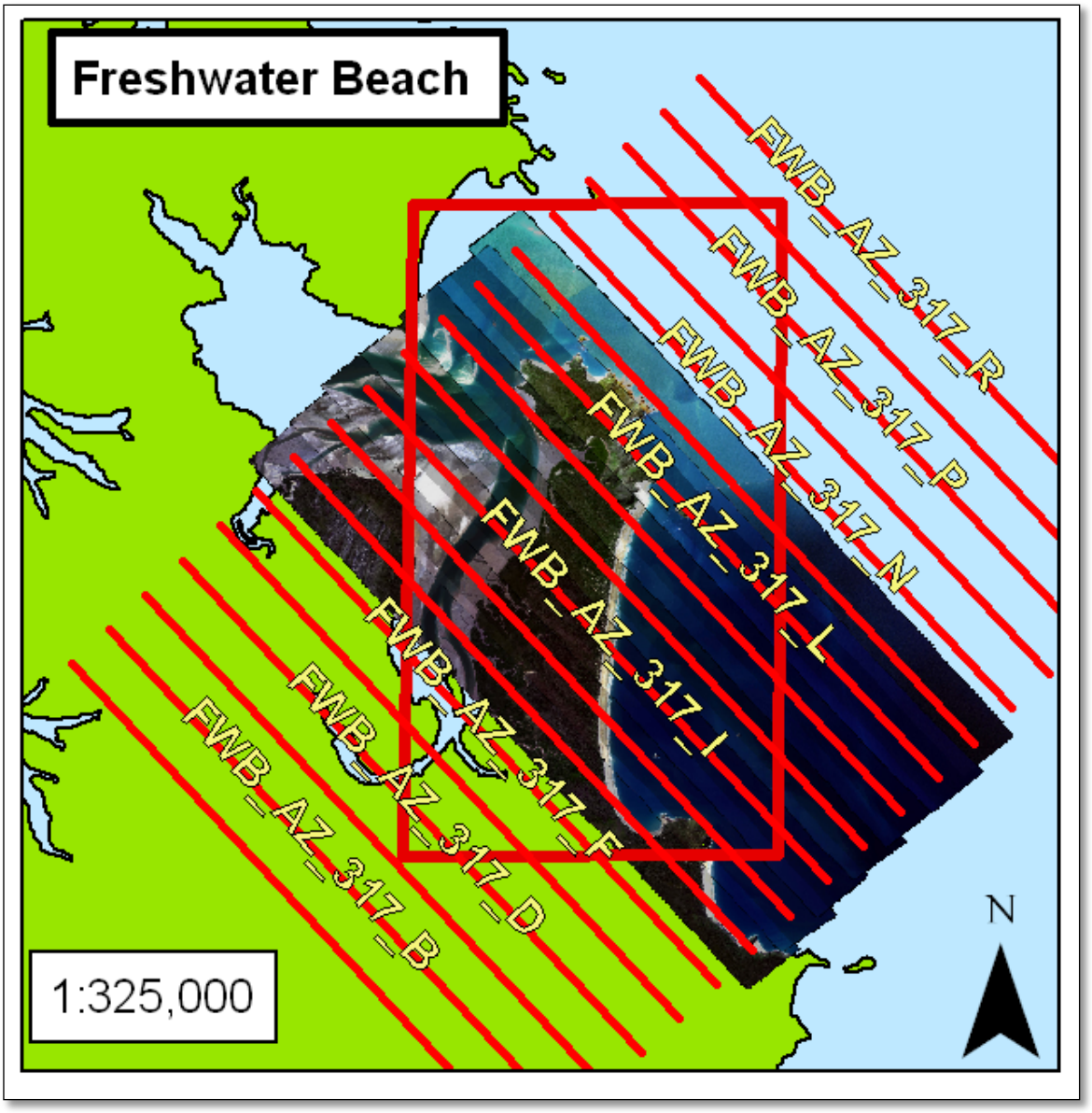

Flight-line boxes with heading along 39 degrees solar azimuth, allowing flights approximately into and out of the sun in order to minimize glint. The HyMap quicklooks can be seen below the name of the flight line. The line appears in the middle of each quicklook image. These flight lines were flown on May 21, 2009. Flight lines not associated with an image were not flown. Flight lines flown on this day include FWB_AZ_39_G, FWB_AZ_39_H, and FWB_AZ_39_I.

**2.4 Freshwater Beach-Azimuth 39 Flight Lines (22-May-09)**



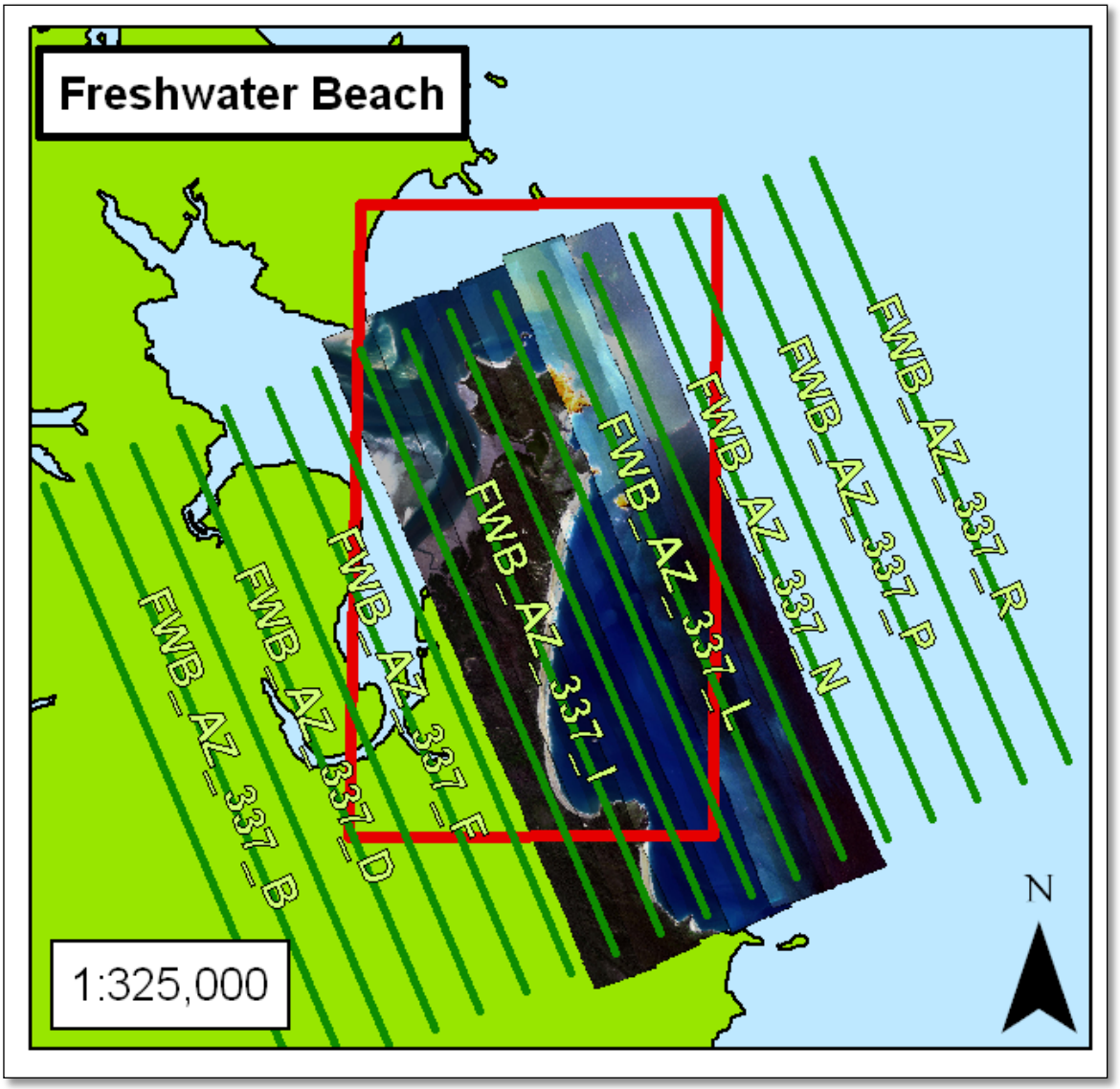

Flight-line boxes with heading along 39 degrees solar azimuth, allowing flights approximately into and out of the sun in order to minimize glint. The HyMap quicklooks can be seen below the name of the flight line. The line appears in the middle of each quicklook image. These flight lines were flown on May 22, 2009. Flight lines not associated with an image were not flown.

## 2.5 Freshwater Beach-Azimuth 317 Flight Lines




Flight-line boxes with heading along 317 degrees solar azimuth, allowing flights approximately into and out of the sun in order to minimize glint. The HyMap quicklooks can be seen below the name of the flight line. The line appears in the middle of each quicklook image. These flight lines were flown on May 23, 2009. Flight lines not associated with an image were not flown.

## 2.6. Freshwater Beach- Azimuth 337 Flight Lines




Flight-line boxes with heading along 337 degrees solar azimuth, allowing flights approximately into and out of the sun in order to minimize glint. The HyMap quicklooks can be seen below the name of the flight line. The line appears in the middle of each quicklook image. These flight lines were flown on May 23, 2009. Flight lines not associated with an image were not flown.

# APPENDIX C

## Imagery Quicklooks

## 1. Introduction

HyMAP imagery is found at the path \TS09_GD\Attribute_Data\HyMap… and is divided by folder into each data and azimuth. Imagery quicklooks are also found in folders at this path. The folder hierarchy is illustrated in Table 1.

**Table 1. HyMAP Data Folder Hierarchy.**

| Filepath | Folder(s) | Contents/Folder Name |
|---|---|---|
| \TS09_GD\Attribute_Data\HyMap… | Shoalwater_20090521, Shoalwater_20090522, Shoalwater_20090523, | Each of the date folders contain folders of each of the individual flight lines flown at different azimuths, as well as the "geocorrection," "georeferenced," and "quicklooks" folders. |
| \TS09_GD\Attribute_Data\HyMap…\Shoalwater_20090521 | FWB_AZ_39_G, FWB_AZ_39_H, FWB_AZ_39_I ,SP_AZ_0_C, SP_AZ_0_D, SP_AZ_0_E, SP_AZ_0_F, SP_AZ_0_G, SP_AZ_18_C, SP_AZ_18_D, SP_AZ_18_E, SP_AZ_18_F, SP_AZ_18_G, SP_AZ_18_H, SP_AZ_18_I. | Each of the flight line folders contains information on/about image products and related files; folder names are auxiliary, mask, radiance, and Tafkaa. "Tafkaa" contains a version of the data as reflectance, obtained by running NRL's TAFKAA atmospheric correction software |
| \TS09_GD\Attribute_Data\HyMap…\Shoalwater_20090521 | FWB_QuickLooks_20090521, SP_QuickLooks_20090521 | Contains one JPEG image for each of the flight lines. |
| \TS09_GD\Attribute_Data\HyMap…\Shoalwater_20090521 | Geocorrection | Contains data files with associated ENVI header files for each of the flight paths. |
| \TS09_GD\Attribute_Data\HyMap…\Shoalwater_20090521 | Geoferenced | Contains atmospherically and georeferenced reflectance images of each flight path. |
| \TS09_GD\Attribute_Data\HyMap…\Shoalwater_20090522 | FWB_AZ_39_F, FWB_AZ_39_G, FWB_AZ_39_H, FWB_AZ_39_I, FWB_AZ_39_J, FWB_AZ_39_K, FWB_AZ_39_L, FWB_AZ_39_M, FWB_AZ_39_N, | Each of the flight line folders contains information on/about; auxiliary, mask, radiance, and Tafkaa. |
| \TS09_GD\Attribute_Data\HyMap…\Shoalwater_20090522 | FWB_QuickLooks_20090522 | Contains one JPEG image for each of the flight lines. |
| \TS09_GD\Attribute_Data\HyMap…\Shoalwater_20090522 | Geocorrection | Contains data files with associated ENVI header files for each of the flight paths. |
| \TS09_GD\Attribute_Data\HyMap…\Shoalwater_20090522 | Geoferenced | Contains atmospherically and georeferenced reflectance images of each flight path. |
| \TS09_GD\Attribute_Data\HyMap…\Shoalwater_20090523 | FWB_AZ_317_G, FWB_AZ_317_H, FWB_AZ_317_I, FWB_AZ_317_J, FWB_AZ_317_K, FWB_AZ_317_L, FWB_AZ_317_M, FWB_AZ_337_G, FWB_AZ_337_H, FWB_AZ_337_I, FWB_AZ_337_J, FWB_AZ_337_K, FWB_AZ_337_L | Each of the flight line folders contains information on/about; auxiliary, mask, radiance, and Tafkaa. |
| \TS09_GD\Attribute_Data\HyMap…\Shoalwater_20090523 | FWB_QuickLooks_20090523 | Contains one JPEG image for each of the flight lines. |
| \TS09_GD\Attribute_Data\HyMap…\Shoalwater_20090523 | Geocorrection | Contains data files with associated ENVI header files for each of the flight paths. |
| \TS09_GD\Attribute_Data\HyMap…\Shoalwater_20090523 | Geoferenced | Contains atmospherically and georeferenced reflectance images of each flight path. |

**Table 2. HyMAP Flight Line Center Time.** The time displayed is given in Australian Eastern Standard Time (EST).

| Flight line | Date | Time of flight line center (EST) |
|---|---|---|
| FWB_AZ_39_G | 21 May 2009 | 10:11:02 |
| FWB_AZ_39_H | 21 May 2009 | 10:19:58 |
| FWB_AZ_39_I | 21 May 2009 | 10:28:48 |
| SP_AZ_0_C | 21 May 2009 | 11:45:06 |
| SP_AZ_0_D | 21 May 2009 | 11:51:33 |
| SP_AZ_0_E | 21 May 2009 | 11:57:48 |
| SP_AZ_0_F | 21 May 2009 | 12:04:15 |
| SP_AZ_0_G | 21 May 2009 | 12:10:10 |
| SP_AZ_18_C | 21 May 2009 | 11:32:57 |
| SP_AZ_18_D | 21 May 2009 | 11:26:56 |
| SP_AZ_18_E | 21 May 2009 | 11:20:30 |
| SP_AZ_18_F | 21 May 2009 | 11:14:21 |
| SP_AZ_18_G | 21 May 2009 | 11:07:53 |
| SP_AZ_18_H | 21 May 2009 | 10:56:36 |
| SP_AZ_18_I | 21 May 2009 | 10:50:29 |
| FWB_AZ_39_F | 22 May 2009 | 10:15:38 |
| FWB_AZ_39_G | 22 May 2009 | 10:06:35 |
| FWB_AZ_39_H | 22 May 2009 | 9:57:04 |
| FWB_AZ_39_I | 22 May 2009 | 9:48:09 |
| FWB_AZ_39_J | 22 May 2009 | 9:38:31 |
| FWB_AZ_39_K | 22 May 2009 | 9:29:25 |
| FWB_AZ_39_L | 22 May 2009 | 9:19:36 |
| FWB_AZ_39_M | 22 May 2009 | 9:10:16 |
| FWB_AZ_39_N | 22 May 2009 | 9:00:35 |
| FWB_AZ_317_G | 23 May 2009 | 13:45:30 |
| FWB_AZ_317_H | 23 May 2009 | 13:54:24 |
| FWB_AZ_317_I | 23 May 2009 | 14:03:34 |
| FWB_AZ_317_J | 23 May 2009 | 14:12:56 |
| FWB_AZ_317_K | 23 May 2009 | 14:22:07 |
| FWB_AZ_317_L | 23 May 2009 | 14:31:36 |
| FWB_AZ_317_M | 23 May 2009 | 14:40:41 |
| FWB_AZ_337_G | 23 May 2009 | 12:26:39 |
| FWB_AZ_337_H | 23 May 2009 | 12:57:31 |
| FWB_AZ_337_I | 23 May 2009 | 13:06:23 |
| FWB_AZ_337_J | 23 May 2009 | 13:15:13 |
| FWB_AZ_337_K | 23 May 2009 | 13:24:24 |
| FWB_AZ_337_L | 23 May 2009 | 13:33:48 |

## 2. Quicklook Imagery

Figures 1 through 6 show the HyMap imagery as thumbnail-sized quicklooks for each flight day. Note: Quicklook images are not to scale. Information on the weather for Sam Hill is located in Table 3. The time is provided in Australian Eastern Standard Time (EST). The time presented is the time when the image center was captured by the sensor.



FWB_AZ_39_G: 10:11:02 EST



FWB_AZ_39_H: 10:19:58 EST



FWB_AZ_39_I: 10:28:48 EST

**Figure 1 May 21, 2009 HyMap Imagery-Freshwater Beach, Azimuth 39, lines G, H, I..** Sky conditions were partly cloudy from 10:00 to 12:00 PM and clear from 12:00 to 2:30 PM. Temperatures ranged from 9.6 to 25.1 ˚C. Relative humidity ranged from 83% at 9:00 AM to 50% at 3:00 PM. Approximately 0.2mm of rainfall was measured at Sam Hill.



SP_AZ_0_C: 11:45:06 EST SP_AZ_0_D : 11:51:33 EST SP_AZ_0_E: 11:57:48 EST SP_AZ_0_F: 12:04:15 EST SP_AZ_0_G: 12:10:10 EST

**Figure 2 May 21, 2009 HyMap Imagery-Sabina Point, Azimuth 0, lines C, D, E, F, G.** . Sky conditions were partly cloudy from 10:00 to 12:00 PM and clear from 12:00 to 2:30 PM. Temperatures ranged from 9.6 to 25.1 ˚C. Relative humidity ranged from 83% at 9:00 AM to 50% at 3:00 PM. Approximately 0.2 mm of rainfall was measured at Sam Hill.



SP_AZ_18_C: 11:32:57 EST



SP_AZ_18_D: 11:26:56 EST



SP_AZ_18_E: 11:20:30 EST



SP_AZ_18_F: 11:14:21 EST



SP_AZ_18_G: 11:07:53 EST



SP_AZ_18_H: 10:56:36 EST



SP_AZ_18_I: 10:50:29 EST

**Figure 3 May 21, 2009 HyMap Imagery-Sabina Point, Azimuth 18, lines C, D, E, F, G, H, I.** Sky conditions were partly cloudy from 10:00 to 12:00 PM and clear from 12:00 to 2:30 PM. Temperatures ranged from 9.6 to 25.1 ˚C. Relative humidity ranged from 83% at 9:00 AM to 50% at 3:00 PM. Approximately 0.2 mm of rainfall was measured at Sam Hill.

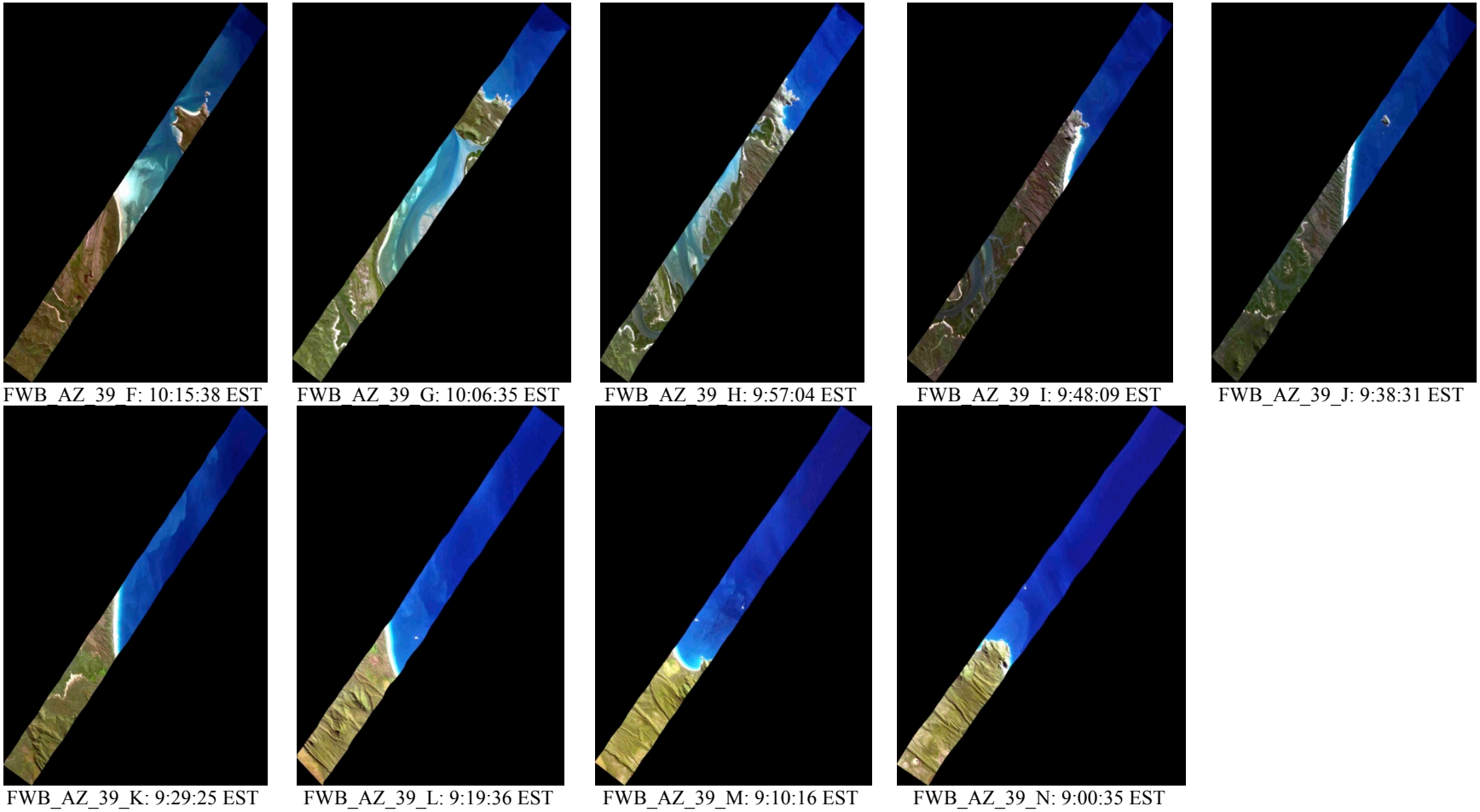



**Figure 4 May 22, 2009 HyMap Imagery-Freshwater Beach, Azimuth 39, lines F, G, H, I, J, K, L, M, N.** Sky conditions vacillated from partly cloudy to scattered clouds to clear from 10:00 AM to 3:00 PM. Temperatures ranged from 8.6 to 24.2 ˚C. Relative humidity ranged from 74% at 9:00 AM to 49% at 3:00 PM. Approximately 0.8 mm of rainfall was measured at Sam Hill.

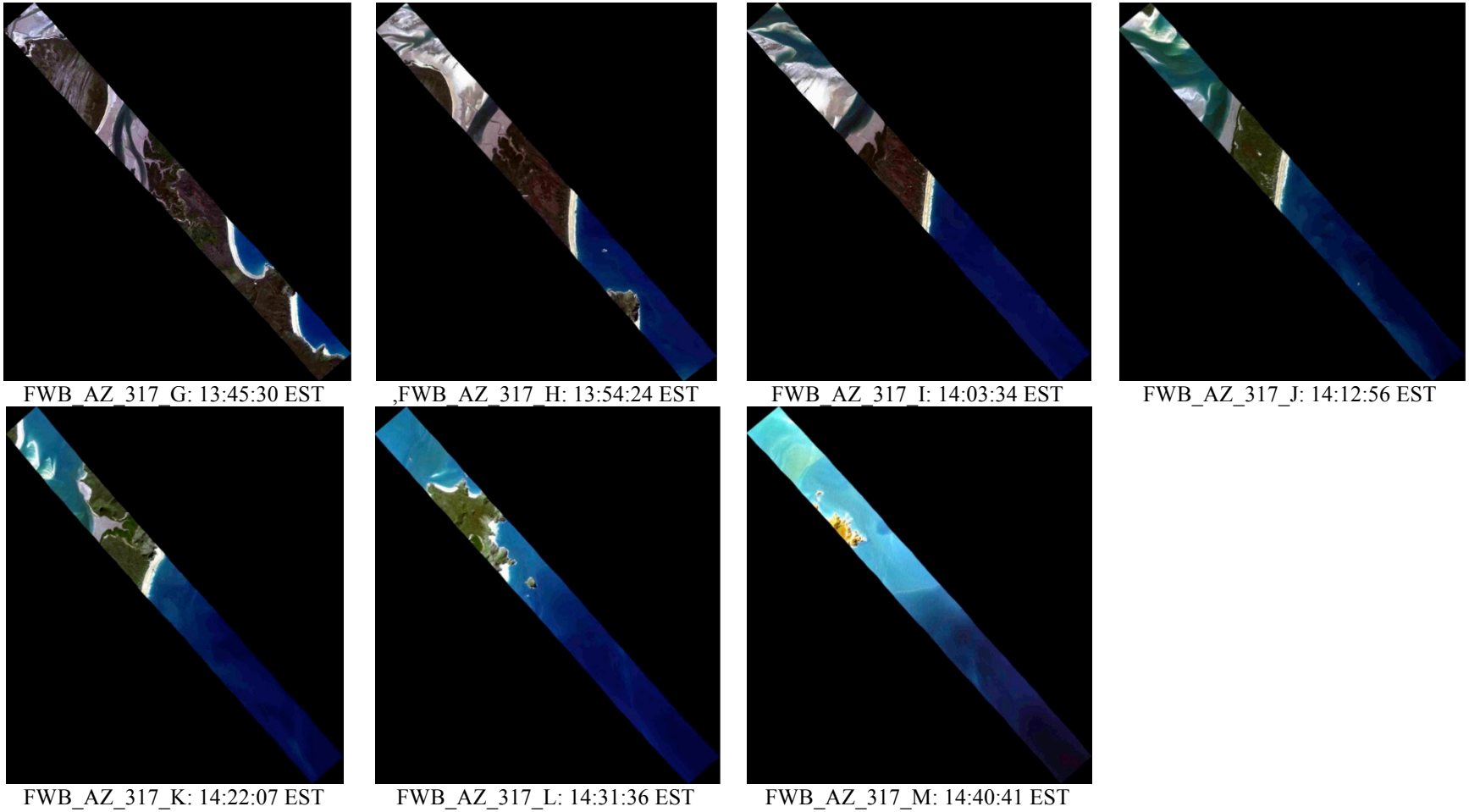
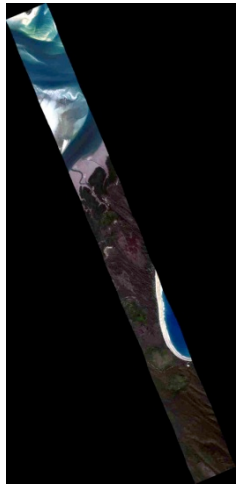
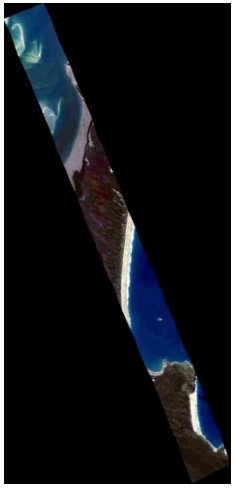



**Figure 5. May 23, 2009 HyMAP Imagery-Freshwater Beach, Azimuth 317, lines G, H, I, J, K, L, M**. Sky conditions vacillated from clear to partly cloudy from 10:00 AM to 3:00 PM. Temperatures ranged from 7.9 to 25.4 ˚C. Relative humidity ranged from 82% at 9:00 AM to 36% at 3:00 PM. Approximately 0.2 mm of rainfall was measured at Sam Hill.



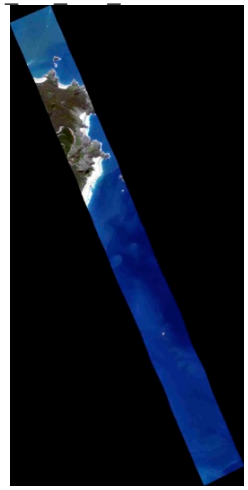
FWB_AZ_337_G: 12:26:39 EST



FWB_AZ_337_H: 12:57:31 EST



FWB_AZ_337_I: 13:06:23 EST



FWB_AZ_337_J: 13:15:13 EST



FWB_AZ_337_K: 13:24:24 EST



FWB_AZ_337_L: 13:33:48 EST

**Figure 6. May 23, 2009 HyMAP Imagery-Freshwater Beach, Azimuth 337, lines G, H, I, J, K, L.** Sky conditions vacillated from clear to partly cloudy from 10:00 AM to 3:00 PM. Temperatures ranged from 7.9 to 25.4 ˚C. Relative humidity ranged from 82% at 9:00 AM to 36% at 3:00 PM. Approximately 0.2 mm of rainfall was measured at Sam Hill.

**Table 3. Daily Weather Observations for Station 033308 sited at Samuel Hill, Queensland for the month of May 2009**

| Day | Temperature (°C) | | Rainfall (mm) | Maximum wind gust | | | 9am | | | | | 3pm | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | | Dir. | Spd (km/h) | Time | Temp. (°C) | rh (%) | wind dir. | wind speed (km/h) | MSL pres. (hPa) | Temp. (°C) | rh (%) | wind dir. | wind spd (km/h) | MSL pres. (hPa) |
| 1 | 11.8 | 26.2 | 0 | SSE | 31 | 10:00 | 22 | 60 | SSE | 15 | 1019.5 | 24.8 | 44 | ESE | 17 | 1017 |
| 2 | 14.5 | 25.3 | 2 | SE | 37 | 14:14 | 20.6 | 95 | SSE | 15 | 1020.6 | 24.1 | 62 | ESE | 24 | 1017.4 |
| 3 | 15.7 | 25.5 | 0 | SE | 39 | 13:08 | 22.2 | 79 | SSE | 17 | 1020.8 | 23.7 | 60 | ESE | 22 | 1019.1 |
| 4 | 13.2 | 25.2 | 0 | SE | 39 | 19:49 | 21.3 | 72 | SSE | 19 | 1021.8 | 23.6 | 64 | SE | 17 | 1019.6 |
| 5 | 17.8 | 24.9 | 9.8 | SE | 50 | 12:36 | 22.1 | 76 | SE | 22 | 1022.8 | 21.3 | 87 | SE | 13 | 1020.7 |
| 6 | 17.8 | 24.8 | 1.4 | ESE | 35 | 0:50 | 21.8 | 74 | S | 15 | 1022.2 | 22.8 | 67 | SE | 19 | 1018.8 |
| 7 | 17.9 | 23.1 | 0 | SSE | 35 | 9:31 | 22.7 | 75 | SE | 20 | 1020.4 | 20 | 98 | | Calm | 1018.5 |
| 8 | 17.4 | 24.1 | 20.8 | SSE | 43 | 11:48 | 20.8 | 87 | S | 13 | 1021.1 | 23.2 | 68 | SE | 20 | 1019.3 |
| 9 | 18.1 | 24.3 | 0.2 | SSE | 33 | 10:28 | 21.1 | 81 | SSE | 15 | 1020.5 | 23 | 67 | SE | 17 | 1017.7 |
| 10 | 12.2 | 24.8 | 0.2 | SSE | 26 | 9:15 | 20.8 | 95 | SE | 11 | 1018.6 | 22.8 | 57 | ESE | 13 | 1016.1 |
| 11 | 14.7 | 24.3 | 0 | S | 37 | 11:39 | 21.9 | 74 | SSE | 19 | 1018.4 | 21.2 | 76 | SSE | 17 | 1016 |
| 12 | 16.4 | 23.4 | 1.2 | SSE | 35 | 12:02 | 19.3 | 94 | SSE | 15 | 1017.8 | 20.9 | 79 | SSE | 13 | 1015.3 |
| 13 | 16.5 | 20.8 | 2.2 | SSE | 24 | 10:59 | 18.1 | 100 | SSE | 13 | 1016.1 | 20.3 | 93 | SSE | 6 | 1013.6 |
| 14 | 17.6 | 24.4 | 4.4 | ESE | 30 | 13:48 | 20.3 | 97 | SSE | 11 | 1015.5 | 22.4 | 67 | SE | 15 | 1013.6 |
| 15 | 11.6 | 22.6 | 0 | SSE | 22 | 9:32 | 21.3 | 87 | SSE | 9 | 1017.8 | 21.9 | 72 | SSE | 9 | 1015.3 |
| 16 | 9.5 | 25.5 | 0.2 | SE | 22 | 12:09 | 18.4 | 87 | S | 6 | 1018.3 | 24.9 | 32 | E | 9 | 1014.6 |
| 17 | 7.4 | 24.9 | 0 | SSE | 41 | 9:12 | 18.1 | 66 | SSE | 7 | 1018.1 | 23.8 | 38 | ENE | 7 | 1013.9 |
| 18 | 9.6 | 25 | 0 | SE | 28 | 12:18 | 19.8 | 73 | SSE | 9 | 1017.3 | 22.6 | 68 | ESE | 13 | 1014 |
| 19 | 17.2 | 22.2 | 2.4 | NE | 22 | 16:35 | 17.8 | 100 | WNW | 6 | 1016.1 | 20.5 | 99 | SE | 9 | 1011.2 |
| 20 | 15.1 | 25.7 | 10.4 | W | 22 | 12:55 | 17.7 | 100 | SW | 7 | 1012 | 24.9 | 47 | WSW | 7 | 1007.6 |
| 21 | 9.6 | 25.1 | 0.2 | WSW | 22 | 19:08 | 17.9 | 83 | SSW | 4 | 1010.1 | 23.7 | 50 | WNW | 6 | 1006.5 |
| 22 | 8.6 | 24.2 | 0.8 | SE | 20 | 12:10 | 17.5 | 74 | W | 9 | 1010.5 | 22 | 49 | S | 7 | 1007.3 |
| 23 | 7.9 | 25.4 | 0.2 | W | 24 | 14:30 | 17.5 | 82 | SSE | 6 | 1012.4 | 25.1 | 36 | SW | 13 | 1008.4 |
| 24 | 12.1 | 22.9 | 0 | SSE | 46 | 17:00 | 20.4 | 80 | SSE | 15 | 1015.8 | 21.2 | 90 | SE | 20 | 1014.5 |
| 25 | 16.3 | 23.7 | 3.2 | SE | 37 | 10:08 | 21.7 | 76 | SE | 20 | 1019.8 | 22.5 | 62 | SE | 19 | 1017.7 |
| 26 | 16.6 | 22.5 | 1 | SE | 28 | 15:41 | 17.5 | 99 | SSE | 13 | 1020.8 | 21.4 | 77 | SE | 15 | 1017.8 |
| 27 | 15.7 | 22 | 15.4 | E | 26 | 14:13 | 18.4 | 100 | SE | 7 | 1019.5 | 21 | 70 | SE | 15 | 1016.6 |
| 28 | 13.2 | 24.4 | 3.4 | ESE | 24 | 15:00 | 20 | 88 | SSE | 13 | 1019.7 | 22.7 | 65 | ESE | 15 | 1016.5 |
| 29 | 11 | 24.9 | 0 | SE | 22 | 11:17 | 19.2 | 94 | SSE | 9 | 1019.6 | 24.3 | 58 | ESE | 9 | 1017.4 |
| 30 | 11.5 | 24.7 | 0 | E | 28 | 12:23 | 19.1 | 100 | S | 6 | 1021.1 | 23.5 | 71 | ESE | 15 | 1019.2 |
| 31 | 16.7 | 23.9 | 1.6 | E | 41 | 11:53 | 20.8 | 85 | SE | 17 | 1023.7 | 21.3 | 76 | SSE | 17 | 1021.2 |

# APPENDIX D

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# Geodatabase

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## 1. Introduction

A geodatabase is an information database that contains data with a geographical component. It is a collection of feature data for use within a GIS package such as ArcMap or ArcGIS Explorer. ArcMap is contained in ArcGIS and is a proprietary software program developed by Environmental Systems Research Institute, INC (ESRI). ArcGIS Explorer is a free software version of ArcGIS which was developed by ESRI and is used mainly for visualization and presentation purposes. The software program is similar to Google® Earth and can manipulate and render shapefiles. It also allows the user to add points and shapes to the viewer, but creating and editing shapefiles is not possible in this version. The structure of the TS'09 geodatabase allows it to be viewed in both ArcGIS and ArcGIS Explorer. The ArcGIS Explorer version was developed in order to accommodate those users who might want to see the positions and type of data collected but do not have access to ArcGIS. Those with access to ArcGIS and the applications of ArcMap, ArcToolbox, and ArcCatalog will have access to the full capabilities of the geodatabase and be able to create and edit data to suit their individual needs.

The ArcGIS Explorer 900 version is available on the geodatabase drive at the path \ArcGIS_Explorer_Program. To download the program, the Microsoft .NET Framework 2.0 Service Pack 1 must be downloaded first (also included on the geodatabase drive). After installation of the Microsoft .NET update, the ArcGISExplorerDownload.exe file can be executed. The ArcGIS Explorer 900 program can also be downloaded from ESRI's website at the URL: http://www.esri.com/software/arcgis/explorer/download.html.

To view the geodatabases, navigate to either the *.mxd* or *.nmf* file in the VCR_GD folder in Windows Explorer. By opening the *.mxd* file, the ArcMap (ArcGIS) version of the geodatabase is opened. Clicking the *.nmf* file opens the ArcGIS Explorer 900 version.

The following sections describe the information that it is included on the geodatabase drive, and basic access of data in the two GIS versions.

**2. Geodatabase Drive**

Navigating the geodatabase drive through Windows Explorer displays the available folders in the TS'09 geodatabase. Figure 1 displays the folder hierarchy that was designed for the TS'09 database. In the figure, the TS'09 database (TS09_GD) contains seven folders (Attribute Data, GIS Data, Metadata, Misc, Products, TS09_GD.gdb, and User Manual Information) and three files (TS09_ALL Data.xls, TS09_ArcGDBS.mxd, and TS09_GD_Explorer.nmf) at the top level. The Attribute Data folder contains sub-folders of each type of data collected during the TS'09 campaign. Most folders contain tabular data for each day that data were collected. The tabular information is combined into *TS09_ALL_DATA.XLS* with each tab containing different types of data. In the Attribute Data folder, non-tabular data are mainly contained in the folders HyMap and Multimedia. These two folders contain raster images that can be opened via ITT's ENVI and Microsoft® Windows Picture and Fax Viewer, respectively. The GIS Data folder contains the ArcGIS Explorer 900 program and associated files, *KML/KMZ* files used for interoperability with Google® Earth, *mxd* files, raster files, and various shapefiles. The raster files and shapefiles in the GIS Data folder are files which have been gathered from multiple sources or created from the TS09 attribute data. Files residing in these folders are the preliminary shapefiles/rasters which have not been exported into "gdb" file format via ArcCatalog. The Metadata folder contains FGDC documentation about shapefile, raster, and geodatabase creation. The Misc folder contains miscellaneous files. The Products folder contains raster, and text products created from the attribute data. The data report resides in the Text subfolder of the Products folder. The User Manual Information folder contains documentation about retrieving data and navigating the database and geodatabase. When navigating via Windows® Explorer the TS09_GD.gdb (File Geodatabase) appears as a folder, but when navigating via ArcCatalog the TS09_GD.gdb appears as a geodatabase icon. The format of the TS09_GD.gdb is a File Geodatabase.

Viewed below Figure 1, Table 1 presents the attribute data collected during the TS'09 field campaign. This can be used as a guideline for accessing data in the TS'09 geodatabase. Each data type is listed along the left hand side with each day listed across the top. Abbreviations are used to make viewing easier and the abbreviation key is listed in the caption above the table.

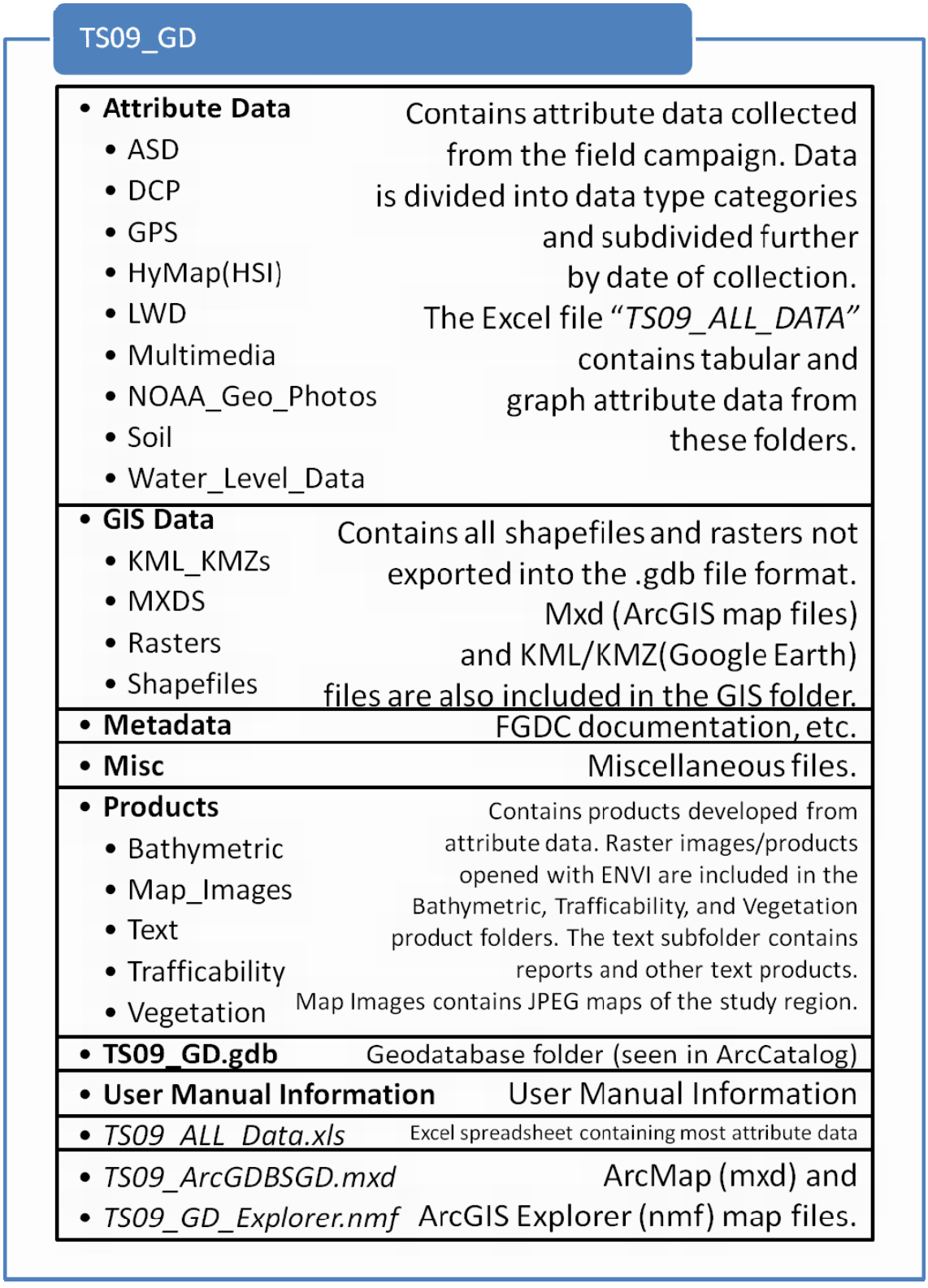



**Figure 1. Typical organization of data on drive.** Top level folders are shown in bold, while sub-folders are shown with non-bold type. Italicized names indicate files. Descriptions of each folder/file are listed on the right hand column.

**Table 1. TS09 Attribute Data Collection Locations:** Abbreviations: CCPB = Cape Clinton Pocket Beach; FWB= Freshwater Beach; SP= Sabina Point; SAE=Southern Arm Estuary; SH= Sam Hill Vicinity;N/A= Not Applicable; NRL1= Unit 1 Camera from NRL; NRL2= Unit 2 Camera from NRL; P= Personal Camera is used.

| Data | | 19 May | 20 May | 21 May | 22 May | 23 May | 25 May | 26 May | 27 May | 28 May | 29 May |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ASD | Site | N/A | FWB | FWB | FWB | SP | N/A | N/A | N/A | CCPB | N/A |
| | Leaf Optics | N/A | N/A | N/A | N/A | N/A | N/A | N/A | SH, FWB (Leaf Collection) | SH | SH |
| | Local Feature/Leaf (In Situ) | N/A | N/A | N/A | FWB | SP | SAE | N/A | N/A | N/A | SH |
| | Calibration Panels | N/A | N/A | Parking Lot @ FWB | Parking Lot @ FWB | N/A | N/A | N/A | N/A | N/A | N/A |
| | Shallow water Bathymetry | N/A | FWB | FWB | FWB | SP | SAE | N/A | N/A | CCPN | N/A |
| DCP | | CCPB | FWB | FWB | FWB | SP | N/A | N/A | N/A | CCPB | N/A |
| Ground Control Points | | SH | N/A | N/A | FWB(Tarps) | N/A | N/A | N/A | N/A | N/A | N/A |
| GPS | Sites | CCPB | FWB | FWB | FWB | SP | N/A | N/A | SH, FWB | CCPB | SH |
| | Soundings | N/A | N/A | N/A | FWB-Bay | SP | SAE | N/A | CCPB, FWB, FWB Bay | CCPB | N/A |
| | Kinematic | CCPB | FWB | FWB | FWB | SP | ? | N/A | N/A | N/A | N/A |
| | Base Station | FWB | FWB | FWB | FWB | SP | FWB | N/A | FWB | N/A | N/A |
| HYMAP | | N/A | N/A | FWB, SP | FWB | FWB | N/A | N/A | N/A | N/A | N/A |
| LWD | | CCPB | FWB | FWB | FWB | SP | N/A | N/A | N/A | FWB | N/A |
| Multimedia-Location, (Camera Used) | | CCPB, (NRL1, P) | FWB, (NRL1, P) | FWB, (NRL1, P) | FWB, (NRL1, NRL2, P) | SP, (NRL2, P) | SAE, (NRL1) | SH, (NRL2, P) | SH, FWB,(NRL1) | CCPB, (NRL1,P); SH, (NRL2) | SH, (NRL2) |
| NOAA_Geotagged Photographs | | FWB | N/A | N/A | N/A | SP | N/A | N/A | N/A | N/A | FWB |
| Soil | | CCPB | FWB | FWB | FWB | SP | N/A | N/A | N/A | CCPB | N/A |
| Tide Buoy | | N/A | FWB | FWB | FWB | SP | SAE | N/A | SAE, CCPB, FWB | CCPB | N/A |

## 3. ArcGIS Explorer Version-Navigation and Data Access

The ArcGIS Explorer version permits the visualization and presentation of data collected during TS'09. Content in this version includes data collected during TS'09 as well as additional data provided by multiple sources. The viewer of ArcGIS Explorer 900 can be seen in Figure 2. The display is similar to ArcMap which has "Tools" along the top, and a "Contents" section which displays the available layers presented in the "Map View" section. The ArcGIS Explorer 900 "Tools" section has similar tabbed navigation as the Microsoft® Office 2007 series.

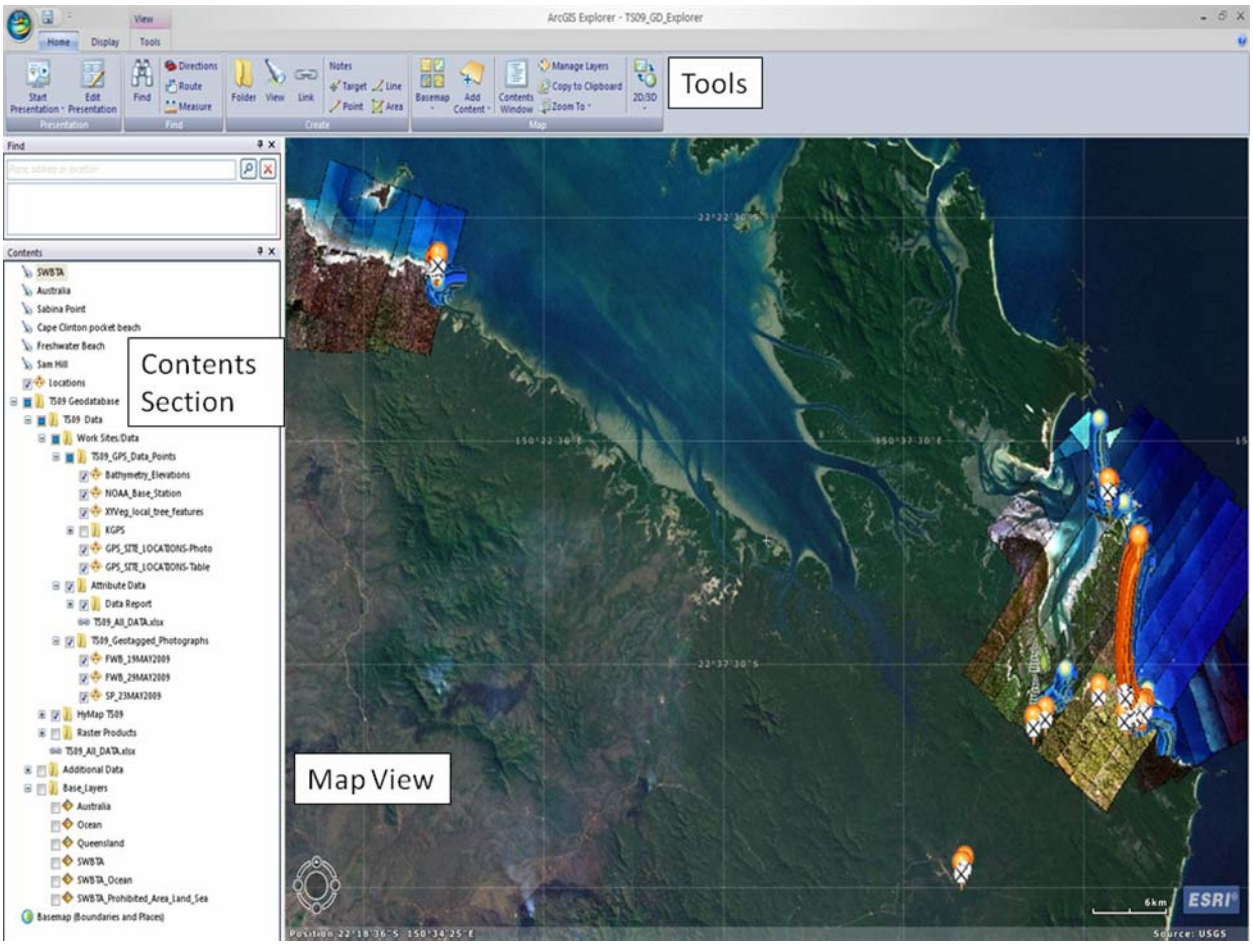



**Figure 2. Sections of ArcGIS Explorer 900.**

Figure 3 displays the items in the contents view of the ArcGIS Explorer version. The data from the TS'09 campaign is divided into three major sections. The "TS09_Data" section contains the data collected at the site by the NRL team and products developed from this data; the "Additional Data" section contains data obtained from multiple sources, all of which may be applicable for TS'09 product development. The "Base Layers" section contains background shapefiles for viewing; this section is especially useful if an internet connection cannot be obtained (ArcGIS Explorer imagery background "basemap" will not be available).

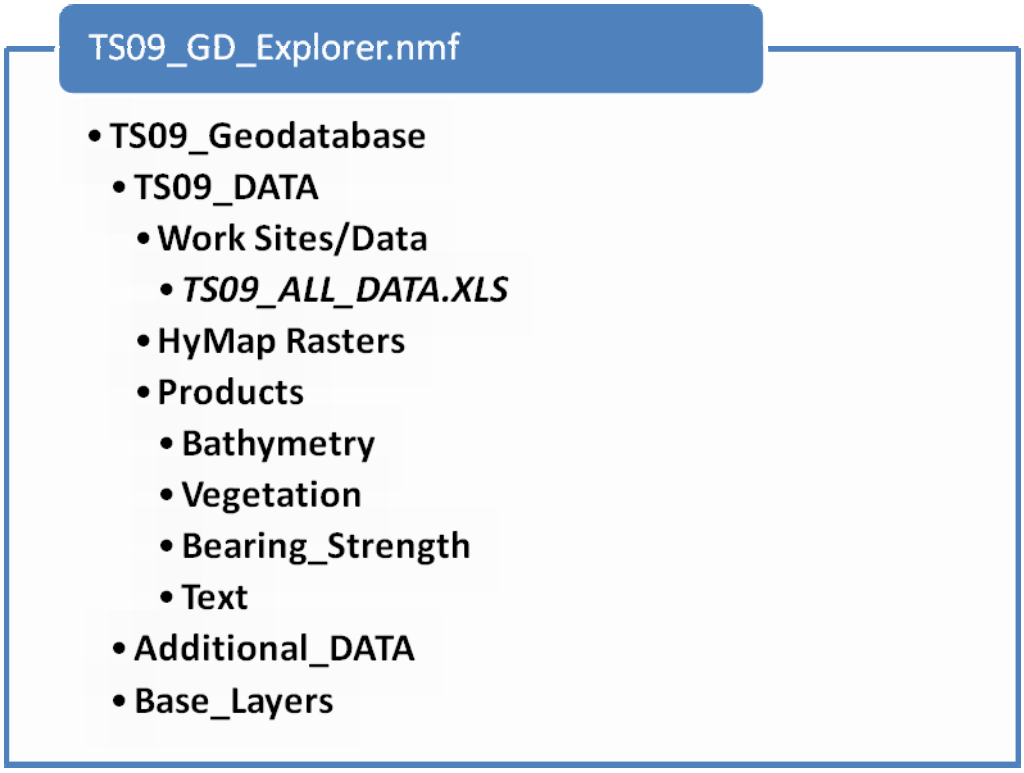



**Figure 3 ArcGIS Explorer geodatabase shapefile groupings.**

Figure 4 displays a screen capture of the TS'09 GPS data and HyMap imagery. In the figure, red dots signify the GPS points where ground data were collected while HyMap imagery is seen as overlapping images from contiguous flight tracks. The types of data can be turned off or on (viewed or not viewed) by checking or unchecking the box in the "Contents" section.

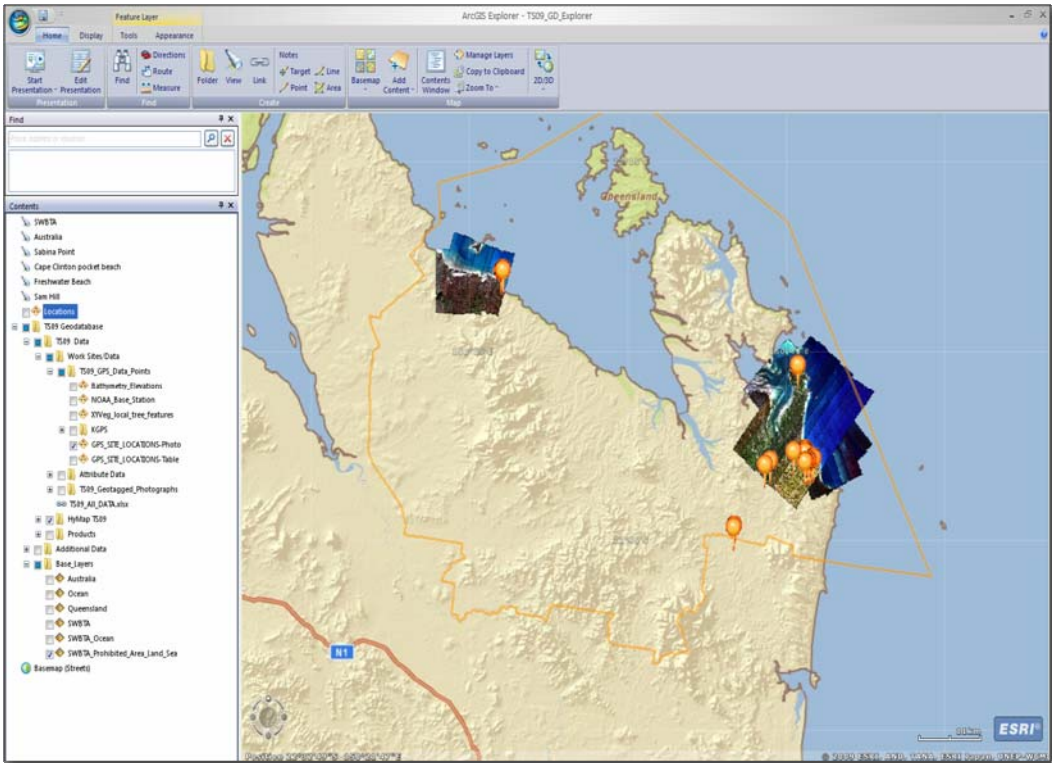



**Figure 4. Screen capture of the TS'09 geodatabase viewed in ArcGIS Explorer 900.** Display of GPS shapefile (red dots) with HyMap imagery displayed overlapping shapefile.

Figure 5 displays four screen captures depicting the access of GPS attribute data collected during the TS'09 campaign. The top left portion of the figure (marked A) shows a screen capture of the Sabina Point region with the GPS_SITE_LOCATIONS-Photo (red dot), GPS_SITE_LOCATIONS-Table (crosshair circle), BATHYMETRY_ELEVATIONS (blue dot) and SP_23_MAY_2009 (green dot) shapefiles being displayed. Clicking on a shapefile point will trigger a pop-up window displaying either tabular information or a photograph. There are two shapefiles that display the GPS_SITE_LOCATIONS points in the viewer and this is done to access a photograph (B in Figure 5) and attribute information (marked C in Figure 5) associated with the point that is clicked. The attribute information shows the site's name, position, time and date, locality, absolute file pathnames/relative pathnames connecting to a photograph of the site, and a link to the attribute data for all sites. One can access attribute data collected during the TS'09 field campaign by clicking the link icon for "TS09_ALL_DATA.XLS" in the contents section of ArcGIS Explorer (marked D in Figure 5).

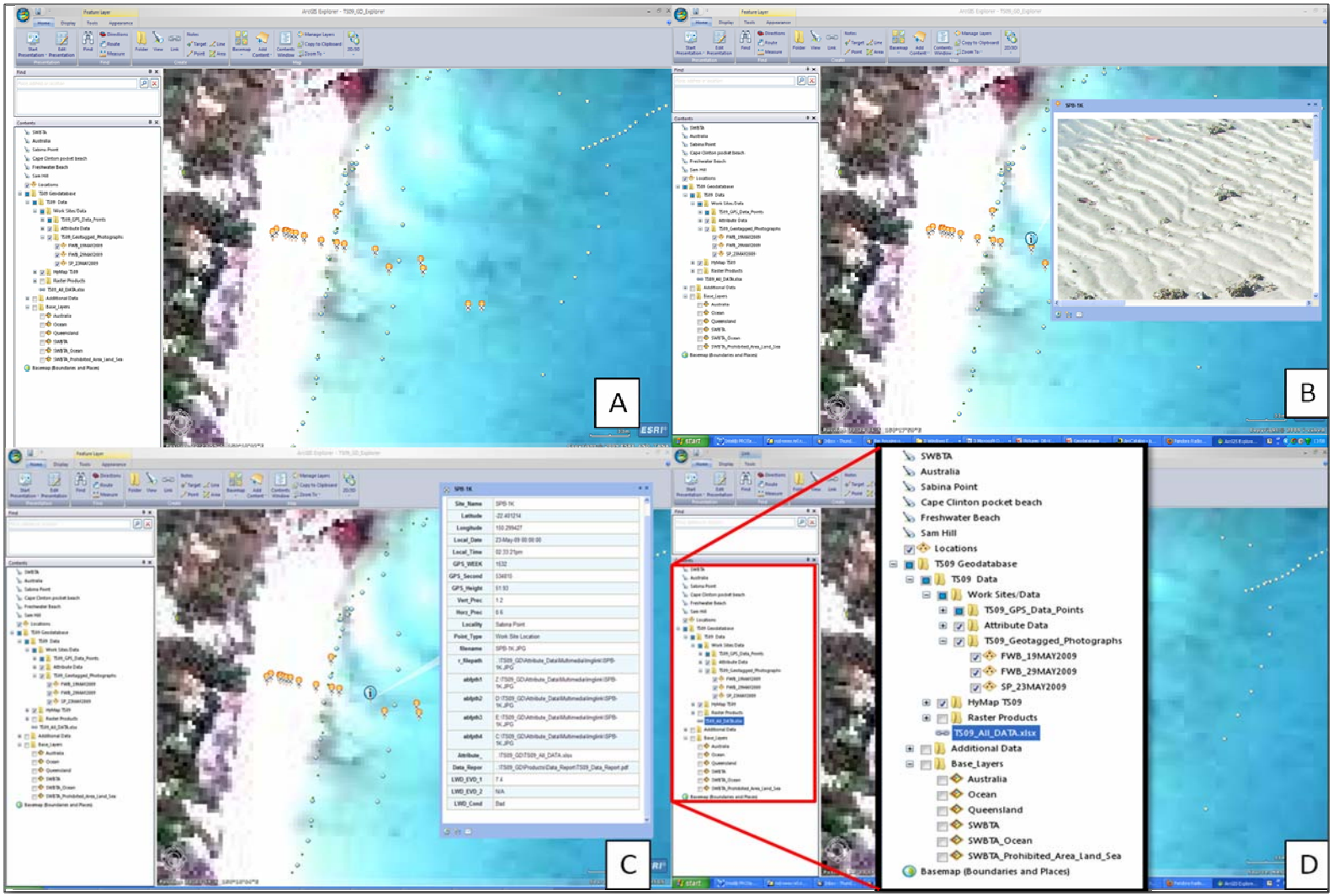



**Figure 5. Data access via ArcGIS Explorer.** (A) Screen capture of Sabina Point area showing various shapefiles and HyMap Imagery (base image). (B) Clicking on GPS point (red dot) opens photo. (C) Clicking on GPS crosshair icon opens tabular attribute information for that point. (D) Clicking on link to "TS09_ALL_DATA.xls" opens that spreadsheet in another window.

## 4. ArcGIS Desktop (ArcView) Version- Navigation and Data Access

The ArcGIS Desktop version allows users to manipulate and edit datasets as well as view the data. Figure 6 displays a screen capture of the ArcMap version of the geodatabase with sections of the ArcMap interface that are labeled. The "Table of Contents" section displays the data available for viewing in the "Map Viewer Section." The "Data Frame" contains all the layers that will be seen in the "Map Viewer." "Layers" represent geographic data, usually grouped in a single theme of shapefiles or rasters. A "shapefile" is a non-topological format for storing the geometric location and attribute information of geographic features and is comprised of the individual components that describe the theme in a "Layer." Shapefiles can represent point, line, or area (polygon) vector files and can be turned off from viewing in the "Map Viewer" by checking the box at the side of the shapefile's name in the "Table of Contents" section. The "Menu Bar" is located at the top of ArcMap and contains drop down menus. The "Tools" toolbar contains basic navigational tools used for navigation in the "Map Viewer." The "ArcToolbox Window" allows the more advanced user to gain access to tools to edit the data.

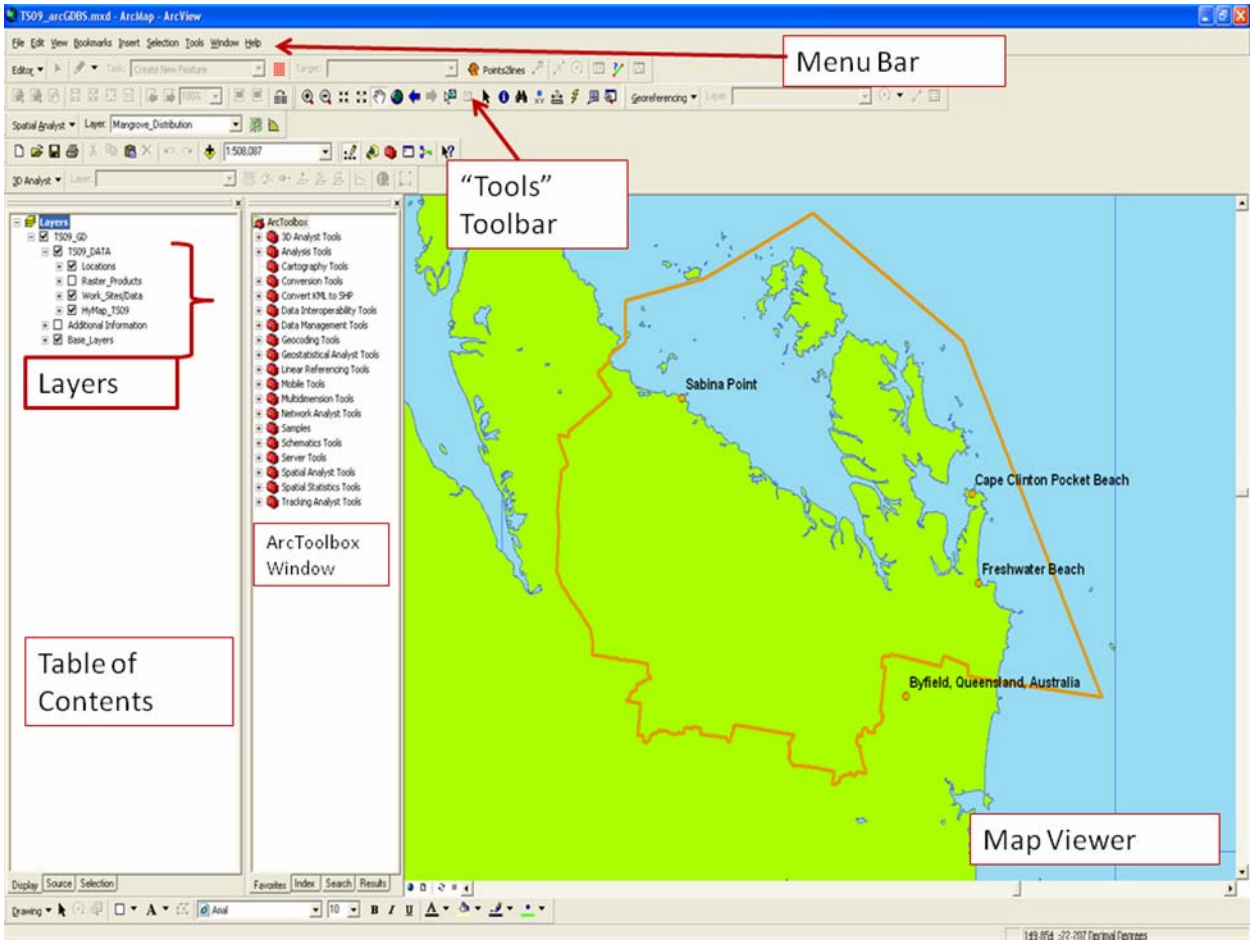



**Figure 6. General sections of ArcMap.**

Figure 7 displays the data groupings seen in the "Table of Contents" section of ArcMap. The data from the TS'09 campaign is broken down into three major sections. The "TS09_Data" section contains the data collected at the site by the NRL team and products developed from this data; the "Additional Data" section contains data obtained from multiple sources that complements the data collected during the TS'09 experiment; and the "Base Layers" section contains background shapefiles for viewing. The ArcMap version is similar to the ArcGIS Explorer version; however, text products and attribute data are not linked in this version as they are in ArcGIS Explorer.

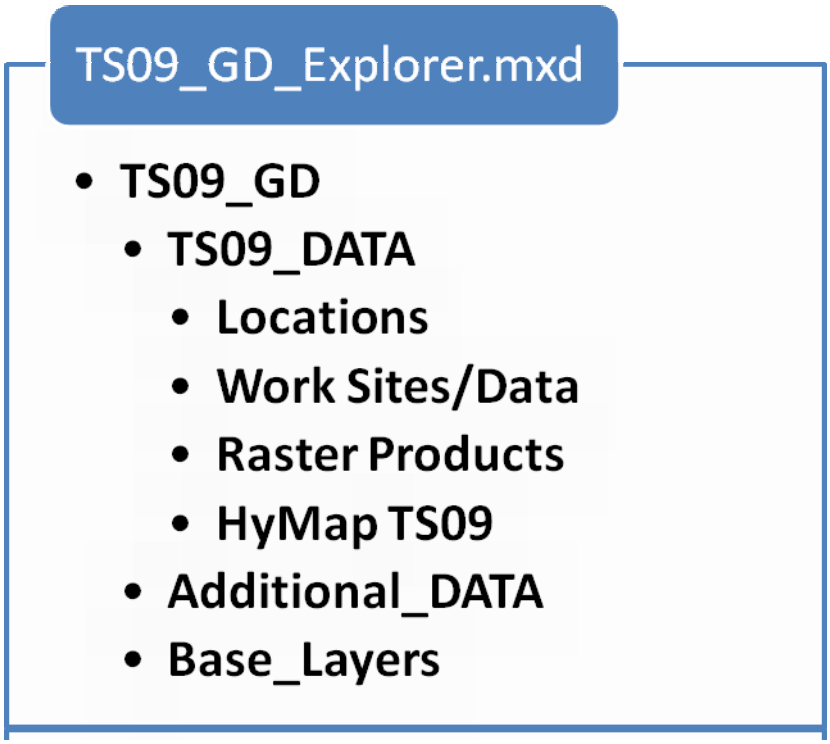



**Figure 7. ArcMap geodatabase data groupings.**

By using the identify feature tool, one can view attribute data of each shapefile. Figure 8 shows various data available when one clicks GPS_SITE_LOCATIONS point shapefile. In the figure, box A shows the pop-up information that appears when one clicks on yellow hyperlink icon for "ab_fpath..."(photograph link). The yellow lightning bolt represents a hyperlink to a URL, photograph, document, or Excel spreadsheet. Box A shows the pop-up of the photograph linked to that work site. When the hyperlink to the data report is clicked, an associated data report from the TS'09 experiment is displayed in another window. Box C displays an Excel spreadsheet which contains all attribute data collected at the site. One can also navigate through Windows ® Explorer to access the attribute data which is hyperlinked above.

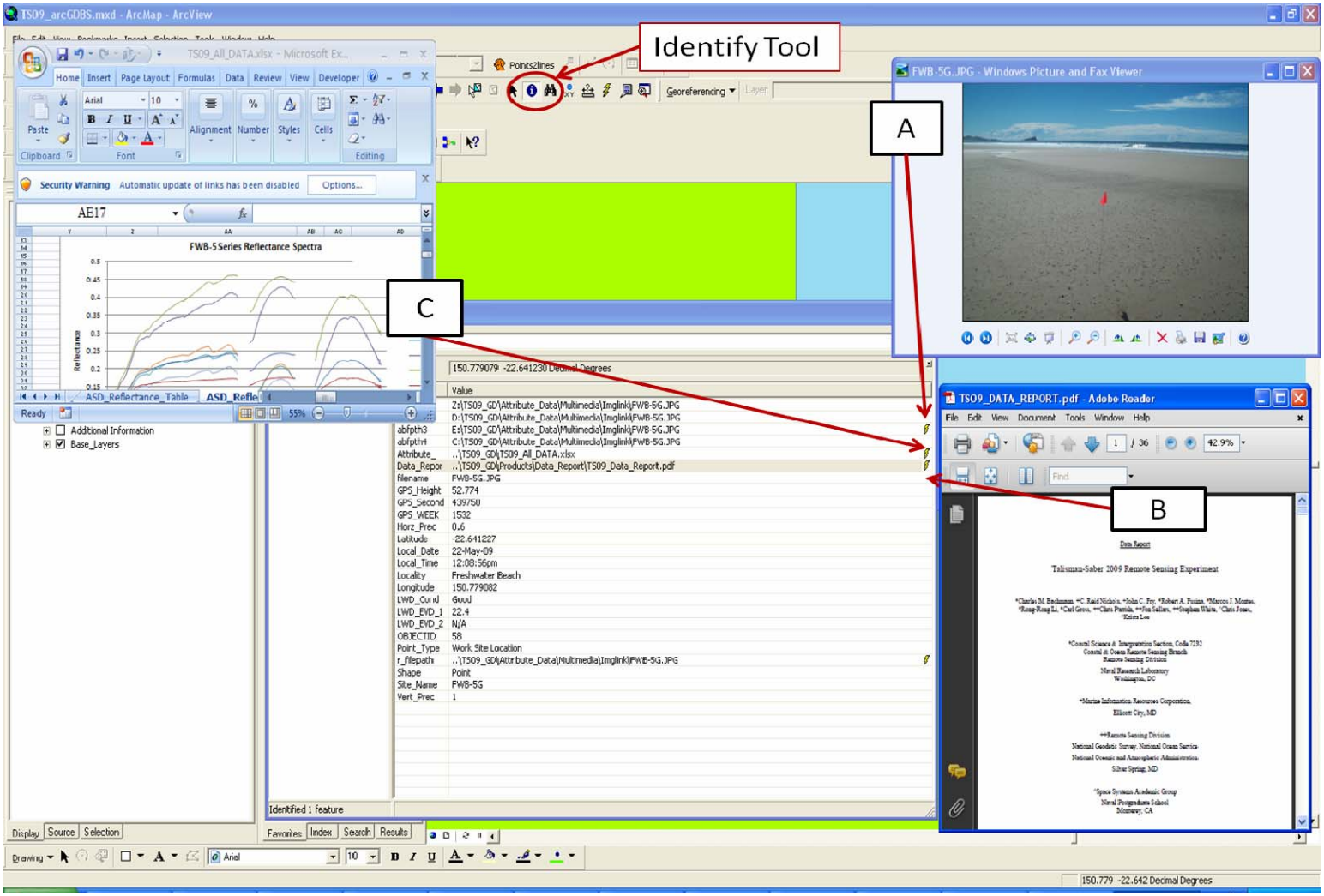



**Figure 8. Using the identify feature tool to access GPS work site attribute data.** (A) Site photograph accessed via hyper-linking; (B) Data Report accessed via hyperlinking; (C) TS09_ALL_DATA.xls file (Attribute data collected during campaign).

# APPENDIX E

## Spectra

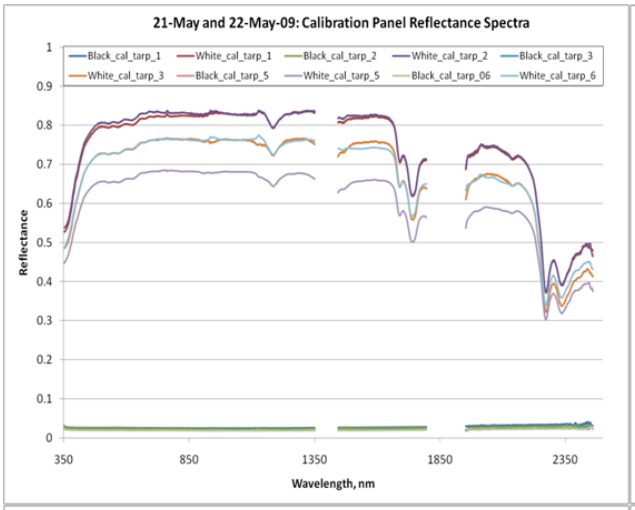
## 1. Introduction

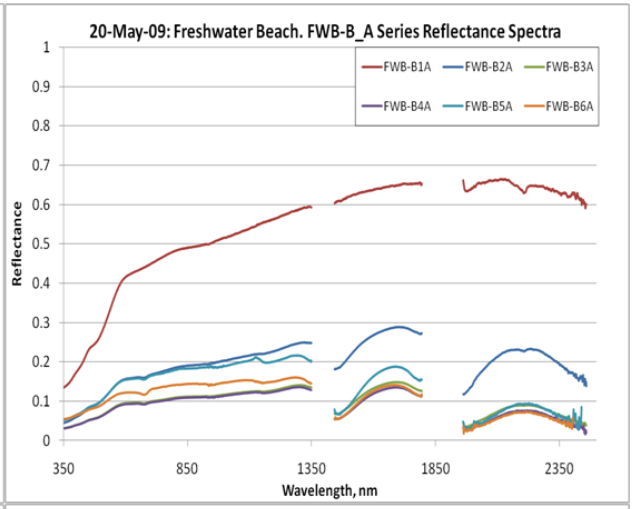
*In situ* spectral reflectance data were measured with four Analytical Spectral Devices (ASD) portable field spectrometers covering the spectral range from 0.35 to 2.5 μm. Spectra measured with the ASD spectrometers in the field used passive solar illumination and a fiber-optic probe to collect light. The solar zenith incidence angle was variable but typically ranged from 40 to 60 degrees. Spectra were corrected to absolute reflectance by comparison against a Spectralon white reference standard. Field spectra have been collected under various sky conditions. Most were collected under optimum conditions of clear skies and within the range of solar zenith angles listed above. Because of limited time for field work, some spectra were collected under partly cloudy skies and less than optimal solar zenith angles. On days with variable cloud conditions, a dual spectrometer method was employed which allowed simultaneous recording of the white reference and the specimen of interest. The spectra were edited to eliminate spectral regions with very high atmospheric water vapor absorption; these regions have low digital number counts and ratios between the spectral response of the white plaque and the specimen are often unstable in these spectral regions. The regions of editing were roughly from 1.35 μm to 1.44 μm, 1.79 μm to 1.95 μm and 2.45 μm to 2.5 μm. Data from cloudy days using the dual spectrometer method revealed a slight spectral miscalibration between the pairs of spectrometers used. Data in our NRL cal facility has been taken subsequently to determine the spectral shift, and data collected in the field simultaneously from white reference plaques by the two spectrometers were used to generate a transfer function and correct for the small relative shift between the two spectrometers when dual mode data collection was necessary to due to sub-optimal sky conditions.

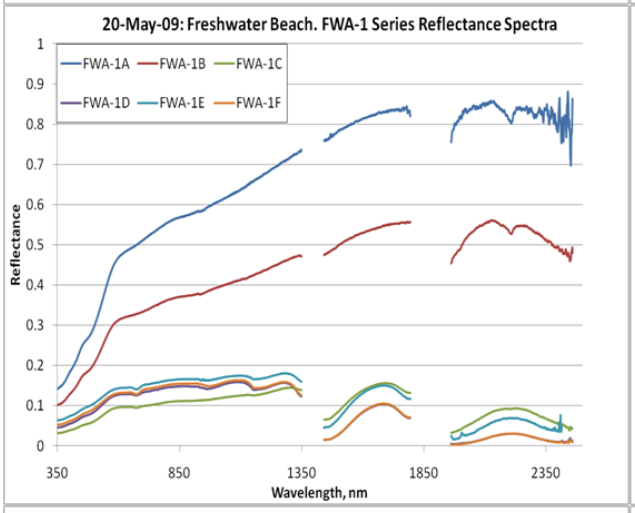
Spectra measured in the lab using the leaf optic apparatus used a light source internal to a contact probe. The contact probe is an accessory for the FieldSpec spectrometer, designed for sampling a small area using only internal illumination from a light source in the contact probe. The leaf optic apparatus is another extension to the ASD FieldSpec.

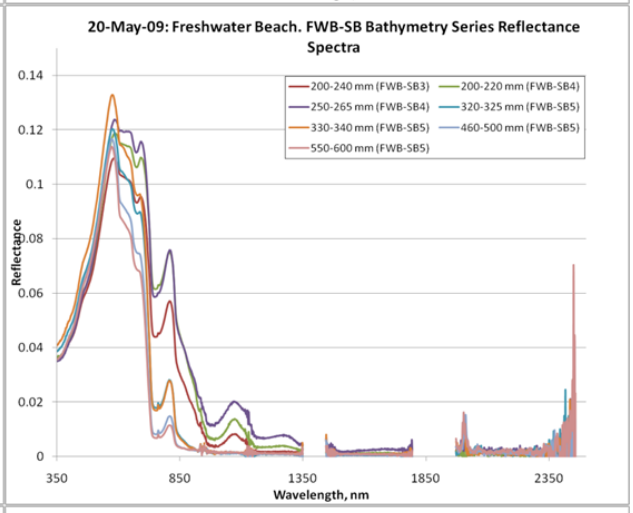
The digital spectral library data is a component of the geodatabase. In the following sections, reflectance spectra, site photographs, and comments about the spectral data are displayed. Reflectance spectra are viewed in Section 2 and are listed in chronological order with the exception of the graph for the calibration panels which is listed first. In the graphs, the *x*-axis displays the wavelength (in nm) and the *y*-axis displays the reflectance value. Photographs of the locations where spectra were collected are presented in Section 3. These photographs are listed in chronological order. The field notes associated with spectral data collection are listed in Section 4, and these appear in chronological order.

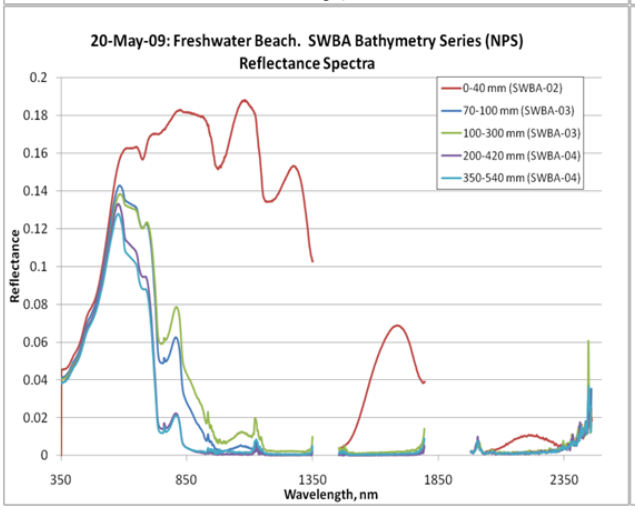
## 2. Reflectance Spectra

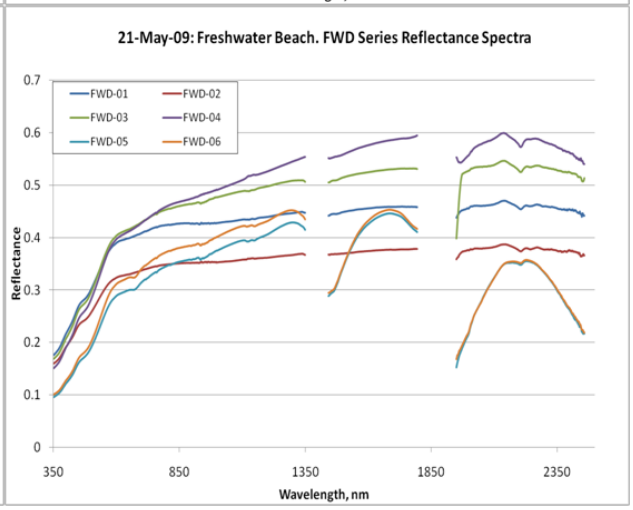


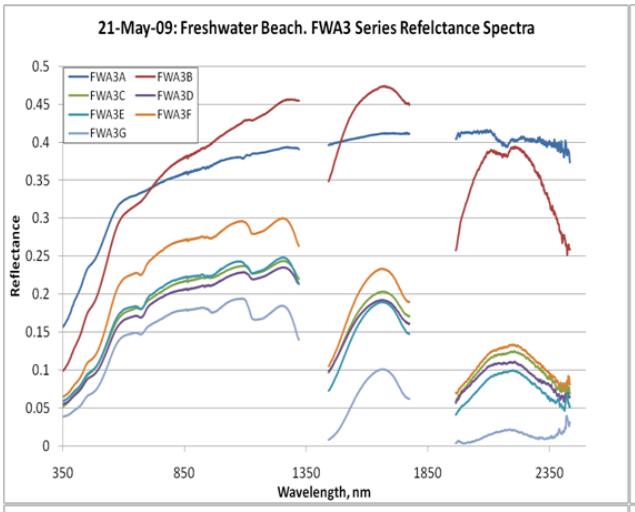



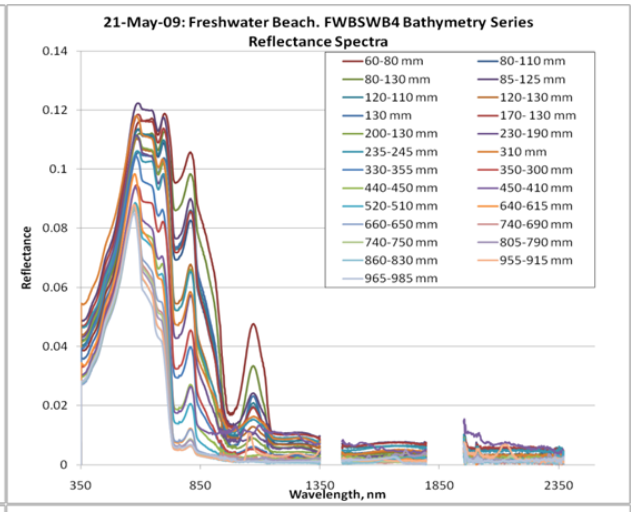



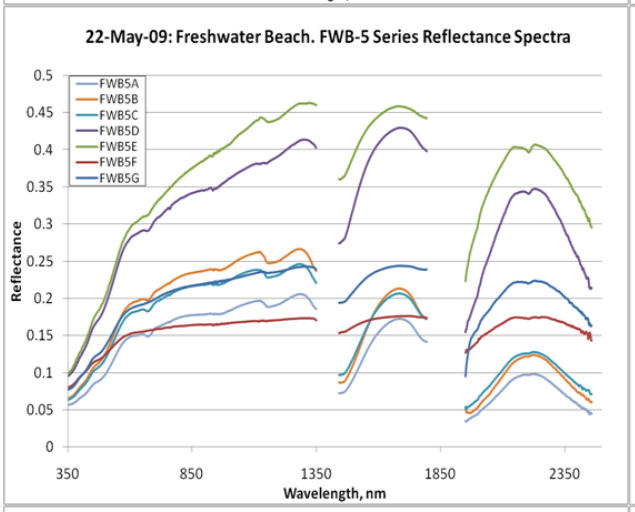



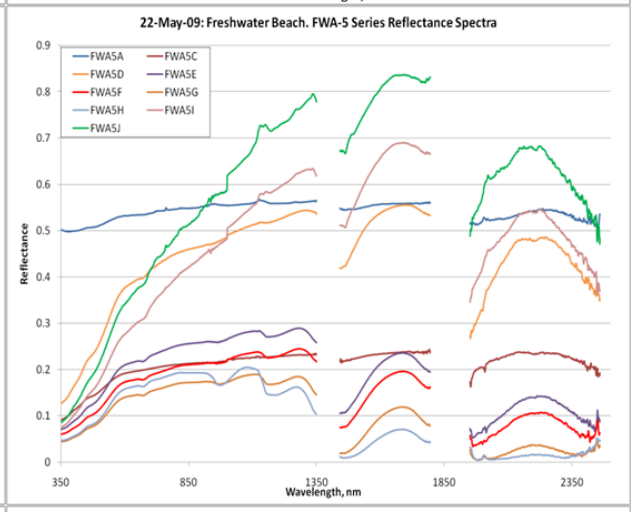



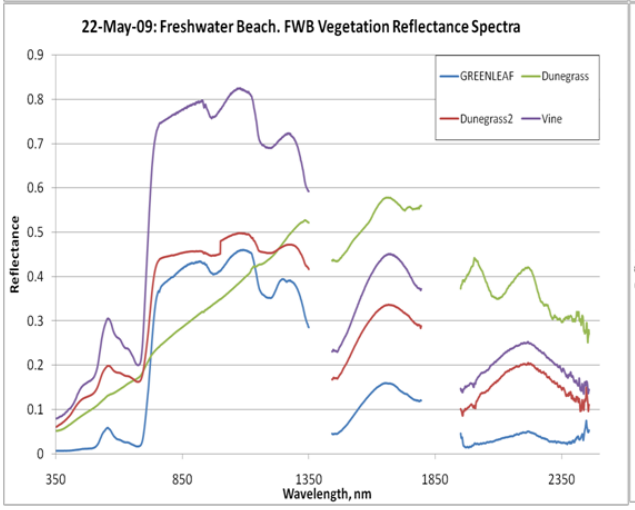



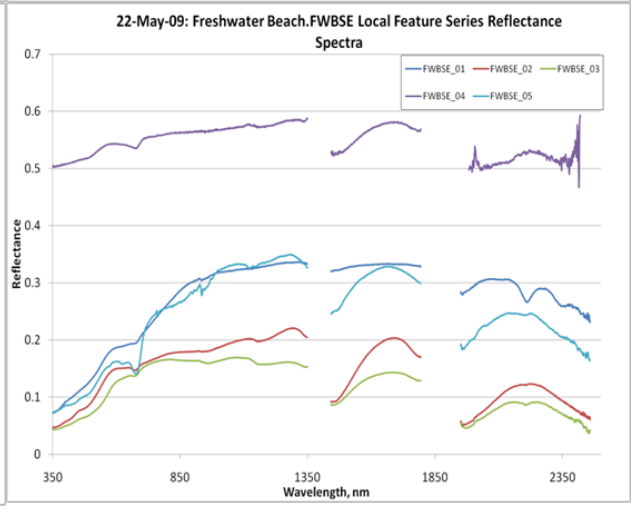

21-May-09: Freshwater Beach. FWA3 Series Refelctance Spectra
FWA3A
FWA3B
FWA3C
FWA3D
FWA3E
FWA3F
FWA3G
Reflectance
Wavelength, nm

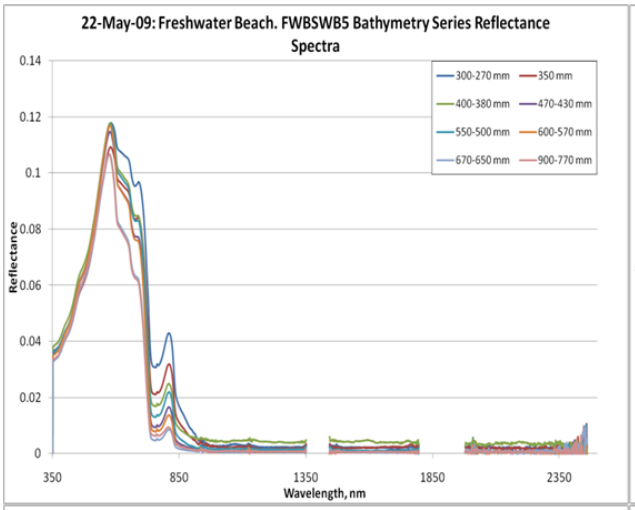

21-May-09: Freshwater Beach. FWBSWB4 Bathymetry Series Reflectance Spectra
60-80 mm
80-110 mm
80-130 mm
85-125 mm
120-110 mm
120-130 mm
130 mm
170- 130 mm
200-130 mm
230-190 mm
235-245 mm
310 mm
330-355 mm
350-300 mm
440-450 mm
450-410 mm
520-510 mm
640-615 mm
660-650 mm
740-690 mm
740-750 mm
805-790 mm
860-830 mm
955-915 mm
965-985 mm
Reflectance
Wavelength, nm

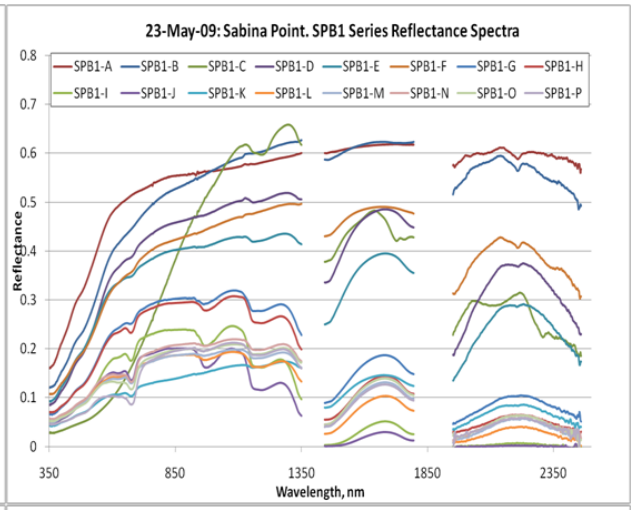

22-May-09: Freshwater Beach. FWB-5 Series Reflectance Spectra
FWB5A
FWB5B
FWB5C
FWB5D
FWB5E
FWB5F
FWB5G
Reflectance
Wavelength, nm

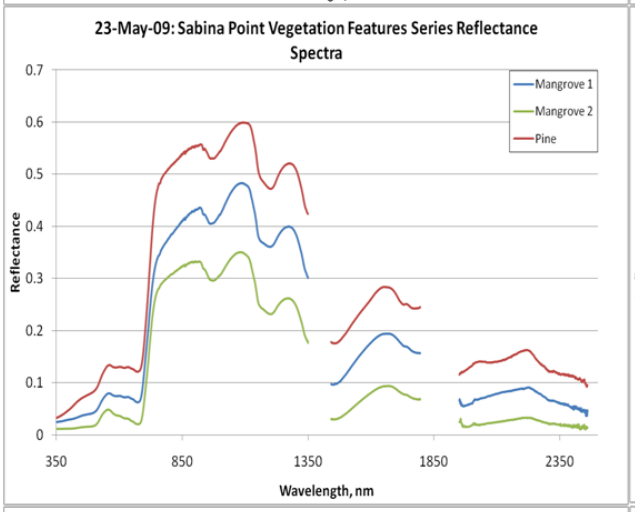

22-May-09: Freshwater Beach. FWA-5 Series Reflectance Spectra
FWA5A
FWA5C
FWA5D
FWA5E
FWA5F
FWA5G
FWA5H
FWA5I
FWA5J
Reflectance
Wavelength, nm

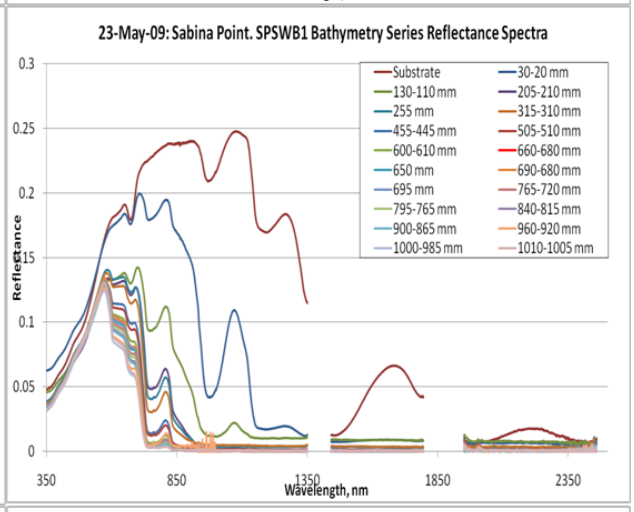

22-May-09: Freshwater Beach. FWB Vegetation Reflectance Spectra
GREENLEAF
Dunegrass
Dunegrass2
Vine
Reflectance
Wavelength, nm

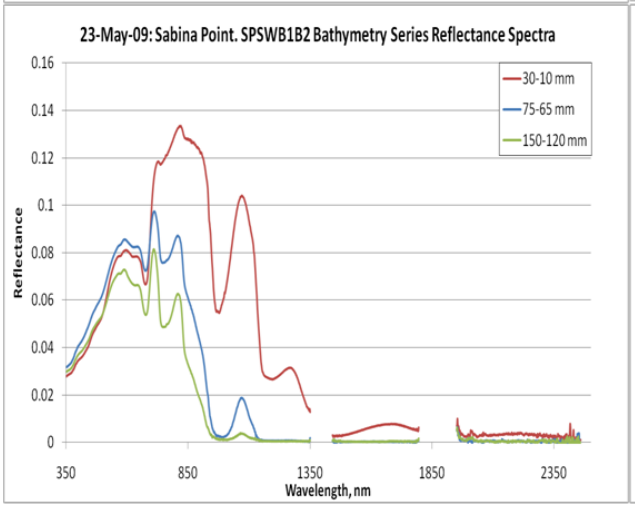

22-May-09: Freshwater Beach.FWBSE Local Feature Series Reflectance Spectra
FWBSE_01
FWBSE_02
FWBSE_03
FWBSE_04
FWBSE_05
Reflectance
Wavelength, nm

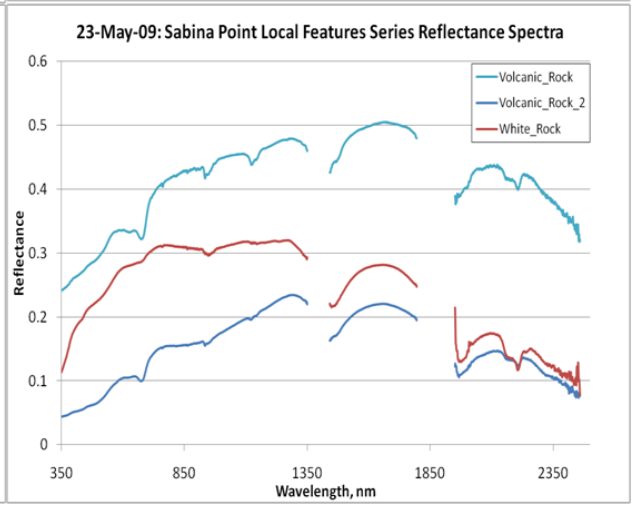

22-May-09: Freshwater Beach. FWBSWB5 Bathymetry Series Reflectance Spectra
300-270 mm
350 mm
400-380 mm
470-430 mm
550-500 mm
600-570 mm
670-650 mm
900-770 mm
Reflectance
Wavelength, nm

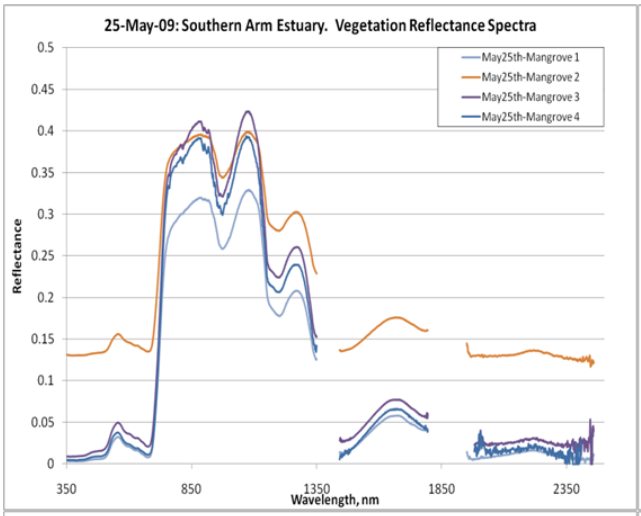

23-May-09: Sabina Point. SPB1 Series Reflectance Spectra
SPB1-A
SPB1-B
SPB1-C
SPB1-D
SPB1-E
SPB1-F
SPB1-G
SPB1-H
SPB1-I
SPB1-J
SPB1-K
SPB1-L
SPB1-M
SPB1-N
SPB1-O
SPB1-P
Reflectance
Wavelength, nm

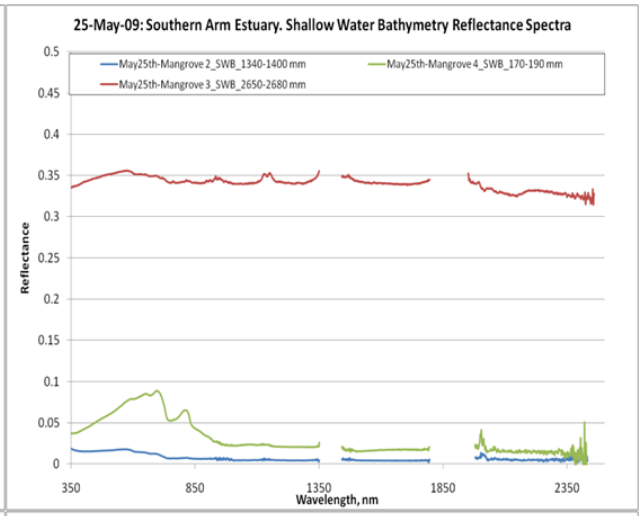

23-May-09: Sabina Point Vegetation Features Series Reflectance Spectra
Mangrove 1
Mangrove 2
Pine
Reflectance
Wavelength, nm

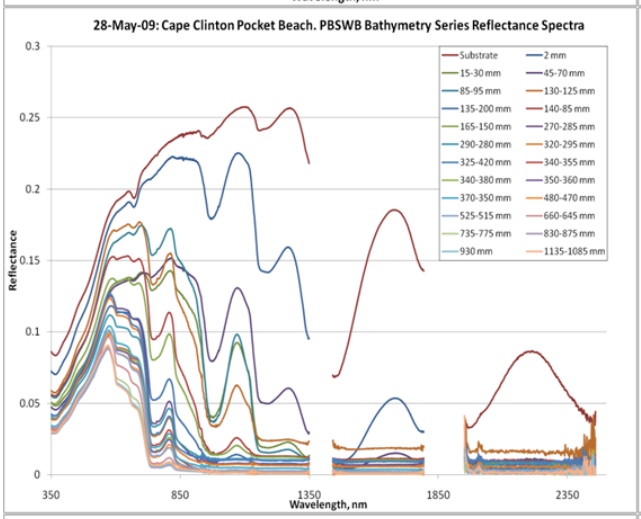

23-May-09: Sabina Point. SPSWB1 Bathymetry Series Reflectance Spectra
Substrate
30-20 mm
130-110 mm
205-210 mm
255 mm
315-310 mm
455-445 mm
505-510 mm
600-610 mm
660-680 mm
650 mm
690-680 mm
695 mm
765-720 mm
795-765 mm
840-815 mm
900-865 mm
960-920 mm
1000-985 mm
1010-1005 mm
Reflectance
Wavelength, nm

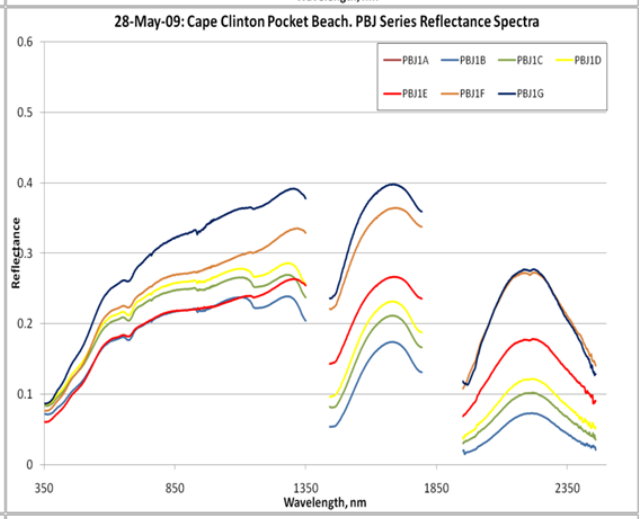

23-May-09: Sabina Point. SPSWB1B2 Bathymetry Series Reflectance Spectra
30-10 mm
75-65 mm
150-120 mm
Reflectance
Wavelength, nm

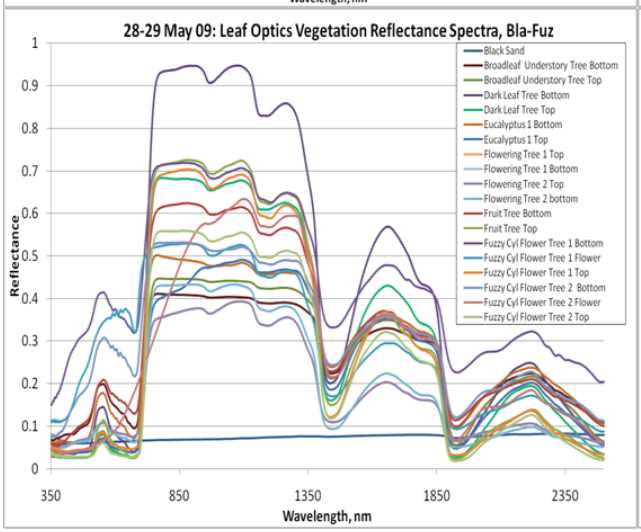

23-May-09: Sabina Point Local Features Series Reflectance Spectra
Volcanic_Rock
Volcanic_Rock_2
White_Rock
Reflectance
Wavelength, nm

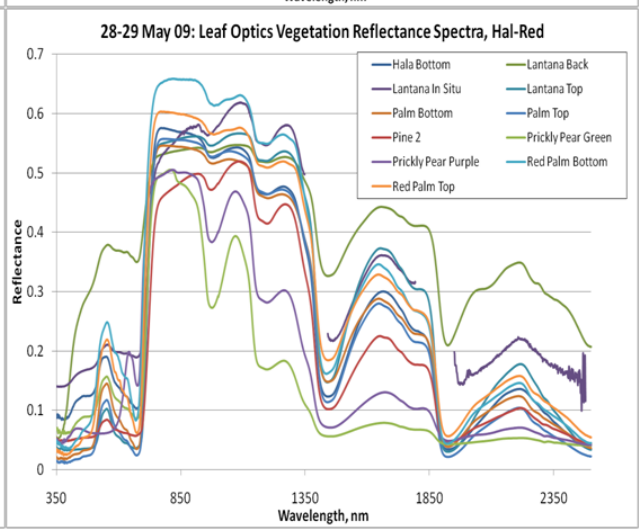

25-May-09: Southern Arm Estuary. Vegetation Reflectance Spectra
May25th-Mangrove 1
May25th-Mangrove 2
May25th-Mangrove 3
May25th-Mangrove 4
Reflectance
Wavelength, nm

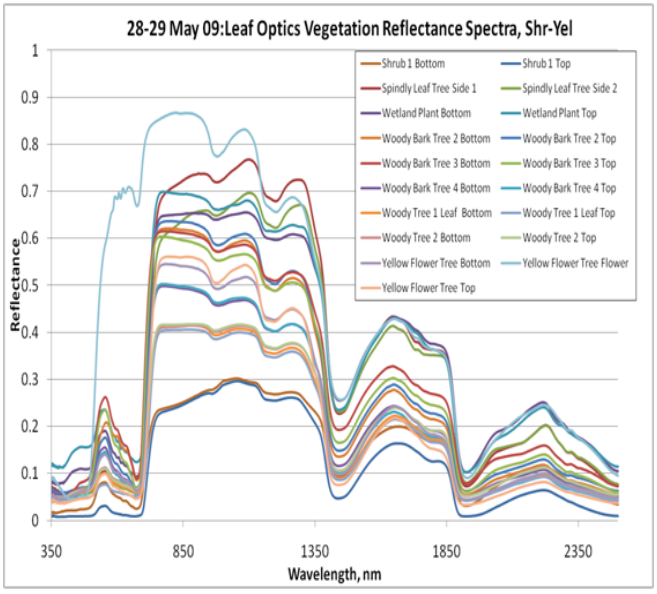

25-May-09: Southern Arm Estuary. Shallow Water Bathymetry Reflectance Spectra
May25th-Mangrove 2_SWB_1340-1400 mm
May25th-Mangrove 4_SWB_170-190 mm
May25th-Mangrove 3_SWB_2650-2680 mm
Reflectance
Wavelength, nm


28-May-09: Cape Clinton Pocket Beach. PBSWB Bathymetry Series Reflectance Spectra
Substrate
2 mm
15-30 mm
45-70 mm
85-95 mm
130-125 mm
135-200 mm
140-85 mm
165-150 mm
270-285 mm
290-280 mm
320-295 mm
325-420 mm
340-355 mm
340-380 mm
350-360 mm
370-350 mm
480-470 mm
525-515 mm
660-645 mm
735-775 mm
830-875 mm
930 mm
1135-1085 mm
Reflectance
Wavelength, nm


28-May-09: Cape Clinton Pocket Beach. PBJ Series Reflectance Spectra
PBJ1A
PBJ1B
PBJ1C
PBJ1D
PBJ1E
PBJ1F
PBJ1G
Reflectance
Wavelength, nm


28-29 May 09: Leaf Optics Vegetation Reflectance Spectra, Bla-Fuz
Black Sand
Broadleaf Understory Tree Bottom
Broadleaf Understory Tree Top
Dark Leaf Tree Bottom
Dark Leaf Tree Top
Eucalyptus 1 Bottom
Eucalyptus 1 Top
Flowering Tree 1 Top
Flowering Tree 1 Bottom
Flowering Tree 2 Top
Flowering Tree 2 bottom
Fruit Tree Bottom
Fruit Tree Top
Fuzzy Cyl Flower Tree 1 Bottom
Fuzzy Cyl Flower Tree 1 Flower
Fuzzy Cyl Flower Tree 1 Top
Fuzzy Cyl Flower Tree 2 Bottom
Fuzzy Cyl Flower Tree 2 Flower
Fuzzy Cyl Flower Tree 2 Top
Reflectance
Wavelength, nm


28-29 May 09: Leaf Optics Vegetation Reflectance Spectra, Hal-Red
Hala Bottom
Lantana Back
Lantana In Situ
Lantana Top
Palm Bottom
Palm Top
Pine 2
Prickly Pear Green
Prickly Pear Purple
Red Palm Bottom
Red Palm Top
Reflectance
Wavelength, nm


28-29 May 09:Leaf Optics Vegetation Reflectance Spectra, Shr-Yel
Reflectance
Wavelength, nm
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
350
850
1350
1850
2350
Shrub 1 Bottom
Shrub 1 Top
Spindly Leaf Tree Side 1
Spindly Leaf Tree Side 2
Wetland Plant Bottom
Wetland Plant Top
Woody Bark Tree 2 Bottom
Woody Bark Tree 2 Top
Woody Bark Tree 3 Bottom
Woody Bark Tree 3 Top
Woody Bark Tree 4 Bottom
Woody Bark Tree 4 Top
Woody Tree 1 Leaf Bottom
Woody Tree 1 Leaf Top
Woody Tree 2 Bottom
Woody Tree 2 Top
Yellow Flower Tree Bottom
Yellow Flower Tree Flower
Yellow Flower Tree Top

## 3. Site Photographs

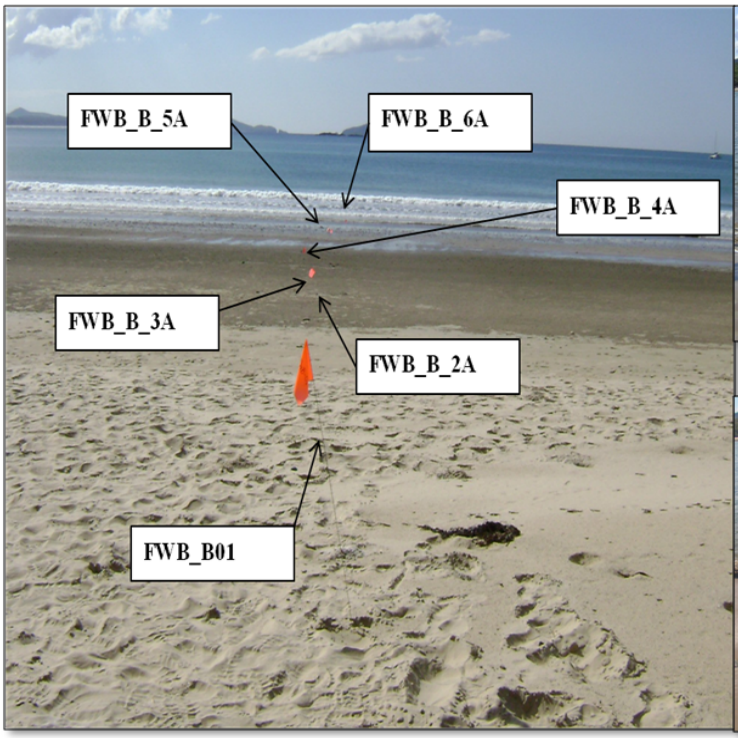
### 3.1. Freshwater Beach:20 May 2009



FWA-1A FWA-1B FWA-1C



FWA-1D FWA-1E FWA-1F




FWB_B Series



FWB-SB Series



SWBA Series

### 3.2 Freshwater Beach: 21 May 2009



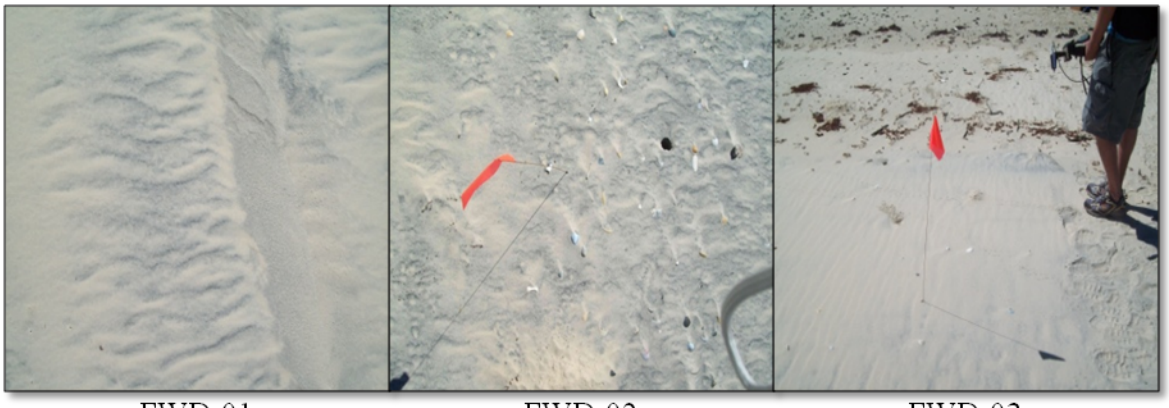
FWA-3A FWA-3B FWA-3C



FWA-3D FWA-3E FWA-3F



FWA-3G



FWD-01 FWD-02 FWD-03

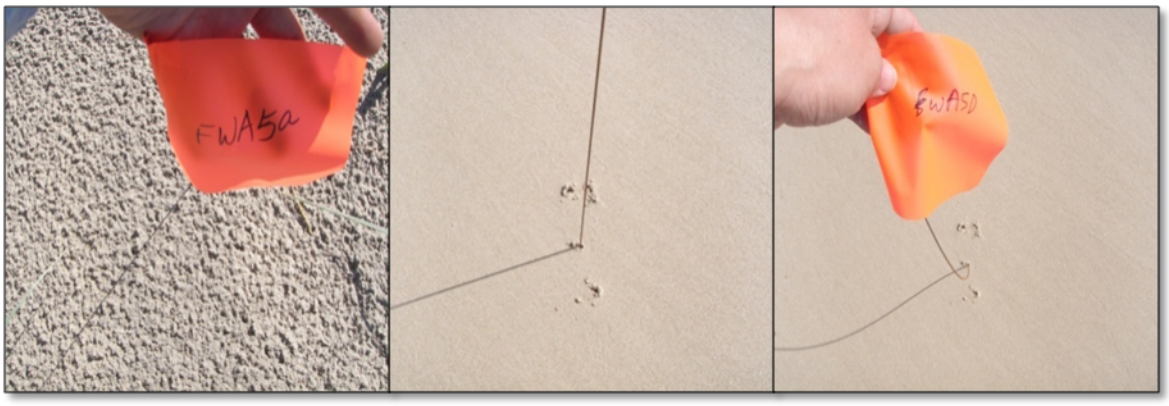


FWD-04 FWD-05 FWD-06



FWBSWB4 Series FWBSWB4 Series

### 3.3 Freshwater Beach: 22 May 2009




FWA5A FWA5C FWA5D



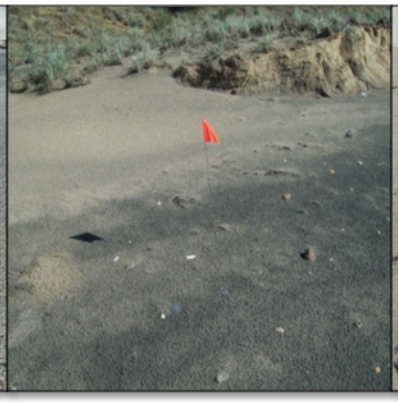

FWA5E FWA5F FWA5G




FWA5H FWA5I FWA5J



FWB5A



FWB5B



FWB5C



FWB5D



FWB5E



FWB5F



FWB5G



Dune grass 1



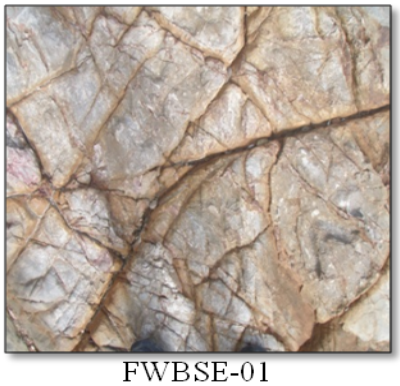
Dune grass 2



Greenleaf



Vine



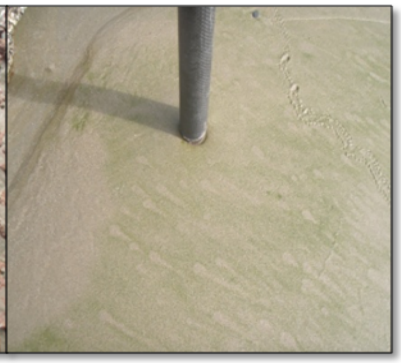
FWBSE-01



FWBSE-02



FWB-SE-03



FWB-SE-04



FWB-SE-05



FWBSWB5

### 3.4. Sabina Point: 23 May 2009



SPB1-A SPB1-B SPB1-C



SPB1-D SPB1-E SPB1-F



SPB1-G SPB1-H SPB1-I



SPB1-J SPB1-K SPB1-L



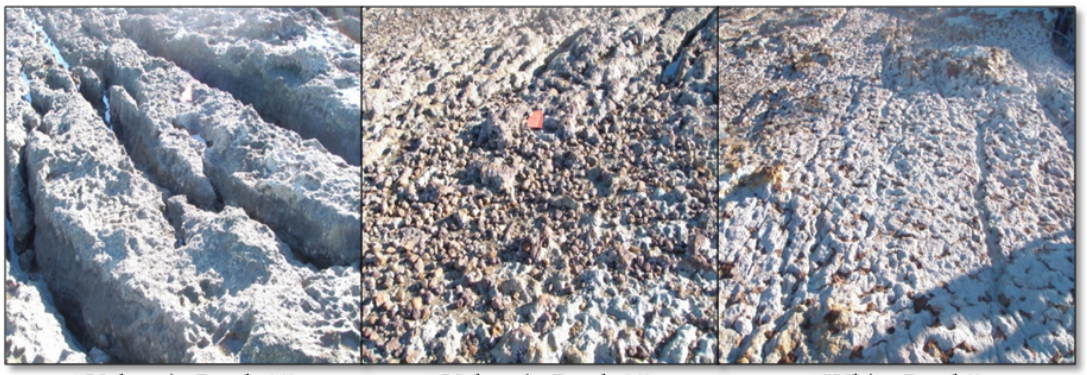
SPB1-M SPB1-N SPB1-O



SPB1-P Mangrove 1 Mangrove 2



Pine SPSWB1 SPSWB2



"Volcanic Rock 1" "Volcanic Rock 2" "White Rock"

### 3.5. Southern Arm Estuary: 25 May 2009



Mangrove 1 Mangrove 2 Mangrove 3



Mangrove 4



Mangrove 2:
SWB 1340-1400 mm

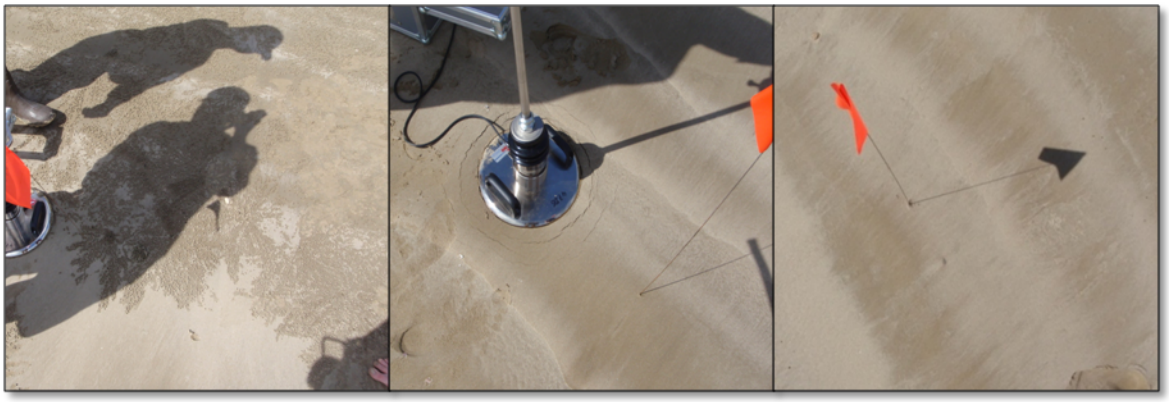
Mangrove 3 :
SWB 2650-2850 mm

Mangrove 4 :
SWB 170-190 mm

### 3.6. Cape Clinton Pocket Beach: 28 May 2009



PBJ1A PBJ1B PBJ1C



PBJ1D PBJ1E PBJ1F



PBJ1G PBSWB Series PBSWB Series

### 3.7. Leaf Optic Spectra: 28-29 May 2009



Black Sand | Broadleaf Understory Tree | Dark Leaf Tree



Dark Leaf Tree Site | Eucalyptus-1 | Eucalyptus-1 Site



Flowering Tree | Flowering Tree Site | Flowering Tree 2



Flowering Tree 2 Site | Fruit Tree | Fruit Tree Site



Fuzzy Cylindrical 1
(*Banksia*)



Fuzzy Cylindrical 1
(*Banksia*)



Fuzzy Cylindrical 2



Fuzzy Cylindrical 2



Hala



Hala Site



Lantana



Lantana Site



Palm 1



Palm 1 Site



Pine-2



Pine 2 Site



Prickly Pear | Prickly Pear Site | Red Palm



Red Palm Site | Shrub 1 | Shrub 1 Site



Spindly Leaf | Spindly Leaf Site | Wetland Plant



Wetland Plant Site | Woody Bark 2 | Woody Bark 2 Site




Woody Bark 3



Woody Bark 3 Site



Woody Bark 4



Woody Bark 4 Site



Woody Tree 1



Woody Tree 1 Site



Woody Tree 2



Woody Tree 2 Site




Yellow Flower 1 (Acacia)



Yellow Flower 1 (Acacia) Site

## 4. Spectra Comments

### 4.1. Freshwater Beach: 21-22 May 2009- Calibration Panels

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| White_cal_tarp_01 (Calpanel01) | 920 | 21-May-09 | White calibration panel | NRL OLD | B | Single | Good | N/A | Calibration Panel |
| Black_cal_tarp_01 (Calpanel01) | 935 | 21-May-09 | Black calibration panel | NRL OLD | B | Single | Good | N/A | Calibration Panel |
| White_cal_tarp_02 (Calpanel02) | 940 | 21-May-09 | White calibration panel | NRL OLD | B | Single | Good | N/A | Calibration Panel |
| Black_cal_tarp_02 (Calpanel02) | 1015 | 21-May-09 | Black calibration panel | NRL OLD | B | Single | Good | N/A | Calibration Panel |
| White_cal_tarp_03 (Calpanel03) | 1220 | 21-May-09 | White calibration panel | NRL OLD | B | Single | Good | N/A | Calibration Panel |
| Black_cal_tarp_03 (Calpanel03) | 1235 | 21-May-09 | Black calibration panel | NRL OLD | B | Single | Good | N/A | Calibration Panel |
| White_cal_tarp_04 (Calpanel04) | 1240 | 21-May-09 | White calibration panel | NRL OLD | B | Single | Cloud intrusion spectra not taken. | N/A | Calibration Panel |
| black_cal_tarp_05 | 925 | 22-May-09 | Black calibration panel | NRL OLD | B | Single | NR | N/A | Calibration Panel |
| white_cal_tarp_05 | 857 | 22-May-09 | White calibration panel | NRL OLD | B | Single | NR | N/A | Calibration Panel |
| black_cal_tarp_06 | 1020 | 22-May-09 | Black calibration panel | NRL OLD | B | Single | NR | N/A | Calibration Panel |
| white_cal_tarp_06 | 935 | 22-May-09 | White calibration panel | NRL OLD | B | Single | NR | N/A | Calibration Panel |

## 4.2. Freshwater Beach: 20 May 2009

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| FWA-1A | 1107 | 20-May-09 | Sand | NPS | B | Dual | Mostly sunny | Falling tide | Site |
| FWA-1B | 1110 | 20-May-09 | Medium grained sand | NPS | B | Dual | Mostly sunny | Falling tide | Site |
| FWA-1C | 1120 | 20-May-09 | Hard sand and crab spheroids | NPS | B | Dual | Mostly sunny | Falling tide | Site |
| FWA-1D | 1248 | 20-May-09 | Wet hard sand | NPS | B | Dual | Mostly sunny | Falling tide | Site |
| FWA-1E | 1240 | 20-May-09 | Rocky hard wet sand | NPS | B | Dual | Partly cloudy | Low tide | Site |
| FWA-1F | 1227 | 20-May-09 | Wet sand | NPS | B | Dual | Partly cloudy | Low tide | Site |
| FWB-B1A | 1029 | 20-May-09 | Sandy beach | NRL NEW | A | Dual | Partly cloudy | Falling | Site |
| FWB-B2A | 1231 | 20-May-09 | Beach | NRL NEW | A | Dual | Partly cloudy | Falling, near low water | Site |
| FWB-B3A | 1251 | 20-May-09 | Beach | NRL NEW | A | Dual | Partly cloudy | Low water | Site |
| FWB-B4A | 1259 | 20-May-09 | Beach | NRL NEW | A | Dual | Partly cloudy | Low water | Site |
| FWB-B5A | 1302 | 20-May-09 | Beach | NRL NEW | A | Dual | Partly cloudy | Low water | Site |
| FWB-B6A | 1308 | 20-May-09 | Beach | NRL NEW | A | Dual | Cloudy | Not recorded | Site |

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| FWB-SB1 | 1439 | 20-May-09 | Sandy/rocky bottom | NRL NEW | A | Dual | Partly cloudy | Substrate | SW Bathymetry |
| FWB-SB2 | 1443 | 20-May-09 | Sandy/rocky bottom | NRL NEW | A | Dual | Partly cloudy | Substrate | SW Bathymetry |
| FWB-SB3 | 1456 | 20-May-09 | Sandy/rocky bottom | NRL NEW | A | Dual | Partly cloudy | 200-240 mm | SW Bathymetry |
| FWB-SB4 | 1502 | 20-May-09 | Sandy/rocky bottom | NRL NEW | A | Dual | Partly cloudy | 200-220 mm | SW Bathymetry |
| FWB-SB4 | 1507 | 20-May-09 | Sandy/rocky bottom | NRL NEW | A | Dual | Partly cloudy | 250-265 mm | SW Bathymetry |
| FWB-SB5 | 1515 | 20-May-09 | Sandy/rocky bottom | NRL NEW | A | Dual | Partly cloudy | 320-325 mm | SW Bathymetry |
| FWB-SB5 | 1521 | 20-May-09 | Sandy/rocky bottom | NRL NEW | A | Dual | Partly cloudy | 330-340 mm | SW Bathymetry |
| FWB-SB5 | 1530 | 20-May-09 | Sandy/rocky bottom | NRL NEW | A | Dual | Partly cloudy | 460-500 mm | SW Bathymetry |
| FWB-SB5 | 1535 | 20-May-09 | Sandy/rocky bottom | NRL NEW | A | Dual | Partly cloudy | 550-600 mm | SW Bathymetry |
| SWBA-01 | 1446 | 20-May-09 | Sandy/rocky bottom | NPS | B | Dual | Partly cloudy | Substrate | SW Bathymetry |
| SWBA-02 | 1453 | 20-May-09 | Sandy/rocky bottom | NPS | B | Dual | Partly cloudy | 0-40 mm | SW Bathymetry |
| SWBA-03 | 1500 | 20-May-09 | Sandy/rocky bottom | NPS | B | Dual | Partly cloudy | 70-300 mm | SW Bathymetry |
| SWBA-03 | 1503 | 20-May-09 | Sandy/rocky bottom | NPS | B | Dual | Partly cloudy | 100-300 mm | SW Bathymetry |
| SWBA-04 | 1506 | 20-May-09 | Sandy/rocky bottom | NPS | B | Dual | Cloudy | 200-420 mm | SW Bathymetry |
| SWBA-04 | 1508 | 20-May-09 | Sandy/rocky bottom | NPS | B | Dual | Partly cloudy | 350-540 mm | SW Bathymetry |

### 4.3. Freshwater Beach: 21 May 2009

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| FWA3A | 1000 | 21-May-09 | Near foredune ridge, sand. | NOAA | D | Single | Clear | Falling | Site |
| FWA3B | 1010 | 21-May-09 | Not recorded | NOAA | D | Single | Clear | Falling | Site |
| FWA3C | 1029 | 21-May-09 | Sand Spheroids present. | NOAA | D | Single | Clear | Falling | Site |
| FWA3D | 1040 | 21-May-09 | Shell/pebble linear beach feature | NOAA | D | Single | Clear | Falling | Site |
| FWA3E | 1143 | 21-May-09 | Near remnant water muddy surface | NOAA | D | Single | Clear | Falling | Site |
| FWA3F | 1157 | 21-May-09 | Sand | NOAA | D | Single | Clear | Low tide | Site |
| FWA3G | 1206 | 21-May-09 | Wet sand above beach swash, some beach scum. | NOAA | D | Single | Clear | Low tide | Site |
| FWD-01 | 1006 | 21-May-09 | Beach | NPS | E | Single | Clear and sunny | | Site |
| FWD-02 | 1018 | 21-May-09 | Beach | NPS | E | Single | Clear and sunny | | Site |
| FWD-03 | 1100 | 21-May-09 | Beach, rocks and shells | NPS | E | Single | Clear and sunny | | Site |
| FWD-04 | 1110 | 21-May-09 | Beach, kelp, rocks and shells | NPS | E | Single | Clear and sunny | | Site |
| FWD-05 | 1141 | 21-May-09 | Moist beach | NPS | E | Single | Clear and sunny | | Site |
| FWD-06 | 1200 | 21-May-09 | Very little rocks | NPS | E | Single | Clear and sunny | | Site |

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| FWBSWB_4 | 1037 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 965-985 mm | SW Bathymetry |
| FWBSWB_4 | 1044 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 955-915 mm | SW Bathymetry |
| FWBSWB_4 | 1049 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 860-830 mm | SW Bathymetry |
| FWBSWB_4 | 1055 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 805-790 mm | SW Bathymetry |
| FWBSWB_4 | 1100 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 740-750 mm | SW Bathymetry |
| FWBSWB_4 | 1104 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 740-690 mm | SW Bathymetry |
| FWBSWB_4 | 1110 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 660-650 mm | SW Bathymetry |
| FWBSWB_4 | 1117 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 640-615 mm | SW Bathymetry |
| FWBSWB_4 | 1124 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 520-510 mm | SW Bathymetry |
| FWBSWB_4 | 1129 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 440-450 mm | SW Bathymetry |
| FWBSWB_4 | 1134 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 450-410 mm | SW Bathymetry |

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| FWBSWB_4 | 1140 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 330-355 mm | SW Bathymetry |
| FWBSWB_4 | 1148 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 350-300 mm | SW Bathymetry |
| FWBSWB_4 | 1152 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 310 mm | SW Bathymetry |
| FWBSWB_4 | 1158 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clear and sunny | 235-245 mm | SW Bathymetry |
| FWBSWB_4a | 1205 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clouding up | 230-190 mm | SW Bathymetry |
| FWBSWB_4a | 1210 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clouding up | 200-130 mm | SW Bathymetry |
| FWBSWB_4a | 1216 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clouding up | 120-130 mm | SW Bathymetry |
| FWBSWB_4a | 1221 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clouding up | 80-110 mm | SW Bathymetry |
| FWBSWB_4a | 1230 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clouding up | 130 mm | SW Bathymetry |
| FWBSWB_4a | 1234 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clouding up | 120-110 mm | SW Bathymetry |
| FWBSWB_4a | 1239 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clouding up | 85-125 mm | SW Bathymetry |
| FWBSWB_4a | 1244 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clouding up | 80-130 mm | SW Bathymetry |
| FWBSWB_4a | 1308 | 21-May-09 | Beach near rocks on SE section of FWB | NRL NEW | | Single | Clouding up | 60-80 mm | SW Bathymetry |

## 4.4. Freshwater Beach: 22 May 2009

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| FWA5A | 914 | 22-May-09 | Sand At Southern Tip of Two Rocks | NOAA | C | Single | Partly Cloudy | High Tide | Site |
| FWA5C | 936 | 22-May-09 | Below Dune, Dark Rippled Sand. | NOAA | C | Single | Clear | High Tide | Site |
| FWA5D | 942 | 22-May-09 | | NOAA | C | Single | Clear | Falling | Site |
| FWA5E | 948 | 22-May-09 | | NOAA | C | Single | Clear | Falling | Site |
| FWA5F | 958 | 22-May-09 | | NOAA | C | Single | Clear | Falling | Site |
| FWA5G | 1004 | 22-May-09 | | NOAA | C | Single | High Cirrus Clouds | Falling | Site |
| FWA5H | 1015 | 22-May-09 | | NOAA | C | Single | Thick Cirrus Clouds | Falling | Site |
| FWA5I | 1134 | 22-May-09 | Foredune Ridge/Grass Shrubs | NOAA | C | Single | Cirrus Clouds | | Site |
| FWA5J | 1157 | 22-May-09 | 2nd level of foredune ridge | NOAA | C | Single | Partly Cloudy | | Site |
| FWB5A | 917 | 22-May-09 | Wet sand with stipples. | NPS | E | Single | Scattered clouds. Slight breeze blue sky with high thin cirrus clouds near sun. Cumulus clouds on horizon. HyVista plane observed. | | Site |
| FWB5B | 925 | 22-May-09 | Dark, wet stippled sand with sparse shells. | NPS | E | Single | Clouds on horizon | | Site |
| FWB5C | 930 | 22-May-09 | Sand with stones shells and seaweed | NPS | E | Single | Not recorded | | Site |
| FWB5D | 1029 | 22-May-09 | Sandy Beach | NPS | E | Single | Cirrus | | Site |
| FWB5E | 1046 | 22-May-09 | Damp smooth sand with small sparse pebbles. | NPS | E | Single | High Clouds | | Site |
| FWB5F | 1058 | 22-May-09 | Damp sand with dense rock coverage. | NPS | E | Single | High Clouds | | Site |
| FWB5G | 1110 | 22-May-09 | Damp sand with sparse pebble and shell coverage. | NPS | E | Single | High Clouds | | Site |

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| FWBSWB5 | 920 | 22-May-09 | beach near rocks on SE section of FWB | NRL NEW | D | Single | Clear and sunny with increasing clouds later in day | 900-770 mm | SW Bathymetry |
| FWBSWB5 | 927 | 22-May-09 | beach near rocks on SE section of FWB | NRL NEW | D | Single | Clear and sunny with increasing clouds later in day | 670-650 mm | SW Bathymetry |
| FWBSWB5 | 932 | 22-May-09 | beach near rocks on SE section of FWB | NRL NEW | D | Single | Clear and sunny with increasing clouds later in day | 600-570 mm | SW Bathymetry |
| FWBSWB5 | 937 | 22-May-09 | beach near rocks on SE section of FWB | NRL NEW | D | Single | Clear and sunny with increasing clouds later in day | 550-500 mm | SW Bathymetry |
| FWBSWB5 | 942 | 22-May-09 | beach near rocks on SE section of FWB | NRL NEW | D | Single | Clear and sunny with increasing clouds later in day | 470-430 mm | SW Bathymetry |
| FWBSWB5 | 946 | 22-May-09 | beach near rocks on SE section of FWB | NRL NEW | D | Single | Clear and sunny with increasing clouds later in day | 380-400 mm | SW Bathymetry |
| FWBSWB5 | 950 | 22-May-09 | beach near rocks on SE section of FWB | NRL NEW | D | Single | Clear and sunny with increasing clouds later in day | 350 mm | SW Bathymetry |
| FWBSWB5 | 955 | 22-May-09 | beach near rocks on SE section of FWB | NRL NEW | D | Single | Clear and sunny with increasing clouds later in day | 300-270 mm | SW Bathymetry |

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| GREENLEAF | 1146 | 22-May-09 | Green leaf plant | NOAA | C | Single | | | Vegetative feature |
| Dunegrass | 1131 | 22-May-09 | Plant | NOAA | C | Single | | | Vegetative feature |
| Dunegrass2 | 1144 | 22-May-09 | Sand with grass | NOAA | C | Single | | | Vegetative feature |
| Vine | 922 | 22-May-09 | Foredune ridge | NOAA | C | Single | | | Vegetative feature |
| FWBSE_01 | 1113 | 22-May-09 | Light gray and brown stratified rock. | NRL NEW | A | Dual | Stratus | Not recorded | Local feature (rock) |
| FWBSE_02 | 1148 | 22-May-09 | Wet sand average measurement | NRL NEW | A | Dual | Stratus | Not recorded | Local feature (rock) |
| FWBSE_03 | 1249 | 22-May-09 | Red rocks and muddy sand. | NRL NEW | A | Dual | Stratus partly cloudy | Falling to low tide | Local feature (rock) |
| FWBSE_04 | 1257 | 22-May-09 | Green algae spots on sand. | NRL NEW | A | Dual | Stratus | Falling to low tide | Local feature (rock) |
| FWBSE_05 | 1307 | 22-May-09 | Whitish gray rocks | NRL NEW | A | Dual | Stratus | Near low tide | Local feature (rock) |

### 4.5. Sabina Point: 23 May 2009

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| SPB1-A | 959 | 23-May-09 | Dunes | NRL OLD | E | Single | Clear | High Tide | Site |
| SPB1-B | 1012 | 23-May-09 | Dried leaves | NRL OLD | E | Single | Clear | High Tide | Site |
| SPB1-C | 1021 | 23-May-09 | Leaves and sticks | NRL OLD | E | Single | Clear | Falling | Site |
| SPB1-D | 1028 | 23-May-09 | Small shells and rocks on beach | NRL OLD | E | Single | Clear | Falling | Site |
| SPB1-E | 1035 | 23-May-09 | Sand | NRL OLD | E | Single | Clear | Falling | Site |
| SPB1-F | 1044 | 23-May-09 | Beach | NRL OLD | E | Single | Clear | Falling | Site |
| SPB1-G | 1116 | 23-May-09 | Damp sand | NRL OLD | E | Single | Clear | Falling | Site |
| SPB1-H | 1133 | 23-May-09 | Wet sand close to water's edge | NRL OLD | E | Single | Clear | Falling | Site |
| SPB1-I | 1302 | 23-May-09 | Beach | NRL OLD | E | Single | Clear | Falling | Site |
| SPB1-J | 1315 | 23-May-09 | Beach | NRL OLD | E | Single | Clear | Falling | Site |
| SPB1-K | 1323 | 23-May-09 | Beach with rocks | NRL OLD | E | Single | Clear | Falling | Site |
| SPB1-L | 1340 | 23-May-09 | Beach | NRL OLD | E | Single | Clear | Falling | Site |
| SPB1-M | 1403 | 23-May-09 | Moderately deep sinking sad/mud. | NRL OLD | E | Single | Clear | Near low tide | Site |
| SPB1-N | 1457 | 23-May-09 | Sparse sea grass in wet sand. | NRL OLD | E | Single | Clear | Low tide | Site |
| SPB1-O | 1507 | 23-May-09 | Sea grass on wet sand | NRL OLD | E | Single | Clear | Low tide | Site |
| SPB1-P | 1518 | 23-May-09 | Denser sea grass | NRL OLD | E | Single | Clear | Low tide | Site |

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| SPSWB1 | 1007 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 1010-1005 mm | SW Bathymetry |
| SPSWB1 | 1024 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 1000-985 mm | SW Bathymetry |
| SPSWB1 | 1028 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 960-920 mm | SW Bathymetry |
| SPSWB1 | 1034 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 900-865 mm | SW Bathymetry |
| SPSWB1 | 1037 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 840-815 mm | SW Bathymetry |
| SPSWB1 | 1040 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 795-765 mm | SW Bathymetry |
| SPSWB1 | 1046 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 765-720 mm | SW Bathymetry |
| SPSWB1 | 1050 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 690-680 mm | SW Bathymetry |
| SPSWB1 | 1053 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 695-695 mm | SW Bathymetry |
| SPSWB1 | 1057 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 680-680 mm | SW Bathymetry |
| SPSWB1 | 1101 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 660-680 mm | SW Bathymetry |
| SPSWB1 | 1107 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 600-610 mm | SW Bathymetry |
| SPSWB1 | 1116 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 505-510 mm | SW Bathymetry |
| SPSWB1 | 1121 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 455-445 mm | SW Bathymetry |
| SPSWB1 | 1130 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 315-310 mm | SW Bathymetry |
| SPSWB1b | 1135 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 255-255 mm | SW Bathymetry |
| SPSWB1b | 1139 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 205-210 mm | SW Bathymetry |
| SPSWB1b | 1145 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 130-110 mm | SW Bathymetry |
| SPSWB1b | 1149 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | 30-10 mm | SW Bathymetry |
| SPSWB1b | 1152 | 23-May-09 | inundated sand | NRL NEW | D | Single | Clear | Dry | SW Bathymetry |
| SPSWB1b2 | 1329 | 23-May-09 | Peat/Seagrass | NRL NEW | D | Single | Clear | 150-120 mm | SW Bathymetry |
| SPSWB1b2 | 1334 | 23-May-09 | Peat/Seagrass | NRL NEW | D | Single | Clear | 75-65 mm | SW Bathymetry |
| SPSWB1b2 | 1338 | 23-May-09 | Peat/Seagrass | NRL NEW | D | Single | Clear | 30-10 mm | SW Bathymetry |

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| "Volcanic-Rock" | 1510 | 23-May-09 | Rocky outcrop | NRL NEW | D | Single | Clear | N/A | Local feature (rock) |
| "Volcanic Rock 2" | 1521 | 23-May-09 | Red stone | NRL NEW | D | Single | Clear | N/A | Local feature (rock) |
| "White_Rock" | 1545 | 23-May-09 | White rock | NRL NEW | D | Single | Clear | N/A | Local feature (rock) |
| Mangrove1 (sp_mangr) | 1442 | 23-May-09 | Juvenile mangroves in rock area | NRL NEW | D | Single | Clear | N/A | Vegetative feature |
| Mangrove2 (sp_mang2) | 1500 | 23-May-09 | Juvenile mangroves in rock area | NRL NEW | D | Single | Clear | N/A | Vegetative feature |
| Pine (sp_pine) | 1425 | 23-May-09 | Pine trees in sand by entrance to Sabina Point Beach | NRL NEW | D | Single | Clear | N/A | Vegetative feature |

## 4.6. Southern Arm Estuary: 25 May 2009

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| Mangrove2_SWB | 1028 | 25-May-09 | Mangrove in estuary area | NRL NEW | B | Dual | Mostly cloudy, variable | 1340-1400 mm | SW Bathymetry |
| Mangrove 3 SWB | 1115 | 25-May-09 | Mangrove in estuary area | NRL NEW | B | Dual | Mostly cloudy | 2650-2680 mm | SW Bathymetry |
| Mangrove4-SWB | 1212 | 25-May-09 | Mangrove in estuary area | NRL NEW | B | Dual | Thin clouds | 170-190 mm | SW Bathymetry |
| Mangrove1 | 944 | 25-May-09 | Mangrove in estuary area | NRL NEW | B | Dual | Cloudy | Tide falling | Vegetative feature |
| Mangrove2 | 1029 | 25-May-09 | Mangrove in estuary area | NRL NEW | B | Dual | Mostly cloudy | Tide falling | Vegetative feature |
| Mangrove3 | 1112 | 25-May-09 | Mangrove in estuary area | NRL NEW | E | Dual | Cloudy | Tide falling | Vegetative feature |
| Mangrove4 | 1212 | 25-May-09 | Mangrove in estuary area | NRL NEW | E | Dual | Cloudy | Tide falling | Vegetative feature |

## 4.7. Cape Clinton Pocket Beach: 28 May 2009

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| PBJ1A | 1055 | 28-May-09 | Beach | NPS | E | Dual | Variable Clouds | | Site |
| PBJ1B | 1114 | 28-May-09 | Beach | NPS | E | Dual | | | Site |
| PBJ1C | 1132 | 28-May-09 | Beach | NPS | E | Dual | | | Site |
| PBJ1D | 1201 | 28-May-09 | Beach | NPS | E | Dual | | | Site |
| PBJ1E | 1217 | 28-May-09 | Beach | NPS | E | Dual | | | Site |
| PBJ1F | 1234 | 28-May-09 | Beach | NPS | E | Dual | | | Site |
| PBJ1G | 1248 | 28-May-09 | Beach | NPS | E | Dual | | | Site |

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| PBSWB_5_28 | 1100 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | dry | SW Bathymetry |
| PBSWB_5_28 | 1101 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | dry-dry | SW Bathymetry |
| PBSWB_5_28 | 1105 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 2- 2 mm | SW Bathymetry |
| PBSWB_5_28 | 1113 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 15-30 mm | SW Bathymetry |
| PBSWB_5_28 | 1119 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 45-70 mm | SW Bathymetry |
| PBSWB_5_28 | 1124 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 85-45 mm | SW Bathymetry |
| PBSWB_5_28 | 1131 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 140-85 mm | SW Bathymetry |
| PBSWB_5_28 | 1135 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 130-125 mm | SW Bathymetry |
| PBSWB_5_28 | 1142 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 165-150 mm | SW Bathymetry |
| PBSWB_5_28 | 1150 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 135-200 mm | SW Bathymetry |
| PBSWB_5_28 | 1157 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 270-285 mm | SW Bathymetry |
| PBSWB_5_28 | 1204 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 290-280 mm | SW Bathymetry |
| PBSWB_5_28 | 1210 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 320-295 mm | SW Bathymetry |
| PBSWB_5_28 | 1215 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 340-355 mm | SW Bathymetry |
| PBSWB_5_28 | 1220 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 325-420 mm | SW Bathymetry |
| PBSWB_5_28 | 1225 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 370-350 mm | SW Bathymetry |
| PBSWB_5_28 | 1232 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 350-360 mm | SW Bathymetry |
| PBSWB_5_28B | 1242 | 28-May-09 | inundated sand position 1 | NRL NEW | D | Dual | Mostly cloudy, variable | 340-380 mm | SW Bathymetry |

| Site Name | Time | Date | Vegetation/Land Cover Type | ASD | ASD Plaque | Spectrometer Mode | Atmospheric Condition | Water Level | Collection Type |
|---|---|---|---|---|---|---|---|---|---|
| PBSWB_5_28B | 1253 | 28-May-09 | inundated sand position 2 | NRL NEW | D | Dual | Mostly cloudy, variable | 480-470 mm | SW Bathymetry |
| PBSWB_5_28B | 1307 | 28-May-09 | inundated sand position 3 | NRL NEW | D | Dual | Partly Cloudy | 525-515 mm | SW Bathymetry |
| PBSWB_5_28B | 1312 | 28-May-09 | inundated sand position 4 | NRL NEW | D | Dual | Partly Cloudy | 660-645 mm | SW Bathymetry |
| PBSWB_5_28B | 1320 | 28-May-09 | inundated sand position 5 | NRL NEW | D | Dual | Partly Cloudy | 735-775 mm | SW Bathymetry |
| PBSWB_5_28B | 1327 | 28-May-09 | inundated sand position 6 | NRL NEW | D | Dual | Partly Cloudy | 830-875 mm | SW Bathymetry |
| PBSWB_5_28B | 1335 | 28-May-09 | inundated sand position 7 | NRL NEW | D | Dual | Partly Cloudy | 930-930 mm | SW Bathymetry |
| PBSWB_5_28B | 1347 | 28-May-09 | inundated sand position 8 | NRL NEW | D | Dual | Partly Cloudy | 1135-1085 mm | SW Bathymetry |

## 4.8. Leaf Optics: 28-29 May 2009

| Description | Date | Time | Coordinates of Collected Sample | ASD | ASD Plaque | Spectrometer Mode | Leaf Optics (LO) Sample Number | Additional Comments |
|---|---|---|---|---|---|---|---|---|
| Black Sand | 29-May-09 | 1448 | | NRL NEW | D | Leaf optics | NR | Contact probe directly on sand. Sample found by J. Sellars. |
| Broadleaf Understory Tree Bottom | 28-May-09 | | 22.653095 S,150.722687 E | NRL NEW | C | Leaf optics | 4 | Broadleaf understory tree. Height 18 ft. |
| Broadleaf Understory Tree Top | 28-May-09 | | 22.653095 S,150.722687 E | NRL NEW | C | Leaf optics | 4 | Broadleaf understory tree. Height 18 ft. |
| Dark Leaf Tree Bottom | 29-May-09 | 1314 | 22.652147 S, 150.785082 E | NRL NEW | D | Leaf optics | 18 | Height about 30 ft. On FWB rd 500m from beach. |
| Dark Leaf Tree Top | 29-May-09 | 1323 | 22.652147 S, 150.785082 E | NRL NEW | D | Leaf optics | 18 | Height about 30 ft. On FWB rd 500m from beach. |
| Eucalyptus 1 Top | 29-May-09 | 1217 | 22.650632 S, 150.78878 E | NRL NEW | D | Leaf optics | 10 | |
| Eucalyptus 1 Bottom | 29-May-09 | 1222 | 22.650632 S, 150.78878 E | NRL NEW | D | Leaf optics | 10 | |
| Flowering Tree 1 Top | 28-May-09 | 1746 | 22.658016 S, 150.714644 E | NRL NEW | C | Leaf optics | 6 | Height about 20 ft. On FWB road. |
| Flowering Tree 1 Bottom | 28-May-09 | 1747 | 22.658016 S, 150.714644 E | NRL NEW | C | Leaf optics | 6 | Height about 20 ft. On FWB road. |

| Description | Date | Time | Coordinates of Collected Sample | ASD | ASD Plaque | Spectrometer Mode | Leaf Optics (LO) Sample Number | Additional Comments |
|---|---|---|---|---|---|---|---|---|
| Flowering Tree 2 Top | 28-May-09 | 1752 | 22.657988 S, 150.714668 E | NRL NEW | C | Leaf optics | 7 | Mislabeled originally. Has pods, directly behind juvenile version of LO #6 but a different species. |
| Flowering Tree 2 Bottom | 28-May-09 | 1755 | 22.657988 S, 150.714668 E | NRL NEW | C | Leaf optics | 7 | Mislabeled originally. Has pods, directly behind juvenile version of LO #6 but a different species. |
| Fruit Tree Bottom | 29-May-09 | 1432 | 22.648915 S, 150.791918 E | NRL NEW | D | Leaf optics | 16 | FWB rocky area east of beach access pt. Orange/yellow fruit with narrow trunk. |
| Fruit Tree Top | 29-May-09 | 1430 | 22.648915 S, 150.791918 E | NRL NEW | D | Leaf optics | 16 | FWB rocky area east of beach access pt. Orange/yellow fruit with narrow trunk. |
| Fuzzy Cyl Flower Tree 1 Bottom | 29-May-09 | 1332 | 22.65433 S, 150.778665 E | NRL NEW | D | Leaf optics | 21 | Banksia genus. |
| Fuzzy Cyl Flower Tree 1 Flower | 29-May-09 | 1338 | 22.65433 S, 150.778665 E | NRL NEW | D | Leaf optics | 21 | Banksia genus. |
| Fuzzy Cyl Flower Tree 1 Top | 29-May-09 | 1335 | 22.65433 S, 150.778665 E | NRL NEW | D | Leaf optics | 21 | Banksia genus. |
| Fuzzy Cyl Flower Tree 2 Bottom | 29-May-09 | 1229 | 22.65446 S, 150.777409 E | NRL NEW | D | Leaf optics | 22 | |
| Fuzzy Cyl Flower Tree 2 Flower | 29-May-09 | 1238 | 22.65446 S, 150.777409 E | NRL NEW | D | Leaf optics | 22 | |

| Description | Date | Time | Coordinates of Collected Sample | ASD | ASD Plaque | Spectrometer Mode | Leaf Optics (LO) Sample Number | Additional Comments |
|---|---|---|---|---|---|---|---|---|
| Fuzzy Cyl Flower Tree 2 Top | 29-May-09 | 1233 | 22.65446 S, 150.777409 E | NRL NEW | D | Leaf optics | 22 | |
| Hala Bottom | 29-May-09 | 1122 | 22.640578 S, 150.759716 E | NRL NEW | D | Leaf optics | 23 | Razor sharp leaves, large fruit approximately pineapple sized. Growing across river near FWB road split. |
| Hala Top | 29-May-09 | 1118 | 22.640578 S, 150.759716 E | NRL NEW | D | Leaf optics | 23 | Razor sharp leaves, large fruit approximately pineapple sized. Growing across river near FWB road split. |
| Lantana Back | 28-May-09 | 1714 | 22.739656 S, 150.664731 E | NRL NEW | C | Leaf optics | 1 | Height=176cm, Near Sam Hill. |
| Lantana In Situ (lantana canopy) | 29-May-09 | 1000 | 22.739656 S, 150.66471 E | NRL NEW | D | Single | N/A | Spectra taken at location on 5/29/09 |
| Lantana Top | 28-May-09 | 1711 | 22.739656 S, 150.664731 E | NRL NEW | C | Leaf optics | 1 | Height=176cm, Near Sam Hill. |
| Palm tree (Coconut) | 27-May-09 | 1329 | 22.650218 S, 150.790923 E | N/A | N/A | N/A | 17 | Sample not taken. Position taken for ground control. |
| Palm tree (Coconut) | 27-May-09 | 1329 | 22.650218 S , 150.790923 E | N/A | N/A | N/A | 17 | Sample not taken. Position taken for ground control. |

| Description | Date | Time | Coordinates of Collected Sample | ASD | ASD Plaque | Spectrometer Mode | Leaf Optics (LO) Sample Number | Additional Comments |
|---|---|---|---|---|---|---|---|---|
| Palm-1 Top | 28-May-09 | 1727 | 22.653095 S, 150.722658 E | NRL NEW | C | Leaf optics | 2 | Palm trees located on FWB rd. Height approx. 22ft. |
| Palm-1 Bottom | 28-May-09 | 1728 | 22.653095 S, 150.722658 E | NRL NEW | C | Leaf optics | 2 | Palm trees located on FWB rd. Height approx. 22ft. |
| Pine 2 | 29-May-09 | 924 | 22.657877 S, 150.714878 E | NRL NEW | D | Leaf optics | 9 | Casuarina genus. Species located on FWB road. |
| Prickly Pear Green | 29-May-09 | 1442 | 22.648957 S, 150.791879 E | NRL NEW | D | Leaf optics | 15 | Found in understory 5/27. Direct contact of probe on plant. |
| Prickly Pear Purple | 29-May-09 | 1444 | 22.648957 S, 150.791879 E | NRL NEW | D | Leaf optics | 15 | Found in understory 5/27. Direct contact of probe on plant. |
| Red Palm Bottom (rtcrpalm) | 29-May-09 | 1400 | 22.640663 S, 150.759616 E | NRL NEW | D | Leaf optics | 24 | Plant height 28ft. On FWB Rd near split around ravine/river. |
| Red Palm Top(rtcrpalm) | 29-May-09 | 1359 | 22.640663 S, 150.759616 E | NRL NEW | D | Leaf optics | 24 | Plant height 28ft. On FWB Rd near split around ravine/river. |
| Shrub 1 Bottom | 28-May-09 | 1054 | FWB Road | NRL NEW | C | Leaf optics | 5 | Height approx 5ft. Location of sample at FWB. |
| Shrub 1 Top | 28-May-09 | 1050 | FWB Road | NRL NEW | C | Leaf optics | 5 | Height approx 5ft. Location of sample at FWB. |
| Spindly Leaf Tree Side 1 | 29-May-09 | 1418 | 22.652762 S, 150.781305 E | NRL NEW | D | Leaf optics | 20 | FWB road. Height= 17ft. |

| Description | Date | Time | Coordinates of Collected Sample | ASD | ASD Plaque | Spectrometer Mode | Leaf Optics (LO) Sample Number | Additional Comments |
|---|---|---|---|---|---|---|---|---|
| Spindly Leaf Tree Side 2 | 29-May-09 | 1421 | 22.652762 S, 150.781305 E | NRL NEW | D | Leaf optics | 20 | FWB road. Height= 17ft. |
| Wetland Plant Bottom (blwp1) | 29-May-09 | 1250 | 22.652069 S, 150.784997 E | NRL NEW | D | Leaf optics | 19 | FWB rd 500m from beach. Height=1.51m. |
| Wetland Plant Top (blwp1) | 29-May-09 | 1253 | 22.652069 S, 150.784997 E | NRL NEW | D | Leaf optics | 19 | FWB rd 500m from beach. Height=1.51m |
| Woody Bark Tree 2 Bottom | 29-May-09 | 1202 | 22.650612 S, 150.788724 E | NRL NEW | D | Leaf optics | 11 | May be another type of eucalyptus. Spatially close to LO #10. |
| Woody Bark Tree 2 Top | 29-May-09 | 1205 | 22.650612 S, 150.788724 E | NRL NEW | D | Leaf optics | 11 | May be another type of eucalyptus. Spatially close to LO #10. |
| Woody Bark Tree 3 Bottom | 29-May-09 | 1410 | 22.650461 S, 150.7892 E | NRL NEW | D | Leaf optics | 12 | Similar to LO # 11. Species isolated and growing in sand. Some type of eucalyptus. |
| Woody Bark Tree 3 Top | 29-May-09 | 1407 | 22.650461 S, 150.7892 E | NRL NEW | D | Leaf optics | 12 | Similar to LO # 11. Species isolated and growing in sand. Some type of eucalyptus. |
| Woody Bark Tree 4 Bottom | 29-May-09 | 1353 | 22.650427 S, 150.78964 E | NRL NEW | D | Leaf optics | 13 | Possibly eucalyptus but could be acacia. White peeling bark. |

| Description | Date | Time | Coordinates of Collected Sample | ASD | ASD Plaque | Spectrometer Mode | Leaf Optics (LO) Sample Number | Additional Comments |
|---|---|---|---|---|---|---|---|---|
| Woody Bark Tree 4 Top | 29-May-09 | 1351 | 22.650427 S, 150.78964 E | NRL NEW | D | Leaf optics | 13 | Possibly eucalyptus but could be acacia. White peeling bark |
| Woody Tree 1 Leaf Bottom | 28-May-09 | 1735 | 22.652979 S, 150.722616 E | NRL NEW | C | Leaf optics | 3 | Understory tree on FWB rd. Height approx 13ft. |
| Woody Tree 1 Leaf Top | 28-May-09 | 1734 | 22.652979 S, 150.722616 E | NRL NEW | C | Leaf optics | 3 | Understory tree on FWB rd. Height approx 13ft. |
| Woody Tree 2 Bottom | 28-May-09 | 1800 | 22.657968 S, 150.714688 E | NRL NEW | C | Leaf optics | 8 | Same species as LO #7 but more mature. |
| Woody Tree 2 Top | 28-May-09 | 1759 | 22.657968 S, 150.714688 E | NRL NEW | C | Leaf optics | 8 | Same species as LO #7 but more mature. |
| Yellow Flower Tree Bottom | 29-May-09 | 1138 | 22.650148 S, 150.790937 E | NRL NEW | D | Leaf optics | 14 | Acacia plant. Above beach dune on FWB. East of beach entrance. Located 5/27/09 |
| Yellow Flower Tree Flower | 29-May-09 | 1146 | 22.650148 S, 150.790937 E | NRL NEW | D | Leaf optics | 14 | Acacia plant. Above beach dune on FWB. East of beach entrance. Located 5/27/09 |
| Yellow Flower Tree Top | 29-May-09 | 1131 | 22.650148 S, 150.790937 E | NRL NEW | D | Leaf optics | 14 | Acacia plant. Above beach dune on FWB. East of beach entrance. Located 5/27/09 |

# APPENDIX F

## Light Weight Deflectometer (LWD) Data

## 1. Introduction

A Light Weight Deflectometer (LWD) is an instrument for measuring the dynamic deflection modulus of a substrate. Components of the LWD include a weight-fix-and-release mechanism, guide rod, falling weight, steel spring, and a base plate with an embedded accelerometer. Once the weight drops, the spring provides the buffer system that transmits the load pulse to the plate resting on the material to be tested. The weight is raised to a fixed height that, when dropped, will impart a standardized force pulse. After the weight has recoiled from the base plate, the resulting vertical surface deflection is measured.

The Zorn ZFG 2000 light weight drop tester is the LWD used to conduct plate-bearing tests during the TS'09 experiment. It is configured with a 10-Kg (22.05 lbs) weight and a 300 mm (11.8 in) diameter plate. The LWD was used to measure bearing capacity (dynamic deflection modulus), one of the two failure mechanisms of soil under load. It is highly portable and was easily transported around the coastal zone. The Zorn ZFG 2000 provides a simple way to estimating bearing capacity and the recorder/printer device gives hard copy results in the field as well as recording data onto a chip card for uploading to a PC. A complete test cycle can be completed in less than a minute.

The LWD measures the *in situ* dynamic deflection modulus of soils. The influence depth is approximately 1 to 1.5 times the plate diameter. Results from TS09 are provided below in table and chart format.

## 2. Light Weight Deflectometer Tabular Data

The tables below present the LWD findings for all GPS points in which LWD measurement was taken. The LWD Evd values were then broken into five bins; "Excellent," (Evd> 28.3 $MNm^{-2}$), "Good," (21.6 $MNm^{-2}$< Evd ≤ 28.3 $MNm^{-2}$), "Fair," (14.9 $MNm^{-2}$< Evd ≤ 21.6 $MNm^{-2}$), "Poor," (8.2 $MNm^{-2}$< Evd ≤ 14.9 $MNm^{-2}$), and "Bad," (Evd ≤ 8.2 $MNm^{-2}$).

### 2.1. Cape Clinton Pocket Beach: 19 May 2009

| No. (of test) | Local Date | Local Time | Deflection [mm] | | | | Evd [MN/m²] | Site Name | LWD | Notes | Trafficability Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | single values | | | mean | | | | | |
| | | | s1 | s2 | s3 | s | | | | | |
| 1 | 19 May 2009 | 14:50 | 2.232 | 1.678 | 1.589 | 1.833 | 12.3 | PB1-01 | 2 | pocket beach | Poor |
| 2 | 19 May 2009 | 14:54 | 2.784 | 1.952 | 1.768 | 2.168 | 10.4 | PB1-02 | 2 | pocket beach | Poor |
| 3 | 19 May 2009 | 15:03 | 2.426 | 1.902 | 1.564 | 1.964 | 11.5 | PB1-03 | 2 | pocket beach | Poor |
| 4 | 19 May 2009 | 15:09 | 3.958 | 2.079 | 1.745 | 2.594 | 8.7 | PB1-04 | 2 | pocket beach | Poor |
| 5 | 19 May 2009 | 15:15 | 3.715 | 1.900 | 1.420 | 2.345 | 9.6 | PB1-05 | 2 | pocket beach | Poor |
| 6 | 19 May 2009 | 15:26 | 4.013 | 1.359 | 1.163 | 2.178 | 10.3 | PB1-06 | 2 | pocket beach | Poor |
| 7 | 19 May 2009 | 15:28 | 2.863 | 1.182 | 1.119 | 1.721 | 13.1 | PB1-07 | 2 | pocket beach | Poor |
| 8 | 19 May 2009 | 15:30 | 3.697 | 1.407 | 1.186 | 2.097 | 10.7 | PB1-08 | 2 | pocket beach | Poor |
| 9 | 19 May 2009 | 15:35 | 2.762 | 1.524 | 1.280 | 1.855 | 12.1 | PB1-09 | 2 | pocket beach | Poor |
| 10 | 19 May 2009 | 15:39 | 6.284 | 6.034 | 5.547 | 5.955 | 3.8 | PB1-10 | 2 | pocket beach | Bad |
| 11 | 19 May 2009 | 15:42 | 9.352 | 6.811 | 5.808 | 7.324 | 3.1 | PB1-11 | 2 | pocket beach | Bad |
| 12 | 19 May 2009 | 15:47 | 10.636 | 9.140 | 8.014 | 9.263 | 2.4 | PB1-12 | 2 | pocket beach | Bad |
| 13 | 19 May 2009 | 15:51 | 8.223 | 7.628 | 7.083 | 7.645 | 2.9 | PB1-13 | 2 | pocket beach | Bad |
| 14 | 19 May 2009 | 15:55 | 10.330 | 5.124 | 4.666 | 6.707 | 3.4 | PB1-14 | 2 | pocket beach | Bad |
| 15 | 19 May 2009 | 15:59 | 6.302 | 4.829 | 4.144 | 5.092 | 4.4 | PB1-15 | 2 | pocket beach | Bad |

## 2.2 Freshwater Beach: 20-21 May 2009

| No. (of test) | Local Date | Local Time | Deflection [mm] | | | | Evd [MN/m²] | Site Name | LWD | Notes | Trafficability Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | single values | | | mean | | | | | |
| | | | s1 | s2 | s3 | s | | | | | |
| 22 | 20 May 2009 | 11:31 | 3.068 | 2.670 | 2.188 | 2.642 | 8.5 | FWA-1A | 1 | | Poor |
| 23 | 20 May 2009 | 11:41 | 1.543 | 1.347 | 1.084 | 1.325 | 17.0 | FWA-1B | 1 | | Fair |
| 27 | 20 May 2009 | 13:31 | 1.586 | 0.896 | 0.831 | 1.104 | 20.4 | FWA-1C | 1 | | Fair |
| 26 | 20 May 2009 | 13:25 | 1.499 | 1.178 | 1.064 | 1.247 | 18.0 | FWA-1D | 1 | | Fair |
| 25 | 20 May 2009 | 13:21 | 1.547 | 1.306 | 1.268 | 1.374 | 16.4 | FWA-1E | 1 | | Fair |
| 24 | 20 May 2009 | 13:06 | 1.401 | 1.143 | 1.107 | 1.217 | 18.5 | FWA-1F | 1 | | Fair |
| 16 | 20 May 2009 | 12:32 | 9.313 | 2.894 | 3.021 | 5.076 | 4.4 | FWB-B1A | 2 | | Bad |
| 17 | 20 May 2009 | 13:02 | 3.183 | 1.386 | 1.147 | 1.905 | 11.8 | FWB-B2A | 2 | | Poor |
| 18 | 20 May 2009 | 13:14 | 1.845 | 1.053 | 0.997 | 1.298 | 17.3 | FWB-B3A | 2 | | Fair |
| 19 | 20 May 2009 | 13:18 | 1.642 | 1.006 | 0.877 | 1.175 | 19.1 | FWB-B4A | 2 | FWB-04 | Fair |
| 20 | 20 May 2009 | 13:21 | 1.654 | 1.102 | 1.007 | 1.254 | 17.9 | FWB-B5A | 2 | FWB-05 | Fair |
| 21 | 20 May 2009 | 13:23 | 2.111 | 1.398 | 1.279 | 1.596 | 14.1 | FWB-B6A | 2 | FWB-06B | Poor |
| 1 | 21 May 2009 | 10:30 | 5.359 | 2.376 | 2.115 | 3.283 | 6.9 | FWD-01 | 2 | | Bad |
| 2 | 21 May 2009 | 10:39 | 10.362 | 4.347 | 3.771 | 6.160 | 3.7 | FWD-02 | 2 | | Bad |
| 3 | 21 May 2009 | 11:17 | 5.590 | 3.768 | 3.662 | 4.340 | 5.2 | FWD-03 | 2 | | Bad |
| 4 | 21 May 2009 | 11:31 | 9.120 | 4.716 | 4.006 | 5.947 | 3.8 | FWD-04 | 2 | | Bad |
| 5 | 21 May 2009 | 12:07 | 6.903 | 3.398 | 2.616 | 4.306 | 5.2 | FWD-05 | 2 | | Bad |
| 6 | 21 May 2009 | 12:13 | 2.335 | 1.405 | 1.257 | 1.666 | 13.5 | FWD-06 | 2 | | Poor |
| 3 | 21 May 2009 | 11:02 | 13.631 | 3.913 | 3.687 | 7.077 | 3.2 | FWA-3A | 1 | | Bad |
| 2 | 21 May 2009 | 10:54 | 3.969 | 3.569 | 3.269 | 3.602 | 6.2 | FWA-3B | 1 | | Bad |
| 1 | 21 May 2009 | 10:38 | 0.963 | 0.767 | 0.700 | 0.810 | 27.8 | FWA-3C | 1 | | Good |
| 7 | 21 May 2009 | 12:57 | 1.612 | 0.799 | 0.755 | 1.055 | 21.3 | FWA-3D | 1 | | Fair |
| 6 | 21 May 2009 | 12:49 | 1.453 | 1.186 | 1.080 | 1.240 | 18.1 | FWA-3E | 1 | | Fair |
| 5 | 21 May 2009 | 12:34 | 0.894 | 0.822 | 0.781 | 0.832 | 27.0 | FWA-3F | 1 | | Good |
| 4 | 21 May 2009 | 12:16 | 0.888 | 0.886 | 0.892 | 0.889 | 25.3 | FWA-3G | 1 | | Good |

## 2.3. Freshwater Beach: 22 May 2009

| No. (of test) | Local Date | Local Time | Deflection [mm] | | | | Evd [MN/m²] | Site Name | LWD | Notes | Trafficability Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | single values | | | mean | | | | | |
| | | | s1 | s2 | s3 | s | | | | | |
| 7 | 22 May 2009 | 11:19 | 7.379 | 3.374 | 3.094 | 4.616 | 4.9 | FWA5A | 1 | | Bad |
| 6 | 22 May 2009 | 11:14 | 8.317 | 3.405 | 3.238 | 4.987 | 4.5 | FWA5C | 1 | | Bad |
| 5 | 22 May 2009 | 11:07 | 6.351 | 3.249 | 3.175 | 4.258 | 5.3 | FWA5D | 1 | | Bad |
| 4 | 22 May 2009 | 10:50 | 0.850 | 0.677 | 0.621 | 0.716 | 31.4 | FWA5E | 1 | | Excellent |
| 3 | 22 May 2009 | 10:37 | 0.775 | 0.622 | 0.574 | 0.657 | 34.2 | FWA5F | 1 | | Excellent |
| 2 | 22 May 2009 | 10:29 | 0.873 | 0.810 | 0.775 | 0.819 | 27.5 | FWA5G | 1 | | Good |
| 1 | 22 May 2009 | 10:21 | 1.049 | 0.912 | 0.870 | 0.944 | 23.8 | FWA5H | 1 | | Good |
| 8 | 22 May 2009 | 12:47 | 6.843 | 3.586 | 3.238 | 4.556 | 4.9 | FWA5I | 1 | | Bad |
| 9 | 22 May 2009 | 12:53 | 7.002 | 5.928 | 4.827 | 5.919 | 3.8 | FWA5J | 1 | | Bad |
| 1 | 22 May 2009 | 9:43 | 3.131 | 3.028 | 2.574 | 2.911 | 7.7 | FWB-5A | 2 | 1st attempt | Bad |
| 2 | 22 May 2009 | 9:46 | 10.866 | 3.832 | 2.908 | 5.869 | 3.8 | FWB-5A | 2 | 2nd attempt | Bad |
| 3 | 22 May 2009 | 9:52 | 4.930 | 3.974 | 3.387 | 4.097 | 5.5 | FWB-5B | 2 | | Bad |
| 4 | 22 May 2009 | 9:57 | 10.247 | 3.387 | 2.737 | 5.457 | 4.1 | FWB-5C | 2 | | Bad |
| 5 | 22 May 2009 | 11:27 | 6.991 | 3.470 | 3.178 | 4.546 | 4.9 | FWB-5D | 2 | | Bad |
| 6 | 22 May 2009 | 11:33 | 2.015 | 0.975 | 0.836 | 1.275 | 17.6 | FWB-5E | 2 | | Fair |
| 7 | 22 May 2009 | 11:46 | 0.968 | 0.678 | 0.630 | 0.759 | 29.6 | FWB-5F | 2 | 1st attempt | Excellent |
| 8 | 22 May 2009 | 11:50 | 1.031 | 0.716 | 0.647 | 0.798 | 28.2 | FWB-5F | 2 | 2nd attempt | Good |
| 9 | 22 May 2009 | 12:06 | 1.423 | 0.826 | 0.763 | 1.004 | 22.4 | FWB-5G | 2 | | Good |

## 2.4. Sabina Point Beach: 23 May 2009

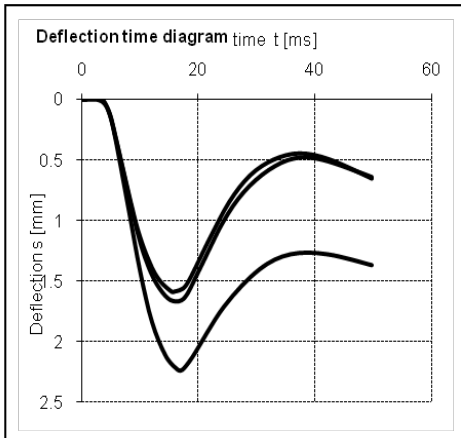
| No. | Local Date | Local Time | Deflection [mm] | | | | Evd [MN/m²] | Site Name | LWD | Notes | Trafficability Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | single values | | | mean | | | | | |
| | | | s1 | s2 | s3 | s | | | | | |
| 1 | 23 May 2009 | 10:10 | 6.9 | 4.3 | 4.0 | 5.0 | 4.5 | SPB-1A | 2 | | Bad |
| 2 | 23 May 2009 | 10:19 | 4.1 | 3.5 | 2.9 | 3.5 | 6.4 | SPB-1B | 2 | | Bad |
| 3 | 23 May 2009 | 10:37 | 15.5 | 8.9 | 8.4 | 10.9 | 2.1 | SPB-1C | 2 | | Bad |
| 4 | 23 May 2009 | 10:40 | 5.8 | 2.9 | 2.5 | 3.7 | 6.1 | SPB-1D | 2 | | Bad |
| 5 | 23 May 2009 | 10:50 | 2.5 | 1.9 | 1.7 | 2.0 | 11.1 | SPB-1E | 2 | | Poor |
| 6 | 23 May 2009 | 10:55 | 3.4 | 2.3 | 1.8 | 2.5 | 8.9 | SPB-1F | 2 | | Poor |
| 7 | 23 May 2009 | 11:25 | 4.9 | 3.0 | 2.5 | 3.4 | 6.5 | SPB-1G | 2 | | Bad |
| 8 | 23 May 2009 | 11:40 | 3.2 | 2.6 | 2.4 | 2.8 | 8.1 | SPB-1H | 2 | | Bad |
| 9 | 23 May 2009 | 13:12 | 1.5 | 1.3 | 1.3 | 1.4 | 16.6 | SPB-1I | 2 | | Fair |
| 10 | 23 May 2009 | 13:22 | 2.2 | 1.4 | 1.2 | 1.6 | 14.1 | SPB-1J | 2 | | Poor |
| 12 | 23 May 2009 | 14:04 | 4.4 | 2.5 | 2.2 | 3.0 | 7.4 | SPB-1K | 2 | Dense rocks--see notes | Bad |
| 11 | 23 May 2009 | 13:56 | 2.7 | 1.8 | 1.5 | 2.0 | 11.2 | SPB-1L | 2 | Dense rocks--see notes | Poor |
| 13 | 23 May 2009 | 14:19 | 8.1 | 6.3 | 5.9 | 6.8 | 3.3 | SPB-1M | 2 | | Bad |
| 14 | 23 May 2009 | 15:04 | 5.9 | 4.2 | 3.9 | 4.7 | 4.8 | SPB-1N | 2 | | Bad |
| 15 | 23 May 2009 | 15:23 | 4.6 | 4.2 | 4.1 | 4.3 | 5.2 | SPB-1O | 2 | | Bad |
| 16 | 23 May 2009 | 15:30 | 6.9 | 6.7 | 6.7 | 6.8 | 3.3 | SPB-1P | 2 | | Bad |

## 2.5. Cape Clinton Pocket Beach: 28 May 2009

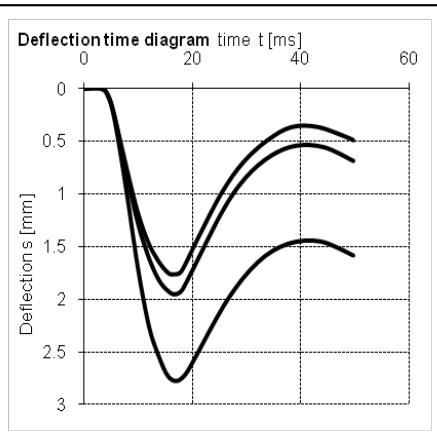
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 28 May 2009 | 11:02 | 2.1 | 1.4 | 1.5 | 1.6 | 13.7 | PBJ-1A | 2 | | Poor |
| 20 | 28 May 2009 | 11:20 | 2.7 | 1.7 | 1.7 | 2.0 | 11.1 | PBJ-1B, drop 1 | 2 | | Poor |
| 21 | 28 May 2009 | 11:22 | 3.0 | 1.9 | 1.7 | 2.2 | 10.2 | PBJ-1B, drop 2 | 2 | | Poor |
| 22 | 28 May 2009 | 11:40 | 2.1 | 1.5 | 1.4 | 1.7 | 13.3 | PBJ-1C | 2 | | Poor |
| 23 | 28 May 2009 | 12:09 | 3.0 | 1.9 | 1.8 | 2.2 | 10.1 | PBJ-1D | 2 | | Poor |
| 24 | 28 May 2009 | 12:25 | 9.5 | 8.2 | 7.2 | 8.3 | 2.7 | PBJ-1E | 2 | | Bad |
| 25 | 28 May 2009 | 12:55 | 14.0 | 11.2 | 9.7 | 11.6 | 1.9 | PBJ-1F | 2 | | Bad |
| 26 | 28 May 2009 | 12:57 | 10.0 | 4.6 | 2.0 | 5.5 | 4.1 | PBJ-1G, drop 1 | 2 | | Bad |
| 27 | 28 May 2009 | 12:59 | 7.0 | 4.4 | 4.3 | 5.2 | 4.3 | PBJ-1G, drop 2 | 2 | | Bad |

## 3. Light Weight Deflectometer Graphical Data

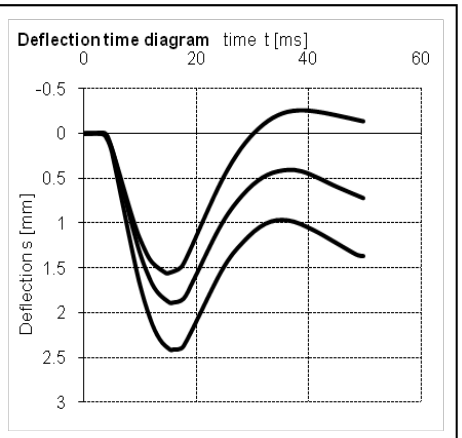
### 3.1. Cape Clinton Pocket Beach: 19 May 2009



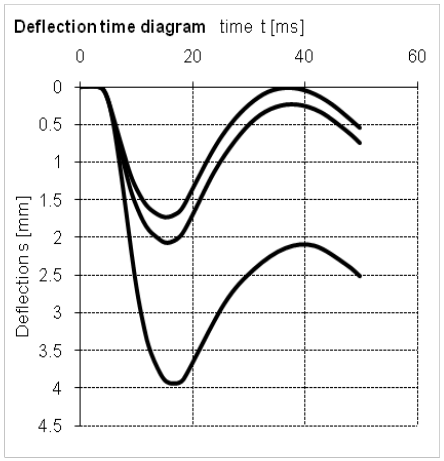

PB1-01



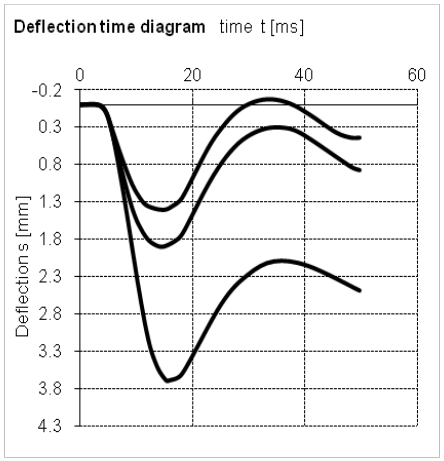

PB1-02



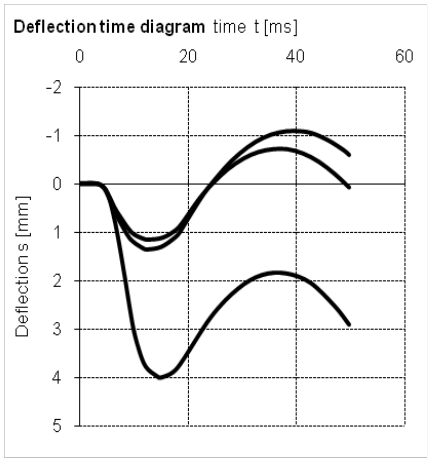

PB1-03



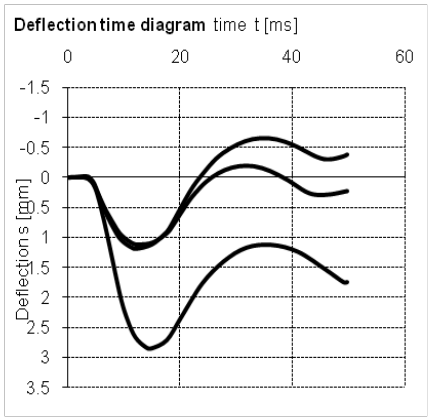

PB1-04



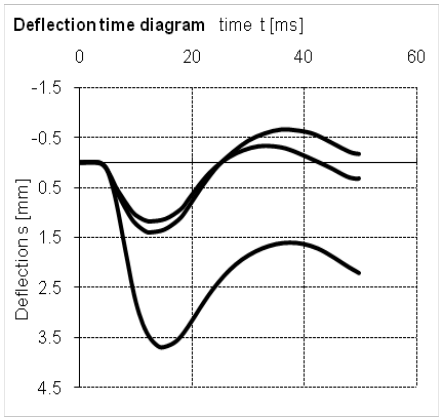

PB1-05



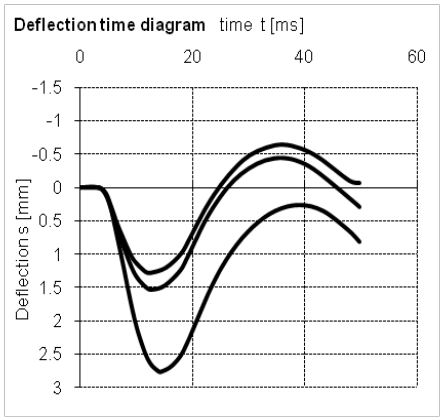

PB1-06



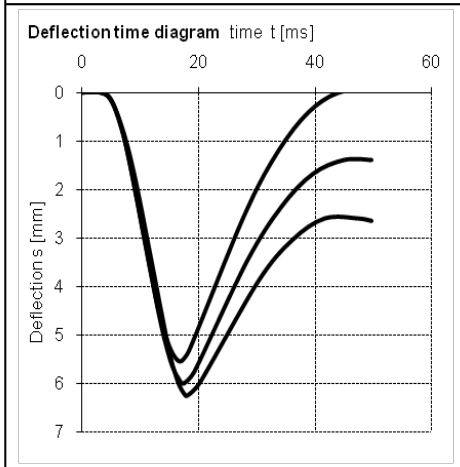

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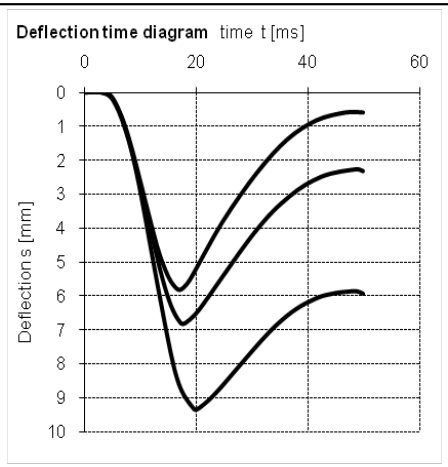

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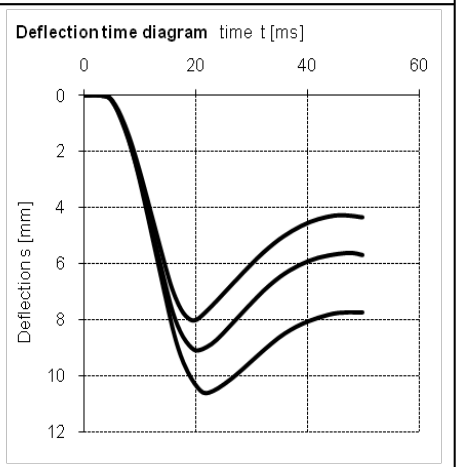

PB1-09



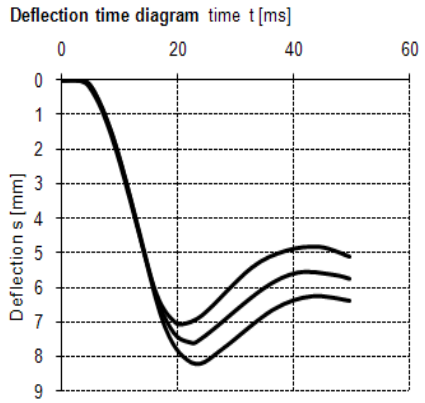
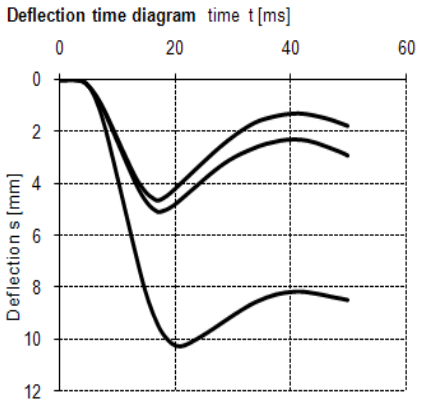
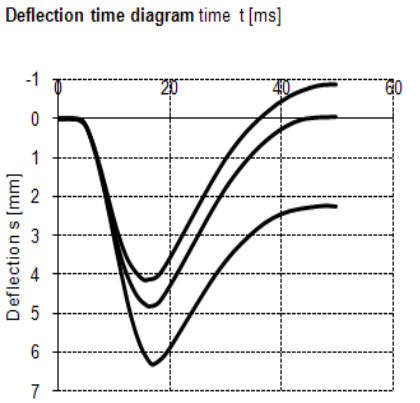

PB1-10



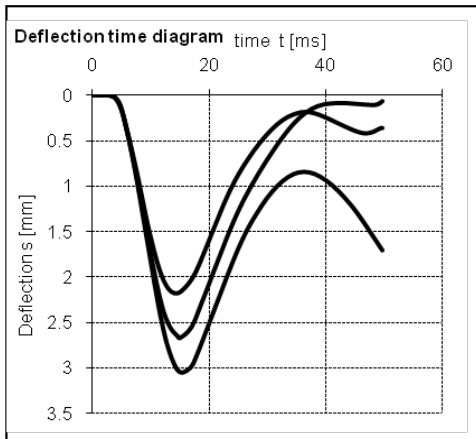

PB1-11



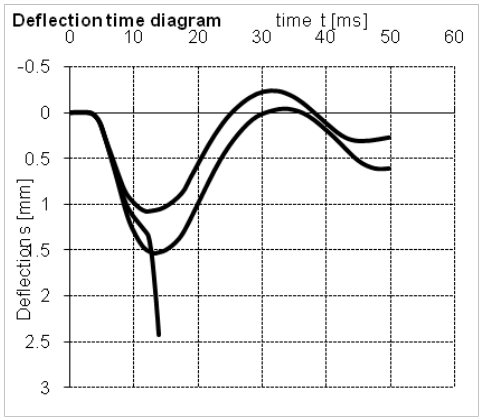

PB1-12

| | | |
|---|---|---|
|  |  |  |
| PB1-13 | PB1-14 | PB1-15 |

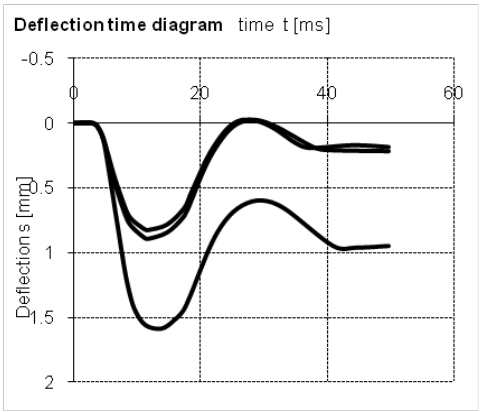
### 3.2. Freshwater Beach: 20 May 2009-FWA Series



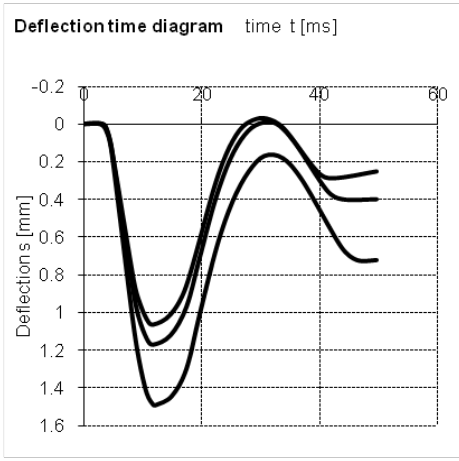

FWA-1A



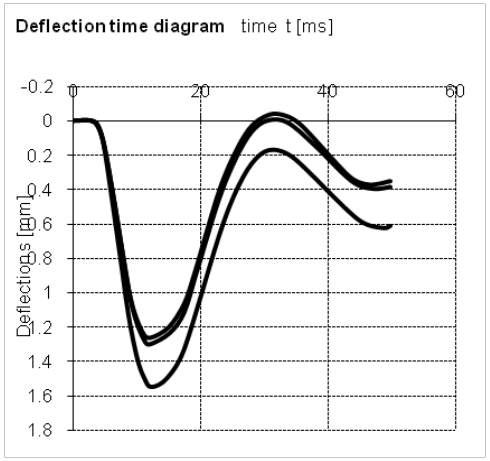

FWA-1B



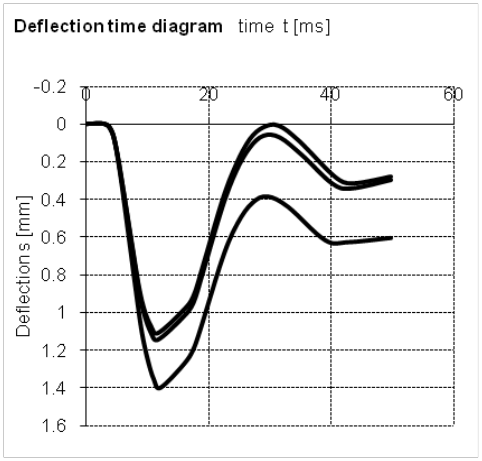

FWA-1C




FWA-1D

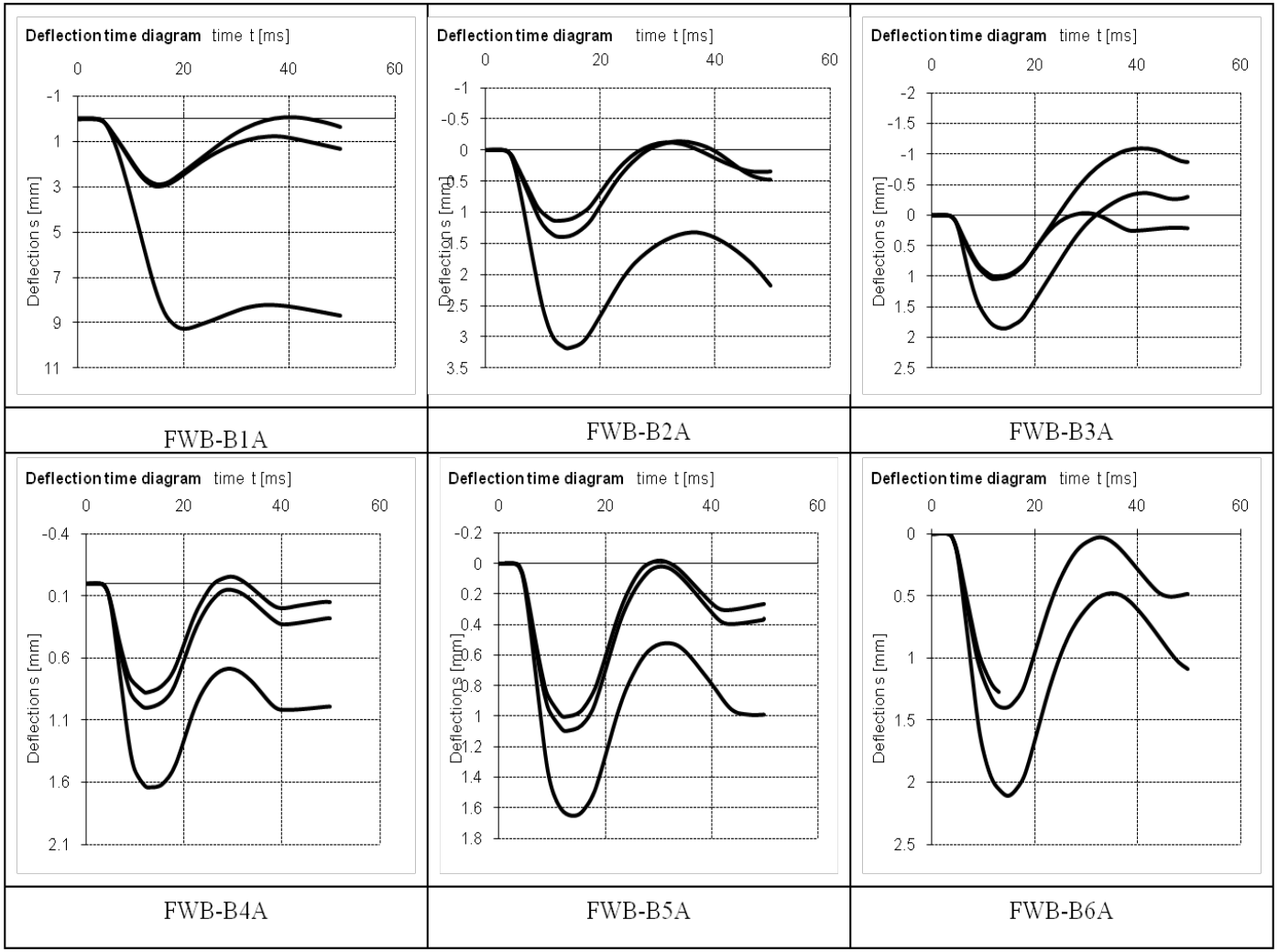



FWA-1E

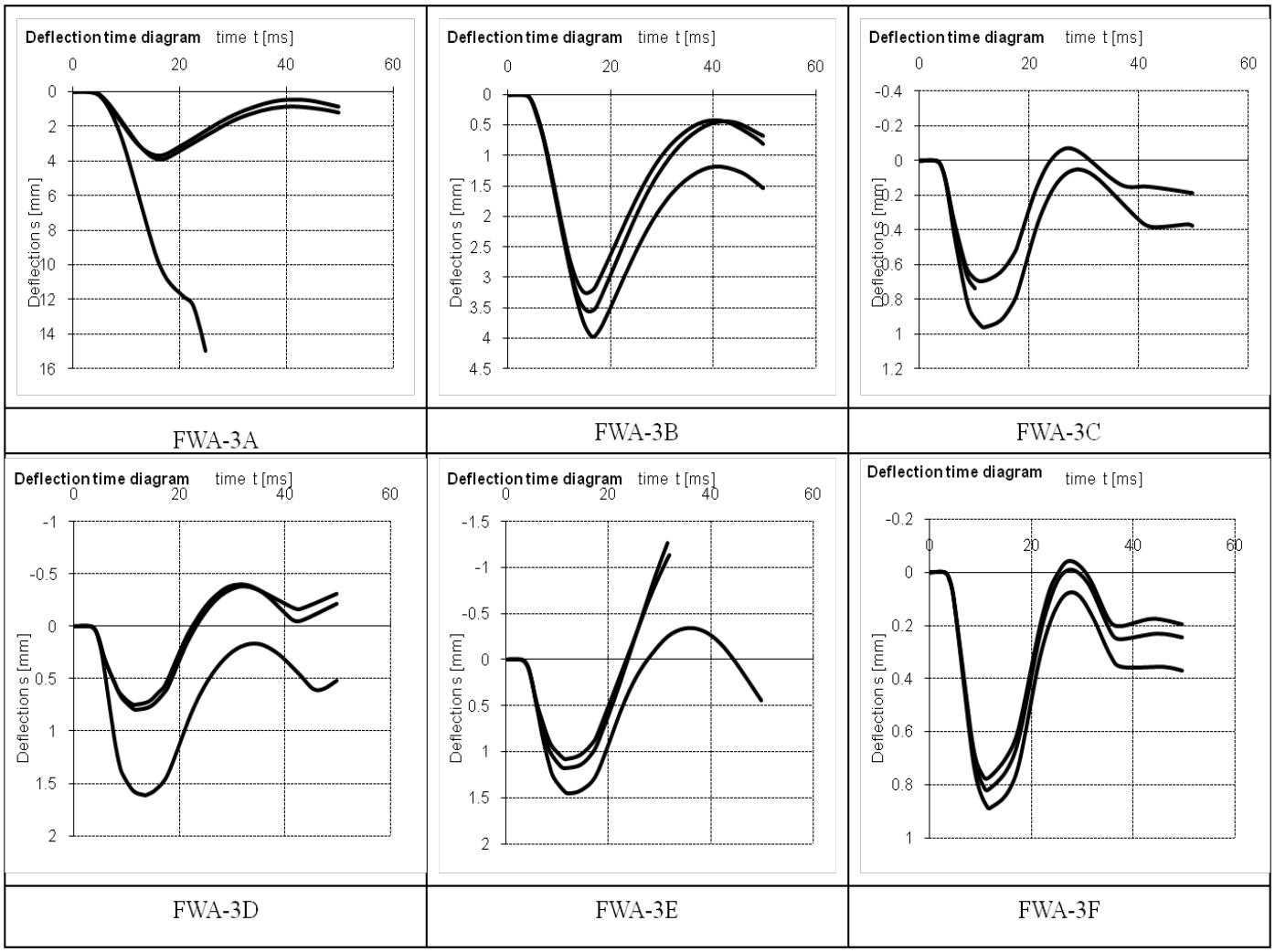


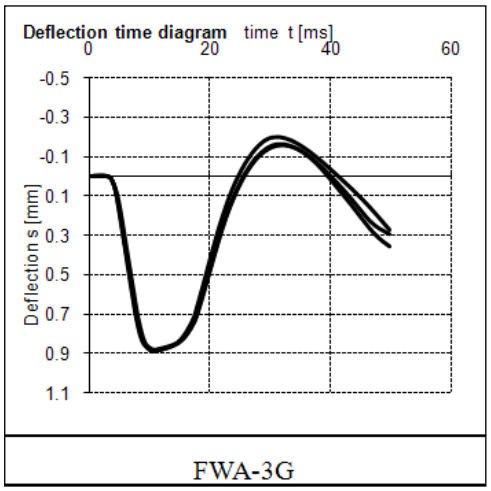

FWA-1F

### 3.3. Freshwater Beach: 20 May 2009-FWB-B Series



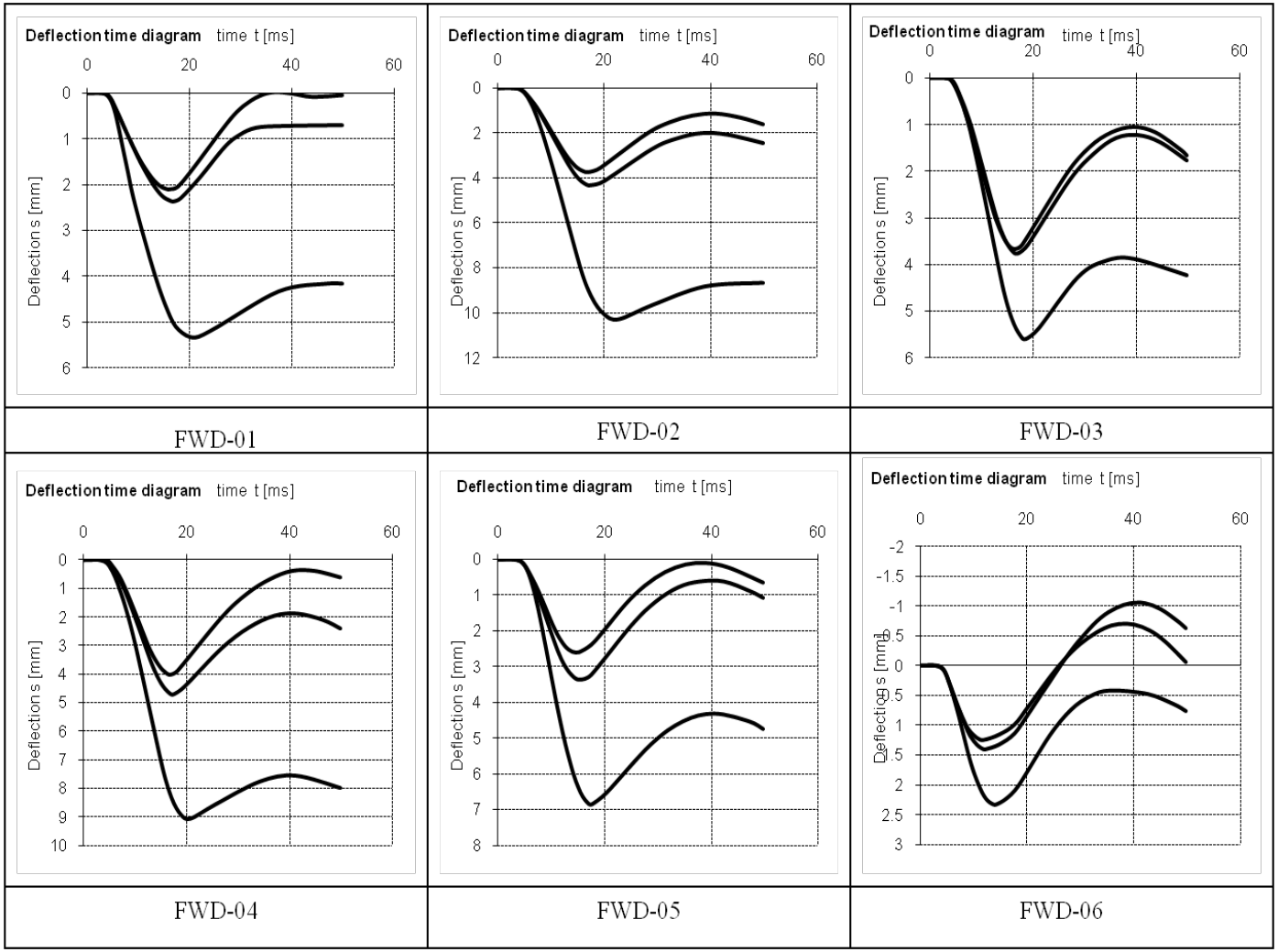
### 3.4. Freshwater Beach: 21 May 2009-FWA-3 Series



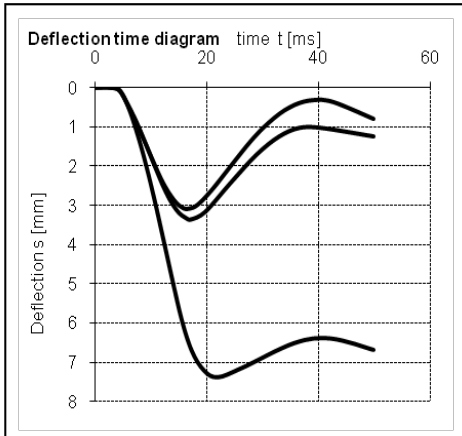

Deflection time diagram
time t [ms]
0
20
40
60
-0.5
-0.3
-0.1
0.1
0.3
0.5
0.7
0.9
1.1
Deflection s [mm]

FWA-3G

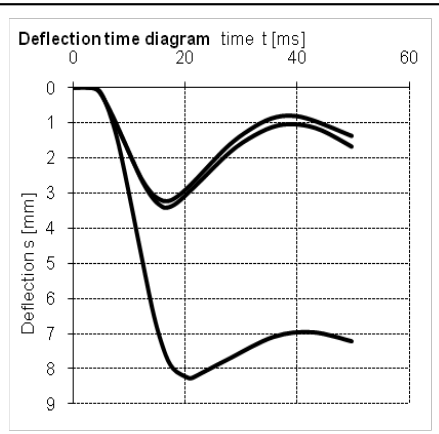
### 3.5. Freshwater Beach: 21 May 2009-FWD Series



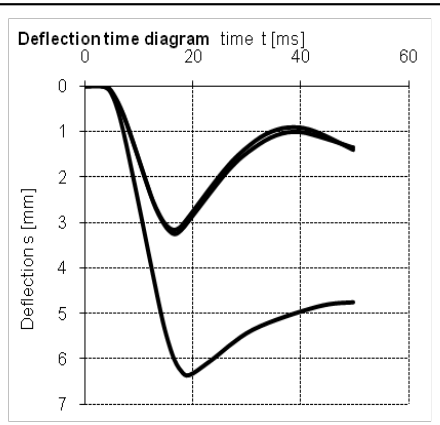
### 3.6. Freshwater Beach: 22 May 2009-FWA Series



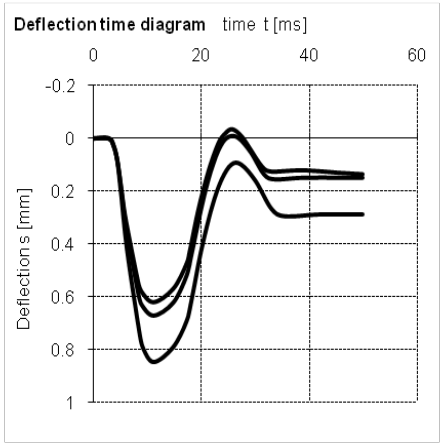

FWA-5A



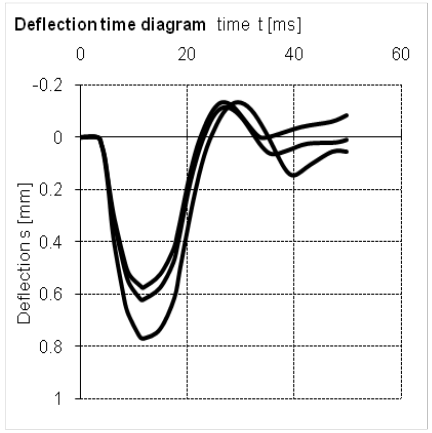

FWA-5C



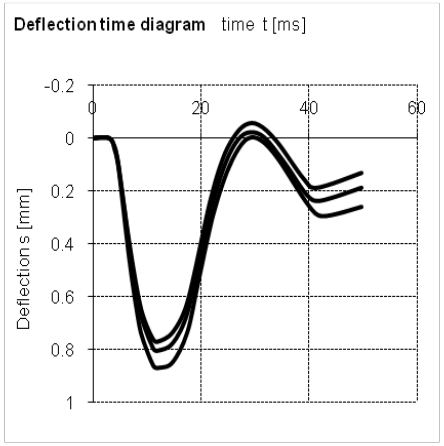

FWA-5D



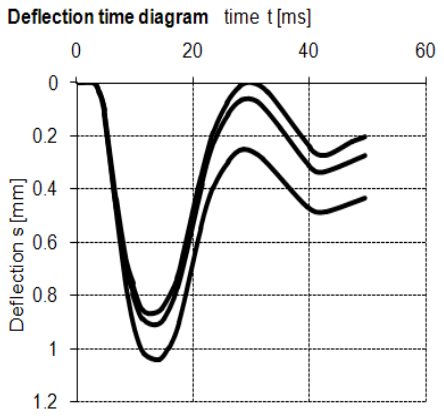
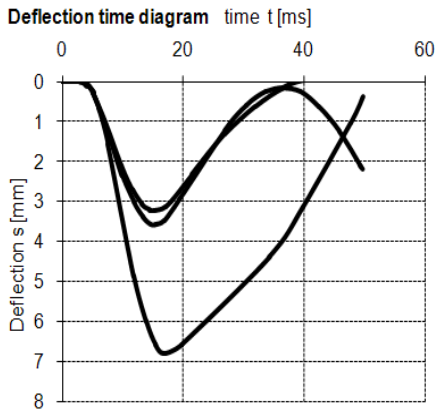
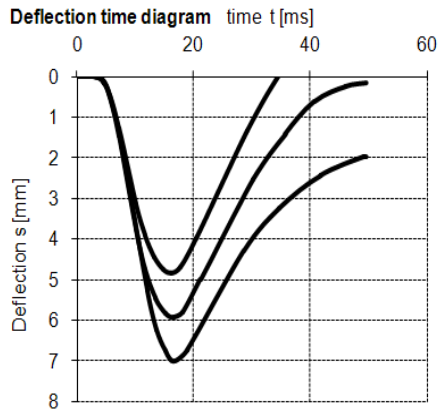

FWA-5E



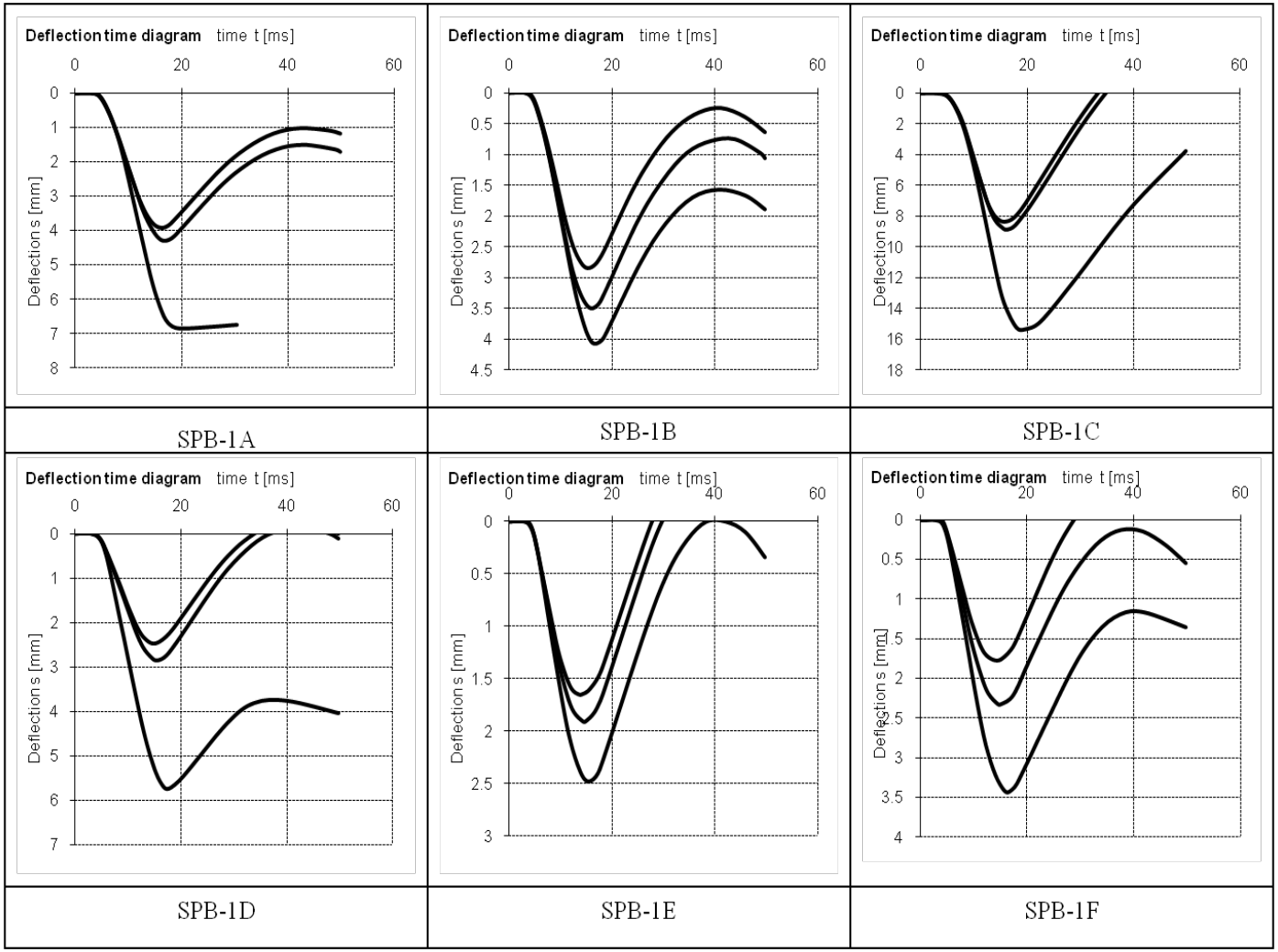

FWA-5F

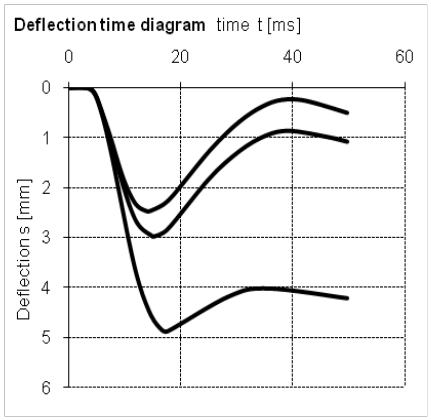



FWA-5G

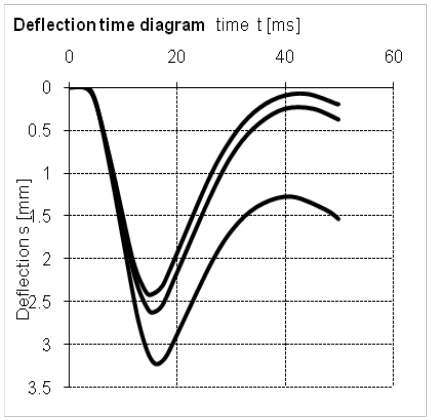
| | | |
|---|---|---|
|  |  |  |
| FWA-5H | FWA-5I | FWA-5J |

### 3.7. Sabina Point: 23 May 2009-SPB-1 Series

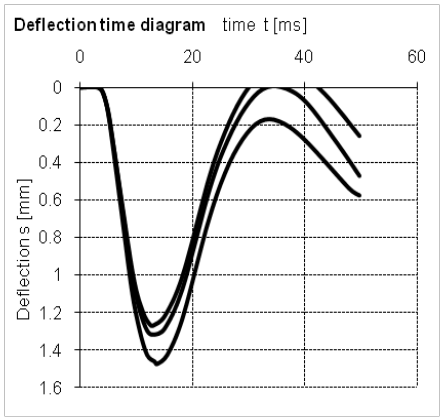




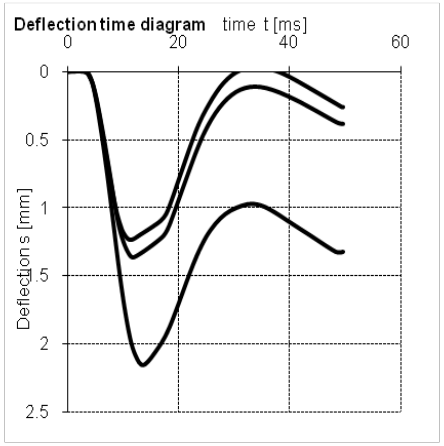

SPB-1G



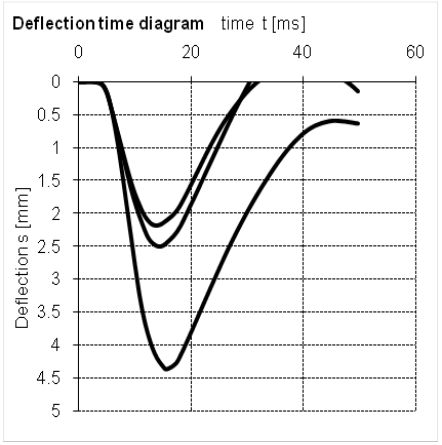

SPB-1H



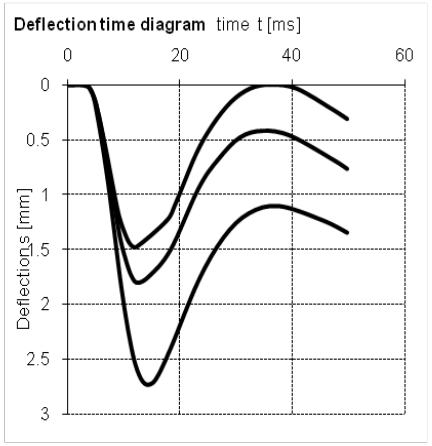

SPB-1I



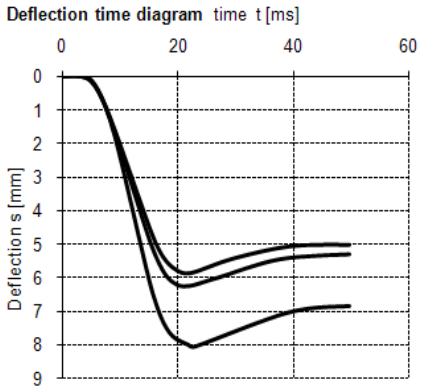

SPB-1J



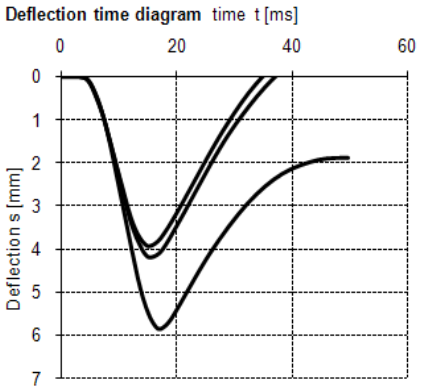

SPB-1K



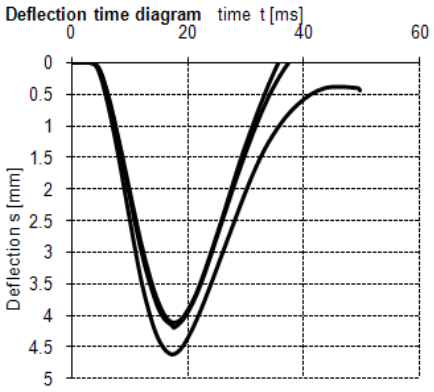

SPB-1L



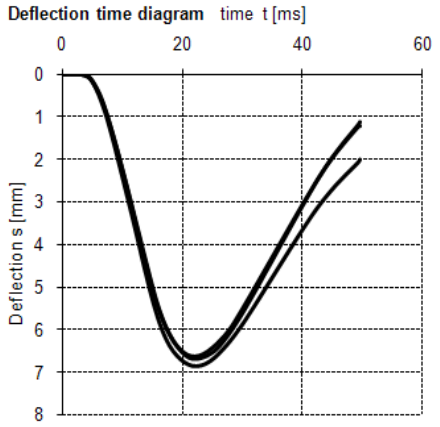

SPB-1M




SPB-1N

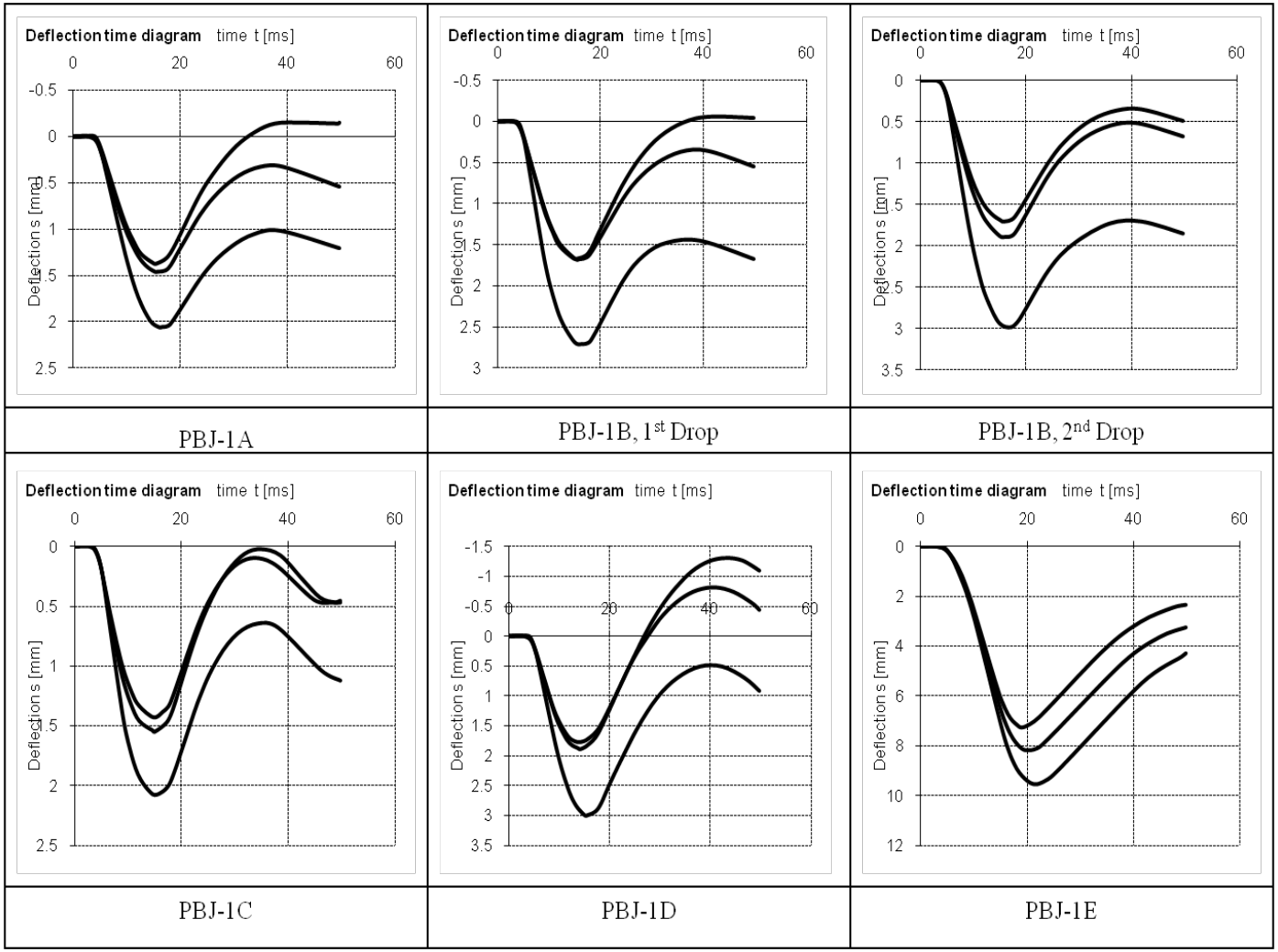


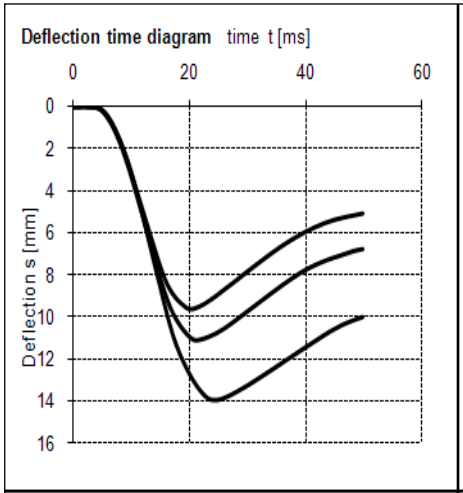

SPB-1O



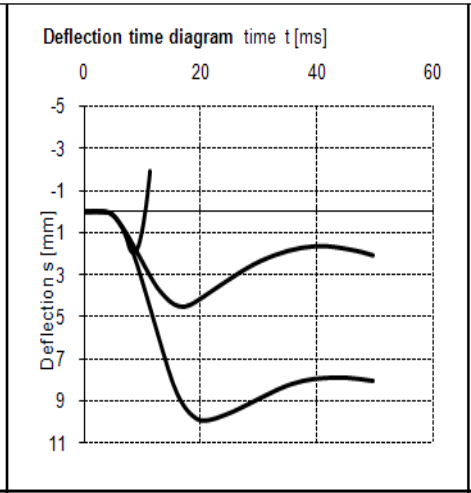

SPB-1P

### 3.8. Cape Clinton Pocket Beach: 28 May 2009-PBJ-1 Series

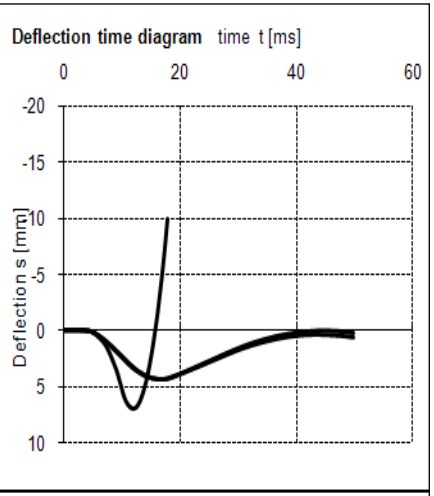





PBJ-1F




PBJ-1G, 1st Drop




PBJ-1G, 2nd Drop

# APPENDIX G

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## California Bearing Ratio

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## 1. Introduction

California Bearing Ratio (CBR) is used as an empirical measurement of shear strength, one of the two failure mechanisms of soil under load. Combat engineers from Marine Wing Support Squadrons determine soil strength or bearing capacity values for expeditionary airfields before the beginning of aircraft operations. At bases and stations, physical scientists or specially trained civil engineer personnel may conduct these evaluations. In hostile situations, combat engineers attempt to conduct the evaluations under adverse conditions. Basically, the engineers determine strength using a Dynamic Cone Penetrometer (DCP), and then correlate the DCP readings to a CBR value for use in supporting operations.

The DCP is the current USMC and USAF standard for measurement of bearing strength for airfields. The use of the DCP is described in ASTM D 6951-03 (American Society for Testing and Materials 2003). The dual-mass DCP consists of a 5/8-in.-diameter steel rod with a steel cone attached to one end, which is driven into the soil by means of a sliding dual-mass hammer. The angle of the cone is 60°, and the diameter of the base of the cone is 0.79 in. For TS09, the DCP was driven into the ground by dropping a 10.1-lb sliding hammer from a height of 22.6 in. The depth of cone penetration is measured at selected penetration or hammer-drop intervals and the soil shear strength is reported as the DCP index in millimeters/blow. Dynamic Cone Penetrometer test data are recorded in two columns, where the first column is number of blows and the second column is cumulative penetration in mm. In accordance with Army Field Manuals, CBR is computed using the following empirical equations

$$CBR = 292 / PR^{1.12}$$

$$\text{CL soils: } CBR < 10: CBR = 1 / (0.017019*PR)^2$$

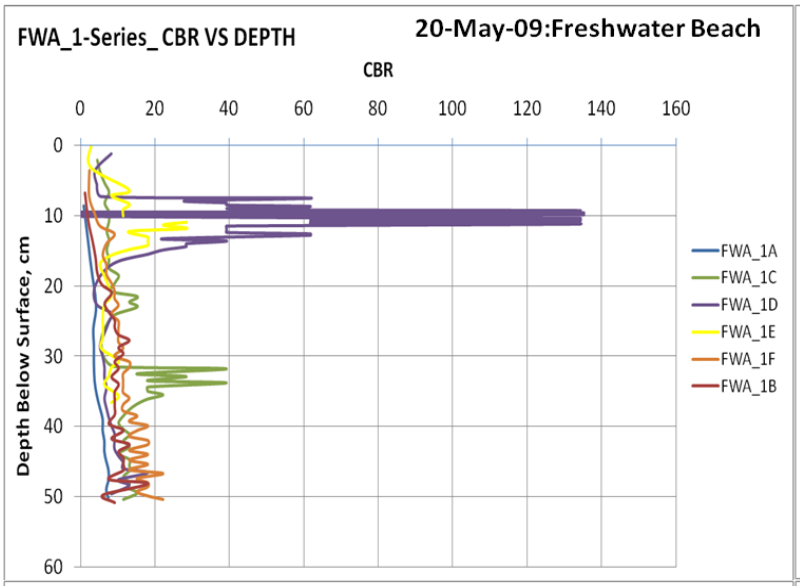
$$\text{CH soils: } CBR = 1/ (0.002871*PR)$$

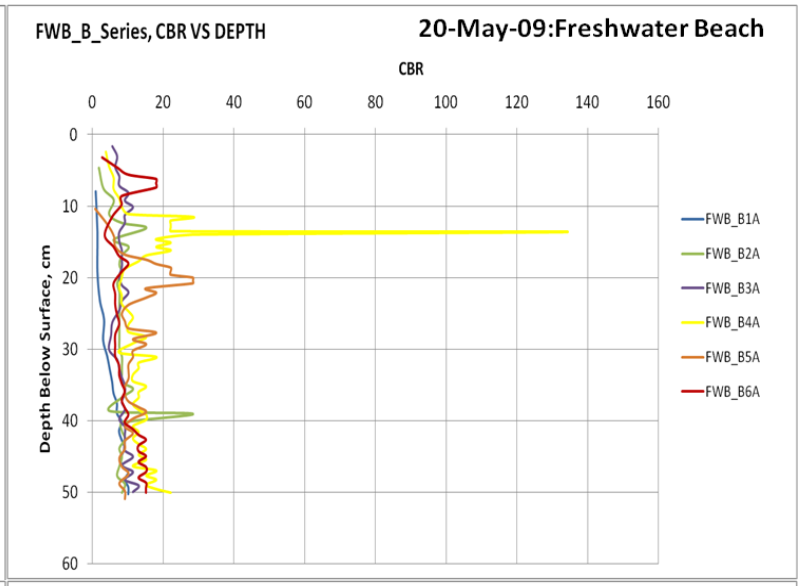
where

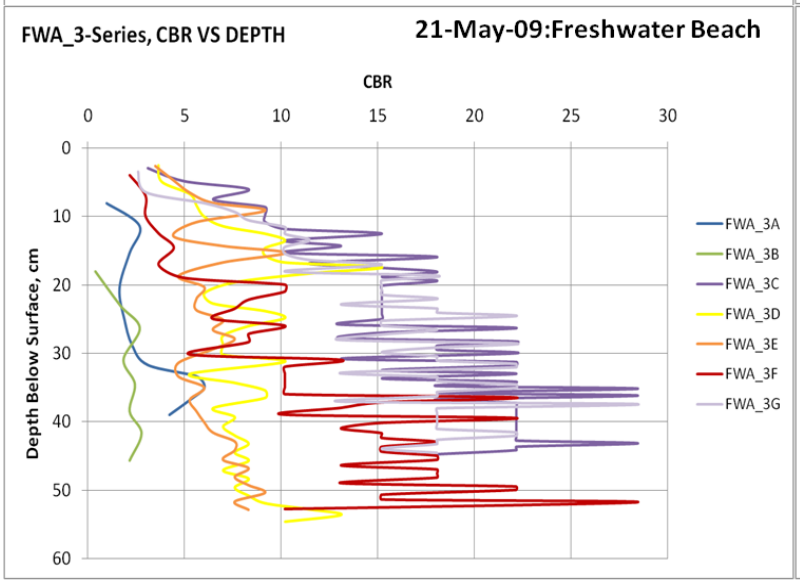
- PR is the DCP penetration rate in mm per blow.
- CL soils are gravelly clays, sandy clays, silty clays, and lean clays.
- CH soils are inorganic clays of high plasticity, including fat clays, gumbo clays, volcanic clays, and bentonite.

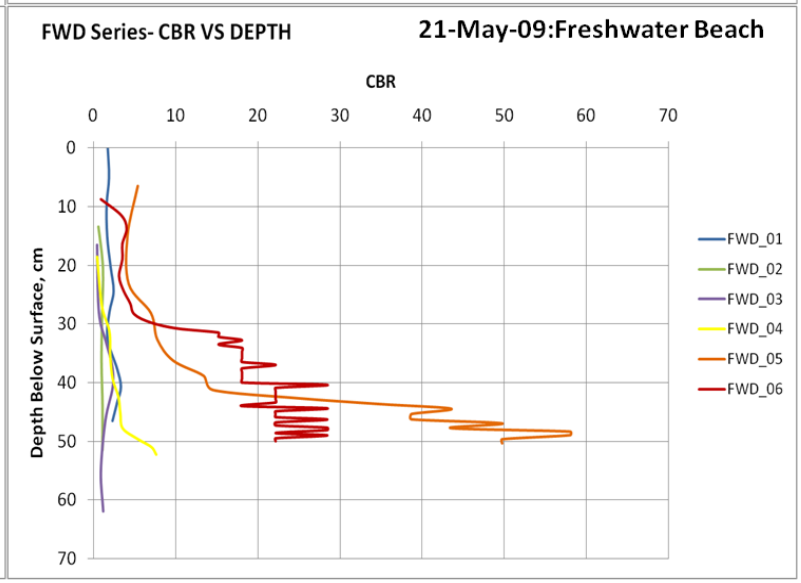
TS09 demonstrated the utility of measuring CBR as a component of littoral penetration point classification and as a trafficability parameter. The CBR was plotted against depth (cm) and can be seen below in Section 2 for each substrate sample position where GPS was used to record position on the coast. In the graphs on the following pages, the CBR is plotted on the x-axis and the depth below the surface in centimeters is plotted on the y-axis. Please note the x and y axes' scale changes among the figures.

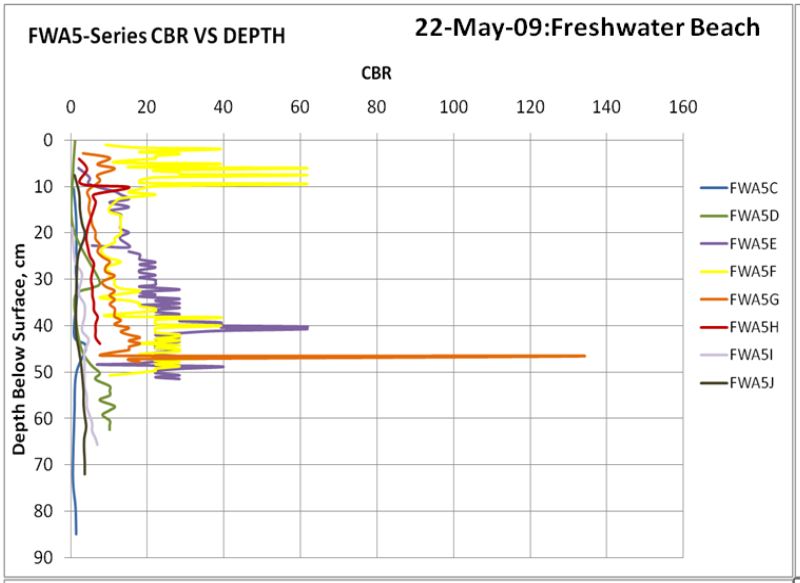
## 2. California Bearing Ratio Figures

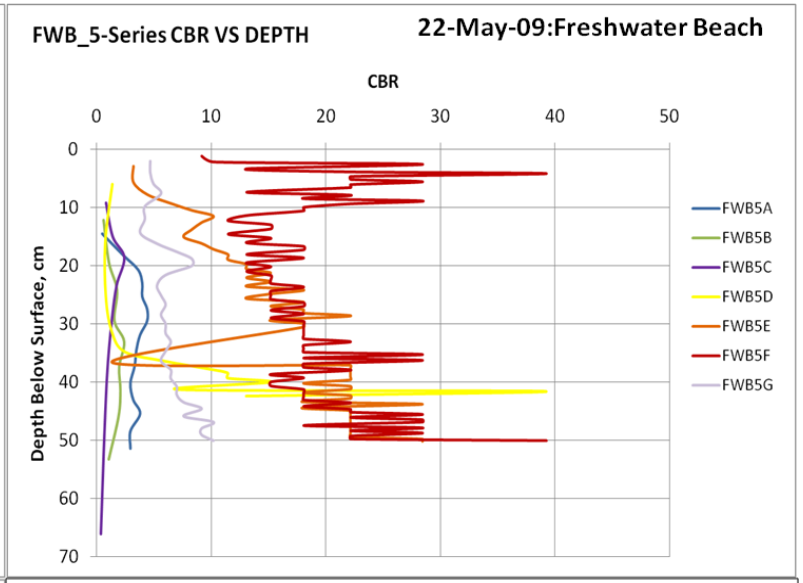


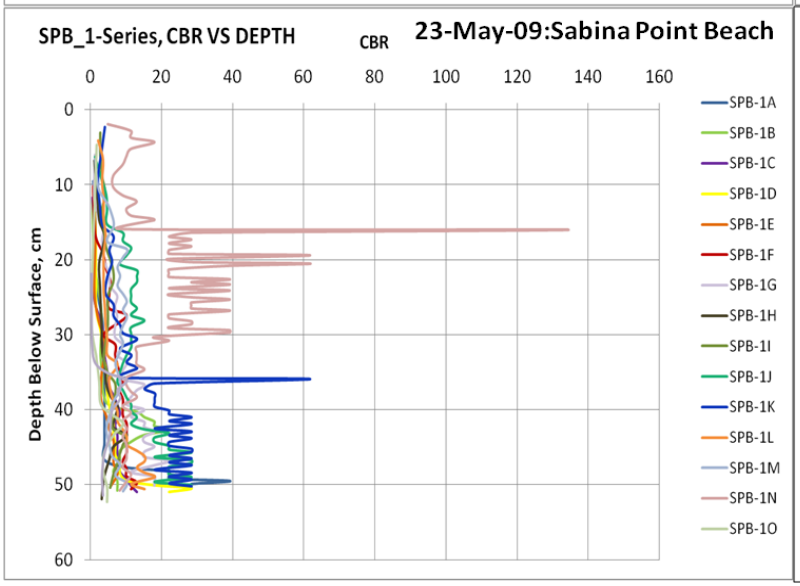



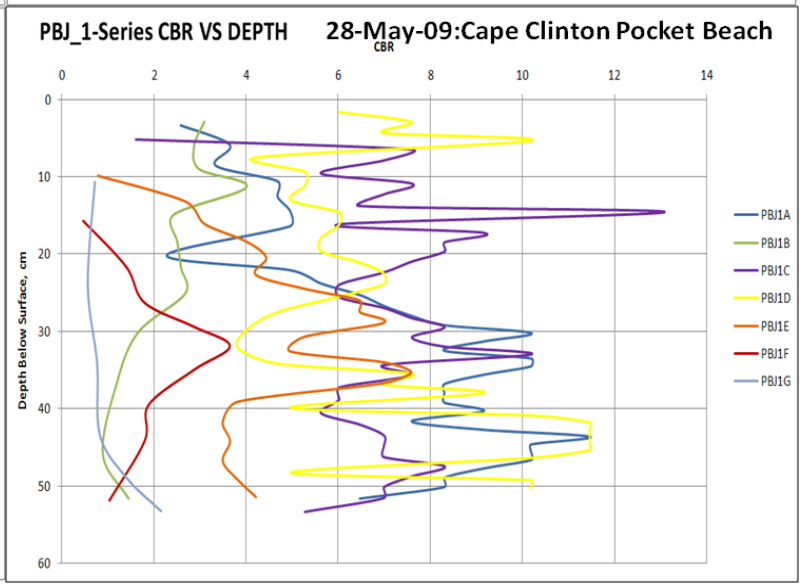




FWA5-Series CBR VS DEPTH
22-May-09:Freshwater Beach
CBR
0 20 40 60 80 100 120 140 160
Depth Below Surface, cm
0 10 20 30 40 50 60 70 80 90
FWA5C
FWA5D
FWA5E
FWA5F
FWA5G
FWA5H
FWA5I
FWA5J


FWB_5-Series CBR VS DEPTH
22-May-09:Freshwater Beach
CBR
0 10 20 30 40 50
Depth Below Surface, cm
0 10 20 30 40 50 60 70
FWB5A
FWB5B
FWB5C
FWB5D
FWB5E
FWB5F
FWB5G


SPB_1-Series, CBR VS DEPTH
CBR
23-May-09:Sabina Point Beach
0 20 40 60 80 100 120 140 160
Depth Below Surface, cm
0 10 20 30 40 50 60
SPB-1A
SPB-1B
SPB-1C
SPB-1D
SPB-1E
SPB-1F
SPB-1G
SPB-1H
SPB-1I
SPB-1J
SPB-1K
SPB-1L
SPB-1M
SPB-1N
SPB-1O


PBJ_1-Series CBR VS DEPTH
28-May-09:Cape Clinton Pocket Beach
CBR
0 2 4 6 8 10 12 14
Depth Below Surface, cm
0 10 20 30 40 50 60
PBJ1A
PBJ1B
PBJ1C
PBJ1D
PBJ1E
PBJ1F
PBJ1G

# APPENDIX H

## Other Soil Properties

## 1. Introduction

Determining beach composition was an essential TS'09 task involving the collection of "grab samples" across the beach. Two of four standard soil tests were accomplished: (1) moisture content determinations and (2) grading or sieve analysis. Future studies will include (3) basic properties tests, and (4) density standards and density determination tests. Sample locations were chosen that were representative of regions such as the beach face, foreshore, dune field, low marsh, high marsh, etc. If there was a major change in soil type, then the area was broken into sub-sites for sampling. Soil samples were collected with a corer to a critical depth of 3 inches (7.62cm). Samples are collected as quickly as possible and stored in either zip-loc bags or sediment corer tubes. This prevents the loss of moisture to evaporation. When possible, samples were placed in a cooler to keep the samples at a moderate temperature. Samples were then taken to the lab to determine soil moisture and grain size distributions.

## 2. Soil Moisture Determination

### 2.1 Preparing the Soil Samples

After soil samples were taken to the lab, quick and careful procedures were taken to determine soil moisture. The moisture content is expressed as a percentage and is the mass of water divided by the dry mass of soil times one hundred. The following steps occurred:

1. We opened windows to ensure good ventilation because of fumes from microwave baking of soil samples.
2. The weighing container was weighed prior to putting soil on the container. This value is needed for the calculation of soil moisture.
3. Approximately 25 grams of wet/moist soil were placed on the container and the weight of soil and container were measured.
4. Drying the sample was done with a microwave oven. The microwave oven is faster for drying then using a field moisture oven. The appropriate steps for drying with a microwave oven are as follows:

### 2.2 Soil Sample Drying in a Microwave Oven

A. Place sample into microwave with a heat sink (brick) and run the microwave oven for 6 minutes.
B. Weigh the sample and return to microwave oven for 1 minute and reweigh. If the weight of the sample has changed, return to the microwave oven for 1 more minute.
C. Repeat the process until a constant weight is achieved.
D. Record the following measurements

- (net weight) - (weight of container) = net soil weight
- (dry weight) - (weight of container) = dry soil weight
- (net soil weight) - (dry soil weight) = water weight

- (water weight) ÷ (dry soil weight) = soil water content

(Typical drying times for a wet sample are less than 20 minutes. Water is the first component of the soil to heat and evaporate. If the sample is dry and microwave drying continues, the soil temperature will increase and oxidize organic matter. This is to be avoided as it would bias results.)

**3. Grain Size Distributions**

After soil moisture is determined, samples are graded using a stack of appropriately sized sieves. For civil engineering applications, a certain series of sizes has come to be standard. Those most commonly used to grade materials have openings varying from 125mm down to 0.075mm and are stacked one on top of the other; in our experiments we added sieves for particles as small as 0.027 mm (27 microns) (Tests are often described by identifying sieve sizes by their opening in millimeters followed by English aperture size: for example, 4.75mm (No. 4) sieve. All sieves have square openings.) For beach composition, the grading analysis is the most important of all the soil tests, since factors such as beach gradient can be estimated from grain size. In order to grade the sample properly, the sieving operation uses a mechanical shaker to obtain lateral, vertical, and jarring actions, which keep the sample moving continuously over the surface of the sieve. After sufficient shaking, the mass of each sieve size is determined on a scale or balance. Then, the total percentage of material passing each sieve is calculated. Percentages are calculated to the nearest whole number except for the amount of material finer than the 0.075mm (No. 200) sieve, which is reported to the nearest 0.1 percent. If the total amount of material finer than 0.075 mm (No. 200) sieve is desired, it is determined by adding the mass of material passing the 0.075mm (No. 200) sieve by dry sieving.

**4. TS09 Data**

Soil moisture and grain size data are provided below. Section 4.1 displays soil moisture data in tabular format (Tables 1-4). Section 4.2 displays soil grain size distributions in tabular format (Tables 5-9). In section 4.3, graphs display soil grain size distribution data with sieve size on the x-axis and % of weight on the y-axis.

## 4.1 Soil Moisture Data

**Table 1. 20 May 2009- 21 May 2009. Freshwater Beach Soil Water %.**

| Date | Sample Name | Sample Depth (in) | Total Sample Wet Wt in bag (g) | Total Sample Dry Wt in bag (g) | Total Sample Water (%) |
|---|---|---|---|---|---|
| 20 May 2009 | FWA-1A | 3" | 575 | 560 | 2.68 |
| 20 May 2009 | FWA-1B | 3" | 460 | 445 | 3.37 |
| 20 May 2009 | FWA-1C | 3" | 555 | 430 | 29.07 |
| 20 May 2009 | FWA-1D | 3" | 310 | 245 | 26.53 |
| 20 May 2009 | FWA-1E | 3" | 505 | 400 | 26.25 |
| 20 May 2009 | FWA-1F | 3" | 473 | 370 | 27.84 |
| 20 May 2009 | FWB-01 | 3" | 480 | 465 | 3.23 |
| 20 May 2009 | FWB-02 | 3" | 470 | 375 | 25.33 |
| 20 May 2009 | FWB-03 | 3" | 635 | 510 | 24.51 |
| 20 May 2009 | FWB-04 | 3" | 510 | 395 | 29.11 |
| 20 May 2009 | FWB-05 | 3" | 400 | 300 | 33.33 |
| 20 May 2009 | FWB-06 | 3" | 570 | 450 | 26.67 |
| 21 May 2009 | FWA-3A | 3" | 720 | 705 | 2.13 |
| 21 May 2009 | FWA-3B | 3" | 597 | 575 | 3.83 |
| 21 May 2009 | FWA-3C | 3" | 860 | 700 | 22.86 |
| 21 May 2009 | FWA-3D | 3" | 721 | 595 | 21.18 |
| 21 May 2009 | FWA-3E | 3" | 785 | 635 | 23.62 |
| 21 May 2009 | FWA-3F | 3" | 448 | 370 | 21.08 |
| 21 May 2009 | FWA-3G | 3" | 667 | 540 | 23.52 |
| 21 May 2009 | FWD-01 | 3" | 458 | 445 | 2.92 |
| 21 May 2009 | FWD-02 | 3" | 545 | 525 | 3.81 |
| 21 May 2009 | FWD-03 | 3" | 730 | 695 | 5.04 |
| 21 May 2009 | FWD-04 | 3" | 520 | 505 | 2.97 |
| 21 May 2009 | FWD-05 | 3" | 800 | 760 | 5.26 |
| 21 May 2009 | FWD-06 | 3" | 540 | 475 | 13.68 |

**Table 2. 22 May 2009. Freshwater Beach Soil Water %..**

| Date | Sample Name | Sample Depth (in) | Total Sample Wet Wt in bag (g) | Total Sample Dry Wt in bag (g) | Total Sample Water (%) |
|---|---|---|---|---|---|
| 22 May 2009 | FWA-5J | 3" | 590 | 565 | 4.42 |
| 22 May 2009 | FWA-5I | 3" | 385 | 360 | 6.94 |
| 22 May 2009 | FWA-5A | 3" | 650 | 610 | 6.56 |
| 22 May 2009 | FWA-5B | 3" | 720 | 675 | 6.67 |
| 22 May 2009 | FWA-5C | 3" | 455 | 420 | 8.33 |
| 22 May 2009 | FWA-5D | 3" | 540 | 510 | 5.88 |
| 22 May 2009 | FWA-5E | 3" | 685 | 545 | 25.69 |
| 22 May 2009 | FWA-5F | 3" | 610 | 520 | 17.31 |
| 22 May 2009 | FWA-5G | 3" | 745 | 595 | 25.21 |
| 22 May 2009 | FWA-5H | 3" | 795 | 645 | 23.26 |
| 22 May 2009 | FWB-5A | 3" | 430 | 405 | 6.17 |
| 22 May 2009 | FWB-5B | 3" | 485 | 445 | 8.99 |
| 22 May 2009 | FWB-5C | 3" | 610 | 565 | 7.96 |
| 22 May 2009 | FWB-5D | 3" | 465 | 430 | 8.14 |
| 22 May 2009 | FWB-5E | 3" | 580 | 445 | 30.34 |
| 22 May 2009 | FWB-5F | 3" | 355 | 290 | 22.41 |
| 22 May 2009 | FWB-5G | 3" | 655 | 565 | 15.93 |

**Table 3. 23 May 2009. Sabina Point Soil Water %.**

| Date | Sample Name | Sample Depth (in) | Total Sample Wet Wt in bag (g) | Total Sample Dry Wt in bag (g) | Total Sample Water (%) |
|---|---|---|---|---|---|
| 23 May 2009 | SPB-1A | 3" | 388 | 388 | 0.00 |
| 23 May 2009 | SPB-1B | 3" | 450 | 445 | 1.12 |
| 23 May 2009 | SPB-1C | 3" | 490 | 475 | 3.16 |
| 23 May 2009 | SPB-1D | 3" | 375 | 360 | 4.17 |
| 23 May 2009 | SPB-1E | 3" | 300 | 290 | 3.45 |
| 23 May 2009 | SPB-1F | 3" | 430 | 420 | 2.38 |
| 23 May 2009 | SPB-1G | 3" | 465 | 385 | 20.78 |
| 23 May 2009 | SPB-1H | 3" | 490 | 400 | 22.50 |
| 23 May 2009 | SPB-1I | 3" | 560 | 435 | 28.74 |
| 23 May 2009 | SPB-1J | 3" | 555 | 475 | 16.84 |
| 23 May 2009 | SPB-1K | 3" | 560 | 480 | 16.67 |
| 23 May 2009 | SPB-1L | 3" | 625 | 505 | 23.76 |
| 23 May 2009 | SPB-1M | 3" | 500 | 345 | 44.93 |
| 23 May 2009 | SPB-1N | 3" | 555 | 415 | 33.73 |
| 23 May 2009 | SPB-1O | 3" | 570 | 450 | 26.67 |
| 23 May 2009 | SPB-1P | 3" | 320 | 250 | 28.00 |

**Table 4. 28 May 2009. Cape Clinton Pocket Beach Soil Water %.**

| Date | Sample Name | Sample Depth (in) | Total Sample Wet Wt in bag (g) | Total Sample Dry Wt in bag (g) | Total Sample Water (%) |
|---|---|---|---|---|---|
| 28 May 2009 | PBJ-1A | 3" | 803 | 608 | 32.07 |
| 28 May 2009 | PBJ-1B | 3" | 590.6 | 447.5 | 31.98 |
| 28 May 2009 | PBJ-1C | 3" | 534.8 | 407.5 | 31.24 |
| 28 May 2009 | PBJ-1D | 3" | 517.6 | 402.4 | 28.63 |
| 28 May 2009 | PBJ-1E | 3" | 484.7 | 384.7 | 25.99 |
| 28 May 2009 | PBJ-1F | 3" | 334.4 | 295 | 13.36 |
| 28 May 2009 | PBJ-1G | 3" | 401.5 | 378.1 | 6.19 |

## 4.2 Soil Grain Size Distribution Data

**Table 5. 20 May 2009. Freshwater Beach Soil Grain Size Distribution.**

| Date | Sample Name | Soil Grain Size Distribution (%) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 600um | 425um | 300um | 150um | 106um | 90um | 75um | 63um | 45um | 27um | pan |
| 20 May 2009 | FWA-1A | 0.05 | 0.18 | 6.36 | 80.37 | 12.25 | 0.54 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 May 2009 | FWA-1B | 0.07 | 0.43 | 4.05 | 88.82 | 6.38 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 May 2009 | FWA-1C | 2.66 | 2.29 | 8.61 | 56.57 | 27.71 | 1.75 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 May 2009 | FWA-1D | 17.35 | 7.47 | 14.62 | 42.26 | 15.19 | 1.76 | 0.57 | 0.24 | 0.09 | 0.07 | 0.16 |
| 20 May 2009 | FWA-1E | 32.34 | 4.39 | 7.71 | 36.66 | 14.81 | 2.37 | 1.00 | 0.32 | 0.09 | 0.09 | 0.12 |
| 20 May 2009 | FWA-1F | 10.13 | 4.29 | 10.13 | 56.70 | 15.00 | 2.42 | 0.74 | 0.19 | 0.09 | 0.09 | 0.14 |
| 20 May 2009 | FWB-01 | 0.41 | 0.06 | 1.75 | 82.14 | 15.15 | 0.49 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 May 2009 | FWB-02 | 0.00 | 2.23 | 6.22 | 78.08 | 13.46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 May 2009 | FWB-03 | 4.00 | 4.23 | 10.87 | 69.92 | 10.28 | 0.55 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 May 2009 | FWB-04 | 6.11 | 3.82 | 8.35 | 50.89 | 27.99 | 2.67 | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 May 2009 | FWB-05 | 9.95 | 3.23 | 6.72 | 52.72 | 24.28 | 2.41 | 0.63 | 0.07 | 0.00 | 0.00 | 0.00 |
| 20 May 2009 | FWB-06 | 6.77 | 4.81 | 10.80 | 55.65 | 19.39 | 2.05 | 0.53 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table 6. 21 May 2009. Freshwater Beach Soil Grain Size Distribution.**

| Date | Sample Name | Soil Grain Size Distribution (%) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 600um | 425um | 300um | 150um | 106um | 90um | 75um | 63um | 45um | 27um | pan |
| 21 May 2009 | FWA-3A | 0.01 | 0.06 | 1.41 | 85.30 | 6.58 | 4.17 | 2.08 | 0.34 | 0.02 | 0.00 | 0.00 |
| 21 May 2009 | FWA-3B | 0.22 | 0.35 | 3.31 | 88.09 | 6.42 | 0.83 | 0.69 | 0.09 | 0.00 | 0.00 | 0.00 |
| 21 May 2009 | FWA-3C | 1.43 | 1.23 | 2.78 | 81.63 | 12.17 | 0.54 | 0.16 | 0.04 | 0.00 | 0.00 | 0.00 |
| 21 May 2009 | FWA-3D | 11.09 | 6.14 | 22.16 | 59.58 | 0.79 | 0.05 | 0.03 | 0.05 | 0.04 | 0.04 | 0.03 |
| 21 May 2009 | FWA-3E | 6.79 | 5.74 | 18.53 | 67.54 | 1.32 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 21 May 2009 | FWA-3F | 8.69 | 9.05 | 22.06 | 56.89 | 2.53 | 0.16 | 0.14 | 0.14 | 0.07 | 0.09 | 0.14 |
| 21 May 2009 | FWA-3G | 11.47 | 25.08 | 35.31 | 27.04 | 0.91 | 0.02 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| 21 May 2009 | FWD-01 | 0.26 | 0.40 | 1.39 | 89.02 | 5.27 | 2.23 | 1.28 | 0.15 | 0.00 | 0.00 | 0.00 |
| 21 May 2009 | FWD-02 | 0.06 | 0.13 | 2.22 | 79.64 | 13.97 | 3.08 | 0.89 | 0.00 | 0.00 | 0.00 | 0.00 |
| 21 May 2009 | FWD-03 | 0.29 | 0.46 | 5.19 | 80.92 | 6.79 | 3.87 | 2.25 | 0.23 | 0.00 | 0.00 | 0.00 |
| 21 May 2009 | FWD-04 | 0.08 | 0.29 | 4.60 | 92.25 | 1.95 | 0.65 | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 |
| 21 May 2009 | FWD-05 | 0.14 | 0.72 | 3.84 | 94.91 | 0.33 | 0.00 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 |
| 21 May 2009 | FWD-06 | 0.52 | 1.89 | 6.78 | 90.56 | 0.21 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.02 |

**Table 7. 22 May 2009. Freshwater Beach Soil Grain Size Distribution.**

| Date | Sample Name | Soil Grain Size Distribution (%) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 600um | 425um | 300um | 150um | 106um | 90um | 75um | 63um | 45um | 27um | pan |
| 22 May 2009 | FWA-5A | 0.15 | 0.05 | 1.22 | 86.52 | 6.66 | 3.11 | 1.96 | 0.29 | 0.02 | 0.00 | 0.00 |
| 22 May 2009 | FWA-5B | 0.04 | 0.01 | 1.23 | 95.11 | 1.86 | 0.97 | 0.65 | 0.10 | 0.00 | 0.00 | 0.00 |
| 22 May 2009 | FWA-5C | 0.31 | 0.40 | 1.78 | 59.67 | 21.91 | 10.16 | 5.09 | 0.68 | 0.00 | 0.00 | 0.00 |
| 22 May 2009 | FWA-5D | 15.92 | 0.30 | 1.04 | 80.07 | 2.32 | 0.02 | 0.06 | 0.08 | 0.07 | 0.05 | 0.06 |
| 22 May 2009 | FWA-5E | 0.70 | 0.48 | 3.21 | 91.77 | 3.50 | 0.31 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 |
| 22 May 2009 | FWA-5F | 41.65 | 1.13 | 4.43 | 50.50 | 1.81 | 0.04 | 0.09 | 0.09 | 0.07 | 0.09 | 0.09 |
| 22 May 2009 | FWA-5G | 2.35 | 1.48 | 6.52 | 86.40 | 2.90 | 0.30 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 |
| 22 May 2009 | FWA-5H | 9.12 | 2.90 | 11.45 | 72.64 | 3.54 | 0.31 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 |
| 22 May 2009 | FWA-5I | 0.54 | -0.06 | -0.17 | 79.85 | 18.43 | 0.71 | 0.14 | 0.14 | 0.09 | 0.09 | 0.14 |
| 22 May 2009 | FWA-5J | 0.88 | 0.21 | 0.54 | 94.25 | 3.66 | 0.02 | 0.21 | 0.05 | 0.07 | 0.05 | 0.05 |
| 22 May 2009 | FWB-5A | 1.11 | 0.62 | 3.13 | 89.34 | 5.45 | 0.07 | 0.05 | 0.05 | 0.05 | 0.05 | 0.07 |
| 22 May 2009 | FWB-5B | 0.31 | 0.34 | 0.85 | 77.64 | 14.09 | 5.55 | 0.97 | 0.09 | 0.04 | 0.05 | 0.07 |
| 22 May 2009 | FWB-5C | 0.28 | 0.16 | 2.04 | 66.73 | 20.28 | 7.84 | 2.35 | 0.14 | 0.05 | 0.07 | 0.07 |
| 22 May 2009 | FWB-5D | 0.30 | 0.35 | 3.35 | 87.12 | 7.28 | 1.35 | 0.05 | 0.05 | 0.05 | 0.05 | 0.07 |
| 22 May 2009 | FWB-5E | 0.22 | 0.75 | 2.61 | 91.19 | 4.65 | 0.44 | 0.07 | 0.02 | 0.02 | 0.02 | 0.02 |
| 22 May 2009 | FWB-5F | 11.94 | 1.38 | 3.67 | 80.44 | 2.04 | -0.03 | 0.10 | 0.14 | 0.05 | 0.05 | 0.10 |
| 22 May 2009 | FWB-5G | 5.47 | 2.28 | 10.80 | 78.28 | 2.83 | 0.14 | 0.02 | 0.04 | 0.05 | 0.05 | 0.05 |

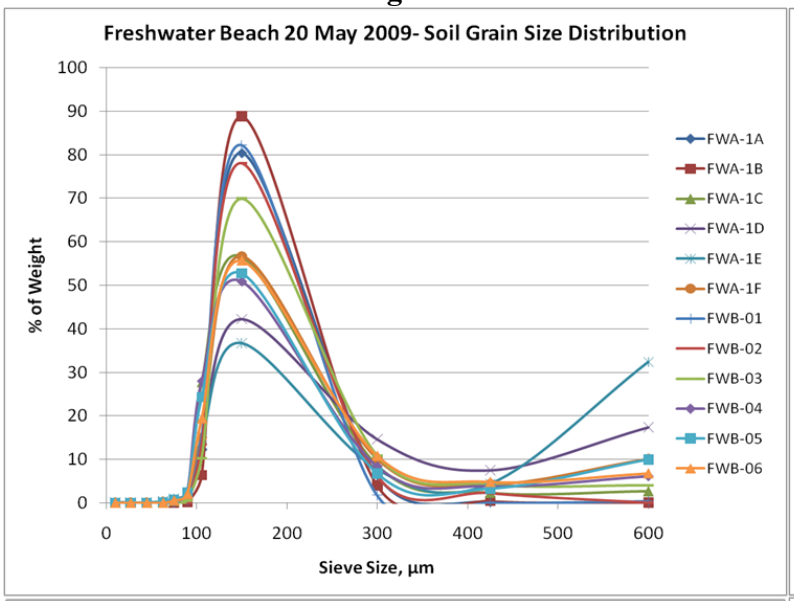
**Table 8. 23 May 2009. Sabina Point Soil Grain Size Distribution.**

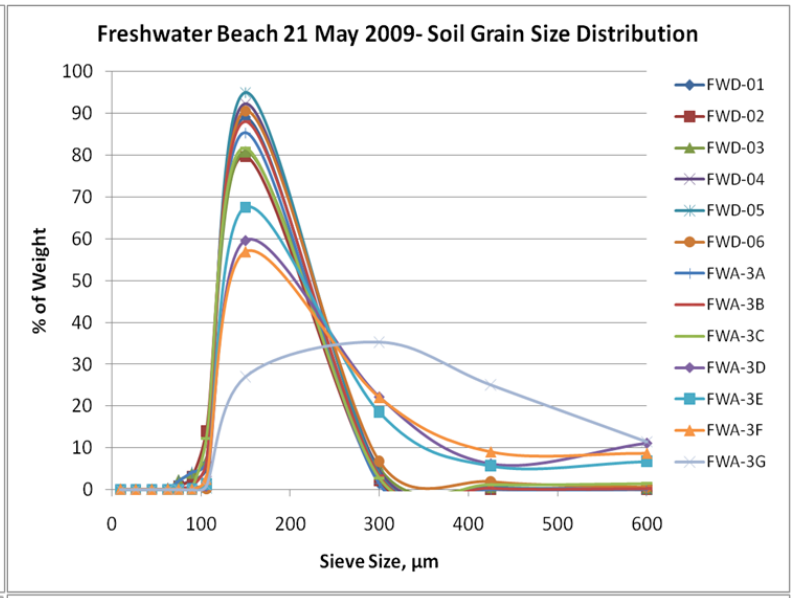
| Date | Sample Name | Soil Grain Size Distribution (%) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 600um | 425um | 300um | 150um | 106um | 90um | 75um | 63um | 45um | 27um | pan |
| 23 May 2009 | SPB-1A | 2.11 | 23.18 | 59.25 | 15.46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 May 2009 | SPB-1B | 59.22 | 31.54 | 8.69 | 0.50 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 May 2009 | SPB-1C | 51.32 | 34.45 | 12.43 | 1.63 | 0.06 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 May 2009 | SPB-1D | 57.32 | 31.48 | 10.06 | 1.09 | 0.03 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 May 2009 | SPB-1E | 21.64 | 48.91 | 27.82 | 1.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 May 2009 | SPB-1F | 71.40 | 22.47 | 5.62 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 May 2009 | SPB-1G | 21.79 | 42.70 | 29.99 | 5.41 | 0.08 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 May 2009 | SPB-1H | 35.27 | 34.03 | 27.02 | 3.54 | 0.08 | 0.03 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 May 2009 | SPB-1I | 27.07 | 28.70 | 33.29 | 10.05 | 0.82 | 0.05 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 |
| 23 May 2009 | SPB-1J | 33.71 | 9.72 | 30.82 | 22.06 | 2.55 | 0.47 | 0.21 | 0.13 | 0.11 | 0.02 | 0.02 |
| 23 May 2009 | SPB-1K | 54.95 | 5.78 | 24.08 | 12.84 | 1.81 | 0.27 | 0.12 | 0.08 | 0.00 | 0.00 | 0.00 |
| 23 May 2009 | SPB-1L | 13.03 | 15.79 | 50.35 | 18.85 | 1.86 | 0.12 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 May 2009 | SPB-1M | 12.78 | 9.94 | 36.93 | 26.93 | 6.86 | 1.63 | 1.25 | 1.07 | 0.41 | 0.11 | 0.17 |
| 23 May 2009 | SPB-1N | 11.74 | 5.29 | 40.22 | 33.89 | 6.29 | 0.83 | 0.58 | 0.51 | 0.14 | 0.09 | 0.12 |
| 23 May 2009 | SPB-1O | 1.84 | 2.15 | 30.56 | 53.96 | 10.15 | 0.89 | 0.29 | 0.13 | 0.00 | 0.00 | 0.00 |
| 23 May 2009 | SPB-1P | 3.36 | 2.84 | 30.27 | 53.66 | 8.64 | 1.00 | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 |

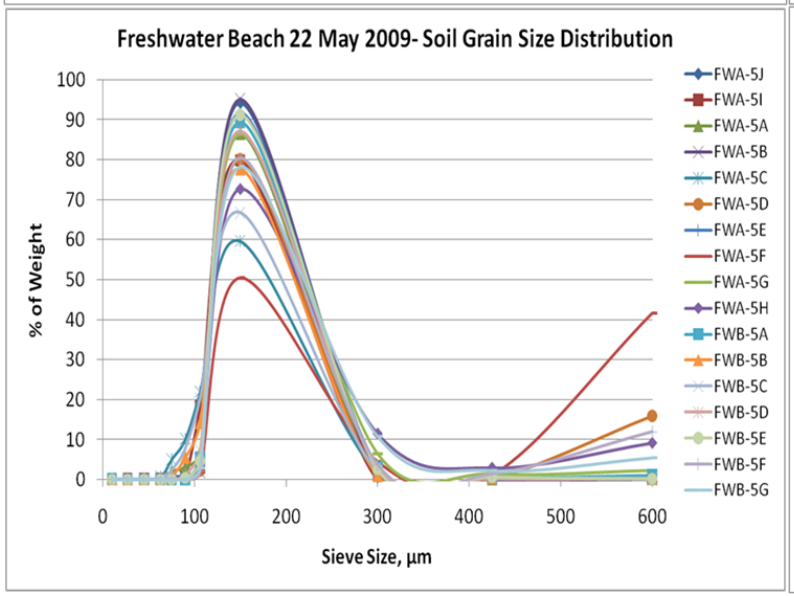
**Table 9. 28 May 2009. Cape Clinton Pocket Beach Soil Grain Size Distribution.**

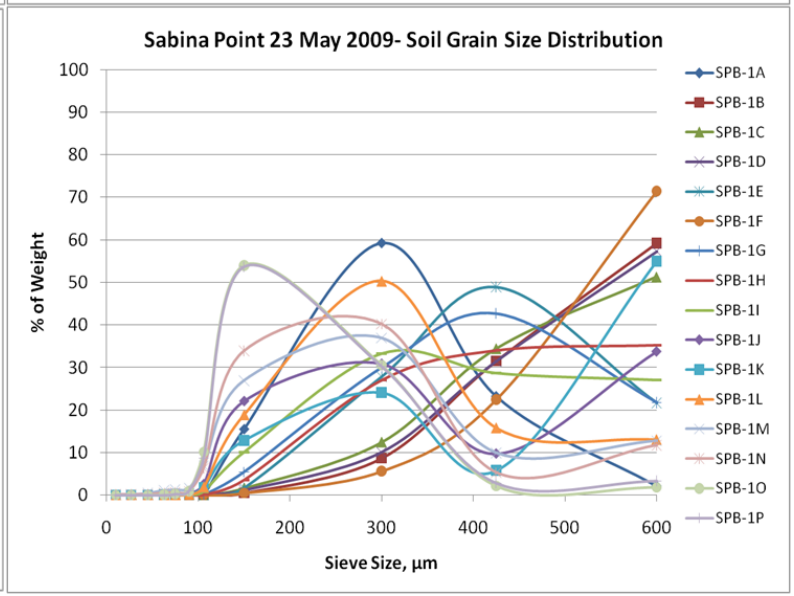
| Date | Sample Name | Soil Grain Size Distribution (%) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 600um | 425um | 300um | 150um | 106um | 90um | 75um | 63um | 45um | 27um | pan |
| 28 May 2009 | PBJ-1A | 0.54 | 0.57 | 1.28 | 53.07 | 38.91 | 3.86 | 0.97 | 0.28 | 0.20 | 0.20 | 0.18 |
| 28 May 2009 | PBJ-1B | 0.67 | 1.12 | 1.97 | 54.29 | 37.60 | 3.20 | 0.65 | 0.16 | 0.11 | 0.09 | 0.11 |
| 28 May 2009 | PBJ-1C | 0.94 | 0.27 | 0.55 | 37.73 | 55.59 | 3.87 | 0.65 | 0.12 | 0.07 | 0.07 | 0.10 |
| 28 May 2009 | PBJ-1D | 0.80 | 0.85 | 1.52 | 55.25 | 37.80 | 3.25 | 0.28 | 0.05 | 0.05 | 0.05 | 0.08 |
| 28 May 2009 | PBJ-1E | 0.50 | 0.26 | 1.15 | 31.41 | 60.74 | 4.34 | 1.23 | 0.13 | 0.07 | 0.05 | 0.08 |
| 28 May 2009 | PBJ-1F | 0.10 | 0.00 | 1.42 | 54.03 | 41.53 | 2.50 | 0.31 | 0.07 | 0.00 | 0.00 | 0.00 |
| 28 May 2009 | PBJ-1G | 0.24 | 0.05 | 0.13 | 27.97 | 65.94 | 4.39 | 0.98 | 0.29 | 0.00 | 0.00 | 0.00 |

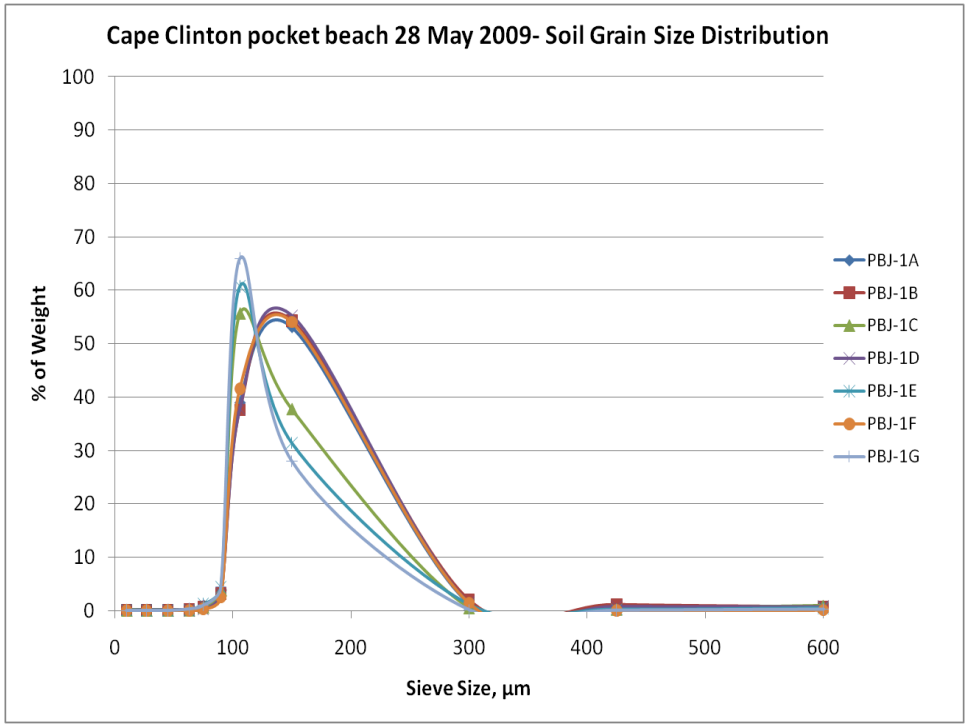
## 4.4 Soil Grain Size Distribution Figures




Cape Clinton pocket beach 28 May 2009- Soil Grain Size Distribution
% of Weight
Sieve Size, µm
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
PBJ-1A
PBJ-1B
PBJ-1C
PBJ-1D
PBJ-1E
PBJ-1F
PBJ-1G

# APPENDIX I

## Geotagged Photographs

## 1. Introduction

Geotagged photographs are photographs which have a global positioning system tag on the image, meaning that when the image is taken, the coordinates of the image are also recorded. These photographs provide a view of what the conditions were at the time the photograph was taken. Efforts were made to capture images of the beach from the perspective of what the amphibious assault personnel would see (images were taken perpendicular to the beach facing onshore). These pictures were taken from a vehicle at Freshwater beach on 19 May 2009 and 29 May 2009 and from a boat at Sabina Point on 23 May 2009. Figure 1 displays the location of all three datasets of imagery. These images are also provided in both the ArcGIS and ArcGIS Explorer versions of the geodatabase and have pop-up capability enabled (i.e. when the point in the shapefile is left-clicked, the image will display in the ArcMap or ArcGIS Explorer display window. Below Figure 1, Tables 1 through 3 lists the positioning, time, and filename of each photograph. The time indicated in these spreadsheets is in UTC time and to convert to Queensland time (EST), the addition of 10 hours is needed. Each picture is located at \TS09_GD\Attribute_Data\NOAA_Geo_Photos\ in the geodatabase.

## 2. Geotagged Photograph Locations

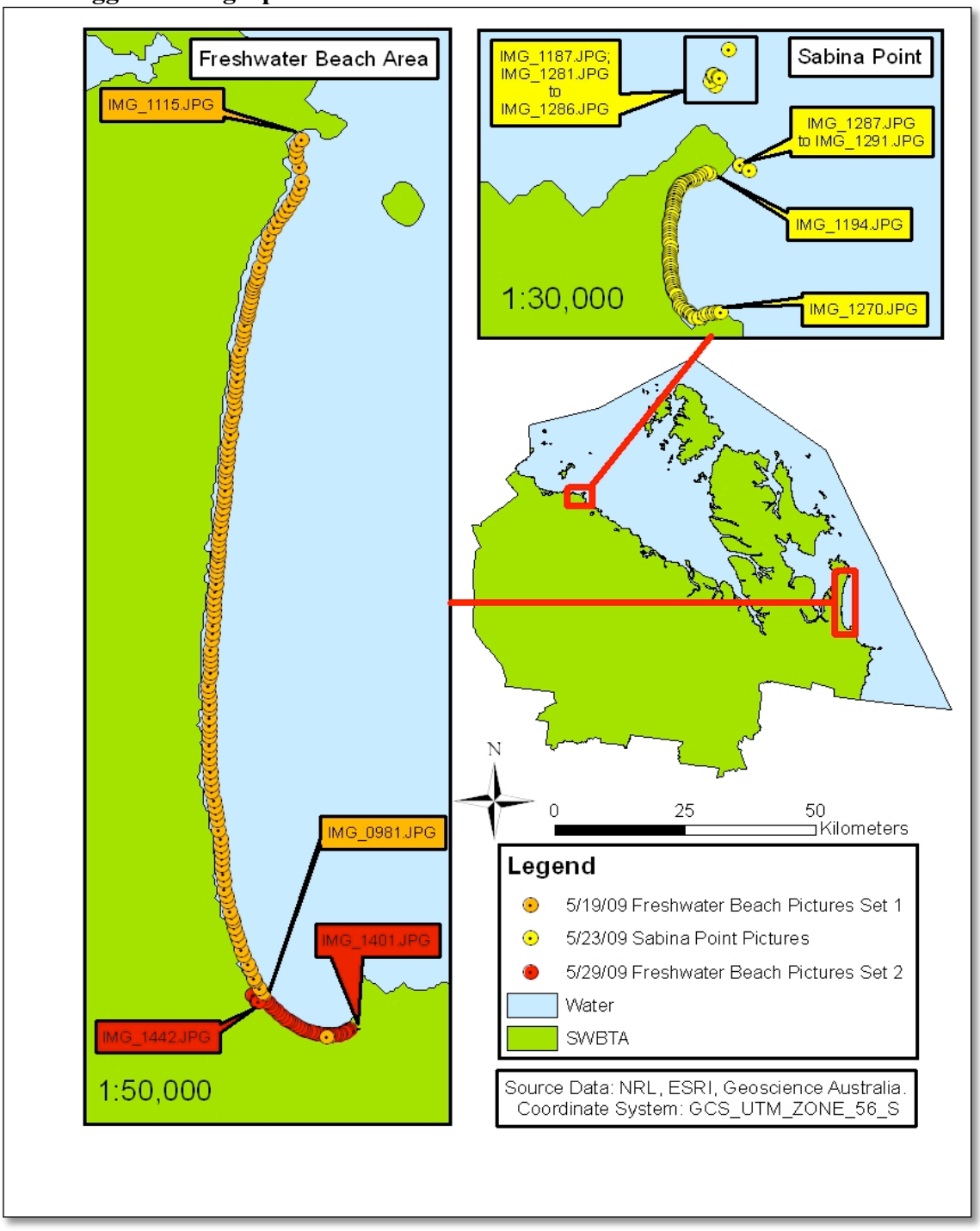



**Figure 1.Geotagged photograph locations during TS09.** Photographs were taken at Freshwater beach on 19 May 2009 and 29 May 2009. Sabina Point photographs were taken on 23 May 2009. Image names appear on the map. The order of these images is in sequential order with the exception of a few instances where non sequential groupings are called out (i.e. Sabina Point Insert).

## 3. Photograph Positional Data

**Table 1. Geotagged photographs from Freshwater Beach, 19 May 2009.** The table below presents the images that were taken on 19 May 2009. The latitude, longitude and altitude can be seen, as well as the time in UTC and the filename of each photograph. The tide condition during the capture of these photographs is approaching low tide. Low tide at Port Clinton Australia is 1:46 AM UTC for 19 May 2009.

| Latitude | Longitude | Altitude | UTC Time (EST ADD 10 Hours) | Filename |
|---|---|---|---|---|
| -22.65027 | 150.78878 | 4.463256836 | 2009/05/19-00:17:00 | IMG_0973.jpg |
| -22.64561 | 150.7819402 | -0.343383789 | 2009/05/19-00:28:15 | IMG_0981.jpg |
| -22.64514 | 150.7816124 | -0.343383789 | 2009/05/19-00:28:21 | IMG_0982.jpg |
| -22.64438 | 150.7811227 | -0.343383789 | 2009/05/19-00:28:30 | IMG_0983.jpg |
| -22.6441 | 150.7809771 | -0.82409668 | 2009/05/19-00:28:33 | IMG_0984.jpg |
| -22.64321 | 150.7805683 | -0.82409668 | 2009/05/19-00:28:42 | IMG_0985.jpg |
| -22.64268 | 150.780334 | -1.3046875 | 2009/05/19-00:28:48 | IMG_0986.jpg |
| -22.64167 | 150.7798884 | -0.82409668 | 2009/05/19-00:29:00 | IMG_0987.jpg |
| -22.6411 | 150.7796666 | -0.82409668 | 2009/05/19-00:29:06 | IMG_0988.jpg |
| -22.64017 | 150.779355 | -0.82409668 | 2009/05/19-00:29:15 | IMG_0989.jpg |
| -22.63951 | 150.7791387 | -0.343383789 | 2009/05/19-00:29:21 | IMG_0990.jpg |
| -22.63884 | 150.778946 | 0.137451172 | 2009/05/19-00:29:27 | IMG_0991.jpg |
| -22.63816 | 150.7787635 | 0.618041992 | 2009/05/19-00:29:33 | IMG_0992.jpg |
| -22.63781 | 150.7786746 | 0.618041992 | 2009/05/19-00:29:36 | IMG_0993.jpg |
| -22.63712 | 150.7784814 | 1.098632813 | 2009/05/19-00:29:42 | IMG_0994.jpg |
| -22.6361 | 150.7782214 | 1.098632813 | 2009/05/19-00:29:51 | IMG_0995.jpg |
| -22.63544 | 150.7780767 | 1.098632813 | 2009/05/19-00:29:57 | IMG_0996.jpg |
| -22.63482 | 150.7779448 | 1.098632813 | 2009/05/19-00:30:03 | IMG_0997.jpg |
| -22.63389 | 150.7778414 | 0.618041992 | 2009/05/19-00:30:12 | IMG_0998.jpg |
| -22.63322 | 150.7777738 | 0.137451172 | 2009/05/19-00:30:18 | IMG_0999.jpg |
| -22.63223 | 150.7776971 | 0.137451172 | 2009/05/19-00:30:27 | IMG_1000.jpg |
| -22.63156 | 150.7776882 | 0.618041992 | 2009/05/19-00:30:33 | IMG_1001.jpg |
| -22.63089 | 150.7776956 | 0.618041992 | 2009/05/19-00:30:39 | IMG_1002.jpg |
| -22.63021 | 150.7776335 | 0.618041992 | 2009/05/19-00:30:45 | IMG_1003.jpg |
| -22.62955 | 150.7775413 | 0.618041992 | 2009/05/19-00:30:51 | IMG_1004.jpg |
| -22.62854 | 150.7774086 | 0.137451172 | 2009/05/19-00:31:00 | IMG_1005.jpg |
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| -22.62686 | 150.7771444 | 0.618041992 | 2009/05/19-00:31:15 | IMG_1007.jpg |
| -22.62618 | 150.7770154 | 0.618041992 | 2009/05/19-00:31:21 | IMG_1008.jpg |
| -22.62552 | 150.776903 | 0.618041992 | 2009/05/19-00:31:27 | IMG_1009.jpg |
| -22.62453 | 150.7767503 | 0.618041992 | 2009/05/19-00:31:36 | IMG_1010.jpg |
| -22.62388 | 150.7766618 | 0.137451172 | 2009/05/19-00:31:42 | IMG_1011.jpg |
| -22.62323 | 150.7765937 | 0.137451172 | 2009/05/19-00:31:48 | IMG_1012.jpg |
| -22.62256 | 150.7765784 | 0.137451172 | 2009/05/19-00:31:54 | IMG_1013.jpg |
| -22.62169 | 150.7765476 | -0.343383789 | 2009/05/19-00:32:03 | IMG_1014.jpg |
| -22.62108 | 150.7765366 | -0.343383789 | 2009/05/19-00:32:09 | IMG_1015.jpg |
| -22.62027 | 150.7765246 | -0.82409668 | 2009/05/19-00:32:18 | IMG_1016.jpg |
| -22.61975 | 150.7765317 | -0.82409668 | 2009/05/19-00:32:24 | IMG_1017.jpg |
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| -22.6183 | 150.7765321 | -0.82409668 | 2009/05/19-00:32:39 | IMG_1019.jpg |
| -22.61772 | 150.776557 | -1.3046875 | 2009/05/19-00:32:45 | IMG_1020.jpg |
| -22.61684 | 150.7765796 | -1.78527832 | 2009/05/19-00:32:54 | IMG_1021.jpg |
| -22.61598 | 150.7765305 | -1.3046875 | 2009/05/19-00:33:03 | IMG_1022.jpg |
| -22.61553 | 150.7765542 | -1.3046875 | 2009/05/19-00:33:09 | IMG_1023.jpg |
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| -22.60982 | 150.7768633 | -1.78527832 | 2009/05/19-00:34:12 | IMG_1032.jpg |
| -22.6088 | 150.776935 | -0.82409668 | 2009/05/19-00:34:27 | IMG_1033.jpg |
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| -22.60728 | 150.7770996 | -0.82409668 | 2009/05/19-00:34:45 | IMG_1035.jpg |
| -22.60633 | 150.7771921 | -0.82409668 | 2009/05/19-00:35:03 | IMG_1036.jpg |
| -22.60565 | 150.7772329 | -1.3046875 | 2009/05/19-00:35:12 | IMG_1037.jpg |
| -22.60514 | 150.7772645 | -1.78527832 | 2009/05/19-00:35:18 | IMG_1038.jpg |
| -22.60438 | 150.777262 | -2.265991211 | 2009/05/19-00:35:33 | IMG_1039.jpg |
| -22.60371 | 150.7773962 | -1.78527832 | 2009/05/19-00:35:42 | IMG_1040.jpg |
| -22.60286 | 150.7774785 | -1.78527832 | 2009/05/19-00:35:51 | IMG_1041.jpg |
| -22.60216 | 150.7775651 | -1.78527832 | 2009/05/19-00:36:00 | IMG_1042.jpg |
| -22.60166 | 150.7776064 | -1.3046875 | 2009/05/19-00:36:09 | IMG_1043.jpg |
| -22.60111 | 150.7776571 | -1.78527832 | 2009/05/19-00:36:15 | IMG_1044.jpg |
| -22.60057 | 150.7776968 | -2.265991211 | 2009/05/19-00:36:21 | IMG_1045.jpg |
| -22.5999 | 150.7778429 | -2.265991211 | 2009/05/19-00:36:30 | IMG_1046.jpg |
| -22.59958 | 150.7778712 | -2.265991211 | 2009/05/19-00:36:36 | IMG_1047.jpg |
| -22.59888 | 150.7778062 | -1.3046875 | 2009/05/19-00:36:45 | IMG_1048.jpg |
| -22.59829 | 150.7778417 | -1.3046875 | 2009/05/19-00:36:51 | IMG_1049.jpg |
| -22.59771 | 150.7780251 | -1.3046875 | 2009/05/19-00:36:57 | IMG_1050.jpg |
| -22.597 | 150.7781566 | -1.3046875 | 2009/05/19-00:37:06 | IMG_1051.jpg |
| -22.59627 | 150.7781563 | -0.82409668 | 2009/05/19-00:37:18 | IMG_1052.jpg |
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| -22.58888 | 150.779052 | -0.82409668 | 2009/05/19-00:38:51 | IMG_1064.jpg |
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| -22.58731 | 150.779345 | -0.82409668 | 2009/05/19-00:39:12 | IMG_1066.jpg |
| -22.58648 | 150.7793216 | 0.137451172 | 2009/05/19-00:39:27 | IMG_1067.jpg |
| -22.58592 | 150.7794504 | -0.343383789 | 2009/05/19-00:39:36 | IMG_1068.jpg |
| -22.58548 | 150.7795584 | -0.343383789 | 2009/05/19-00:39:42 | IMG_1069.jpg |
| -22.58472 | 150.7797626 | -0.82409668 | 2009/05/19-00:39:54 | IMG_1070.jpg |
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| -22.57916 | 150.7803178 | -1.3046875 | 2009/05/19-00:41:03 | IMG_1079.jpg |
| -22.57849 | 150.7805354 | -1.3046875 | 2009/05/19-00:41:12 | IMG_1080.jpg |
| -22.57754 | 150.780829 | -2.265991211 | 2009/05/19-00:41:24 | IMG_1081.jpg |
| -22.57704 | 150.7809042 | -2.265991211 | 2009/05/19-00:41:30 | IMG_1082.jpg |
| -22.57657 | 150.780947 | -2.746704102 | 2009/05/19-00:41:36 | IMG_1083.jpg |
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| -22.57145 | 150.7823049 | -1.3046875 | 2009/05/19-00:42:48 | IMG_1094.jpg |
| -22.57107 | 150.7824498 | -1.3046875 | 2009/05/19-00:42:54 | IMG_1095.jpg |
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| -22.56659 | 150.7837451 | 1.579345703 | 2009/05/19-00:44:27 | IMG_1101.jpg |
| -22.56582 | 150.784477 | 1.098632813 | 2009/05/19-00:44:45 | IMG_1102.jpg |
| -22.56522 | 150.7848398 | 1.579345703 | 2009/05/19-00:44:54 | IMG_1103.jpg |
| -22.56459 | 150.7853409 | 1.579345703 | 2009/05/19-00:45:03 | IMG_1104.jpg |
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| -22.55858 | 150.7868807 | 0.618041992 | 2009/05/19-00:46:12 | IMG_1112.jpg |
| -22.5579 | 150.7868763 | 1.579345703 | 2009/05/19-00:46:21 | IMG_1113.jpg |
| -22.55729 | 150.7870908 | 1.579345703 | 2009/05/19-00:46:30 | IMG_1114.jpg |
| -22.55668 | 150.7874804 | 0.618041992 | 2009/05/19-00:46:42 | IMG_1115.jpg |

**Table 2. Geotagged photographs from Sabina Point, 23 May 2009.** The table below presents the images that were taken on 23 May 2009. The latitude, longitude and altitude can be seen, as well as the time in UTC and the filename of each photograph. The tide condition during the capture of these photographs is approaching low tide. Low tide for Port Clinton, Australia for 23 May 2009 is 4:41AM UTC.

| Latitude | Longitude | Altitude | UTC Time (EST ADD 10 Hours) | Filename |
|---|---|---|---|---|
| -22.3917 | 150.3029 | 10.71179 | 2009/05/23-00:39:35 | IMG_1187.jpg |
| -22.3994 | 150.3015 | 3.02124 | 2009/05/23-00:59:03 | IMG_1194.jpg |
| -22.3994 | 150.3012 | 1.579346 | 2009/05/23-00:59:30 | IMG_1195.jpg |
| -22.3995 | 150.3009 | 3.982666 | 2009/05/23-01:00:03 | IMG_1196.jpg |
| -22.3996 | 150.3007 | 4.943848 | 2009/05/23-01:00:24 | IMG_1197.jpg |
| -22.3998 | 150.3005 | 4.463257 | 2009/05/23-01:00:45 | IMG_1198.jpg |
| -22.3999 | 150.3004 | 3.501953 | 2009/05/23-01:01:03 | IMG_1199.jpg |
| -22.3999 | 150.3002 | 4.463257 | 2009/05/23-01:01:21 | IMG_1200.jpg |
| -22.3999 | 150.3 | 3.02124 | 2009/05/23-01:01:39 | IMG_1201.jpg |
| -22.4 | 150.2999 | 2.540649 | 2009/05/23-01:01:51 | IMG_1202.jpg |
| -22.4 | 150.2998 | 2.540649 | 2009/05/23-01:02:00 | IMG_1203.jpg |
| -22.4001 | 150.2997 | 2.540649 | 2009/05/23-01:02:09 | IMG_1204.jpg |
| -22.4002 | 150.2996 | 2.540649 | 2009/05/23-01:02:27 | IMG_1205.jpg |
| -22.4002 | 150.2995 | 2.060059 | 2009/05/23-01:02:39 | IMG_1206.jpg |
| -22.4004 | 150.2994 | 3.501953 | 2009/05/23-01:03:06 | IMG_1207.jpg |
| -22.4005 | 150.2993 | 2.540649 | 2009/05/23-01:03:22 | IMG_1208.jpg |
| -22.4007 | 150.2992 | 1.098633 | 2009/05/23-01:03:37 | IMG_1209.jpg |
| -22.4007 | 150.2993 | 1.098633 | 2009/05/23-01:05:13 | IMG_1210.jpg |
| -22.4008 | 150.2992 | 0.137451 | 2009/05/23-01:05:34 | IMG_1211.jpg |
| -22.4009 | 150.2992 | 0.137451 | 2009/05/23-01:05:49 | IMG_1212.jpg |
| -22.4011 | 150.2991 | -0.8241 | 2009/05/23-01:06:01 | IMG_1213.jpg |
| -22.4011 | 150.2991 | -1.78528 | 2009/05/23-01:06:10 | IMG_1214.jpg |
| -22.4013 | 150.2991 | -0.8241 | 2009/05/23-01:06:25 | IMG_1215.jpg |
| -22.4014 | 150.2991 | 1.098633 | 2009/05/23-01:06:40 | IMG_1216.jpg |
| -22.4015 | 150.2991 | 1.098633 | 2009/05/23-01:06:49 | IMG_1217.jpg |
| -22.4016 | 150.299 | 0.137451 | 2009/05/23-01:07:04 | IMG_1218.jpg |
| -22.4018 | 150.299 | 3.02124 | 2009/05/23-01:07:25 | IMG_1219.jpg |
| -22.4019 | 150.299 | 1.579346 | 2009/05/23-01:07:43 | IMG_1220.jpg |
| -22.4021 | 150.299 | 1.579346 | 2009/05/23-01:08:04 | IMG_1221.jpg |
| -22.4023 | 150.2989 | 0.618042 | 2009/05/23-01:08:25 | IMG_1222.jpg |
| -22.4024 | 150.2988 | 2.060059 | 2009/05/23-01:08:40 | IMG_1223.jpg |
| -22.4026 | 150.2988 | 1.098633 | 2009/05/23-01:08:55 | IMG_1224.jpg |
| -22.4027 | 150.2988 | 2.060059 | 2009/05/23-01:09:17 | IMG_1225.jpg |
| -22.4029 | 150.2988 | 0.137451 | 2009/05/23-01:09:39 | IMG_1226.jpg |
| -22.4031 | 150.2988 | 1.579346 | 2009/05/23-01:09:57 | IMG_1227.jpg |
| -22.4033 | 150.2988 | 2.540649 | 2009/05/23-01:10:12 | IMG_1228.jpg |
| -22.4034 | 150.2988 | 1.579346 | 2009/05/23-01:10:27 | IMG_1229.jpg |
| -22.4036 | 150.2988 | 0.137451 | 2009/05/23-01:10:48 | IMG_1230.jpg |
| -22.4038 | 150.2988 | 0.618042 | 2009/05/23-01:11:09 | IMG_1231.jpg |
| -22.404 | 150.2988 | 0.618042 | 2009/05/23-01:11:33 | IMG_1232.jpg |
| -22.4042 | 150.2988 | 0.618042 | 2009/05/23-01:12:03 | IMG_1233.jpg |
| -22.4044 | 150.2988 | -0.34338 | 2009/05/23-01:12:21 | IMG_1234.jpg |
| -22.4046 | 150.2988 | -0.8241 | 2009/05/23-01:12:36 | IMG_1235.jpg |
| -22.4047 | 150.2988 | -0.34338 | 2009/05/23-01:12:54 | IMG_1236.jpg |
| -22.4048 | 150.2988 | 0.618042 | 2009/05/23-01:13:06 | IMG_1237.jpg |

| Latitude | Longitude | Altitude | UTC Time (EST ADD 10 Hours) | Filename |
|---|---|---|---|---|
| -22.405 | 150.2988 | 0.137451 | 2009/05/23-01:13:21 | IMG_1238.jpg |
| -22.4052 | 150.2988 | -0.8241 | 2009/05/23-01:13:45 | IMG_1239.jpg |
| -22.4053 | 150.2988 | 0.137451 | 2009/05/23-01:13:57 | IMG_1240.jpg |
| -22.4055 | 150.2988 | 0.137451 | 2009/05/23-01:14:18 | IMG_1241.jpg |
| -22.4057 | 150.2988 | 0.137451 | 2009/05/23-01:14:36 | IMG_1242.jpg |
| -22.4058 | 150.2988 | 0.137451 | 2009/05/23-01:14:48 | IMG_1243.jpg |
| -22.4059 | 150.2988 | 0.618042 | 2009/05/23-01:15:00 | IMG_1244.jpg |
| -22.406 | 150.2989 | -0.34338 | 2009/05/23-01:15:12 | IMG_1245.jpg |
| -22.4062 | 150.2989 | 0.618042 | 2009/05/23-01:15:24 | IMG_1246.jpg |
| -22.4063 | 150.2989 | -0.34338 | 2009/05/23-01:15:42 | IMG_1247.jpg |
| -22.4065 | 150.299 | -0.34338 | 2009/05/23-01:15:57 | IMG_1248.jpg |
| -22.4067 | 150.299 | 0.137451 | 2009/05/23-01:16:15 | IMG_1249.jpg |
| -22.4068 | 150.299 | -1.78528 | 2009/05/23-01:16:30 | IMG_1250.jpg |
| -22.4069 | 150.2991 | -0.8241 | 2009/05/23-01:16:42 | IMG_1251.jpg |
| -22.407 | 150.2991 | 0.137451 | 2009/05/23-01:16:54 | IMG_1252.jpg |
| -22.4073 | 150.2993 | -0.34338 | 2009/05/23-01:17:30 | IMG_1253.jpg |
| -22.4074 | 150.2993 | -1.30469 | 2009/05/23-01:17:42 | IMG_1254.jpg |
| -22.4076 | 150.2994 | -1.30469 | 2009/05/23-01:18:00 | IMG_1255.jpg |
| -22.4077 | 150.2994 | -1.30469 | 2009/05/23-01:18:15 | IMG_1256.jpg |
| -22.4078 | 150.2995 | -0.34338 | 2009/05/23-01:18:33 | IMG_1257.jpg |
| -22.4079 | 150.2997 | -2.26599 | 2009/05/23-01:18:51 | IMG_1258.jpg |
| -22.4081 | 150.2999 | -2.26599 | 2009/05/23-01:19:09 | IMG_1259.jpg |
| -22.4082 | 150.3 | -0.8241 | 2009/05/23-01:19:30 | IMG_1260.jpg |
| -22.4083 | 150.3001 | -0.34338 | 2009/05/23-01:19:42 | IMG_1261.jpg |
| -22.4084 | 150.3002 | -0.34338 | 2009/05/23-01:19:57 | IMG_1262.jpg |
| -22.4085 | 150.3003 | -0.8241 | 2009/05/23-01:20:12 | IMG_1263.jpg |
| -22.4085 | 150.3006 | -0.8241 | 2009/05/23-01:20:36 | IMG_1264.jpg |
| -22.4083 | 150.301 | 4.463257 | 2009/05/23-01:21:12 | IMG_1265.jpg |
| -22.4082 | 150.3012 | 3.501953 | 2009/05/23-01:21:30 | IMG_1266.jpg |
| -22.4082 | 150.3015 | 2.540649 | 2009/05/23-01:21:51 | IMG_1267.jpg |
| -22.4082 | 150.3017 | 2.060059 | 2009/05/23-01:22:06 | IMG_1268.jpg |
| -22.4082 | 150.3019 | 0.618042 | 2009/05/23-01:22:21 | IMG_1269.jpg |
| -22.4082 | 150.302 | 0.137451 | 2009/05/23-01:22:30 | IMG_1270.jpg |
| -22.3939 | 150.3019 | 0.618042 | 2009/05/23-03:56:26 | IMG_1281.jpg |
| -22.3937 | 150.3016 | -1.78528 | 2009/05/23-03:57:14 | IMG_1282.jpg |
| -22.3933 | 150.3018 | -3.22729 | 2009/05/23-03:58:32 | IMG_1283.jpg |
| -22.3933 | 150.3019 | -3.70789 | 2009/05/23-03:58:41 | IMG_1284.jpg |
| -22.3934 | 150.3021 | -3.70789 | 2009/05/23-03:59:05 | IMG_1285.jpg |
| -22.3935 | 150.3022 | -2.7467 | 2009/05/23-03:59:17 | IMG_1286.jpg |
| -22.399 | 150.3035 | -3.70789 | 2009/05/23-04:14:23 | IMG_1287.jpg |
| -22.399 | 150.3034 | -1.78528 | 2009/05/23-04:14:29 | IMG_1288.jpg |
| -22.3993 | 150.3041 | -3.22729 | 2009/05/23-04:16:23 | IMG_1291.jpg |

**Table 3. Geotagged photographs from Freshwater Beach, 29 May 2009.** The table below presents the images that were taken on 29 May 2009. The latitude, longitude and altitude can be seen, as well as the time in UTC and the filename of each photograph. The tide condition during the capture of these photographs is approaching high tide. High tide for Port Clinton, Australia is 3:51AM UTC.

| Latitude | Longitude | Altitude | UTC Time (EST ADD 10 Hours) | Filename |
|---|---|---|---|---|
| -22.6496 | 150.7913 | -1.30469 | 2009/05/29-01:12:02 | IMG_1401.jpg |
| -22.6497 | 150.791 | -0.8241 | 2009/05/29-01:12:11 | IMG_1402.jpg |
| -22.6498 | 150.7908 | -0.8241 | 2009/05/29-01:12:19 | IMG_1403.jpg |
| -22.6499 | 150.7907 | -0.8241 | 2009/05/29-01:12:26 | IMG_1404.jpg |
| -22.65 | 150.7903 | -0.8241 | 2009/05/29-01:12:44 | IMG_1405.jpg |
| -22.6501 | 150.7901 | -0.8241 | 2009/05/29-01:12:50 | IMG_1406.jpg |
| -22.6501 | 150.7898 | 0.137451 | 2009/05/29-01:13:02 | IMG_1407.jpg |
| -22.6501 | 150.7895 | 1.098633 | 2009/05/29-01:13:11 | IMG_1408.jpg |
| -22.6501 | 150.7892 | 2.060059 | 2009/05/29-01:13:20 | IMG_1409.jpg |
| -22.6501 | 150.7889 | 2.540649 | 2009/05/29-01:13:26 | IMG_1410.jpg |
| -22.6501 | 150.7886 | 2.540649 | 2009/05/29-01:13:32 | IMG_1411.jpg |
| -22.6501 | 150.7884 | 2.540649 | 2009/05/29-01:13:38 | IMG_1412.jpg |
| -22.65 | 150.788 | 1.579346 | 2009/05/29-01:13:47 | IMG_1413.jpg |
| -22.6499 | 150.7877 | 1.098633 | 2009/05/29-01:13:53 | IMG_1414.jpg |
| -22.6498 | 150.7873 | 1.098633 | 2009/05/29-01:14:02 | IMG_1415.jpg |
| -22.6497 | 150.7869 | 1.098633 | 2009/05/29-01:14:11 | IMG_1416.jpg |
| -22.6496 | 150.7865 | 0.618042 | 2009/05/29-01:14:20 | IMG_1417.jpg |
| -22.6495 | 150.7862 | 0.618042 | 2009/05/29-01:14:26 | IMG_1418.jpg |
| -22.6493 | 150.7859 | 0.618042 | 2009/05/29-01:14:32 | IMG_1419.jpg |
| -22.6492 | 150.7856 | 1.098633 | 2009/05/29-01:14:41 | IMG_1420.jpg |
| -22.6489 | 150.7852 | 0.137451 | 2009/05/29-01:14:50 | IMG_1421.jpg |
| -22.6487 | 150.7848 | 0.137451 | 2009/05/29-01:14:59 | IMG_1422.jpg |
| -22.6485 | 150.7845 | 0.137451 | 2009/05/29-01:15:05 | IMG_1423.jpg |
| -22.6484 | 150.7843 | 0.618042 | 2009/05/29-01:15:11 | IMG_1424.jpg |
| -22.6481 | 150.784 | 2.060059 | 2009/05/29-01:15:20 | IMG_1425.jpg |
| -22.6478 | 150.7836 | 2.060059 | 2009/05/29-01:15:29 | IMG_1426.jpg |
| -22.6475 | 150.7833 | 2.060059 | 2009/05/29-01:15:38 | IMG_1427.jpg |
| -22.6472 | 150.783 | 2.540649 | 2009/05/29-01:15:47 | IMG_1428.jpg |
| -22.647 | 150.7828 | 2.060059 | 2009/05/29-01:15:53 | IMG_1429.jpg |
| -22.6467 | 150.7825 | 2.060059 | 2009/05/29-01:16:02 | IMG_1430.jpg |
| -22.6465 | 150.7823 | 1.579346 | 2009/05/29-01:16:08 | IMG_1431.jpg |
| -22.6462 | 150.782 | 1.579346 | 2009/05/29-01:16:17 | IMG_1432.jpg |
| -22.6459 | 150.7818 | 1.098633 | 2009/05/29-01:16:23 | IMG_1433.jpg |
| -22.6457 | 150.7816 | 1.098633 | 2009/05/29-01:16:29 | IMG_1434.jpg |
| -22.6454 | 150.7814 | 1.579346 | 2009/05/29-01:16:38 | IMG_1435.jpg |
| -22.6459 | 150.7808 | 5.424561 | 2009/05/29-01:35:51 | IMG_1436.jpg |
| -22.6459 | 150.7808 | 5.905273 | 2009/05/29-01:36:06 | IMG_1437.jpg |
| -22.6459 | 150.7808 | 3.02124 | 2009/05/29-01:36:30 | IMG_1438.jpg |
| -22.6465 | 150.7813 | 4.463257 | 2009/05/29-01:38:24 | IMG_1439.jpg |
| -22.6465 | 150.7813 | 6.385864 | 2009/05/29-01:38:36 | IMG_1440.jpg |
| -22.6466 | 150.7813 | -0.8241 | 2009/05/29-01:38:54 | IMG_1441.jpg |
| -22.6466 | 150.7814 | 9.269897 | 2009/05/29-01:39:27 | IMG_1442.jpg |

# APPENDIX J

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# NOAA Survey Data

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## 1. Introduction

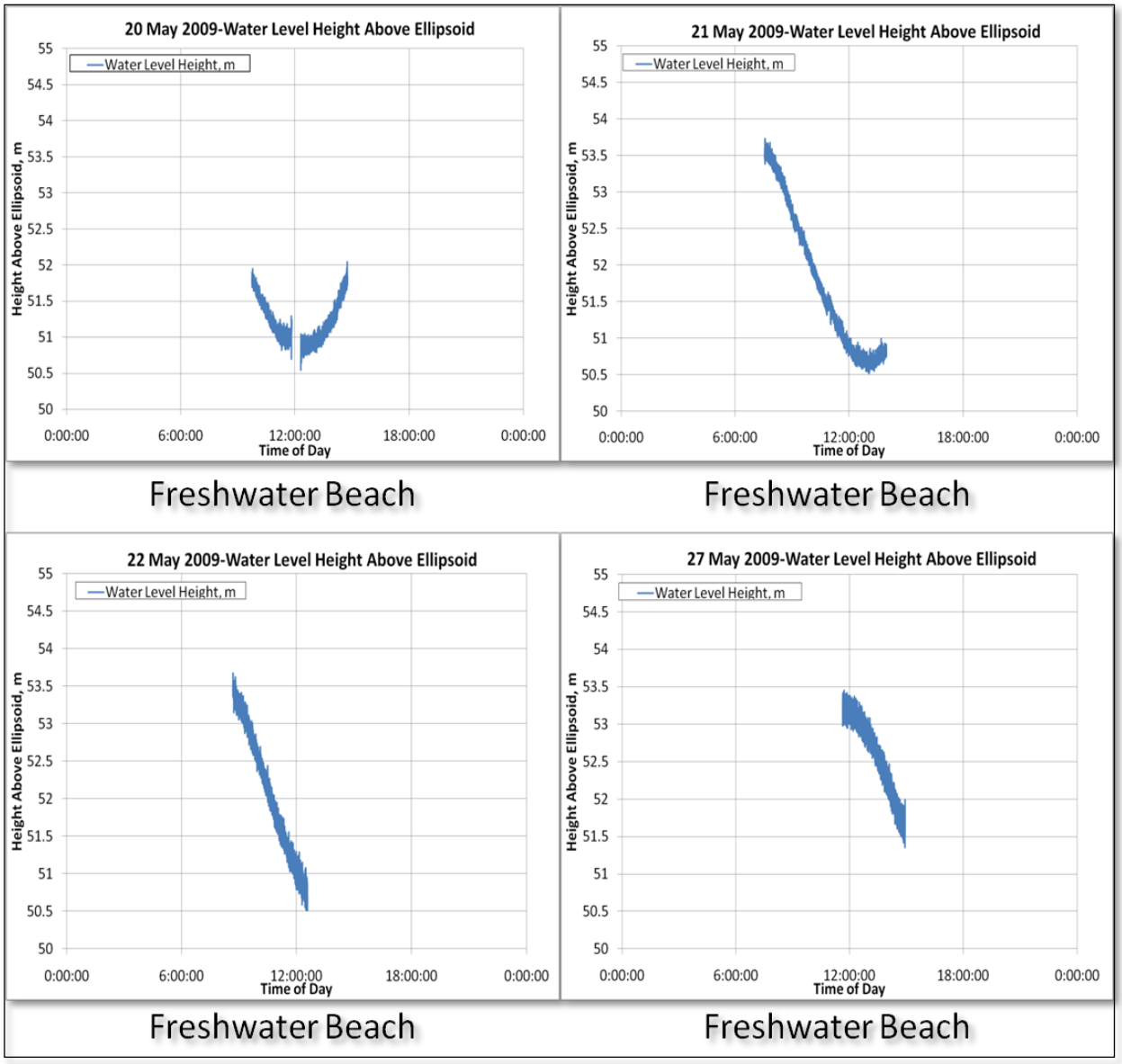
### 1.1. Water Level Buoy Data

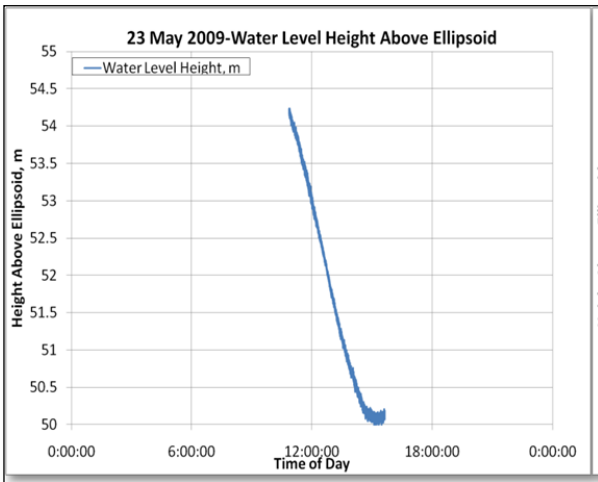
A water level buoy instrument was developed in order to accurately record water level height. The results were then used to validate sounding data and results from HSI developed models. The buoy was composed of a floating frame with a GPS unit attached above the frame. A photograph of the buoy can be seen in the main body section (Figure 12). In Section 2, plots of the water level data can be seen. The data that were collected contained the position of the buoy, the time of data collection, and height above the ellipsoid. The frequency of data collection is one sample per second. The plots describe the water level heights at Freshwater Beach on 20-23 May and 27 May 2009; Sabina Point on 23 May 2009; Southern Arm Estuary on 25 May 2009; and at the pocket beach at Cape Clinton on 28 May 2009. The data presented in these figures was divided into subsets in order to excise the actions of entry and exit from the beach to the water. The height levels were recorded in height above ellipsoid (WGS_84).

### 1.2. Kinematic GPS Survey Data

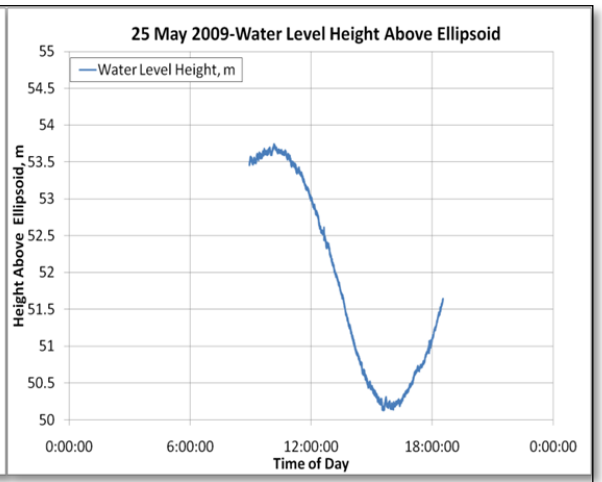
Team members from NOAA performed a geographic survey of the shore regions of Freshwater Beach, Sabina Point, and the pocket beach at Cape Clinton through the use of a post-processed kinematic GPS. Each position was recorded from the GPS receiver, with the positioning being based on the GCS WGS 1984 coordinate system. The GPS base station provided differential correction capabilities with the kinematic units. The data from the kinematic GPS were provided in shapefile format. This data were used to analyze the accuracy of developed bathymetric models and other products. Section 3 lists the available shapefiles developed by NOAA.

## 2. Water Level Buoy Graphs

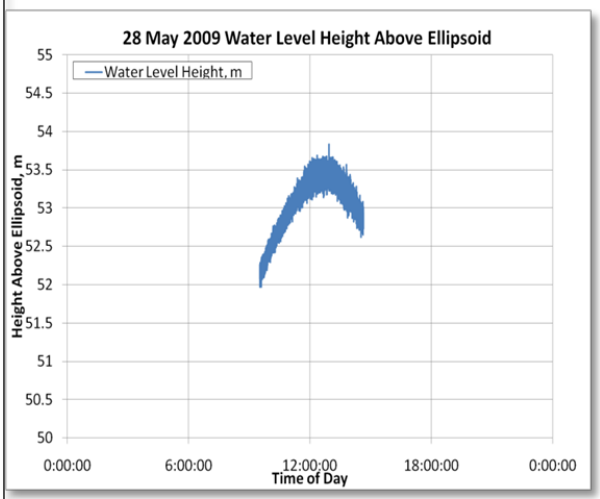





Sabina Point




Southern Arm Estuary




Cape Clinton Pocket Beach

**3. Kinematic GPS Survey Data Shapefiles**

| File Name | Date of Capture | Geographic Location | File Size, KB |
|---|---|---|---|
| 143_spb_wheel_kin.dbf | 23 May 2009 | Sabina Point | 3460 |
| 143_spb_wheel_kin.prj | 23 May 2009 | Sabina Point | 1 |
| 143_spb_wheel_kin.shp | 23 May 2009 | Sabina Point | 192 |
| 143_spb_wheel_kin.shp.xml | 23 May 2009 | Sabina Point | 11 |
| 143_spb_wheel_kin.shx | 23 May 2009 | Sabina Point | 55 |
| fwb_kin_merge.dbf | Multiple | Freshwater Beach | 7437 |
| fwb_kin_merge.prj | Multiple | Freshwater Beach | 1 |
| fwb_kin_merge.sbn | Multiple | Freshwater Beach | 765 |
| fwb_kin_merge.sbx | Multiple | Freshwater Beach | 19 |
| fwb_kin_merge.shp | Multiple | Freshwater Beach | 3409 |
| fwb_kin_merge.shp.xml | Multiple | Freshwater Beach | 10 |
| fwb_kin_merge.shx | Multiple | Freshwater Beach | 620 |
| tarp_gcps.dbf | 22 May 2009 | Freshwater Beach | 1 |
| tarp_gcps.evf | 22 May 2009 | Freshwater Beach | 2 |
| tarp_gcps.prj | 22 May 2009 | Freshwater Beach | 1 |
| tarp_gcps.shp | 22 May 2009 | Freshwater Beach | 1 |
| tarp_gcps.shx | 22 May 2009 | Freshwater Beach | 8 |
| tarp_gcps.shp.xml | 22 May 2009 | Freshwater Beach | 1 |

| Location | GPS Data Points |
|---|---|
| Sabina Point | 6986 |
| Freshwater Beach | 79,322 |
| Tarps at Freshwater Beach | 19 |