Environmental Impact Assessment

PROPOSED OLD HARBOUR PLANT RE-POWERING PROJECT (190 MW), OLD HARBOUR BAY, ST. CATHERINE, JAMAICA

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ENVIRONMENTAL IMPACT ASSESSMENT FOR PROPOSED OLD HARBOUR PLANT RE-POWERING PROJECT (190 MW), OLD HARBOUR BAY, ST. CATHERINE, JAMAICA

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A	amsl	Above mean sea level
C	C	Celsius
	CBD	Convention on Biological Diversity
	CDMP	Caribbean Disaster Mitigation Project
	CN	Curve number
D	DAFOR	Dominant, Abundant, Frequent, Occasional, Rare
	dBA	A-weighted sound level (decibel)
	DBH	Diameter at breast height
	DEM	Digital elevation model
	DO	Dissolved oxygen
E	E	East/ Easting
	EIA	Environmental Impact Assessment
	EMP	Environmental Monitoring Programme
	ESRI	Environmental Systems Research Institute
	FOG	Fats Oil and Grease
F	ft	Feet
G	g/l	Grams per litre
	GIS	Geographic information system
	GOJ	Government of Jamaica
	GPS	Global Positioning System
H	HA	Hectares
	hr	Hour
	Hz	Hertz
I	IPCC	Intergovernmental Panel on Climate Change
	IUCN	International Union for Conservation of Nature
J	JAD 2001	Jamaica Grid 2001
	JNHT	Jamaica National Heritage Trust
K	km	Kilometre
L	LDUC	Land Development and Utilization Commission
	Leq	Time-average sound level
	Lj	jth sound level
M	m	Metre
	m/s	Metres per second
	m^3/sec	Cubic metres per second
	mg/l	Milligrams per litre
	mg/m^3	Milligrams per cubic metre
	min	Minute (s)
	mm	Millimetre
	mm/24 hr	Millimetres per 24 hour period
	mS/cm	milli Siemens per cm
	MSDS	Material Safety Data Sheets

N	N	North/ Northing
	NAAQS	National Ambient Air Quality Standards
	NEPA	National Environment and Planning Agency
	NMIA	Norman Manley International Airport
	NO_2	Nitrogen Dioxide, Nitrite
	NO_3	Nitrate
	NOx	Nitrogen Oxides
	NRCA	Natural Resources Conservation Act
	NSWMA	National Solid Waste Management Authority
	NTU	Nephelometric turbidity units
	NWA	National Works Agency
	NWC	National Water Commission
O	ODPEM	Office of Disaster Preparedness and Emergency Management
	OSHA	Occupational Safety and Health Administration
P	PEL	Hearing Conservation and Permissible Exposure Limit
	PIF	Project Information Form
	PM10	Particulate matter smaller than 10 microns in diameter, respirable particulate matter
	PM2.5	Particulate matter smaller than 2.5 microns in diameter, fine particulate matter
	ppm	parts per million
	ppt	parts per thousand
Q	QSP II	Quest suite Professional II
S	s	Second
	SCS	US Soil Conservation Service
	SIA	Social Impact Area
	SO_2	Sulfur Dioxide, sulfite
	SO_4	Sulfate
	SOx	Sulfur Oxides
	STATIN	Statistical Institute of Jamaica
T	TCP Act	Town and Country Planning Act
	TDS	Total dissolved solids
	TSS	Total Suspended Solids
U	USEPA	United States Environmental Protection Agency
W	WHO	World Health Organization
	WRA	Water Resources Authority
Y	yr	Year

1.0 EXECUTIVE SUMMARY

INTRODUCTION

The Jamaica Public Service Company (JPS), the sole distributor of electricity in Jamaica, is planning to construct a 190 MW nominal combined cycle power plant, adjacent to JPS' existing Old Harbour facility, which currently has 220 MW of generation. Specifically, it is intended that liquefied natural gas (LNG) will be used to fuel the proposed power plant.

Impacts from the construction and operation of the proposed facility will potentially arise and it is considered imperative to consider these likely impacts and assess the vulnerability of environmental features in proximity to the project location, as well as on a national scale. In order to evaluate these impacts, an Environmental Impact Assessment (EIA) is required by the National Environment and Planning Agency for the proposed project. The specific tasks, as outlined by the Terms of Reference (TORs) have been executed by the contracted entity, CL Environmental Co. Ltd., and this report serves to compile and present the findings of the EIA. It should be noted that the fuelling of the proposed power plant with LNG is considered a separate project, for which an additional EIA will be required.

COMPREHENSIVE DESCRIPTION OF PROJECT

Project Concept and Description

JPS negotiated over the past year though a licence amendment that was gazetted, the right to replace its own generation. The Plan to build a 190 MW new gas-fired plant was endorsed by the ESET on Feb 4 2015. This represents base load generation to replace existing oil fired units of equal capacity. The target capacity was determined through various resource scenarios which optimize use of existing contract generation and renewables. The plant is a combined cycle 3x1 configuration designed to have maximum flexibility and to integrate renewables.

This 190 MW Nominal combined cycle development will be undertaken from Q1 2016 to Q1 2018. This new capacity will be base-loaded and is intended to replace the heavy fuel oil burning aged steam unit plants. Jamaica Public Service Company Limited (JPS) was awarded the right to go forward with the project.

Proposed Project Location and Siting

The Old Harbour 190 MW Nominal combined cycle power plant is to be located approximately 75.6 kilometres (47 miles) from the city of Kingston near the community of Old Harbour on the south coast. The proposed is adjacent to JPS' existing Old Harbour facility, which currently has 220 MW of generation and houses major transmission and distribution operation along with a privately owned diesel power plant (Doctor Bird I & II).

The community of Old Harbour Bay, located on the south-western coast of Jamaica in the parish of St. Catherine, was estimated to have a total population of 8,537 in 2009. Located approximately 5km from the town of Old Harbour, the Old Harbour Bay community consists of twenty-four (24) small communities, which include Blackwood Gardens, Kelly Pen, Thompson Pen, Bay Bottom, Terminal, Dagger Bay, More Pen Lane, Peter's Land, Sal Gully, Cross Road and Panton Town. Bordered by the Colbeck Castle community to the east and Bourkesfield to the southeast, the Old Harbour Bay community is one of many residential fishing villages found along the coast in Jamaica, and is considered the largest fishing village on the island. The other industries and sources of employment include mining, manufacturing, small retail shops and subsistence farming.

The proposed project site is bounded on the east by the existing Old Harbour Power Plant, to the northeast by the existing switch yard, to the west by Thorn Savanna and to the south by the ocean. The proposed site is largely flat area with clay type soils with site elevation varying from approximately 1.5 meters to 3.0 meters above mean sea level.

The proposed site of the new power plant is on the storage area for the existing Old Harbour 220 MW plant and is located near the Intermediate Acacia Forest (Thorn Savannah) ecosystem. This ecosystem is comprised mainly of Acacia sp. trees and stands. The Intermediate is distinguished from the Secondary Acacia Forest ecosystem in three main ways: (i) the under storey vegetation tends to be more pioneer, monocotyledonous, vegetation (i.e. grass, etc.), (ii) the canopy is more open, and (iii) the trees are more low-profile (i.e. only a couple of meters high). Typical bird species within this zone of vegetation are warblers.

The Intermediate Acacia Forest ecosystem is less significant/ecologically important than the Mangrove Ecosystem and Salina Ecosystem. Although the relative species diversity and abundance of avifauna tends to be average for this type of ecosystem, avifauna species tend to be more robust than their marine/salina counterparts and they, therefore, have more habitat options to migrate to, during development and construction within this vegetation zone. C.L. Environmental, 2007.

The proposed site for the power plant is on the existing JPSCo Old Harbour plant in an area used for storage, in addition to an area immediately west of the storage area to be purchased from the National Land Agency. The project site is located in the Portland Bight Protected Area.

Proposed Plant Technical Specifications

The new plant proposed herein will consist of one (1) power block of nominal 190MW combined cycle plant. The block's configuration consists of 3 combustion turbine generators x 3 heat recovery steam generators (HRSGs) x1 steam turbine generator. The combustion turbines will be dual fuel capable, however, the plant is designed for using natural gas fuel only. Each gas turbine unit is a 40 MW class, the steam turbine is a 75 MW class, providing nominal 190 MW block size in the 3 x 3 x 1 combined cycle duct fired configuration.

The exhaust gas from the gas turbine is led to the associated HRSG for generating the steam which in turn will be fed to a common steam turbine generator. The HRSGs will be dual pressure, non-reheat type, with duct burners, in order to obtain optimum exhaust gas energy utilization based on thermo-economic considerations.

The plant is designed for both base load and cycling duty (two shift operation) in order to be able to comply with all instructions from the system load dispatcher. The plant will operate with a 98% average annual equivalent availability factor (EAF) for the life time of the plant. This reliability is based on the inherent reliability of the Original Equipment Manufacturer (OEM) turbine packages, the unique features of the OEM gas turbines that allow for optimum maintenance schedules, a robust balance of plant (BOP) design, all coupled with a competent operations and maintenance staff that will be provided. In addition, the company intends to enter into a long term service agreement (LTSA) with the OEM for scheduled maintenance on the gas turbines. This will ensure that maintenance is done in accordance with OEM requirements, with genuine OEM parts and service, and in an expeditious manner.

A metering system is used in order to measure net energy output from the plant, and to monitor and co-ordinate operation of the facility. The location of the metering system will be in a 138 kV substation control building, and potential transformers for the metering system will be located on the 138 kV side of each generator transformer feeders in the 138 kV switchyard to measure net electrical energy outputs.

Continuous emissions monitoring (CEM) ports will be provided for the measurement of air emission levels in the exhaust stack of each HRSG.

Plant effluents will be treated to comply with the effluent discharge limit criteria (National Resources Conservation Authority's (NRCA) Jamaican National Trade Effluent Standards) and discharged to Old Harbour Bay through the existing cooling water discharge flume of the Old Harbour power plant. The Global Positioning System (GPS) location for the discharge point will be determined following the dispersion modelling exercise. The EIA will assess the suitability of the location for the discharge of plant liquid effluent.

The plant will be designed to meet the regulatory standards and is designed for an operating life of at least 25 years.

The design of the buildings will meet or exceed the requirements as established in the latest updates to the National Building Code and Caribbean Uniform Building Code. The civil structures for the project will be designed to meet the seismic requirement for ground acceleration of 0.4 g with a 10% probability of occurrence over a 50 years period and withstand maximum hurricane intensity wind speeds of 67.0m/s (241 km/h).

Project Construction

<u>Schedule</u>

Site preparation will commence by the first quarter 2016 and construction of the JPS power plant is scheduled to commence in by the second quarter of 2016. Commercial operation of Unit #1 is expected 22 months after the commencement of construction and the commercial operation of the other two units are slated one month after each other.

COST BENEFIT ANALYSIS

The UNIDO Approach for Social Cost Benefit Analysis as prescribed by United Nation Industrial Development Organization (UNIDO) was used to analyse the JPS natural gas power plant at Old Harbour, St. Catherine.

The cost benefit shows that the project has a positive net present value (NPV) using all recommended methodologies.

IDENTIFICATION AND ASSESSMENT OF POTENTIAL DIRECT AND INDIRECT IMPACTS AND RECOMMENDED MITIGATION

Site Preparation and Construction

<u>Noise Pollution</u>

Heavy Equipment

Site clearance for the proposed development necessitates the use of heavy equipment to carry out the job. Equipment to be used include bulldozers, backhoes etc. They possess the potential to have a direct negative impact on the noise climate. Noise directly attributable to site clearance activity should not result in noise levels in the residential areas to exceed 55dBA during day time (7am – 10 pm) and 50dBA during night time (10 pm – 7 am). Where the baseline levels are above the stated levels then it should not result in an increase of the baseline levels by more than 3dBA at the nearest residence.

Construction noise can result in short-term impacts of varying duration and magnitude. The construction noise levels are a function of the scale of the project, the phase of the construction, the condition of the equipment and its operating cycles, the number of pieces of construction equipment operating concurrently.

Access Road

During the site clearance and construction phases of the Proposed Project, an access road will be built to the site which will facilitate the movement of heavy vehicles and equipment. It is anticipated that during the site filling phase is when the highest daily volume of vehicular traffic will occur. It is anticipated that during this phase approximately 70 truck trips per day to carry fill material to the site. SoundPlan 7.3 model was used to determine the potential noise impact to the community for this activity (worst case scenario). A speed limit of 30 km/h for the trucks was used in the model.

Recommended Mitigation

i. Use equipment that has low noise emissions as stated by the manufacturers.
ii. Use equipment that is properly fitted with noise reduction devices such as mufflers.

iii. Operate noise-generating equipment during regular working hours (e.g. 7 am – 7 pm) to reduce the potential of creating a noise nuisance during the night.
iv. Construction workers operating equipment that generates noise should be equipped with noise protection. A guide is workers operating equipment generating noise of ≥ 80 dBA (decibels) continuously for 8 hours or more should use ear muffs. Workers experiencing prolonged noise levels 70 - 80 dBA should wear earplugs.
v. Management controls will be used to mitigate the potential noise impacts along the access route. These are;
    a. Trucks and other heavy duty vehicles will be required to travel at 30 km/h along the access route.
    b. Truck and heavy duty vehicles should travel along the access route only during day time hours 7 am – 5 pm.

The avifauna will be marginally affected by changes in the noise environment; the community dynamics and population have already been shaped by elevated noise levels in the project area and zone of influence. Therefore, no mitigation is required.

Vibration

Construction activities often generate vibration complaints. This may be as a result of interfering with persons normal routines/activities. This can become more acute if the community has no understanding of the extent and duration of the construction. This can lead to misunderstandings if the contractor is considered to be insensitive by the communities although he may believe he is in compliance with the required conditions/ordinances.

Construction activities can result in various degrees of ground vibration. This is dependent on the type of equipment used and the methodologies employed. Comparing these level with the British Standard from a human standpoint, most equipment used would result in no vibration being perceived except with pile driving which might just be perceptible. From a building standpoint, the vibration levels predicted will have no effect residential buildings within proximity of the JPS 190MW Power Plant project.

Recommended Mitigation

a. Sequence of operations:
    i. Phase demolition, earth-moving and ground-impacting operations so as not to occur in the same time period. Unlike noise, the total vibration level produced could be significantly less when each vibration source operates separately.
    ii. Avoid night time activities. People are more aware of vibration in their homes during the night time hours.
b. Alternative construction methods:
    i. Avoid impact pile-driving where possible in vibration-sensitive areas. Drilled piles or the use of a sonic or vibratory pile driver causes lower vibration levels where the geological conditions permit their use.
    ii. Select demolition methods not involving impact, where possible.

iii. Avoid vibratory rollers near sensitive areas.

c. Have regular meetings or devise a communication strategy to inform the residents of construction activities.

Storage of Raw Material and Equipment

Any raw materials used in construction will be stored onsite. There will be a potential for them to become air or waterborne. Stored fuels and the repair of construction equipment has the potential to leak hydraulic fuels, oils etc.

Recommended Mitigation

i. A central area should be designated for the storage of raw materials. This area should be lined in order to prevent the leakage of chemicals into the sediment.
ii. Raw materials that generate dust should be covered or wetted frequently to prevent them from becoming air or waterborne.
iii. Fine grained materials (sand, marl, etc.) will be stockpiled away from drainage channels and low berms will be placed around the piles which themselves will be covered with tarpaulin to prevent them from being eroded and washed away.
iv. Raw material should be placed on hardstands surrounded by berms.
v. Equipment should be stored on impermeable hard stands surrounded by berms to contain any accidental surface runoff.
vi. Bulk storage of fuels and oils should be in clearly marked containers (tanks/drums etc.) indicating the type and quantity being stored. In addition, these containers should be surrounded by bunds to contain the volume being stored in case of accidental spillage.

Transportation of Raw Material and Equipment

The transportation and use of heavy equipment and trucks is required during construction. Trucks will transport raw materials and heavy equipment. This has the potential to directly impact traffic flow along local roads.

Recommended Mitigation

i. Paths of the planned roadways should be used, rather than creating temporary pathways just for equipment access.
ii. Adequate and appropriate road signs should be erected to warn road users of the construction activities. For example reduced speed near the construction site.
iii. Raw materials such as marl and sand should be adequately covered within the trucks to prevent any escaping into the air and along the roadway.
iv. The trucks should be parked on the proposed site until they are off loaded.
v. Heavy equipment should be transported early morning (12 am – 5 am) with proper pilotage.
vi. The use of flagmen should be employed to regulate traffic flow.

Wastewater Generation and Disposal

With every construction campsite comes the need to provide construction workers with showers and sanitary conveniences. The disposal of the wastewater generated at the construction campsite has the potential to have a minor negative impact on groundwater.

Recommended Mitigation

i. Provide portable sanitary conveniences for the construction workers for control of sewage waste. A ratio of approximately 25 workers per chemical toilet should be used.

Air Quality

Site preparation has the potential to have a two-folded direct negative impact on air quality of the surrounding residential area. The first impact is air pollution generated from the construction equipment and transportation. The second is from fugitive dust from the proposed construction areas and raw materials stored on site. Fugitive dust has the potential to affect the health of construction workers, the resident population and the surrounding vegetation.

Recommended Mitigation

i. Areas should be dampened every 4-6 hours or within reason to prevent a dust nuisance and on hotter days, this frequency should be increased.
ii. Minimize cleared areas to those that are needed to be used.
iii. Cover or wet construction materials such as marl to prevent a dust nuisance.
iv. Where unavoidable, construction workers working in dusty areas should be provided and fitted with N95 respirators.

Habitat Fragmentation

The effects of habitat fragmentation are expected to be minimal negative since the study site and surrounding areas were already degraded and the species composition limited by current land use practices (e.g. logging, burning and livestock grazing). Although planned access roads and fencing may limit the movement of animal vectors, the grasses and some of the common herbs present are wind propagated. The marine environment also appears to be heavily degraded and may also experience some habitat fragmentation as a result of the lying of various pipelines. However the impacts of these activities is expected to be minimal.

Recommended Mitigation

i. Limit rights-of-passage to areas already showing noticeable signs of habitat degradation. For example areas with open fields and pastureland.
ii. Develop thorough procedures for the proper disposal of solid waste as well as hazardous and flammable materials. Restrict their disposal into surrounding locales.

Accidental or Intentional Removal of Important Plant Species or Communities

Over 52 plant species were encountered. This moderate species richness is possibly due to the mixture of vegetation types present and the then prevailing drought. Although none were endemic, endangered, threatened or rare, the diversity of the area is important. Therefore, minimising the negative impact on the flora during the construction phase of the development is also important.

Recommended Mitigation

i. The removal of vegetation should be strictly limited to the development site.
ii. Altering the orientation or placement of the development's footprint should be considered in more densely vegetated or otherwise sensitive communities mentioned above are not or minimally disturbed.
iii. A proper plan should be developed concerning transportation routes and storage for equipment and material.
iv. The proposed post construction or operation road network should be kept simple as well as be used throughout the preparation and construction phases of the project.
v. Proper planning regarding access points to the construction site should be established.
vi. A buffer area should be established and maintained between the project area and the surrounding vegetation.

<u>Increased Soil/Substrate Erosion and Flooding</u>

The potential for land erosion and flooding is greatly increased as a result of vegetation removal. A plant's roots act as a mesh within the substrate increasing its cohesiveness and improving drainage. Areas where bare ground is exposed tend to erode faster than areas inhabited by plants as they help percolate rainwater into the substrate below. There was evidence on site that some soil compaction and erosion was occurring due primarily to the degraded nature of the community. As such any further vegetation removal would intensify these impacts.

Recommended Mitigation

i. If possible, trees with trunks of DBH 20 cm and greater should be left intact.
ii. Remove trees only as would be necessary. A tree removal protocol should be developed for site preparation prior to project initiation.
iii. Prepare vegetation restoration plan to be implemented once construction is complete.

<u>Storage and Transportation of Raw Materials</u>

Plant growth and health can be significantly affected by dust, grime and toxic emissions. Leaching from storage areas can disturb the pH balance in the soil and result in plant loss.

Recommended Mitigation

i. A central area should be designated for the storage of raw materials. This area should be lined in order to prevent the leakage of paints and chemicals into the sediment.
ii. In terms of transporting equipment, the paths of the planned roadways should be used, rather than creating temporary pathways just for equipment access.

Fauna

Overall, the proposed development will have an impact on the fauna on the property with special emphasis on the birds, as a result of the modification or removal of some of their habitat such as the mudflats, mangrove forest and the old fish ponds. However during the survey no animals with special conservation status were encountered on the property.

Recommended Mitigation

- Planting of trees on the property will increase avifauna and terrestrial invertebrates' number.
- The re-vegetation of the site will not have a significant impact on the crocodile population. However the vegetation can help hide the juvenile crocodiles from predators.
- A winter bird survey should be a part of the monitoring plan for the project.

The removal of the vegetation will change the bird species composition in the area. In order to reduce the negative impact of the development, trees can be planted which could attract a number of birds.

Marine Benthic Environment

Runoff and or siltation as a result land based activities may result in reduced water quality resulting in affecting marine benthos.

Recommended Mitigation

- Construct berms around the construction site
- Sediment barriers/silt screens are recommended.

Further to this special care should be taken in the placement of these screens around these systems, in particular where seagrass beds occur near to shoreline areas. Small sections of seagrass were found within the footprint near the shoreline. These areas should be avoided where possible.

Employment

There is the potential for increased employment during the pre-clearance and construction phases. It is anticipated that approximately 70 persons will be employed directly during the site clearance and an average of 200 persons to a maximum of 400 -450 persons at the peak during construction.

Recommended Mitigation

No mitigation required.

Traffic Management (Commuters and Pedestrians)

The construction process may necessitate the re-routing of some vehicular and pedestrian traffic and introducing traffic delays thereby increasing in travel time. Any re-routing of vehicular traffic has the potential to lead to increase fares. Increased accident potential from additional trucks traversing the main roads is also a possibility.

Recommended Mitigation

During the site preparation and construction phases, the following should be enforced:

i. Trucks should operate ideally during off peak hours.

ii. Loading of trucks as per NWA axel load guidelines.
iii. Traffic diversion routes must be identified and constructed as necessary.
iv. Adequate caution signage as per NWA guidelines and the use of flagmen where necessary.
v. Trucks must be properly covered and loaded so as to not let loose material fall during transport.

Aesthetics

Solid waste generation during the construction period can have a potential negative impact on visual aesthetics if improperly collected and stored on site. There is also the potential for vermin infestation if discarded food and food containers are present.

Recommended Mitigation

i. Skips and bins should be strategically placed within the campsite and construction site.
ii. The skips and bins at the construction campsite should be adequately designed and covered to prevent access by vermin and minimise odour.

Operations

Hydrology and Runoff

Runoff was estimated for both existing (predevelopment) and post development scenarios. The post development scenario for the site considered climate change impacts.

The flows from this area will increase from 15 to 22 percent for the 10 to 100 year event due to the increased impermeable areas after the construction of the power plant.

Recommended Mitigation

i. In order to minimize quantity of waste water, rain water from clean areas such as roads, paved areas free from contamination and buildings, etc. will be collected through open ditches (and/or) road side gutters. Collected rainwater will be routed to the holding area before being re-routed to the sea. This will allow for sediments to fall out before discharge to the sea. The recommended volume for the holding area should contain the first flush or ½ inch of rainfall before it discharges to the sea.
ii. Oily water on the site will generally originate from two area, plant floor and car park area. Floor water will originate from a number of activities; these will include wash down operations, maintenance operations, and spills during loading. Oily water in car park area may be as a result of spills from delivery trucks or any other vehicles undergoing mechanical problem or maintenance. Floor water will be directed to floor drains which will terminate at oil water separators. Similarly car park runoff will be directed to storm drains which will terminate in oil water separators as well. Class 1 separators are recommended for both circumstances given the bay is an environmentally sensitive area.

Noise

The predicted noise from the proposed power plant was determined by using SoundPlan version 7.3. The noise spectrum for both the Steam Turbine Generators and the Gas Turbine Generators and other major equipment provided by the manufacturer was used to calibrate the model. Once the model was calibrated then structures such as the auxiliary buildings, tank farm, ground and other buildings within the area were added. The noise impact from the proposed plant at the fence line (industrial), institutional (schools) and residential location were assessed and reported. All predicted noise levels were compliant with both the NEPA daytime standard and the World Bank guideline

Recommended Mitigation

No mitigation is required.

<u>Vibration</u>

The operation of the power plant has the potential to create vibration that may cause a nuisance to both employees and residents alike.

Recommended Mitigation

i. Ensure that the equipment are placed on the manufacturer's recommended dampening system.
ii. Monitor the following:
    a. Speed (RPM) and Power (MW)
    b. Bearing vibration: seismic, shaft rider, or shaft x-and-y proximity probes (as applicable)
    c. Journal bearing and thrust bearing metal temperature
iii. Install the continuous monitoring system for GE steam turbines - The Turbine Supervisory Instrumentation (TSI) System. This monitoring includes the typical radial displacement vibration and axial position measurements used for GE steam turbines.
iv. Vibration-monitoring capability and evaluation is one of the most important portions of the TSI system for trending and predicting changes in turbine health and thermodynamic performance. Overall, vibration monitoring provides the means to track various problems.

<u>Pollution of Water Resources</u>

Non-hazardous and Hazardous Wastes

Non-hazardous and hazardous wastes include general solid waste, waste oils, oil contaminated rags, hydraulic fluids, used batteries, empty paint cans, waste chemicals and used chemical containers, oily sludge from oil water separators and scrap metals among others. These have the possibility of polluting nearby surface water bodies as a result of improper disposal practices.

Recommended Mitigation

Waste materials should be segregated into non-hazardous and hazardous wastes and considered for re-use /recycling prior to disposal. A waste management plan should be developed that contains a waste tracking mechanism from the originating location to the final waste reception location. Storage, handling and disposal of hazardous and non-hazardous waste should be conducted in a way consistent with good EHS practice for waste management.

Natural Disasters

With any natural disaster comes the possibility of fuel/oil spill as a result of storage tank or pipeline damage. This may affect nearby surface water bodies and/or groundwater.

Recommended Mitigation

Each storage tank should be surrounded by a bund which is designed to contain at least 110% of the storage tank capacity.

The tanks should also be designed for the seismic rating of the region and the tank profile should take into account the wind loads (both typical and maximum) for the region and must be able to withstand a Category 5 hurricane. Equipment and structures must also be designed to withstand the harshest recorded environment for the region.

Oily Water Management

Oily water on the site will generally originate from two areas, plant floor and the car park area. Floor water will originate from a number of activities; these will include wash down operations, maintenance operations, and spills during loading. Oily water in the car park area may be as a result of spills from delivery trucks or any other vehicles undergoing mechanical problem or maintenance.

Recommended Mitigation

i. Direct rainfall into the areas or floor washing water will be led to an oil separator by gravity and connected to the industrial waste piping network. The Oil removal system receives oil-contaminated water from all over the plant. Oil removed from the Oil/water separator will be stored within the separator for periodic removal and off-site disposal.

Sewage and Wastewater Management

Water for plant and sanitary processes will be obtained from a well source. The wastewater produced from the power plant operations will include wastes from the following sources:

- RO plant reject water (brine)
- Demineralization waste water
- Filter backwash water
- Cooling tower

Recommended Mitigation

All wastewater from the plant will be collected in a concrete tank and pre-treated to a satisfactory level and routed through a holding area to make it fully compliant with NEPA effluent quality standards before being re-routed back to the flume. The effluent quality will also be monitored by a continuous monitoring system. Sewage effluent from various buildings will be piped to the central sewage treatment plant.

Cooling Water Management

The cooling water from the plant will be discharged from the plant at a rate of 282,812 GPM and at a higher temperature than that of the seawater. The background or ambient temperature of seawater was measured at 30.71 degrees Celsius on average whereas the discharge from the plant will be at 35.5 degrees Celsius.

In order to predict the behaviour of the plume in terms of its movement and temperature, scaled and calibrated numerical models are generally employed. The nearfield and far field modelling are generally separated to because of scaling differences. Nearfield models simulate the behaviour of the Gully in the vicinity of the discharge point.

<u>Air Quality</u>

The following conclusions may be made as a result of the conduct of the air dispersion modelling analyses for the proposed LNG-fired power plant:

- The emission rates derived from the use of emission factors for each combustion turbine burning LNG, comply with the CO and PM emission standards, but exceeded the NO_x standards. It was deduced that in order to achieve compliance with the NO_x emission standard, certain changes with the design of the diluent injection technology to be employed for NOx reduction will have to be made.
- The model predictions for the LNG-fired proposed power plant revealed compliance with the CO, TSP, NO_2 and SO_2 ambient air quality standards and the priority air pollutant guideline concentrations for the requisite averaging periods. The incremental impact of the criteria air pollutants were also less than the established values that would have created a significant air quality impact.
- Based on the modelling results, the replacement of the existing JPS oil-fired power plant with the proposed LNG-fired power plant would cause a marked improvement to the prevailing SO_2 ambient air quality concentration within the air shed, while its impact on the prevailing TSP, CO and NOx concentrations will only have marginal improvement.
- Since the proposed LNG fired power plant sources demonstrated compliance with the ambient air quality standards and the guideline concentrations, as well as with the significant impact incremental values, it is envisaged that approval will be granted for the establishment of the facility. Nevertheless, it is anticipated that certain changes would need to be done for each combustion turbine's NOx emissions to achieve compliance with the NOx emission standard for a 40 MW capacity LNG-fired unit.

2.0 INTRODUCTION

The Jamaica Public Service Company (JPS), the sole distributor of electricity in Jamaica, is planning to construct a 190 MW nominal combined cycle power plant, adjacent to JPS' existing Old Harbour facility, which currently has 220 MW of generation. It is intention that this new facility will repower the existing power plant at Old Harbour plant and replace the inefficient heavy fuel oil being used currently. Specifically, it is intended that liquefied natural gas (LNG) will be used to fuel the proposed power plant.

Impacts from the construction and operation of the proposed facility will potentially arise and it is considered imperative to consider these likely impacts and assess the vulnerability of environmental features in proximity to the project location, as well as on a national scale. In order to evaluate these impacts, an Environmental Impact Assessment (EIA) is required by the National Environment and Planning Agency for the proposed project. The specific tasks, as outlined by the Terms of Reference (TORs) have been executed by the contracted entity, CL Environmental Co. Ltd., and this report serves to compile and present the findings of the EIA. It should be noted that the fuelling of the proposed power plant with LNG is considered a separate project, for which an additional EIA will be required.

3.0 POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

3.1 EIA FRAMEWORK

3.1.1 Rationale and Basis

An Environmental Impact Assessment (EIA) is "a structured approach for obtaining and evaluating environmental information prior to its use in decision-making in the development process. This information consists, basically, of predictions of how the environment is expected to change if certain alternative actions are implemented and advice on how best to manage environmental changes if one alternative is selected and implemented" (Bisset, 1996).

The basis and rationale of an EIA has been summarised as follows[1]:

- Beyond preparation of technical reports, EIA is a means to a larger end - the protection and improvement of the environmental quality of life.
- It is a procedure to discover and evaluate the effects of activities on the environment - natural and social. It is not a single specific analytical method or technique, but uses many approaches as appropriate to the problem.
- It is not a science but uses many sciences in an integrated inter-disciplinary manner, evaluating relationships as they occur in the real world.
- It should not be treated as an appendage, or add-on, to a project, but regarded as an integral part of project planning. Its costs should be calculated as a part of adequate planning and not regarded as something extra.
- EIA does not 'make' decisions, but its findings should be considered in policy - and decision-making and should be reflected in final choices. Thus, it should be part of decision-making processes.
- The findings of EIA should focus on the important or critical issues, explaining why they are important and estimating probabilities in language that affords a basis for policy decisions.

3.1.2 National Environment and Planning Agency

The National Environment and Planning Agency (NEPA) is the government executive agency and represent a merger of the Natural Resources Conservation Authority (NRCA), the Town Planning Department (TPD) and the Land Development and Utilization Commission (LDUC). Among the reasons for this merger was the streamlining of the planning application process in Jamaica. The Agency is moving towards one application to NEPA for new developments and new modifications that will review

[1] Wood, C., "Environmental Impact Assessment: A Comparative Review" p. 2. (from Caldwell, 1989, p.9)

and approve environmental aspects as well as planning, building control and zoning considerations. It is this agency that will review the Environmental Impact Assessment.

The National Environment and Planning Agency (NEPA) has been given responsibility for environmental management in Jamaica under the NRCA Act of 1991. Since the promulgation of the Act, the NRCA has been developing local standards. The Act was strengthened by supporting regulations, which became effective in January 1997. The underlying principles, which have been used in the development of the Act, are:

- The Polluter pays Principle
- The Cradle to Grave approach to waste management

3.1.3 Permits and Licenses

The Environmental Permit and License System (P&L) is administered by NEPA through the Applications Section. It was introduced in 1997 to ensure that all developments meet required standards and negative environmental impacts are minimized. Under the NRCA Act of 1991, the NRCA has the authority to issue, suspend and revoke environmental permits and licenses. An applicant for a Permit or License must complete a Permit Application Form (PAF) as well as a Project Information Form (PIF) for submission to the NRCA/NEPA.

3.1.4 EIA Components

3.1.4.1 Process

Under Section 9 of the NRCA Act, all activities associated with Power Plant facilities (e.g. wind farms, hydro, thermal and nuclear) such as the proposed power plant will require a Permit for construction and may, under Section 10 of the Act, require an EIA. The EIA Process is described below:

- The NRCA permit procedure is initiated by the submission of the Project Information Form (PIF) to the Authority. The PIF screening form is reviewed to determine whether an EIA is required and to begin determining areas of environmental significance, especially in waste discharge.
- Based on the review of the PIF, the NRCA advises if an EIA would be required for the proposed project and determines the scope of the EIA through proposed Terms of Reference (TORs). The TORs are proposed using NRCA guidelines and are ultimately approved by the NRCA. Appendix 1 gives the approved final TORs for the proposed project.
- The NRCA requires that the EIA include the following:
    - A description of the present environment, i.e. physical, biological and social environment. This includes, for example, consideration of economic situations, cultural heritage and ecological preservation;
    - A description of the significant impacts the environmental professionals expect the development to have on the environment, compared to the environment that would remain if there were no development. This will include indirect and cumulative impacts;

  - An analysis of alternatives that were considered in order to consider means of minimising or eliminating the impacts identified above; and
  - An Environmental Management Plan, which includes a Monitoring & Hazard Management Plan and an Auditing schedule.
- The NRCA guidance on EIAs states that this process "should involve some level of stakeholder consultation in either focus groups or using structured questionnaires." A draft EIA is submitted to the developer to solicit the proponents' input into the description of the project (to check for accuracy of statements, and to enter into realistic discussions on the analysis of alternatives, as well as to inform the proponents of any other relevant legislation with which they must comply).
- Fourteen copies of the finalised draft are then submitted to NRCA, two to the client, and the consultant keeps one (17 in all are produced). The NRCA distributes these to various other public sector institutions who sit on the Technical Committee (e.g. Water Resources Authority (WRA), Environmental Control Division in the Ministry of Health (ECD), Jamaica National Heritage Trust (JNHT)) for their comments. Typically this depends on the nature of the project.
- As deemed necessary by the NRCA, Public Meeting(s) are then held, following the deposition of the Draft EIA at Parish Libraries (by the NRCA). A verbatim report of the public meetings is required, as well as a summary report of the main stakeholder responses which emerged.
- The comments of the NRCA, the other GOJ interests and the public are compiled and submitted in writing to the consultant not only for finalisation of the report, but for incorporation into the development's design.
- The NRCA then reviews this report again, and if further clarifications are needed, these are again requested. Once the NRCA is satisfied, the EIA is submitted to the Technical Committee of the NRCA Board for final approval. If the EIA is not approved, the proponents may appeal to the Office of the Prime Minister.

3.1.4.2 Public Participation

There are usually two forms of public involvement in the EIA process. The first is direct involvement of the affected public or community in public consultations and surveys during the EIA study. These consultations allow the developer to provide information to the public about the project and to determine what issues the public wishes to see addressed. The extent and results of these consultations are included in the documented EIA report. The second level of involvement is at the discretion of the NRCA and takes place after the EIA report and addendum, if any, has been prepared and after the applicant has provided the information needed for adequate review by NRCA and the public.

Community interaction and transparency is a critical area of focus for the success of this development and the second level of involvement described above is possible. Please see Appendix 2 for the NRCA reference document entitled "Guidelines for Public Participation" in EIAs.

3.2 NATIONAL LEGISLATION

The following sections include a discussion of relevant national legislation, regulations/standards, policies and other material thought to be relevant to the proposed project. The following main areas are covered:

- *Development Control*: construction (including building codes and site management controls) and subsidiary inputs (quarry material, etc.), public safety and vulnerability to disasters.
- *Environmental Conservation*: forestry, wildlife and biodiversity, protected areas and species, water resources, heritage and cultural resources.
- *Public Health & Waste Management*: air quality, noise levels, public health, solid waste, storm water, etc.

3.2.1 Development Control

This section deals with planning and development issues that can affect the establishment of a Power Generating Plant at Old Harbour Bay. Several development and planning related laws and regulations may affect the project. The applicability of these laws is dependent on the location of the development chosen, social and socio-economic issues as well as the availability of land for acquisition. Described in subsequent sections below are the relevant legislations and regulations that may affect the project. The following agencies are those that may be encountered for planning and development approvals:

- St. Catherine Parish Council (Local Planning Authority - LPA) – All development applications are made through the LPA which include enquiries, planning, building and subdivision approvals.
- National Environment and Planning Agency (NEPA) - Applications reviewed by NEPA include enquiries, planning applications, and building and subdivision applications.
- Factories Cooperation of Jamaica- Guidelines for safety, health and welfare of factory employees.

3.2.1.1 Local Improvement Act 1944

The Local Improvements Act is the primary statute that controls the subdivision of land.

3.2.1.2 Parish Councils Act 1901 (Amended 2007)

Under the Parish Council Act each Local Planning Authority may revoke or alter regulations concerning the construction and restrictions as to the elevation, size and design of buildings built with the approval of the relevant Minister. It may also make regulations concerning the installation of sewers on premises.

3.2.1.3 Town and Country Planning Act (TCP Act), 1957 (Amended 1987)

The Town and Country Planning Act (TCP Act) 1957 (Amended 1987) provides the statutory requirements for the orderly development of land through planning, as well guidelines for the preparation of Development Orders. A Development Order is a legal document which is used to guide development in the area to which it applies and the TCP Act is only applicable in an area where a Development Order exists. It constitutes land use zoning map/s, policy statements and standards relating to land use activities. Tree Preservation Areas and Conservation Areas (as specified areas the gazetted Development Orders) are two types of protected areas associated this Act. As seen in Figure 3-1, the Development Order relevant to this proposed is the St Catherine Coastal Development Order. Please see section 5.6.2.3 (Zoning) for further details.

The TCP Act establishes the Town and Country Planning Authority, which in conjunction with the Local Planning Authorities (Parish Councils), are responsible for land use zoning and planning regulations as described in their local Development Orders. The TCP Act is administered by the National Environment and Planning Agency.

3.2.1.4 Office of Utilities Regulation (OUR) Act 1995 (Amended 2000)

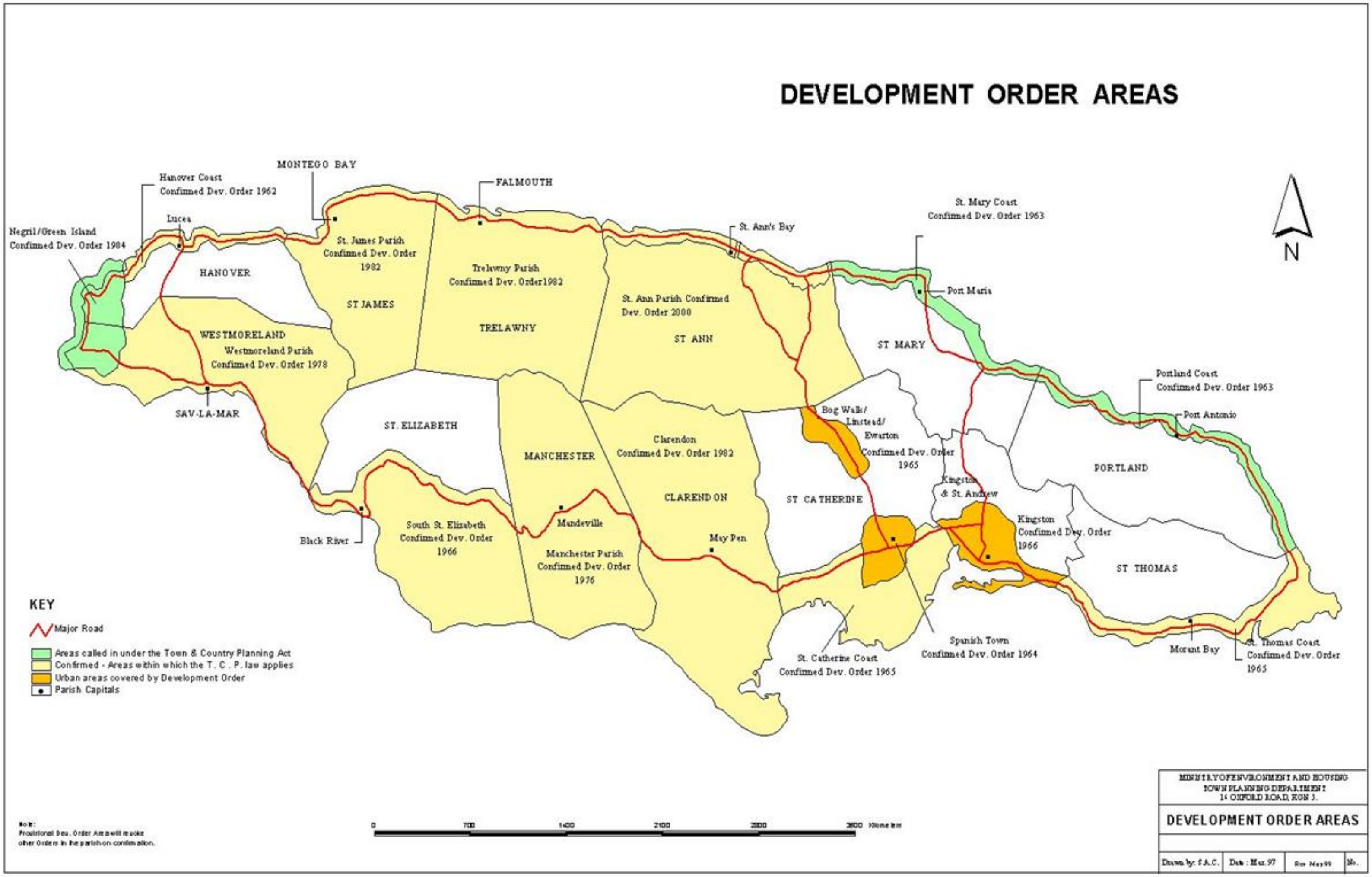
This Act was promulgated in 1995. Under this legislation, the OUR receives and processes applications for a licence to provide a prescribed utility service and make such recommendations to the Minister in relation to the application as the Office considers necessary or desirable. In relation to environmental management and protection, the OUR may, where it considers necessary, give directions to any licensee or specified organization with a view to ensuring that the prescribed utility service operates efficiently and in a manner designed to:

1. Protect the health and well-being of users of the service and such elements of the public as would normally be expected to be affected by its operation;
2. Protect and preserve the environment; and
3. Afford to its consumers economical and reliable service.

3.2.1.5 The Jamaica National Heritage Trust Act 1985

The Jamaica National Heritage Trust Act established the Jamaica National Heritage Trust (JNHT) and has been in operation since 1985. The main goal is the preservation and protection of the country's national heritage. The Act states the following offences are liable to a fine and/or imprisonment:

- Wilfully defacing, damaging or destroying any national monument or protected national heritage;
- Wilfully defacing, destroying, concealing or removing any mark affixed or connected to a national monument or protected national heritage;
- Altering any national monument or marking without the written permission of the Trust;
- Removing any national monument or protected national heritage to a place outside of Jamaica.



Source: National Environment and Planning Agency[2]

Figure 3-1 Development Order Areas in Jamaica

[2] http://www.nepa.gov.jm/symposia_03/Laws/Maps/Map_of_Development_Orders.htm

3.2.1.6 Vision 2030 and National Energy Policy

Vision 2030 is a National Development Plan for Jamaica, promoting four National Goals as well as associated National Outcomes for each goal, to be achieved by 2030, with the objective of developing Jamaica into a country with a vibrant and sustainable economy, society and environment; a high level of human capital development; greater opportunities and access to these opportunities for the population; and a high level of human security. Of the aforementioned outcomes, two apply directly to the proposed project:

- National Outcome 10: Energy Security and Efficiency (under Goal 3: "Jamaica's Economy is prosperous.") and;
- National Outcome 13: Sustainable Management and Use of Environmental and Natural Resources (under Goal 4: "Jamaica has a healthy natural environment.")

The outcomes outlined above are incorporated in the proposed project by directly increasing the country's energy efficiency, as well as considering environmental repercussions and outlining mitigation activities throughout the development of this plant. In further accordance with Vision 2030, the proposed development also aligns with the Ministry of Energy and Mining's National Energy Policy, created under the umbrella of Vision 2030. A synopsis of the goals and elements of the National Energy Policy (Vision of Jamaica's Energy Sector 2009 – 2030) is as follows:

- Goal 1: Jamaicans use energy wisely and aggressively pursue opportunities for conservation and efficiency.
- Goal 2: Jamaica has a modernized and expanded energy infrastructure that enhances energy generation capacity and ensures that energy supplies are safely, reliably, and affordably transported to homes, communities and the productive sectors on a sustainable basis.
- Goal 3: Jamaica realizes its energy resource potential through the development of renewable energy sources and enhances its international competitiveness, energy security whilst reducing its carbon footprint.
- Goal 4: Jamaica's energy supply is secure and sufficient to support long-term economic and social development and environmental sustainability.
- Goal 5: Jamaica has a well-defined and established governance, institutional, legal and regulatory framework for the energy sector that facilitates stakeholder involvement and engagement.
- Goal 6: Government ministries and agencies are a model/leader in energy conservation and environmental stewardship in Jamaica.
- Goal 7: Jamaica's industry structures embrace eco-efficiency for advancing international competitiveness and moves towards building a green economy.

The National Energy Policy seeks to develop a modern, efficient, diversified and environmentally sustainable energy sector providing affordable and accessible energy supplies, with long-term energy security and supported by informed public behaviour on energy issues and an appropriate policy, regulatory and institutional framework. This expansion project being undertaken fulfils the goal of modernizing the energy sector as well as making it more efficient through the primary use of LNG and allowing energy to be more accessible through the replacement of an older, less efficient, power plant with a newer, higher capacity, dual fuel capable plant.

3.2.2 Environmental Conservation

3.2.2.1 Policy for the National System of Protected Areas 1997

The system of protected areas should be an essential tool for environmental protection, conserving essential resources for sustainable use, helping to expand and diversify economic development, and contributing to public recreation and education. Six types of protected areas are proposed in order to encompass the diverse natural resources and landscape, and are comparable to those of the IUCN (International Union for Conservation of Nature)[3]:

1) National Nature Reserve/Wilderness Area (Equivalent to IUCN Category I)
2) National Park, Marine Park (Equivalent to IUCN Category II).
3) Natural Landmark/National Monument (Equivalent to IUCN Category III)
4) Habitat/Species Management Area (Equivalent to IUCN Category IV)
5) National Protected Landscape, or Seascape (Equivalent to IUCN Category V)
6) Managed Resource Protected Area (Equivalent to IUCN Category VI)

This legislative instrument is a White Paper and essentially proposes a comprehensive protected areas system for Jamaica. However, as seen in Table 3-1, there are a greater number of protected area categories existing at present than being proposed, with varying responsible agencies and legislative tools.

Table 3-1 Existing categories of protected areas in Jamaica (as at 1 January 2012) - protected area system categories

Source: (Protected Areas Committee, 2012)

CATEGORY	RESPONSIBLE AGENCY	LAW
Protected Area	Forestry Department: Water, Land, Environment and Climate Change (MWLECC)	Forest Act, 1996 and Forest Regulations
	NEPA: MWLECC	NRCA Act, 1991
	NEPA: MWLECC	Beach Control Act, 1956
National Park	NEPA: MWLECC	NRCA Act, 1991
Marine Park	NEPA: MWLECC	NRCA Act, 1991
Environmental Protection Area	NEPA: MWLECC	NRCA Act, 1996
Forest Reserve	Forestry Department: MWLECC	Forest Act, 1996 and Forest Regulations

[3] It should be noted that since the publication of the Policy for Jamaica's System of Protected Areas 1997, the IUCN has revised the categories system and guidelines (http://cmsdata.iucn.org/downloads/guidelines_for_applying_protected_area_management_categories.pdf)

CATEGORY	RESPONSIBLE AGENCY	LAW
Fish Sanctuary	Fisheries Division: Ministry of Agriculture and Fisheries	Fishing Industry Act, 1976
National Monument	Jamaica National Heritage Trust(JNHT) Ministry of Youth and Culture (MYC)	JNHT Act, 1985
Protected National Heritage	JNHT: MYC	JNHT Act, 1985
Game Sanctuary	NEPA (NRCA): MWLECC	Wild Life Protection Act, 1945
Game Reserve	NEPA (NRCA): MWLECC	Wild Life Protection Act, 1945

Table 3-2 Existing categories of protected areas in Jamaica (as at 1 January 2012) - other designations not considered part of the system

Source: (Protected Areas Committee, 2012)

CATEGORY	RESPONSIBLE AGENCY	LAW
Tree Order Preservation	Local Authority (Town and Country Planning Authority): MWLECC and Local Government Department, through Parish Councils	Town and Country Planning Act, 1958
Conservation Area	NEPA (Town and Country Planning Authority, parish councils): MWLECC	Town and Country Planning Act, 1958
Protected Watershed	NEPA (NRCA): MWLECC	Watershed Act, 1963 Protection

Table 3-3 Existing categories of protected areas in Jamaica (as at 1 January 2012) - international designations

Source: (Protected Areas Committee, 2012)

CATEGORY	RESPONSIBLE AGENCY	CONVENTION
Ramsar Site	NEPA (NRCA): MWLECC	Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention)
World Heritage Site (no existing sites, however submissions have been made)	Jamaica National Heritage Trust: MYC	World Heritage Convention

The Natural Resources Conservation Authority (NRCA)/National Environment and Planning Agency (NEPA) is the lead agency with responsibility for the protected area system; however a number of other government , local management entities, non-governmental entities, privet sector and individuals are outlined as important role players as well.

As seen in Figure 3-2, the proposed study falls within an area protected under various legal instruments and agreements - Portland Bight Protected Area (declared April 22, 1999 under Natural Resources Conservation Authority (NRCA) Act) and the Portland Bight Wetlands and Cays Ramsar Site. Two game reserves are located to the southwest and southeast, namely Long Island Game Reserve (declared August 21, 1998 under Wild Life Protection Act (WLPA)) and Amity Hall Game Reserve (declared August 22, 1997, amended July 28, 2004) respectively. In addition, the Galleon Harbour SFCA and the Salt Harbour SFCA are also located to the southwest and southeast of the project area. Also protected by law is the Great Goat Island forest reserve, 4km southeast of the project area.

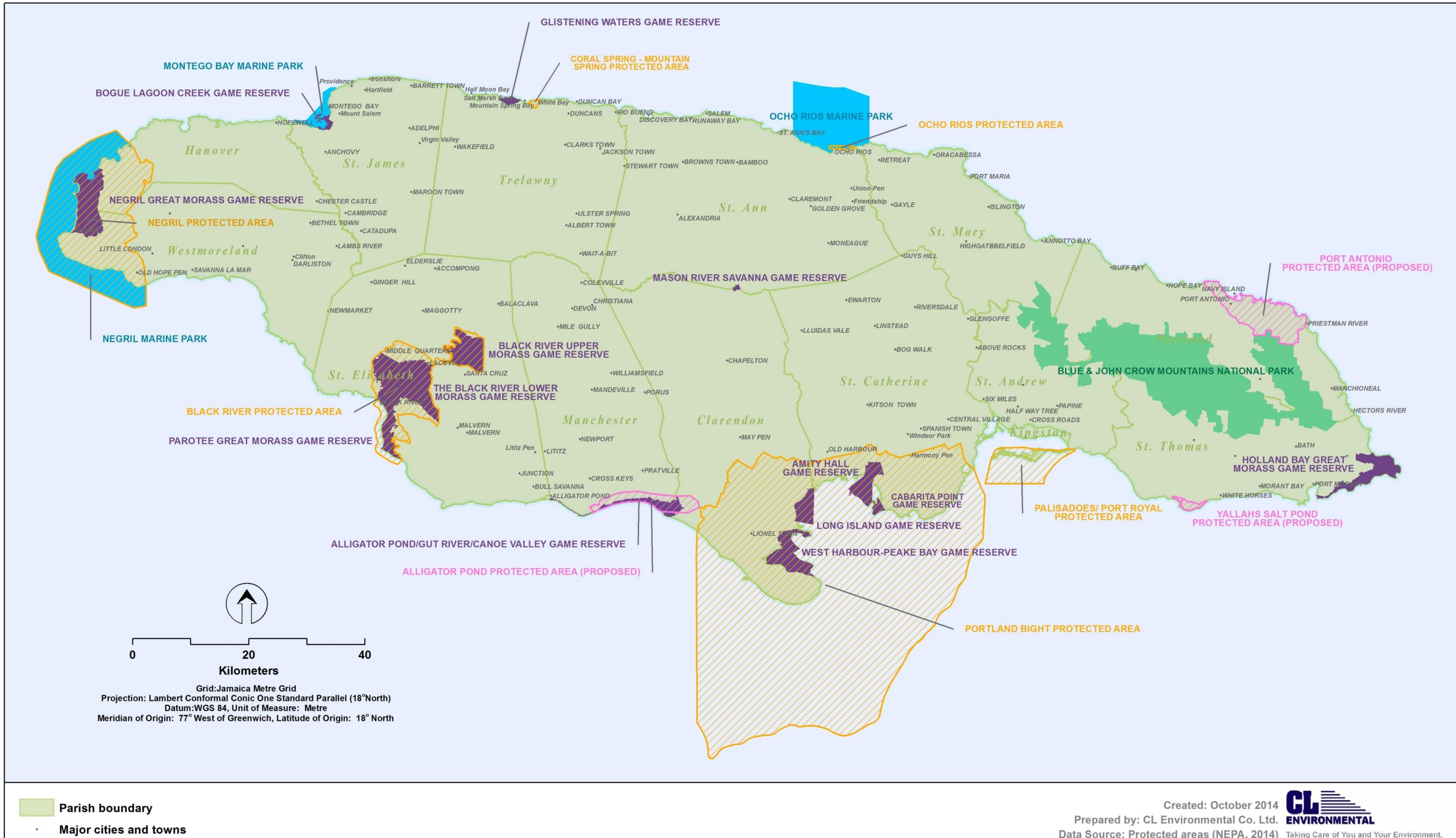


Figure 3-2 Protected areas system in Jamaica

3.2.2.2 Natural Resources Conservation Authority Act 1991

The Natural Resources Conservation Authority Act (NRCA) may be considered Jamaica's umbrella environmental law. The purpose of the Act is to provide for the management, conservation and protection of the natural resources of Jamaica. This Act was passed in the Jamaican Parliament in 1991 and subsequent to this; the Natural Resources Conservation Authority (NRCA) was established. The NRCA Act, under Sections 9 and 10 specifies that an Environmental Impact Assessment (EIA) is required from an applicant for a permit for undertaking any new construction, enterprise or development. It also speaks to the designation of national parks, protected areas etc.

The Act also gave power of enforcement of a number of environmental laws to the NRCA, namely the *Beach Control Act*, *Watershed Act* and the *Wild Life Protection Act*, as well as a number of regulations and orders including *The Natural Resources (Permit and Licences) Regulations (1996), The Natural Resources (Marine Park) Regulations 1992, The Natural Resources (Marine Park) (Amendment) Regulations 2003* and *The Natural Resources (Prescribed Areas) (Prohibition of Categories of Enterprise, Construction and Development) Order 1996.*

The Natural Resources Conservation (Permit and Licences) Regulations 1996 (Amended 2015)

A permit and licencing system was established under these regulations in order to control the undertaking of any new construction or development of a prescribed nature in Jamaica and the handling of sewage or trade effluent and poisonous or harmful substances discharged into the environment. As part of the April 2015 amendment, regulations 3, 7 and 24, concerning permit application forms, duration and fees respectively, were substituted.

The Natural Resources (Prescribed Areas) (Prohibition of Categories of Enterprise, Construction and Development) Order 1996 (Amended 2015)

The Natural Resources (Prescribed Areas) (Prohibition of Categories of Enterprise, Construction and Development) Order (1996) and the Permits & Licensing Regulations was passed as a result of section 9 of the NRCA Act. Section 9 of the NRCA Act declare the entire island and the territorial sea as a ‘prescribed area’, in which specified activities require a permit, and for which activities an environmental impact assessment may be required. The major amendment made in 2015 was the substitution of the Categories of Enterprises, Construction and Development (Column A), which lists the various activities, by category, for which a permit is required. As discussed previously, an EIA was required for the proposed project and this report fulfils one component of the EIA process.

3.2.2.3 The Fishing Industry Act 1975

The Fishing Industry Act 1975 is the overarching instrument relating to fishing activities within Jamaica. The Act speaks to registration and licensing, fisheries protection, prohibited activities and the declaration of an area as a fish sanctuary. Under the most recent Fishing Industry (Special Fishery Conservation Area) Regulations 2012, Special Fishery Conservation Areas (SFCAs), more commonly known as fish sanctuaries, are declared. As mentioned previously, the Galleon Harbour SFCA and the Salt Harbour SFCA are located to the southwest and southeast of the project area. Further, although fishing is not an activity to be carried out intentionally during the proposed project, it must be kept in mind during construction activities that it is an offence, during closed seasons, to take, disturb or injure fish, as well as to destroy or land berried lobster and spiny lobster smaller than 3 inches (7.5 cm).

3.2.2.4 Wild Life Protection Act 1945

The Wild Life Protection Act of 1945 is mainly concerned with the protection of specified faunal species and is the only statute in Jamaica specifically designated to this. This Act protects several rare and endangered faunal species including six species of sea turtle, one land mammal, one butterfly, three reptiles and a number of game birds. A list of these protected species is provided in this Act under the Second and Third Schedules and is presented in Figure 3-3. The establishment of two types of protected areas, namely Game Sanctuaries and Game Reserves is authorized under this Act. As mentioned previously, two game reserves are located to the southwest and southeast, namely Long Island Game Reserve (declared August 21, 1998) and Amity Hall Game Reserve (declared August 22, 1997, amended July 28, 2004) respectively.

3.2.2.5 The Endangered Species (Protection, Conservation and Regulation of Trade) Act 2000 (Amended 2015)

The Endangered Species (Protection, Conservation and Regulation of Trade) Act was created in 2000 in order to ensure the codification of Jamaica's obligations under the Convention for the International Trade in Endangered Species of Wild Fauna and Flora. This Act governs international and domestic trade in endangered species in and from Jamaica. The regulations associated with this Act were amended in 2015, and include updated fees for the various permits and certificates granted through this legislation.

3.2.2.6 Water Resources Act 1995

The Water Resources Act (1995) established the Water Resources Authority (WRA), which is authorized to regulate, allocate, conserve and manage the water resources of the island. Section 25 advises that a proposed user will have to obtain planning permission, if this is a requirement, under the Town and Country Planning Act. In addition, under Section 21 it states that if the water to be used will result in the discharge of effluents, an application for a license to discharge effluents will have to be made to the Natural Resources Conservation Authority or any other relevant body as indicated by the Minister.

3.2.2.7 The Forest Act 1996

The 1996 Forest Act repealed the 1937 legislation and was the legal basis for the organization and functioning of the Forestry Department. The Forestry Department is the lead agency responsible for the management and conservation of the forest resources in Jamaica. A "Forest Reserve" is defined to be any area of land declared by or under this Act to be a forest reserve. In 1938, the Forest Branch gazetted some 78,800 hectares of Crown Lands as forest reserves, this making up more than 75% of the present day forest reserves (Figure 3-4). The Great Goat Island forest reserve is situated 4km southeast of the project area.

Protected Jamaican Animals

Common Names	Scientific Names
Sperm Whale	*Physeter macrocephalus*
Baird's beaked Whale	*Berardius bairdii*
Short-finned pilot Whale	*Globicephala macrorhynchus*
Humpback Whale	*Megaptera novaeangliae*
Common Bottlenose Dolphin	*Tursiops truncatus*
Pantropical spotted Dolphin	*Stenella attenuata*
West Indian Manatee	*Trichechus manatus manatus*
Caribbean Monk Seal (Pedro Seal)	*Monachus tropicalis*
Jamaican Hutia (Coney)	*Geocapromys brownii*
American Crocodile	*Crocodylus acutus*
Jamaican Iguana	*Cyclura collei*
Yellow Snake/Jamaican Boa	*Epicrates subflavus*
Green Turtle	*Chelonia mydas*
Hawksbill Turtle	*Eretmochleys imbricata*
Loggerhead Turtle	*Caretta caretta*
Atlantic Kemps Ridley	*Lepidochelys kempii*
Leatherback turtle	*Dermochelys coriacea*
Reid Seahorse	*Hippocampus reidii*
Jamaican Kite Swallowtail	*Eurytides marcellinus*
Giant Swallowtail Butterfly	*Papilio homerus*
Black Coral	*Antipathes* species
White Coral	Scleractinian or Madreporarian

All birds are protected except the following:

Cattle Egret	*Bubulcus ibis*
Rock Dove (Pigeon)	*Columba livia*
Ringed-turtle Dove (Barble Dove)	*Streptopelia risoria*
European Starling	*Sturnus vulgaris*

National Environment and Planning Agency

Protected Jamaican Animals Cont'd

All birds are protected except the following:

Saffron Finch (Wild Canary)	*Sicalis flaveola*
House Sparrow	*Passer domesticus*
Yellow-crowned Bishop	*Euplectes afer*
Red Bishop	*Euplectes orix*
Nutmeg Mannikin	*Lonchura punctulata*
Chestnut Mannikin	*Lonchura Malacca*
Shiny Cowbird	*Molothrus bonariensis*
Chickens	*Gallus gallus*
Geese	*Anser* spp.
Turkey	*Meleagris gallopavo*
Guinea fowl	*Numida meleargris*
Pea fowl	*Pavo cristatus*
Budgerigars	*Melopsittacus undulates*
Cockatiel	*Nymphicus hollandicus*
Ducks excluding endemic and migratory species	

GAME BIRDS (These are protected outside of the bird shooting season)

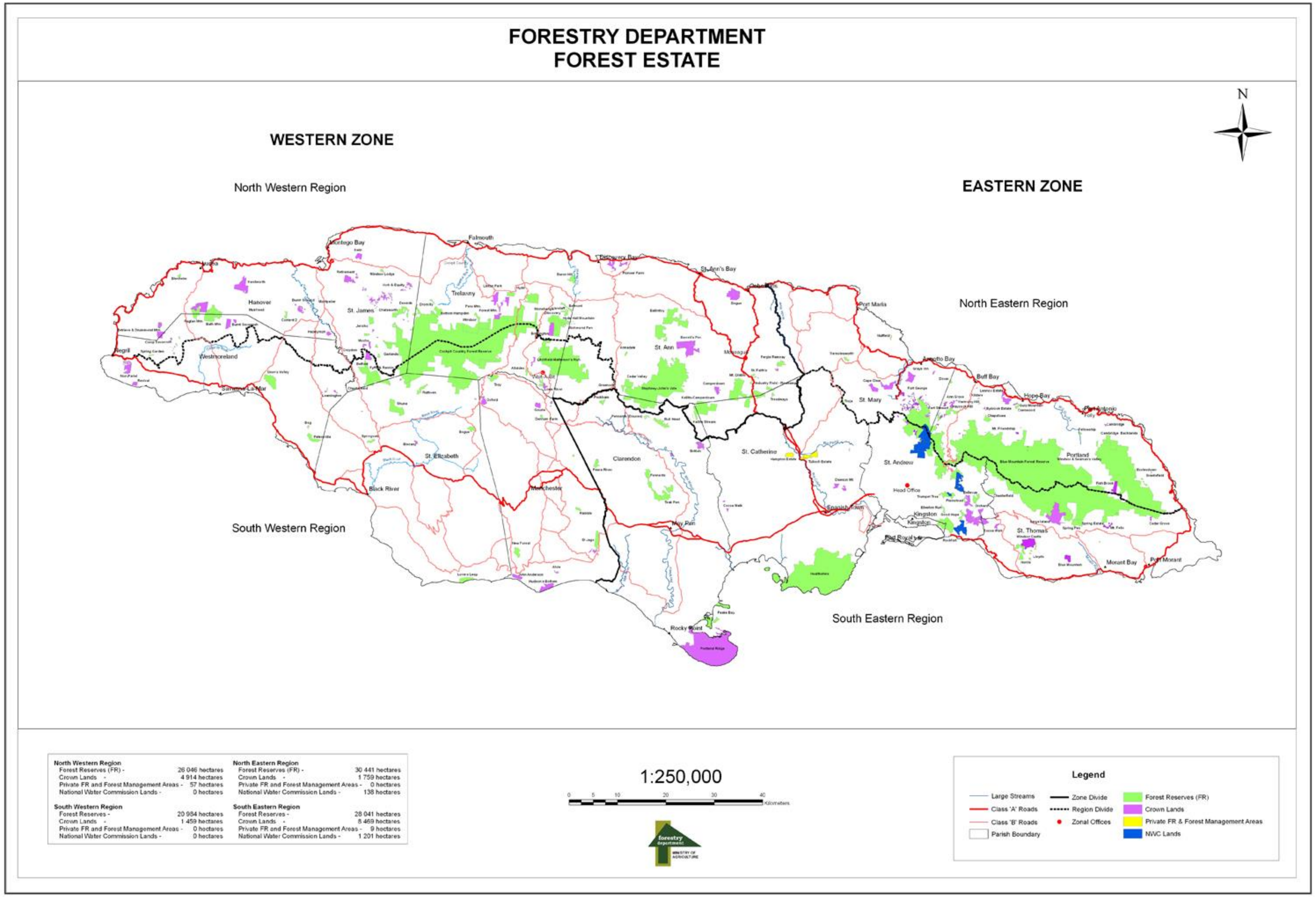
Mourning Dove (Long-tailed Pea Dove)	*Zenaida macroura*
White-winged Dove	*Zenaida asiatica*
White-crowned Pigeon (Bald pate)	*Columba leucocephala*
Blue-winged Teal	*Anas discors*
Green-winged Teal	*Anas crecca*

Prepared by the Biodiversity Branch, National Environment and Planning Agency
Updated March, 2005

Source: National Environment and Planning Agency (NEPA) [4]

Figure 3-3 Protected animals in Jamaica

[4] http://www.nepa.gov.jm/publications/brochures/flyers/protected%20Jamaican%20animals.pdf



Source: Forestry Department [5]

Figure 3-4 Map showing forest estates across the island, including reserves, crowned lands, private areas and NWC lands

[5] http://www.forestry.gov.jm/images/res250k_bg.jpg

3.2.2.8 The Beach Control Act 1956

This Act was passed to ensure the proper management of Jamaica's coastal and marine resources by means of a licensing system. This system regulates the use of the foreshore and the floor of the sea. In addition, the Act speaks to other issues including access to the shoreline, rights related to fishing and public recreation and establishment of marine protected areas. The Beach Control Authority (Licensing) Regulations of 1956 require a permit for any works on a beach, coastline or foreshore. Application for this permit must be made to NEPA.

3.2.3 Public Health & Waste Management

3.2.3.1 The Natural Resources Conservation Authority (Air Quality) Regulations, 2002

Under section 38 of the NRCA Act, regulations pertaining to air quality in Jamaica are stipulated. The National standards, known as the National Ambient Air Quality Standards (NAAQS) are categorized into two groups. Part I of the NRCA Air Quality Regulations (2002) instructs on license requirements and indicates that every owner of a major or significant facility shall apply for an air pollutant discharge license. Part II makes reference to the stack emission targets, standards and guidelines.

3.2.3.2 Water Quality Standards

The NRCA has primary responsibility for control of water pollution in Jamaica. National Standards for industrial and sewage discharge into rivers and streams, in addition to standards for ambient freshwater exist. For drinking water, World Health Organization (WHO) Standards are utilized and these are regulated by the National Water Commission (NWC). Since 1996, Jamaica has had draft regulations governing the quality of the effluent discharged from facilities to public sewers and surface water systems. These draft guidelines require the facility to meet certain basic water quality standards for trade effluent including sewage.

Table 3-4 Draft national ambient marine water quality standards for Jamaica, 2009

Source: National Environment and Planning Agency (NEPA)

Parameter	Measured as	Standard Range	Unit
Phosphate,	P*	0.001-0.003	mg/L
Nitrate,	N**	0.007-0.014	mg/L
BOD_5	O	0.0-1.16	mg/L
pH		8.00-8.40	
Total Coliform		2-256	MPN/100mL
Faecal Coliform		<2-13	MPN/100mL

*Reactive phosphorus as P
**Nitrates as Nitrogen

3.2.3.3 The Clean Air Act 1964

The Clean Air Act (1964) refers to premises on which there are industrial works, the operation of which is, in the opinion of an inspector, likely to result in the discharge of smoke, fumes, gases or dust in the air. An inspector may enter any affected premises to examine, make enquiries, conduct tests and take samples of any substance, smoke, fumes, gas or dust that may be considered necessary or proper for the performance of his/her duties.

3.2.3.4 The National Solid Waste Management Authority Act 2001

The National Solid Waste Management Authority Act of 2001 is "an act to provide for the regulation and management of solid waste; to establish a body to be called the National Solid Waste Management Authority and for matters connected therewith or incidental thereto". The National Solid Waste Management Authority (NSWMA) was established in April 2002 as a result of this Act to effectively manage and regulate the collection and disposal of solid waste in Jamaica.

3.2.3.5 Public Health Act 1985

The Public Health Act is administered by the Ministry of Health through Local Boards, namely the parish councils. *The Public Health (Nuisance) Regulations 1995* aims to, control reduce or prevent air, soil and water pollution in all forms. Under the regulations:

- No individual or organization is allowed to emit, deposit, issue or discharge into the environment from any source;
- Whoever is responsible for the accidental presence in the environment of any contaminant must advise the Environmental Control Division of the Ministry of Health and Environmental Control, without delay;
- Any person or organization that conducts activities which release air contaminants such as dust and other particulates is required to institute measures to reduce or eliminate the presence of such contaminants; and
- No industrial waste should be discharged into any water body, which will result in the deterioration of the quality of the water.

3.2.3.6 The Natural Resources (Hazardous Waste) (Control of Transboundary Movement) Regulations 2003

These regulations seek to implement the *Basel Convention on the Transboundary Movement of Hazardous Waste* and control transboundary movement and prevent the illegal trafficking of certain hazardous wastes. It is an offence to unlawfully dump or otherwise dispose of hazardous waste in area under jurisdiction of Jamaica. Waste resulting from the proposed project should be properly disposed of, and special attention should be paid to those considered hazardous under these regulations and as listed above.

3.2.3.7 Noise Abatement Act 1997

The Noise Abatement Act of 1997 was created in order to regulate noise caused by amplified sound and other specified equipment. This act has been said to address "some concerns but is too narrow in scope and relies on a subjective criterion" (McTavish). Given this, McTavish conducted a study to recommend wider and more objective criteria in accordance with international trends and standards, but tailored to Jamaica's conditions and culture. To date, apart from the Noise Abetment Act (1997), Jamaica has no other national legislation for noise.

3.2.3.8 Factories Act 1961

The Factories Act guides employers operating factories in safety, health and welfare provisions. Any plans for new factories need to be provided to the Chief Factory Inspector. Some of the issues outlined under safety include having proper fire escapes and that all electrical apparatus must be properly installed. Under health and welfare, issues such as suitable sanitary conveniences, effective lighting, reasonable temperatures shall be maintained and personal protective equipment (PPE) shall be provided where applicable.

3.3 REGIONAL AND INTERNATIONAL LEGISLATIVE AND REGULATORY CONSIDERATIONS

3.3.1 Cartagena Convention (Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region), 1983

Adopted in March 1983 in Cartagena, Colombia, the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, more commonly referred to as the Cartagena Convention, is the sole legally binding environmental treaty for the Wider Caribbean. The Convention came into force in October 1996 as a legal instrument for the implementation of the Caribbean Action Plan and represents a commitment by the participating countries to protect, develop and manage their common waters individually and jointly. The Convention is currently supported by three Protocols as follows:

- *The Protocol Concerning Co-operation in Combating Oil Spills in the Wider Caribbean Region* (The Oil Spills Protocol), which was adopted and entered into force at the same time as the Cartagena Convention;
- *The Protocol Concerning Specially Protected Areas and Wildlife in the Wider Caribbean Region* (The SPAW Protocol), which was adopted in two stages, the text in January 1990 and its Annexes in June 1991. The Protocol entered into force in 2000;
- *The Protocol Concerning Pollution from Land-based Sources and Activities in the Wider Caribbean Region* (LBS Protocol), which was adopted in October, 1999.

3.3.2 United Nations Convention on Biological Diversity

Signed by 150 government leaders at the 1992 Rio Earth Summit, the Convention on Biological Diversity (CBD) is committed to promoting sustainable development. The CBD is regarded as a means of translating the principles of Agenda 21 into reality and recognizes that "biological diversity is about more than plants, animals and microorganisms and their ecosystems – it is about people and our need for food security, medicines, fresh air and water, shelter, and a clean and healthy environment in which to live". Jamaica's Green Paper Number 3/01, 'Towards a National Strategy and Action Plan on Biological Diversity in Jamaica', is evidence of Jamaica's continuing commitment to its obligations as a signatory to the Convention.

3.3.3 Convention on Wetlands of International Importance especially as Waterfowl Habitat, "Ramsar Convention" 1971

The Ramsar Convention is an intergovernmental treaty that focuses on maintaining ecological wetland systems and planning for sustainable use of their resources. It was adopted on 2 February 1971 in Ramsar, Iran. The mission of the Convention was adopted by the Parties in 1999 and revised in 2005 - "the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world". Under Article 2.2 it is stated:

> Wetlands should be selected for the List on account of their international significance in terms of ecology, botany, zoology, limnology or hydrology" and indicates that "in the first instance, wetlands of international importance to waterfowl at any season should be included.

Jamaica became a contracting party on 7 February 1998 and has 4 sites covering a combined total of 37,847 hectares (378.47 km^2).

3.3.4 Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES)

CITES generally seeks to protect endangered plants and animals and owing to the cross boundary nature of animals and plants, this protection requires international cooperation. It aims to ensure that international trade of wild animal and plant species does not threaten the survival of the species in the wild, and it accords varying degrees of protection to over 35,000 species. This convention was drafted in 1963 at a meeting of members of the International Union for Conservation of Nature (IUCN) and finalised in 1973. After being opened for signatures in 1973, CITES entered into force on 1 July 1975.

3.3.5 Equator Principle Requirements

The Equator Principles (EPs) is a credit risk management framework for determining, assessing and managing environmental and social risk in Project Finance transactions. Project Finance is often used to fund the development and construction of major infrastructure and industrial projects. The EPs are adopted by financial institutions and are applied where total project capital costs exceed US$10 million. The EPs are primarily intended to provide a minimum standard for due diligence to support responsible risk decision-making[6]. The EPs are based on the International Finance Corporation Performance Standards on Social and Environmental Sustainability and on the World Bank Group Environmental, Health, and Safety Guidelines (EHS Guidelines).

[6] http://www.equator-principles.com/index.php/about-ep

3.3.5.1 IFC Performance Standards on Social and Environmental Sustainability

Of the eight (8) Performance Standards, seven (7) are applicable:

- Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts
- Performance Standard 2: Labour and Working Conditions
- Performance Standard 3: Resource Efficiency and Pollution Prevention
- Performance Standard 4: Community Health, Safety, and Security
- Performance Standard 5: Land Acquisition and Involuntary Resettlement
- Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources
- Performance Standard 8: Cultural Heritage

3.3.5.2 World Bank Group Environmental, Health, and Safety Guidelines

The Jamaican EIA process has been strongly influenced by the original World Bank Guidelines on EIAs. This EIA report has been reviewed for compliance with International Finance Performance (IFC) Standards 2012 and The World Bank Group Environmental, Health and Safety Guidelines (2007 & 2008) and meets all requirements for the Project from design to implementation. The Bank also provides guidelines which promote minimal resource consumption, including energy use, and the elimination or reduction of pollutants at the source. Pollution control systems are required to meet these specified emission limits. All of the maximum levels should be achieved for at least 95% of the time that the plant or unit is operating. Guidelines are provided for the following pollution factors (See Appendix 3 Relevant sections of the Environmental Health and Safety Guidelines – Thermal Power: Guidelines for New Plants):

- Air Emissions
- Energy efficiency and Greenhouse Gas emissions
- Water consumption and aquatic habitat alteration
- Effluents
- Solid wastes
- Hazardous materials and oil
- Noise
- Occupational Health and Safety

This power plant is more than 50 MW. This EIA is, as required, "commensurate with the project's potential impacts" and contains the items required in the World Bank Operational Procedures (OP 4.01) updated February 2011, including:

- Executive Summary
- Policy, legal and administrative framework
- Project description

- Baseline data
- Environmental Impacts
- Analysis of Alternatives
- Environmental Management Plan (EMP) considering
    - Mitigation
    - Monitoring
    - Capacity development and training (to ensure maintenance)
    - Implementation Schedule and Cost Estimates for mitigation, monitoring and capacity building
    - Integration of the EMP with the Project
- Appendices including list of report preparers (individuals and organizations), references (published and unpublished), record of interagency and consultation meetings, tables presenting the relevant data referred to or summarized in the main text and list of associated reports (e.g., resettlement plan or indigenous peoples development plan).

4.0 COMPREHENSIVE DESCRIPTION OF THE PROPOSED PROJECT

4.1 THE PROPONENT

Jamaica Public Service Company (JPS) is the sole distributor of electricity in Jamaica and is a proud inheritor of a tradition that dates back to 1892, when Jamaica first received electricity. This placed Jamaica in the enviable position of being one of the first in the world to have electricity, and only thirteen years after American scientist Thomas Edison had invented the electric lamp. In that year, the first electricity service in the island was supplied by the Jamaica Electric Light Company from a plant at Gold Street, in Kingston. In 1897, another company, the West India Electric Company, established an office in Kingston at 151 Orange Street. They built the hydroelectric plant on the Rio Cobre River at Bog Walk, which consisted of three machines, each with the capacity to deliver over 300 kilowatts of energy. West India Electric not only extended electricity service to other areas, but also introduced a new element to the city scene – electric tramcars. Tramcars later replaced the horse drawn cabs, which had been providing public transport, and remained in service until 1948.

Early in 1907, a severe earthquake destroyed a section of Kingston, disrupting city life and public services. Following this, West India Electric leased the property and businesses of Jamaica Light & Power Company Ltd, successors to the Jamaica Electric Light Company and integrated the Gold Street station into the Bog Walk Supply system. This resulted in a significant improvement in the service available to customers. In the early days, several towns had their own electric companies; but through a process of consolidation, buy-outs and amalgamations, Jamaica Public Service Company Limited emerged and was registered in 1923. At that time, JPS had 3,928 customers, a far cry from today's customer base of over 585,000. JPS was granted an all-island franchise in 1966, and today remains the sole public supplier of electricity.

The nature of the ownership of JPS has changed several times throughout time. The company started out as a private company, owned by foreign shareholders. In 1970, the Government of Jamaica acquired controlling interest. In 2001, ownership of JPS returned to private hands when Mirant Corporation, a US-based energy service provider acquired 80 percent of the company, with the Government retaining almost 20 percent. The remainder, amounting to less than 1 percent, is owned by a small group of shareholders. In 2007, Mirant sold its majority shares to Marubeni Caribbean Power Holdings (MCPH) Inc., a subsidiary of Marubeni Corporation of Japan. In early 2009 Abu Dhabi National Energy Company (TAQA) of the United Arab Emirates, joined Marubeni as co-owner of the Jamaica Public Service Co. Ltd. Majority shares were therefore jointly held by Marubeni TAQA Caribbean. In the first quarter of 2011, TAQA withdrew from the partnership with Marubeni in the Caribbean, due to a change in its corporate strategy. TAQA signalled its intention to focus primarily on the power sector in the Middle East and North Africa region. In the second quarter of 2011, Korea East West Power (EWP) entered into a Purchase and Sale Agreement with Marubeni Corporation for joint ownership of majority shares (80%) in the company. Today, Marubeni Caribbean and Korea East-

West Power Company Ltd are the majority shareholders in the Jamaica Public Service Company Ltd with the Government of Jamaica owning most of the remaining shares and a small group of minority shareholders maintains a less than 1 percent stake (Source: http://www.jpsco.com/ accessed July 25, 2012).

4.2 PROJECT CONCEPT AND DESCRIPTION

4.2.1 Background

The Office of Utilities Regulation (OUR) invited proposals for the Supply of up to 480 MW of Base-Load Generating Capacity on a Build, Own and Operate (BOO) Basis to increase the generating capacity on the island. This did not materialize. Subsequently, the OUR invited proposals to expand the generating capacity on the Island by installing an additional 360 MW Power Plant. This development was to be done by 2016. However, EWI licence was revoked and JPS is now planning to construct approximately 180 -200 MW of combined cycle plant as a repowering of our existing power plant.

JPS negotiated over the past year though a licence amendment that was gazetted, the right to replace its own generation. The Plan to build a 190 MW new gas-fired plant was endorsed by the Electricity Sector Enterprise Team (ESET) on February 4, 2015. This represents base load generation to replace existing oil fired units of equal capacity. The target capacity was determined through various resource scenarios which optimize use of existing contract generation and renewables. The plant is a combined cycle 3x1 configuration designed to have maximum flexibility and to integrate renewables.

This 190 MW Nominal combined cycle development will be undertaken from Q1 2016 to Q1 2018. This new capacity will be base-loaded and is intended to replace the heavy fuel oil burning aged steam unit plants. Jamaica Public Service Company Limited (JPS) was awarded the right to go forward with the project.

4.2.2 Project Location and Siting

The Old Harbour 190 MW Nominal combined cycle power plant is to be located approximately 75.6 kilometres (47 miles) from the city of Kingston near the community of Old Harbour on the south coast. The proposed is adjacent to JPS' existing Old Harbour facility, which currently has 220 MW of generation and houses major transmission and distribution operation along with a privately owned diesel power plant (Doctor Bird I & II).

The community of Old Harbour Bay, located on the south-western coast of Jamaica in the parish of St. Catherine, was estimated to have a total population of 8,537 in 2009. Located approximately 5km from the town of Old Harbour, the Old Harbour Bay community consists of twenty-four (24) small communities, which include Blackwood Gardens, Kelly Pen, Thompson Pen, Bay Bottom, Terminal, Dagger Bay, More Pen Lane, Peter's Land, Sal Gully, Cross Road and Panton Town. Bordered by the Colbeck Castle community to the east and Bourkesfield to the southeast, the Old Harbour Bay community is one of many residential fishing villages found along the coast in Jamaica, and is considered the largest fishing village on the island. The other industries and sources of employment include mining, manufacturing, small retail shops and subsistence farming.

The proposed project site is bounded on the east by the existing Old Harbour Power Plant, to the northeast by the existing switch yard, to the west by Thorn Savanna and to the south by the ocean (Figure 4-1). It also shows areas to be reserved for construction, as well as areas to be preserved in their existing state are depicted. The proposed site is largely flat area with clay type soils with site elevation varying from approximately 1.5 meters to 3.0 meters above mean sea level.

The proposed site of the new power plant is on the storage area for the existing Old Harbour 220 MW plant and is located near the Intermediate Acacia Forest (Thorn Savannah) ecosystem (Figure 4-2). This ecosystem is comprised mainly of Acacia sp. trees and stands. The Intermediate is distinguished from the Secondary Acacia Forest ecosystem in three main ways: (i) the under storey vegetation tends to be more pioneer, monocotyledonous, vegetation (i.e. grass, etc.), (ii) the canopy is more open, and (iii) the trees are more low-profile (i.e. only a couple of meters high). Typical bird species within this zone of vegetation are warblers.

The Intermediate Acacia Forest ecosystem is less significant/ecologically important than the Mangrove Ecosystem and Salina Ecosystem. Although the relative species diversity and abundance of avifauna tends to be average for this type of ecosystem, avifauna species tend to be more robust than their marine/salina counterparts and they, therefore, have more habitat options to migrate to, during development and construction within this vegetation zone. C.L. Environmental, 2007

The proposed site for the power plant is on the existing JPSCo Old Harbour plant in an area used for storage and an area immediately west of the storage area. The additional land area west of the storage area will be purchased from the National Land Agency (NLA) (please see Appendix 4 for the No Objection Letter regarding the purchase of this land). The project site is located in the Portland Bight Protected Area (Figure 4-3).

4.2.3 Rationale and Objectives

The current 220 MW Old Harbour Power Plant utilizes heavy fuel oil for power generation and is considered inefficient. This new 190 MW Nominal combined cycle development will be undertaken from Q1 2016 to Q1 2018.

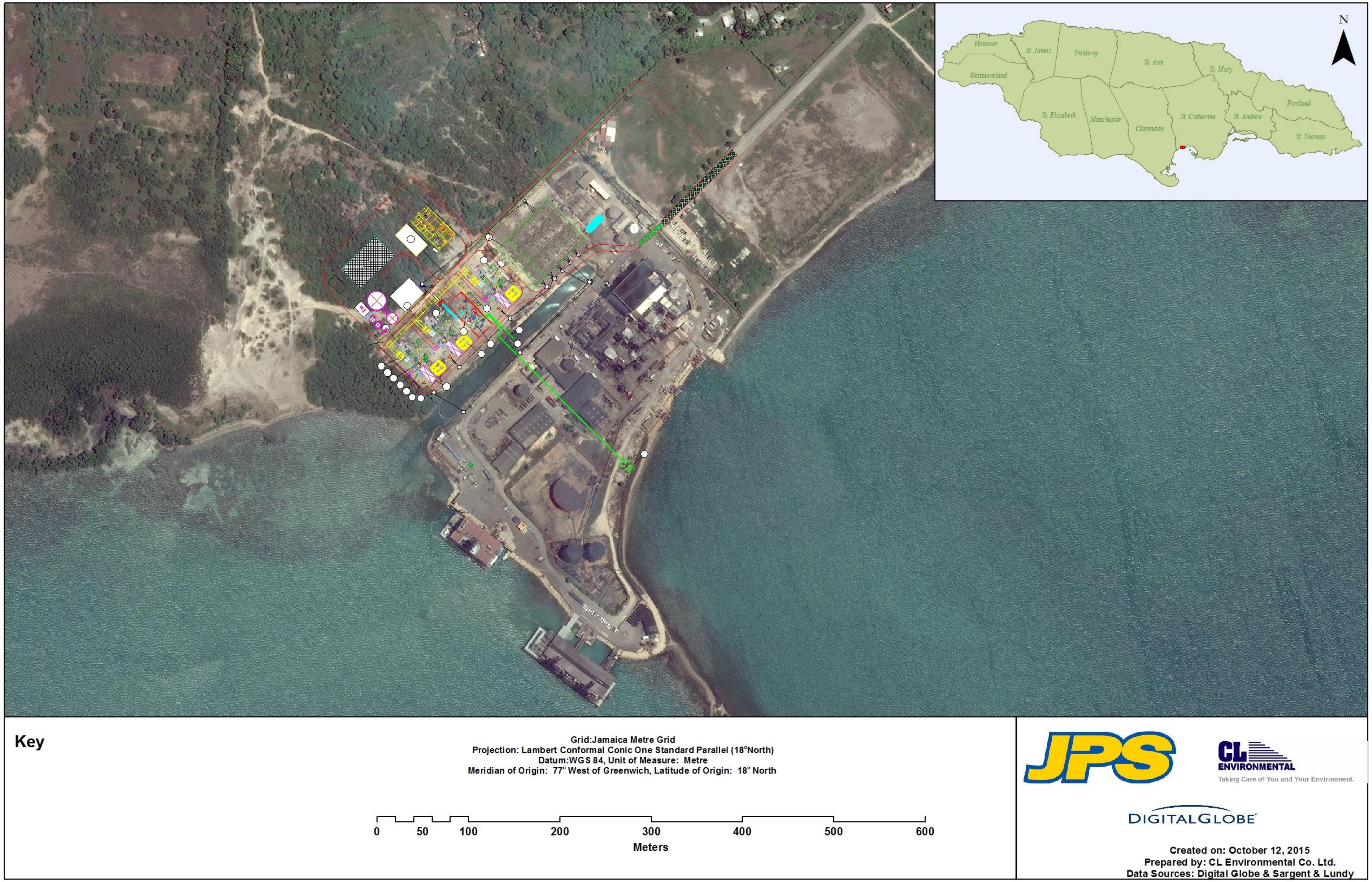


Figure 4-1 General layout of the proposed JPS 190MW Combined Cycle Power Regasification Plant

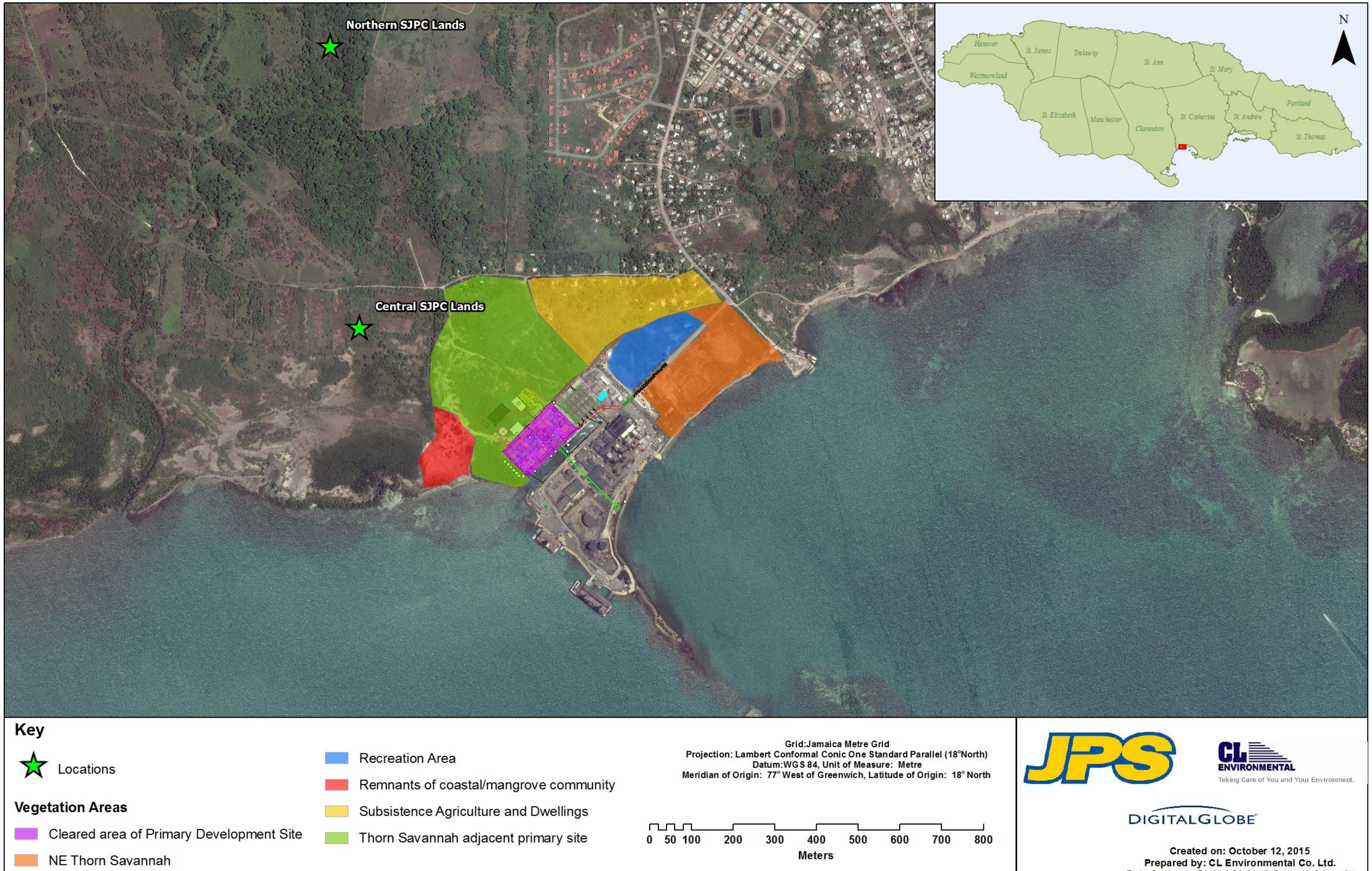


Figure 4-2 General Layout of the proposed 190 MW power plant with vegetation areas

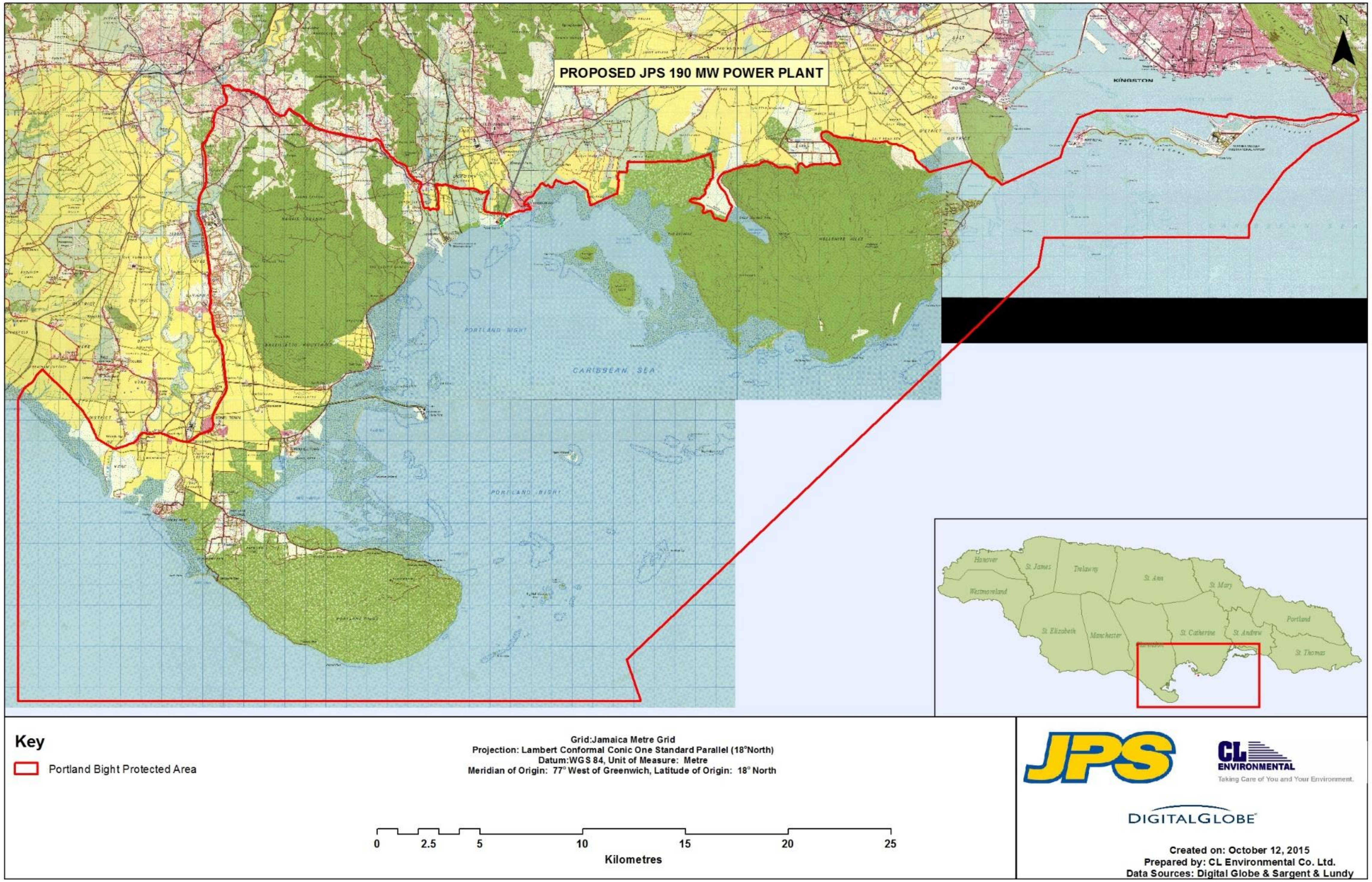


Figure 4-3 Portland Bight Protected Area boundary

4.3 PROJECT INFRASTRUCTURE

4.3.1 Power Plant

The new plant proposed herein will consist of one (1) power block of nominal 190MW combined cycle plant. The block's configuration consists of 3 combustion turbine generators x 3 heat recovery steam generators (HRSGs) x1 steam turbine generator. The combustion turbines will be dual fuel capable, however, the plant is designed for using natural gas fuel only. Each gas turbine unit is a 40 MW class, the steam turbine is a 75 MW class, providing nominal 190 MW block size in the 3 x 3 x 1 combined cycle configuration with duct firing. The exhaust gas from the gas turbine is led to the associated HRSG for generating the steam which in turn will be fed to a common steam turbine generator. The HRSGs will be dual pressure, non-reheat type, with duct burners, in order to obtain optimum exhaust gas energy utilization based on thermo-economic considerations.

The plant is designed for both base load and cycling duty (two shift operation) in order to be able to comply with all instructions from the system load dispatcher. The plant will operate with a 98% average annual equivalent availability factor (EAF) for the life time of the plant. This reliability is based on the inherent reliability of the Original Equipment Manufacturer (OEM) turbine packages, the unique features of the OEM gas turbines that allow for optimum maintenance schedules, a robust balance of plant (BOP) design, all coupled with a competent operations and maintenance staff that will be provided. In addition, the company intends to enter into a long term service agreement (LTSA) with the OEM for scheduled maintenance on the gas turbines. This will ensure that maintenance is done in accordance with OEM requirements, with genuine OEM parts and service, and in an expeditious manner.

A metering system is used in order to measure net energy output from the plant, and to monitor and co-ordinate operation of the facility. The location of the metering system will be in a 138 kV substation control building, and potential transformers for the metering system will be located on the 138 kV side of each generator transformer feeders in the 138 kV switchyard to measure net electrical energy outputs.

Continuous emissions monitoring (CEM) ports will be provided for the measurement of air emission levels in the exhaust stack of each HRSG.

Plant effluents will be treated to comply with the effluent discharge limit criteria (National Resources Conservation Authority's (NRCA) Jamaican National Trade Effluent Standards) and discharged to Old Harbour Bay through the existing cooling water discharge flume of the Old Harbour power plant. The Global Positioning System (GPS) location for the discharge point will be determined following the dispersion modelling exercise. The EIA will assess the suitability of the location for the discharge of plant liquid effluent.

The plant will be designed to meet the regulatory standards and is designed for an operating life of at least 25 years.

The design of the buildings will meet or exceed the requirements as established in the latest updates to the National Building Code and Caribbean Uniform Building Code. The civil structures for the project will be designed to meet the seismic requirement for ground acceleration of 0.4 g with a 10% probability of occurrence over a 50 years period and withstand maximum hurricane intensity wind speeds of 67.0m/s (241 km/h).

4.3.2 Fuel Supply

Natural gas will be supplied by a third party and subject to a separate Environmental Impact Assessment (EIA). The fuel supply plan will entail the importation of Liquefied Natural Gas (LNG) from the United States which will be supplied to a Floating Storage and Regasification Unit (FSRU). The FSRU would provide a level of storage and would convert the fuel into a gaseous form which would be piped to the JPS 190 MW facility either by terrestrial or marine pipeline, the determination of which will depend on the findings of the EIA.

4.3.3 Water Supply

4.3.3.1 Raw / Fire Water Storage Tank

The onsite wells pump water to the Raw / Fire Water Storage Tank. Sodium Hypochlorite is injected into the well water prior to entering this tank to minimize biological growth. The raw water for distribution to the plant is via an internal standpipe in the tank to the suction of the two (2) Raw Water Pumps. A Fire water reserve is stored in the bottom portion of this tank below the standpipe level. Concentrate water from the Electrodeionization units (a part of the Demineralized water Treatment System) is also returned to the Raw / Fire Water Storage Tank as a clean water recycle stream. Also taking suction from the standpipe are the two (2) Filter Backwash Pumps.

After the raw water utility users (i.e. hose stations, pump seals, etc.) are supplied off the main raw water line, a 5-10 micron tubular filter is provided to remove any suspended solids in the raw water. This filter will be automatically backwashed periodically as solids build-up on the filter media as detected by a high differential pressure across the filters. The low turbidity of the well water is indicative of a clean water stream and should result in fewer backwashes of these filters.

Filtered raw water is supplied to the Demineralized Water System and Potable Water System for further treatment.

4.3.3.2 Reverse Osmosis (R.O.) and Potable Water Systems

The Demineralized Water Treatment System consists of two (2) parallel 100%, double pass, Reverse Osmosis Trains. The Reverse Osmosis system is designed for up to 77% recovery. Each train consists of a cartridge filter, high pressure pump, first pass membranes, interstage booster pump, second pass membranes, and Electrodeionization unit for polishing. The resultant demineralized water is stored in a Demineralized Water Storage Tank. Demineralized Water Pumps supply this water to the Condensate Tank as make-up to the boiler feedwater cycle.

The projected demineralized water quality will meet G.E. specifications as described below:

- pH 6.0-8.0
- Specific conductance: 0.1 µS / cm
- Chlorides: < 3 ppb
- Total SiO2: < 10 ppb
- Sodium < 3 ppb
- Total organic carbon < 100 ppb

The two (2) x 100 % treatment system has been designed for generating 1.1 m^3/h of chlorinated potable water. The potable water produced will meet the NSF 61 and WHO standards and will be used for drinking water, administrative building and safety showers.

Filtered raw water is pumped to the Potable Water Treatment system which consists of two (2) 100% nanofiltration skids. Each skid contains a 5 micron bag type filter, high pressure booster pump, and a single pass nanofiltration unit. As with the Reverse Osmosis system, sodium bisulfite is injected for de-chlorination and also an antiscalant is injected to help maintaining the cleanliness of the nanofiltration system membranes.

As the permeate flows to the Potable Water Storage tank, sodium hypochlorite is injected to maintain residual chlorine in the Potable Water Tank and distribution system. Two (2) 100% Potable Water Distribution Pumps supply water at a consistent pressure to the distribution system feeding drinking water, building potable water users, and for emergency eyewash & showers. The Potable Water Treatment system also has a dedicated Clean in Place skid for periodic cleaning of the nanofiltration membranes.

Figure 4-4 illustrates the flow of all water and wastewater throughout the proposed plant.

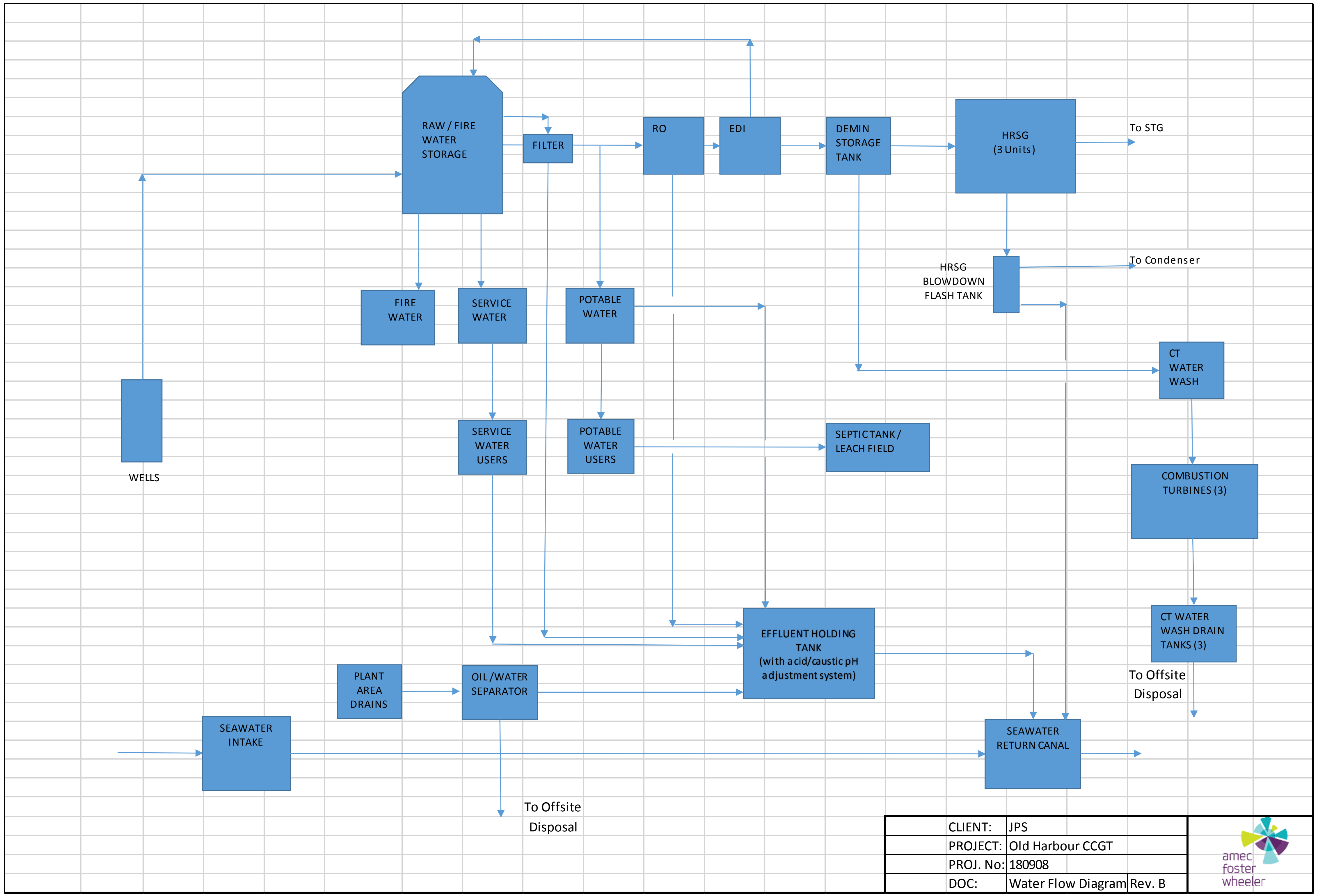


Figure 4-4 Flow of water and wastewater throughout the proposed power plant

4.3.4 Wastewater Handling Systems

Area drains in the HRSG, Gas Turbine, Condenser, and Steam Turbine areas will be directed to a common Power Generation Area Wastewater Pit. From this pit two (2) vertical sump pumps will transfer the wastewater to an oil / water separator unit. The accumulated oil will be removed periodically using a vacuum truck and transported off-site for disposal. Clean water from the oil / water separator is pumped to the Effluent Holding Tank.

The Effluent Holding Tank receives wastewater from the oil / water separator, concentrate from the two (2) Reverse Osmosis Trains (normally only one in service), filter backwash water from the tubular filters ahead of the Reverse Osmosis System and concentrate from the Potable Water Treatment Nanofilter trains (normally only one in service).

The Effluent Holding Tank Pumps send the wastewater from the tank to the Seawater Return Canal to mix with the circulating water prior to discharge. This wastewater is monitored for pH and the flow is measured. Acid and caustic storage and metering pumps are provided to maintain the pH within the limits specified in the discharge permit.

Wastewater from the HRSG blowdowns and sample panel drains are combined with seawater, flow through the Closed Cooling Water System heat exchangers and are discharged to the Seawater Return Canal. Due to the low turbidity in the well water and the water, wastewater treatment systems do not generate any additional solids. The clarifier and its auxiliary equipment has been removed. Based on the well water information, the total suspended solids (TSS) in the discharge will be below the limit of 50 mg/L TSS.

The combustion turbines have a water wash system used for both online and offline cleaning. Demineralized water is supplied to this system and mixed with a detergent and sprayed into the turbine during a cleaning cycle to help keep the internal surfaces clean. During the online cleaning the water is evaporated. During the offline cleaning the water, residual detergent, and suspended solids from deposits (combustion products) are drained to a drains tank adjacent to the combustion turbine. The wastewater in this tank is drained out using a vacuum truck and hauled offsite for disposal.

Sanitary waste will be collected and transferred to a septic tank that will be located at the northwest corner of the Plant. Depending on the findings of Final Geotechnical Study, if required a sanitary lift station will be installed at the point where the site topography does not allow for gravity flow of sanitary waste from plant users to the tank. A drain field (leach field) will be built next to the septic tank that will be designed and sized per site specific percolation tests and that will conform to local and/or governing agency regulations.

Figure 4-5 illustrates the sewerage system.

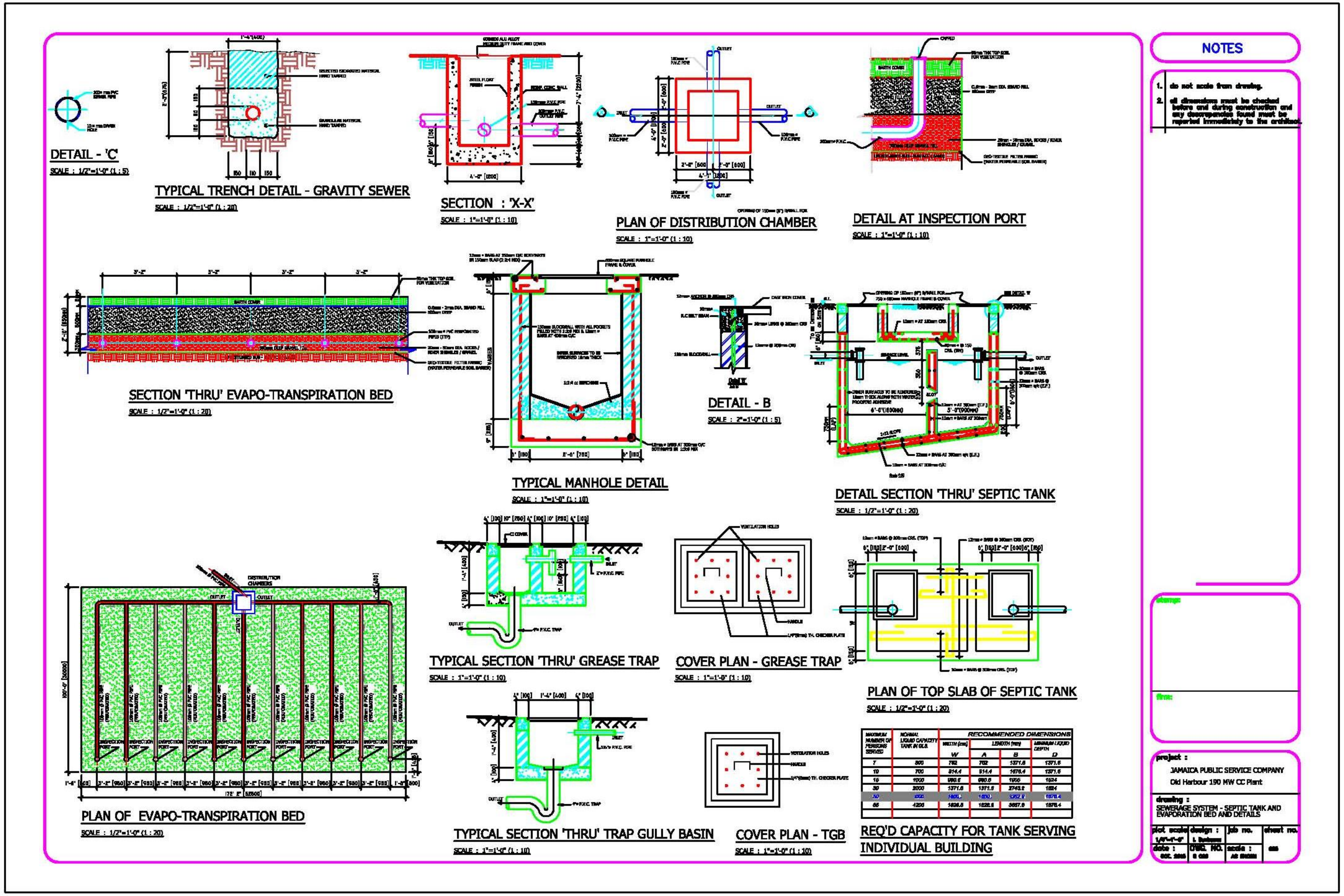


Figure 4-5 Sewerage System drawing for proposed power plant

4.3.5 Storm Water Drainage

Figure 4-6 illustrates the storm water drainage for the proposed power plant site.

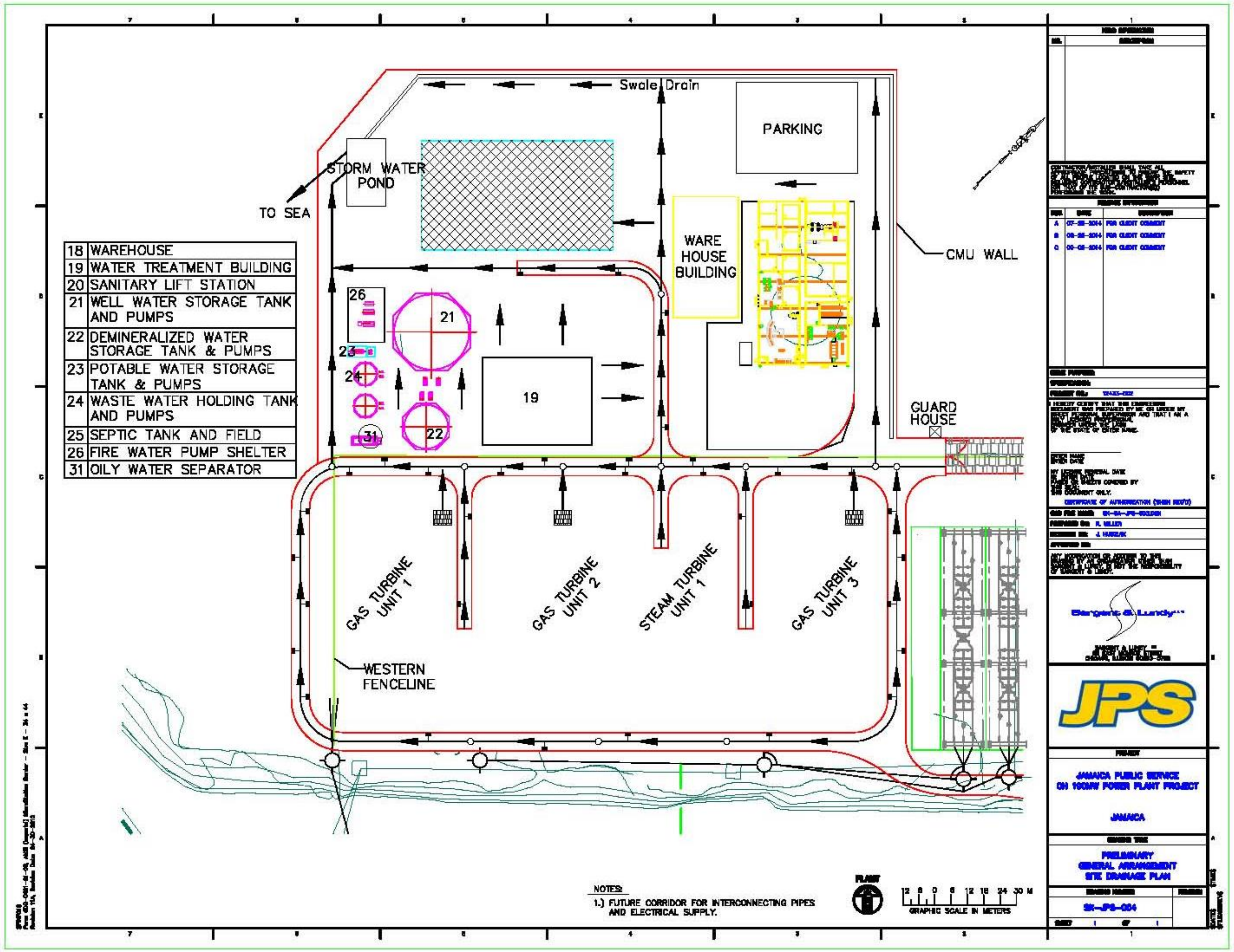


Figure 4-6 Storm water drainage drawing for proposed power plant site

4.3.6 Seawater Intake System

Water for the circulating water system will be drawn from the ocean through the seawater intake structure. The circulating water system will provide cooling water for the once through condenser of the steam turbine and the auxiliary heat exchanger for the closed cooling water system. The intake structure will include the intake siphon, bar grills with trash rake cleaning, traveling screens, pump house forebay and provisions for stop logs to isolate intake chambers. The vertical circulating pumps and associated electrical facilities will be located indoors inside the pump house.

The cooling water will be drawn through an intake structure. Three (3) x 50 % capacity streams consisting of removable coarse bar screens, stop gates, rotating self-cleaning band screens, and debris filters will be provided. The overall screening will be sized to suit the maximum allowable particle size of 6 mm in the cooling water system to protect the once-through condenser. As in Jamaica Public Services' current design, the screen openings will be designed to allow maximum velocity or 0.76 m / s at average daily flow to protect marine life. The low water depth will be approximately three (3) m. A total flow of 68,410 m^3 / h will be drawn through the intake structure.

In order to meet the maximum allowable circulating water temperature rise of 2.2 °C, a portion of the ocean water (37,740 m^3 / h) bypasses the condenser and auxiliary heat exchangers and will be mixed with the condenser and heat exchanger return water prior to discharge to the ocean.

4.3.7 Auxiliary Heat Exchanger

Two (2) x 100 % shell and tube heat exchangers will be provided for the auxiliary cooling system. Each unit will cool 985,610 kg / hr of water from 49.8 ºC to 44 ºC using 1,045,981 kg / hr of 33.1 ºC sea cooling water. The heat exchangers are industrial grade, single pass, with all titanium grade, two (2) tube side components and all 304L stainless steel shell side components and all 304L stainless steel shell side components and require no further finishing.

Closed loop cooling water of condensate quality will be provided to the shell side of the heat exchanger. The shell side of the exchanger has an inlet water pressure of 2.5 bara and a pressure drop of approximately 0.7 bar. The tube side sea cooling water has an inlet pressure of 6.9 bara and a pressure drop of approximately 0.1 bar. Overall heat exchanged is 24,484 MJ / h.

One (1) vertical, shop fabricated, stainless steel, Auxiliary Cooling Water Head Tank will make up the difference in volume of the closed loop cooling system brought on by changes in temperature and density of the users. The auxiliary cooling water tank will be designed, constructed, and tested to ASME Section VIII, Division 1 and rated for full vacuum service. The tank's working volume is 12.5 m_3.

One (1) vertical, shop fabricated, HDPE, Chemical Mix Tank will be provided to add chemicals to be used in the closed cycle cooling system as needed. The tank will consist of a mixer with an attached motor on the tank roof. The tank's working volume is 0.34 m_3.

4.3.8 Steam/Water Chemical Feed System

The chemical feed systems for the feedwater cycle includes packaged skids for ammonia, sodium hypochlorite, sodium bisulfite, and phosphate injection system. The chemical feed system allows the Owner to operate with all volatile treatment (AVT) on a normal basis.

The chemical feed systems for the circulating water include packaged feed systems for ammonia, bisulfite, hypochlorite, and trisodium phosphate with bulk storage for seven (7) days and metering skids to inject chemicals into the circulating water to control pH and corrosion. There will also be sodium bisulfite injection into the seawater return piping for dechlorination. All HRSG and chemical feed skids will be installed outdoors. Chemical feed systems will be in a separate curbed area with nearby safety showers. On all skids, the pumps are provided with local control capabilities. On each skid, there will be two (2) feed pumps arranged as one duty pump and one spare pump.

4.3.9 Fire Protection System

A complete fire protection system will be provided for personal safety and property protection through prompt detection, alarm, suppression and extinguishing of fires in accordance with NFPA and local code requirements. The fire protection system's major components consist of the following:

- Fire pump system: One 340.67 m^3 / h primary electric motor driven fire pump and one 340.67 m^3 / h backup diesel driven fire pump will be provided. The equipment will be located in the pump house, ventilated and protected by a sprinkler system. The system will also include a flow meter, relief valve, muffler and 1 m^3 fuel tank.
- Complete underground fire loop: A fire loop PVC header will be provided. All trenching, backfill, thrust blocks and restraints will be accordance with NFPA. The system supply will include hydrostatic commissioning and flushing per NFPA.
- Valve sheds: Three (3) 2.43 m x 2.44 m x 2.29 m enclosures will be provided including heating, cooling, lighting and receptacles.

4.3.9.1 Fire Suppression

The following Fire Suppression systems will be provided:

- Combustion turbine generator
  - The CT manufacturer will provide a CO_2 extinguishing system.
  - Interconnecting piping and installation will be provided.
- Steam turbine generator
  - One (1) turbine generator pre-action type system will be provided.
  - One (1) open sprinkler deluge system will be provided for lube oil fire protection.
  - Four (4) surface mounted class III hose station with 23 m collapsible hose and valve with cap and chain.
- LNG fuel gas
  - This will have deluge protection over the exterior surface area and equipment in the LNG area.

- CTG step-up transformer
  - Deluge protection will be provided over the exterior surface area of the transformer.
  - Deluge protection will also be provided over the containment area surrounding the transformer.
- Control and administration area
  - One (1) wet system will be provided for a light hazard protection in accordance with NFPA.
  - One (1) pre-action system will be provided for the control, electrical and DCS rooms in accordance with NFPA.
- Maintenance and warehouse
  - One (1) wet system will be provided for an ordinary hazard protection at the exposed roof level.
- Water treatment building
  - One (1) wet system will be provided for extra hazard protection at the exposed roof level.
- Chemical storage building: Addressable monitoring devices will be provided to monitor the wet system (flow and tamper switches).
- LNG fuel gas area
  - Addressable monitoring devices will be provided for three (3) deluge sprinkler systems (alarm pressure, tamper, and hi / low air switches) and three (3) linear heat detection zone for deluge sprinkler release.
- CTG step-up transformer area(s)
  - Addressable monitoring devices will be provided for three (3) deluge sprinkler systems (alarm pressure, tamper, and hi / low air switches) and three (3) linear heat detection zone for deluge sprinkler release.
- STG step-up transformer
  - Addressable monitoring devices will be provided for a deluge sprinkler system (alarm pressure, tamper, and high / low air switches) and a linear heat detection zone for deluge sprinkler release.
- Diesel generator building
  - Heat detectors will be provided.
- CEMS enclosure(s)
  - Addressable smoke detectors, addressable manual pull stations and horn / strobes will be provided.

4.4 PROJECT CONSTRUCTION

4.4.1 Schedule

Site preparation will commence by the first quarter 2016 and construction of the JPS power plant is scheduled to commence in by the second quarter of 2016. Commercial operation of Unit #1 is expected 22 months after the commencement of construction and the commercial operation of the other two units are slated one month after each other (Figure 4-7).

4.4.2 Construction Activities to be Carried Out

4.4.2.1 Site Development and Earthwork

All excavations will be carried out and supported in such a manner as to prevent flooding or ponding of water, damage or interference to structure services, or stored equipment/materials.

I. Clearing and Grubbing
   a. Areas to be graded will be cleared of all bushes and trees to within 6 inches (150 mm) of grade. All stumps and roots will be removed. Waste from clearing will be disposed of in an off Site disposal area in accordance with all environmental regulations.

II. Stripping
   a. All topsoil and other organic materials will be stripped from the areas to be graded before starting earthwork. Topsoil will be placed in a stockpile for later recovery and use for landscaping the Site.

III. Disposal of Unusable Materials
   a. All excess excavated materials and all excavated materials unusable for fills shall be disposed of at an approved off site facility.

IV. Site Grading
   a. Facility grading includes the following items:
      i. Shaping the natural grade to accommodate permanent facilities and construction facilities while minimizing earthwork;
      ii. Obtaining proper cross section, longitudinal slopes, and curvature for roads;
      iii. Obtain stable area slopes to provide drainage without ponding;
      iv. Construct adequate surface drainage to discharge the 10 year runoff without flooding roads and the 50 years runoff without flooding any area in the Facility; and
      v. Construct stable, erosion-resistant earthen side slopes.

V. Erosion Control
   a. Temporary facilities will be provided to control erosion and turbidity of runoff during earthwork operations and from graded areas until they are surfaced or seeded. Temporary facilities may include: Silt fences and Other requirements to satisfy relevant Codes and Standards, rules and regulations

VI. Compaction Requirements
   a. Compaction will be conducted based on the specification required in each area of the Facility.

VII. Lining
   a. The following liner thicknesses are minimums and shall be determined by appropriate Codes and Standards and shall meet local and national regulations. The following Facility areas shall be lined for protection of the groundwater.

Area	**Minimum Lining**
Exterior chemical spill containment compounds	**Concrete with epoxy coating or 1 foot (300 mm])**
Oil transformer spill containment compounds	Graded rock fill over **6 inches (150 mm)** concrete

4.4.2.2 Civil Works

I. Earthworks
   a. The earthwork to be carried out, will be subjected to engineering designs based on the geotechnical investigation, and bathymetric and topographical surveys.

II. Piling
   a. Suitable foundation type will be based on the soil investigation. Where the geotechnical report recommends the use of piles; piles will be designed, manufactured and installed according to ACI 543 and ACI 543R. The size, type and capacity of the piles selected will be capable of resisting the loads and will be suitable for the soil and groundwater properties.
   b. 40 MPa grade concrete will be used for piles. Accurate records of all pile installation will be maintained. Piles will be tested per:
      i. ASTM D1143 (Compression load)
      ii. ASTM D3689 (Uplift load)
      iii. ASTM D3966 (Lateral load)

4.4.3 Sources of Raw Material

Material will be sourced from licensed quarries; this will be carried out by the EPC contractor based on required raw material constituents.

4.4.4 Transportation of Heavy Equipment - Route from Port Esquivel to proposed Project Site

A route survey was conducted by Zoukie Trucking in February 2011 to determine the potential obstacles along the possible transportation routes. The assessment was done based on information supplied by the Client which consisted of the loads with different configurations. Based on this assessment standard size cargo can be transported along the normal route with normal access not interrupting vehicular traffic. Standard size loads are considered 8ft wide or less, 9 ft tall or less, 45ft in length or less.

For oversize loads, excess in height, width, weight, different routes can be chosen depending on the nature of each load. There is only one route (from Port Esquivel) which does not have permanent overhead obstructions and this is similar to the route in Figure 4-8, but to detour around the underpass. There would be two underpasses along this route. One is very high and doesn't pose an obstruction and one is low - 16.9 feet. Plate 4-1 depicts the first underpass one would encounter from Port Esquivel. This bridge does not pose a problem as it relates to transporting the oversized loads. Plate 4-2 shows the underpass to enter Old Harbour Bay. This underpass is 16.9 feet high and poses a problem with oversized loads.

A solution to this problem is to bypass the underpass by entering the highway heading to Kingston and making a U turn to exit on the opposite side of the road to continue to Old Harbour Bay. In order to make the U turn, special arrangements will need to be made with the Highway Authority (National Road Operating and Constructing Company) to remove approximately 100 feet of railings along the highway and also for traffic management (Figure 4-8 and Plate 4-3). There are a number of overhead wires that will need to be lifted or raised prior to the transports (Plate 4-4). These wires are mainly through Old Harbour town area and the residential areas. There are also areas on the road heading to Old Harbour Bay which will need to be widened in order to create space to manoeuvre the oversize loads (Plate 4-5). General cargo and equipment will be transported by truck from Kingston.

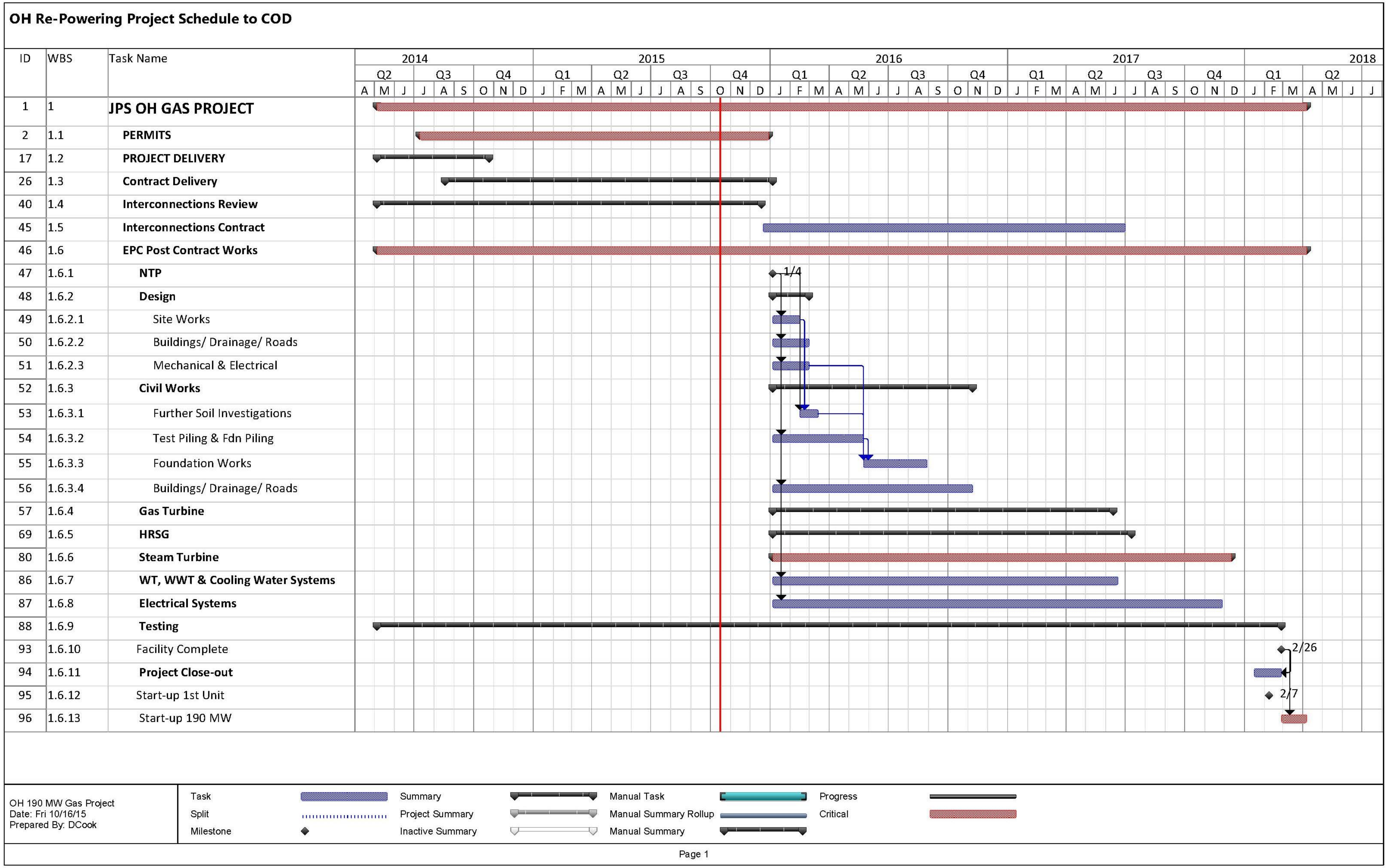


Figure 4-7 Proposed JPS 190 MW Old Harbour repowering project schedule

Figure 4-8 Proposed transportation route to plant site via Old Harbour

Plate 4-1 Underpass at the exit of Port Esquivel (Source: Zoukie Trucking)

Plate 4-2 Low underpass on the way to Old Harbour Bay (Source: Zoukie Trucking)

Plate 4-3 Possible location for the removal of the railings for the U Turn (Source: Zoukie Trucking)

Plate 4-4 Overhead wires in Old Harbour Town (Source: Zoukie Trucking)

Plate 4-5 An area on the road heading to Old Harbour Bay that needs to be widened (Source: Zoukie Trucking)

4.4.5 Organization Chart

The Organizational Chart for the construction phase of the JPS 190MW Old Harbour Plant Re-Powering Project is depicted in Figure 4-9.

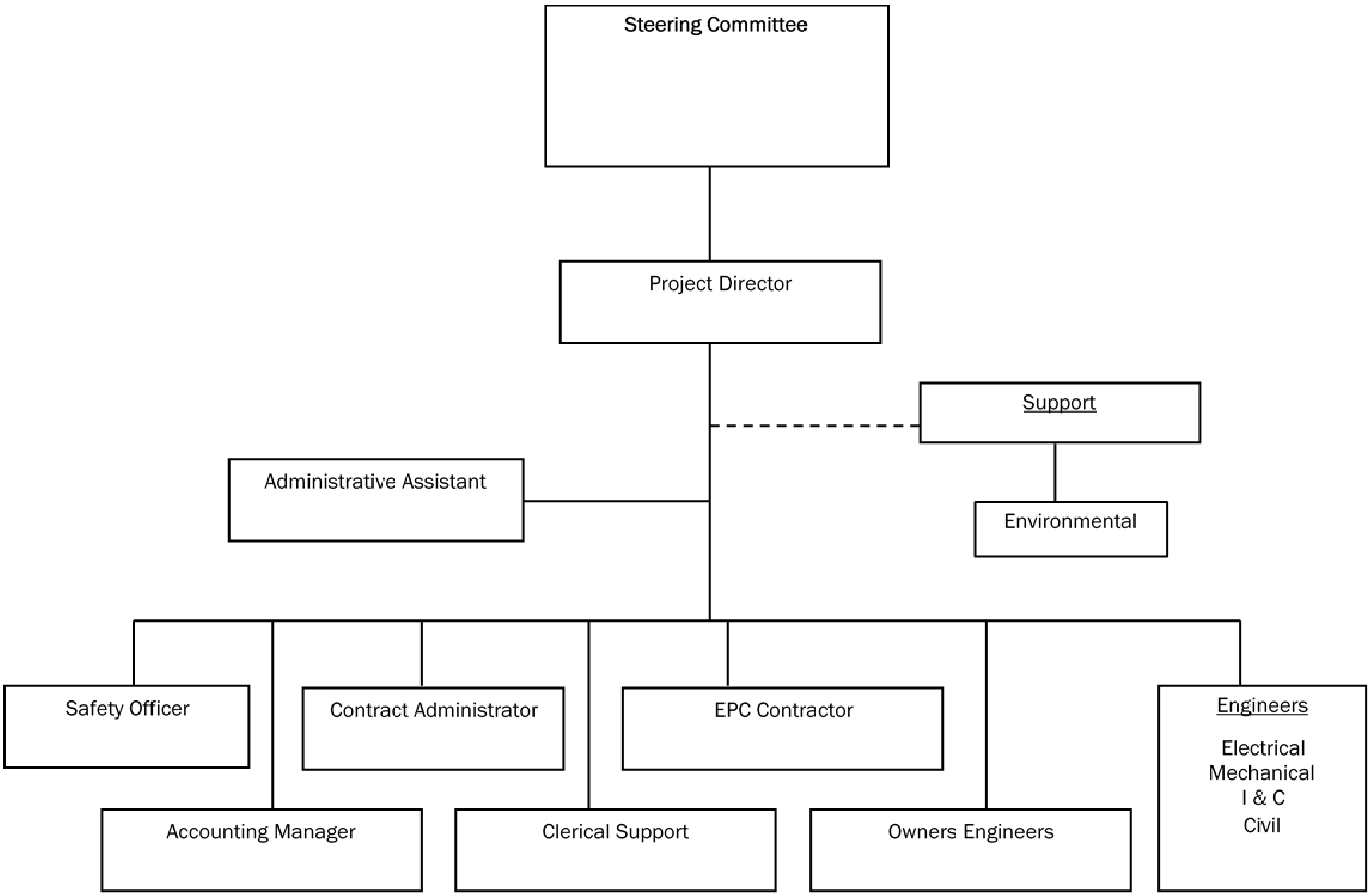


Figure 4-9 Organizational Chart for Construction Phase of the JPS Old Harbour Plant Re-Powering Project

4.5 POST CONSTRUCTION PLANS - PROJECT OPERATIONS AND MAINTENANCE

The plant will be operated and maintained by competent staff taken from the retired assets, other plants and possible new recruits. The proposed staff complement is 45 and these persons will be employed on a staggered basis, with the first set of staff to be brought in more than 12 months prior to commercial operation date (COD) (Table 4-1). Staff will be recruited primarily from Jamaica. Some entry level personnel without prior power generation experience may be employed and will be provided training and developmental experiences. An extensive training programme will be undertaken as part of the pre-commissioning activities. The staff will be trained by experienced expatriate persons with specialized skills for the initial years. These expatriates may include field engineers and technicians from the OEMs and experienced professionals from the majority shareholder's independent power divisions.

The company will implement a detailed "Operational Readiness" plan which will outline all of the steps and time schedule necessary to prepare for successful operation of the facility. Pre-operational activities will include preparing operating procedures, checklists, and operator rounds; setting up of an Enterprise Asset management platform ,work management systems for preventative, predictive and scheduled maintenance programmes; ordering and receiving spare parts and other inventory; supporting the EPC contractor's commissioning activities; implementing the training and qualification programmes; setting in place other procedures and programmes for human resources, administration, purchasing and accounting, environmental, health and safety, etc.

4.5.1 Operations

The operations management of the plant operation will be led by an Operations Manager supported by a 24-hour shift team with week day support from operations specialists. Based on industry best practice for combined cycle plants, as well as JPS's own successful local experience, a four-shift, 12-hour shift cycle will be used comprising the following: Shift Supervisors (5), Unit Controllers (5), Unit Operators (12). The week day team of operations specialists (including Operations Engineer and Station Chemist) will provide technical support to the shift team.

The Organizational Chart for the operation of the JPS Old Harbour Plant Re-Powering Project is depicted in Figure 4-10.

Table 4-1 Staffing Plan for Operations Phase

Position	Number in Position
Station Manager	1
Administrative Assistant	1
HSSE Specialist	1
Operations Manager	1
Operations Engineer	1
Chemist	1

Position	Number in Position
Shift Supervisor	5
Unit Controller	5
Unit Operator	12
Maintenance Manager	1
Maintenance Engineer	1
Administrative Officer	1
Maintenance Supervisor	2
Maintenance Technician	10
Stores Supervisor	1
Bearer/Driver	1
Clerk	1
Total	**45**

4.5.2 Maintenance

The maintenance plan is designed to ensure that the plant operates safely, efficiently with very high level of reliability and availability consistently throughout its operating life time. The maintenance program activities will include equipment routine maintenance, preventative maintenance periodic inspection, minor inspection and major inspection.

The program will be underpinned by a Service Agreement (SA) from reputable vendors.

Routine maintenance requirements for the plants will be the responsibility of the maintenance team who will be led by the maintenance manager, and will include a work crew comprising one maintenance engineer, 2 supervisors/planners, ten maintenance technicians skilled in the areas of I&C, mechanical, and electrical and other support staff.

The program will be underpinned by a Contractual Service Agreement (CSA) with the manufacturer. The plant will operate for a combined 32,000 hours (8,000 Factored Fired Hours per year/gas turbine) before major inspection, which results in major servicing occurring approximately every four (4) years. Once the servicing schedule is adhered to the plant should have an operational availability of 98%.

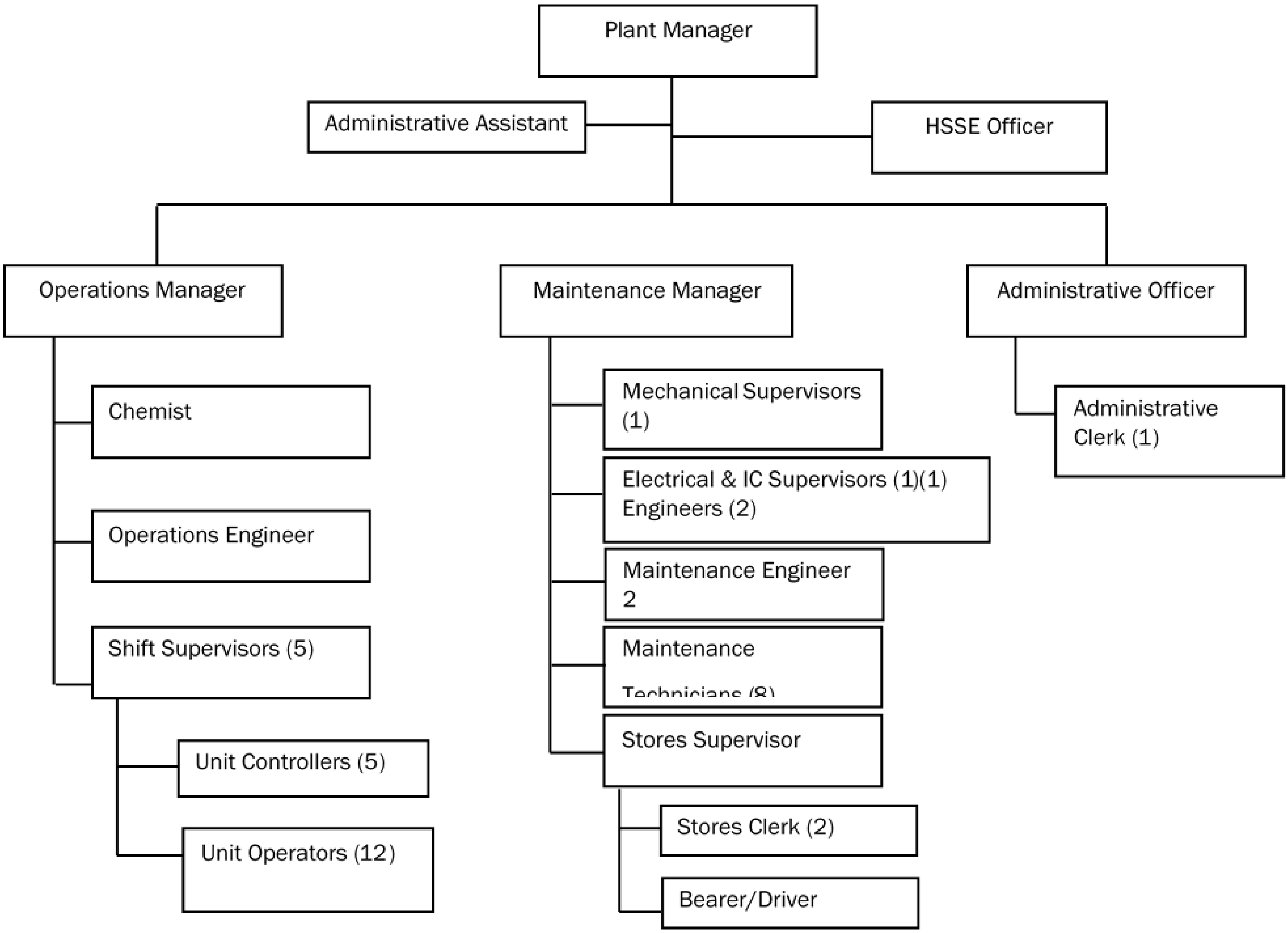


Figure 4-10 Organizational Chart for Commercial Operation Phase of the 190MW Old Harbour Plant Re-Powering Project

5.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

5.1 PHYSICAL

5.1.1 Climate and Meteorology

5.1.1.1 Climate within Study Area

2012 Study

METHODOLOGY

Temperature, relative humidity, wind speed and direction, rainfall and barometric pressure were recorded at one (1) location adjacent to the proposed site (atop the JEP Dr Bird Barge security post building). This weather station had been recording data from January 6th, 2011 until present. Weather data was recorded by using a Davis Instruments wireless Vantage Pro2 weather system with a data logger and a complete system shelter erected on a tripod. Data were collected every fifteen minutes and stored on the data logger. This information was downloaded using the WeatherLink 5.9.3 software.

RESULTS

Over the course of January 6th, 2011 – August 23rd, 2014:

- Average temperature was 26.73 ^{o}C and ranged from a low of 18.4 ^{o}C to a high of 36.3 ^{o}C.
- Average relative humidity was 80.85% and ranged from a low of 40% to a high of 97%.
- Average wind speed was 3.17 m/s and ranged from a low of 0 m/s to a high of 15.6 m/s.
- Dominant wind direction was from the east.
- Mean barometric pressure was 1013.3 millibar and ranged from a low of 982.4 millibar to a high of 1019.8 millibar.

The total amount of rainfall over the period was 3946.15mm. This is divided as is:

- 2169.82 mm from January 6 – December 31, 2011
- 917.28 mm in 2012
- 626.56 mm in 2013
- 232.49 mm from January 1 – August 23, 2014.

Figure 5-1 to Figure 5-4 show the rainfall patterns per month for each year. In 2011, rainfall peaked in July, while in 2012 and 2013 rainfall peaked in May and September. In 2014, there was high rainfall in March and May.

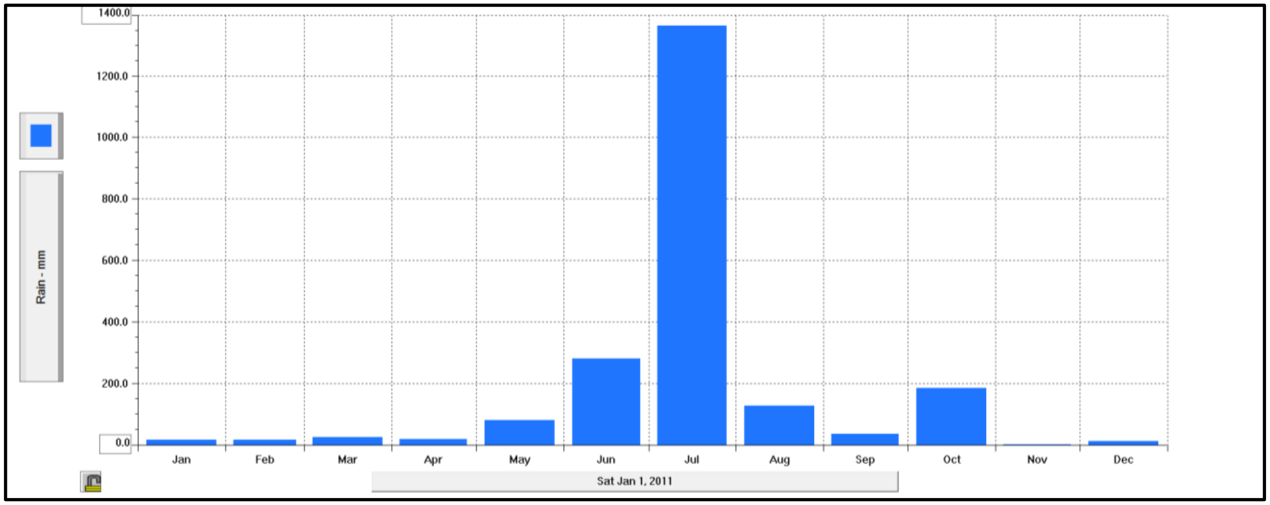


Figure 5-1 Rainfall rates for 2011

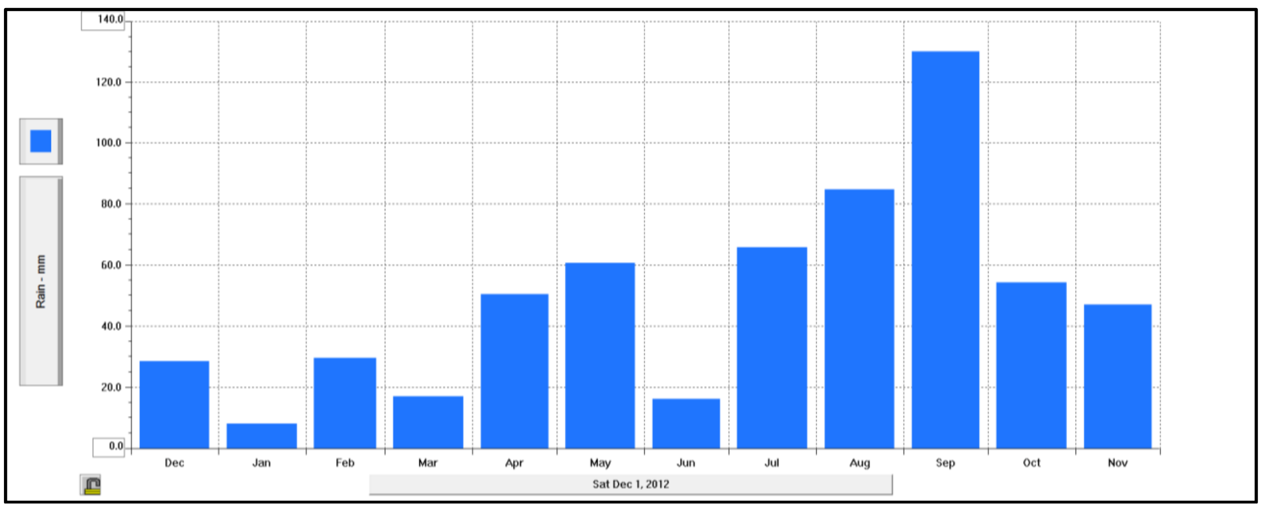


Figure 5-2 Rainfall rates for 2012

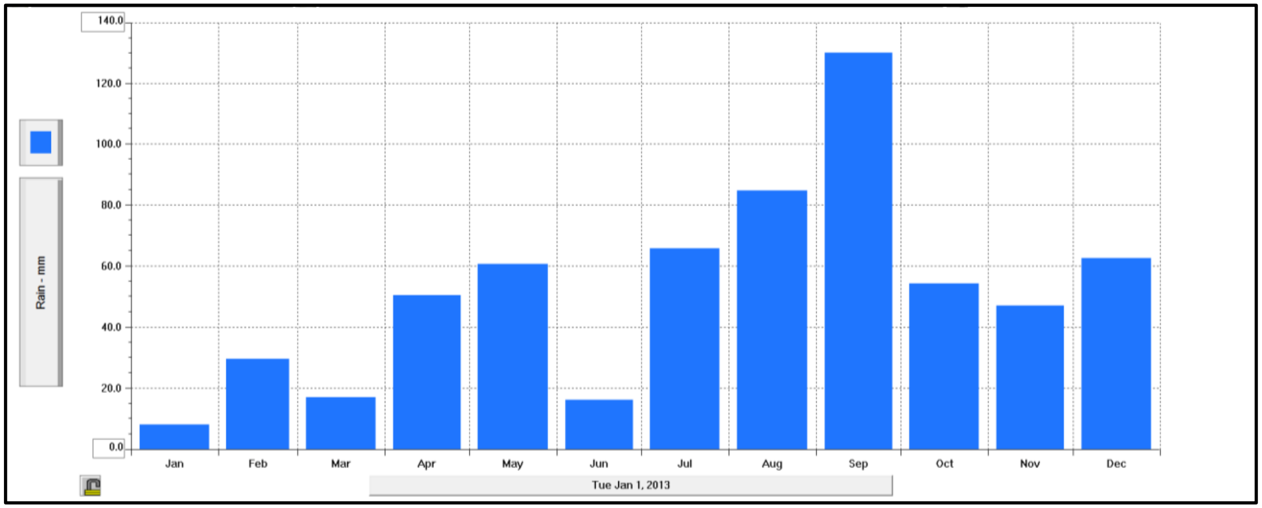


Figure 5-3 Rainfall rates for 2013

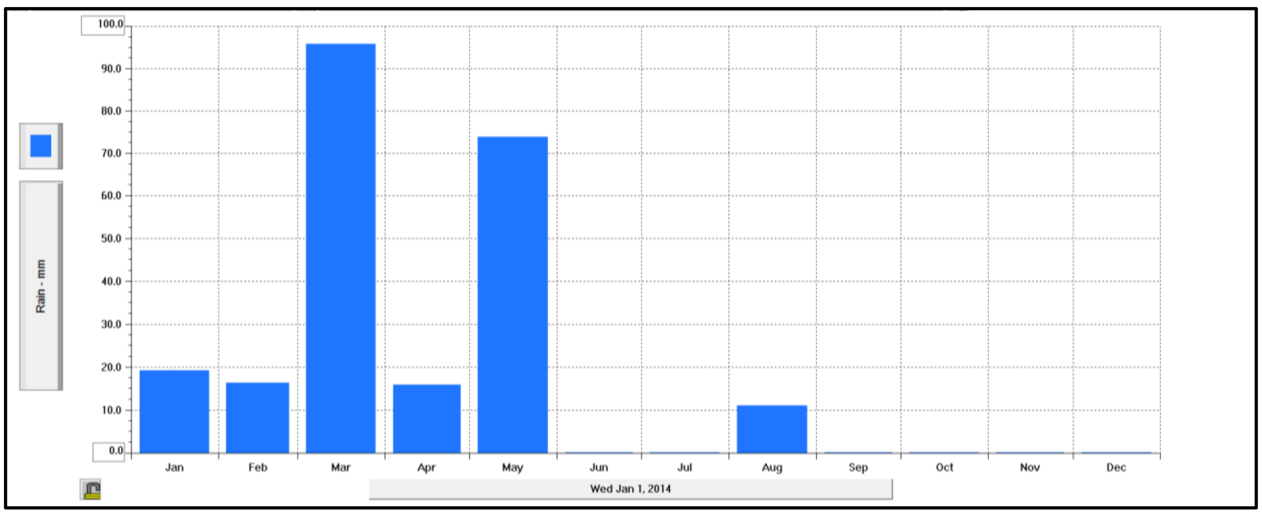


Figure 5-4 Rainfall rates for 2014

5.1.1.2 Historical Climate Data

Rainfall

30 YEAR CLIMATOLOGICAL DATA (1951-1980)

As seen below in Table 5-1 and Figure 5-5 temperatures are greatest during the months of June through September. Lowest mean minimum temperature of 15.3 ^{0}C is seen to occur in the month of February and the greatest mean maximum temperature of 31.9 occurs in between June and July. Rainfall is seen to have two yearly peaks of greater than 150 mm in September and October. January and February are seen to be the driest months of the year.

Table 5-1 Mean Climatological data for Bodles (1951-1980) – Jamaica Meteorological Service.

1951-80 MEAN CLIMATOLOGICAL DATA FOR SELECTED LOCATIONS													
Station (Altitude)	Parameter	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Bodles (Old Harbour) (St.Catherine) (alt. 37 metres)	Max Temp. (C)	29.3	29.2	29.4	30.4	30.4	31.1	31.9	31.9	31.1	30.7	30.4	30.2
	Min Temp. (C)	16.3	15.3	17.0	18.1	19.3	20.1	20.3	20.2	19.7	18.9	19.2	18.1
	Rainfall (mm)	41	42	49	56	123	91	58	97	161	198	83	53
	Rel. Hum.- 7am (%)	94	92	92	88	89	87	86	89	92	94	93	91
	Rel. Hum.- 1pm (%)	64	65	63	62	69	66	63	68	70	70	66	66

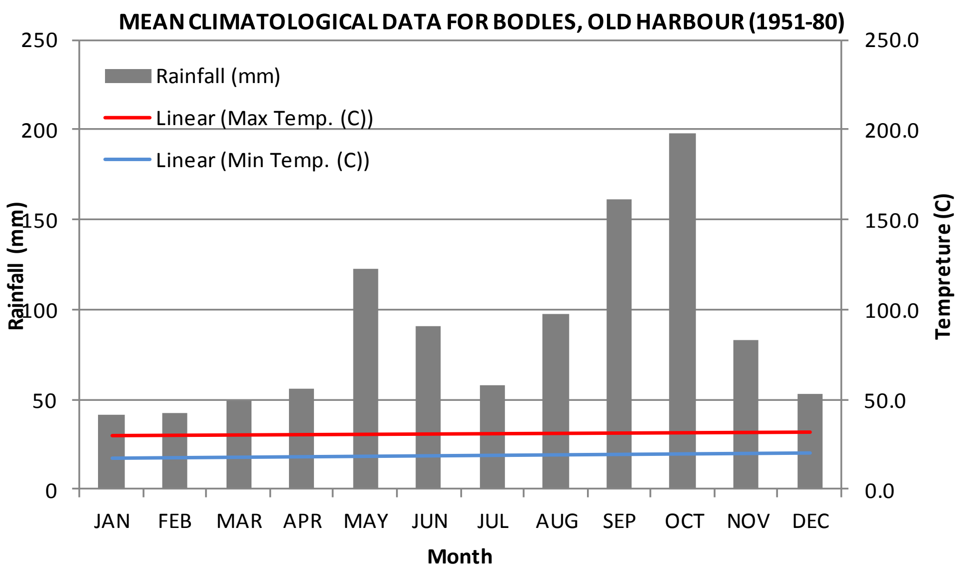


Figure 5-5 Mean Climatological data for Bodles (1951-1980) – Jamaica Meteorological Service.

EXTREME RAINFALL

The rainfall data for gauges in Jamaica were obtained from the Meteorological Office of Jamaica. Information for the gauges spanned 1930 to 1980 and 1992 to 2008. Both sets of data were subjected to Weibull analysis for the extreme rainfall data ranging for the 2, 5, 10, 25, 50 and 100 year. Historical rainfall extremes for stations across the island for the period 1930 to 1988 were compared with the extremes determined for the period 1992 to 2008. Rainfall depths for corresponding return periods were subjected to comparative analysis in order to determine if there was an overall increase or decrease in extreme rainfall. The analysis has indicated that there has been an overall increase ranging from 11.7% (for the 2 year Return Period Event) to 1.5% (for the 100 year Return Period event) for all stations. This increase has occurred over a time frame of 21 years (1988 to 2009). This equates to 0.7% to 5.6% increase per decade.

Table 5-2 Overall increase in 24-hours rainfall intensity (1988 – 2009).

	Return Period (yr)					
	2	5	10	25	50	100
Number of stations considered	117	117	117	117	117	116
Average increase (mm)	14.0	10.0	5.6	5.9	6.3	5.3
Average rainfall depth (mm) 1930 to 1988	119.8	175.0	217.7	268.2	307.8	345.7
Overall increase	11.7%	5.7%	2.6%	2.2%	2.1%	1.5%
Increase per decade	5.6%	2.7%	1.2%	1.0%	1.0%	0.7%

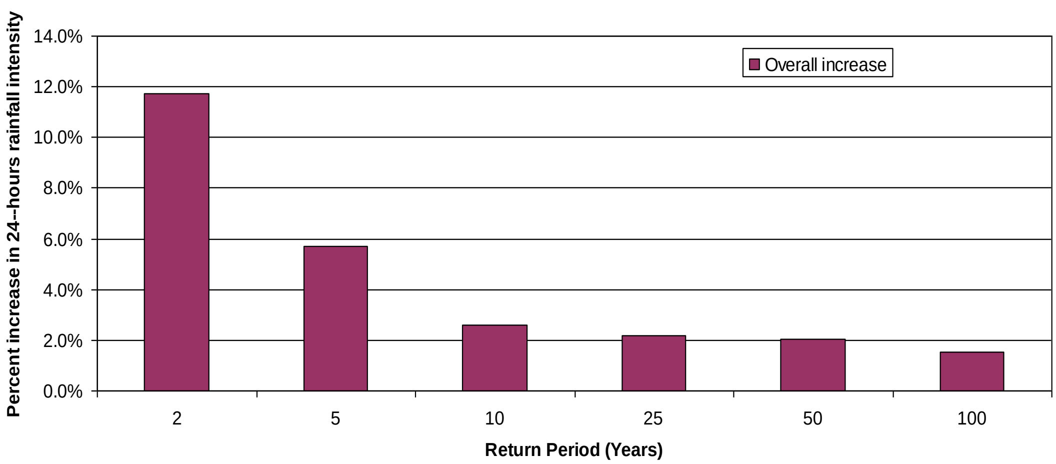


Figure 5-6 Overall increase in 24-hours rainfall intensity for the period between 1988 and 2009.

Given the design life of the project is 25 years, due consideration should be given to the changes in extreme rainfall as the old data appears to be irrelevant in light of the new data supplied by the Meteorological Office of Jamaica. See Figure 5-7 and Figure 5-8 below for the rainfall changes estimated for the 50year and 100year 24 hour extreme rainfall.

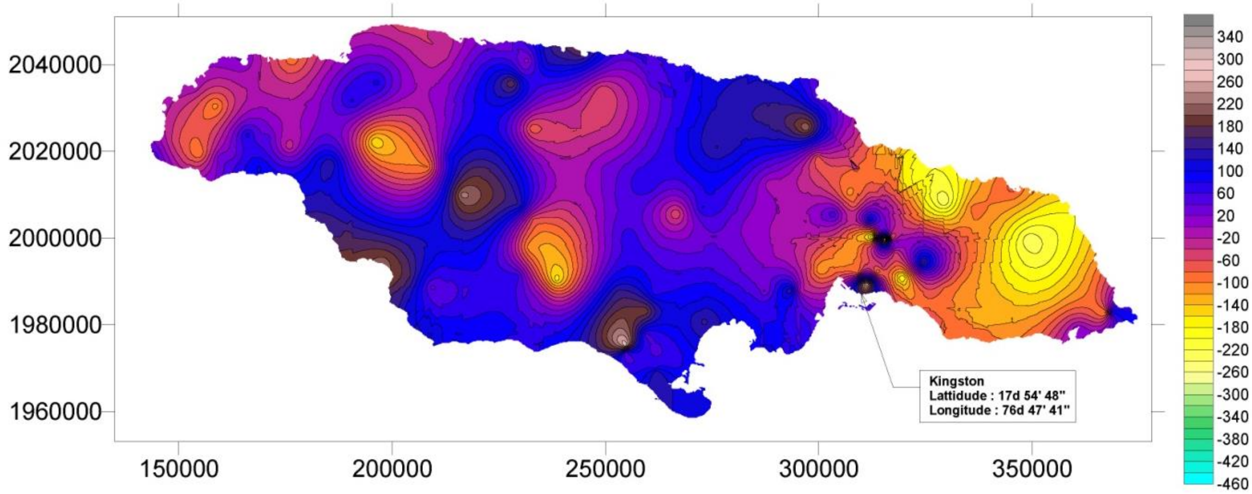


Figure 5-7 Difference (mm) between the 1930-1988 and 1992 to 2008 24-hours Extreme rainfall intensities for the 50 Year Return Period Event.

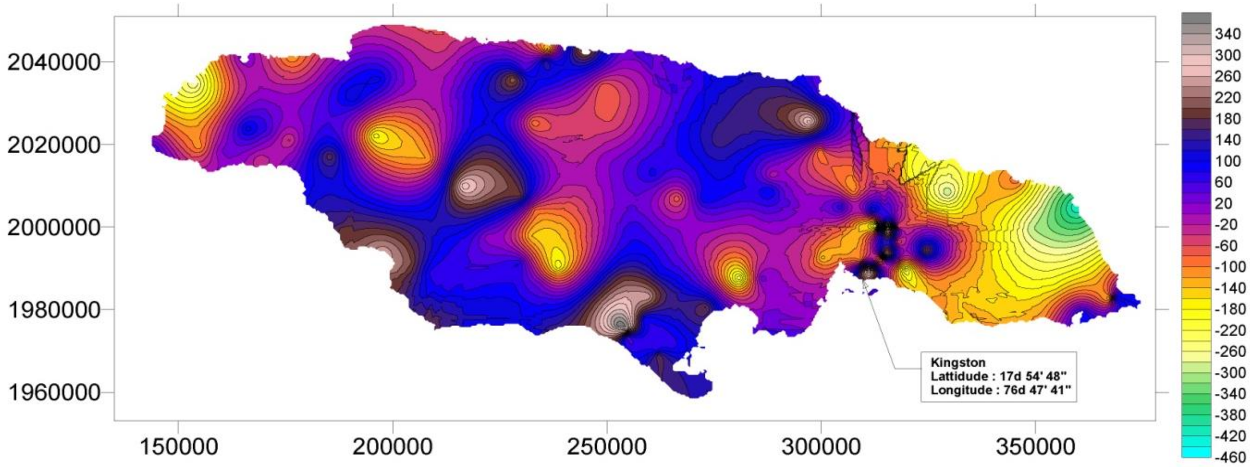


Figure 5-8 Difference (mm) between the 1930-1988 and 1992 to 2008 24-hours Extreme rainfall intensities for the 100 Year Return Period Event.

5.1.2 Topography and Landscape

The site is located on very gently sloping lands which falls off to the sea in the south. This area is also within the flood plain of the Bowers Gully which flows from the hills in the north. Topographical data obtained from the Survey department 12,500 map series revealed the Bowers Gully catchment encompasses steep mountainous regions to the North which have elevation of up to 610 metres above mean sea level (msl). The area encompassed by the project site has elevations varying from 0.5m to 2.0m above msl. See Figure 5-9 and Figure 5-10 for the topography map of the wider project area derived from the survey department' 12500 map series. The general area surrounding the site has slopes of less than two percent (2%), whereas the hills in the north are dominated by slopes between 20 and 30 percent.

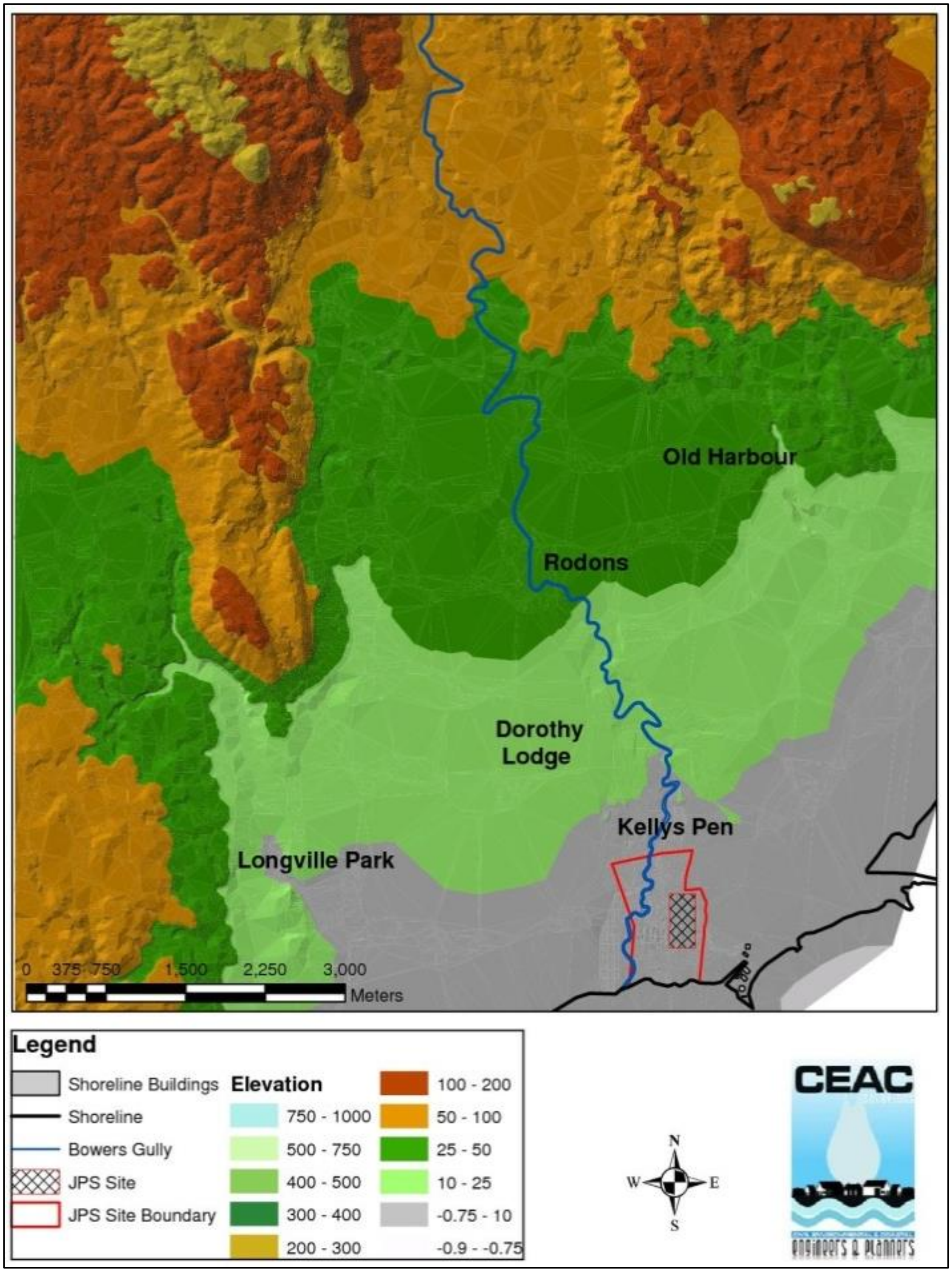


Figure 5-9 Digital terrain map of the project area created from Survey Department 1:12,500 map series.

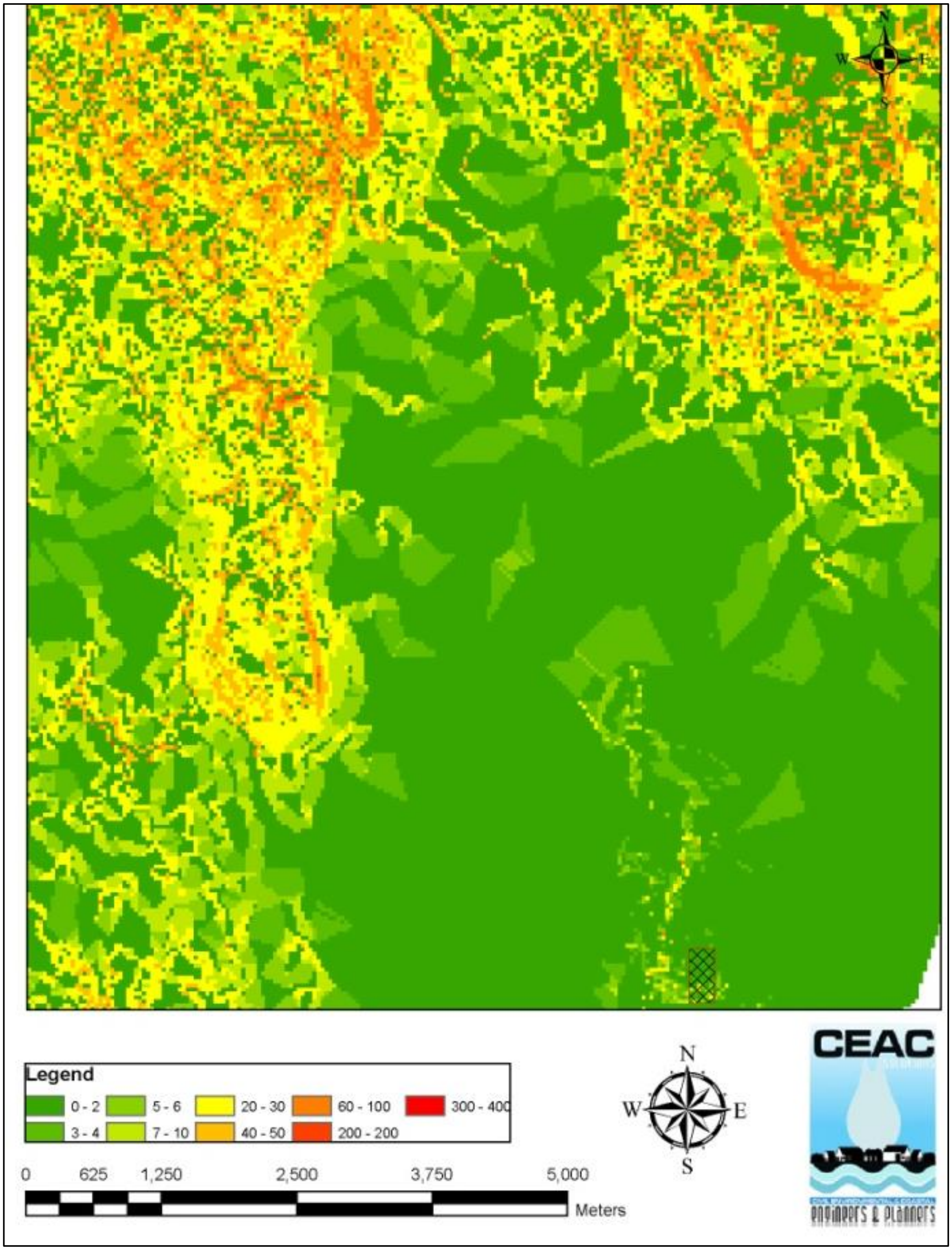


Figure 5-10 Slope analysis of the project is showing the percent slope of the terrain.

5.1.3 Geology and Structure

5.1.3.1 Geology

The geology of the area adjacent to the site consists of unconsolidated sands and sandy clays, and carbonaceous sandy clays and clays of Holocene age (last 12,000 years, marked as Qm on Figure 5-11). The present beach sediments consist mainly of non-carbonate grains (Wood, 1976). Unconsolidated or semi-consolidated deposits of Holocene age probably extend to a depth exceeding 100 metres (Figure 5-11; data from Porter and Bateson, 1974, Fernandez, 1983; Halcrow, 1998). This depression probably marks the position of an old channel of the Rio Cobre excavated during one or more low sea-level stands of the Pleistocene Epoch. Its continuation is evident through Old Harbour Bay. Regionally, the lower part of the Holocene section is probably dominated by clays, possibly older than Holocene (Fernandez, 1983; Aspinall and Shepherd, 1978), grading up into sandier deposits in the higher part of the section. All these are underlain by lithified rocks of the White Limestone Group. A low raised beach (about 1 metre in elevation) was reported at Old Harbour Bay (Porter and Bateson, 1974).

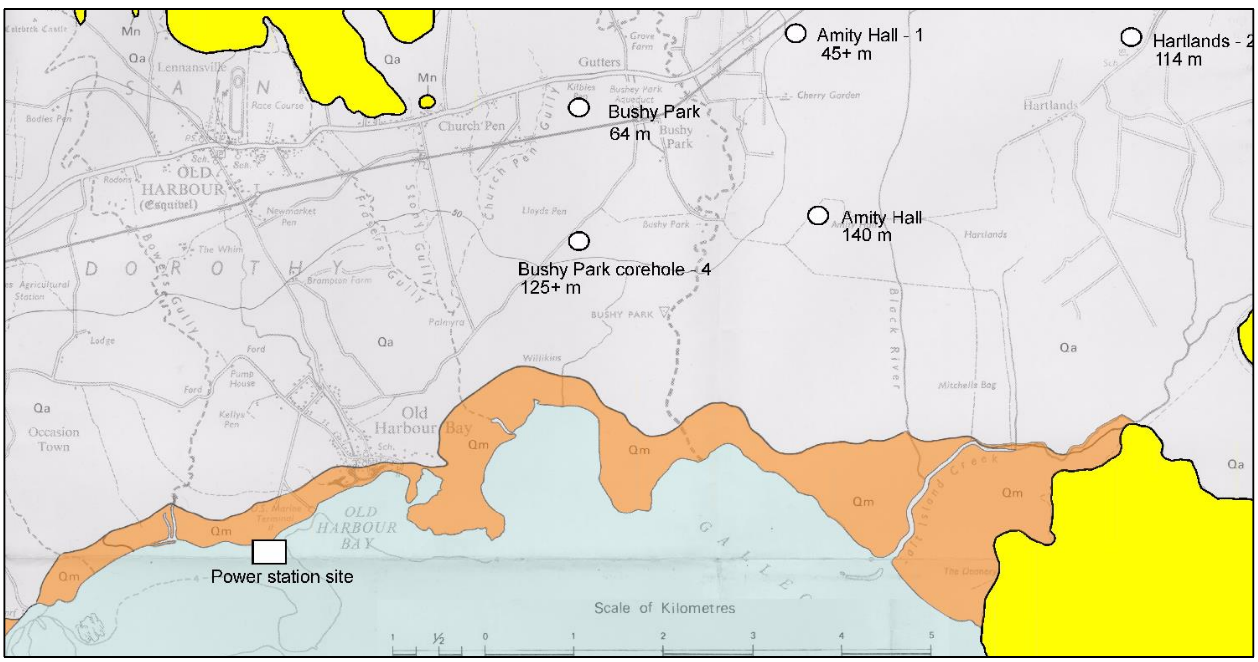


Figure 5-11 Regional geology of the site. Yellow, White Limestone Group; grey, Quaternary sediments of the Rio Cobre alluvial fan; brown, Holocene superficial sediments and soils of the coastline. Large striped rectangle is the proposed new site.

5.1.3.2 Borehole Logs

Logs for boreholes BH A to BH D were available for inspection, all of which were sited on the area of interest. All boreholes were done in locations where the major foundations of the proposed plant will be situated (Gas Turbines 1 – 3 and the Steam Turbine). Logs can be seen in the NHL Engineering June 30, 2015 Soil Investigation Report.

5.1.3.3 Structure

There is no evidence of structural complications within the superficial sediments of the area. Evidence of such features as faults is difficult to obtain from unconsolidated deposits. Fernandez (1983) demonstrated the existence of faulting in the White Limestone bedrock. Examination of his borehole logs also indicates the probability of normal faulting (possibly growth faults) in the post-White Limestone sediments, which thicken towards the central axis of the St. Catherine Plains Quaternary basin.

5.1.4 Soils

5.1.4.1 Soil Distribution

The spatial distribution of the soils present at the proposed site is shown in Figure 5-12 and has been modified from Campbell et al (1986) and their soil names and codes followed. Ground truthing of these were carried out during the site visit. The published soil and land use surveys (Netherlands; Campbell et al 1986 and Vernon and Jones, 1958) identify 4 soil types (Lodge Clay; Lodge Clay, Saline-Sodic phase; Whim Clay Loam (PRb3); Salina undifferentiated (TMX1)) in the study area and we follow their classification in the descriptions below.

Lodge Clay (POc1)

Lodge Clay (POc1) described by (Campbell et al 1986) is equivalent to the Lodge Clay loam (low salinity phase) mapped by Vernon (1958). It is formed from a very mixed gravelly and sandy old alluvium (Campbell et al 1986 and Vernon, 1958) that is from Bowers Gully source. These clays are moderately well drained deep reddish brown cracking clays occurring in primarily topographically flat areas, dominant slope range is 0-2°, but also at slightly elevated sites on the old alluvial clay plain. This soil is typically moist throughout with fair external drainage. Internal drainage is good to 11” (5 cm) and moderate below. Permeability is however low after cracks have been closed. Soils are very hard when dry and very sticky when wet (Campbell et al 1986). The surface layer is dark brown in colour, and ranges in thickness from 40-70 cm (Agricultural Chemistry Division 1964). A saline old alluvial soil, derived partly from mixed gravel is found in the Bowers Gully; depth very deep- more than 60” (1.5 m) (Agricultural Chemistry Division 1964).

Lodge Clay Saline- Sodic Phase (POc1/sa)

Lodge Clay Saline- Sodic phase (POc1/sa) described by (Campbell et al 1986) is equivalent to the lodge clay loam (saline) mapped by Vernon (1958). It is characteristically similar to the Lodge Clay (POc1) but saline and sodic in the subsoil. It is a moderately well (internally) drained old alluvium that occurs primarily on the lower slopes (slope range 0-2°) of the coastal (clay) plain towards the sea (Campbell et al 1986) and has erosional hazards. The soil is non-saline at the surface becoming moderately saline at depth (Campbell et al 1986; Ministry of Agriculture and Fisheries 2009).

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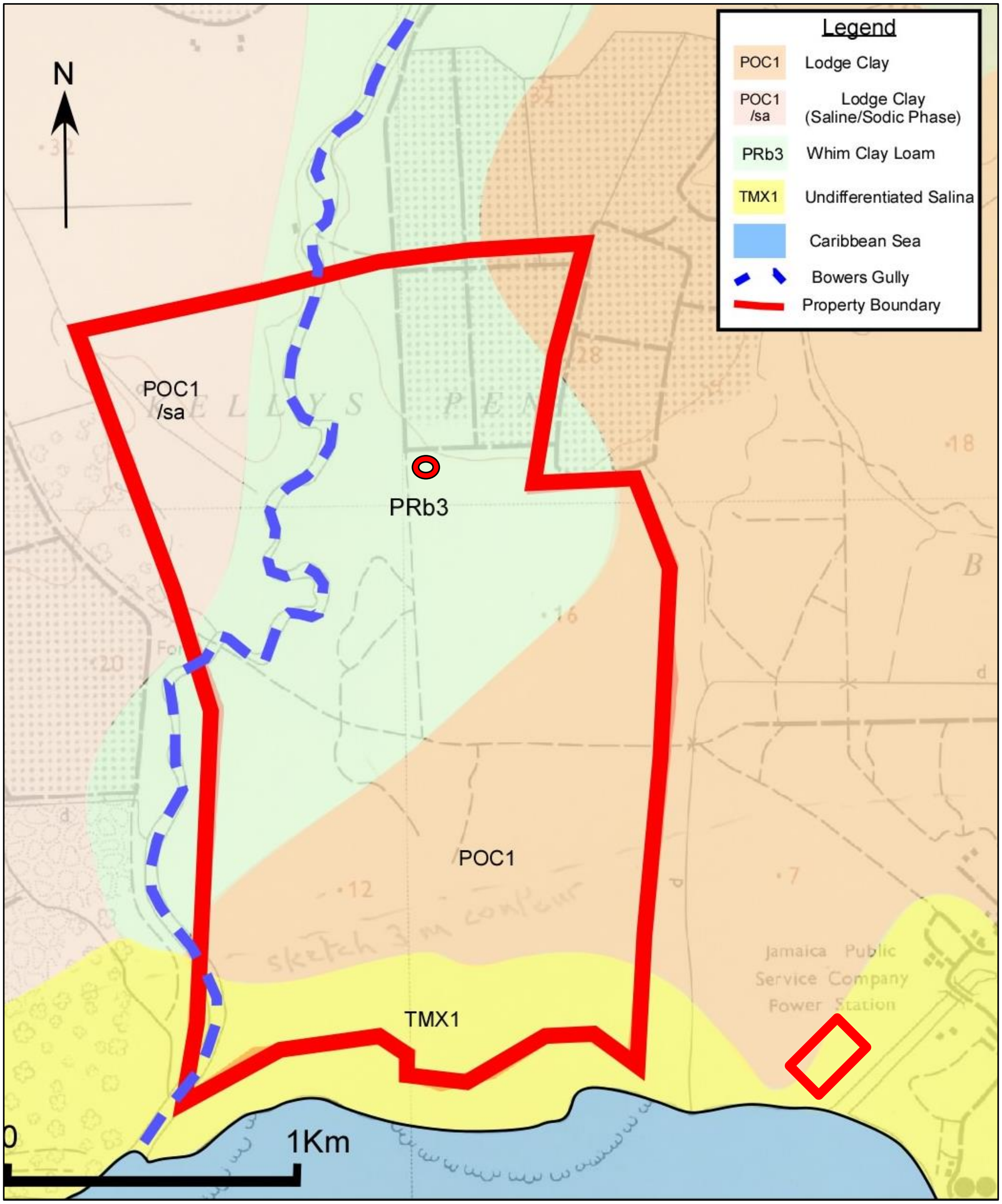


Figure 5-12 Map showing the spatial distribution of soils associated with the area of interest (map modified from Campbell et al 1986).

Whim Clay Loam (PRb3)

Whim clay loam (PRb3) is a well-drained stratified soil developed on recent alluvium of river plains from alluvial soil derived from mixed rocks of the upper catchment of the Bowers Gully. The soils occur on level smooth sites along major stream channels. Soil thicknesses may exceed 60" (1.5 m) and the Agricultural Chemistry Division report (1964) reports that soil colour and weight increases with depth. Colour varies from a dark brown sandy loam or sandy clay to a yellowish brown. It has moderate internal drainage and occurs on slopes of 0-2° (Ministry of Agriculture and Fisheries 2009).

Salina Undifferentiated

Saline areas are located between the sea, mangrove swamps and the alluvial coastal plain swamps. They consist of poorly drained, deep, strongly saline and sodic soils of varying textures and colours and are strongly calcareous (Campbell et al 1986). They are mostly devoid of tree/shrub vegetation except for some salt tolerant plants. Soil is classified as typic halaquepts (Campbell et al 1986)

5.1.4.2 Geotechnical Survey

NHL Engineering Ltd. conducted a geotechnical survey on the proposed site located in Old Harbour, St. Catherine in April 2015. The field investigation entailed the drilling and sampling of four (4) locations to a depth of 40m (131'). The testing results revealed that four (4) distinct types of soils were encountered: a mixture of loose compact sands with some gravels and silts, very soft/very loose silty clays, very stiff – hard silty clays with some silts and sands and dense – very dense sands with some gravels and silts (Figure 5-13). Ground water was encountered the boreholes at an average depth of 2.4 m below existing ground elevation. These results indicate the foundation need specialist attention in terms of their design. Shallow isolated pad or strip foundations placed on this site will be susceptible to settlement and displacement without replacement or soil modification. A Soils engineer is therefore to be consulted to design the fill and foundation that are required to mitigate against differential settlement of the power plant. Detailed results can be found in the 'Soil Investigation Report' prepared by NHL Engineering Ltd (June 2015).

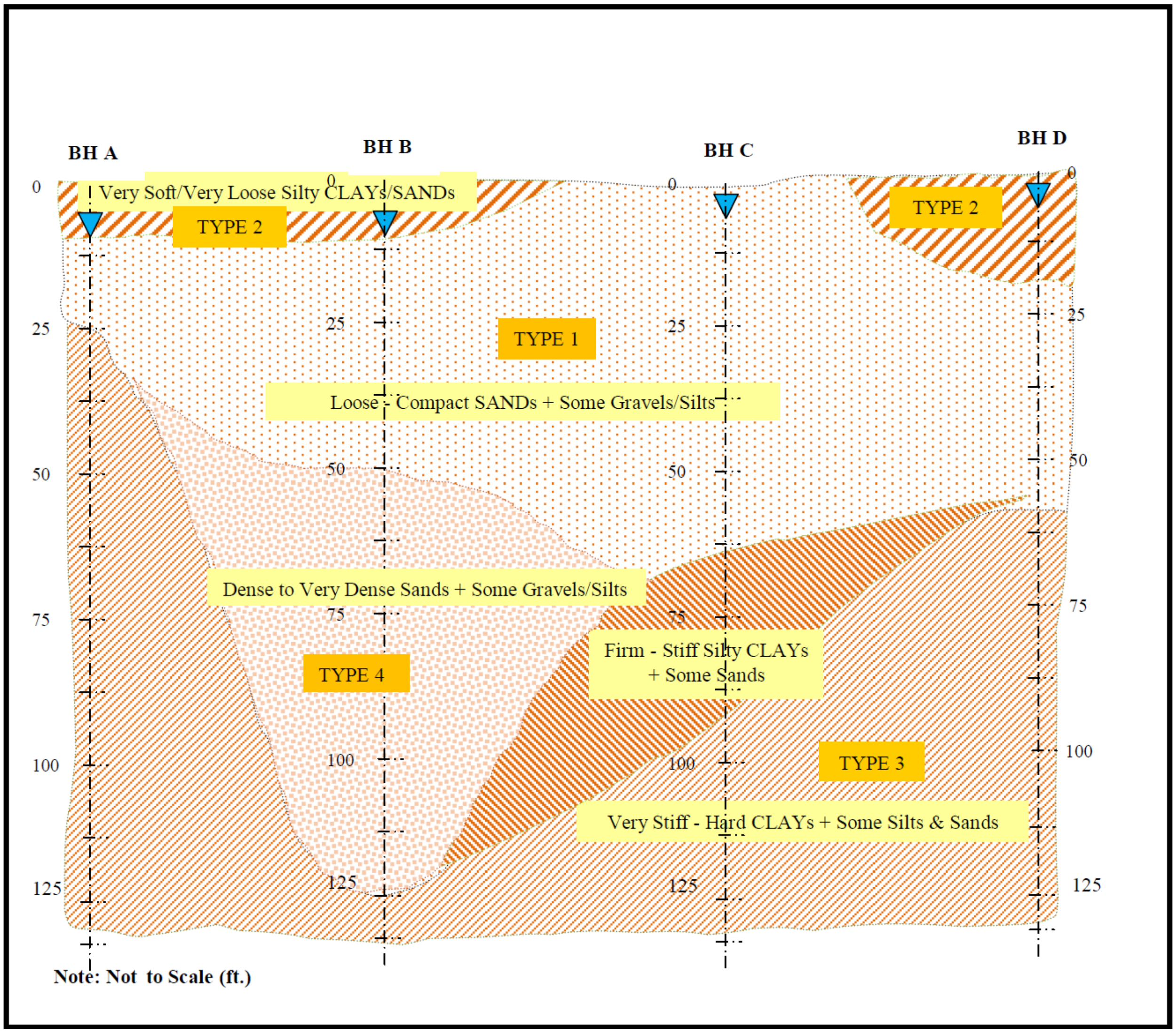


Figure 5-13 Presumptive profile boreholes A, B, C and D

5.1.5 Well Analysis

The Bodles Rosehall and Experimental wells are located in the western section of the St. Catherine plains approximately 2.2 kilometres southwest of Old Harbour.

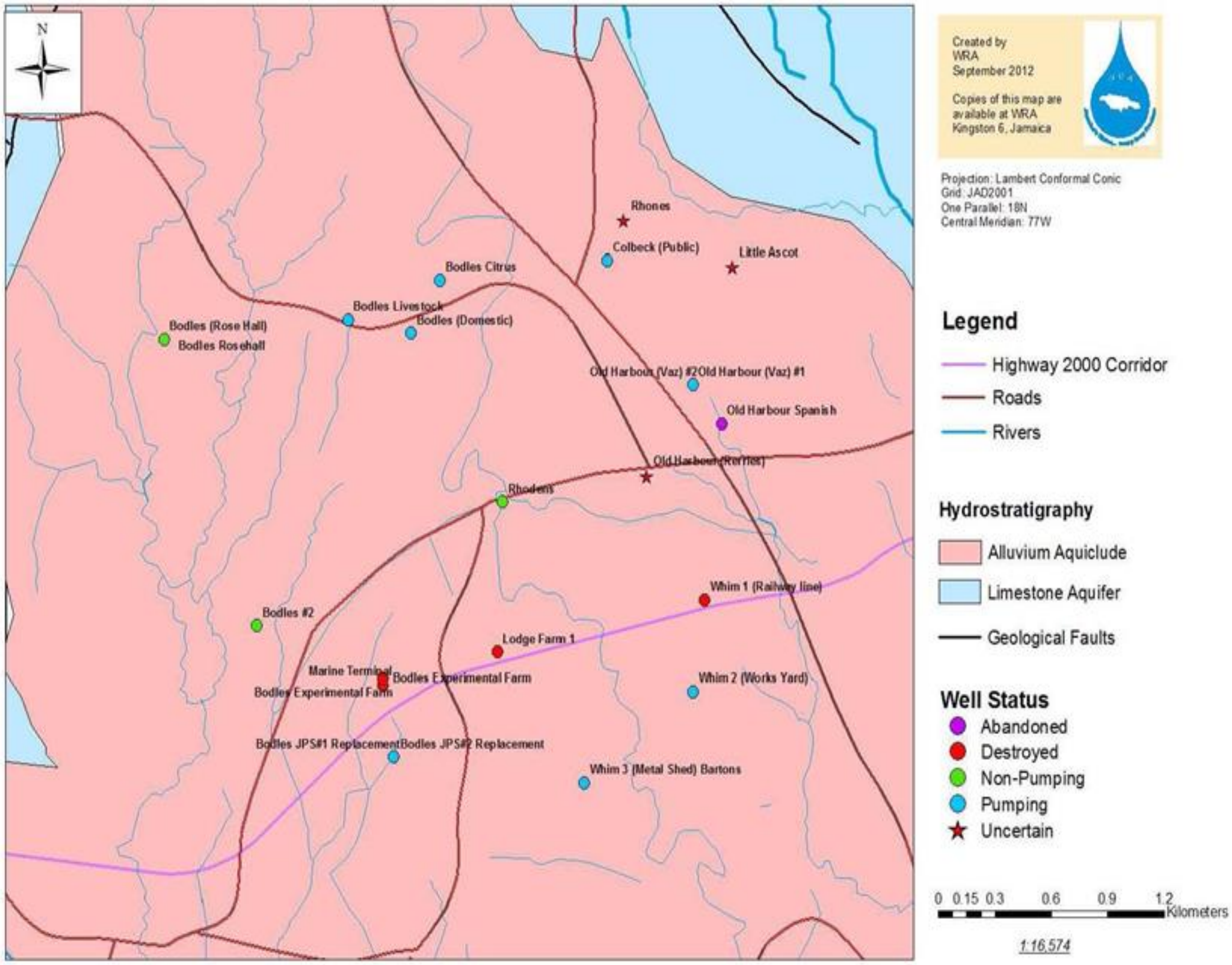


Figure 5-14 Map Showing Bodles Hydrostratigraphy (Source: WRA assessment Bodles Rosehall and Bodles Experimental Wells).

5.1.5.1 Bodles Rosehall

A pump test was done on the Bodles Rosehall well in 2000 and had a specific capacity of 111,741.55m³/day/m which was calculated at its highest rate of 14,526.4m³/day. The static water level was 29.87 metres below ground level and a measured drawdown of 0.13 metres at yield testing. This high productivity maybe as a result of the prevailing geology in the Bodles area indicating the well taps a conduit with high flows (underground river) where recharge equals discharge during testing.

Information from the well record includes:

- Diameter: 508mm
- Depth: 53.34 metres
- Casing:
    - Plain 508mm casing from 0.31m – 27.13m
    - Slot 508mm casing from 27.13m – 42.34m

Information from Telelog:

- Diameter: 508mm (20 inches)
- Depth : 53.34m (175 feet)
- Casing : Plain 508mm from 0.31m -27.13m
- Slot 508 mm from 27.13m -33.22m
- Slots 457.2mm from 33.22m -43.89m
- Open Hole from 43.89m -53.34m

5.1.5.2 Bodles Experimental Farm

The Bodles Experimental Farm well was a moderate producer at its yield testing in 2000 with a specific capacity of 769.3m^3/day/m when tested at its highest rate of 2,594.67m^3/day. The static water level was 21.52 metres below ground level and a measured drawdown of 3.37 metres at yield testing. The stabilisation of the drawdown indicated that the aquifer was continuously recharged. However, with ground elevation at 23.32 metres above sea level a licenced volume of 1,000m^3/day was assigned which would result in pumping water levels of 0.8 metres above sea level. Any higher pumping would result in below sea level pumping thereby inducing seawater intrusion.

Information from well record:

- Diameter: 250mm
- Depth : 35.97metres
- Casing: no information

The water supply to the proposed plant will use the existing supply from the existing Old Harbour Power Plant and cooling water from once through cooling using seawater.

5.1.6 Hydrology and Runoff

The site as is does not receive flows from offsite sources. The site catchment is therefore contained within its boundaries. Hydrologic analysis of the site was undertaken to determine runoff for the 10, 50, and 100 year return rainfall events. Hydrological modelling of the watersheds encompassed three main elements:

- Precipitation
- Rainfall abstraction model (Curve number method) – determines how much of the precipitation is initially absorbed before runoff takes place
- Runoff model (Dimensionless unit hydrograph)

The SCS curve number method was used to determine the rainfall excess P_e using the following equation:

$$P_e = \frac{(P^2 - I_a^2)}{P - I_a} + S$$

Where:

P = precipitation
I_a = initial abstraction
S = Potential retention which is a measure of the retention capacity of the soil.

The Maximum Potential retention, S, and the watershed characteristics are related through the Curve number CN.

$$S = \frac{25400 - (254 \times CN)}{CN}$$

The Curve Numbers used were those developed by the NRCS on the basis of soils group, soil cover or land use, and antecedent moisture conditions. The values used were for AMC II which represents average conditions.

Historical precipitation data was obtained from the Meteorological office of Jamaica and analysed to determine the different return periods. The peak runoffs were calculated using the type III rainfall distribution curve, the hydraulic properties of the soils in the catchment as well as the existing land use properties. The primary inputs into the model can be summarized as follows:

- Drainage area size (A) in square miles (square kilometres);
- Time of concentration (Tc) in hours;
- Weighted runoff curve number (RCN), (based on soils and land use);
- Rainfall distribution;
- Total design rainfall (P) in inches (millimetres).

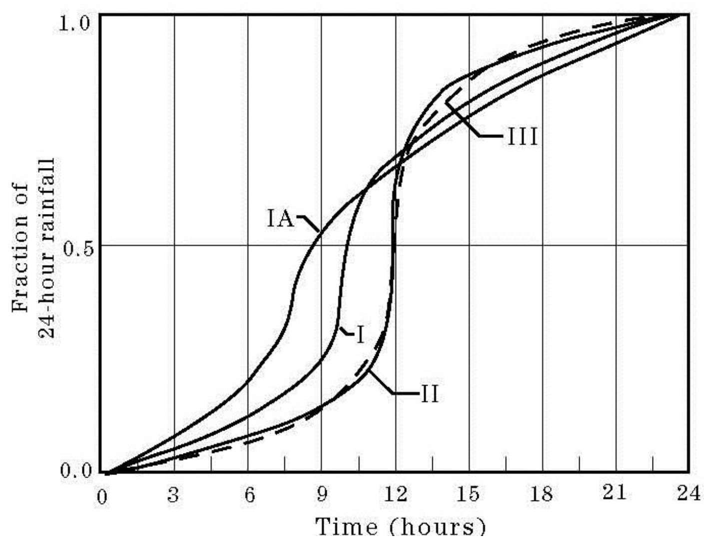


Figure 5-15 CS 24-hour Rainfall Distributions.

Runoff was estimated for the site in its current "undeveloped" or existing condition. A post development scenario was also modelled (see Land Impacts, section 7.2.1.1). Existing predevelopment flows were estimated as follows for the three return period storms investigates follows:

- 10yr = 198 m^3/s
- 50yr = 406 m^3/s
- 100yr = 473 m^3/s

5.1.7 Bathymetry

5.1.7.1 Existing Data

Detailed bathymetric data for the project area was essential for formulating both the hydrodynamic model (Finite Element Model, FEM) and wave model. This also allowed for the generation of a Digital Elevation Model (DEM) which was used to specify volumes of excavation required for the power plant. Existing bathymetric data within the Portland Bight area was available from:

- Admiralty Charts;
- CEAC (2009) study for Jamalco and Rinker Minerals at Rocky Point;
- CEAC (2010) study for the National Works Agency for beach stabilization of Old Harbour;
- CEAC (2011 and 12) study JPS 360 MW power plant.

5.1.7.2 Bathymetric Survey (2014)

The 2012 Study of the SJPC 360 MW Power plant had bathymetric data in the project area, but these were based on a lower precision instrument as well as the sea floor could have experienced minor changes since then. An additional survey was carried out on August 13 to 15, 2014 in order help close the gaps between existing surveys.

Single beam sonar with real time kinematic (RTK) GPS correction was used for this exercise. The general specifications of the survey was to national standards and are listed as follows:

- Survey on 30 meters (perpendicular to shore) grid x 100 meters tie lines grid, 200 KHz sounder, at 1 second intervals at a maximum speed of 6 knots. No surveys will be done in heave or swell conditions exceeding 1.0 metres in wave height or in water depths less than 1 metre;
- Chart datum determination from temporary tide gauge to national survey system;
- Automatic tide correction by dynamic real time ellipsoid height GPS measurements. Statistic Ellipsoid height from pre-survey field checks in the area and correlation to Chart Datum;
- All surveys to 0.05 metres depth accuracy and +/- 0.1 metres horizontal accuracy, using real-time Trimble DSM 232 DGPS system and ODOM sounder;
- Shallow and deep water bar check before survey.

The areas surveyed were:

- Port Esquivel outfall and intake sites over a nominal area of 800 x 400 meters;
- Old Harbour Bay FSRU site over a nominal area of 300x1400 meters;
- Gap in reef offshore Doctor Bird 1/fuel line over a nominal area of 200 x 900 meters.

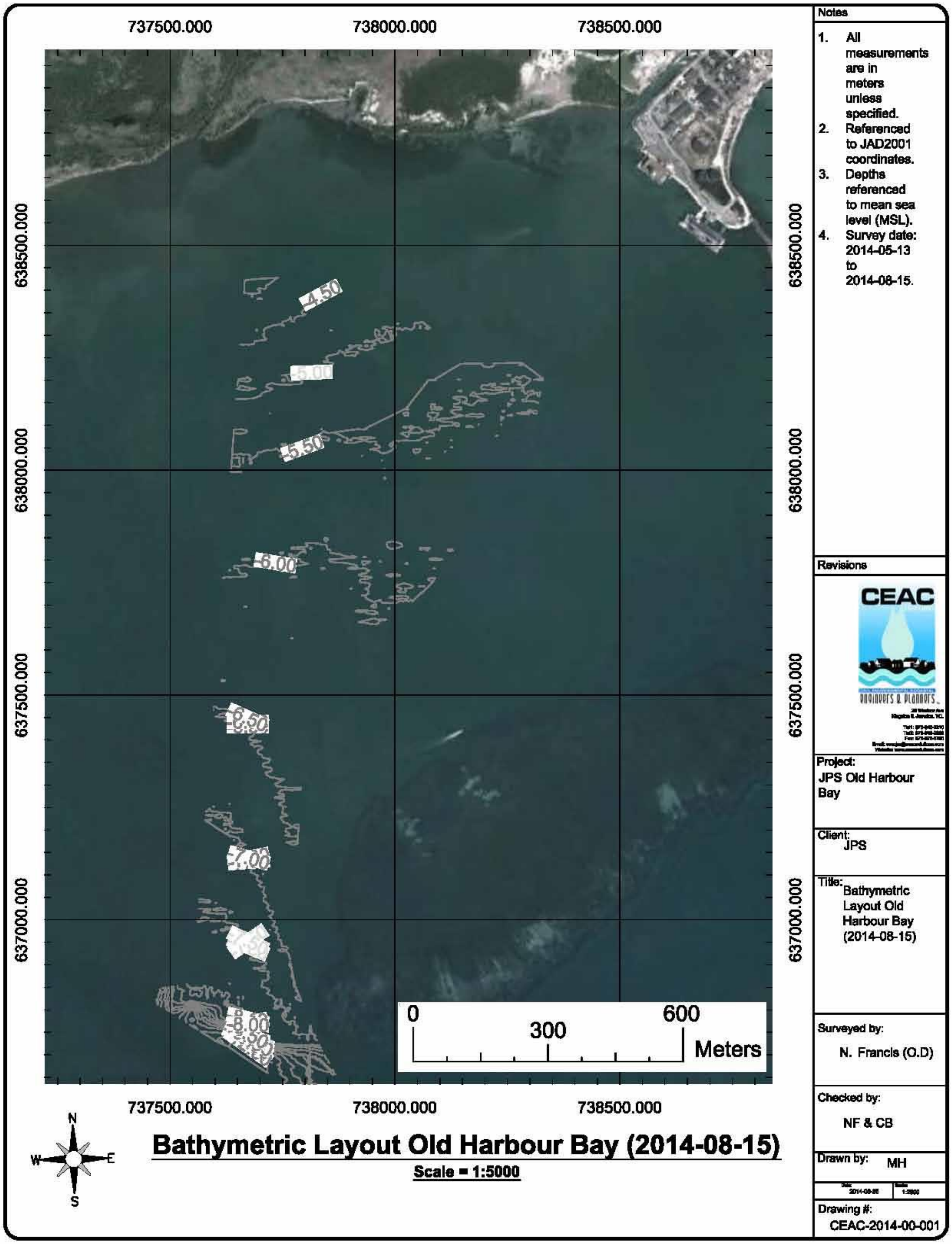


Figure 5-16 Map of bathymetric survey contours

Shallow (<3.0 metres) and deep water (<15.0 metres) bar checks were carried out before the survey to verify the accuracy of the survey. A simplified bathymetric chart is shown in Figure 5-16, indicating depths of 4.0 to 12.0m across the surveyed area. The contours in the area also indicated an area extending to the west of the Doctor Bird 1 having a trench with bottom elevations of -4.5 to -5m. The data obtained revealed that the bathymetry is relatively shallow out to the reefs which are approximately 1.6 km from the shoreline. The seafloor slopes gently at an average of 2 percent from the shoreline out to the reefs, with depths of 5 to 6 meters between the reefs and the shoreline.

5.1.8 Hydrodynamics

5.1.8.1 Current Drogue Survey

Methodology

In order to facilitate the development of the hydrodynamic model for the area and to fully understand the relationship amongst tides, winds and currents, current speed and direction information was required. This information was acquired by carrying out drogue tracking missions. A two-day drogue tracking programme was executed by the CEAC team on August 21st, 2014 and August 22nd, 2014. Four (4) drogues were placed within the Old Harbour Bay; two (2) surface and two (2) sub-surface drogues (with sail depths ranging from 2 to 4 metres) were placed near shore and further offshore. The drogues were tracked during two separate sessions over the two days, one in the morning and the other in the evening, in order to capture the rising and falling tides on each day.

The GPS and drogue log sheet results from the drogue tracking missions were reduced and incorporated in a database. The data was then analysed in order to determine current speed and directions, and current speed vectors were produced for the rising and falling tides.

Plate 5-1 Drogues during the tracking mission in Old Harbour Bay

Winds during Drogue Tracking Session

It was necessary to collect wind data as well, specifically wind speed and direction on the days when drogues were done. This parameter is vital in calibrating the hydrodynamic model before it can be used to predict the circulation patterns in the bay.

NOAA BUOY DATA

The online database of National Oceanic and Atmospheric Administration (NOAA) was consulted for the deep water/offshore winds which occurred during the drogue tracking sessions on August 21st and 22nd. The data obtained shows that the wind speeds varied between 7 to 11 m/s during the day on the 21st and 4 to 9 m/s on the 22nd. The wind directions changed frequently on the 21st while they were fairly stable between 0 to 90 degrees on the 22nd.

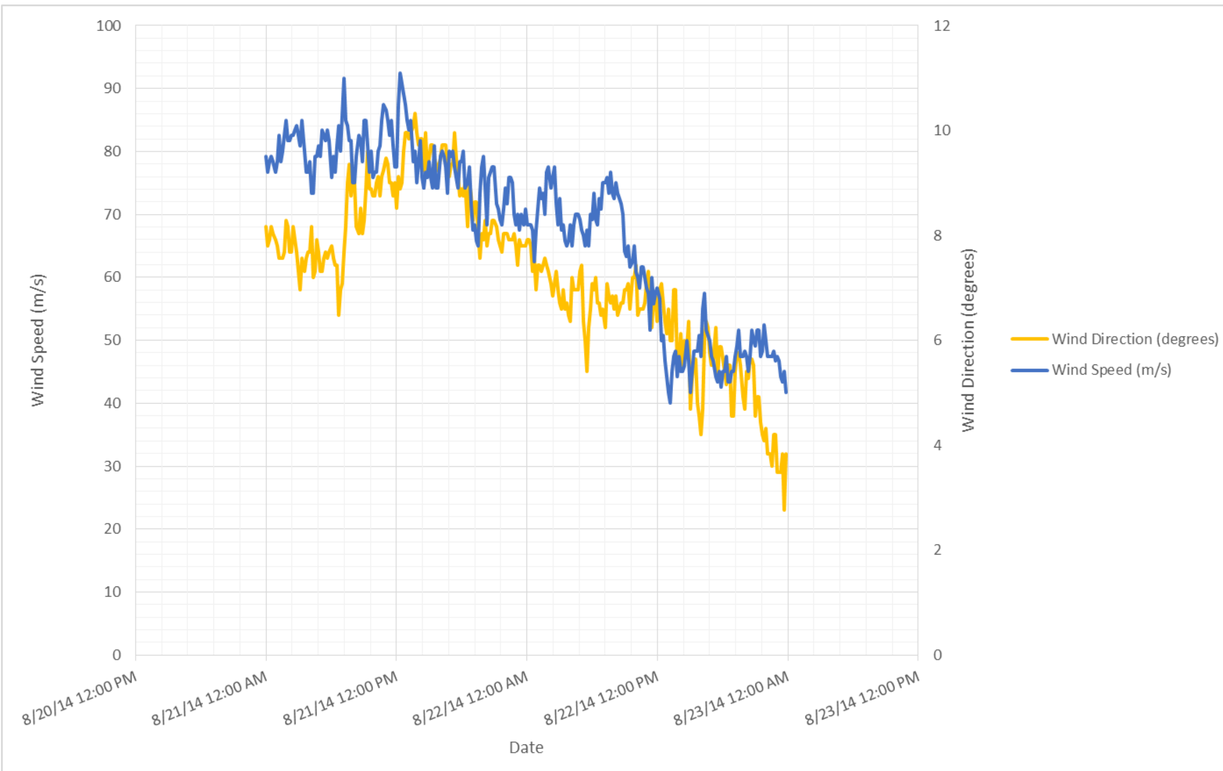


Figure 5-17 Variation of the wind speeds and directions on the measured by the NOAA Buoy to the SW of Jamaica between August 21st and 22nd 2014

WIND SUMMARY

The average wind speeds and directions during the drogue tracking exercises are seen in Table 5-3 below. The two wind stations have shown marked differences in the wind speeds and directions recorded. The onshore met station whilst being closer to the site is less likely to have captured the wind speed that was experienced on the sea. This is due to the fact that the wind speeds are normally changed at the coast as a result of the change in surface friction characteristics. The directions however are normally correct. These factors were taken into consideration when calibrating the hydrodynamic model.

Table 5-3 Average wind speeds and directions during drogue tracking sessions

	Time			Wind (Onshore)		Wind (NOAA Buoy)	
				Avg. Dir	Avg. speed (m/s)	Avg. Dir	Avg. speed (m/s)
Session 1	11:00	-	12:00	SE	8.7	NE	0.1
Session 2	12:30	-	14:00	SE	10.0	E	0.1
Session 3	07:30	-	10:20	NE	1.9	NE	0.08
Session 4	13:00	-	15:00	NE	1.5	NE	0.05

January 2014 (Onsite Anemometer)

A temporary weather station maintained by environmental consultants, CL Environmental Ltd, was located north of the JEP barges on the JPS property. Wind readings were obtained for the days of the drogue tracking missions, the data was analysed, and graphs plotted. From Figure 5-18 and Figure 5-19 we see distinctive peaks of wind speed and wind direction respectively. The general trend shows that the peak wind speeds occur after 12 pm each day. The maximum wind speed observed during the period was 14.2 m/s. These high wind speeds tend to blow to a generally westerly direction (blowing from east to west).

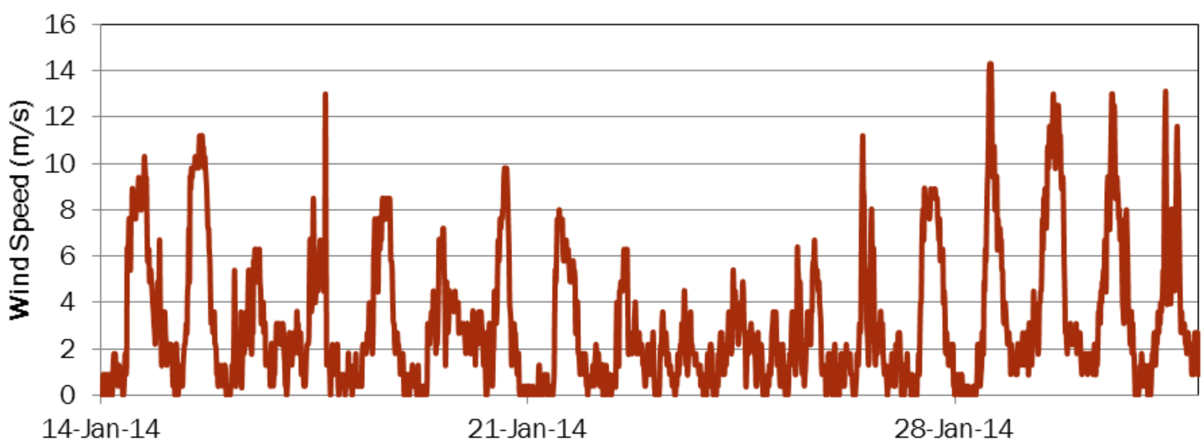


Figure 5-18 Graph showing wind speed from JPS weather station from January 14,2014 to January 31,2014

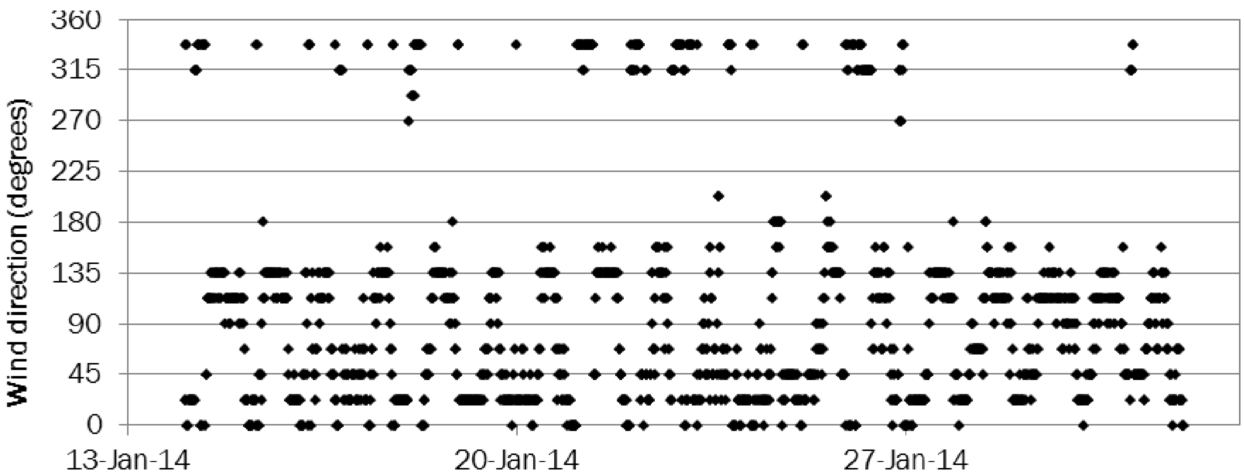


Figure 5-19 Graph showing wind direction from JPS weather station from January 14, 2014 to January 31, 2014

Drogue Tracking Results

FALLING TIDE

Sessions 1 and 3 were conducted during falling tide conditions. The average wind speed recorded for session 1 was 10.8 m/s and that for session 3 was 2.8m/s. The average wind directions were SE for both days.

Near Shore

During sessions 1 and 3, the surface drogues near shore were tracked moving in north westerly and south westerly directions, at speeds of 9.7 cm/s and 6.7 cm/s respectively. The sub-surface drogues deployed near shore travelled in a north westerly and westerly direction at average speeds of 6.5 cm/s and 3.1 cm/s for sessions 1 and 3 respectively. The directions of the drogues for session 1 correspond to the wind directions measured by the onshore wind station while the results for session 3 did not. This difference indicates the main driver of nearshore currents were not due to winds.

Deep Off Shore

The offshore drogues were only tracked in session 3. The surface drogues were observed moving in a westerly direction at speeds of 10.5 cm/s. The sub-surface drogues travelled south westerly with average speeds of 7.1 cm/s, indicating that they were current driven. The current speeds were greater than the wind speeds indicating winds are not the only drivers of currents further offshore.

Table 5-4 Summarized drogue tracking session #1 - Falling tide conducted on August 21st, 2014

Drogue #	Time	Depth of Sail	Notes	Easting	Northing	Location	Distance Travelled (m)	Time (s)	Speed (cm/s)	Average Speed (cm/s)	Average Direction of Motion	
6B	11:30	SURFACE	deploy	276500	1979666	ADCP1	141.174	1449	9.743	9.743	304.028	North Westerly
6B	11:54		remove	276383	1979745							
5	11:30	2m	deploy	276485	1979662		104.809	1374	7.628	6.533	298.312	North Westerly
5	11:53		measurement	276394	1979714		26.249	521	5.038			
5	12:02		measurement	276369	1979722		46.043	664	6.934			
5	12:13		remove	276331	1979748							

Table 5-5 Summarized drogue tracking session #3 - Falling tide conducted on August 22nd, 2014

Drogue #	Time	Depth of Sail	Notes	Easting	Northing	Location	Distance Travelled (m)	Time (s)	Speed (cm/s)	Average Speed (cm/s)	Average Direction of Motion	
6B	7:57	SURFACE	deploy	276623	1979621	ADCP1	48.415	1061	4.563	6.647	224.401	South Westerly
6B	8:15		measurement	276593	1979583		103.175	1759	5.866			
6B	8:44		measurement	276536	1979497		68.819	1477	4.659			
6B	9:09		remove	276480	1979457							
6B	9:15		deploy	276520	1979652		109.124	1412	7.728			
6B	9:38		measurement	276448	1979570		236.764	2272	10.421			
6B	10:16		remove	276264	1979421							
5	7:57	2m	deploy	276621	1979624		33.242	1050	3.166	3.135	249.938	Westerly
5	8:14		measurement	276597	1979601		44.204	1694	2.609			
5	8:43		measurement	276562	1979574		68.622	1665	4.121			
5	9:10		remove	276497	1979552							
5	9:15		deploy	276506	1979668		37.054	1342	2.761			
5	9:37		measurement	276469	1979670		73.110	2424	3.016			
5	10:18		remove	276396	1979666							
11	8:05	SURFACE	deploy	276775	1978204	ADCP2	162.807	1692	9.622	10.476	247.866	Westerly
11	8:33		measurement	276640	1978113		177.260	1647	10.763			
11	9:01		measurement	276485	1978027		179.335	1436	12.489			
11	9:25		remove	276325	1977946							

Drogue #	Time	Depth of Sail	Notes	Easting	Northing	Location	Distance Travelled (m)	Time (s)	Speed (cm/s)	Average Speed (cm/s)	Average Direction of Motion	
11	9:27		deploy	276675	1977967		137.004	1592	8.606			
11	9:54		measurement	276538	1977968		106.607	978	10.900			
11	10:10		remove	276436	1977937							
8	8:05	4m	deploy	276770	1978181		129.850	1721	7.545	7.050	243.928	South Westerly
8	8:34		measurement	276660	1978112		150.233	1650	9.105			
8	9:02		measurement	276531	1978035		115.109	1438	8.005			
8	9:26		remove	276422	1977998							
8	9:28		deploy	276694	1977958		80.000	1612	4.963			
8	9:54		measurement	276614	1977958		48.104	854	5.633			
8	10:09		remove	276569	1977941							

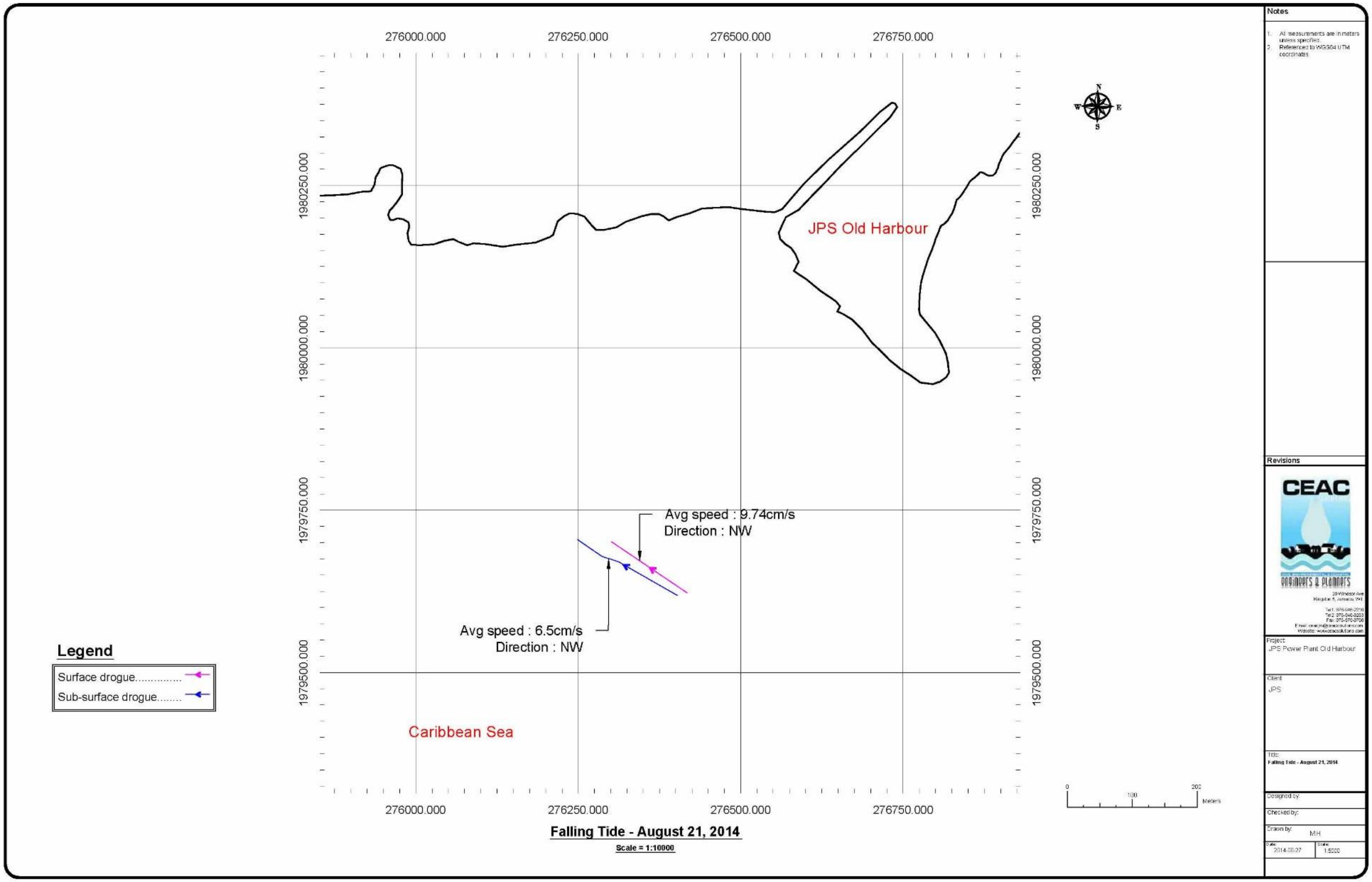


Figure 5-20 Approximate path and direction of the drogues during drogue session #1 Surface drogues are in pink, while sub-surface drogues are in blue.

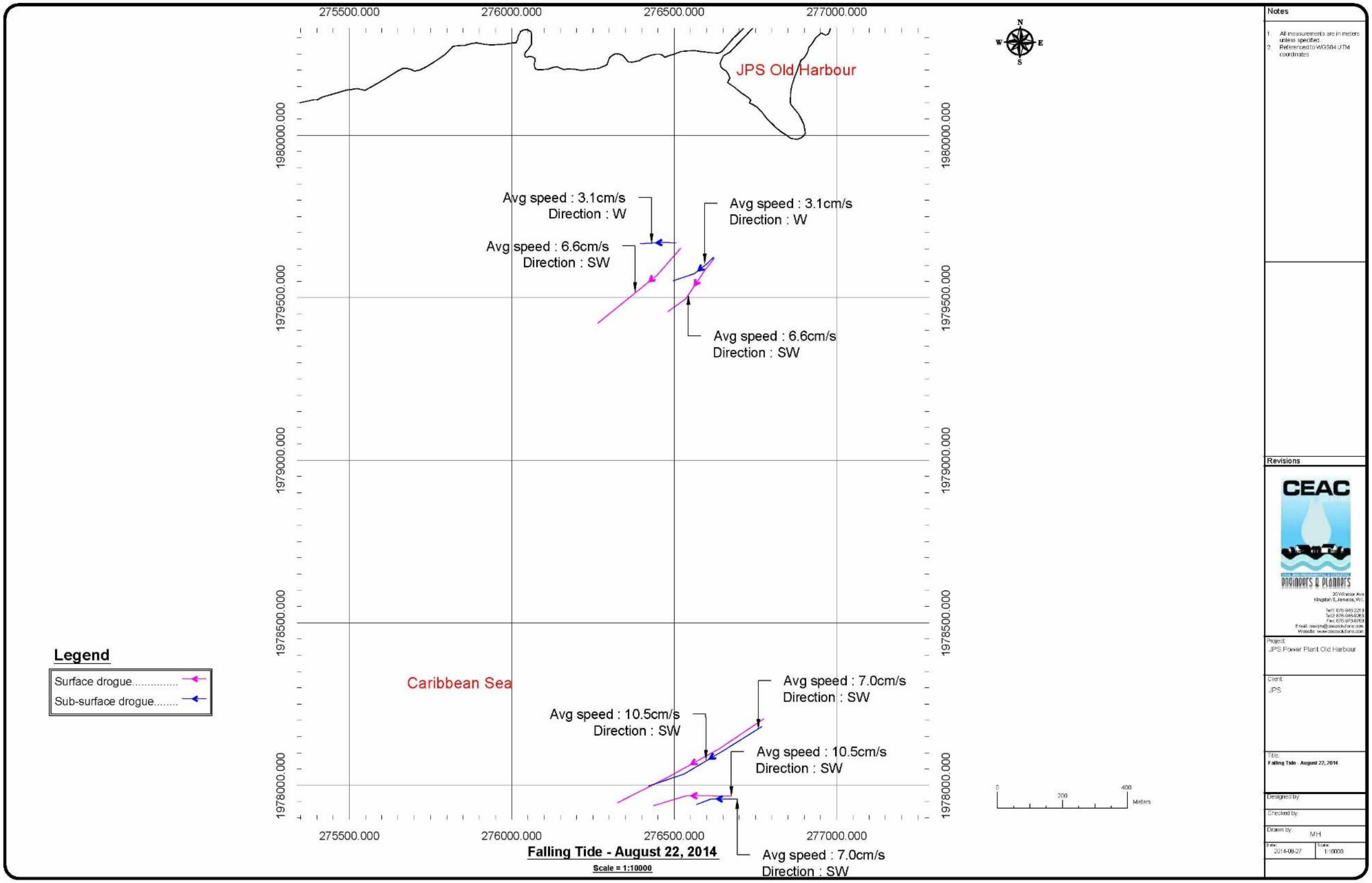


Figure 5-21 Approximate path and direction of the drogues during Drogue session #3.

RISING TIDE

Sessions 2 and 4 were conducted during rising tide conditions. The average wind speed recorded for session 2 was 10.8 m/s and that for session 4 was 3.9 m/s. The average wind directions were SE for session 2 and SE for session 4.

Near Shore

During session 2, the surface drogue near shore was observed moving in a north westerly direction at a velocity of 9.7 cm/s. The sub-surface drogue travelled in the same direction at an average speed of 8.4 cm/s. The movement of the drogues indicate the nearshore currents appear to be mostly wind driven.

During session 4, the surface drogue near shore was observed moving in a north westerly direction at a velocity of 7.5 cm/s. The sub-surface drogue travelled in the same direction at an average speed of 4.2 cm/s. The nearshore currents appear to be mostly wind driven.

The directions of the nearshore drogues correspond to the wind directions measured by the onshore both the onshore and offshore wind stations, indicating the nearshore currents are predominantly wind driven.

Deep Off Shore

The surface drogues placed outside the reefs in the bay were observed to be moving in a north westerly direction at a speed of 10.7 cm/s during this session. The sub-surface drogue (4m) travelled north westerly at an average velocity of 10.4 cm/s.

The directions of the offshore drogues correspond to the wind directions measured by the onshore wind station, indicating the nearshore currents are predominantly wind driven.

Table 5-6 Summarized drogue tracking session # 2 – Rising tide conducted on August 21st, 2014

Drogue #	Time	Depth of Sail	Notes	Easting	Northing	Location	Distance Travelled (m)	Time (s)	Speed (cm/s)	Average Speed (cm/s)	Average Direction of Motion	
6B	12:17	SURFACE	deploy	276516	1979656	ADCP1	92.650	1168	7.932	9.678	297.852	North Westerly
6B	12:37		measurement	276438	1979706		175.514	1771	9.910			
6B	13:06		measurement	276285	1979792		138.293	1607	8.606			
6B	13:33		remove	276159	1979849							
6B	13:36		deploy	276599	1979611		127.094	1202	10.574			
6B	13:56		measurement	276491	1979678		58.310	513	11.366			
6B	14:04		remove	276437	1979700							
5	12:17	2m	deploy	276526	1979658		93.941	1158	8.112	8.408	294.744	North Westerly
5	12:37		measurement	276443	1979702		141.873	1723	8.234			
5	13:06		measurement	276311	1979754		130.920	1609	8.137			
5	13:32		remove	276187	1979796							
5	13:36		deploy	276596	1979607		113.159	1124	10.068			
5	13:55		measurement	276502	1979670		45.541	608	7.490			
5	14:05		remove	276459	1979685							

Table 5-7 Summarized drogue tracking session #4 - Falling tide conducted on August 22nd, 2014

Drogue #	Time	Depth of Sail	Notes	Easting	Northing	Location	Distance Travelled (m)	Time (s)	Speed (cm/s)	Average Speed (cm/s)	Average Direction of Motion	
11	14:08	SURFACE	deploy	276508	1979666	ADCP1	84.723	1072	7.903	7.531	347.406	North Westerly
11	14:25		measurement	276491	1979749		69.231	758	9.133			
11	14:38		measurement	276478	1979817		75.710	905	8.366			
11	14:53		measurement	276462	1979891		9.487	201	4.720			
11	14:57		remove	276459	1979900							
5	14:08	2m	deploy	276503	1979675		56.921	1017	5.597	4.274	345.742	North Westerly
5	14:25		measurement	276485	1979729		38.833	815	4.765			
5	14:39		measurement	276477	1979767		45.398	908	5.000			
5	14:54		measurement	276471	1979812		2.236	129	1.733			
5	14:56		remove	276470	1979814							
6B	13:04	SURFACE	deploy	276842	1977985	ADCP2	115.884	745	15.555	10.713	328.831	North Westerly
6B	13:17		measurement	276787	1978087		123.004	912	13.487			

Drogue #	Time	Depth of Sail	Notes	Easting	Northing	Location	Distance Travelled (m)	Time (s)	Speed (cm/s)	Average Speed (cm/s)	Average Direction of Motion	
6B	13:32		measurement	276730	1978196		56.727	848	6.690			
6B	13:46		measurement	276693	1978239		74.632	1048	7.121			
6B	14:03		remove	276650	1978300							
8	13:05		deploy	276855	1977984		46.228	737	6.272			
8	13:17		measurement	276826	1978020		58.694	933	6.291			
8	13:33	4m	measurement	276784	1978061		61.522	840	7.324	10.379	326.359	North Westerly
8	13:47		measurement	276741	1978105		215.188	995	21.627			
8	14:03		remove	276650	1978300							

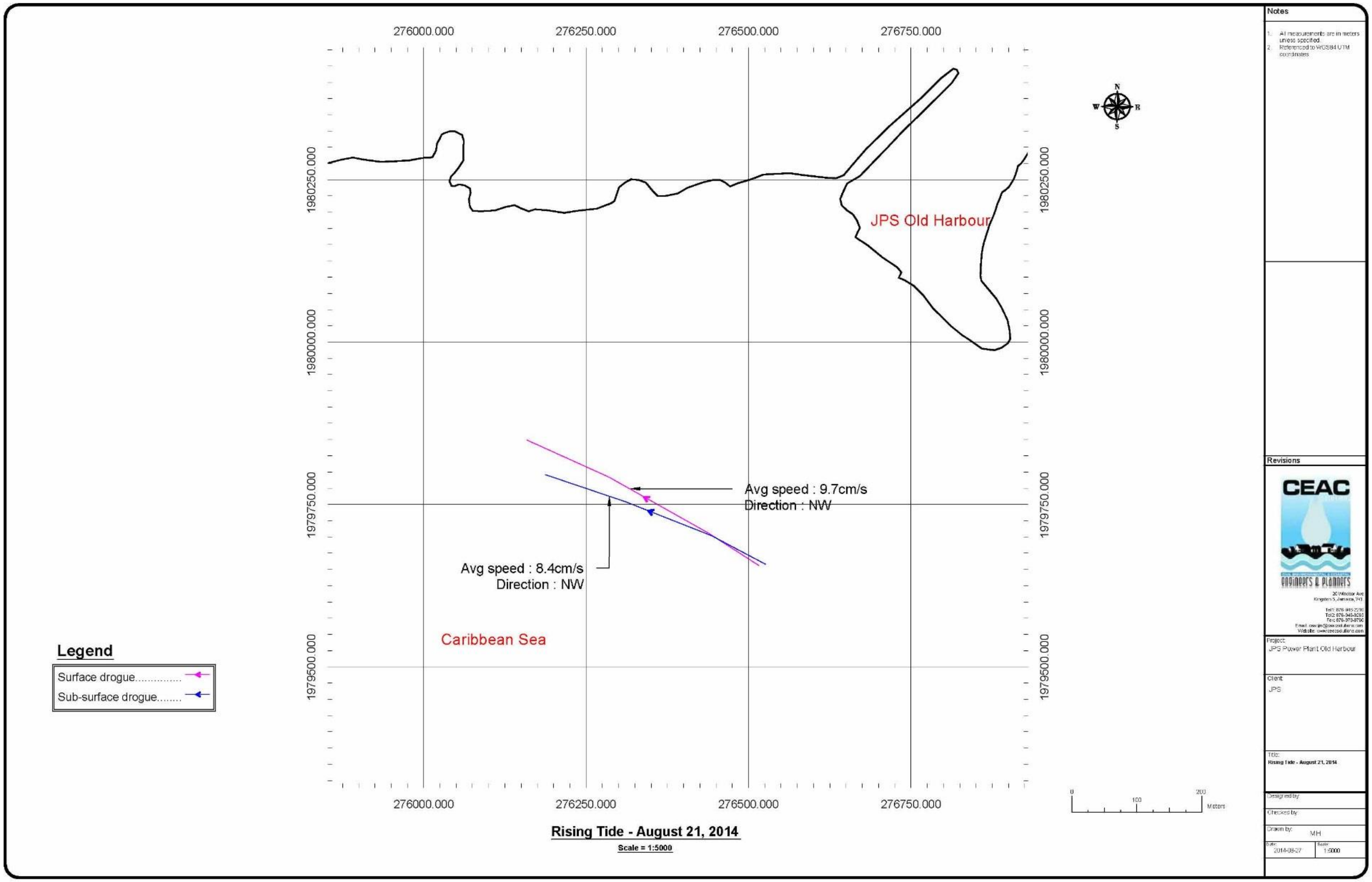


Figure 5-22 Approximate path and direction of the drogues during drogue session #2. Surface drogues are in pink, while sub-surface drogues are in blue.

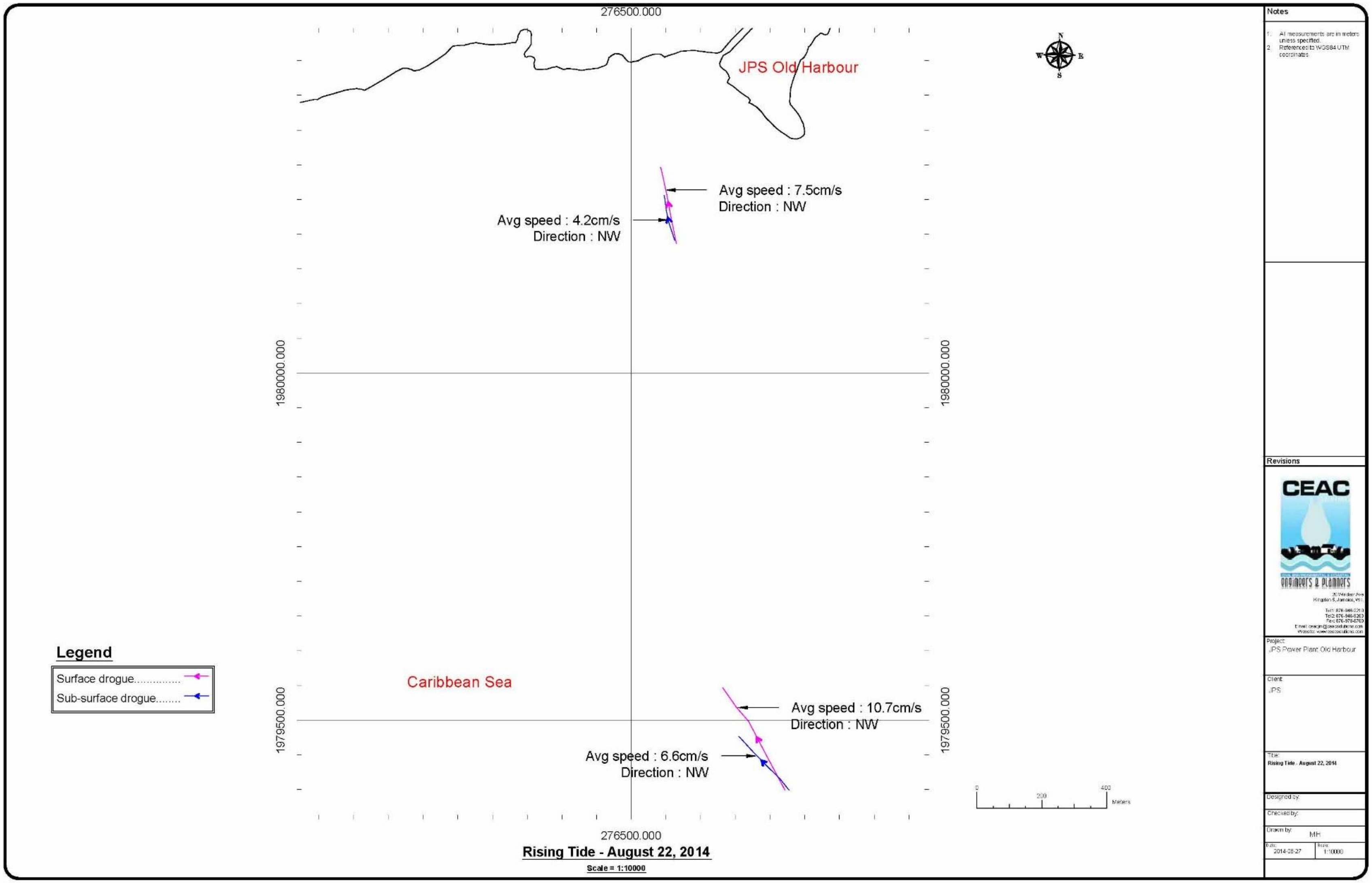


Figure 5-23 Approximate path and direction of the drogues during drogue session #4 Surface drogues are in pink, while sub-surface drogues are in blue.

Summary

The two days of drogue tracking involved four (4) sessions total; two (2) falling tides and two (2) rising tide. The currents in this area appear to be mostly wind driven during the rising and falling tides session. In regards to nearshore, the current speeds varied from 6.6 cm/s to 9.7 cm/s and 3.1 cm/s to 6.5 cm/s for the surface and sub-surface drogues respectively for the falling tides. The current speeds varied from 7.5 cm/s to 9.7 cm/s and 4.3 cm/s to 8.4 cm/s for the surface and sub-surface currents during the rising tides.

Further offshore, the current speeds averaged 10.5 cm/s and 7.1 cm/s for the surface and sub-surface drogues respectively for the falling tides. The speeds during the rising tide averaged 10.7 cm/s and 10.4 cm/s for the surface and sub-surface currents.

Knowledge of the prevailing wind conditions allowed for the determination of the effect of wind speed and direction. The current speeds are generally higher for the rising tides than for the falling tide session. It is evident that the deeper waters in the bay area tidally dominated (as expected) and the shallower waters are wind dominated.

5.1.8.2 Moored ADCP Current Survey

Methodology

An ADCP determines current speed and direction by detecting the Doppler shift of reflected acoustic signals which bounce off particles moving with the water. The ADCP separates depth cells or bins in the water column from which it measured the current speed and direction. Two (2) ADCP devices were deployed (near-shore and off-shore) over a five (5) weeks period from July 14th to August 27th, 2014. Unfortunately, due to interference with the recording instrument, current data for the July 27th to August 8th was lost.

Waves and Tides

Tidal information was important in order to build a numerical hydrodynamic model to simulate the currents and water level fluctuations in the Bay. Tides were recorded at two (2) locations – inside and outside the reef.

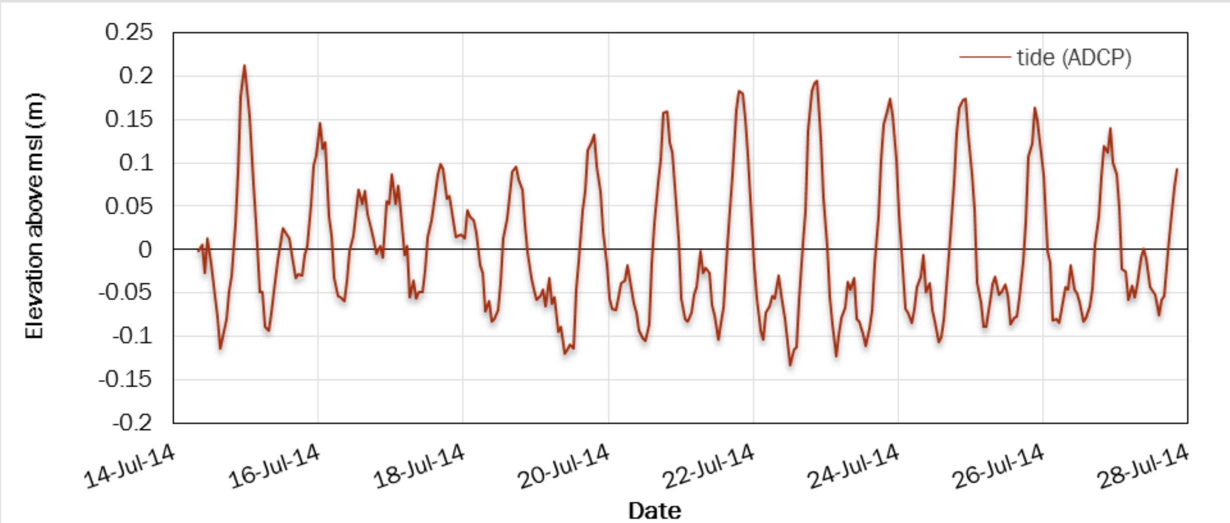


Figure 5-24 Tide signal recorded using the ADCP at location #1 during the period 14th of July to 27th of July, 2014 for project area – outside of reef

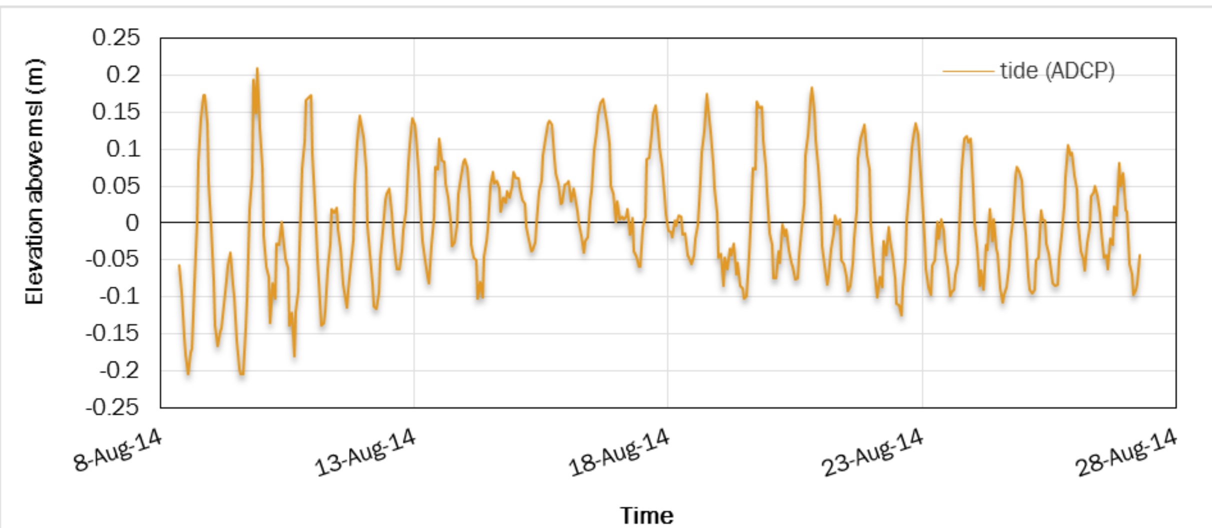


Figure 5-25 Tide signal recorded using the ADCP at location #2 for the period 8th of August to 27th of August, 2014 for project area – outside of reef

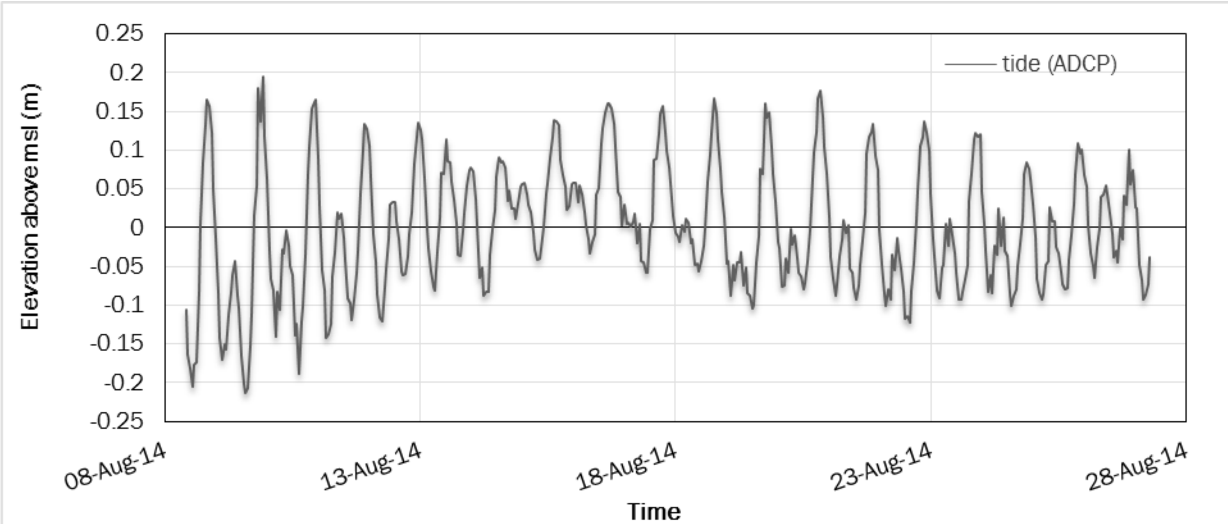


Figure 5-26 Tidal signal recorded during the ADCP deployment #3 for the period 8th of August to 27th of August, 2014 for project area – inside of reef

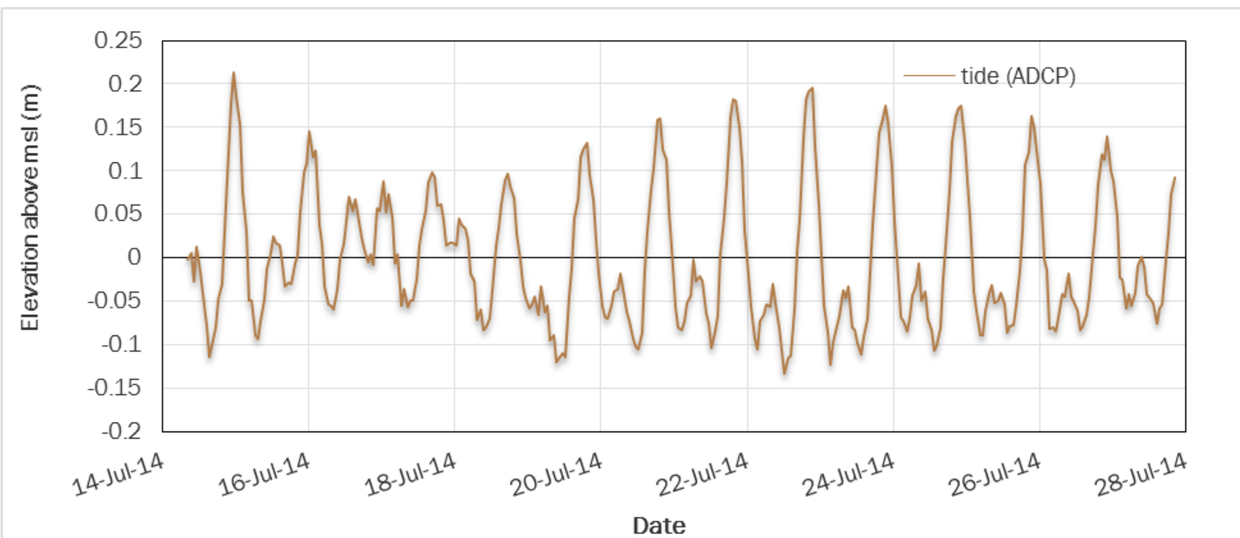


Figure 5-27 Tidal signal recorded during the ADCP deployment #3 for the period 27th of August to 15th of September, 2014 for project area – inside of reef

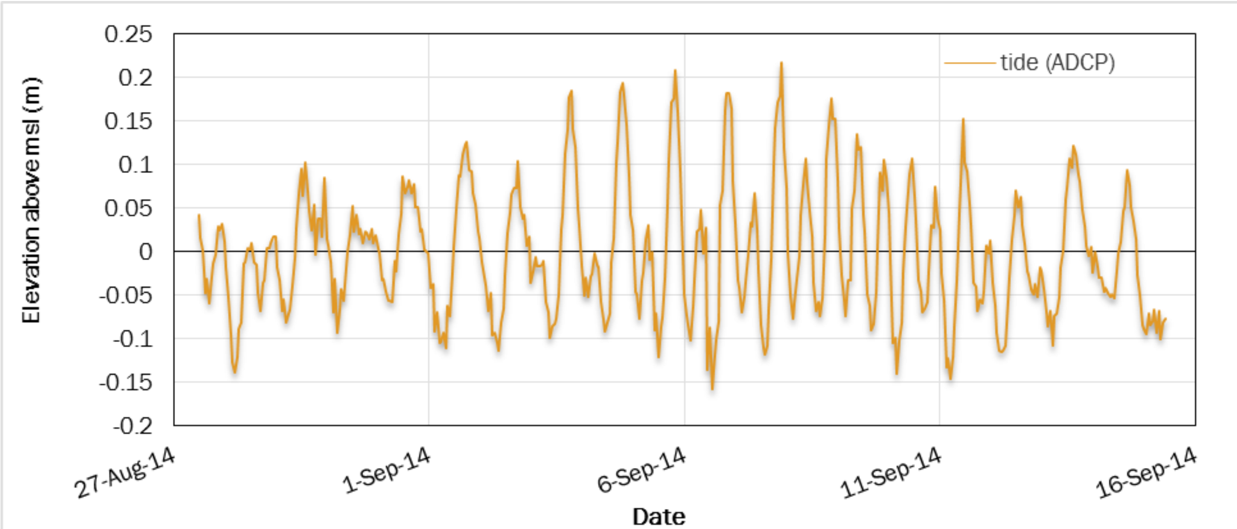


Figure 5-28 Tidal signal recorded during the ADCP deployment #5 for the period 27th of August to 15th of September, 2014 for project area – outside of reef

5.1.8.3 Tidal Harmonics

Tidal variations can be represented by summing a series of harmonic terms. Each harmonic term has the cosine form:

$$H_n \cos(\sigma_n t - g_n)$$

Where:

H_n is amplitude in metres,
g_n is a phase lag in degrees,
σ_n is an angular speed and t is time

Tidal harmonics is essentially the blending of the different cosine curves for each harmonic constituent of the tide until it closely matches that obtained from the recorded tidal signature. This is useful for predicting the tides for future times when there is no data available. The amplitudes of the seven most significant harmonic constituents were determined from the raw tide data by utilizing the least squares method. In this method, a set of cosine terms is used as a model. The blended curve is made to fit the data recorded by the ADCP by choosing a combination of R and N that causes the sum of the squared differences between observed and model-predicted tides to be as small as possible. The resulting amplitudes and phase lag are outlined below in Table 5-8 through Table 5-12, and it allowed reasonable tide predictions for future times when running FEM and wave models. It is evident that the K1 consistent, that is, the diurnal tide, is dominant. Both semi-diurnal tidal constituents were detected.

Table 5-8 Tidal constituents obtained from the harmonic analysis of the raw ADCP data collected July 14th, 2013 to July 27th, 2014 (outside reef)

Tide Constituent	M2	S2	O1	K1	N2	P1	L2
Speed	12.42	12	25.82	23.93	12.66	24.07	12.19
Phase lag	-1.93	-0.39	0.77	9.67	-1.73	0.87	-2.55
Amplitude	0.049	0.041	0.050	0.164	0.029	0.107	0.010

Table 5-9 Tidal constituents obtained from the harmonic analysis of the raw ADCP data collected August 8th, 2013 to August 27th, 2014 (outside reef)

Tide Constituent	M2	S2	O1	K1	N2	P1	L2
Speed	12.42	12	25.82	23.93	12.66	24.07	12.19
Phase lag	-5.82	-0.12	-3.84	10.71	0.74	2.01	-4.31
Amplitude	0.076	0.022	0.050	0.148	0.023	0.138	0.019

Table 5-10 Tidal constituents obtained from the harmonic analysis of the raw ADCP data collected August 8th, 2013 to August 27th, 2014 (inside reef)

Tide Constituent	M2	S2	O1	K1	N2	P1	L2
Speed	12.42	12	25.82	23.93	12.66	24.07	12.19
Phase lag	-5.28	0.36	2.70	10.95	1.17	-3.99	-3.75
Amplitude	0.078	0.019	0.050	0.135	0.024	0.123	0.021

Table 5-11 Tidal constituents obtained from the harmonic analysis of the raw ADCP data collected August 27th, 2013 to September 15th, 2014 (inside reef)

Tide Constituent	M2	S2	O1	K1	N2	P1	L2
Speed	12.42	12	25.82	23.93	12.66	24.07	12.19
Phase lag	-0.73	1.26	1.18	10.70	-3.59	1.83	-0.46
Amplitude	0.058	0.050	0.050	0.098	0.032	0.049	0.032

Table 5-12 Tidal constituents obtained from the harmonic analysis of the raw ADCP data collected August 27th, 2013 to September 15th, 2014 (outside reef)

Tide Constituent	M2	S2	O1	K1	N2	P1	L2
Speed	12.42	12.00	25.82	23.93	12.66	24.07	12.19
Phase lag	-6.42	1.50	-5.02	10.71	3.22	1.67	-0.36
Amplitude	0.056	0.046	0.050	0.091	0.030	0.036	0.021

Figure 5-29 through Figure 5-33 shows a comparison plot of the predicted versus actual tides recorded. These tides were found to be comparable to the British admiralty tidal Predictions for Port Esquivel.

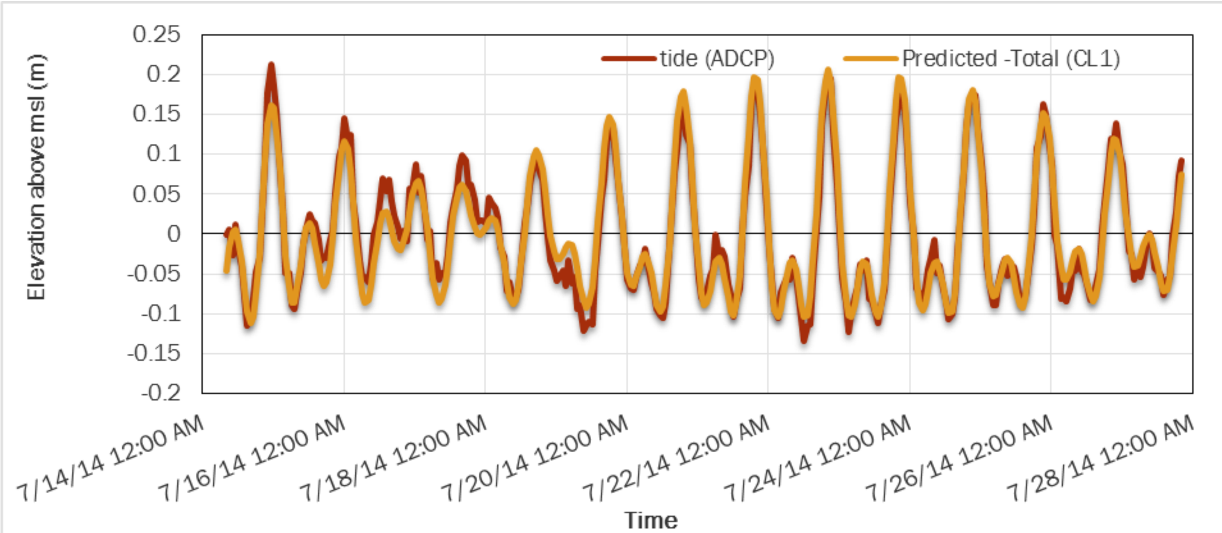


Figure 5-29 Measured and predicted tidal signature for the project area for the period July 14th, 2013 to July 27th, 2014 (outside reef)

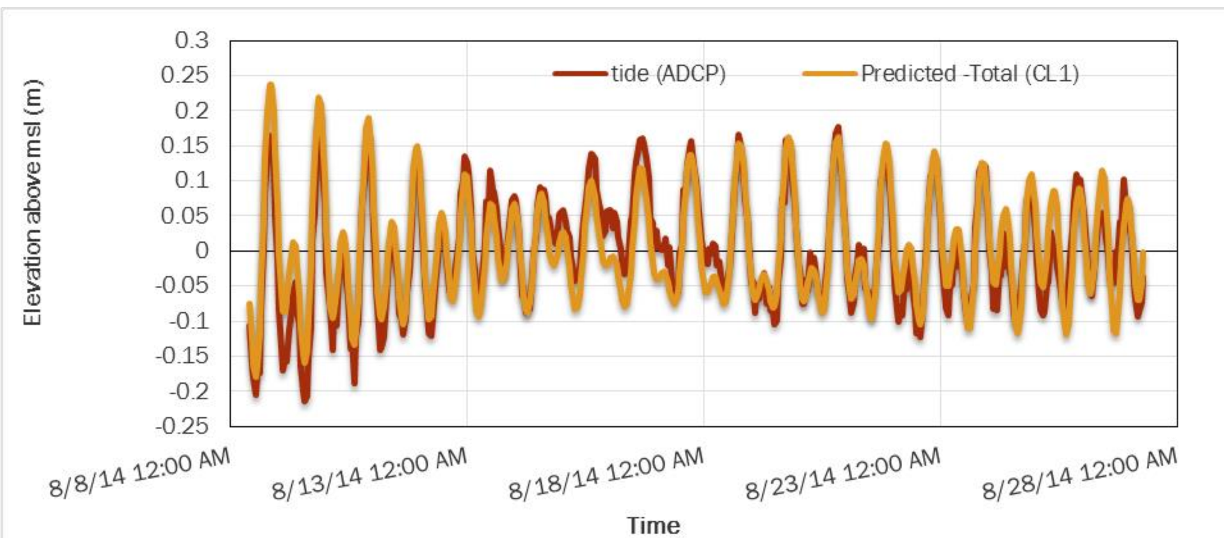


Figure 5-30 Measured and predicted tidal signature for the project area for the period August 8th, 2013 to August 27th, 2014 (outside reef)

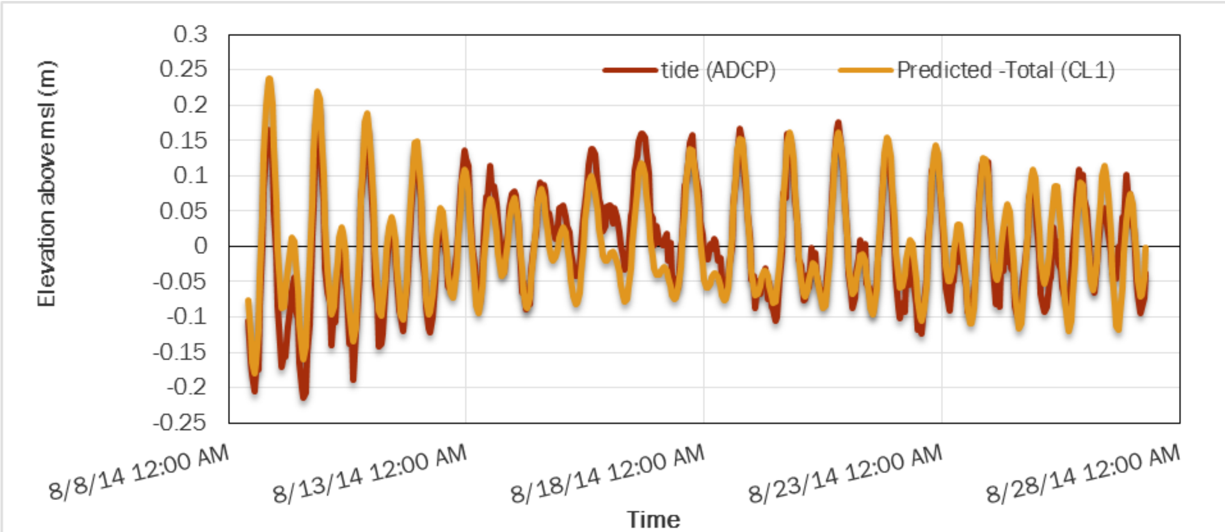


Figure 5-31 Measured and predicted tidal signature for the project area for the period August 8th, 2013 to August 27th, 2014 (inside reef)

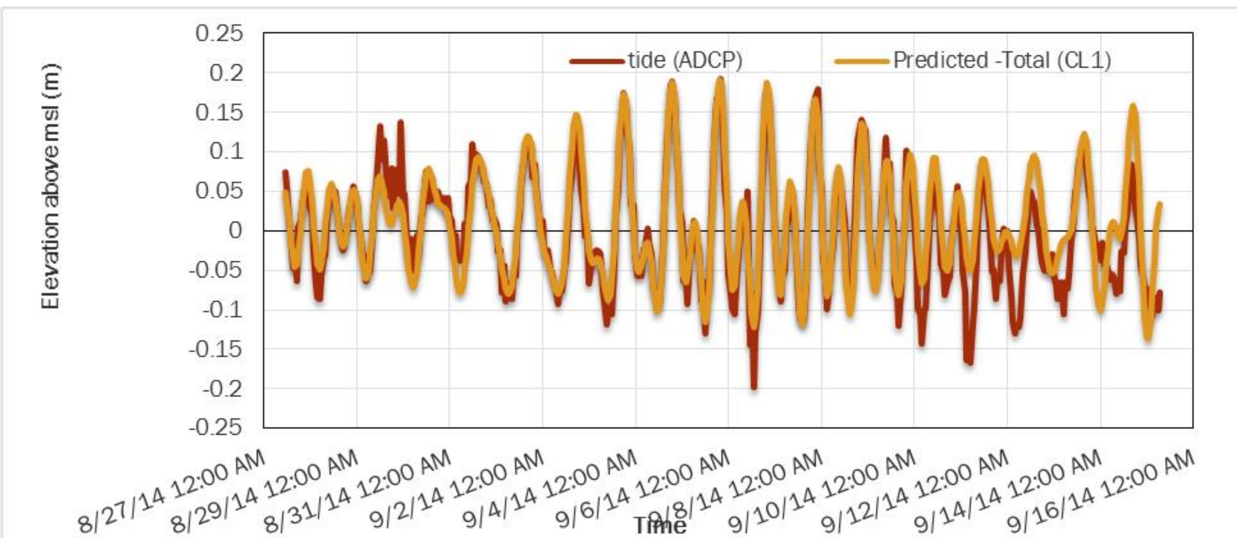


Figure 5-32 Measured and predicted tidal signature for the project area for the period August 27th, 2013 to September 15th, 2014 (inside reef)

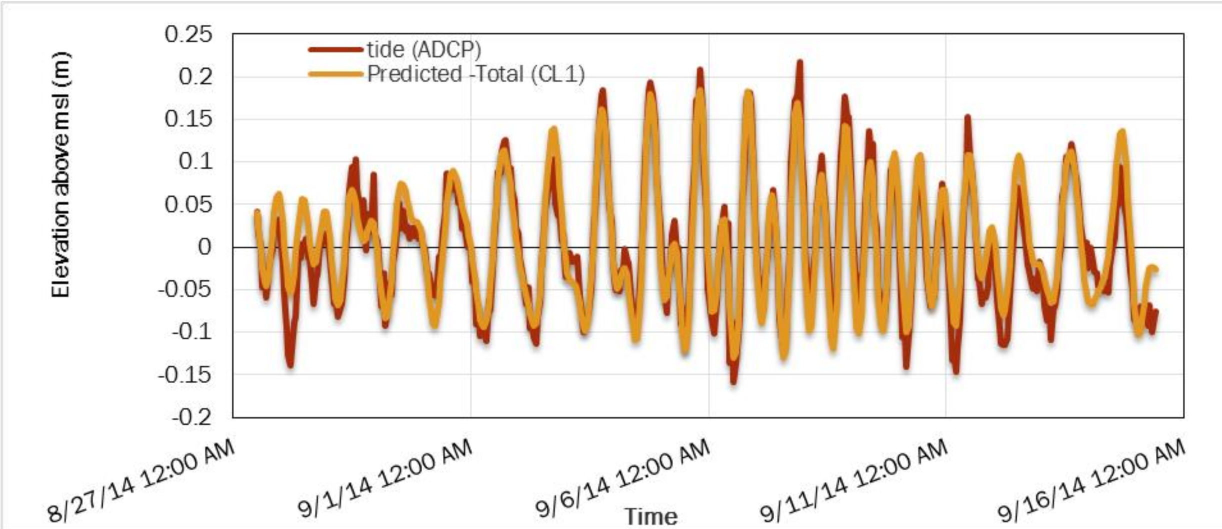


Figure 5-33 Measured and predicted tidal signature for the project area for the period August 27th, 2013 to September 15th, 2014 (outside the reef)

5.1.8.4 Historical Wind Data

Historical and current wind data for the project area was obtained from two main sources:

- Offshore measurements - NOAA climate service floating stations (buoys)
- Onshore measurements – Weather station on JPS site and Norman Manley International Airport (NMIA) Meteorological Station.

NOAA Climate Service

A node was chosen in front of the bay and the wind and wave data corresponding to that node obtained. The node used was:

- Zone: 18
- Easting: 286049
- Northing: 1948299

The data spanned the years of 1999 to 2007 recorded on a daily basis at three hour intervals. The data is shown in a wind rose in Figure 5-34. The data was analysed in terms of percentage occurrence of various wind speed and direction combinations in order to characterize the wind climate for the site. The analysis revealed that the winds have a direction of NE to ESE direction with wind speeds of 20 m/s or less approximately. Southerly and Westerly wind directions were noted to occur but rarely. Overall the average wind speed and direction is between 6 to 8 m/s from the ENE to ESE.

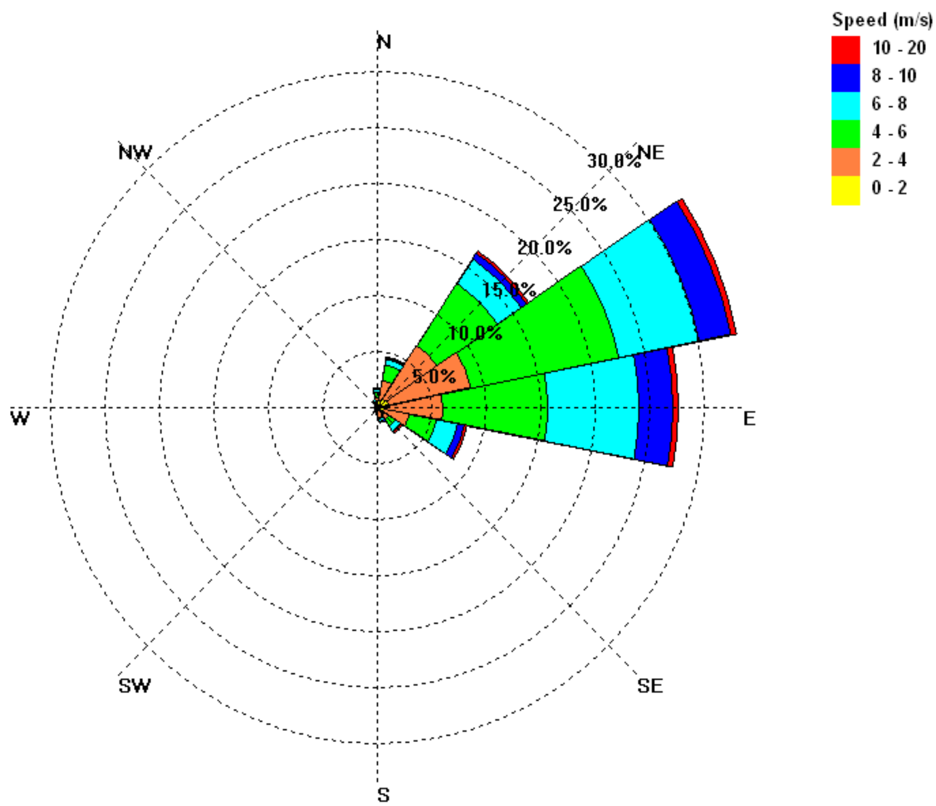


Figure 5-34 Wind Rose of NOAA Wind Data for 1999 - 2007

NMIA Meteorological Station

The data obtained from the NMIA Meteorological station spanned the years 2004 to 2009. Analysis of this data revealed that the winds were predominantly from the ENE to ESE directions approximately with winds of 6-8m/s over 20 percent of the time.

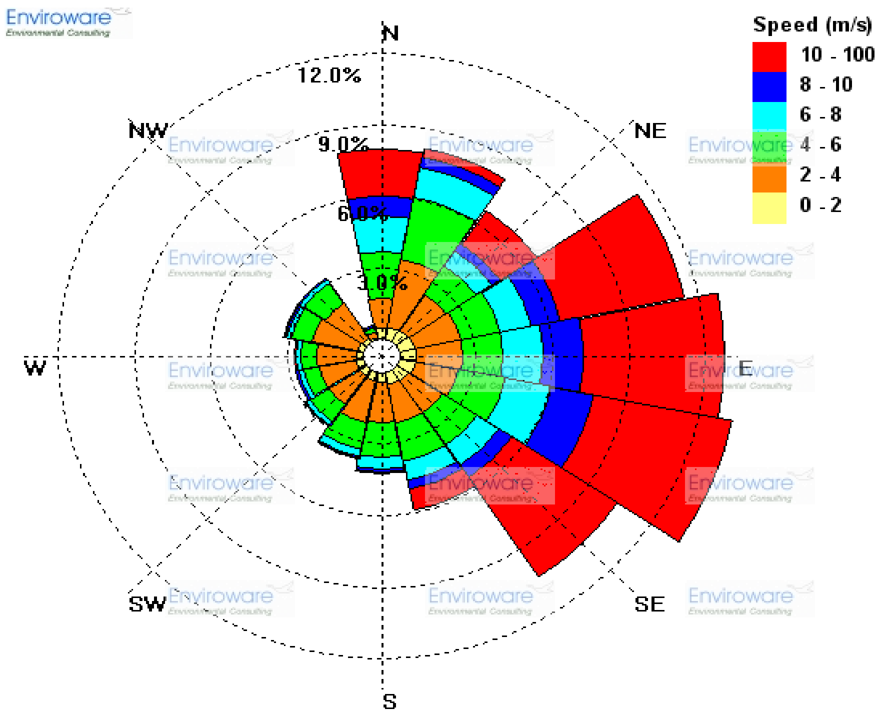


Figure 5-35 Wind Rose of Norman Manley International Airport wind data (2004-2009)

5.1.8.5 Hydrodynamic Model Development

Description of Model (RMA 10)

The model used to simulate the currents across the project area is known as the RMA 10 model developed in Australia. RMA-10 is a three-dimensional finite element model for stratified flow by King (1993). The primary features of RMA-10 are:

- The solution of the Navier-Stokes equations in three-dimensions;
- The use of the shallow-water and hydrostatic assumptions;
- Coupling of advection and diffusion of temperature, salinity and sediment to the hydrodynamics;
- The inclusion of turbulence in Reynolds stress form;
- Horizontal components of the non-linear terms are included;
- A capacity to include one-dimensional, depth-averaged, laterally-averaged and three-dimensional elements within a single mesh as appropriate;
- No-, partial- and full-slip conditions can be applied at both lateral boundaries;
- Partial or no-slip conditions can be applied at the bed;
- Depth-averaged elements can be made wet and dry during a simulation; and
- Vertical turbulence quantities are estimated by either a quadratic parameterisation of turbulent exchange or a Mellor-Yamada Level 2 turbulence sub-model.

Finite Element Mesh Development

The process of mesh developments entails the following steps:

- Input of bathymetric data for the wider area and in detail for the project area
- Specifying of nodes in the mesh
- Element construction in the mesh
- Interpolation for depth at nodes
- Specifying of open boundaries

The mesh was constructed for the existing configuration of the bay and it extends some 34 kilometres in a southerly direction. The outer deep water areas were gridded with large mesh which gradually decreases on approach to the project area (Figure 5-36) in order to strike a balance between accuracy and modelling speed. The eastern and western boundaries were used as the open boundaries on which tides were applied.

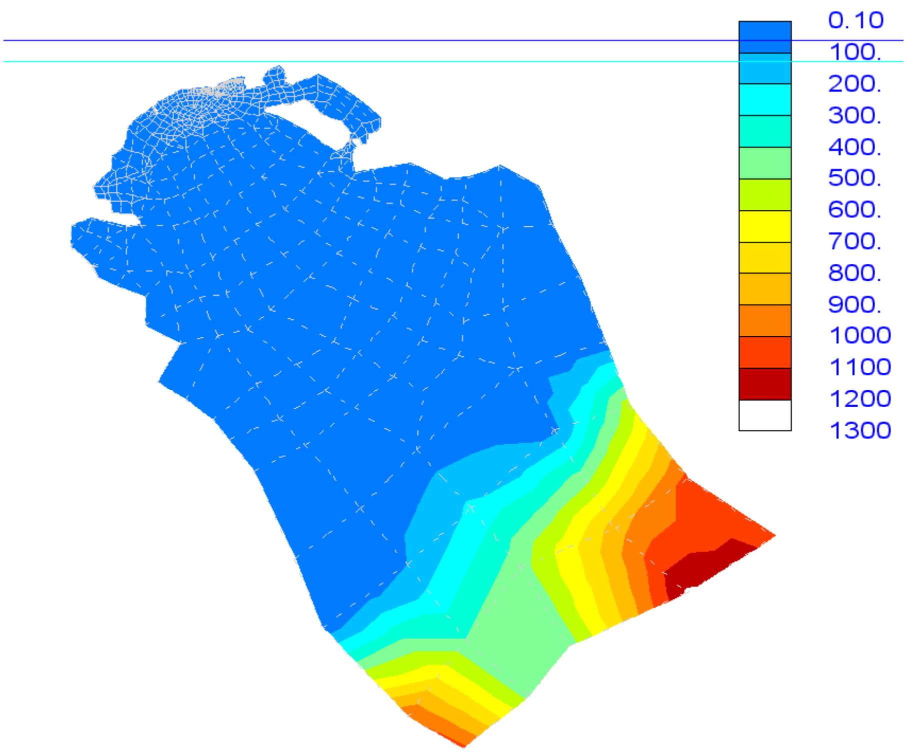


Figure 5-36. Overview of entire Finite Element Mesh (FEM) used for this project showing depth in metres

Model Calibration

The RMA10 model was calibrated and validated on both drogue and new ADCP dataset, by adjusting the tide elevation signal on the model boundaries, turbulence and viscosity parameters, until there was reasonable agreement between the observed currents and model predictions. See Figure 5-37, Figure 5-38 and Figure 5-39 for the predicted currents.

The predicted current speeds and directions, versus the data from the drogue tracking sessions are summarized in Table 5-13. The model predictions were within the data ranges for the observed occurrences in most instances. The calibration data essentially indicates that there is reasonable agreement between the model and the data.

Table 5-13 Calibration data for FEM for the existing bathymetric configuration based on drogue and wind data for the 2006/06/20

Session	Location	Observations		Model Predictions	
		Speed (cm/sec)	Direction	Speed	Direction
1	Nearshore	9.25	W	9-10	W
	Offshore	12.63	NW	8-9	W
	Deep offshore	14.72	W	6 - 9	SW - NW
2	Nearshore	13.34	W	8-9	W-SW
	Offshore	6.61	NW	6-8	W-SW
	Deep offshore	4.64	N	4-6	W-NW
3	Nearshore	9.52	W	9-11	W-SW
	Offshore	7.46	SW	6-8	SW
	Deep offshore	1.65	SW	9-10	SW

Validation

The model was validated using the ADCP X and Y components of the measured current speeds. The correlations were 0.66 and 0.74 for the Vx and Vy components respectively, when obvious outliers were not considered. The predicted current speeds and directions, versus the data from the ADCP deployments are summarized in Table 5-14 for the correlation coefficient and variance between the predicted and observed currents. The model predictions agreed with the observations in most instances and indicate that the model can be used with confidence.

Table 5-14 Correlation coefficient and bias between the observed (ADCP for October 15 2014 and November 15 2013) and predicted (hydrodynamic model) currents.

Direction (vector)	Vx (m/s)	Vy (m/s)
Correlation (model predictions VS ADCP readings)	0.66	0.74
Variance	0.7%	1.0%
Std. Deviation	0.08	0.10

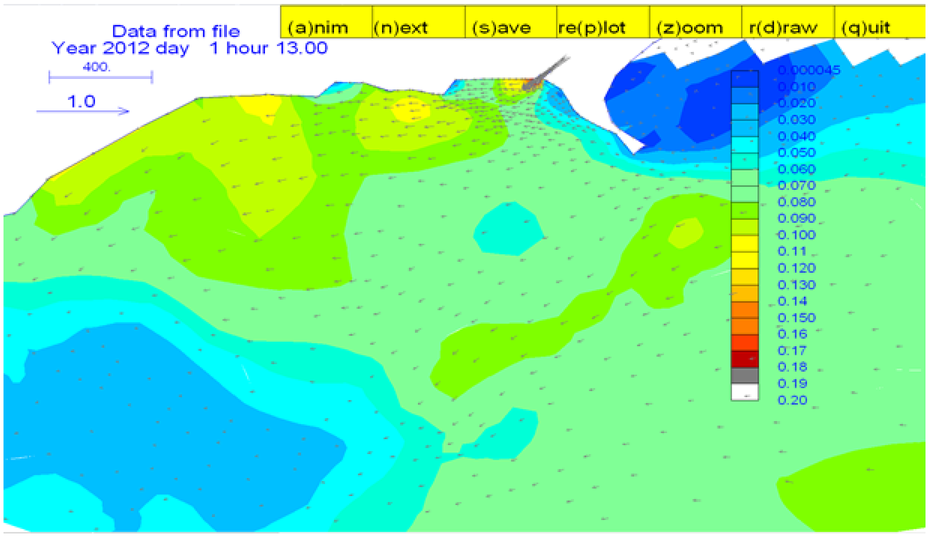


Figure 5-37 Calibration plot of currents (in m/s) for day one corresponding to drogue session 1

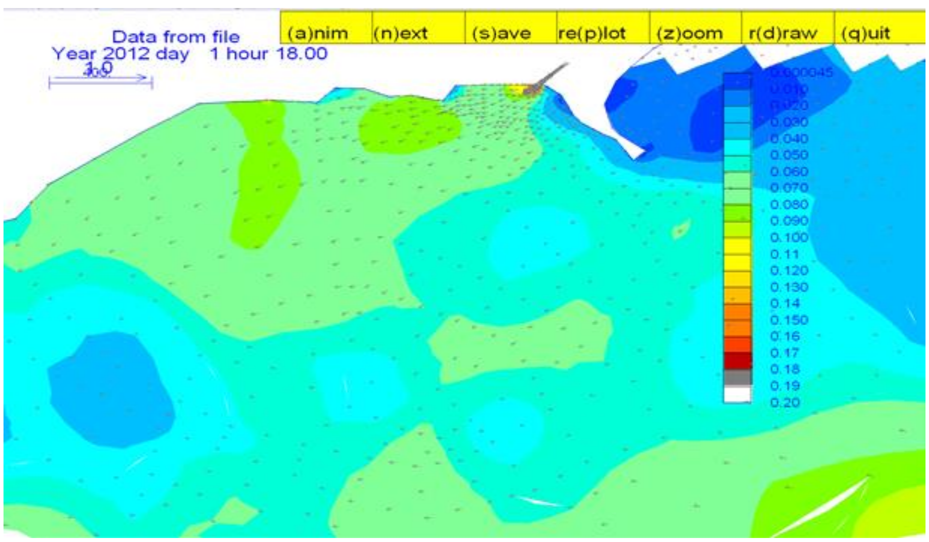


Figure 5-38 Calibration plot of currents (in m/s) for day one corresponding to drogue session 2

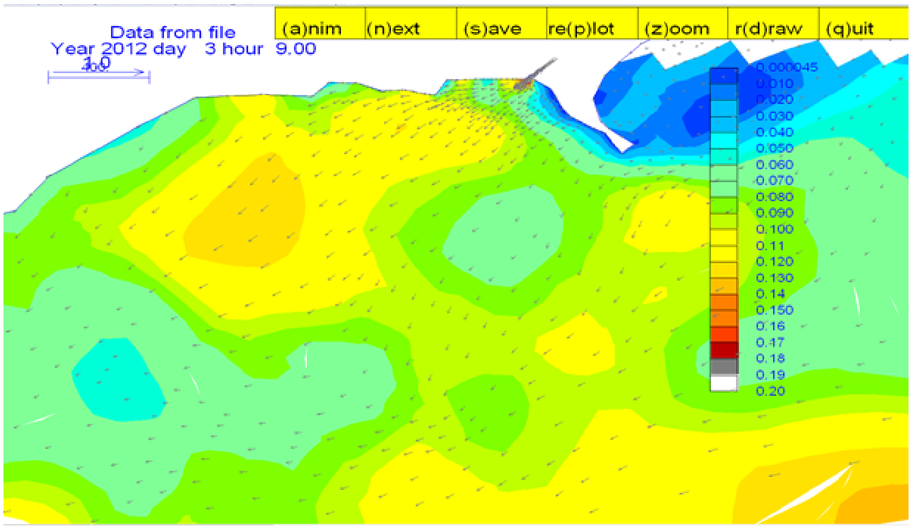


Figure 5-39 Calibration plot of currents (in m/s) for day one corresponding to drogue session 3

Operational Wind Results

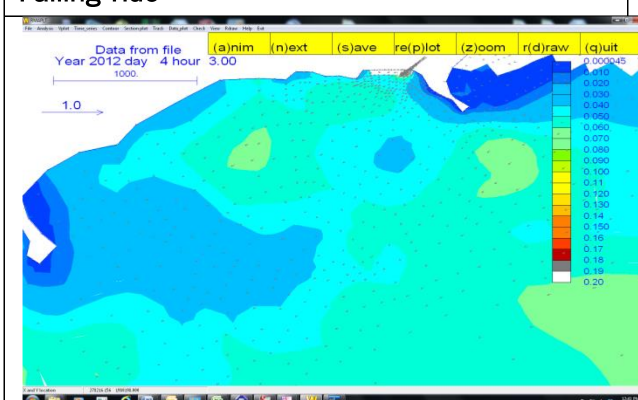
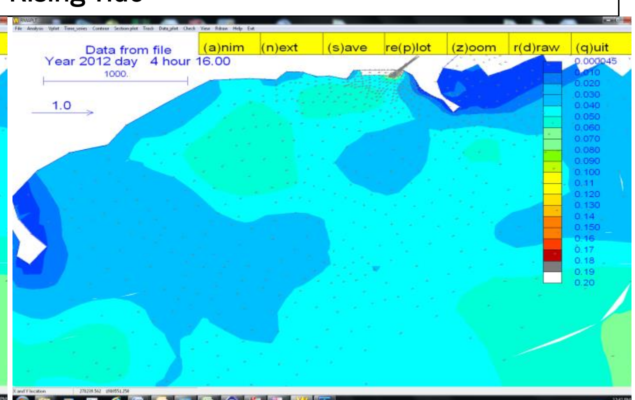
The operational wind speed and direction scenarios investigated are shown in Table 5-15.

Table 5-15 Summary of wind speeds and directions investigated

Conditions	Speed (m/s)	Direction
Slow	2.0	Easterly
Average	5.5	Easterly
Fast	15.5	Easterly

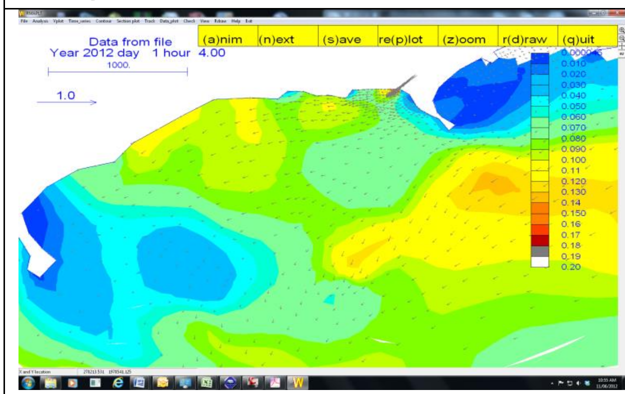
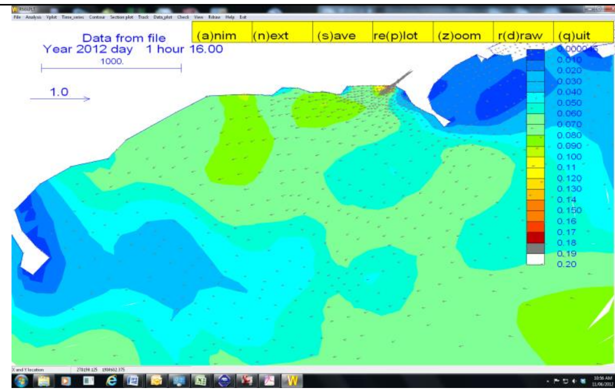
Surface current predictions for the slow wind speed meteorological conditions indicate that current velocities below 6 cm/sec can be expected within the bay. The current directions are predominantly towards the west which indicates the surface currents are predominantly wind driven. See Table 5-16.

Table 5-16 Falling Tide and Rising Tide – Slow Wind Conditions

Falling Tide	Rising Tide
	

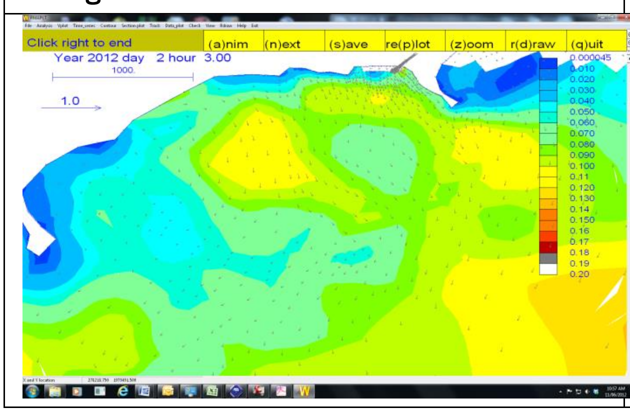
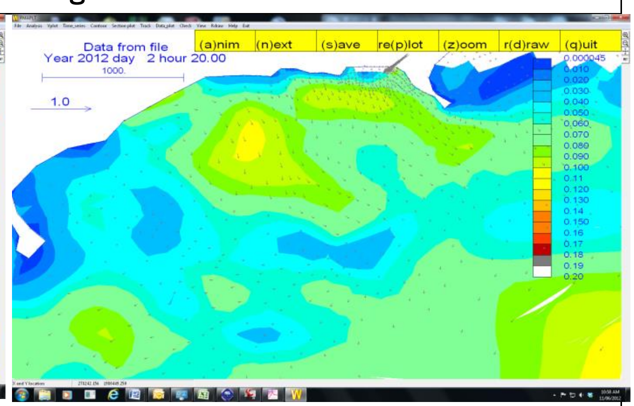
Surface current predictions for the average wind speed meteorological conditions for the existing shoreline configuration indicate that current velocities below 13 cm/sec for falling tides and 10 cm/sec for rising tides can be expected within the bay. The current directions are predominantly towards the west which indicates the surface currents are predominantly wind driven. See Table 5-17.

Table 5-17 Falling Tide and Rising Tide – Average Wind Conditions

Falling Tide	Rising Tide
	

Surface current predictions for the fast wind speed meteorological conditions for the existing shoreline configuration indicate that current velocities below 13 cm/sec for falling and rising tides can be expected within the bay. The currents are driven by the winds and tides. See Table 5-18.

Table 5-18 Falling Tide and Rising Tide – Fast Wind Conditions

Falling Tide	Rising Tide
	

5.1.9 Water Quality

5.1.9.1 Introduction

This section of the EIA report entails the results derived from water quality surveys conducted on July 9, July 22 and August 7, 2014. The water quality sampling stations are the same as those sampled in the 2012 SJPC 360MW Environmental Impact Assessment by C.L. Environmental.

5.1.9.2 Methodology

Three water quality sampling exercises were conducted on July 9, July 22 and August 7, 2014. Weather conditions were fair and sunny on all sampling events. Physical data (temperature, conductivity, salinity, dissolved oxygen, pH, turbidity, and total dissolved solids - TDS) was collected *in situ* at identified aquatic locations within the project environs and potable water location, using a Hydrolab MiniSonde MS-5 meter (Appendix 5). Measurements were taken at intervals throughout the water column. Chemical and biological data were obtained from whole water samples collected at a depth of approximately 0.5 m. The samples were collected in pre-cleaned 1L plastic bottles. Bacterial samples were collected in sterilised 100 ml bottles at above mentioned depth. Fats Oil and Grease samples were collected in glass bottles. The samples were stored on ice in a cooler and transported to Caribbean Environmental Testing and Monitoring Services, and Test America Pensacola Laboratory for laboratory analyses. Thirteen (13) aquatic and one (1) potable water quality sampling stations were sampled. The potable water sample was taken from the JPS Old Harbour Bay power station bathroom faucet (station 12). Their locations in JAD2001 are listed in Table 5-19 and depicted in Figure 5-40.

Table 5-19 Water quality stations coordinates in JAD 2001

STATION NUMBER	JAD 2001	
	NORTHINGS	EASTINGS
1	639438.343	737654.465
2	638597.429	737507.143
3	638357.524	738155.675
4	637987.383	738937.267
5	638813.095	738832.651
6	637216.854	738447.687
7	636661.153	739006.650
8	636051.270	737552.652
9	636842.198	736505.603
10	637635.129	737550.379
11	637982.890	736600.345
13	638772.680	738504.530
14	634110.970	737380.530

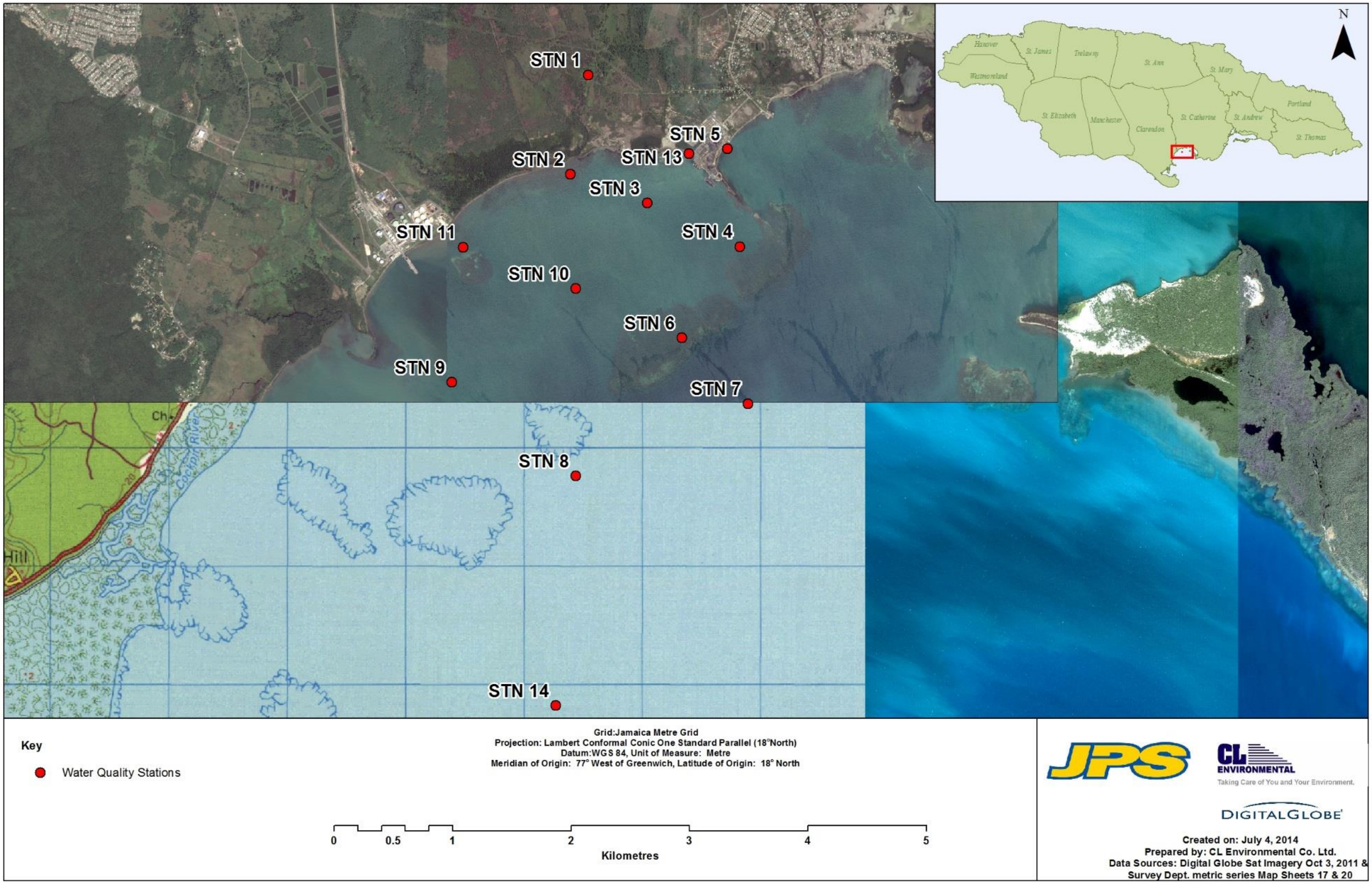


Figure 5-40 Map showing water quality sampling locations

The parameters analysed for the aquatic water samples were: BOD, Total Suspended Solids, Nitrates, Phosphates, Oil and Grease, Faecal Coliform and Total Petroleum Hydrocarbons (TPH) – Gasoline Range Organics (GRO) and Diesel Range Organics (DRO). The parameters analysed for the potable water sample were: barium, boron, fluoride, manganese, nitrates, faecal coliform, residual chlorine, arsenic, cadmium, chromium, copper, cyanide, lead, mercury, nickel and selenium. The water quality stations were accurately mapped using a Trimble® Geo XT GPS unit(s) allowing for spatial interpolation of the data (Temperature, conductivity and salinity).

The results from these sampling runs were compared to National Environment and Planning Agency (NEPA) Standards and World Health Organization (WHO) Guidelines where applicable.

5.1.9.3 Results

Table 5-20 shows the average physicochemical water quality data for each station while Table 5-21 shows the average biochemical data. Table 5-22 shows the minimum and maximum values for the biochemical water quality parameters.

Table 5-20 Mean Physicochemical water quality values

Stn.	Depth (m)	Temp. (°C)	Cond. (mS/cm)	Sal. (ppt)	pH	PAR (uE/m²/s)	D.O. (mg/l)	Turb (NTU)	TDS (g/l)
JWQ 1	0	29.82	59.05	39.56	7.92	-	4.74	23.03	37.81
JWQ 2	0	29.83	55.61	36.95	8.27	741.7	5.27	17.80	35.56
	1	29.91	55.54	36.93	8.26	689.3	5.23	19.43	35.55
JWQ 3	0	29.99	55.25	36.35	8.31	916.0	6.13	5.83	35.36
	1	29.81	55.25	36.70	8.31	636.3	6.12	5.90	35.35
	2	29.53	55.29	36.74	8.31	572.7	6.12	6.23	35.40
	3	29.40	55.29	36.75	8.31	362.0	6.08	6.50	35.39
	4	29.34	55.28	36.74	8.30	212.0	6.08	6.50	35.39
	5	29.35	55.40	36.82	8.29	137.0	5.77	9.43	35.46
JWQ 4	0	29.14	55.12	36.60	8.31	557.0	5.91	3.77	35.27
	1	29.14	55.13	36.60	8.31	410.7	5.91	3.77	35.28
	2	29.14	55.13	36.62	8.30	278.7	5.86	4.07	35.28
	3	29.15	55.19	36.63	8.30	242.7	5.83	4.27	35.30
	4	29.15	55.17	36.64	8.30	175.7	5.83	4.57	35.30
	5	29.24	55.39	36.81	8.27	117.0	5.36	11.70	35.46
JWQ 5	0	29.07	55.16	36.64	8.31	574.3	6.20	10.70	35.32
	1	29.08	55.20	36.66	8.31	383.0	6.20	10.30	35.33
	2	29.08	55.24	36.69	8.31	236.3	6.15	9.47	35.36
	3	29.40	55.27	36.73	8.31	41.5	6.16	14.10	35.38
JWQ 6	0	29.22	55.03	36.55	8.30	270.3	5.61	3.20	35.23
	1	29.23	55.05	36.56	8.30	231.3	5.57	3.30	35.24
	2	29.23	55.06	36.57	8.30	174.7	5.56	3.50	35.25

Stn.	Depth (m)	Temp. (°C)	Cond. (mS/cm)	Sal. (ppt)	pH	PAR (uE/m^2/s)	D.O. (mg/l)	Turb (NTU)	TDS (g/l)
JWQ 7	0	29.20	54.94	36.48	8.33	219.0	6.21	4.23	35.17
	1	29.21	54.95	36.49	8.33	204.3	6.23	8.50	35.18
	2	29.21	54.96	36.50	8.33	159.0	6.24	7.87	35.18
	3	29.22	54.99	36.51	8.32	129.7	6.24	5.43	35.19
	4	29.21	54.99	36.51	8.32	115.3	6.23	4.87	35.20
	5	29.22	55.00	36.51	8.32	91.3	6.23	4.60	35.19
	6	29.22	55.00	36.52	8.32	70.3	6.23	4.47	35.21
	7	29.22	55.00	36.52	8.32	51.7	6.22	4.67	35.20
	8	29.23	55.02	36.53	8.32	37.3	6.22	4.70	35.22
	9	29.24	55.05	36.57	8.32	27.3	6.18	4.97	35.23
	10	29.31	55.29	36.73	8.30	21.0	6.00	5.77	35.30
	11	29.34	55.32	36.76	8.30	15.3	5.85	10.03	35.41
JWQ 8	0	29.28	54.97	36.67	8.34	299.0	6.21	8.90	35.19
	1	29.20	54.98	36.43	8.32	251.3	5.89	8.23	35.19
	2	29.20	54.98	36.49	8.31	164.7	5.86	8.40	35.19
	3	29.21	55.00	36.52	8.31	126.3	5.91	8.03	35.20
	4	29.23	55.03	36.54	8.32	104.3	6.04	7.17	35.22
	5	29.23	55.03	36.54	8.32	83.3	6.07	6.97	35.22
	6	29.23	55.03	36.54	8.32	55.0	6.10	6.50	35.22
	7	29.24	55.03	36.55	8.32	56.3	6.12	6.40	35.22
JWQ 9	0	29.73	55.17	36.64	8.34	384.0	6.22	6.87	35.31
	1	29.74	55.19	36.66	8.34	325.7	6.20	6.40	35.31
	2	29.74	55.19	36.66	8.33	268.3	6.20	6.23	35.32
	3	29.76	55.21	36.68	8.33	187.0	6.18	6.47	35.33
	4	29.77	55.21	36.68	8.33	115.0	6.19	6.67	35.33
	5	29.78	55.23	36.69	8.32	88.3	6.13	6.83	35.35
	6	29.76	55.26	36.71	8.31	54.3	5.98	8.83	35.36
JWQ 10	0	29.55	55.33	36.76	8.33	883.3	6.20	5.50	35.40
	1	29.55	55.32	36.76	8.33	667.3	6.18	5.73	35.41
	2	29.51	55.30	36.64	8.33	335.7	6.19	5.87	35.39
	3	29.49	55.29	36.74	8.33	224.7	6.17	5.97	35.39
	4	29.49	55.29	36.74	8.32	141.3	6.18	6.03	35.38
	5	29.45	55.29	36.73	8.32	87.3	6.14	6.27	35.38
	6	29.43	55.28	36.72	8.32	57.0	6.13	6.70	35.37
	7	29.43	55.27	36.73	8.31	53.0	6.07	9.17	35.37
JWQ 11	0	29.82	55.31	36.87	8.33	722.0	6.06	6.43	35.39
	1	29.84	55.31	36.85	8.32	527.3	6.03	8.87	35.40
	2	29.85	55.32	36.75	8.32	330.0	6.01	8.47	35.41
	3	30.12	55.39	36.82	8.31	285.5	5.83	11.00	35.45

Stn.	Depth (m)	Temp. (°C)	Cond. (mS/cm)	Sal. (ppt)	pH	PAR (uE/m²/s)	D.O. (mg/l)	Turb (NTU)	TDS (g/l)
JWQ 13	0	37.35	55.05	36.60	8.25	1156.0	5.94	7.37	35.06
	1	36.04	54.91	36.43	8.23	632.0	5.91	10.60	35.09
	2	36.25	55.12	36.59	8.19	957.0	6.14	18.90	35.25
JWQ 14	0	29.23	54.94	36.47	8.34	424.7	6.34	4.53	35.16
	1	29.23	54.95	36.48	8.34	360.3	6.30	4.33	35.17
	2	29.23	54.94	36.48	8.34	247.3	6.34	4.13	35.16
	3	29.24	54.95	36.31	8.33	227.7	6.35	4.23	35.17
	4	29.24	54.95	36.49	8.33	192.0	6.35	4.30	35.17
	5	29.24	54.95	36.48	8.33	126.7	6.34	4.30	35.17
	6	29.24	54.95	36.48	8.33	108.3	6.35	4.40	35.17
	7	29.24	54.96	36.49	8.33	87.0	6.36	4.70	35.18
	8	29.23	54.97	36.49	8.33	58.7	6.34	4.97	35.18
	9	29.21	54.97	36.53	8.33	42.0	6.33	4.93	35.19
	10	29.20	54.98	36.50	8.32	32.3	6.32	4.90	35.19
	13	29.24	55.04	36.56	8.31	11.0	6.16	9.30	35.23

Table 5-21 Mean biochemical water quality values

Stn	BOD (mg/l)	TSS (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	FOG (mg/l)	Faecal Coliform (mpn/100ml)	DRO (mg/l)	GRO (mg/l)
JWQ 1	2.33	39.33	0.90	1.14	2.67	103.33	ND	ND
JWQ 2	2.00	19.00	1.00	0.88	2.67	10.00	ND	ND
JWQ 3	2.33	5.00	2.03	0.81	3.33	10.00	ND	ND
JWQ 4	1.67	7.00	1.23	2.11	2.67	10.00	ND	ND
JWQ 5	2.00	6.67	1.40	0.63	3.00	97.33	ND	ND
JWQ 6	2.33	5.00	1.87	2.06	2.67	83.33	ND	ND
JWQ 7	4.00	8.33	2.03	1.21	4.67	60.00	ND	ND
JWQ 8	1.33	4.67	1.60	2.00	3.33	10.00	ND	ND
JWQ 9	1.00	8.33	1.83	0.51	2.33	87.33	ND	ND
JWQ 10	2.67	5.67	1.10	0.47	1.67	46.67	ND	ND
JWQ 11	3.33	10.00	1.10	0.31	2.67	18.67	ND	ND
JWQ 13	1.67	7.33	2.07	2.48	2.33	18.67	ND	ND
JWQ 14	2.67	6.33	1.57	1.34	2.00	10.00	ND	ND

Table 5-22 Range of values (minimum and maximum) for biochemical parameters

Stn	BOD (mg/l)	TSS (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	FOG (mg/l)	Faecal Coliform (mpn/100ml)
JWQ 1	0-4	35-46	0.5-1.2	0.16-2.2	2-3	<11-231
JWQ 2	1-3	3-39	0.4-1.4	0.12-1.27	2-3	<11
JWQ 3	2-3	4-6	1.7-2.3	0.13-1.56	2-4	<11

Stn	BOD (mg/l)	TSS (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	FOG (mg/l)	Faecal Coliform (mpn/100ml)
JWQ 4	0-3	2-12	0.9-1.6	0.17-3.9	1-5	<11
JWQ 5	2	5-8	1.2-1.6	0.05-1.06	2-4	<11-231
JWQ 6	0-4	4-6	1.2-2.6	0.09-4.8	2-3	<11
JWQ 7	1-6	4-17	1.4-3.2	0.08-2.2	3-7	<11-160
JWQ 8	1-2	2-9	0.9-2.2	0.23-4	2-4	<11
JWQ 9	1	7-10	1.6-2.3	0.12-0.73	1-3	<11-230
JWQ 10	2-3	3-10	0.4-1.9	0.05-1.14	1-2	<11-120
JWQ 11	1-5	7-16	0.7-1.5	0.07-0.74	1-5	<11-36
JWQ 13	1-3	4-11	1.5-3.2	0.25-5.9	1-3	<11-36
JWQ 14	1-3	6-7	1.3-2	0.13-2.8	2	<11

Temperature

Average temperature values ranged from 29.07 – 37.35°C across the stations. The highest temperature value was reported at station JWQ13 (by the JPS cooling water outlet) and the lowest temperature was at station JWQ5. Compared to depth, the temperature at each station (excepting for station 13) varied little (Figure 5-41). Figure 5-42 shows the spatial temperature comparison in contour form for depths of 0m, 1m, 2m and 3m. It clearly shows that the source of higher temperature water within the bay is from the JPS cooling water outlet and gradually spreads along the nearshore down past the WINDALCO pier in a southwesterly direction.

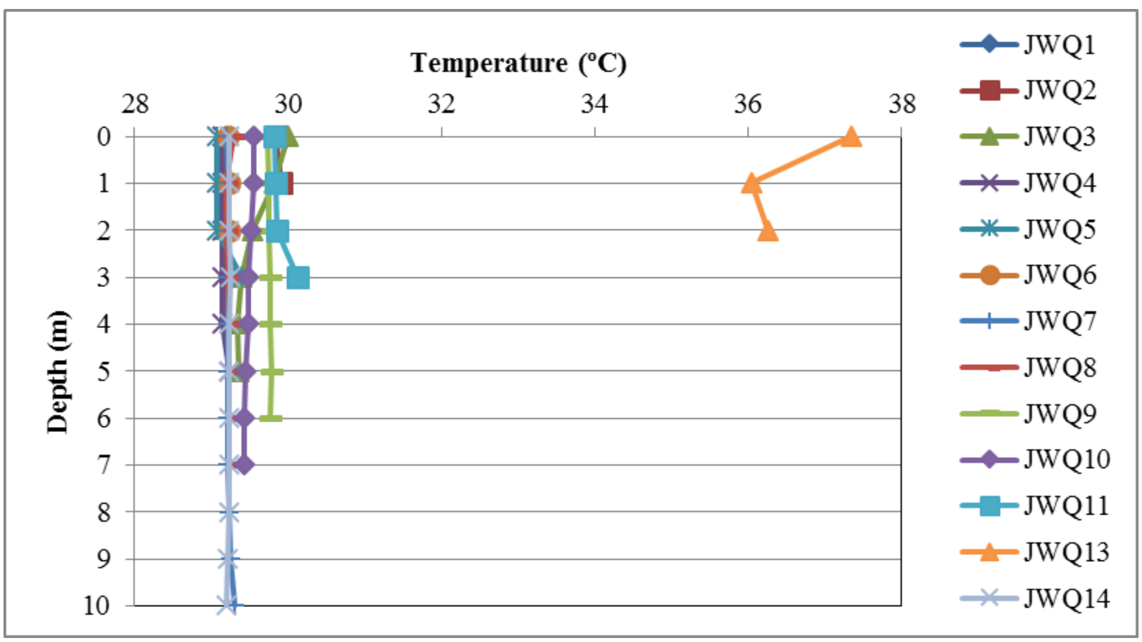


Figure 5-41 Temperature values at the various stations

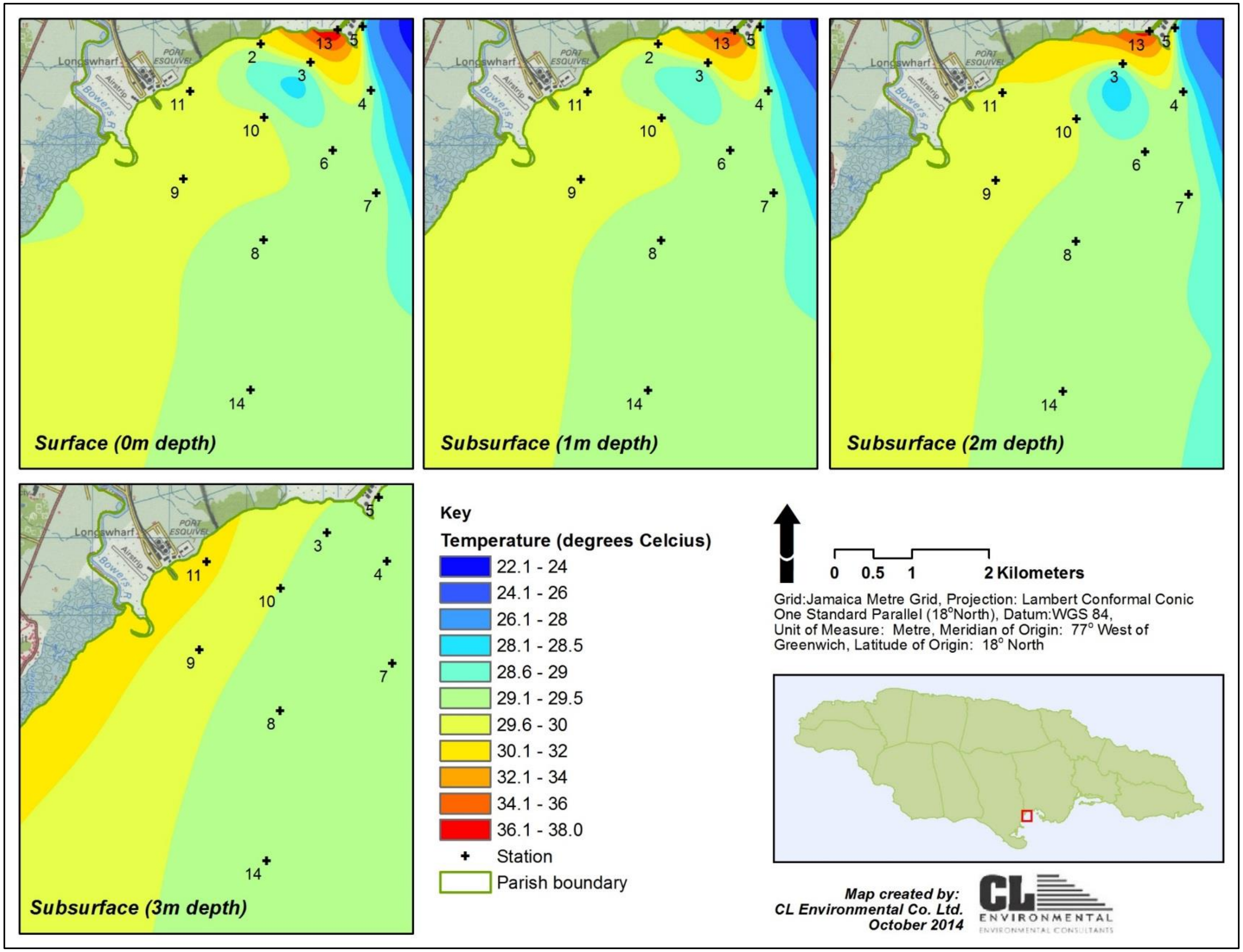


Figure 5-42 Spatial temperature comparison for 0m, 1m, 2m and 3m depths

Specific Conductivity (SpC)

Average specific conductivity values ranged from 54.91 – 59.05mS/cm across the stations. The lowest values were reported at station JWQ13 while station JWQ1 had the highest value. JWQ1 is located within the Bowers Gully. This extreme salinity/conductivity within the gully could be a combination of salt water intrusion from the sea and drought conditions throughout the island during the sampling period. When compared to depth, the values at each station varied little (except for Station 1) (Figure 5-43). Figure 5-44 shows the spatial conductivity comparison in contour form for depths of 0m, 1m, 2m and 3m. It clearly shows that the source of higher conductivity/salinity water (at the time of sampling) is from the Bowers Gully and gradually spreads outwards in a south southeasterly direction into and throughout the bay. Although Station 1 is not seen on the map, Station 2 is located at the mouth of the Bowers Gully and shows the highest conductivity values. Figure 5-44 also shows a source of lower conductivity/salinity water to be the JPS cooling water outlet (Station 13) compared to the conductivity/salinity at Station 2.

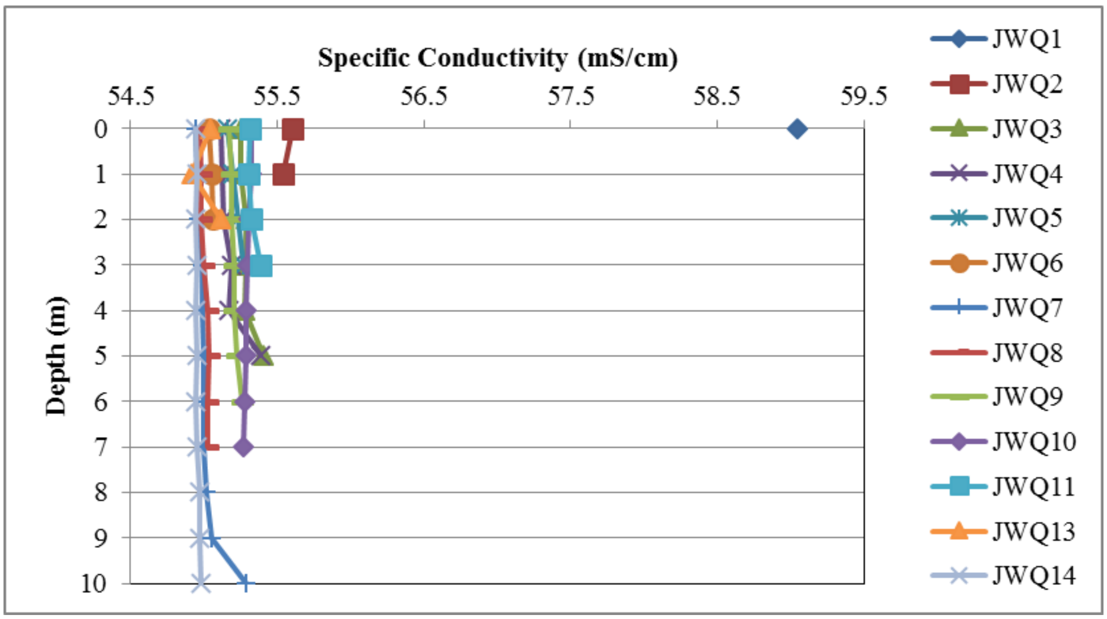


Figure 5-43 Conductivity values at the various stations

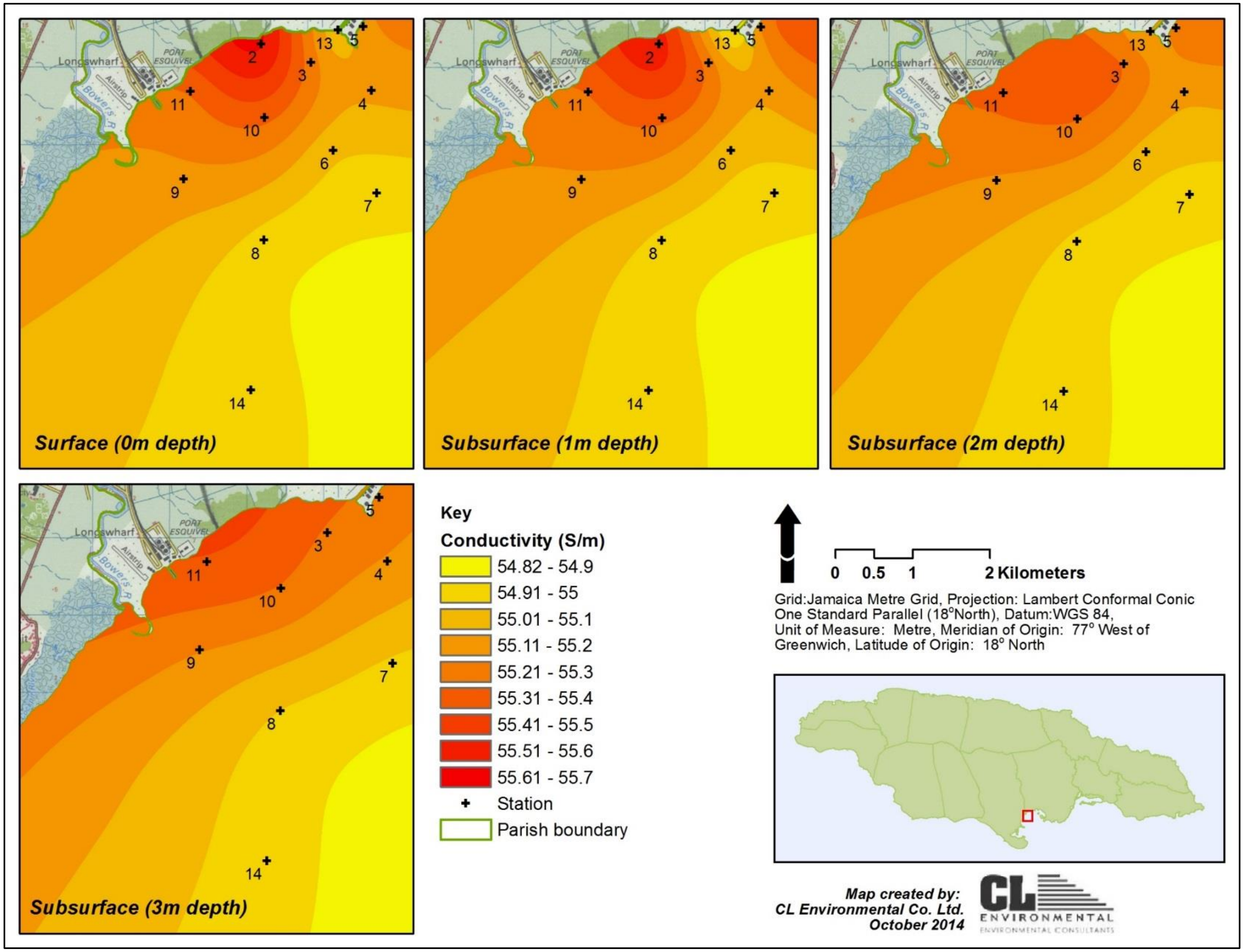


Figure 5-44 Spatial conductivity comparison for 0m, 1m, 2m and 3m depths

Salinity

Average salinity values ranged from 36.31 – 39.56ppt across the stations. The lowest values were reported at station JWQ14 while station JWQ1 had the highest value. JWQ1 is located within the Bowers Gully. This extreme salinity within the gully could be a combination of salt water intrusion from the sea and drought conditions throughout the island during the sampling period. When compared to depth, the values at each station varied little (except for Station 1) (Figure 5-45). Figure 5-46 shows the spatial salinity comparison in contour form for depths of 0m, 1m, 2m and 3m. It clearly shows that the source of more saline water (at the time of sampling) is from the Bowers Gully and gradually spreads outwards in a south southeasterly direction into and throughout the bay. Although Station 1 is not seen on the map, Station 2 is located at the mouth of the Bowers Gully and shows the highest salinity values. Figure 5-46 also shows a source of lower salinity water to be the JPS cooling water outlet (Station 13) compared to the salinity at Station 2.

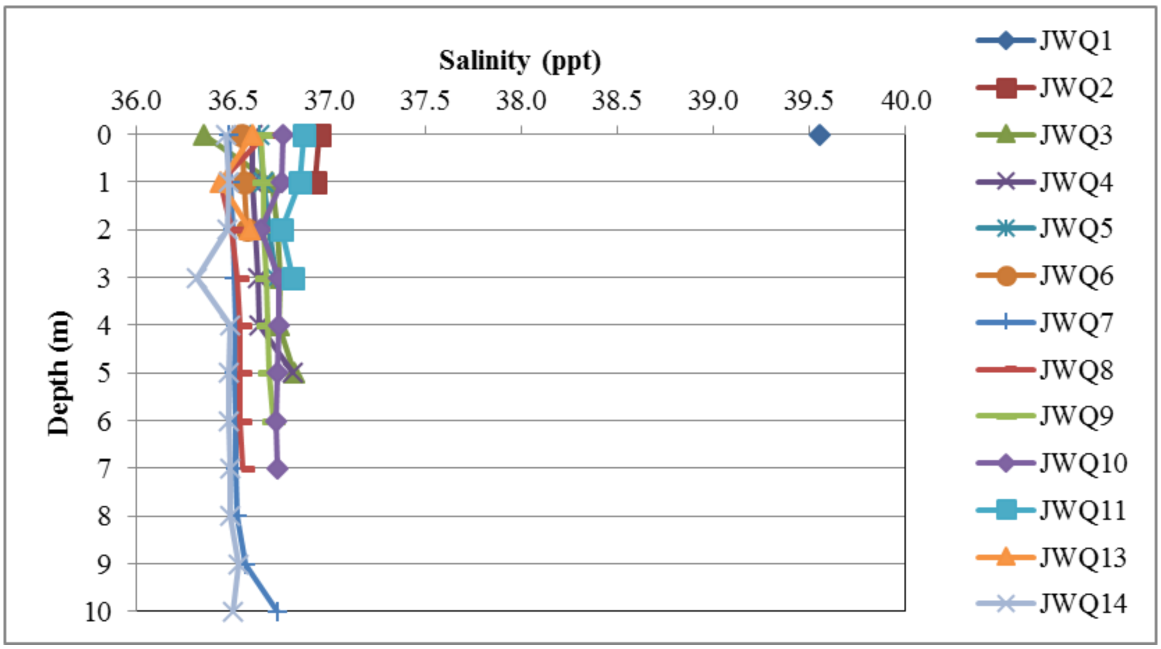


Figure 5-45 Salinity values at the various stations

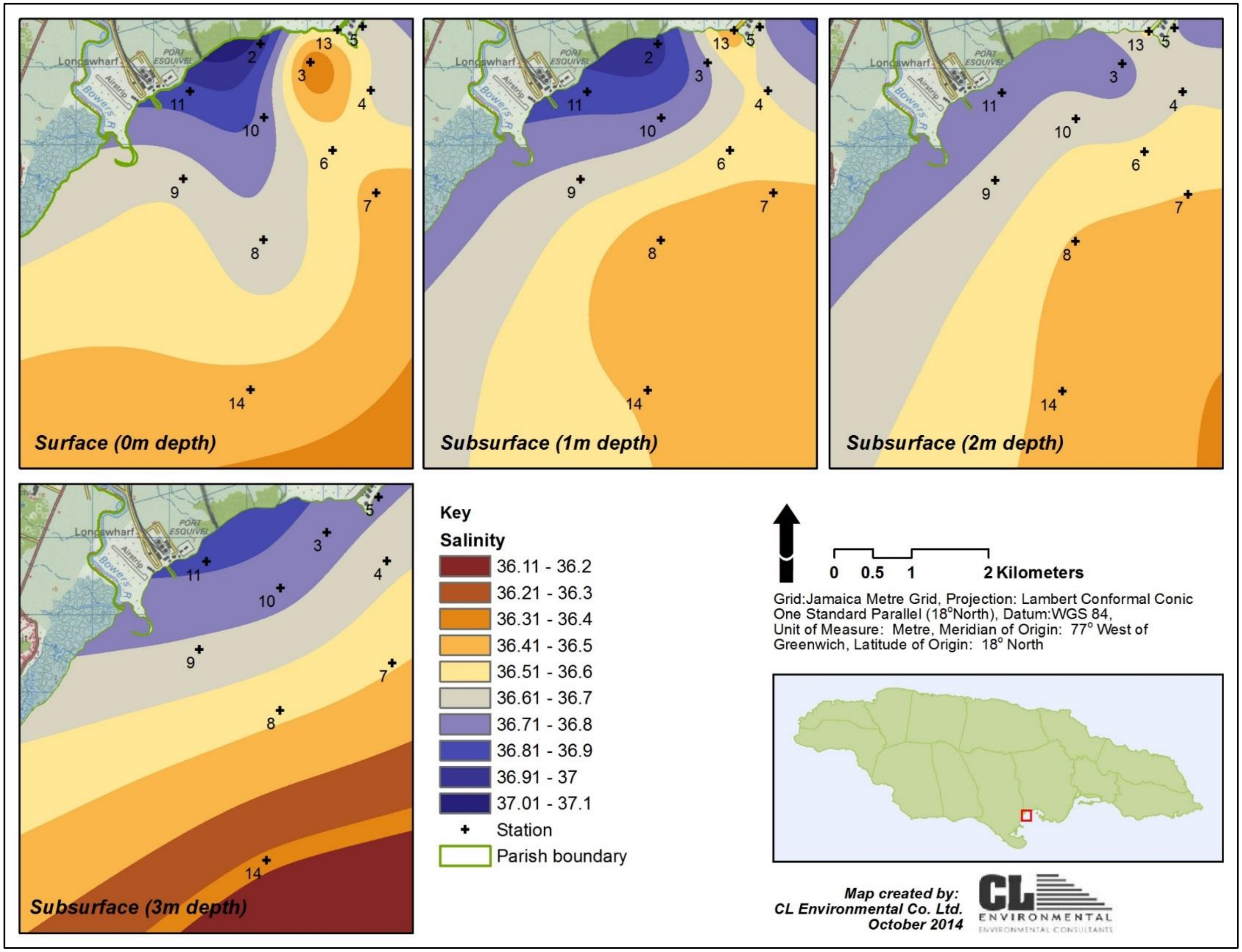


Figure 5-46 Spatial salinity comparison for 0m, 1m, 2m and 3m depths

pH

Average pH values ranged from 7.92 – 8.34 across the stations. The highest pH value was reported at stations JWQ9 and JWQ14 and the lowest pH was reported at station JWQ1. When compared to depth the pH values at each station showed little variation. All stations were within the NEPA Standard for Seawater of 8.0 – 8.4 for pH, excepting for Station JWQ1 located in the Bowers Gully (Figure 5-47).

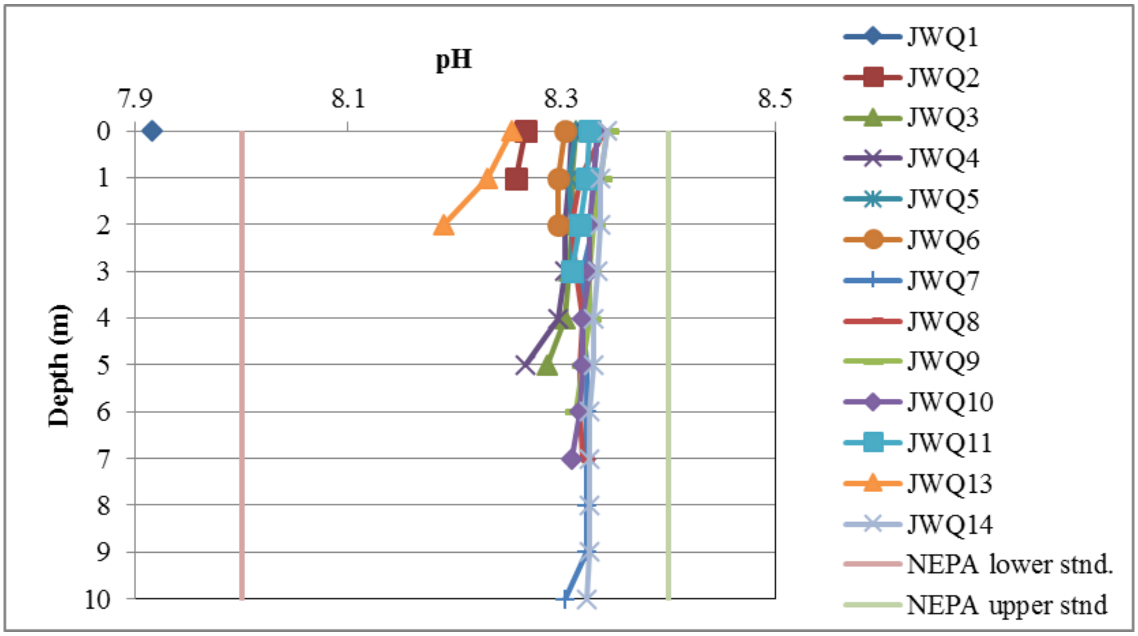


Figure 5-47 pH values at the various stations

Dissolved Oxygen (DO)

Dissolved oxygen values ranged from 4.74 – 6.36mg/l across the stations. The highest value was observed at station JWQ14, as this was the station located furthest from the coastline and prone to having less anthropogenic pollution sources thus higher dissolved oxygen content. The lowest D.O. value was reported at station JWQ1 as this station is located in the Bowers Gully. When compared to depth, the D.O. levels showed a slight decrease across the stations with a few stations showing a slight increase. Average D.O. values at all locations (except for Station JWQ1) were above the NEPA standard of 5 mg/l (Figure 5-48).

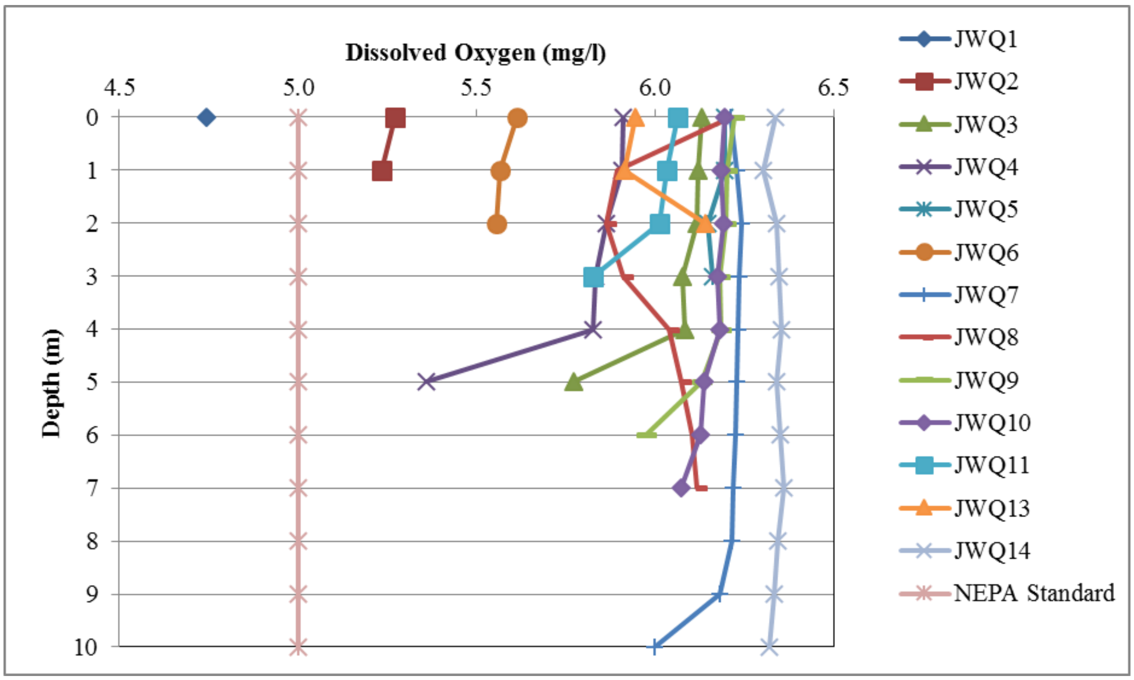


Figure 5-48 Dissolved oxygen values at the various stations

Turbidity

Turbidity values ranged from 3 – 23 NTU across the stations. The highest turbidity value was reported at station JWQ1 which is located in the Bowers Gully which is prone to high turbidity from land based sources of pollution and terrigenous sediments. The lowest value was observed at station JWQ6 which is located on a shallow area of reef northeast of the entrance to the shipping channel. Turbidity values varied when compared to depth at each station with a general increase with depth observed across the stations (Figure 5-49).

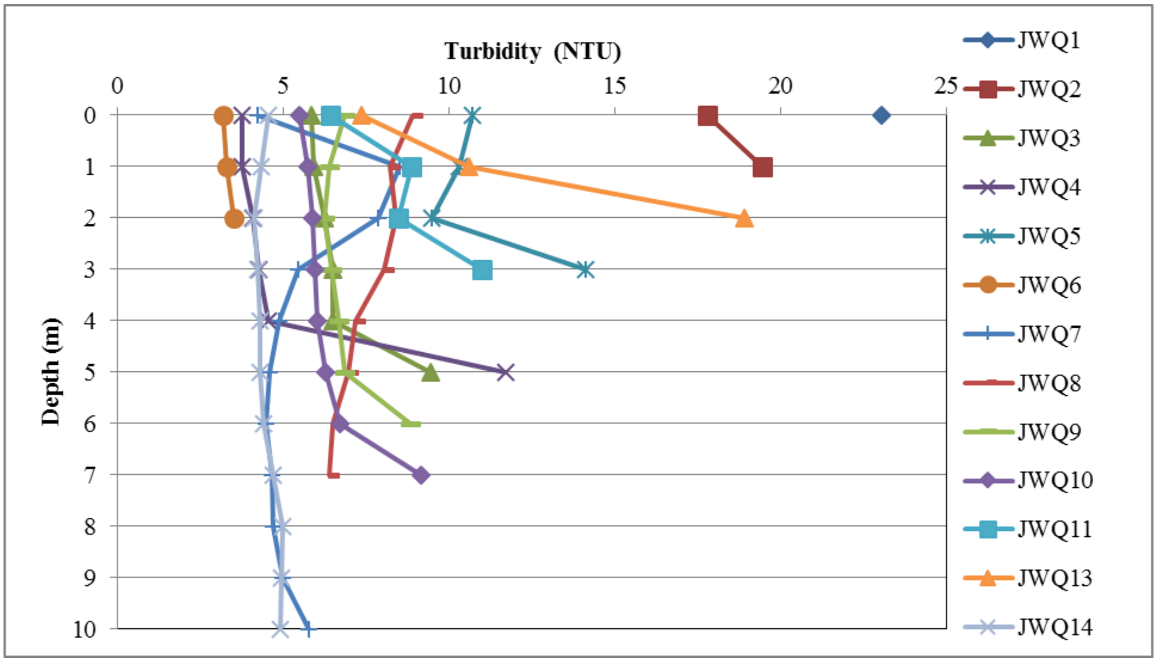


Figure 5-49 Turbidity values at the various stations

Total Dissolved Solids (TDS)

TDS varied little across the stations ranging from 35.06 – 37.81g/l. The lowest value was reported at JWQ13 and the highest TDS value was reported at station JWQ1 (Bowers Gully). When compared to depth at each station, the values showed little variation (Figure 5-50).

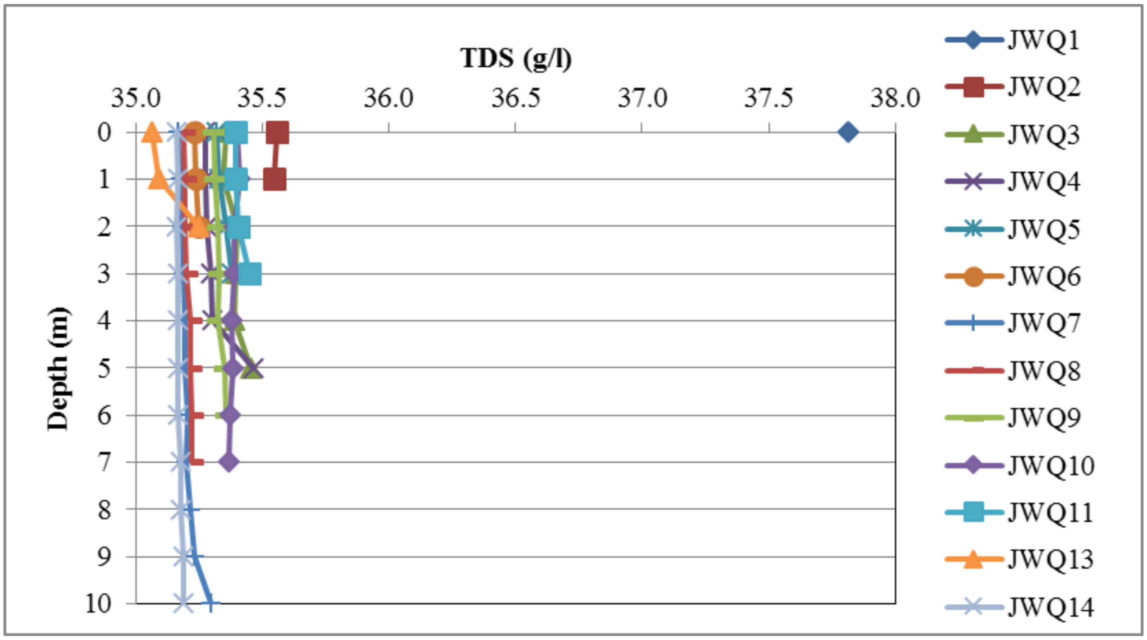


Figure 5-50 TDS values at the various stations

Photosynthetically Active Radiation (PAR)

PAR values ranged from 15.3 – 1156 uE/m^2/s across the stations. The lowest PAR reading was obtained at station JWQ7 at 11m depth as this was one of the deepest stations. The highest value was obtained at station JWQ13 at 0m depth, closest to the water's surface, thus higher light penetration. When compared with depth, all stations showed a general decrease in PAR levels with increasing depth. This is expected as with increasing depth less active radiation is able to penetrate. Station JWQ13 showed an increase in PAR from 1m to 2m; this is probably due to previous cloud cover at 1m depth (Figure 5-51).

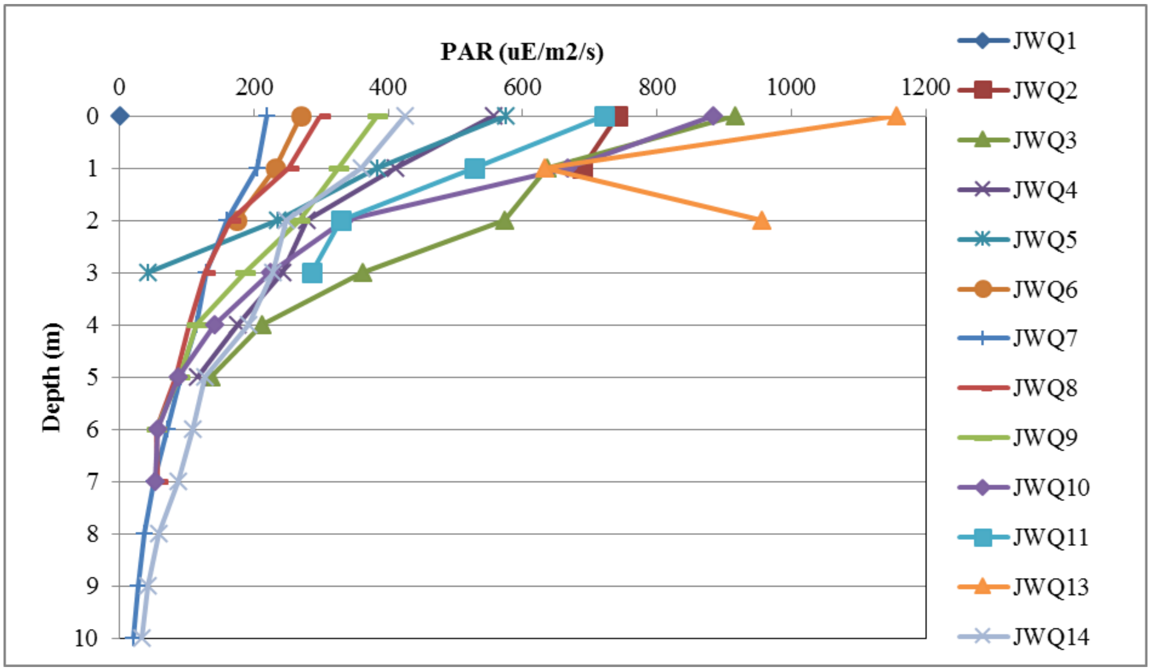
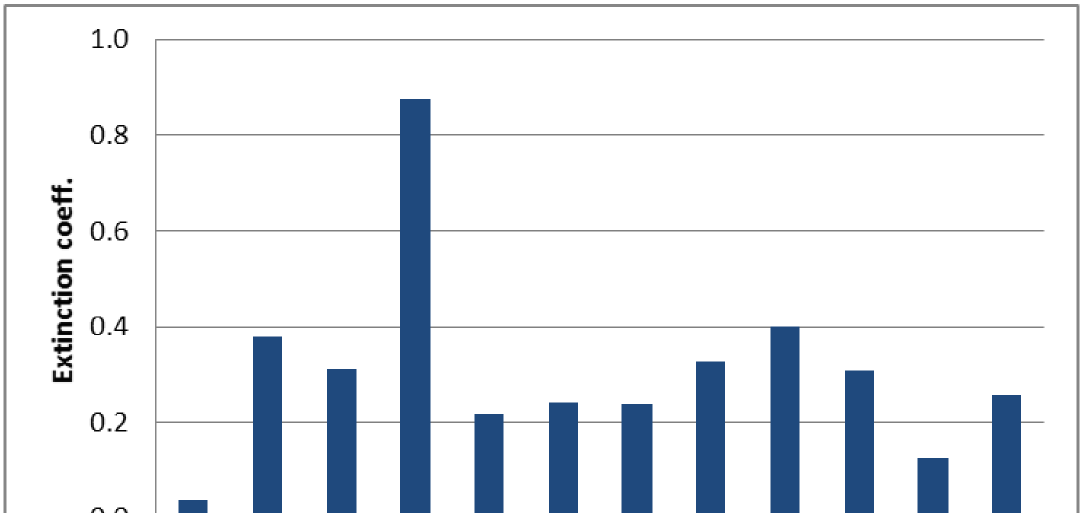


Figure 5-51 PAR values at the various stations

Light Extinction

Light extinction coefficients at each station ranged from 0.04 – 0.87. The highest value was obtained at station JWQ5 and the lowest was obtained at station JWQ2 (Figure 5-52). The extinction coefficient indicates the rate of loss of light through the water column with increasing depth. Station JWQ5 showed the greatest loss of light (0.87), which would indicate some particles (turbidity) in the water column affecting light penetration. This site is located by the cooling water intake point and visibility and circulation at this location is poor.

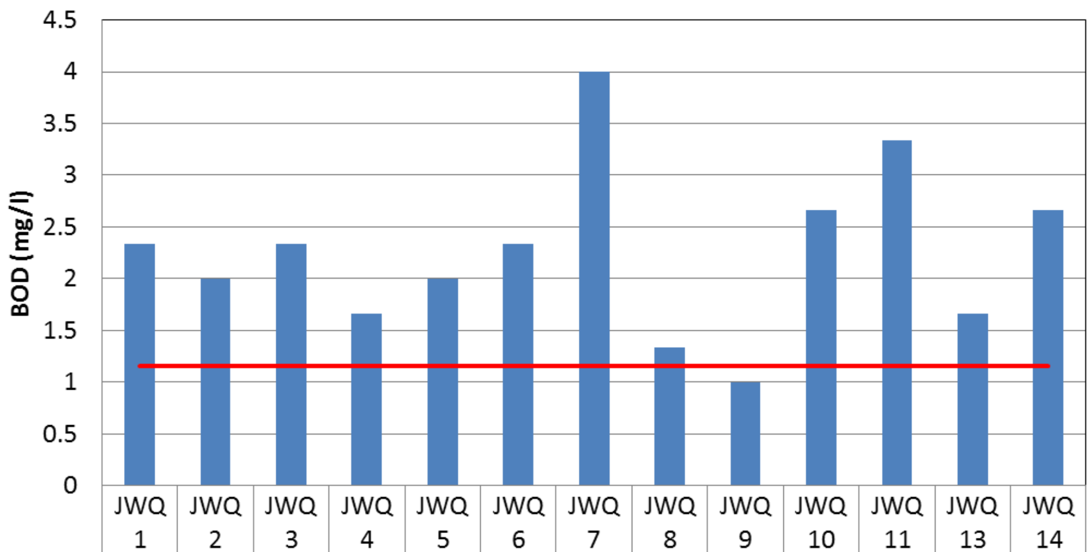


	JWQ 2	JWQ 3	JWQ 4	JWQ 5	JWQ 6	JWQ 7	JWQ 8	JWQ 9	JWQ 10	JWQ 11	JWQ 13	JWQ 14
EC	0.04	0.38	0.31	0.87	0.22	0.24	0.24	0.33	0.40	0.31	0.13	0.26

Figure 5-52 Light extinction at the various stations

Biochemical Oxygen Demand (BOD)

The BOD values ranged from 1 – 4 mg/l across the stations. The highest average BOD value was reported at station JWQ7 whereas the lowest value was observed at station JWQ9. All stations except for JWQ9 had values that were above the NEPA BOD Standard for Seawater of 1.16mg/l (Figure 5-53).



	JWQ 1	JWQ 2	JWQ 3	JWQ 4	JWQ 5	JWQ 6	JWQ 7	JWQ 8	JWQ 9	JWQ 10	JWQ 11	JWQ 13	JWQ 14
BOD	2.333	2	2.333	1.667	2	2.333	4	1.333	1	2.667	3.333	1.667	2.667
NEPA stnd.	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16

Figure 5-53 BOD values at the various stations

Total Suspended Solids (TSS)

Average TSS values ranged from 4.67 – 39.33mg/l across the stations. Station JWQ1 reported the highest value whereas the lowest value was observed at station JWQ8. The highest turbidity value was reported at station JWQ1 which is located in the Bowers Gully which is prone to high suspended solid content from land based sources of pollution and terrigenous sediments. The lowest value was observed at station JWQ8 which is located far from the coastline and prone to having low sediment churning and low anthropogenic pollution sources thus low suspended solid content (Figure 5-54).

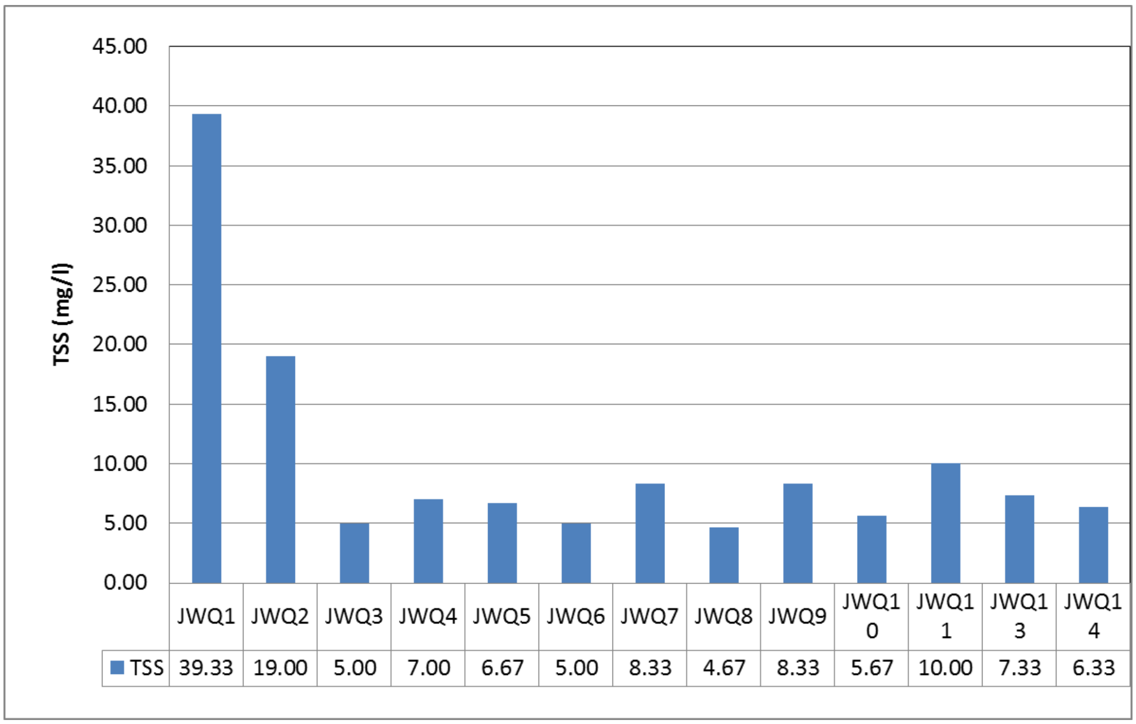
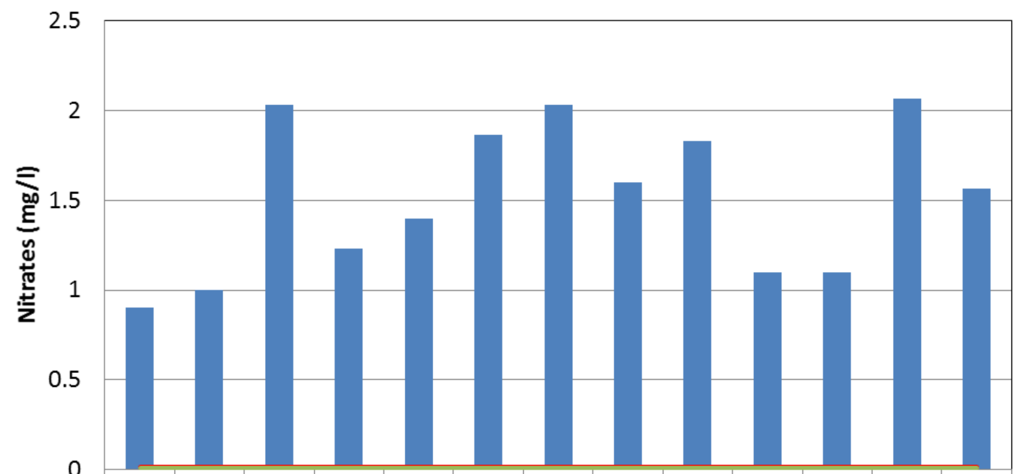


Figure 5-54 TSS values at the various stations

Nitrate

Nitrate values ranged from 0.9 – 2.067mg/l across the stations. The lowest nitrate value was reported at station JWQ1 which is the Bowers Gully. The highest nitrate value was observed at station JWQ13 located by the JPS cooling water outlet. All stations were above the NEPA standard for Seawater for nitrates; however these values are typical for Jamaican coastal waters (Figure 5-55).

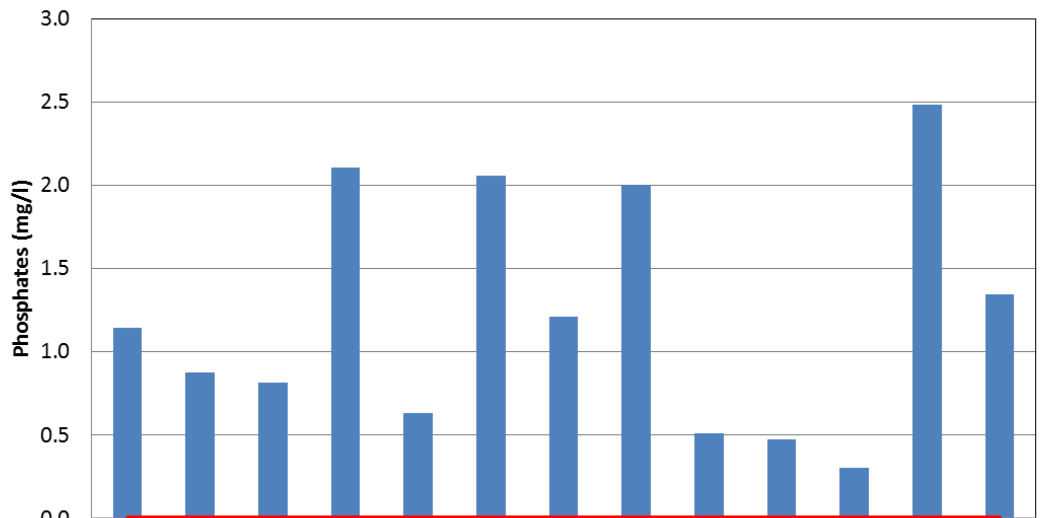


	JW Q1	JW Q2	JW Q3	JW Q4	JW Q5	JW Q6	JW Q7	JW Q8	JW Q9	JW Q10	JW Q11	JW Q13	JW Q14
Nitrates	0.9	1	2.033	1.233	1.4	1.867	2.033	1.6	1.833	1.1	1.1	2.067	1.567
NEPA stnd (upper)	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
NEPA stnd (lower)	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007

Figure 5-55 Nitrate values at the various stations

Phosphate

Phosphate values ranged from 0.3 – 2.5mg/l across the stations. The lowest phosphate value was reported at station JWQ11 while the highest phosphate value was observed at station JWQ13 located by the JPS cooling water outlet. Similar to the nitrate values, all stations were above the NEPA standard for seawater for phosphates; however these values are typical for Jamaican coastal waters (Figure 5-56).



	JWQ 1	JWQ 2	JWQ 3	JWQ 4	JWQ 5	JWQ 6	JWQ 7	JWQ 8	JWQ 9	JWQ 10	JWQ 11	JWQ 13	JWQ 14
Phosphates	1.1	0.9	0.8	2.1	0.6	2.1	1.2	2.0	0.5	0.5	0.3	2.5	1.3
NEPA stnd (lower)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
NEPA stnd (upper)	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

Figure 5-56 Phosphate values at the various stations

Fats, Oils and Grease (FOG)

FOG values ranged from 1.67 – 4.67mg/l across the stations. The highest value was reported at station JWQ7 while the lowest value was reported at station JWQ10. High FOG values are expected at Station JWQ7 as it is in close proximity to where the fuel delivery vessel anchors when delivering fuel to the Doctor Bird Barges and to JPS plant. In fact, during the third sampling event on August 7th, a fuel delivery vessel was anchored nearby Station 7 at the time of sampling (Figure 5-57).

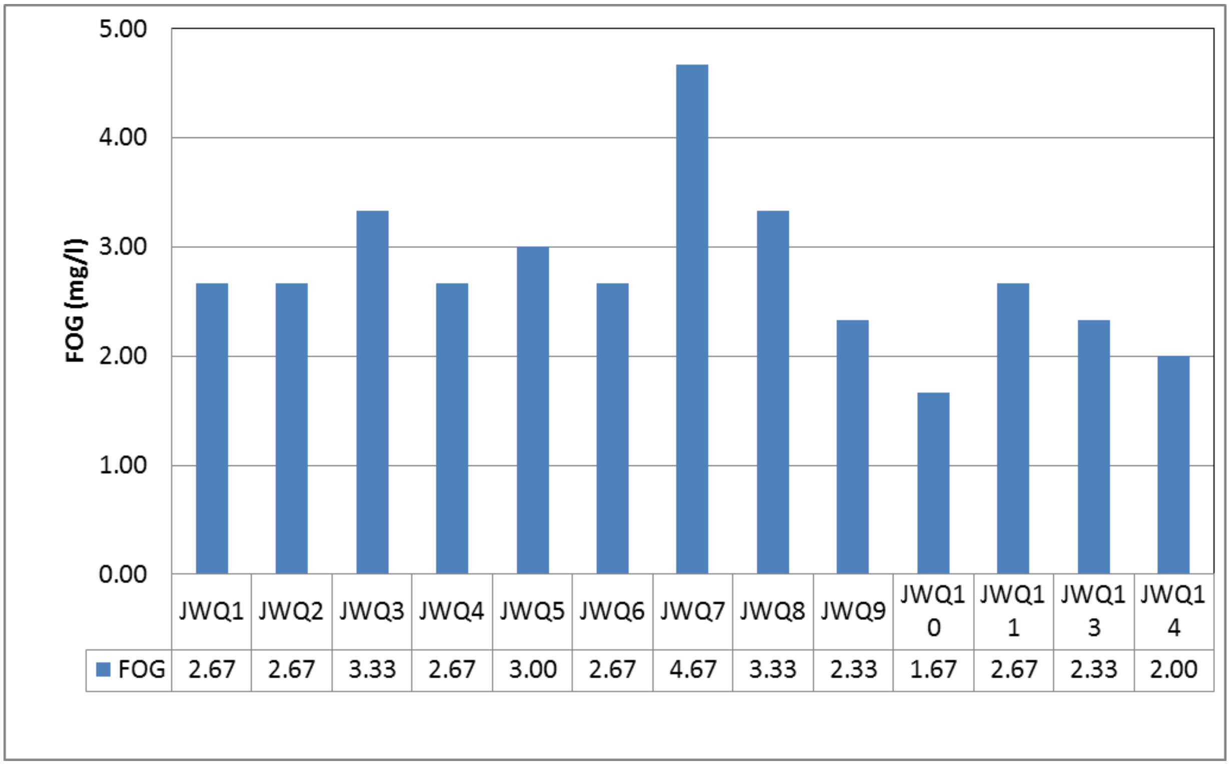
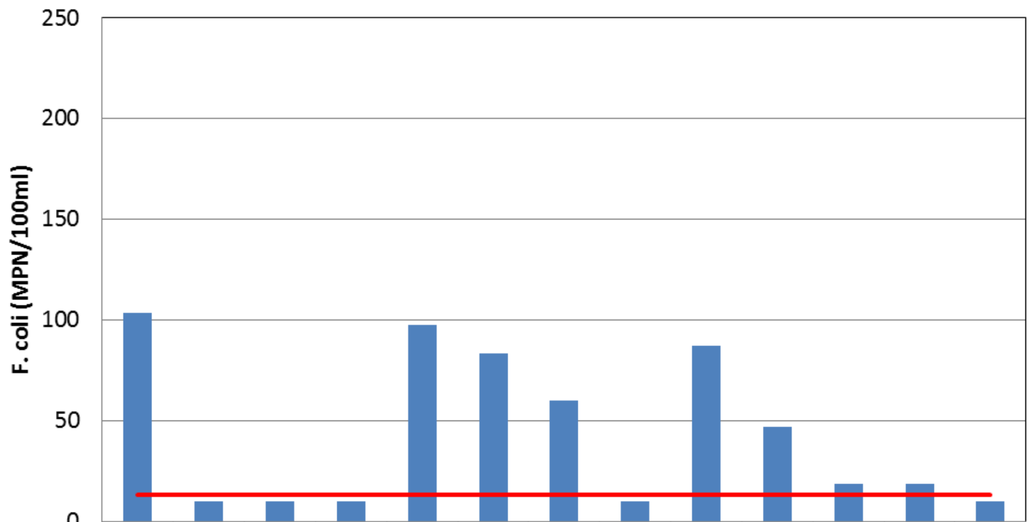


Figure 5-57 FOG values at the various stations

Faecal Coliform

Faecal coliform values ranged from <11 – 103.3 MPN/100ml across the stations. The highest value was reported at station JWQ1 while the lowest values were reported at stations JWQ 2, 3, 4, 8 and 14. Station JWQ1 is located in the Bowers Gully and is most prone to anthropogenic pollution sources hence the high coliform levels (Figure 5-58). Goat and cattle farming are also prevalent in the area close to the Bowers Gully where the sample was taken and informal settlements are also located in and around this area.



	JWQ 1	JWQ 2	JWQ 3	JWQ 4	JWQ 5	JWQ 6	JWQ 7	JWQ 8	JWQ 9	JWQ 10	JWQ 11	JWQ 13	JWQ 14
F.Coli	103.3	10	10	10	97.33	83.33	60	10	87.33	46.67	18.67	18.67	10
NEPA stnd	13	13	13	13	13	13	13	13	13	13	13	13	13

Figure 5-58 Faecal Coliform values at the various stations

Total Petroleum Hydrocarbons – DRO and GRO

No TPH (GRO and DRO) were detected at any stations on any of the sampling runs.

Potable Water (Station JWQ 12)

Table 5-23 and Table 5-24 show the potable water quality values for Station JWQ12, compared with the NEPA Draft Ambient Freshwater Standards, 2009 and World Health Organization Drinking Water Guidelines. The results for JWQ12 indicate that the water is of good quality. The TDS and conductivity values on all three sampling dates for Station 12 were above the respective NEPA Standard. The residual chlorine values on July 22nd and August 7th were above the respective WHO Guidelines. All other parameters for which WHO Guidelines exist were compliant.

Table 5-23 Physicochemical data for potable water station JPS 12.

Station	Sample Date	Temp. (°C)	Cond. (mS/cm)	Sal. (ppt)	pH	D.O. (mg/l)	Turb (NTU)	TDS (g/l)
JWQ 12	July 9th	29.44	1.613	0.85	7.57	7.35	1.00	0.88
JWQ 12	July 22nd	29.99	1.215	0.64	7.65	8.51	0.30	0.774
JWQ 12	Aug. 7th	30.96	1.23	0.65	7.45	6.46	0.40	0.78
NEPA Standard		-	*0.15–0.6*	-	*7 – 8.4*	-	-	*0.12-0.3*
WHO Guideline		-	-	-	-	-	-	-

Values in red are non-compliant with Standard/Guideline

Table 5-24 Chemical data for potable water station JWQ 12.

Station	Sample Date	Residual Chlorine (mg/l)	Nitrate (mg/l)	F.coliform (mpn/100ml)	Arsenic (mg/l)	Barium (mg/l)	Boron (mg/l)	Cadmium (mg/l)	Chromium (mg/l)
JWQ 12	July 9th	0.03	2.3	10	ND	0.077	ND	ND	ND
JWQ 12	July 22nd	0.56	2.4	69	ND	0.076	ND	ND	ND
JWQ 12	Aug. 7th	0.91	2.6	10	ND	0.078	ND	ND	ND
NEPA Standard		-	*0.1-7.5*	-	-	-	-	-	-
WHO Guideline		*0.2*	*50*	-	*0.01*	*0.7*	*0.5*	*0.003*	*0.05*
		Copper (mg/l)	Lead (mg/l)	Manganese (mg/l)	Nickel (mg/l)	Selenium (mg/l)	Mercury (mg/l)	Tot. Cyanide (mg/l)	Fluoride (mg/l)
JWQ 12	July 9th	0.013	ND	0.025	ND	ND	ND	ND	0.12
JWQ 12	July 22nd	0.02	ND	ND	ND	ND	ND	ND	0.11
JWQ 12	Aug. 7th	0.016	ND	ND	ND	ND	ND	ND	0.12
NEPA Standard		-	-	-	-	-	-	-	-
WHO Guideline		*2*	*0.01*	*0.4*	*0.07*	*0.01*	*0.006*	*0.07*	*1.5*

ND – None Detected

Values in red are non-compliant with Standard/Guideline

5.1.9.4 Comparison with 2012 Study

Physicochemical values were similar for the 2012 study and the current study. Station 1, located in the Bower's Gully, had lower salinity and conductivity values in 2012, ranging from 29.96 – 30.98 ppt and 46.11 – 47.49 mS/cm respectively. Average nitrate and phosphate concentrations were higher in the current study while FOG concentrations were slightly lower when compared to the 2012 study. In 2012, TPH (DRO) was detected at Station 3 (1.5mg/l) only, while no TPH was detected in any of the stations in the current 2014 study.

5.1.10 Sediments

5.1.10.1 Shoreline Sediments

Sediment Size

Surface sediment samples were recovered from the project area at two locations east of the SJPC proposed site. Two samples were collected from each location; one from the Beach front (BF) and the other from the back of the beach (BB). See Figure 5-59 below for the sediment sample location points. Grain size analysis of these samples was conducted and the results of this analysis are summarized in Figure 5-59 and Table 5-25.

Figure 5-59 Sediment grain size sampling locations

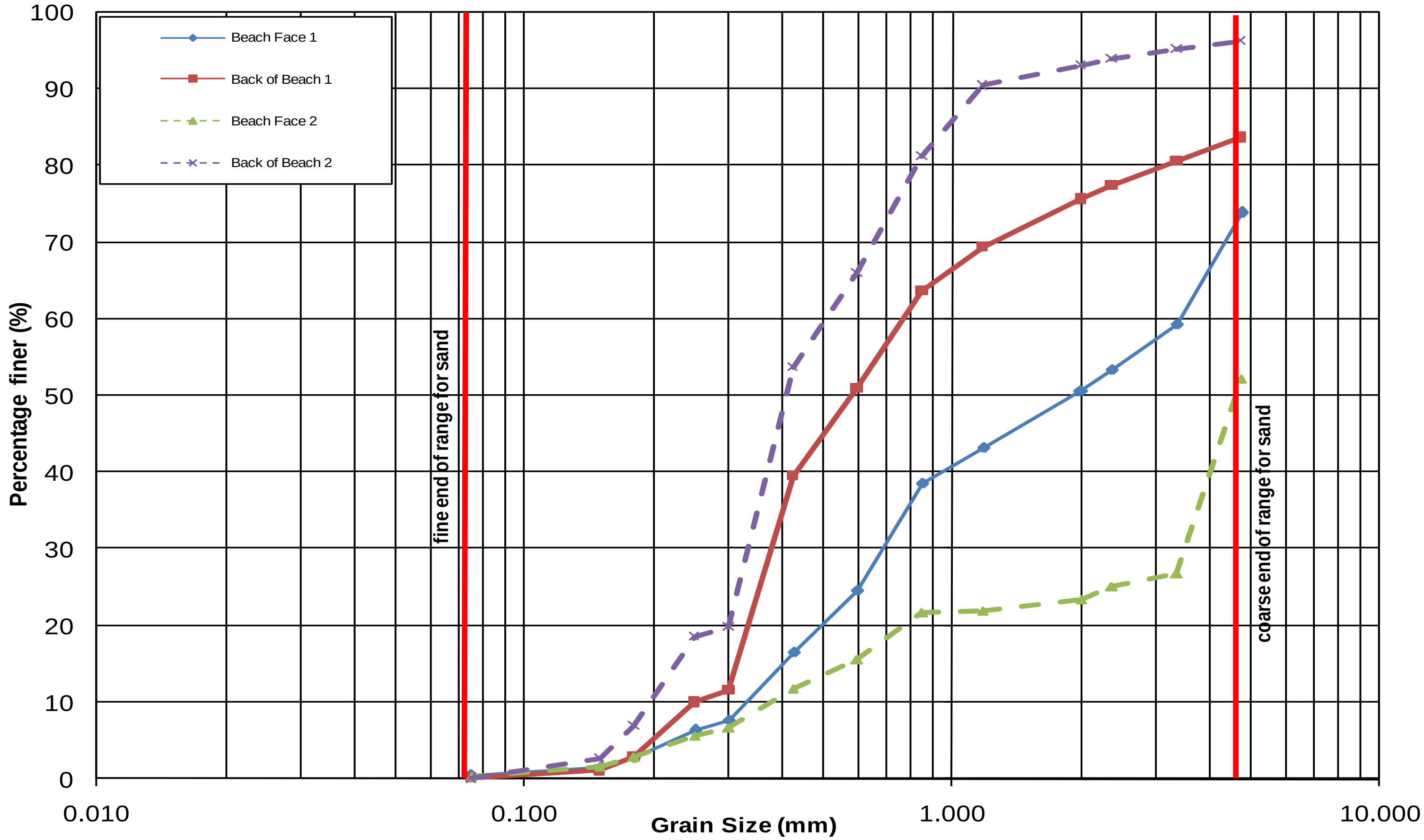


Figure 5-60 Sieve analysis results (graph).

Table 5-25 Sieve analysis results.

Sample ID		Beach Face 1	Back of Beach 1	Beach Face 2	Back of Beach 2
Mean (mm)		1.932	0.586	4.626	0.411
Mean (phi)		-0.950	0.771	-2.210	1.283
Description		very coarse sand	coarse sand	gravel	medium sand
Percentage silt		0.38%	0.13%	0.3%	0.0%
Percentage >0.06mm and <6.0 mm		73%	84%	52%	96%
Uniformity Coefficient		10.257	2.789	17.469	2.589
Standard Deviation		1.441	1.968	1.299	1.143
		poorly sorted	poorly sorted	poorly sorted	poorly sorted
Skewness		0.608	-0.152	2.616	0.986
		strongly positive skewed	negative skewed	V. strongly positive skewed	strongly positive skewed
Kurtosis		0.264	1.095	0.204	1.412
		extremely leptokurtic	mesokurtic	extremely leptokurtic	leptokurtic

The grain size analysis was done using the unified classification which is widely used for classification of granular material. The sand sizes vary from very coarse to coarse sand moving from the front of the beach to the back the beach at sample location one with grain sizes of 1.93mm to 0.586mm respectively. Sample location two had grain sizes varying from gravel to medium sand from the front of the beach to the back of the beach with median grain size of 4.626mm and 0.411mm respectively. The levels of silt present in the sands are consistent with what was observed on the beach, with sample location one having the highest concentration/percentage of silt.

Uniformity Coefficient

The uniformity coefficient is a measure of the variation in particle sizes. It is defined as the ratio of the size of particle that has 60 percent of the material finer than itself, to the size of the particle that has 10 percent finer than itself.

The uniformity coefficient is calculated as:

$$Uc = D60/D10$$

Where:

U_c – uniformity coefficient
D60 - The grain size, in mm, for which 60% by weight of a soil sample is finer
D10 - The grain size, in mm, for which 10% by weight of a soil sample is finer

Within the unified classification system, the sand is well graded if U_c is greater than or equal to 6. The samples collected from the front of the beach at both sample locations have well graded sand as the uniformity coefficients were greater than 6. The back of the beach had uniformity coefficient values of 2.8 and 2.6 for sample locations one and two respectively. This sand in this area is considered to be poorly graded.

Standard Deviation

The Standard deviation is a measure of the degree of sorting of the particles in the sample. A standard deviation of one or less defines a sample that is well sorted while values above one are poorly sorted.

The sand samples for the respective beaches are:

- Sample Location 1 (Beach Back- Poorly sorted)
- Sample Location 1 (Beach Front - Poorly sorted)
- Sample Location 2 (Beach Back- Poorly sorted)
- Sample Location 2 (Beach Front - Poorly sorted)

Skewness

Skewness describes the shift in the distribution about the normal. The skewness is described by the equation:

$$S = \frac{\phi 84 + \phi 16 - 2(\phi 50)}{2(\phi 84 - \phi 16)} + \frac{\phi 95 + \phi 5 - 2(\phi 50)}{2(\phi 95 - \phi 5)}$$

This formula simply averages the skewness obtained using the 16 phi and 84 phi points with the skewness obtained by using the 5 phi and 95 phi points, both determined by exactly the same principle. This is the best skewness measure to use because it determines the skewness of the "tails" of the curve, not just the central portion, and the "tails" are just where the most critical differences between samples lie. Furthermore, it is geometrically independent of the sorting of the sample.

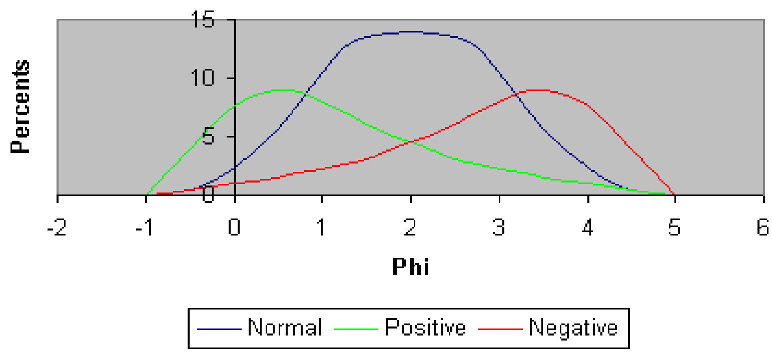


Figure 5-61 Skewness curves.

Symmetrical curves have skewness=0.00; those with excess fine material (a tail to the right) have positive skewness and those with excess coarse material (a tail to the left) have negative skewness. The more the skewness value departs from 0.00, the greater the degree of asymmetry. The limits on skewness are outlined in Table 5-26.

Table 5-26 Descriptive limits of skewness.

Values from:	Values to:	Mathematical Description	Graphical Skew
+1.00	+0.30	Strongly positive skewed	Very Negative phi values, coarse
+0.30	+0.10	Positive skewed	Negative phi values
+0.10	- 0.10	Near symmetrical	Symmetrical
- 0.10	- 0.30	Negative skewed	Positive phi values
- 0.30	- 1.00	Strongly negative skewed	Very Positive phi values, fine

The results for skewness for the stretch of shoreline can be summarized as follows:

- Sample Location one and two at the front of the beach along with sample location two back of the beach has a strong positive skewness ranging from 0.61 to 2.62. This is indicative excessive fine material and a moderated wave climate that does not wash out the fine sediment particles.

- Sample location one at the back of beach has negative skewness of -0.15. This is indicative of a long coarse tail of particles and an aggressive wave climate that washes out the fines particles.

Kurtosis

Kurtosis describes the degree of peakedness or departure from the "normal" frequency or cumulative curve. In the normal probability curve, defined by the Gaussian formula; the phi diameter interval between the 5 phi and 95 phi points should be exactly 2.44 times the phi diameter interval between the 25 phi and 75 phi points. If the sample curve plots as a straight line on probability paper (i.e., if it follows the normal curve), this ratio will be obeyed and we say it has normal kurtosis (1.00). Departure from a straight line will alter this ratio, and kurtosis is the quantitative measure used to describe this departure from normality. It measures the ratio between the sorting in the "tails" of the curve and the sorting in the central portion. If the central portion is better sorted than the tails, the curve is said to be excessively peaked or leptokurtic; if the tails are better sorted than the central portion, the curve is deficiently or flat-peaked and platykurtic.

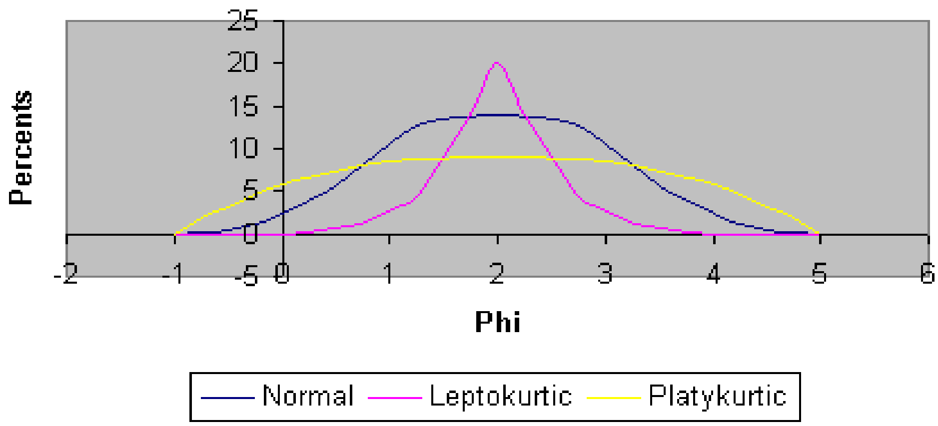


Figure 5-62 Kurtosis curves.

Strongly platykurtic curves are often bimodal with subequal amounts of the two modes; these plot out as a two-peaked frequency curve, with the sag in the middle of the two peaks accounting for its platykurtic character. For normal curves, kurtosis equals 1.00. Leptokurtic curves have a kurtosis over 1.00 (for example a curve with kurtosis=2.00 has exactly twice as large a spread in the tails as it should have, hence it is less well sorted in the tails than in the central portion); and platykurtic have kurtosis under 1.00. Kurtosis involves a ratio of spreads; hence it is a pure number and should not be written with a phi attached.

Table 5-27 Descriptive limits of kurtosis.

Values from	To	Equal
0.41	0.67	very platykurtic
0.67	0.90	platykurtic
0.90	1.11	mesokurtic
1.10	1.50	leptokurtic
1.50	3.00	very leptokurtic
3.00	∞	extremely leptokurtic

A similar trend was observed in the Kurtosis analysis as was observed in the skewness analysis. The following is a summary:

- Sample location two front and back of beach sediment is leptokurtic to extremely leptokurtic and sample location one of beach is extremely leptokurtic. This is indicative of aggressive coastal processes that sort out the particles into a discrete particle size.
- Sample location one back of beach is mesokurtic. This is indicative of mild to moderate sediment transport processes.

5.1.10.2 Marine Benthic Sediments

Method

Sediment sampling was conducted on July 22nd, 2014. Five (5) sediment samples were taken using a sediment grab sampler, and analysed for the heavy metals (Pb - lead, As - Arsenic, Cd - Cadmium, Hg-Mercury) and Total Petroleum Hydrocarbons (DRO and GRO). The sediment sampling locations are shown in Table 5-28 and depicted in Figure 5-63. The samples were stored on ice in a cooler and transported to Test America Pensacola Laboratory in Florida for analyses.

Table 5-28 Sediment sampling stations in JAD2001 with corresponding water quality stations

SEDIMENT SAMPLING STATION	NORTHING	EASTING
JP Soil 1	637939.98	736562.72
JP Soil 2	638212.01	736685.40
JP Soil 3	637345.73	737652.15
JP Soil 4	637940.01	737698.80
JP Soil 5	637182.43	739350.31

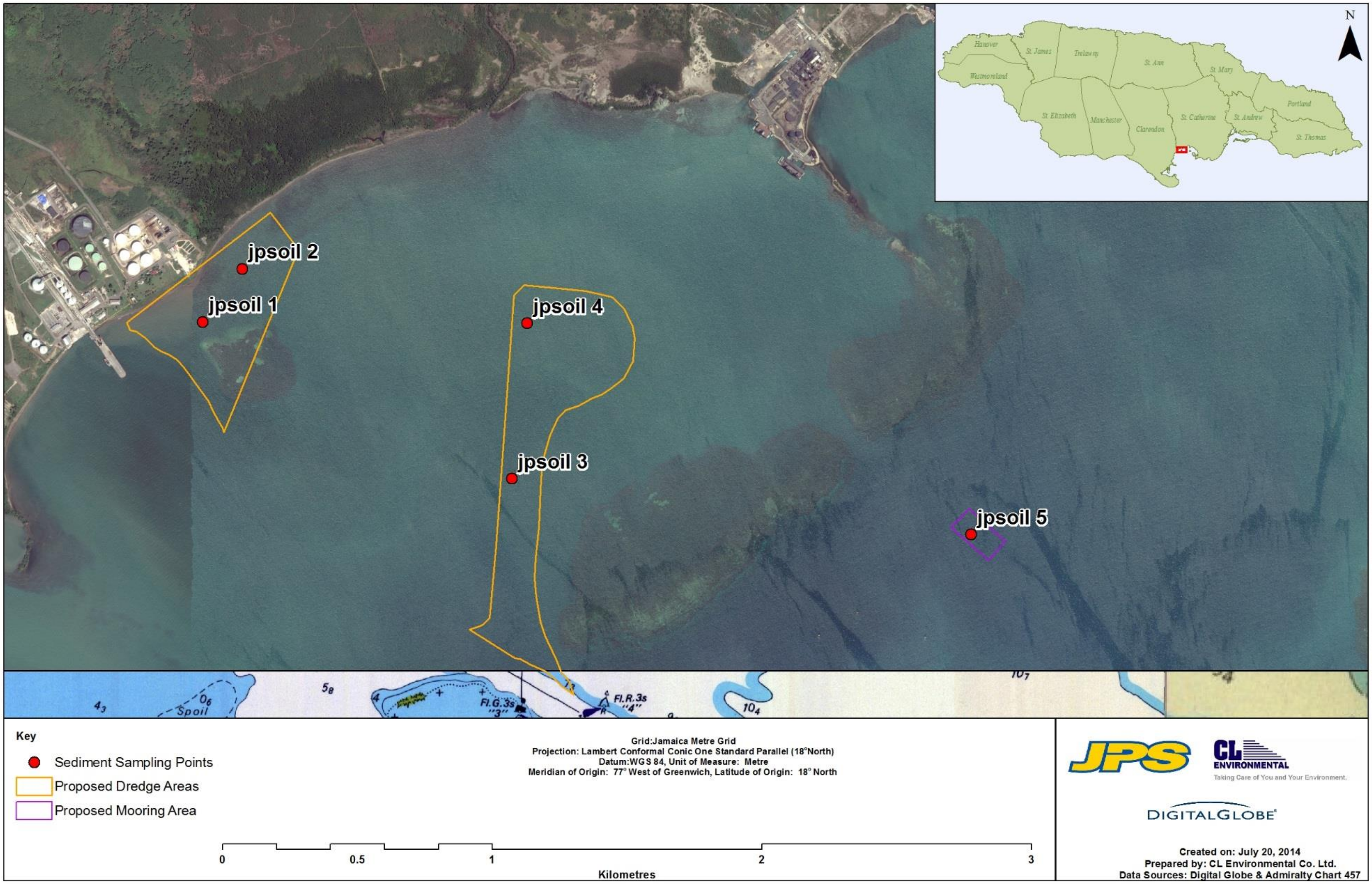


Figure 5-63 Map showing sediment sampling locations

Results

Table 5-29 displays the sediment sampling results for various parameters at the various sampling locations. Arsenic values were similar throughout stations, ranging from a low of 5.9 mg/kg at Station 2 to a high of 8.9 mg/kg at Station 3. Lead values were similar throughout the stations with Stations 1, 2 and 3 have concentrations of 11 mg/kg each, with a low of 8.4 mg/kg at Station 5 and a high of 12 mg/kg at Station 4. Mercury values also varied slightly amongst the stations, with Station 2 having a low of 0.088 mg/kg and Station 5 having a high of 0.18 mg/kg. No cadmium, GRO or DRO were detected in any of the samples taken. When compared to the average levels found in Jamaican Soils (Table 5-30), all values were below reported averages.

Table 5-29 Marine Sediment results

Stn	Arsenic (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	GRO (mg/kg)	DRO (mg/kg)
JPSoil 1	7	ND	11	0.1	ND	ND
JPSoil 2	5.9	ND	11	0.088	ND	ND
JPSoil 3	8.9	ND	11	0.14	ND	ND
JPSoil 4	6.7	ND	12	0.11	ND	ND
JPSoil 5	7.4	ND	8.4	0.18	ND	ND

ND – None Detected

Table 5-30 Heavy Metal Concentrations in Jamaican Soils

Metal	Average Conc. (mg/KG)	Range (mg/Kg)	95th Percentile (mg/KG)
Arsenic	25	1.4-203	<64.9
Cadmium	20	0.2-409	<77.6
Lead	46.5	6-897	<90
Mercury	0.2	0.04-0.83	<0.46

Source: A Geochemical Atlas of Jamaica, Centre for Nuclear Sciences, UWI, 1995, Canoe Press.

Comparison with other Sites

The heavy metal concentrations are within the average soil concentrations in Jamaica as listed in the Soil Atlas of Jamaica and had lower concentrations when compared with sediment concentrations at three other marine areas around Jamaica (Table 5-31). Comparison with other international ports and harbours has also shown that the concentrations obtained in Old Harbour 190 MW were below those obtained at the other locations (Table 5-32). Total Petroleum Hydrocarbon (TPH) is not considered a heavy metal, however, the concentrations obtained in Old Harbour 190 MW were in compliance with the NRCA standard of 1000 mg/KG.

Table 5-31 Heavy metal concentrations at various sites in Jamaica and worldwide

METAL	NEGRIL	OLD HARBOUR 360 MW	PALISADOES CARIBBEAN SEA SIDE	GEOCHEMICAL ATLAS OF JAMAICA	COMMERCIAL PORTS SAMOA	FISIHING PORTS SAMOA	EAST LONDON HARBOUR	PORT ELIZABETH HARBOUR
Arsenic (As) (mg/KG)	1.1 – 4.5	6.50 – 8.67	9.1 - 14	25				
Cadmium (Cd) (mg/KG)	ND	ND	ND	20			0.3 – 0.7	0.3 – 1.2
Lead (Pb) (mg/KG)	0.93 – 4.0	9.77 – 13.33	0.74 – 5.1	46.5	1,230 – 2,820	790 – 2,030	11.3 – 36.8	15.4 - 44
Mercury (Hg) (mg/KG)	ND	0.04 – 0.05	ND	0.2				
TPH (mg/KG)	140 - 1100	11 – 68.67	ND					

Table 5-32 Heavy metal concentration (mg/g) in the sediment from the different regions of the world

Rivers	Cu	Pb	Reference
This study	0.97-3.82	1.23-2.82	
Cochin estuary, India	53.15	71.28	Balachandran *et al.* (2005)[16]
Jurujuba sound, Brazil	51.0	61.0	Baptista Neto *et al.* (2000)[17]
Tolo harbour, Hong Kong	84.0	144.0	Owen and Sandhu, (2000)[18]
Izmit Bay, Turkey	67.6	102.0	Pekey (2006)[19]
Koahsiung Harbour, Taiwan	5-946	9.5-470	Chen *et al.* (2004)[20]
Eastern Harbour, Egypt	14.09	-	Abdallah and Abdallah (2007)[21]
River Ganga, India	0.09	-	Singh *et al.* (2012)[22]
Mudflat of Salinas de San Pedro Lagoon, California, USA	0.085 - 0.47	0.05 - 0.38	Mohammad H.R *et al.* (2013)[23]

Source: Imo T et al. 2014

5.1.11 Noise

5.1.11.1 Introduction

This report entails the results derived from the noise survey conducted for twenty four (24) hours between 7:00 hrs Tuesday 11th, to 7:00 hrs Wednesday 12th, November 2014. Noise sampling stations from the 2012 Environmental Impact Assessment (EIA) that were also assessed for this EIA were:

- Blackwood Gardens
- Old Harbour Bay Police Station
- Longville Park Housing Scheme

5.1.11.2 Methodology

A data logging noise survey exercise was conducted to establish baseline conditions along the proposed boundaries of the power plant and its environs. The data logging exercise was conducted for twenty four (24) hours between 7:00 hrs Tuesday 11th, to 7:00 hrs Wednesday 12th, November 2014. The readings were taken at nine (9) locations (Stations N1 – N9) listed in Table 5-33 and depicted in Figure 5-64.

Noise level readings were taken by using Quest Technologies SoundPro DL Type 1 hand held sound level meters with real time frequency analyser setup in outdoor monitoring kits. The octave band analysis was conducted concurrently with the noise level measurements. Measurements were taken in the third octave which provided thirty three (33) octave bands from 12.5 Hz to 20 kHz (low, medium and high frequency bands). The noise meters were calibrated pre and post noise assessment by using a Quest QC - 10 sound calibrator (Appendix 6). The meters were programmed using the Quest suite Professional II (QSP II) software to collect third octave, average sound level (Leq) over the period, Lmin (The lowest level measured during the assessment) and Lmax (The highest level measured during the assessment) every ten (10) seconds.

Average noise levels over the period were calculated within the QSP II software using the formula:

$$\textit{Average dBA} = 20 \log 1/N \sum_{j=1}^{N} 10^{(Lj/20)}$$

Where N = number of measurements, Lj = the jth sound level and j = 1, 2, 3 .... N.

A windscreen (sponge) was placed over the microphone to prevent measurement errors due to noise caused by wind blowing across the microphone. Plate 5-2 shows a photo of the noise meter setup.

Table 5-33 Station numbers and locations in JAD2001

STATIONS	LOCATIONS	JAD 2001 (m)	
		E	N
N1	North-Western Property Boundary	638937.99	738508.72
N2	South-Western Property Boundary	638860.04	738486.45

STATIONS	LOCATIONS	JAD 2001 (m)	
		E	N
N3	South-Eastern Property Boundary	638884.88	738573.82
N4	North-Eastern Property Boundary	638979.11	738614.94
N5	Informal Settlement Area	639265.58	738505.24
N6	Blackwood Garden Housing Scheme	738916.05	639430.47
N7	Old Harbour Bay Police Station	639705.67	739747.33
N8	New Harbour Village Phase II Housing Scheme	640820.15	738540.52
N9	Longville Park Housing Scheme	639734.29	733211.19

Plate 5-2 Example of noise meter setup

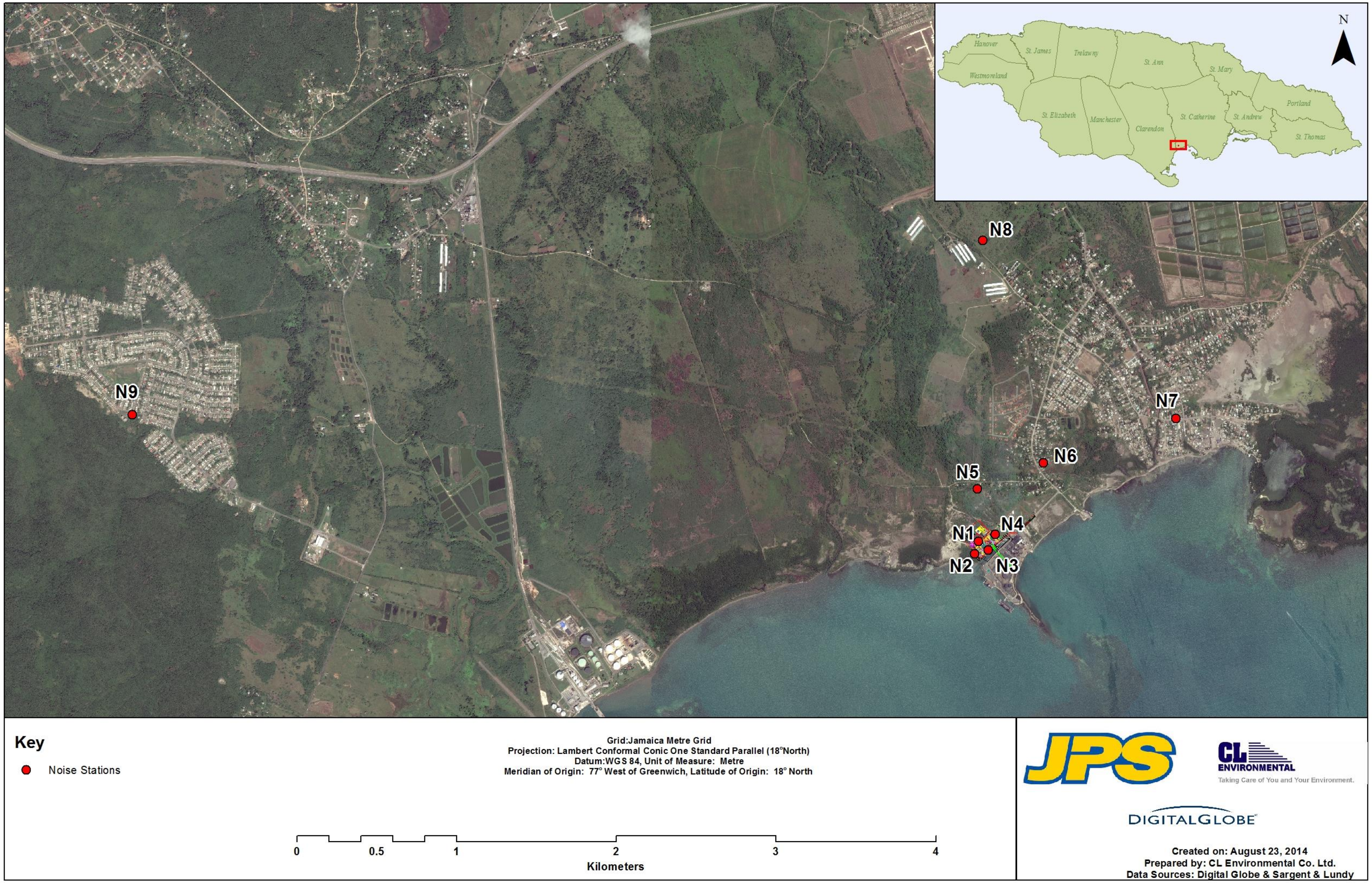


Figure 5-64 Locations of noise survey stations

5.1.11.3 Results

This section outlines the results of the twenty four (24) hour noise monitoring exercise at the nine (9) monitoring stations.

Station N1

During the 24-hour period, noise levels at this station ranged from a low (Lmin) of 54.2 dBA to a high (Lmax) of 84.3 dBA. Average noise level for this period was 64.9L_{Aeq} (24h). The fluctuation in noise levels over the 24 hour period is depicted in Figure 5-65.

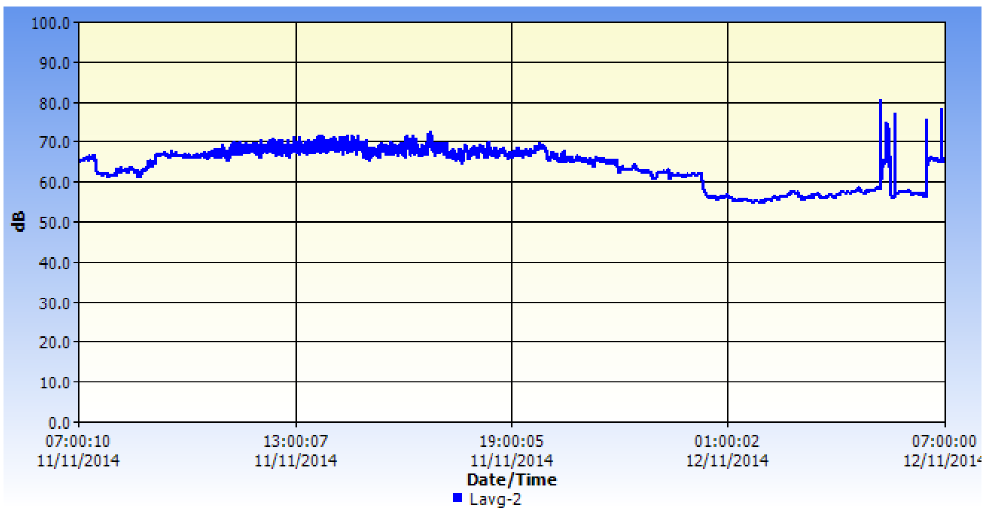


Figure 5-65 Noise fluctuation (Leq) over 24 hours at Station 1

OCTAVE BAND ANALYSIS AT STATION 1

The noise at this station during the 24 hour period was in the low frequency band centred around the geometric mean frequency of 50 Hz (octave frequency range is 45 - 56 Hz) (Figure 5-66).

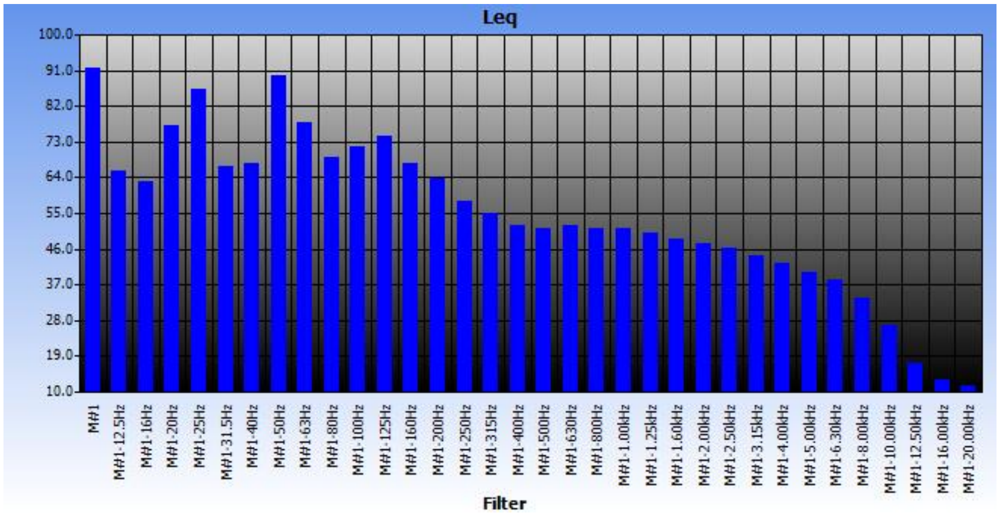


Figure 5-66 Octave band spectrum of noise at Station N1

L10 AND L90 – N1

The two most common **L_n** values used are **L_{10}** and **L_{90}** and these are sometimes called the 'annoyance level' and 'background level' respectively. **L_{10}** is almost the only statistical value used for the descriptor of the higher levels, but **L_{90}**, is widely used to describe the ambient or background level. L10-L90 is often used to give a quantitative measure as to the spread or "how choppy" the sound was.

L10 is the noise level exceeded for 10% of the time of the measurement duration. This is often used to give an indication of the upper limit of fluctuating noise, such as that from road traffic. L90 is the noise level exceeded for 90% of the time of the measurement duration.

The difference between L10 and L90 gives an indication of the noise climate. When the difference is < 5 dBA then it is considered that there are no significant fluctuations in the noise climate, moderate fluctuations 5-15 dBA and large fluctuations >15 dBA.

Figure 5-67 depicts the hourly L10 and L 90 statistics for this station over the noise assessment period. The data shows no significant fluctuations (L10 – L90) ≈ 91.67% of the time and moderate fluctuations (L10 – L90) ≈8.33% of the time in the noise climate at this station.

The overall L10 and L 90 at this station for the time assessed were 68.6 dBA and 56.1 dBA respectively.

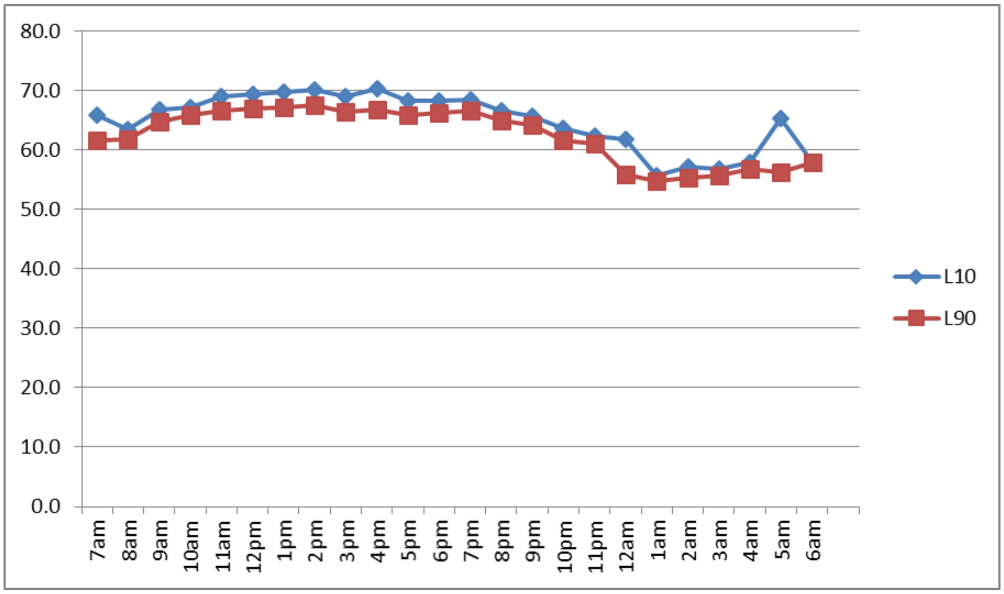


Figure 5-67 L10 and L90 for Station 1

Station N2

During the 24-hour period, noise levels at this station ranged from a low (Lmin) of 51 dBA to a high (Lmax) of 87.5 dBA. Average noise level for this period was 60.7 L_{Aeq} (24h). The fluctuation in noise levels over the 24 hour period is depicted in Figure 5-68.

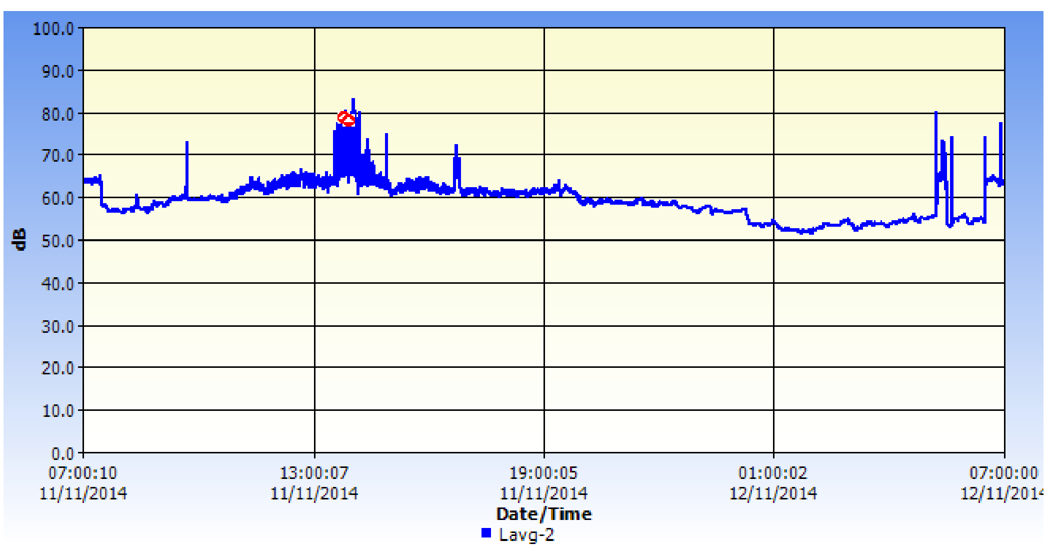


Figure 5-68 Noise fluctuation (Leq) over 24 hours at Station 2

OCTAVE BAND ANALYSIS AT STATION N2

The noise at this station during the 24 hour period was in the low frequency band centred around the geometric mean frequency of 25 Hz (octave frequency range is 22 - 28Hz) (Figure 5-69).

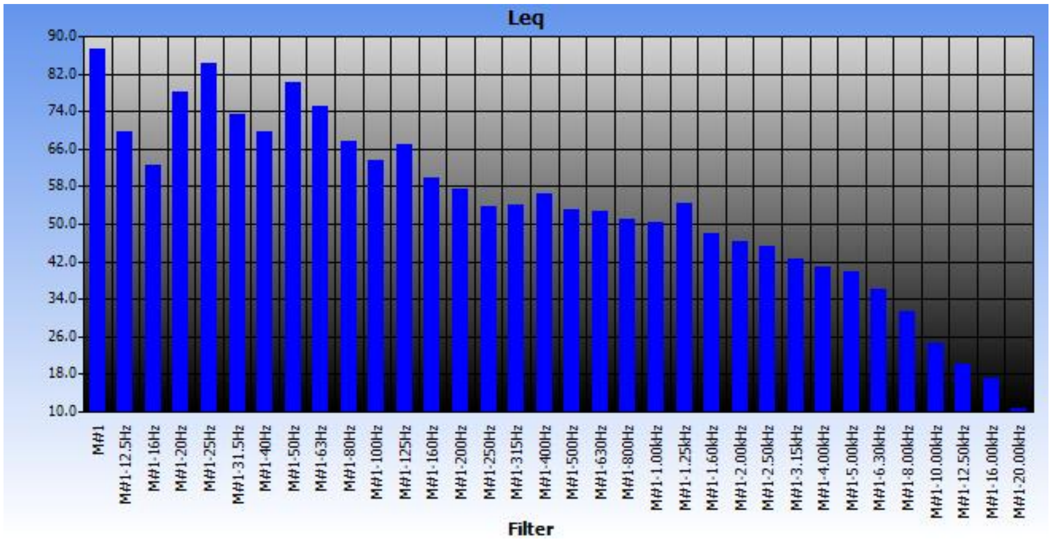


Figure 5-69 Octave band spectrum of noise at Station 2

L10 AND L90 – STATION N2

Figure 5-70 depicts the hourly L10 and L 90 statistics for this station over the noise assessment period. The data shows no significant fluctuations in the noise climate (L10 – L90) ≈83.3% of the time and moderate fluctuations (L10 – L90) ≈16.7 of the time in the noise climate at this station.

The overall L10 and L 90 at this station for the time assessed were 63.7 dBA and 53.4 dBA respectively.

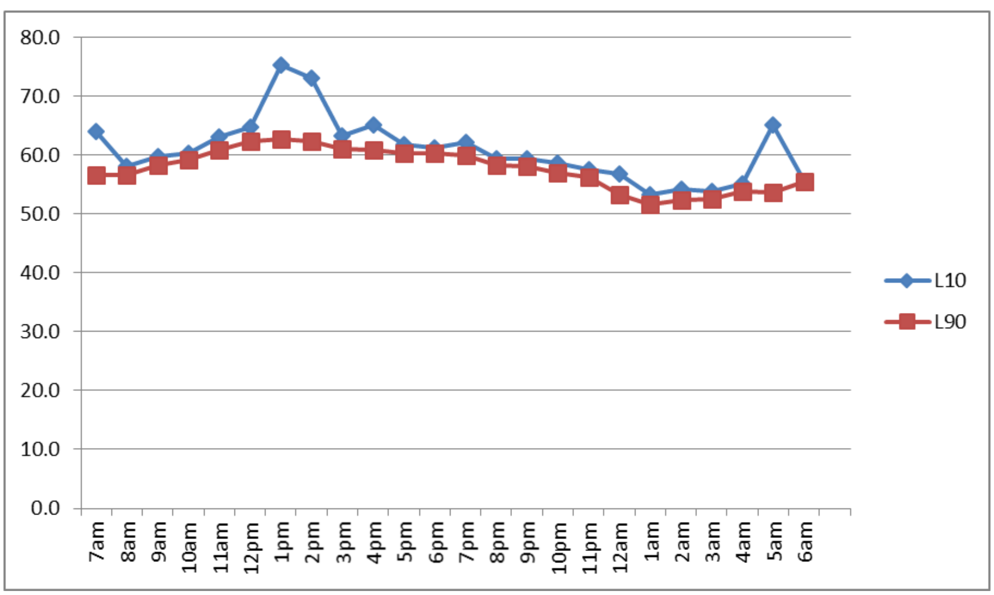


Figure 5-70 L10 and L90 for Station 2

Station N3

During the 24-hour period, noise levels at this station ranged from a low (Lmin) of 53.8 dBA to a high (Lmax) of 82.5 dBA. Average noise level for this period was 62.3 LAeq (24h). The fluctuation in noise levels over the 24 hour period is depicted in Figure 5-71.

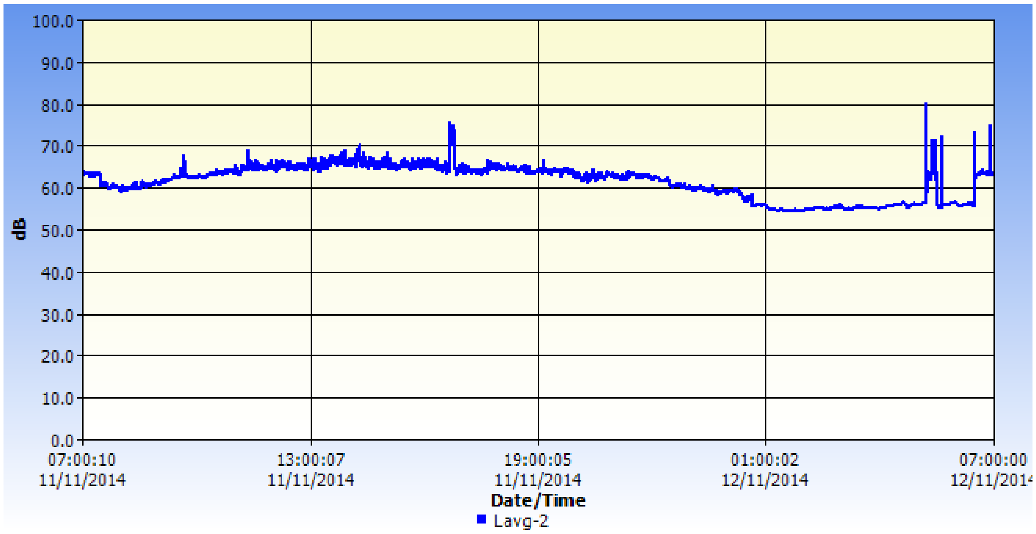


Figure 5-71 Noise fluctuation (Leq) over 24 hours at Station 3

OCTAVE BAND ANALYSIS AT STATION 3

The noise at this station during the 24 hour period was in the low frequency band centred around the geometric mean frequency of 25 Hz (octave frequency range is 22 - 28 Hz) (Figure 5-72).

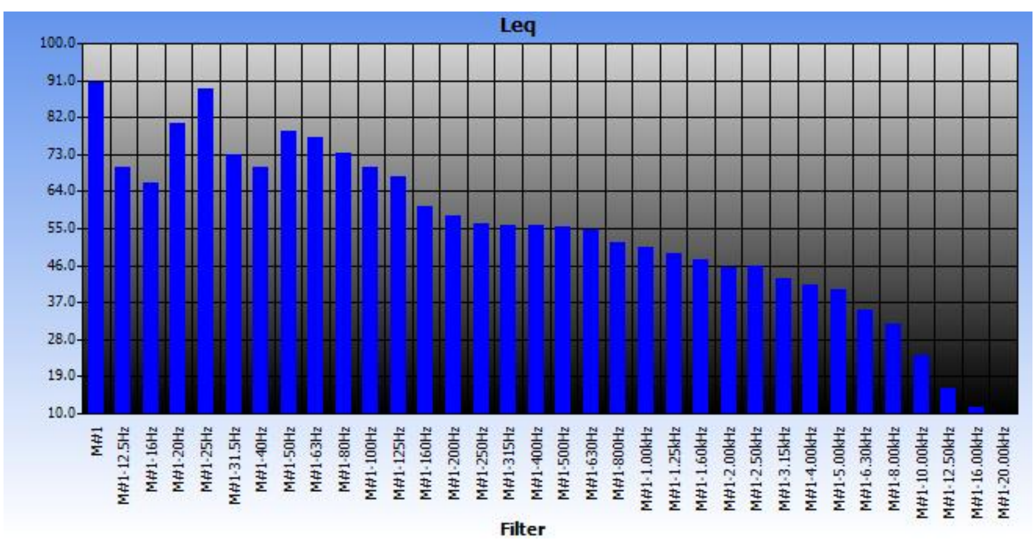


Figure 5-72 Octave band spectrum of noise at Station 3

L10 AND L90 – STATION N3

Figure 5-73 the noise assessment period. The data shows no significant fluctuations in the noise climate (L10 – L90) ≈91.67% of the time and moderate fluctuations (L10 – L90) ≈8.33% of the time in the noise climate at this station.

The overall L10 and L 90 at this station for the time assessed were 65.4 dBA and 55.1 dBA respectively.

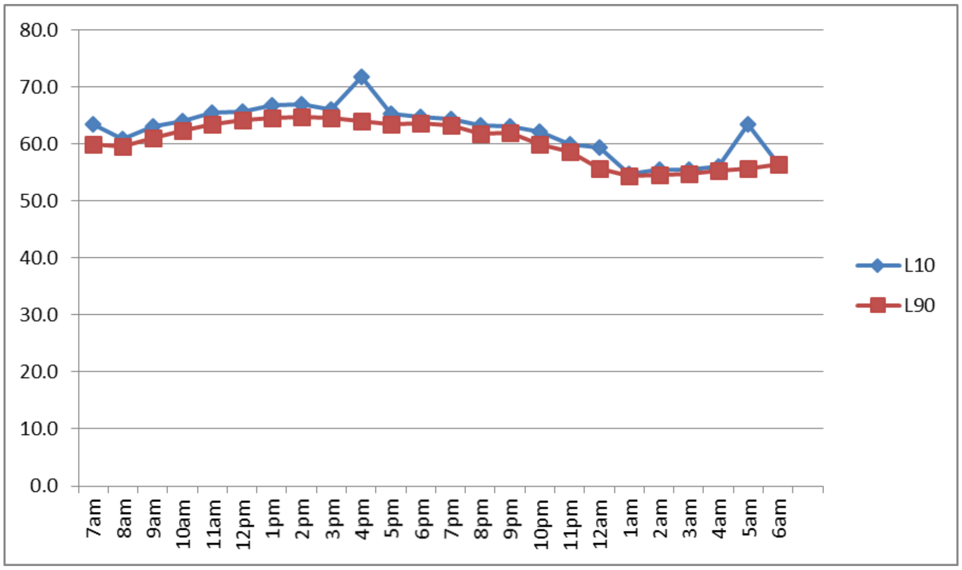


Figure 5-73 L10 and L90 for Station 3

Station N4

During the 24-hour period, noise levels at this station ranged from a low (Lmin) of 56.7 dBA to a high (Lmax) of 87.7 dBA. Average noise level for this period was 61.8 L_{Aeq} (24h). The fluctuation in noise levels over the 24 hour period is depicted in Figure 5-74.

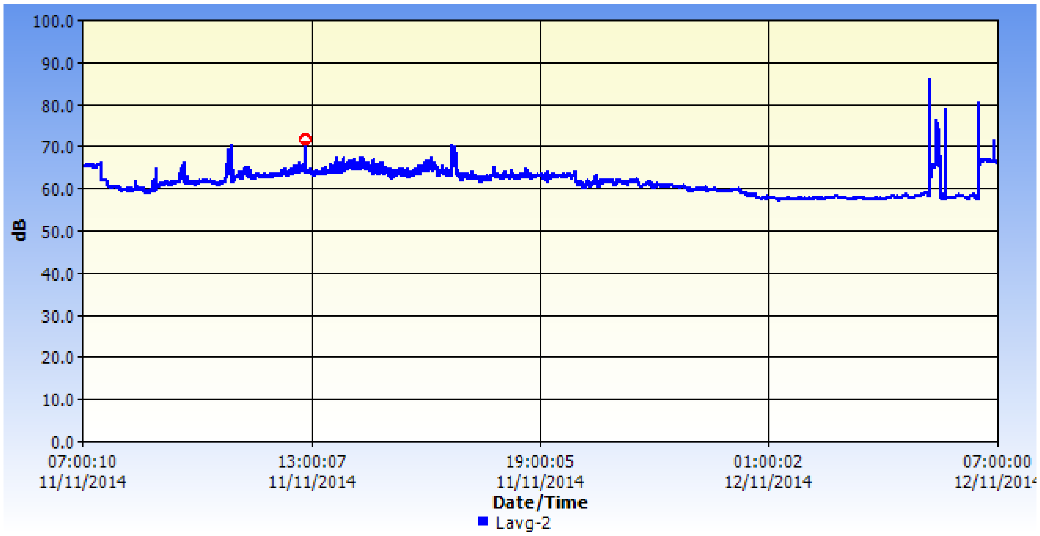


Figure 5-74 Noise fluctuation (Leq) over 24 hours at Station 4

OCTAVE BAND ANALYSIS AT STATION 4

The noise at this station during the 24 hour period was in the low frequency band centred around the geometric mean frequency of 25 Hz (octave frequency range is 22 - 28 Hz) (Figure 5-75).

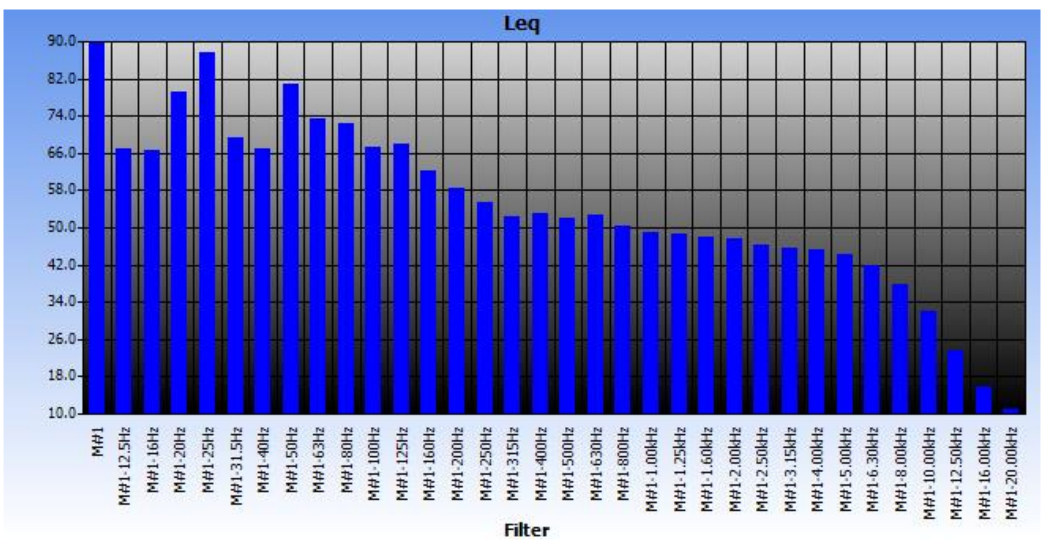


Figure 5-75 Octave band spectrum of noise at Station 4

L10 AND L90 – STATION N4

Figure 5-76 depicts the hourly L10 and L 90 statistics for this station over the noise assessment period. The data shows no significant fluctuations in the noise climate (L10 – L90) ≈91.67% of the time and moderate fluctuations in the noise climate (L10 – L90) ≈8.33% of the in the noise climate at this station.

The overall L10 and L 90 at this station for the time assessed were 64.7 dBA and 57.6 dBA respectively.

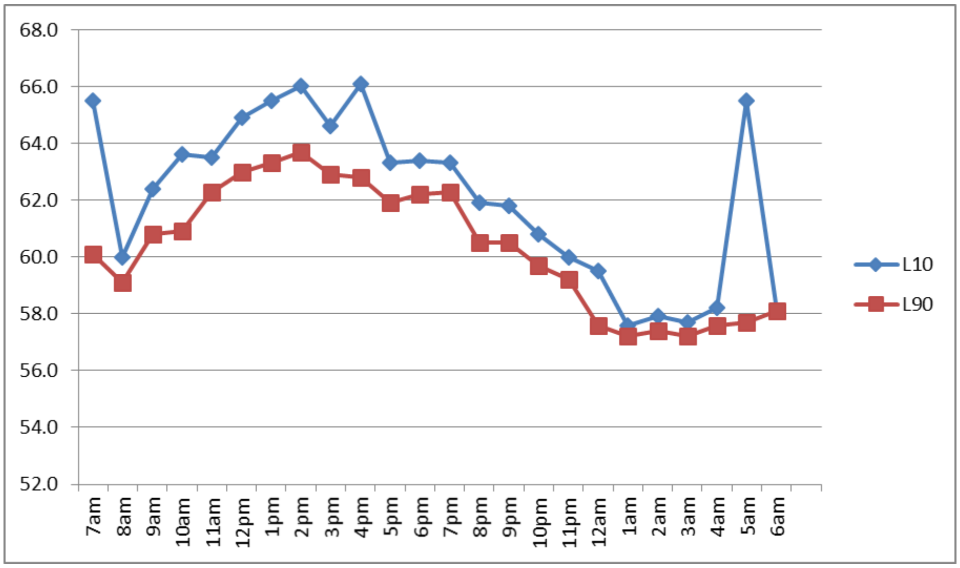


Figure 5-76 L10 and L90 for Station 4

Station N5

During the 24-hour period, noise levels at this station ranged from a low (Lmin) of 34.4 dBA to a high (Lmax) of 90.4 dBA. Average noise level for this period was 50.7 L_{Aeq} (24h). The fluctuation in noise levels over the 24 hour period is depicted in Figure 5-77.

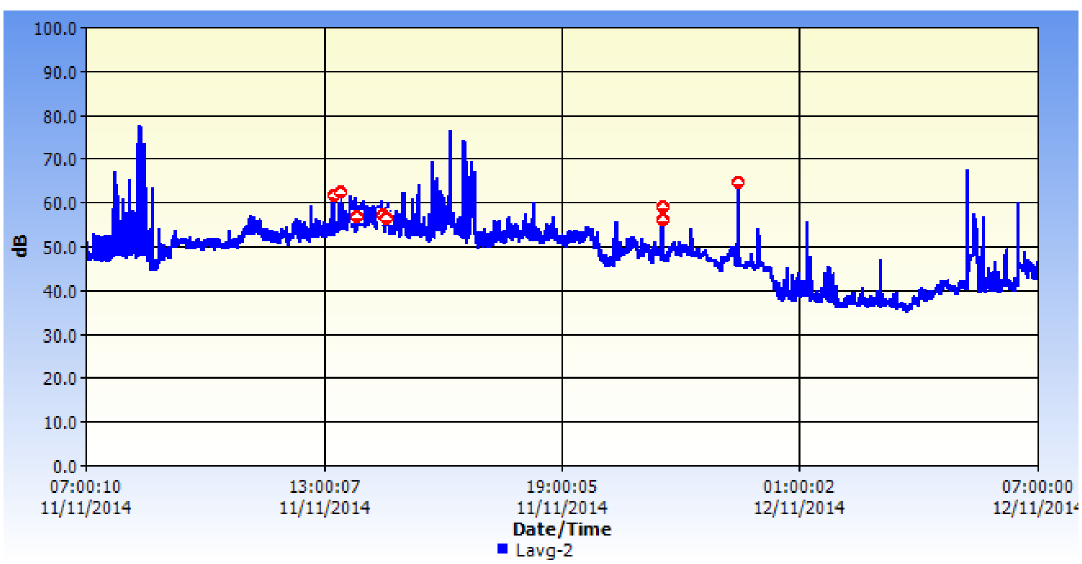


Figure 5-77 Noise fluctuation (Leq) over 24 hours at Station 5

OCTAVE BAND ANALYSIS AT STATION 5

The noise at this station during the 24 hour period was in the low frequency band centred around the geometric mean frequency of 25 Hz (octave frequency range is 22 - 28 Hz) (Figure 5-78).

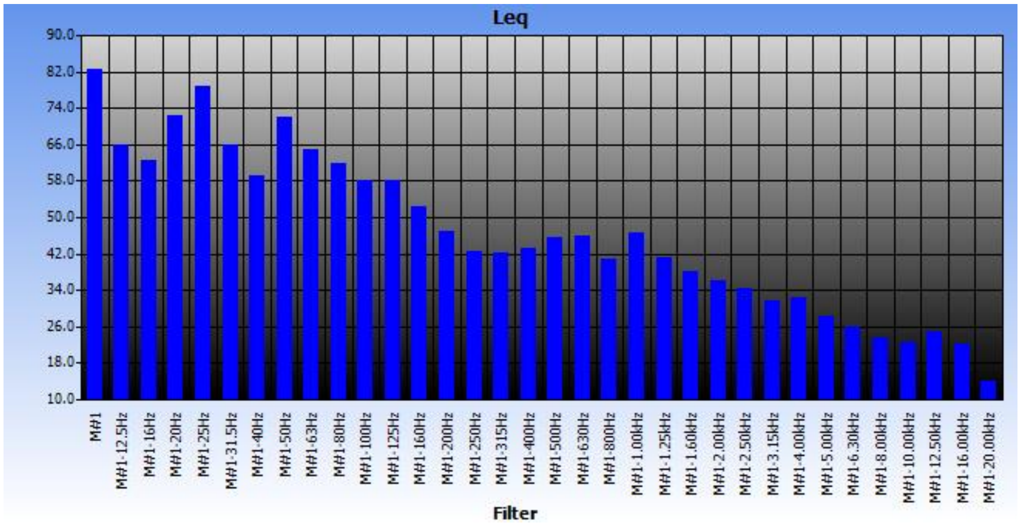


Figure 5-78 Octave band spectrum of noise at Station 5

L10 AND L90 – STATION N5

Figure 5-79 depicts the hourly L10 and L 90 statistics for this station over the noise assessment period. The data shows no significant fluctuations in the noise climate (L10 – L90) ≈75% of the time and moderate fluctuations (L10 – L90) ≈25% of the time in the noise climate at this station. The overall L10 and L90 at this station for the time assessed were 55.1 dBA and 37.9 dBA respectively.

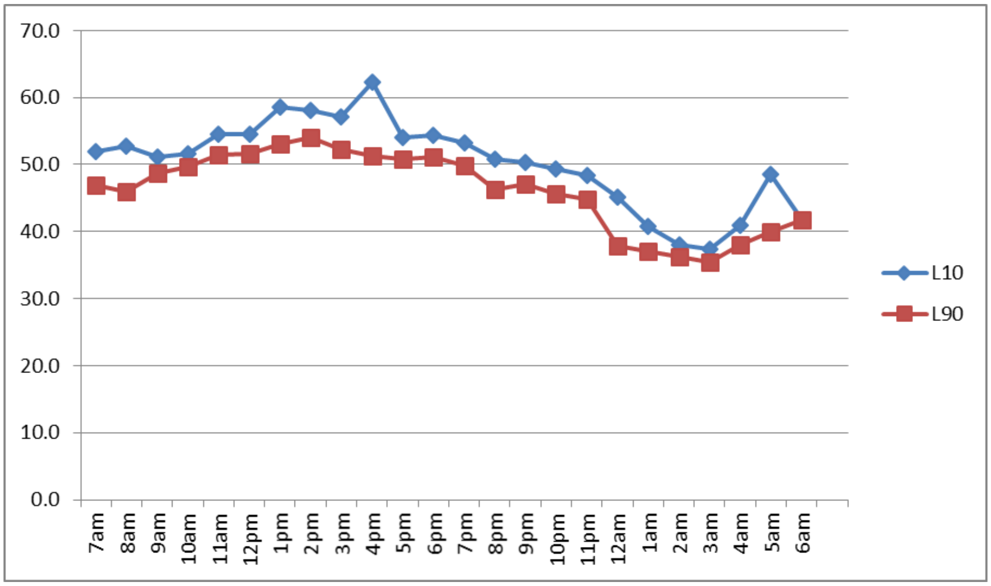


Figure 5-79 L10 and L90 for Station 5

Station N6

During the 24-hour period, noise levels at this station ranged from a low (Lmin) of 32.2 dBA to a high (Lmax) of 85.8 dBA. Average noise level for this period was 48.3 L_{Aeq} (24h). The fluctuation in noise levels over the 24 hour period is depicted in Figure 5-80.

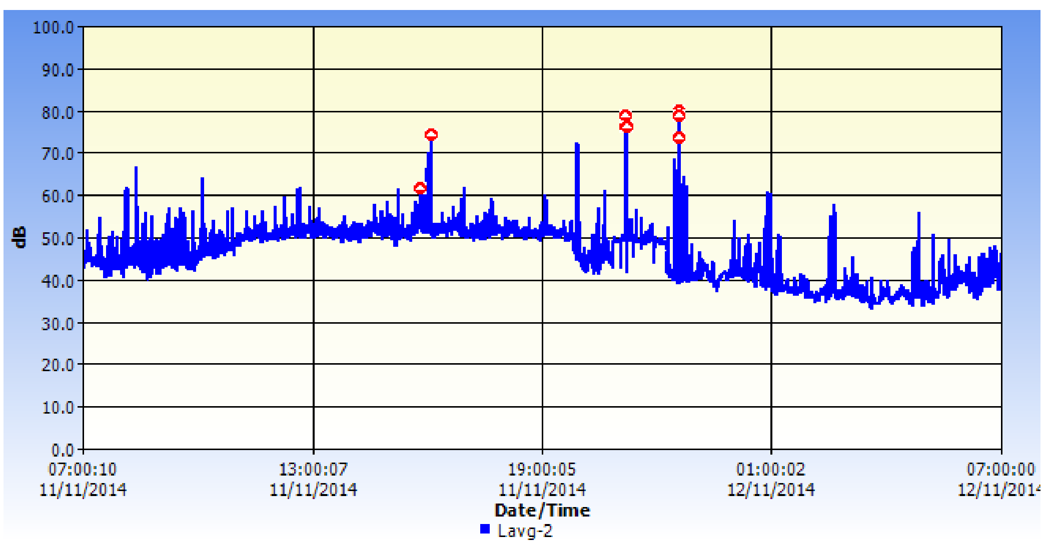


Figure 5-80 Noise fluctuation (Leq) over 24 hours at Station 6

OCTAVE BAND ANALYSIS AT STATION 6

The noise at this station during the 24 hour period was in the low frequency band centred around the geometric mean frequency of 50 Hz (octave frequency range is 45 - 56 Hz) (Figure 5-81).

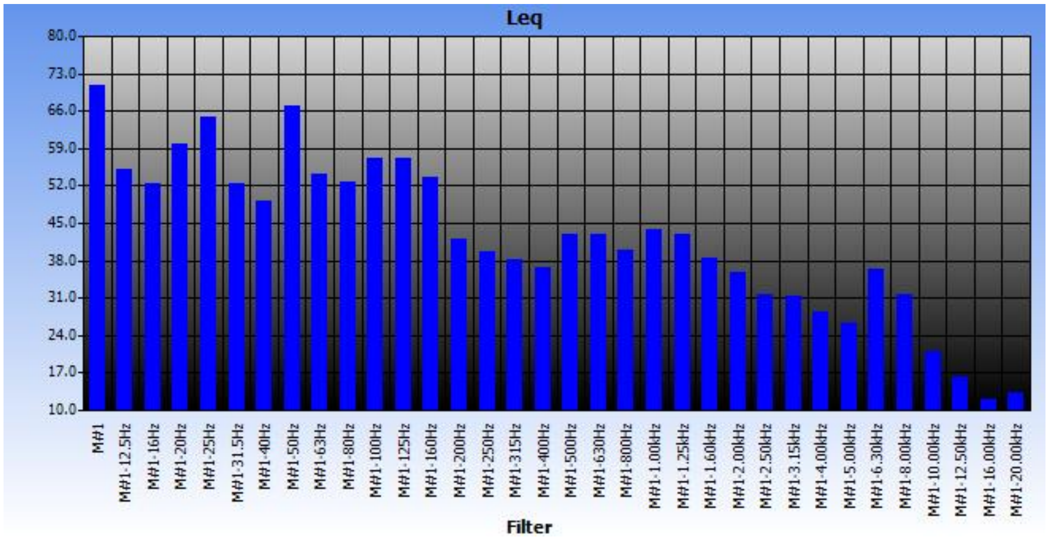


Figure 5-81 Octave band spectrum of noise at Station 6

L10 AND L90 – STATION N6

Figure 5-82 depicts the hourly L10 and L 90 statistics for this station over the noise assessment period. The data shows moderate fluctuations (L10 – L90) ≈33.33% of the time and no significant fluctuations in the noise climate (L10 – L90) ≈66.67% of the time in the noise climate at this station.

The overall L10 and L 90 at this station for the time assessed were 52.2 dBA and 36.6 dBA respectively.

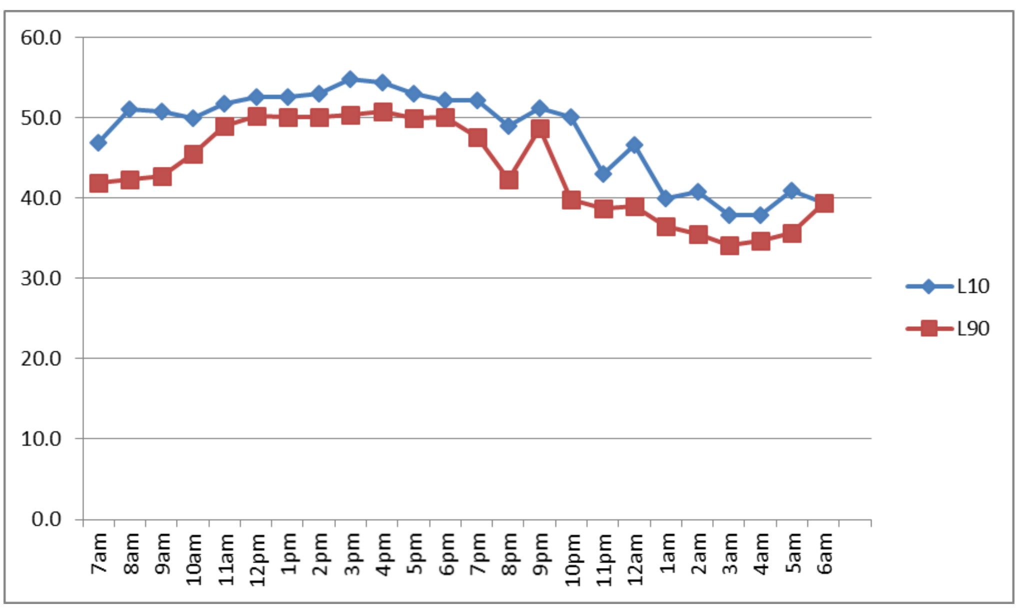


Figure 5-82 L10 and L90 for Station 6

Station N7

During the 24-hour period, noise levels at this station ranged from a low (Lmin) of 30.8 dBA to a high (Lmax) of 86 dBA. Average noise level for this period was 51.7 L_{Aeq} (24h). The fluctuation in noise levels over the 24 hour period is depicted in Figure 5-83.

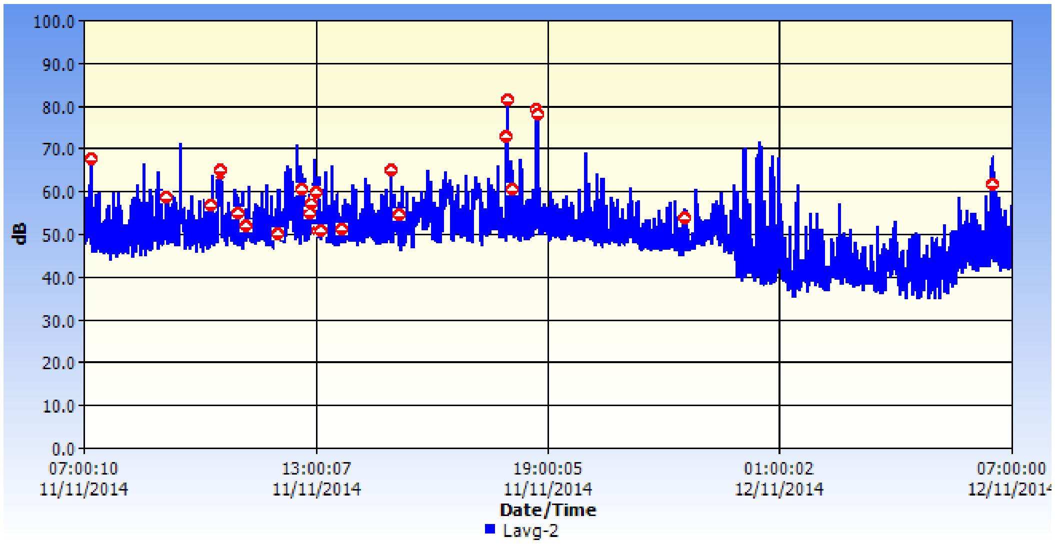


Figure 5-83 Noise fluctuation (Leq) over 24 hours at Station 7

OCTAVE BAND ANALYSIS AT STATION 7

The noise at this station during the 24 hour period was in the low frequency band centred around the geometric mean frequency of 25 Hz (octave frequency range is 22 - 28 Hz) (Figure 5-84).

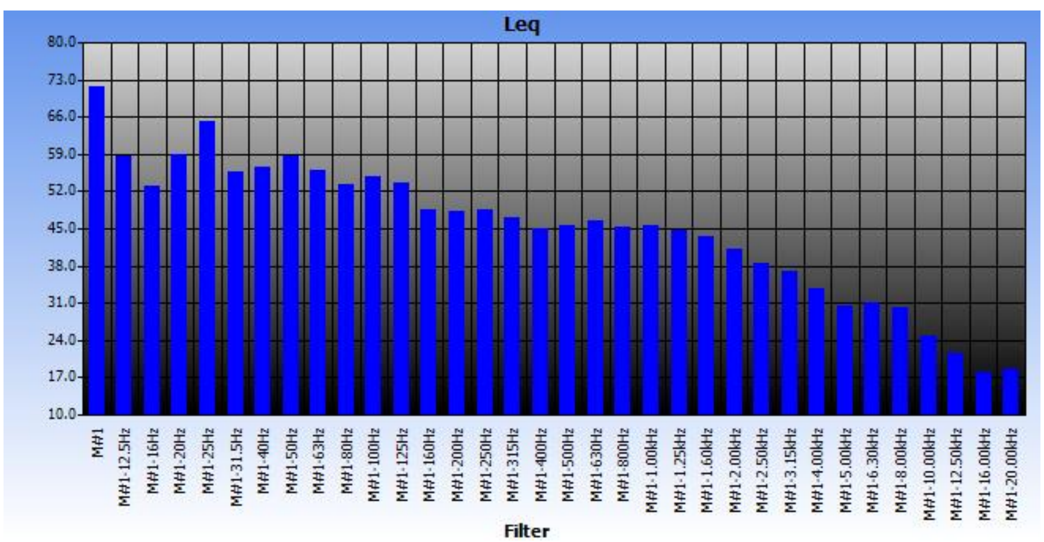


Figure 5-84 Octave band spectrum of noise at Station 7

L10 AND L90 – STATION N7

Figure 5-85 depicts the hourly L10 and L 90 statistics for this station over the noise assessment period. The data shows moderate fluctuations in the noise climate (L10 – L90) ≈87.5% of the time, no significant fluctuations in the noise climate (L10 – L90) ≈8.3% of the time and large fluctuations (L10 – L90) ≈4.2% of the time in the noise climate at this station.

The overall L10 and L 90 at this station for the time assessed were 56.0 dBA and 40.9 dBA respectively.

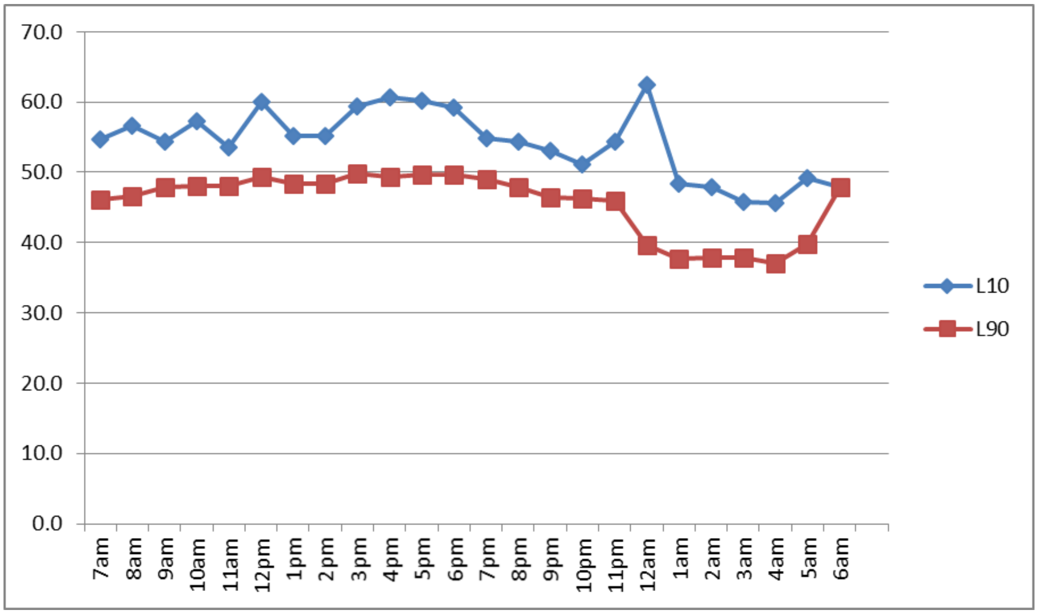


Figure 5-85 L10 and L90 for Station 7

Station N8

During the 24-hour period, noise levels at this station ranged from a low (Lmin) of 32.2 dBA to a high (Lmax) of 75.8 dBA. Average noise level for this period was 42.6 L_{Aeq} (24h). The fluctuation in noise levels over the 24 hour period is depicted in Figure 5-86.

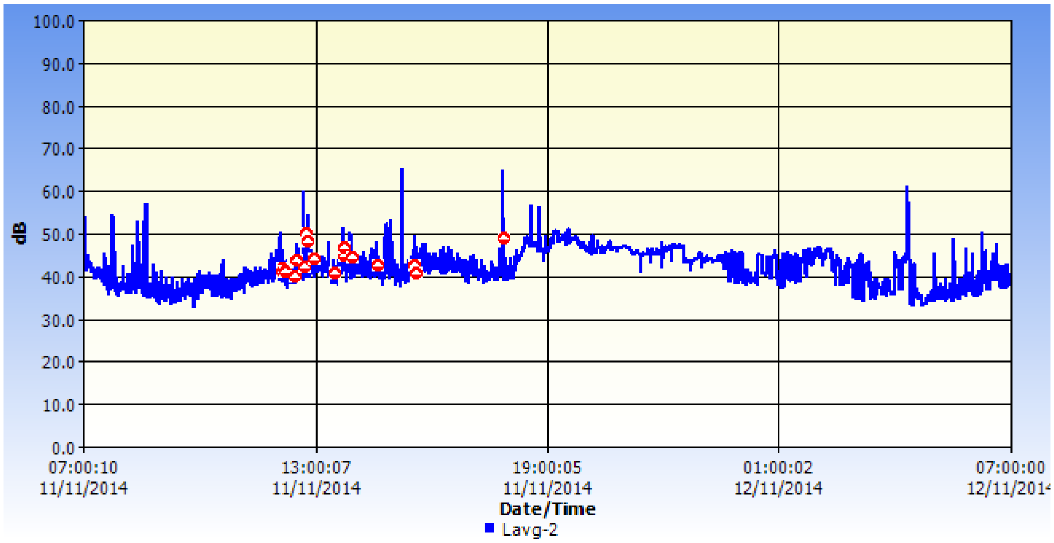


Figure 5-86 Noise fluctuation (Leq) over 24 hours at Station 8

OCTAVE BAND ANALYSIS AT STATION 8

The noise at this station during the 24 hour period was in the low frequency band centred around the geometric mean frequency of 25 Hz (octave frequency range is 22 - 28 Hz) (Figure 5-87).

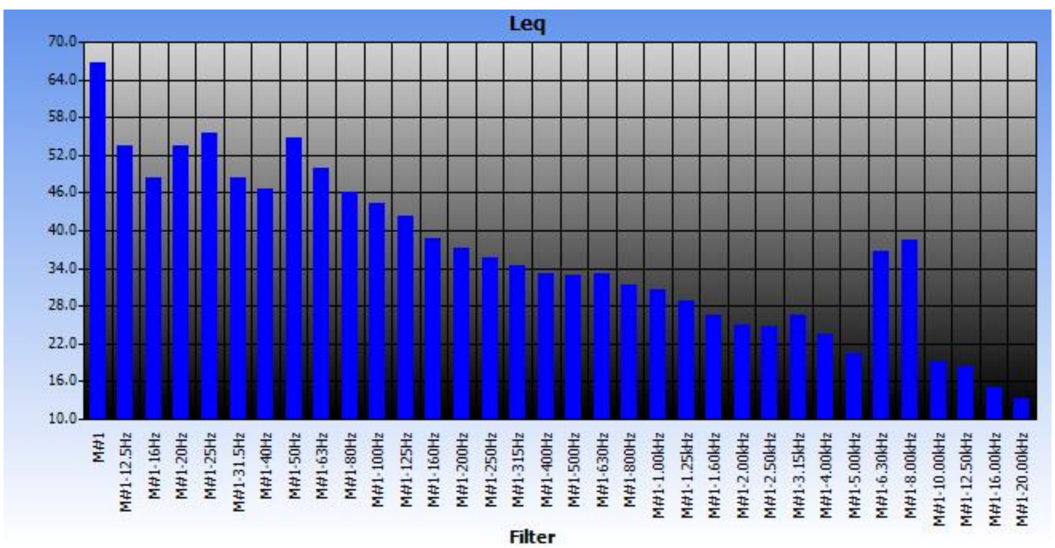


Figure 5-87 Octave band spectrum of noise at Station 8

L10 AND L90 – STATION N8

Figure 5-88 depicts the hourly L10 and L 90 statistics for this station over the noise assessment period. The data shows moderate fluctuations in the noise climate (L10 – L90) ≈41.7% of the time and no significant fluctuations (L10 – L90) ≈58.3% of the time in the noise climate at this station.

The overall L10 and L 90 at this station for the time assessed were 46.6 dBA and 36.1 dBA respectively.

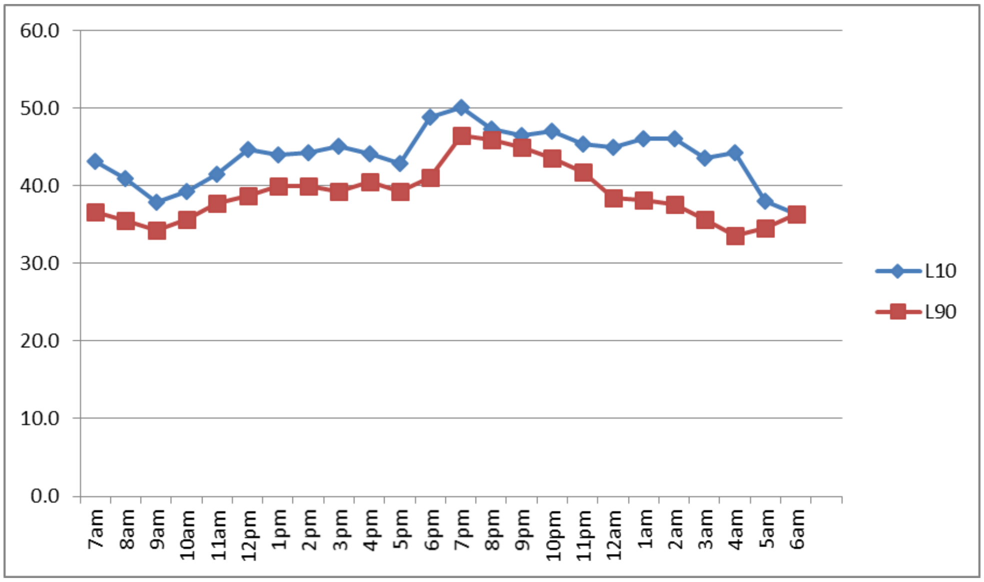


Figure 5-88 L10 and L90 for Station 8

Station N9

During the period, noise levels at this station ranged from a low (Lmin) of 31.5 dBA to a high (Lmax) of 71.6 dBA. Average noise level for this period was 42.9 L_{Aeq}. The fluctuation in noise levels over the period is depicted in Figure 5-89. Due to battery failure on the meter at this station, noise data was logged from 7:00:00am – 15:00:50pm (8 hours).

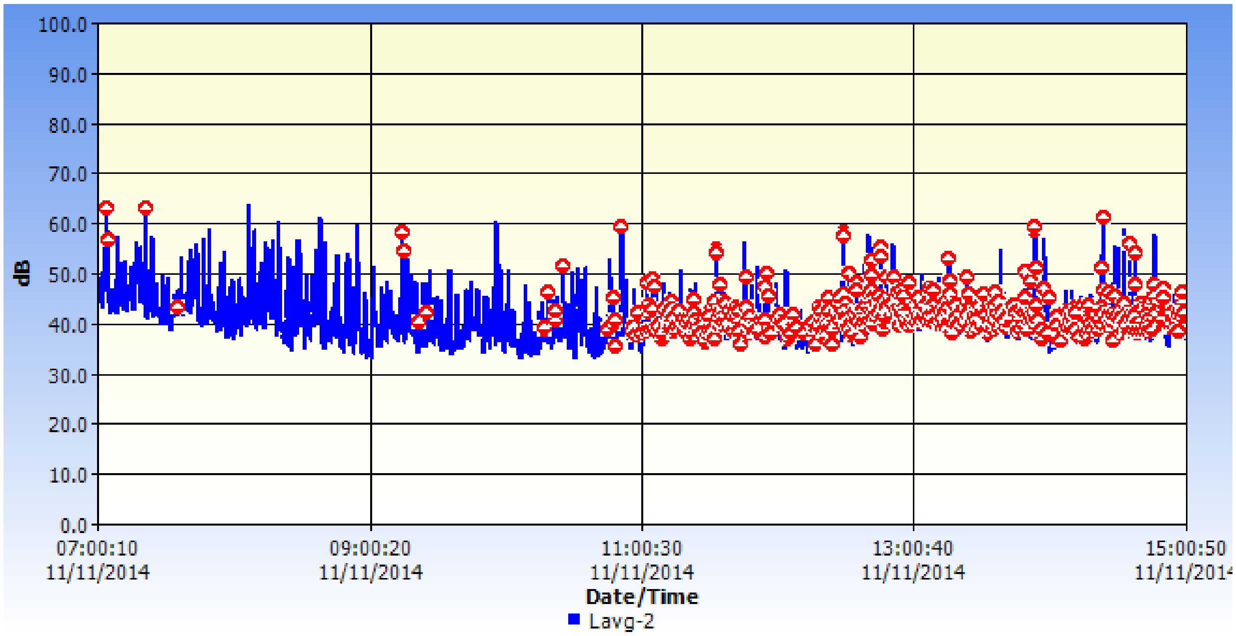


Figure 5-89 Noise fluctuation (Leq) over 24 hours at Station 9

OCTAVE BAND ANALYSIS AT STATION 9

The noise at this station during the period was in the low frequency band centred around the geometric mean frequency of 12.5 Hz (octave frequency range is 11 - 14 Hz) (Figure 5-90).

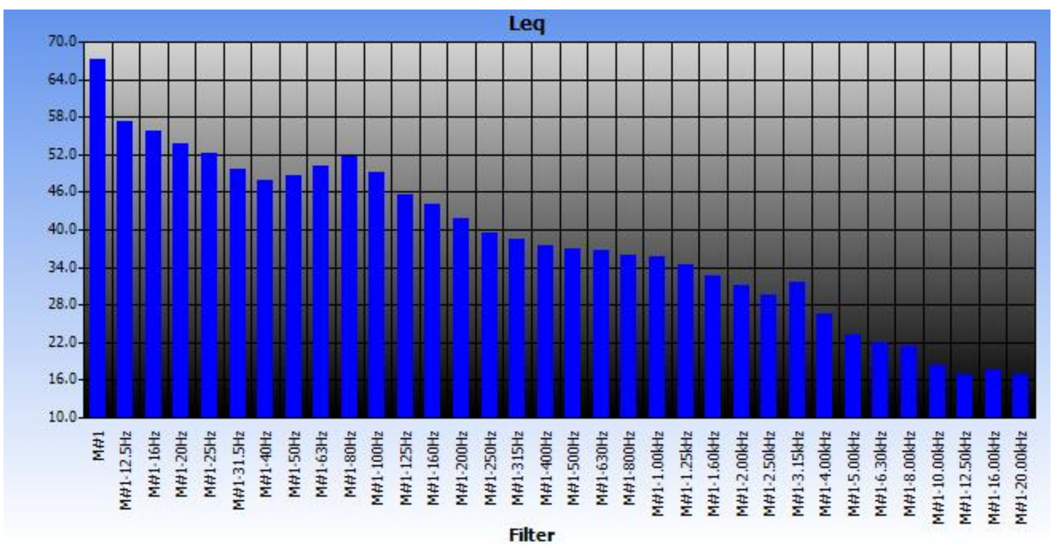


Figure 5-90 Octave band spectrum of noise at Station 9

L10 AND L90 – STATION N9

Figure 5-91 depicts the hourly L10 and L 90 statistics for this station over the noise assessment period. The overall L10 and L 90 at this station for the time assessed were 46.8 dBA and 36.1 dBA respectively.

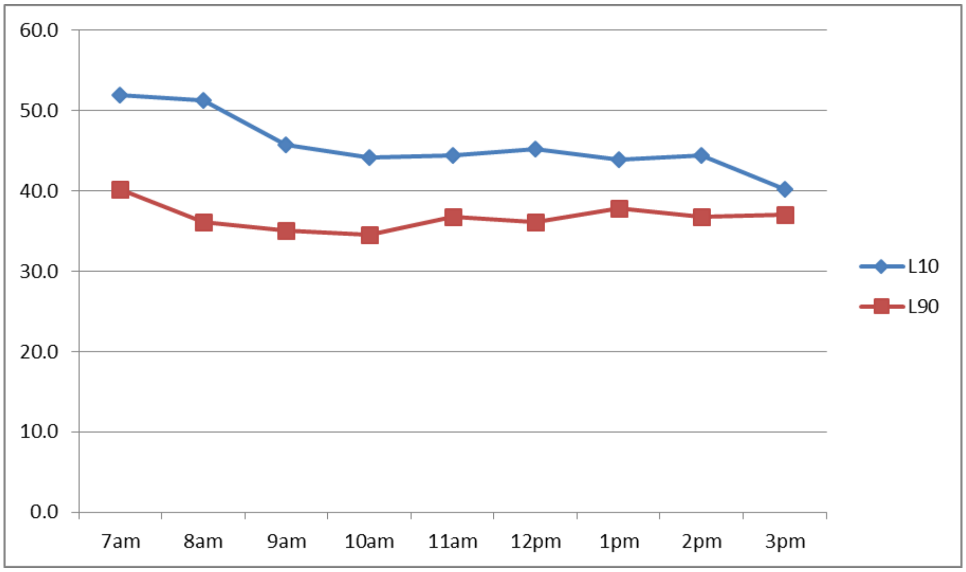


Figure 5-91 L10 and L90 for Station 9

5.1.11.4 Comparisons of Ambient Noise Levels with NEPA Guidelines

Comparison of the ambient noise levels in the study area with NEPA guidelines are shown in Table 5-34. All stations (N1-N8) were compliant with the NEPA noise guidelines during the daytime (7am – 10 pm) and during the night time (10 pm – 7 am).

Table 5-34 Comparison of noise levels at the stations with the NEPA guidelines

STN #	ZONE	7 am. - 10 pm. (dBA)	NEPA Guideline (dBA)	10 pm. - 7 am. (dBA)	NEPA Guideline (dBA)
N1	Industrial	66.9	75	59.6	70
N2	Industrial	62.4	75	56.5	70
N3	Industrial	64.0	75	58.0	70
N4	Industrial	62.9	75	59.8	70
N5	Residential	53.1	55	43.0	50
N6	Residential	50.5	55	42.4	50
N7	Residential	53.3	55	47.9	50
N8	Residential	43.1	55	41.9	50
N9	Residential	N/A	55	N/A	50

5.1.11.5 Comparison with 2012 Study

The average noise levels for the three noise stations in common with the 2012 study (Blackwood Gardens, Old Harbour Bay Police Station and Longville Park Housing Scheme) were lower for the current noise survey. Average noise levels (dBA) decreased in the following ways:

- From 51.3 dBA in 2012 to 48.3 in 2014 at Blackwood Gardens.
- From 57.3 dBA in 2012 to 51.7 in 2014 at Old Harbour Bay Police Station.
- From 51.1 dBA in 2012 to 42.9 in 2014 at Longville Park Housing Scheme.

5.1.12 Air Quality

5.1.12.1 Historical Ambient Air Quality Data

Data from the Lauderwood Air Quality Monitoring Station operated by JPS are indicated in Table 5-35. All measurements for all five years are below the National Ambient Air Quality Standards for the respective averaging periods.

Table 5-35 Historical ambient air quality monitoring data including measured 1-h and 24-h maximum and annual mean SO2 concentrations, the 1-h maximum and annual mean NOx concentrations and the 1-h maximum O3

Pollutant	Year	Max 1-h, μg/m³	Max 24-h, μg/m³	Annual Mean, μg/m³
SO_2	2009	235.4	75.6	15.5
SO_2	2010	47.1	17.95	8.9
SO_2	2011	258.2	174.7	3.1
SO_2	2012	146.5	31.5	6.5
SO_2	2013	505.1	38.0	5.7
SO_2	Standard	700	280	60
NO_2	2009	103.4	N/A	11.2
NO_2	2010	105.3	N/A	6.4
NO_2	2011	157.9	N/A	5.5
NO_2	2012	377.9	N/A	11.1
NO_2	2013	45.9	N/A	8.8
NO_2	Standard	400	N/A	100
O_3	2009	134.4	N/A	18.3
O_3	2010	51	N/A	9.9
O_3	2011	82.4	N/A	15.75
O_3	2012	227.5	N/A	11.6
O_3	2013	113.8	N/A	25.9
O_3	Standard	235	N/A	N/A

5.1.12.2 Particulates (PM10, PM2.5 and TSP)

Introduction

This report entails the results derived from the PM10, PM2.5 and Total Suspended Particulates (TSP) particulates survey conducted from November 11th – November 27th, 2014. None of the sampling locations from the 2012 EIA study were assessed for this present EIA.

Methodology

PM2.5, PM10 and Total Suspended Particles (TSP) particulate sampling was conducted for 24 hours using Airmetrics Mini-Volume Tactical Air Samplers. A total of two (2) sampling runs for each particle size class was conducted The first PM10 sampling exercise was conducted from 12:00am on November 11th, 2014 until 12:00am November 12th, 2014. The second PM10 sampling exercise was conducted from 12:00am on November 18th, 2014 until 12:00am November 19th, 2014. The first PM2.5 sampling exercise was conducted from 12:00am on November 20th, 2014 until 12:00am November 21st, 2014. The second PM2.5 sampling exercise was conducted from 12:00am on November 22nd, 2014 until 12:00am November 23rd, 2014. The first TSP sampling exercise was conducted from 12:00am on November 24th, 2014 until 12:00am November 25th, 2014. The second TSP sampling exercise was conducted from 12:00am on November 26th, 2014 until 12:00am November 27th, 2014.

Coarse particles (PM10) are airborne pollutants that fall between 2.5 and 10 micrometres in diameter. Sources of coarse particles include crushing or grinding operations and dust stirred up by vehicles traveling on roads. Fine particle (PM2.5) are airborne pollutants that fall below 2.5 micrometres in diameter. Sources of fine particles include all types of combustion, including motor vehicles, power plants, residential wood burning, forest fires, agricultural burning, and some industrial processes. TSP are particles of sizes 100 micrometres or less and include coarse (PM10) and fine (PM2.5) particles.

In 1987, U.S. Environmental Protection Agency replaced TSP with PM10 as the indicator for both the annual and 24-hour health-related standards. The reason for this is because exposure to PM10 particles may cause serious health/respiratory related issues as these particles are retained deep in the lungs.

Particulate measurements were conducted at five (5) locations (Figure 5-92) (Table 5-36).

Table 5-36 Particulate sampling locations

STATION	LOCATION	JAD 2001	
		Northing (m)	Easting (m)
P1	North-Western Property Boundary	638937.99	738508.72
P2	South-Western Property Boundary	638860.04	738486.45
P3	South-Eastern Property Boundary	638884.88	738573.82
P4	North-Eastern Property Boundary	638979.11	738614.94
P5	Old Harbour Bay Police Station	639705.67	739747.33

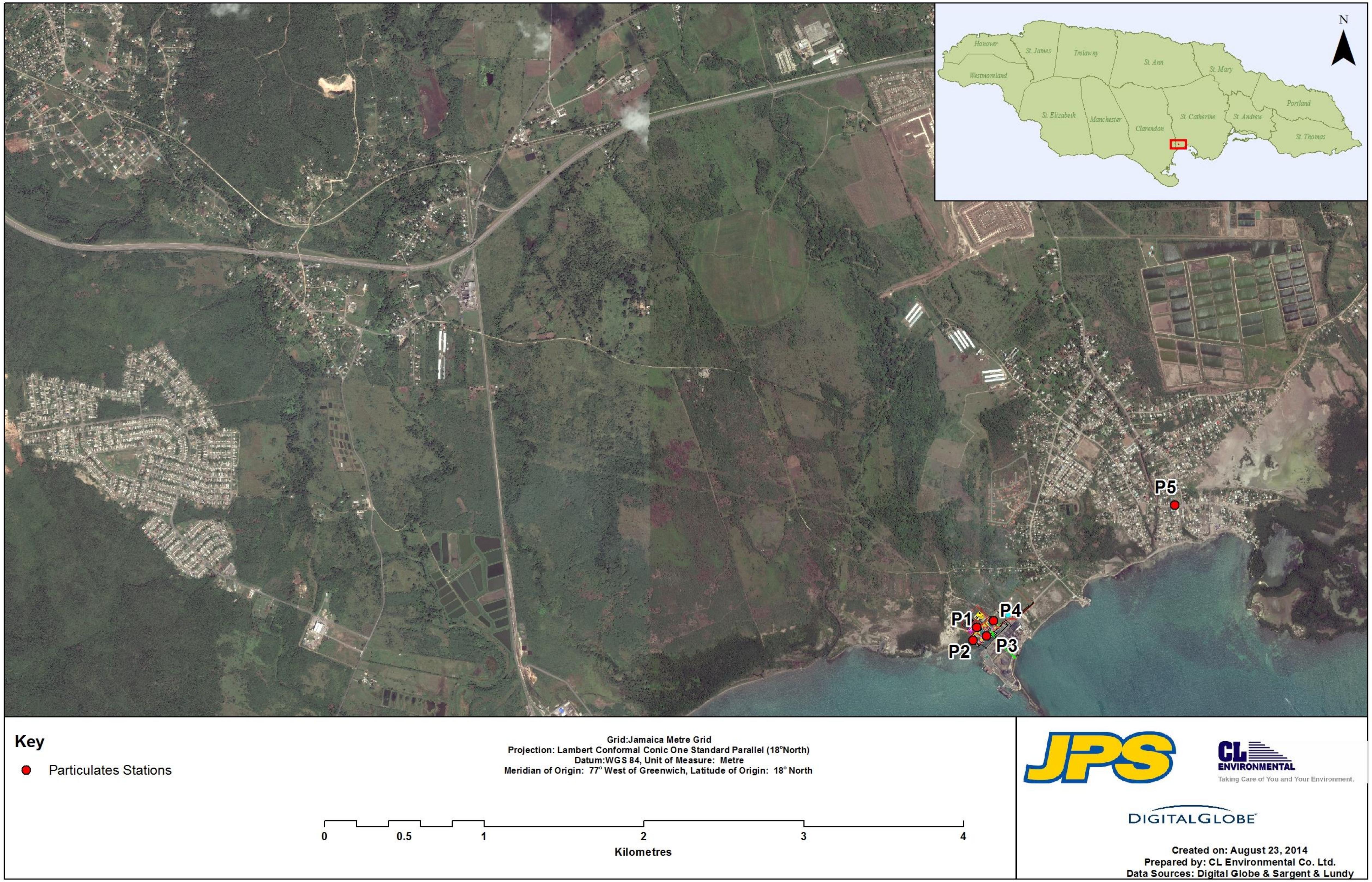


Figure 5-92 Map depicting the particulate sampling stations

Plate 5-3 Example of particulate sampler

Results

PM10 RESULTS

The PM10 results indicate that all locations had particulate values compliant with the 24-hour US EPA standard of 150 µg/m3. Results were similar for the locations at the boundaries of the proposed site, with the southwestern boundary having the highest mean value and the northwestern boundary having the lowest. Old Harbour Bay police station had the highest overall PM10 value; this station is prone to high particulate levels due to the road and vehicles which traverse this road stirring up dust.

The results of the PM10 sampling runs are shown in Table 5-37.

Table 5-37 PM10 Results

Station	Location	Range Result (µg/m^3)	Mean Result (µg/m^3)	US EPA Std. (µg/m^3)
P1	North-Western Property Boundary	17.64 – 26.39	22.02	**150**
P2	South-Western Property Boundary	26.67 – 41.53	34.1	**150**
P3	South-Eastern Property Boundary	18.75 – 36.25	27.5	**150**
P4	North-Eastern Property Boundary	19.17 – 30.14	24.65	**150**
P5	Old Harbour Bay Police Station	42.36 – 44.17	43.26	**150**

PM2.5 RESULTS

The PM2.5 results indicate that all locations had particulate values compliant with the 24-hour US EPA standard of 35 µg/m^3. Results were similar for the locations at the northeastern and northwestern boundaries of the proposed site; while those at the southeastern and south western boundaries were similar. On average, PM2.5 readings at the northern boundaries were higher than those on the southern boundaries. Old Harbour Bay police station had the highest overall PM2.5 value; this station is prone to PM2.5 particulates due to exhaust from the vehicles which traverse this road.

The results of the PM2.5 sampling runs are shown in Table 5-38.

Table 5-38 PM2.5 Results

Station	Location	Range Result (µg/m³)	Mean Result (µg/m³)	US EPA Std. (µg/m³)
P1	North-Western Property Boundary	11.94 – 16.53	14.24	**35**
P2	South-Western Property Boundary	4.17 – 11.39	7.78	**35**
P3	South-Eastern Property Boundary	7.08 – 11.39	9.24	**35**
P4	North-Eastern Property Boundary	13.06 – 16.25	14.66	**35**
P5	Old Harbour Bay Police Station	15.42 – 17.36	16.39	**35**

TSP RESULTS

The TSP results indicate that all locations had particulate values compliant with the 24-hour NEPA standard of 150 µg/m³. TSP results were somewhat similar for the locations at the boundaries of the proposed site. The southeastern boundary had the highest TSP value on the proposed site, while the other three boundary locations had similar TSP values. Old Harbour Bay police station is prone to high particulate levels due to the road and vehicles which traverse this road stirring up dust and other coarse and fine particulates.

The results of the TSP sampling runs are shown in Table 5-39.

Table 5-39 TSP Results

Station	Location	Range Result (µg/m³)	Mean Result (µg/m³)	NEPA TSP Standard (µg/m³)
P1	North-Western Property Boundary	41.94 – 69.44	55.69	**150**
P2	South-Western Property Boundary	53.19 – 74.58	63.89	**150**
P3	South-Eastern Property Boundary	67.5 – 99.58	83.54	**150**
P4	North-Eastern Property Boundary	45.42 – 78.89	62.16	**150**
P5	Old Harbour Bay Police Station	69.72 – 72.78	71.25	**150**

5.1.13 EMF

Electromagnetic fields (EMF) are invisible, but exist everywhere on Earth. EMF radiation is mainly characterized by its frequency and its strength. The frequency is measured in the unit hertz, which means "cycles per second". The gauss meter measures the strength of the low-frequency EMF radiation, like that coming from electrical wires (50 or 60 hertz). The better models can also show some higher frequencies (thousands of hertz, kilo hertz), which come from some electronic appliances, such as power supplies.

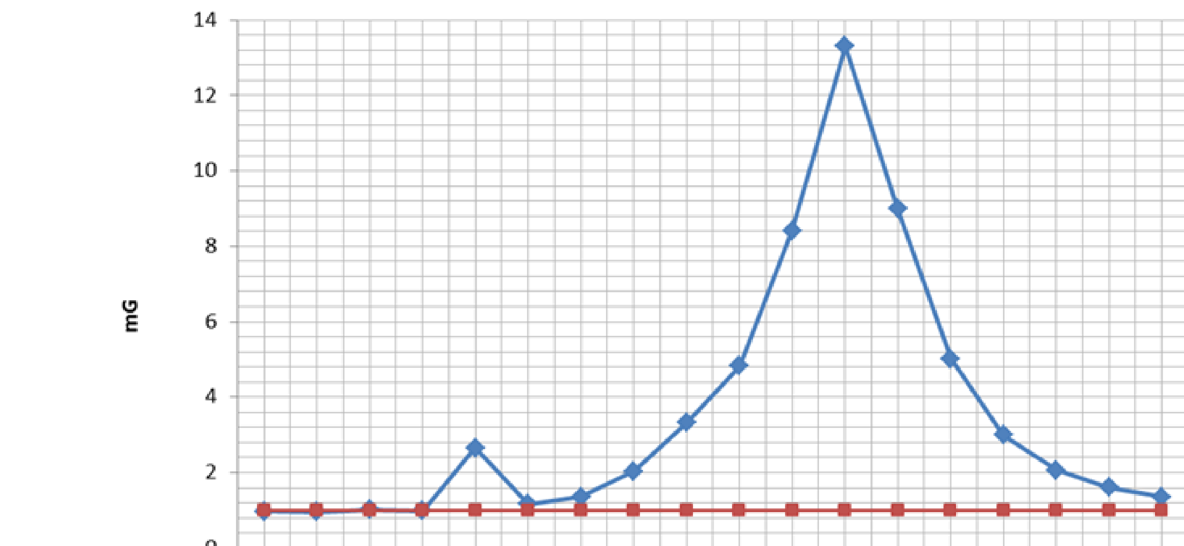
5.1.13.1 Methodology

EMF was measured at the 69 kV and 138 kV power lines on the proposed property and at approximately 10m intervals to determine the impact of distance from the source on EMF strength using a TM 192 triaxial Gauss meter. The readings were taken on May 19, 2012 between 9:00 and 11 am. The results for the previous EIA conducted for SJPC in 2012 are used, as it is not anticipated that the results will change.

5.1.13.2 Results

While there is still no internationally accepted limit for EMF there are a number of guidelines that have been outlined by scientific bodies. In November, 2009, a scientific panel met in Seletun, Norway, for three days of intensive discussion on existing scientific evidence and public health implications. They recommended an Exposure Limit guideline of 1 mG for extremely low frequency (fields from electrical power) for all new installations, such as powerlines, indoor electric appliances, house-hold items, TVs, radios, computers, and telecommunication devices.

The data from the measurement exercise are depicted Figure 5-93 and Table 5-40.



	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
XYZ (mG)	0.98	0.96	1.02	0.99	2.65	1.17	1.36	2.04	3.32	4.83	8.42	13.3	8.99	5.02	3	2.07	1.61	1.36
Upper Limit (mG)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

DISTANCE (m)

Figure 5-93 EMF measurement results in relation to distance

Table 5-40 EMF results by axis

DISTANCE (m)	DATE AND TIME	AXIS			XYZ (mG)
		X (mG)	Y (mG)	Z (mG)	
10	5/19/2012 9:00	0.52	0.81	0.2	0.98
20	5/19/2012 9:16	0.48	0.81	0.19	0.96
30	5/19/2012 9:24	0.52	0.85	0.24	1.02
40	5/19/2012 9:38	0.51	0.83	0.2	0.99
50	5/19/2012 10:31	0.93	0.97	2.29	2.65
60	5/19/2012 10:33	0.68	0.85	0.44	1.17
70	5/19/2012 10:34	0.93	0.82	0.57	1.36
80	5/19/2012 10:36	1.05	1.41	1.05	2.04
90	5/19/2012 10:39	1.14	1.97	2.43	3.32
100	5/19/2012 10:41	0.82	2.29	4.18	4.83
110	5/19/2012 10:42	1.72	2.32	7.91	8.42
120	5/19/2012 10:43	12.64	3.7	1.86	13.3
130	5/19/2012 10:45	0.65	5.44	7.13	8.99
140	5/19/2012 10:48	0.59	1.25	4.83	5.02
150	5/19/2012 10:49	0.47	1.56	2.52	3
160	5/19/2012 10:50	0.51	1.39	1.46	2.07
170	5/19/2012 10:51	0.48	1.27	0.87	1.61
180	5/19/2012 10:51	0.48	1.13	0.59	1.36

5.1.13.3 Easement Guidelines

The data obtained has indicated that a buffer of approximately 10 m is needed from the 69 kV and approximately 62 m for the 138 kV power lines respectively at their present heights for the EMF values to fall within the guideline set by the Swedish scientists of 1 mG. Information obtained has indicated that a buffer of approximately 7.6m on either side is required for the 69 kV and approximately 15.24 m for the 138 kV power lines as guidelines set by the Jamaica Public Service Co. Ltd.

5.2 NATURAL HAZARDS

5.2.1 Riverine Flooding

Bowers Gully forms the lower part of a relatively complex drainage system with a catchment area in excess of thirty six square kilometres (Figure 5-94), part of the Central Inlier. Here the surface drainage is perennial, collected by the Myttins River and Cedar Gully. Below the confluence of these tributaries the system, known as the Plantain River, develops seasonal flow through limestone terrain before exiting onto the St. Catherine plain near Colbeck. By the time the river exits onto the plain, the system has lost most of its surface flow to the subsurface. However, Bowers Gully is susceptible to flooding under extreme precipitation conditions. Field investigations showed silt and clay overlying sand and gravel in the vicinity of the gully, indicative of flood events. This is a typical feature of fan deposits, particularly debris fans. Although the highest layers associated with the gully are clays, the presence of gravels lower in the exposures of the gully is suggestive of debris flows as well.

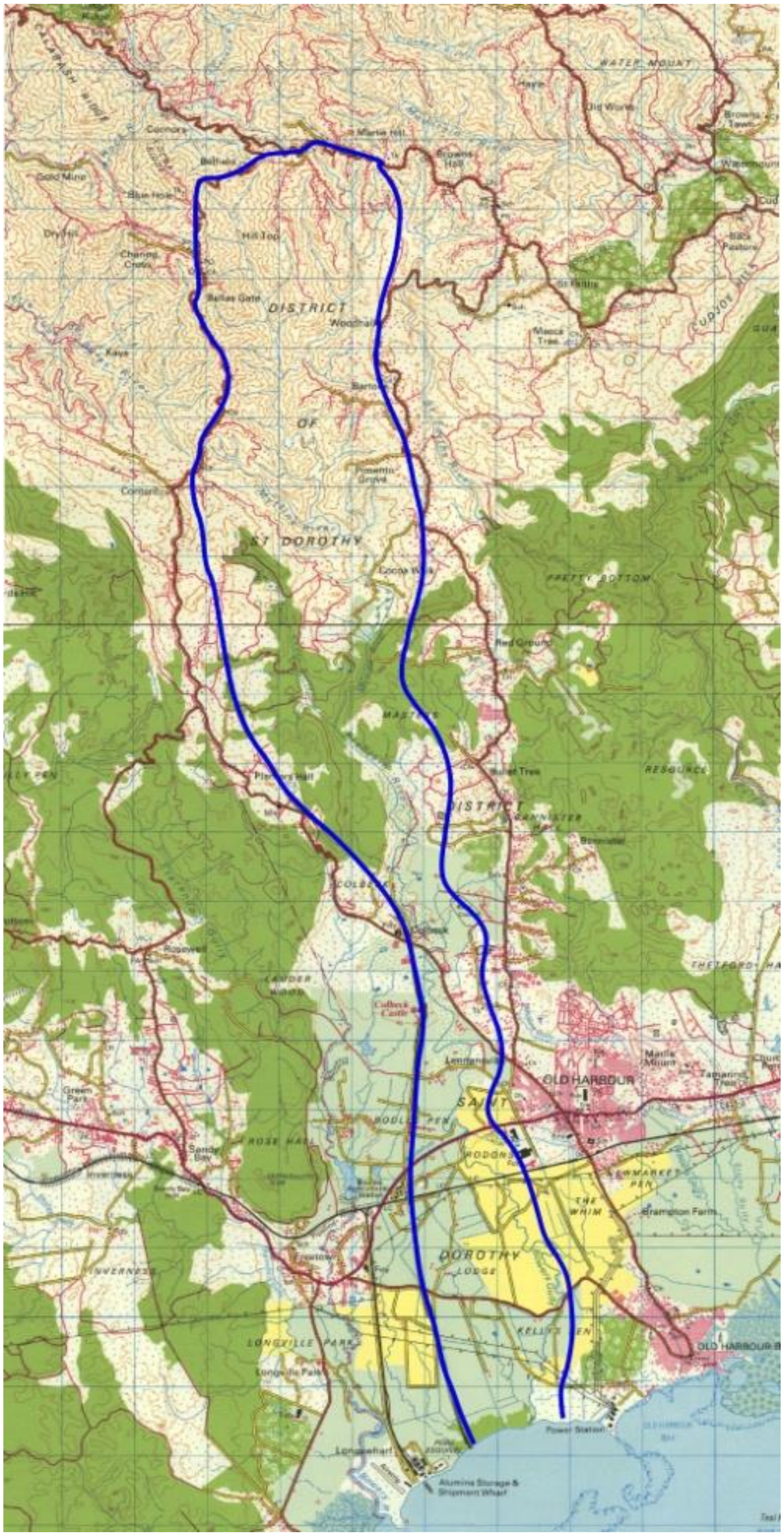


Figure 5-94 Approximate boundary of the Bowers Gully catchment. Grid squares are 1 km each side.

5.2.2 Hurricane Waves

The Old Harbour Bay is part of a larger bay known as the Portland Bight. The Portland Bight is exposed to the Caribbean Sea from a southerly direction, even though the Bay is partly enclosed, the potential is there for sufficiently large and destructive waves can enter from the Caribbean Sea. Similarly, Portland Bight is significantly large with a fetch of approximately 15.7 km in a southerly direction from the Old Harbour Bay to the Rocky point headland. It is therefore quite possible for local waves with significant wave heights to reach the shoreline.

A rapid assessment of both local and deep water waves that could potentially reach the shoreline from deep water was done using a database of hurricanes, dating back to 1886. The database was searched for storms that passed within a 500km radius from the site and the following procedure was carried out.

1. Extraction of storms and storm parameters from the historical database: A historical database of storms was searched for all storms passing within a 500km radius of the site.
2. Application of the JONSWAP wind-wave model. A wave model was used to determine the wave conditions generated at the site due to the rotating hurricane wind field. This is a widely applied model and has been used for numerous engineering problems. The model computes the wave height from a parametric formulation of the hurricane wind field.
3. Application of extremal statistics. Here the predicted maximum wave height from each hurricane was arranged in descending order and each assigned an exceedance probability by Weibull's distribution.
4. A bathymetric profile from deep water to the site was then defined and each hurricane wave transformed along the profile. The wave height at the nearshore end of the profile was then extracted from the model and stored in a database. All the returned nearshore values were then subjected to an Extremal Statistical analysis and assigned exceedance probabilities with a Weibull distribution. Table 5-41 shows the incident wave heights and periods obtained from the JONSWAP model.

Table 5-41 Incident wave heights and periods obtained for 1-in-50 year hurricane waves.

		SSW	S	SSE	SE	ESE
Local	**Hurricane**					
	Hs (m)	4.93	4.93	4.93	2.16	2.16
	Tp (s)	6.65	6.65	6.65	3.83	3.83
Deepwater	**Hurricane**					
	Hs (m)	5.9	5.9	5.9	7	7
	Tp (s)	12.1	12.1	12.1	13.2	13.2

Table 5-42 Bi-variant table showing incident wave heights and periods for the specific return periods and directions.

Return Periods	Wave height (m)											
	All		SW		W		E		SE		S	
	Hs	Tp	Hs	Tp	Hs	Tp	Hs	Tp	Hs	Tp	Hs	Tp
1	2.0	7.2	1.0	5.1	1.0	5.1	1.0	5.1	1.0	5.1	1.0	5.1
2	3.6	9.5	3.3	9.2	3.5	9.5	4.6	10.7	4.0	10.1	3.4	9.3
5	4.9	11.0	4.1	10.1	4.6	10.7	5.7	11.9	5.2	11.4	4.4	10.5
10	5.7	11.9	4.4	10.5	5.1	11.3	6.3	12.5	5.9	12.1	5.0	11.1
20	6.4	12.6	4.7	10.9	5.6	11.8	6.8	13.0	6.4	12.6	5.4	11.6
25	6.6	12.8	4.8	11.0	5.7	11.9	6.9	13.1	6.6	12.8	5.6	11.7
50	7.3	13.4	5.1	11.2	6.1	12.3	7.3	13.4	7.0	13.2	5.9	12.1
75	7.7	13.7	5.2	11.4	6.3	12.5	7.5	13.6	7.3	13.4	6.1	12.3
100	7.9	14.0	5.3	11.5	6.4	12.6	7.7	13.7	7.5	13.5	6.3	12.5
150	8.3	14.3	5.4	11.6	6.6	12.8	7.9	13.9	7.7	13.7	6.5	12.6
200	8.6	14.5	5.5	11.7	6.7	12.9	8.0	14.0	7.8	13.9	6.6	12.8

5.2.2.1 Locally Generated Hurricane Waves

Methodology

The incident wave height and period to be used in the model corresponding to the locally generated waves was calculated using the JONSWAP equation. This equation determines wave height and period from fetch, storm duration and depth of water in the generating area, where fetch is the distance into the wind direction from a point of interest to the nearest shoreline[7]. Portland Bight is significantly large with a maximum fetch of approximately 19 km for a storm moving across the Bay. It is quite possible for local waves with significant wave heights to reach the project area and damage the outfall pipe and so it was necessary for locally generated hurricane waves to also be determined as well.

Results

The shoreline is most vulnerable to waves from the south eastern and southern direction. The JONSWAP equation determined that under hurricane conditions, a 100 year return period event moving in a south easterly direction will generate a wave height of 3.6 m and a wave period of 5.4 s. For the southern direction it will generate a wave height of 5.2 m and a wave period of 7.0 s; these results are summarized in Table 5-43. If climate changes are considered, the hurricane waves are expected to be increased. The results under future climate conditions (50 yrs. from present) are wave heights and periods of 5.4 m and 7.3 s for the south easterly event, and 3.7 m and 5.7 s for the southern event.

[7] Kamphuis, J (2002), Introduction to Coastal Engineering and Management, *Advanced Series on Ocean Engineering – Volume 16*

Table 5-43 Results from the JONSWAP method of determining wave height and period based on fetch limited conditions

Wind speed (m/s)	Wind direction	Fetch (km)	Duration (h)	Depth (m)	F*	t*	Feff*	Feff*	Hmo*	Tp*	Hmo (m)	Tp (s)	Set-up
73.7	SE	9	4	10	16	1919	147	16	0.01	1.51	**3.57**	**5.44**	1.01
73.7	S	19	4	10	34	1919	147	34	0.01	1.51	**5.19**	**6.98**	2.13

5.2.2.2 Nearshore Wave Climate

Methodology

The objective of this exercise is to derive a nearshore wave climate in order to estimate the wave forces on the existing shoreline and the proposed marine outfall. The weakly nonlinear combined refraction and diffraction model described here denoted REFDIF simulated the behaviour of a random sea over an irregular bottom bathymetry incorporating the effects of shoaling, refraction, energy dissipation and diffraction. Although the model is developed to simulate a random sea state, it can also be used to model the behaviour of monochromatic waves.

The output from the storm surge model used for hurricane impact analysis provided the incident wave height and period as well as the water setup for the deepwater extremal analysis, while locally generated waves were predicted using the JONSWAP equations. These incident wave heights and periods were then used to determine the hurricane climate under future conditions (climate change). Both the existing and future climate condition results were utilized in the REFDIF model to generate the nearshore wave climate. See Table 5-44 for a summary of the incident wave conditions used for the analysis. Based on the deepwater wave climate, storm surge analysis, shoreline shape and the geographical location of the project area, it was determined that the project area or the proposed pipeline will be most vulnerable to waves from the southern and southeastern directions.

Table 5-44 Incident wave heights and periods obtained for hurricane waves generated locally and offshore (deepwater) used to derive the nearshore wave climate for the 100 year storm event.

Wave Climate	DP	Existing Climate Environment	
		Hs (m)	Tp (s)
Local	S	4.12	6.07
	SE	4.28	6.22
Deepwater	S	7.70	13.7
	SE	7.70	13.7

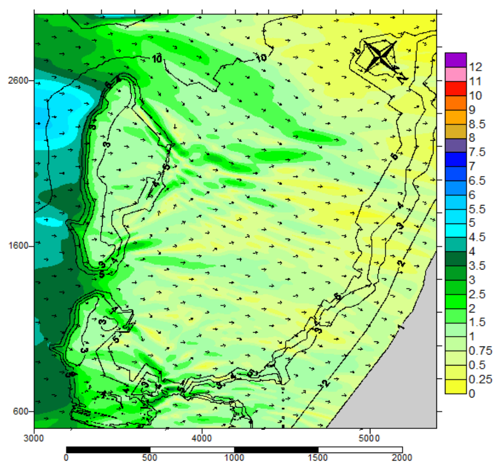
Results

During hurricane events there will be a wave setup and so an elevation of 2.44 m and 2.76 m was added to the simulation for the 100 year events under existing climate conditions. See Table 5-45 and Table 5-46 for the resultant wave plots from the REFDIF modelling exercise.

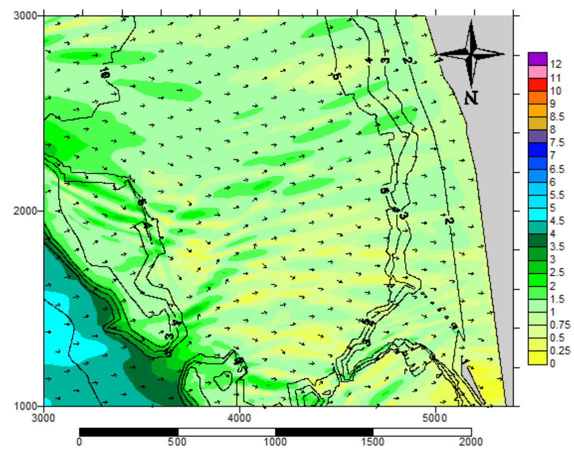
HURRICANE WAVES (LOCALLY GENERATED)

Considering the size of the bay, it was important that we model hurricane wind generated waves which could form within the bay. Given that wind generated waves originating nearshore in relatively shallow water need a long fetch to generate significant wave heights, we modelled two directions, S, and SE for both 50 and 100 years return periods. These directions show that a wave would have a fetch of approximately 14 km and so show great potential for significant wave generation. The wave plots generated from the model showed that during hurricane conditions, wave heights of up 1.5 m reaching the shoreline each direction, with the waves from the southern direction affecting the shoreline more severely.

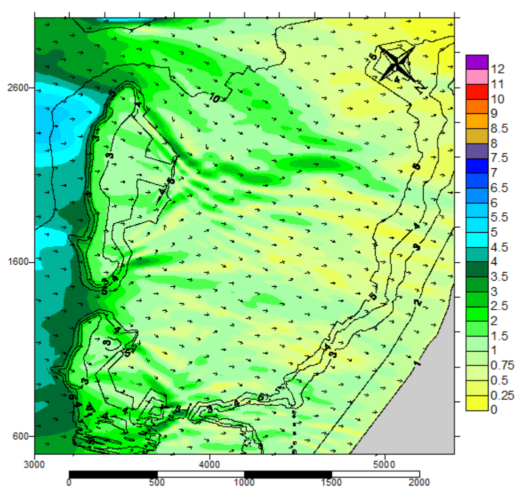
Table 5-45 Hurricane wave plots generated from the local hurricane wave climate for a 100 year return period event under existing and future climate conditions



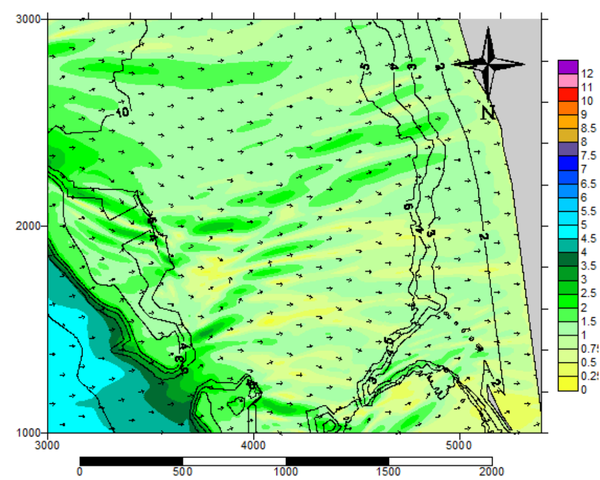
SE 50 year



S 50 year



SE 100 year

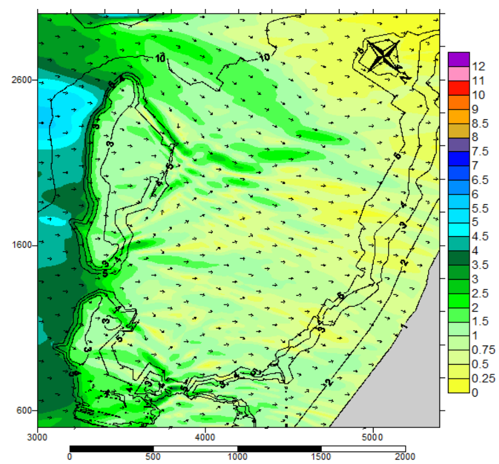


S 100 year

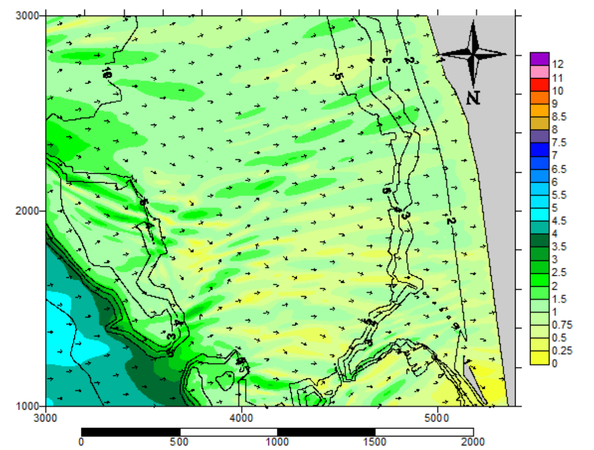
HURRICANE WAVES (DEEPWATER)

It was very important to model hurricane wind generated waves from deepwater. We modelled two directions, S, and SE for both 50 and 100 years return periods. These directions show that a wave would have a fetch of approximately 14 km and so show great potential for significant wave generation. The largest predicted wave heights to reach the shoreline were generated from the SE and S directions ranging from 1.5 to 2 m for the 100 year return period. While for the 50 year return period wave heights of up to 1.5m was noticed reaching the shoreline. The JPS shoreline is sheltered by the reefs located south east of the shoreline resulting in a reduction in the size of the waves reaching the shoreline.

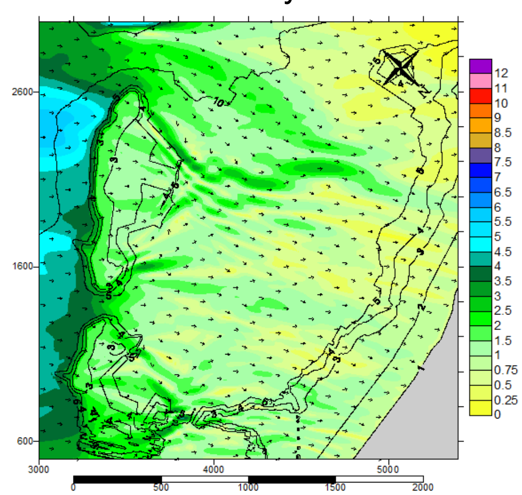
Table 5-46 Hurricane wave plots generated from the deepwater hurricane wave climate for a 50 and 100 year return period event



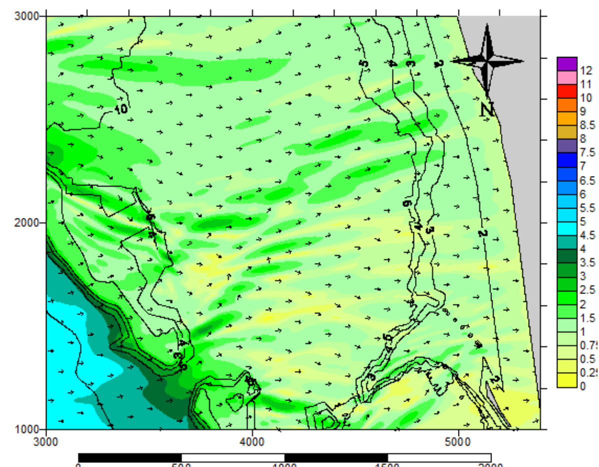
SE 50 year



S 50 year



SE 100 year



S 100 year

5.2.3 Storm Surge and Coastal Inundation

5.2.3.1 Anecdotal Information

Hurricane Ivan storm surge at the site was estimated to be 1 to 1.5 m, based on conversations with observers at the existing JPS plant. Figure 5-95 indicates the values for storm surge height and inundation distance for four localities at Old Harbour Bay during hurricane Dean, 2007. A storm surge of 3+ m was recorded at the Port Esquivel bauxite terminal just west of the site, and 3.1 m at the conch port of Old Harbour Bay, east of the site, with an inundation distance of about 180 m (Robinson & Khan, 2011). Hurricanes and tropical storms are frequently accompanied by heavy rainfall. It has also been widely suggested that the Atlantic-Caribbean region has already moved, into a cycle of more frequent and more severe tropical disturbances.

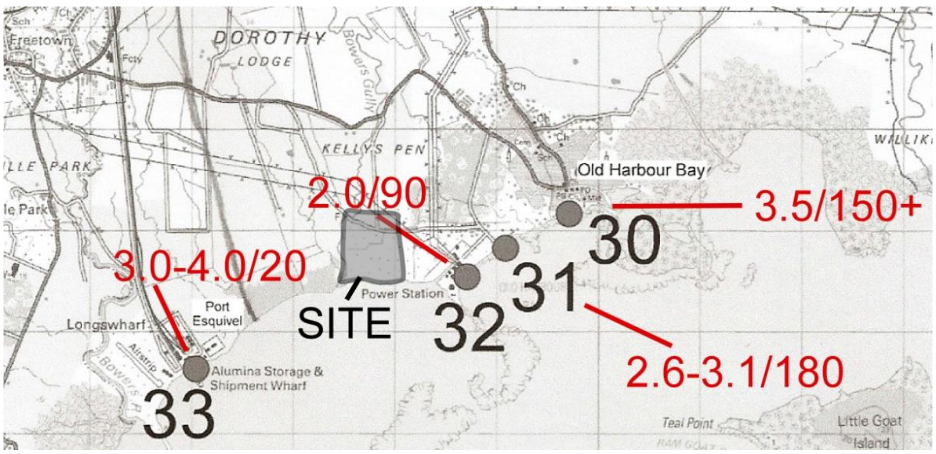


Figure 5-95 Hurricane Dean 2007 surge heights (first red number) and inundation distances (red number after the slash) for four localities in Old Harbour Bay. Locality 30, from Mines & Geology Division data; localities 31-33 from Marine Geology Unit data. Figure modified from Robinson & Khan, 2011, Fig. 15).

5.2.3.2 Rapid Assessment

It is important to define the design water levels in the project area in order to define the appropriate crest elevations for floor levels of importance structure as well as setbacks for buildings. A rapid assessment similar to that for the hurricane waves was carried out, the results of this assessment clearly indicate the sites overall vulnerability to such systems. In summary:

- 88 hurricane systems came within 300 kilometres of the project area.
- 8 of which were classified as catastrophic (Category 5).
- 14 were classified as extreme (Category 4).
- Wind speeds in excess of 35 metres/second are expected to impact the site for a 50 year storm.
- The setup is expected to be in excess of 1.2m above MSL for a 50yr event.

5.2.3.3 Storm Surge and Overland Flooding

It is possible for storm surge to occur simultaneously with overland flooding in coastal areas such as the proposed site. It is therefore crucial that this possibility be investigated with a view to mitigating possible flooding of the site and equipment during such an event. Information regarding historical hurricane and rainfall events was obtained by conducting interviews with residents along Terminal Lane and the fishing beach in Old Harbour Bay, with living first hand memory of hurricane events in the area. This information was also compared against a storm surge model written by CEAC Solution Company Ltd ant it was found that they had reasonable agreement.

Table 5-47 Observed average setup (based on interviews) versus model predicted setup.

Hurricane	Oberved-Average setup (m)	Predicted-Average setup (m)	Difference (m)
Dean	3.073	2.415	0.658
Ivan	3.250	4.462	-1.212
		Average	**-0.277**

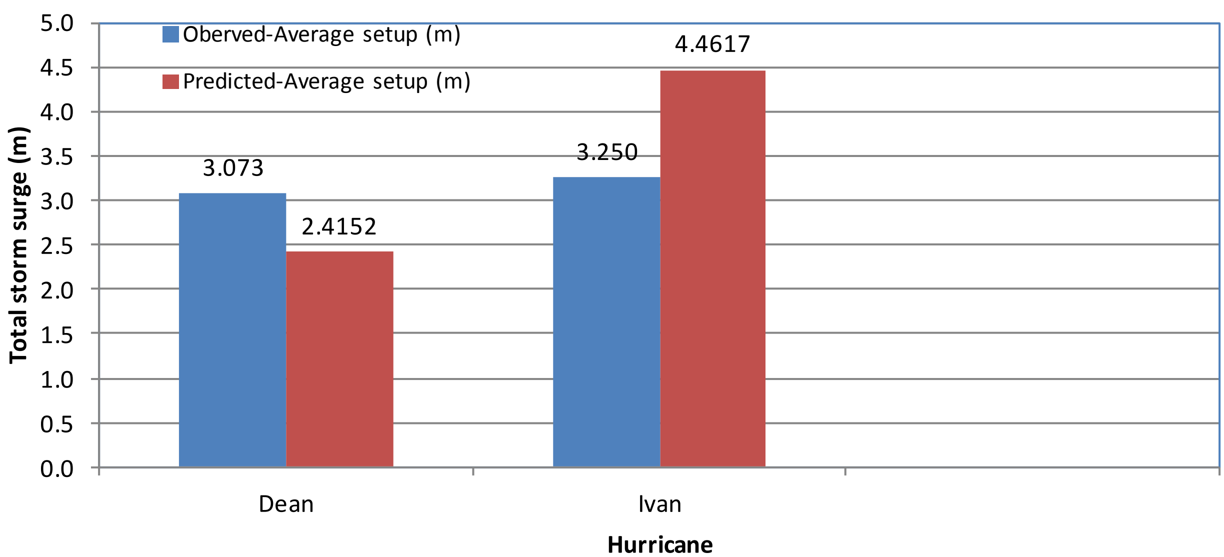


Figure 5-96 Observed average setup (based on interviews) versus model predicted setup.

The observed setups were subjected to extremal statistical analysis to estimate the return period of the setups experienced. The statistical tool used was the Weibull function which is widely used for this type of extremal data analysis due to it having three variables which enables it to obtain a better fitted curve than others which have only two variables.

A storm surge inundation map of the area was plotted to highlight the areas that would flood as a result of storm surge only. The resulting map shows the entire project site is susceptible to flooding as result of the 50 year storm surge (Figure 5-97).

Table 5-48 Predicted storm surge values.

Return Period	Predicted Storm Surge (from Observations) (m)
2	2.85
5	3.17
10	3.32
25	3.46
50	3.55
100	3.63

5.2.4 Long Term Sea Level Rise

A study was conducted by the Climate Studies Group at the University of the West Indies (UWI) Mona (Group, 2013). It assessed literature on current and projected trends in sea level rise with a particular emphasis on future values for Jamaica.

Global sea level trends have risen through the 20th century, and it is expected to accelerate through to the 21st century and beyond because of global warming, but their magnitude remains uncertain. Two main factors contribute to this increase: thermal expansion of sea water due to ocean warming and water mass input from land ice melt and land water reservoirs. In Jamaica, and the region near it, the sea level rise is approximately the global average[8] of 3.2 mm/yr (± 0.4). Projected increases in global and Caribbean mean sea level by 2100 relative to the 1980-1999 is 0.37m[9] (± 0.5 m relative to global mean) and this is equivalent to 3.7 mm/yr.

[8] IPCC 2013
[9] IPCC 2007

Figure 5-97 Storm Surge inundation Map showing the extents of the 10 year and 50 year storm surge incorrect map wrong site

5.2.5 Coastal Erosion Hazard and Vulnerability

5.2.5.1 Long Term Coastal Erosion Trends

The shoreline positions over a number of years were plotted and compared in order to determine the long-term spatial and temporal erosion trends across the bay; this was important in order to identify the erosion hotspots.

Methodology

The overall long-term erosion trend was estimated by:

1) Observation of actual long-term shoreline positions from dated aerial photography.
2) The global sea level rise component was estimated to determine the erosion that was due to chronic global trends versus event based erosion events (i.e. hurricanes and swell events).

Historical Shoreline Assessment

Figure 5-98 shows satellite imagery (March 2010) over which the observed shorelines from Aerial photos of the area obtained from the Survey department for the years 1968, 1991, and 2000. Close examination of the image in Figure 5-98 reveals a general trend of erosion occurring along the shoreline of the proposed site from 1968 to 2010. The central section of the shoreline between chainage 0+450 and 0+700 shows a general pattern of accretion. Table 5-49 summarizes the results of measuring and noting the displacements of the shoreline at intervals of 50m along the shoreline. The rates of accretion and or erosion between the time intervals and the overall time interval were determined using the following relationship:

$$E_y^1 = \frac{D}{N},$$

Where:

E = the rate of erosion or accretion between two successive intervals (metres per year)
D = the displacement between two intervals (metres)
N = the number of years between two successive intervals (years)

And

$$E_y^0 = \frac{D_T}{N_T},$$

Where:

E_y^0 = the rate of erosion or accretion from the datum year to the final interval
D_T = the displacement from the datum to the final interval
N_T = the number of years from datum year to final interval

Table 5-49 Summary of shoreline changes

Year	Shoreline Intervals											
	1968	1991			2000			2010			Overall	
Chainage	Datum	Process	Accretion/Erosion Rate (m/year)	distance from datum (m)	Process	Accretion/Erosion Rate (m/year)	distance from datum (m)	Process	Accretion/Erosion Rate (m/year)	distance from datum (m)	Process	Rate
0+000	0	erosion	-1.366	-31.41	accretion	0.803	-24.18	erosion	-0.448	-28.21	erosion	-0.672
0+050	0	erosion	-0.727	-16.71	accretion	0.752	-9.94	erosion	-1.743	-25.63	erosion	-0.610
0+100	0	erosion	-0.664	-15.27	accretion	0.298	-12.59	erosion	-1.458	-25.71	erosion	-0.612
0+150	0	erosion	-0.815	-18.74	accretion	0.550	-13.79	erosion	-1.032	-23.08	erosion	-0.550
0+200	0	erosion	-0.654	-15.04	accretion	0.501	-10.53	erosion	-0.812	-17.84	erosion	-0.425
0+250	0	erosion	-1.657	-38.1	accretion	0.420	-34.32	erosion	-0.359	-37.55	erosion	-0.894
0+300	0	erosion	-1.833	-42.15	erosion	-1.564	-56.23	erosion	-0.851	-63.89	erosion	-1.521
0+350	0	erosion	-1.967	-45.23	erosion	-3.820	-79.61	erosion	-3.803	-113.84	erosion	-2.710
0+400	0	erosion	-0.606	-13.94	accretion	0.924	-5.62	accretion	0.403	-1.99	erosion	-0.047
0+450	0	erosion	-0.618	-14.21	accretion	1.704	1.13	accretion	0.598	6.51	accretion	0.155
0+500	0	accretion	0.189	4.34	accretion	1.211	15.24	erosion	-0.047	14.82	accretion	0.353
0+550	0	accretion	0.041	0.95	accretion	1.278	12.45	erosion	-0.076	11.77	accretion	0.280
0+600	0	accretion	0.022	0.5	accretion	1.903	17.63	erosion	-0.286	15.06	accretion	0.359
0+650	0	accretion	0.451	10.37	accretion	0.669	16.39	accretion	0.910	24.58	accretion	0.585
0+700	0	accretion	0.903	20.77	erosion	-0.061	20.22	erosion	-0.700	13.92	accretion	0.331
0+750	0	accretion	0.205	4.72	erosion	-2.490	-17.69	accretion	0.034	-17.38	erosion	-0.414
0+800	0	accretion	0.454	10.44	erosion	-1.808	-5.83	erosion	-1.467	-19.03	erosion	-0.453
0+850	0	erosion	-0.489	-11.25	erosion	-0.603	-16.68	erosion	-1.618	-31.24	erosion	-0.744
0+900	0	erosion	-0.610	-14.04	erosion	-0.006	-14.09	erosion	-1.380	-26.51	erosion	-0.631
0+950	0	erosion	-0.447	-10.29	accretion	0.354	-7.1	erosion	-0.667	-13.1	erosion	-0.312

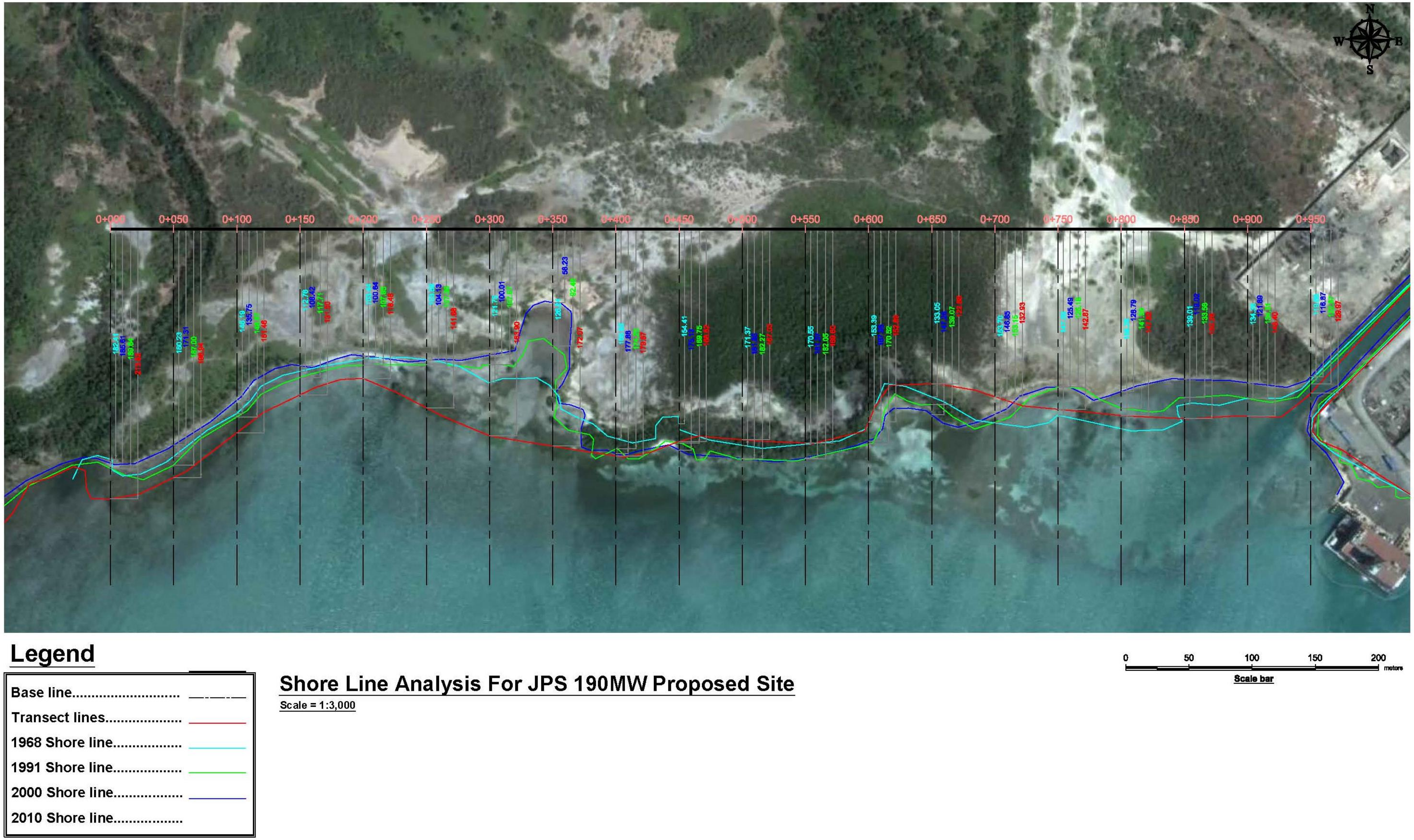


Figure 5-98 Historical Shoreline positions plotted over a satellite image of the area. The red, cyan green and blue lines represent the 1968, 1991, 2000 and 2010 shoreline positions respectively. The image is oriented north.

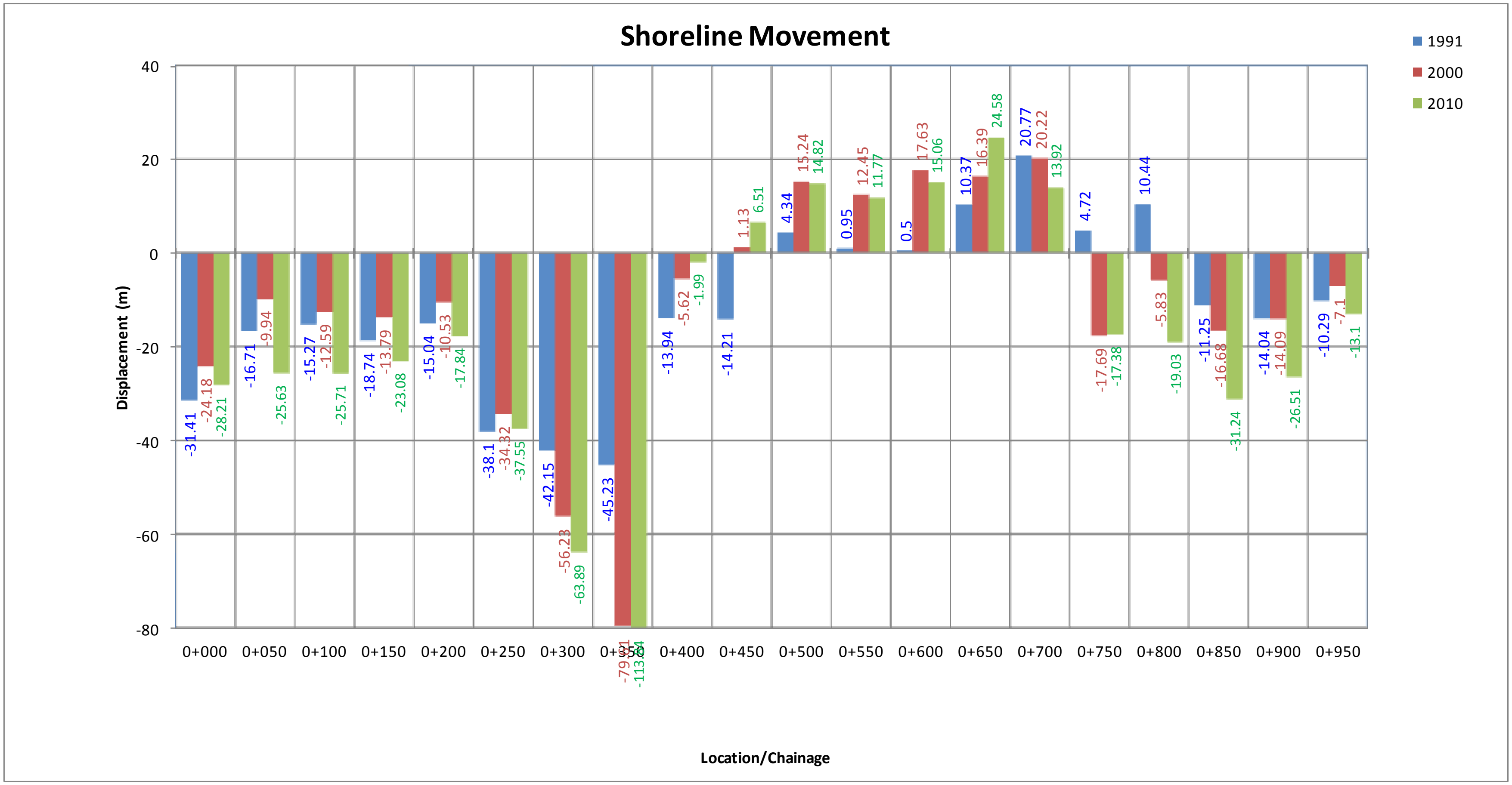


Figure 5-99 Graph showing the displacements of the shoreline for different years about the 1968 shoreline for Old Harbour Bay (1964 to 20010)

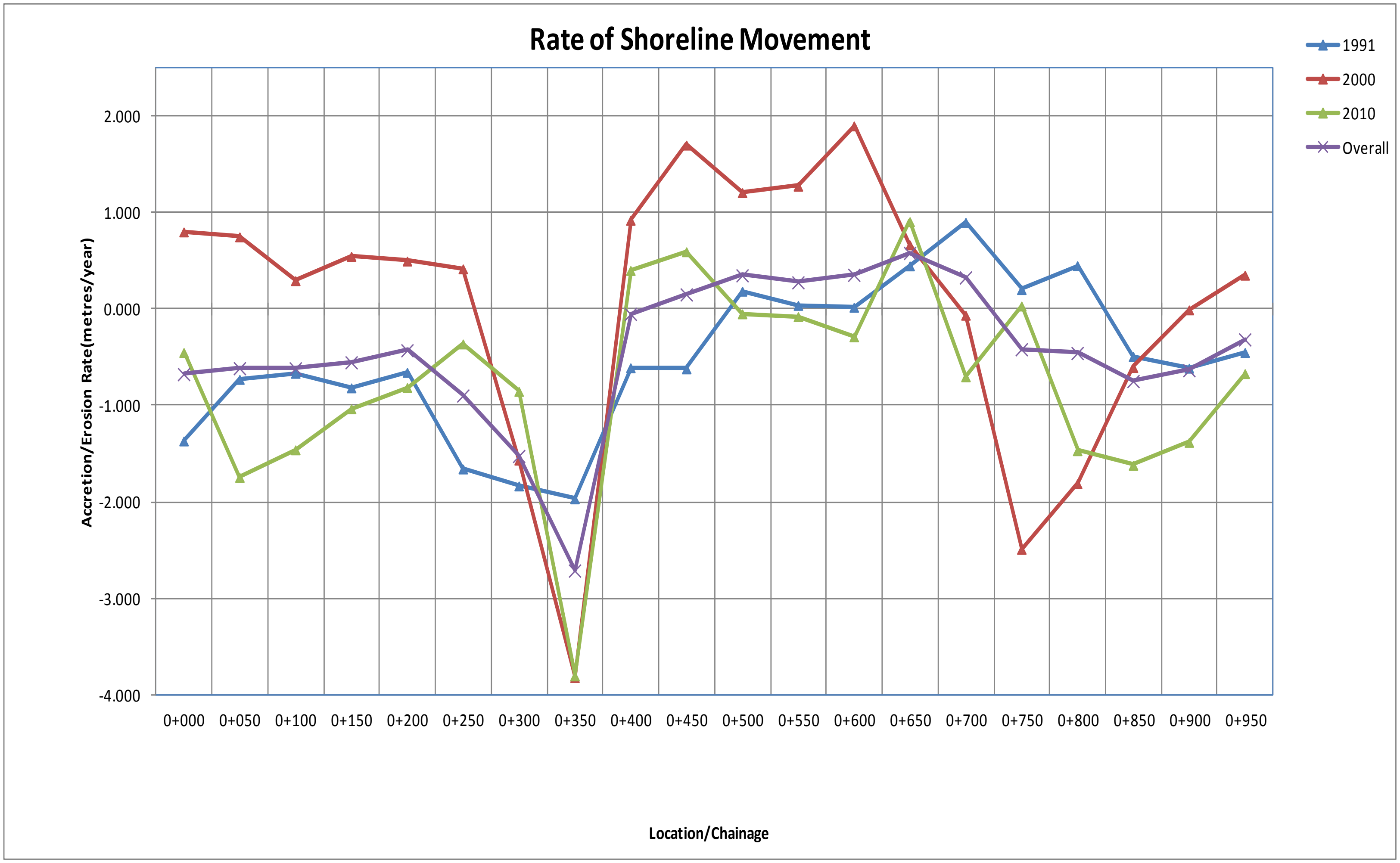


Figure 5-100 Graph showing the rates of erosion/accretion for the shoreline about the 1968 shoreline for different time intervals for Old Harbour Bay (1964 to 2010)

Estimation of Shoreline Retreat

BRUUN MODEL

The Bruun model is perhaps the best-known and most commonly used of the models that relate shoreline retreat to sea level rise. This two-dimensional model assumes an equilibrium profile. Thus, it inherently assumes that the volume of sediment deposited is equal to that eroded from the dunes and that the rise in the nearshore bottom as a result of the deposited sediment is equal to the rise in sea level. The original Bruun model is expressed below, and this mathematical relationship was the basis for estimating shoreline retreat within the study area.

$$\Delta y = \frac{\Delta s \cdot l*}{h*}$$

Where:

Parameter	Description	Units
Δy	Dune line erosion	m
Δs	Rate of sea level rise	m
$l*$	Length of the offshore profile out to a supposed depth, h*, of the limit of material exchange from the beach and the offshore	m
$h*$	Depth at offshore limit of l*, to which nearshore sediments exist (as opposed to finer-grained continental shelf sediments)	m

RATE OF SEA LEVEL RISE, ΔS

Inspection of research in this area revealed that global sea level may rise as a result of greenhouse gas-induced global warming at a rate of 5 mm/year over the next 100 years. Indeed, there will be regional variation in the sea level rise signal, and for this reason regions may undertake sea-level rise scenario modelling, which takes into account various factors such as land movement and region-specific oceanographic data.

For the purposes of this project, a simple scenario, based on one estimate of sea level rise will be utilized (not taking into account any vertical tectonic movements of the shoreline nor any discernible change in the ocean geodynamic surface). Typically, a mid-range or upper estimate is chosen for such types of scenarios. The Intergovernmental Panel on Climate Change's (IPCC) Special Report on Emissions Scenarios (SRES) estimate global sea-level to rise 9-88 cm in the next 100 years (McCarthy et al, 2001) was considered for the calculations, and specially the upper limit of this range, 8.9 cm by 2025 (0.00445 m/yr) was utilized.

Sea-level rise is projected to the year 2025, as the shelf life of the project was chosen to be 20 years. Using the upper limit value of 8.9 cm by 2025 allowed this analysis to test whether the coastal region of Old Harbour Bay is vulnerable to a plausible upper limit of climate change and simultaneous storm-induced short-term erosion for the 100-year return period.

DEPTH TO WHICH NEARSHORE SEDIMENTS EXIST, H*

A beach profile has a practical seaward limiting depth, where the wave conditions can no longer change the profile. Sand may move back and forth along this equilibrium profile, but there is no perceptible change in depth. This seaward limiting depth is equivalent to the depth at which nearshore sediments exist (*h**). Hallermeier (Hallermeier, 1981 in Kamphuis, 2000) refers to this depth as the critical or closure depth (d_c), and approximates it using the following equation.

$$d_c = 1.6 H_{s,12}$$

Where:

$H_{s,12}$ = significant wave height which occurs 12 hrs/yr on average

It was therefore necessary to determine the operational wave climate within the study area between the shoreline and the reefs in order to estimate the critical depth. Long term wave data available for the south of Portland Bight was analysed to determine the 12 hour wave ($H_{s,\ 12}$). The $H_{s,\ 12}$ was determined to be a 11.5 second, 2.5 metre swell wave.

LENGTH OF OFFSHORE PROFILE, L*

The calculated critical depth (or *h**) was used to estimate the length of the offshore profile. This was done by inspecting each of the three (3) profiles cut for the REFDIF modelling and obtaining profile lengths for the corresponding critical depth. These profile lengths obtained were incorporated into the Bruun Model equation.

CALCULATIONS

Overall the shoreline has been eroding based on the 42 years of imagery data examined. The Bruun model indicates some of the erosions (67 to 100 percent) measured from the imagery can be attributed to sea level rise. It would also indicate that short term erosions due to extreme events are not the key drivers of erosion but the rise rising sea levels.

Table 5-50 shows the calculation of the long term trends expected in 25 years along the Old Harbour Bay beaches. As seen in this table, the following input values were incorporated into the Bruun Model to arrive at an estimate for the long-term erosion trend at each of the six (6) profile shoreline positions:

- Rate of sea-level rise = 0.0047 m/yr (IPCC 2007)
- Depth to which nearshore sediment exists (*h**, d_c) = 2.5 m

It should be emphasized here that the results of these calculations are an estimate of the projected shoreline retreat using a simplistic approach with an upper limit of global sea level rise. Indeed, the changes in beach profile over the years may have been impacted by the annual sea level rise as well as operational and storm-induced erosion estimated. This estimation of the sea level rise will assist in the determination of the true impacts that are due to operational a storm induces erosion.

The shoreline along the study area was estimated to retreat at varying rates between 0.4 and 0.6 metres per year as a result of global sea level rise. The historical erosions at each profile location (1-4) were compared to the Bruun estimated erosion due to sea level rise. The results indicated sea level rise may actually be a major contributor to shoreline erosion. At location 1 SLR may actually account for 67 percent of the erosion that occurred, at locations 2 and 3 all the erosion that occurred may be due to SLR, and at location 4 the growth of the area has been limited by around 67 percent.

Overall the shoreline has been eroding based on the 42 years of imagery data examined. The Bruun model indicates some of the erosions (67 to 100 percent) measured from the imagery can be attributed to sea level rise. It would also indicate that short term erosions due to extreme events are not the key drivers of erosion but the rise rising sea levels.

Table 5-50 Comparison of long-term erosion trends for Old Harbour Bay beaches to the estimates of erosion due to sea level rise using Bruun Model.

Beach	**1**	**2**	**3**	**4**
Profile	1	2	3	4
Chainage	0+250	0+550	0+750	1+600
Long term erosion (m) (42 years)				
Brune	25.03	16.42	21.40	42.32
Historical	37.55	11.77	17.38	-20.49
Difference (m)	12.52	-4.65	-4.02	-62.81
Difference (%)	67%	140%	123%	-67%

Limitations

Estimating long-term erosion trends as result of global sea level rise was not the main focus of this section. Given the anecdotal information in the area, it was important to know how the area is affected by long term and short term weather/climate events. The two most applicable approaches were chosen in order to arrive at a shoreline retreat rate which may be useful in determining how much of the observed erosion as actually due to events and short term erosion. The maps obtained were only snapshots at a moment in time that cannot be manipulated to show years or times of interest. Therefore some of the maps may be displaying short term shoreline configurations while others long term. The accuracy of the rates is therefore subjected to the use of more aerial photos at strategic times which cannot be sourced. Bruun model gives an estimate of the dune line erosion rate, however does not implicitly explore the possible changes in the profile owing to this retreat. These profile changes would have undoubtedly had an effect on any predicted storm-induced erosion on the shoreline and may certainly have explained why there is accretion at profile #2 and erosion for profiles 1 and 2.

5.2.5.2 Event Based Short Term Coastal Erosion

Model Description

SBEACH is an empirically based numerical model for estimating beach and dune erosion due to storm waves and water levels. The magnitude of cross-shore sand transport is related to wave energy dissipation per unit water volume in the main portion of the surf zone. The direction of transport is dependent on deep water wave steepness and sediment fall speed. SBEACH is a short-term storm processes model and is intended for the estimation of beach profile response to storm events. Typical simulation durations are limited to hours to days (1 week maximum).

Model Input

Profiles were cut from deep water to land up to a maximum elevation of approximately 10 metres from four Profiles spanning the entire shoreline. The wave data from the deep water hurricane model were utilized for this analysis. The wave characteristics used in this model are the same as those used for the wave transformation modelling.

Table 5-51 Input parameters for 50 year return storm.

Return Period	Direction	Hs (s)	Tp (s)	Setup (m)	Storm Duration (days)
50	S	7.2	13.3	2.15	2
	SE	7.2	13.3	2.15	2
100	S	7.7	13.7	2.44	2
	SE	7.7	13.7	2.44	2

Results

No erosion was shown for the 50 and 100 year storm at the four locations analysed along the shoreline. These results are consistent with the previous cross shore sediment transport model and wave transformation results that indicate the shoreline is stable for the 50 year and 100 year wave conditions.

5.2.6 Seismicity and Earthquakes

Evidence of fault movements affecting the White Limestone bedrock (five million years and older) in the Old Harbour Bay region is provided by data from water supply wells and geophysical studies (Fernandez, 1983), confirmed from numerous surface outcrops throughout the island. Although no younger rocks outcrop in the immediate vicinity of the site, in other parts of the island rocks of the Coastal Group (130,000 to 3 million years old) are warped and/or faulted (Horsfield 1973). As noted above, faulting affecting more recent unconsolidated or semi-consolidated sediments may frequently be difficult to identify, and is not evident in the field at Old Harbour Bay. Fault displacements measured on rocks as young as 130,000 years old, together with continuing seismic events in present times indicates that Jamaica is in a seismically active part of the North Caribbean Plate boundary zone. Figure 5-101, a map showing the relative frequency of seismic events in different parts of Jamaica, indicates that between 5 and 9 events greater than intensity MM VI on the Mercalli scale occur per century.

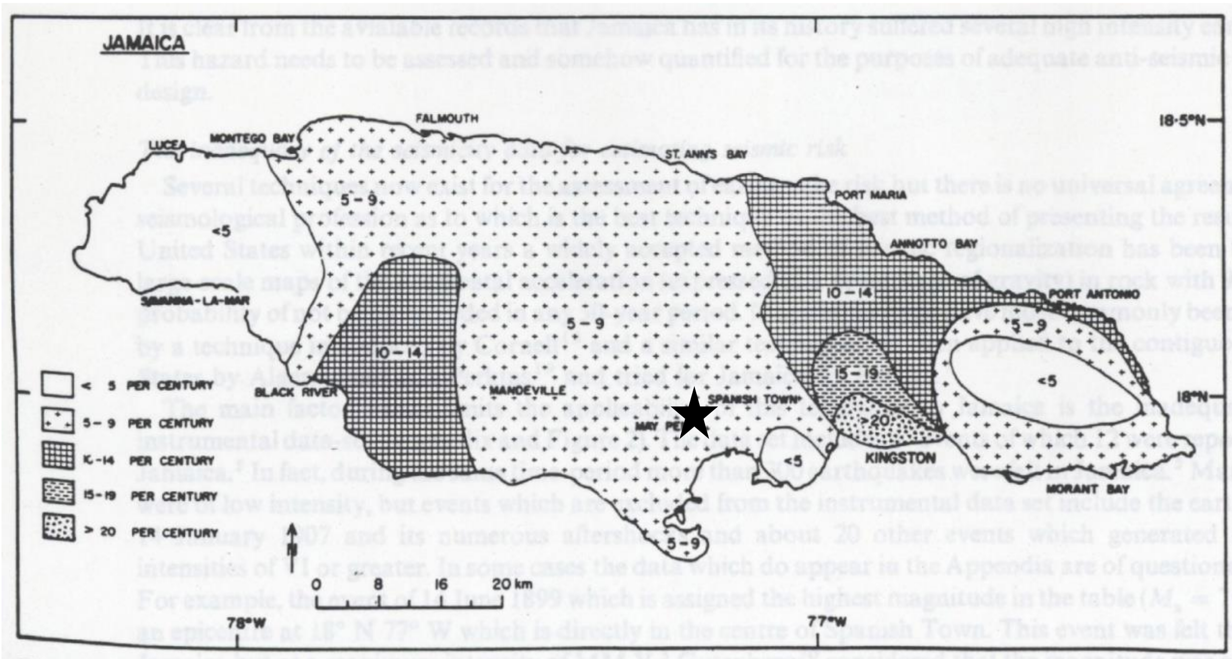


Figure 5-101 - Map showing number of times per century that intensities of MM VI or greater have been reported, 1880-1960 (from Shepherd & Aspinall, 1980). Black star is JPS 190 MW site

Figure 5-102 shows the probability of incidence of horizontal ground accelerations with a 10% probability of exceedence in fifty years in different areas of Jamaica (Shepherd et al. 1999). The Old Harbour Bay area (starred) has a 10% probability of experiencing accelerations of about 260 gals (26% g) per fifty years. The intensity of seismic shaking depends largely on the quality and thickness of the unconsolidated or semi-consolidated sediments overlying the bedrock. Shallow (less than 50 m) thicknesses transmit short period motions to best effect. Longer period motions are transmitted most effectively by thicknesses up to about 100 m (Aspinall & Shepherd, 1978). Thicknesses of semi-consolidated sediments exceeding 100 m tend to suppress the periods of engineering interest (CDMP 2001 Kingston study).

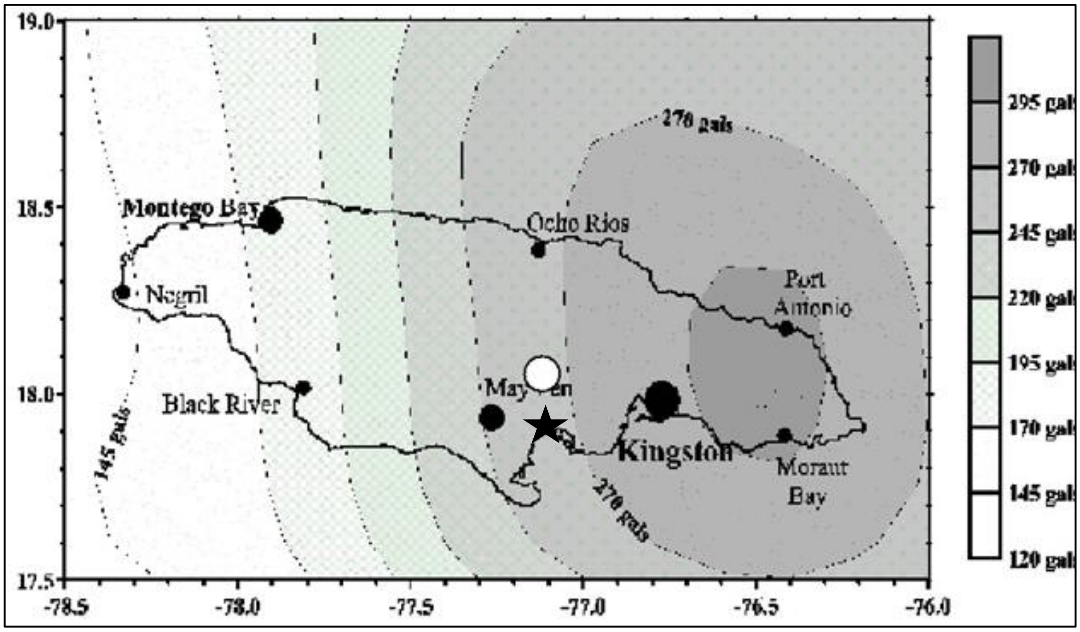


Figure 5-102 - Horizontal ground acceleration with 10% probability of exceedence in fifty years (Shepherd et al. 1999 in CDMP 2001), Contour interval is 25 gals (2.5%g). Modified from CDMP 2001. Black star is JPS 190 MW site

As described in the "Liquefaction Potential Analysis" report by Earth Systems Engineering, Ltd., the project site is in a historically active seismic area and the soils types in the vicinity of the proposed marine structures are subject to potential liquefaction in the sandy lenses of the upper 5 to 10 meters caused by seismic distress.

5.2.7 Tsunami

Although tsunami (seismic sea waves) are rare for Jamaica, there are a number of records of their occurrence along the coast (Ahmad, 1998). A tsunami event of the magnitude already recorded for the Caribbean (A.M. Scheffers at www.sthjournal.org/shelf2.pdf), and for the 'worst case scenario' resulting from a submarine eruption of Kick 'em Jenny volcano (Smith and Shepherd, 1993) would be hazardous for the site. Historical records for Jamaica indicate that the highest inundation elevation ever reported for the Jamaican south coast was 2.2 m at Port Royal (NOAA/NGDC, 2012). A similar event at Old Harbour would immerse some two fifths of the area of interest and most of the site of the proposed power station.

5.3 BIOLOGICAL

5.3.1 Overview

Previous studies of the proposed project area/impact area/ area of influence have also been included as part of this report. According to the Portland Bight Sustainable Development Area Management Plan (C-CAM, 1999), the development site falls within the Portland Bight Protected Area (PBPA). The PBPA is an environment management zone encompassing large sections of southern St. Catherine and Clarendon, totalling 519.8 km^2 of land (IVM, 2000). The boundaries of the PBPA delineate 82.0 km^2 of wetland and 210.3 km^2 of forest, which is known for its pockets of ecologically important flora and fauna communities; namely, Hellshire Hills, Brazilletto Mountains, Portland Ridge and Kemps Hill. These localities possess significant stands of dry limestone forest; however, the two proximal areas, Brazilletto Mountains and Hellshire Hills, are far removed: approximately 4.5 km west and 10.5 km east of the study site respectively. Furthermore, the site is centred on an alluvial plain and not highland, limestone substratum. These factors, combined with the severity of disturbance observed on-site, have given rise to vegetation that differs notably in stature, structure and composition when compared to the forest flora in the Brazilletto Mountains and Hellshire Hills (Halcrow and Associates, 1998; C-CAM, 1999).

A few mangrove species were found along an adjacent, earthen drainage canal, but no true wetland occurs on the property. The marine environment was also heavily degraded with some patches of seagrass in the nearshore environment. The coral community consists of a few random colonies occurring in the back reef, a few along a rubble crest and along the forereef. Most of the structure and rugosity of the comes from a large rubble area, held together with seagrass, sponges and other fouling and encrusting organisms and not the typical reef crest composed of hard corals, fire coral and some soft corals.

5.3.2 Portland Bight Protected Area

Jamaica currently lacks a comprehensive system of classification of protected areas. This reflects the ad hoc growth of the system under at least five Acts, each of which contains provisions that are relevant to protected area classifications. The four main governmental agencies whose legislation defines protected areas are:

- Department of Forestry
- Fisheries Department
- National Environment and Planning Agency

The following definitions are used as guidelines for the currently designated protected areas.

- According to Article 2 of the Biodiversity Convention, "Protected area" means “a geographically defined area which is designated or regulated and managed to achieve specific conservation objectives”

- A more detailed description is given by the IUCN definition: "An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and natural and associated cultural resources, and managed through legal or other effective means."

The Portland Bight is one of three of these protected areas and represents Jamaica's largest and most dynamic protected area.

The project site is located in the Portland Bight Protected Area (PBPA), at 1,876.2 km^2 (724.4 $miles^2$) or 187,615 ha the PBPA is by far the largest protected area in Jamaica. Its land area [519.8 km^2 (200.7 $miles^2$) or 51,975 ha] is 4.7% of the island of Jamaica, and its marine area [1,356.4 km^2 (523.7 $miles^2$) or 135,640 ha] is a significant part of Jamaica's shallow shelf. In comparison, the land area of the PBPA is a bit larger than the area of the Blue Mountain/John Crow Mountain National Park [488.4 km^2 (188.6 $miles^2$) or 48,835 ha], and larger than each of the independent nation states of Barbados, Grenada (and its outer islands), Antigua & Barbuda and St. Vincent & the Grenadines.

More than half of the land area of the PBPA is in its natural state, in dry limestone forests [210.3 km^2 (81.2 $miles^2$) or 21,025 ha] and wetlands [82.0 km^2 (31.7 $miles^2$) or 8,200 ha]. The rest is cultivated in sugar cane, or is used for human settlement. About 50,000 persons live within the boundaries of the PBPA in some forty-four (44) residential communities.

Of the approx. 16,000 fishers in Jamaica, about 4,000 (approximately 25%) are based in the coastal communities of the PBPA, the highest concentration in Jamaica. The vast majority of the households in the PBPA fall at or below the poverty line.

Industrial activity in the PBPA includes portions of four sugar estates (Monymusk, New Yarmouth, Bernard Lodge, and Innswood), several small farming and livestock entities, several limestone mining and sand/aggregate quarrying operations, two international shipping ports (Port Esquivel and Rocky Point), two electricity-generating plants, and a bauxite-alumina plant (ALCOA). With substantial marine and terrestrial areas, hosting industry, commerce and human settlements in close proximity to wilderness ecosystems, the PBPA is a microcosm of an island state in urgent need of sustainable development.

According to the Portland Bight Sustainable Development Area Management Plan (C-CAM, 1999), the development site falls within the industrial zone in the protected area. The proposed site is on abandoned agricultural lands with several old fish ponds, a small mangrove forest and mudflats. The overgrown vegetation, seasonal wetlands, old fish ponds, mudflats and the mangrove wetland provide a habitat for several birds' species including the migratory birds. It should be noted that there is limited literature available on the avifauna in the disturbed areas in the Portland Bight protected area. Most of the works have been done on the Cays, undisturbed dry forest and the wetland areas.

Due to the size and diversity of the PBPA, baseline data is sparse and specific to entities/habitats identified as sensitive and of either national or international significance. Large expanses of the area have no baseline data and only generalizations of the identified ecosystems have been used for designated zoning/land uses guidelines. Several faunal species have been identified either by historical evidence or actual on site observations. This includes the Jamaican iguana, once thought to be extinct, and now was rediscovered in the Hellshire Hills. These hills represent the only known habitat of the iguana and are a dry limestone forest of global significance. This is in stark contrast to Old Harbour Bay an area zoned for industrial activities which includes an Ethanol plant, JEP barges and the JPS Power-plant within disturbed coastal systems. The marine environment in the area has also suffered from severe anthropogenic influences, including dynamiting and over fishing as well as hurricane damage. The coral cays in the Bight also suffer from similar pressures but again in contrast are home to important birds, turtles and potentially manatees.

Table 5-52 - Table 5-54 below summarizes the sensitive areas/habitats, major taxonomic/sensitive faunal groups and the proposed zonation within Portland Bight as outlined in C-CAM (2007) Management Plan, The Draft Three Bays Fish Sanctuary Management Plan (2010) and those documented in the EIA.

The project area is located in an area with disturbed vegetation, giving rise to a habitat of low diversity. That is, of the species of interest identified by C-CAM, only the American Crocodile was found on site. Sensitive ecosystems or those of international significance are also not found in the project area or in the zone of influence. A limited mangrove stand is located along the banks of the Bowers Gully. A mixed seagrass bed and a poor reef community were also observed in the back reef area. These systems are within the zone of influence but can be described as currently having major anthropogenic influences. None of the habitats are expected to be negatively impacted by the project.

Table 5-52 Sensitive Areas, their locations and inclusion in Project Site and Zone of Influence

Sensitive Areas/Habitat	Location	Project Area	Zone of Influence	Impacts
RAMSAR Wetlands	The wetlands of Portland Bight received international recognition when they were designated Jamaica's 3rd RAMSAR site (i.e. Wetland of international importance) under the RAMSAR Convention for the Protection of Wetlands and Waterfowl on 2nd February 2006.	No	No	None
Dry Limestone Forest	Portland Ridge, Braziletto Mountain, Kemps Hill , Hellshire Hills	No	No	None
Forested Areas	Portland Ridge, Braziletto Mountain, Kemps Hill , Hellshire Hills	No	No	None
Seagrass Beds	Goat Islands, along sections of the Mainland, around sections of the cays	No	Yes	A mixed seagrass bed community was observed in the back reef area- within the zone of influence but can be described as currently having major anthropogenic influences.
Caves	Jackson Bay Caves, Jamaica's most extensive cave system	No	No	
Fish Sanctuaries	C-CAM No fish Zones- Galleon Harbour, Salt Harbour, Rocky Point, Three Bays, West Harbour	No	No	
Reef/Coral Areas	Fourteen (14) Coral Cays,	No	Few coral colonies in a poorly assembled reef area in-front of the project site	A poor coral reef community was observed - within the zone of influence but can be described as currently having major anthropogenic influences
Mangrove Areas	Over 30 miles of a mangroves extending from Galleon Harbour, West Harbour, Goat Islands and areas in between Pigeon Island	Yes (few Black Mangrove species located in the project area)	Few Riparian Mangroves line Bowers Gully	A limited mangrove stand is located along the banks of the Bowers Gully- within the zone of influence but can be described as currently having major anthropogenic influences

Table 5-53 Sensitive Zones, their locations and inclusion in Project Site and Zone of Influence

Biologically Sensitive Zones	Location	Project Area	Zone of Influence	Impacts
Forest Conservation Areas	Peake Bay, Hellshire Hills, Portland Ridge	No	No	None
Wetland Conservation Areas	Extensive mangroves of West Harbour, Clarendon, wetlands between the Cockpit Salt Marsh and Peake Bay, Salt Island Lagoon, Rocky Point fishing beach and Jackson's Bay, Goat islands	No	No	None
Fish Nursery Conservation Areas	Three Bays Fish Sanctuary (Fisheries Division), Galleon Harbour Fish Sanctuary, Salt Harbour (C-CAM)	No	No	None
Wildlife Reserve	Western Cays, Hellshire Hills	No	No	None
Game Reserves	Peake Bay, Cockpit Salt Marsh, including Salt Island and Long and Short Island, Amity Hall mangal, Two Goat Islands and the mangroves joining them	No	No	None

Table 5-54 Sensitive/Endangered Fauna, their locations and inclusion in Project Site and Zone of Influence

Sensitive/Endangered Fauna	Occurrence/ Location	Project Area	Zone of Influence	Impacts
American Crocodile *(Crocodylus acutus)*	Bowers River, Salt River, Cockpit River, Salt Island Creek, Bower's Gully, Breadnut Gully, Calabash Gully, Coleburn's Gully, Salt Gully, Rocky Point fishing beach and Jackson's Bay	Yes	Yes	Limited- slightly positive- afforded some protection by reduced human access to breeding areas
Hawksbill Turtle *(Eretmochelys imbricata)*	Nests on many of the Coral Cays and Parts of the Mainland	No	No	None
Green Turtle (*Chelonia mydas)*	Nests on many of the Coral Cays and Parts of the Mainland	No	No	None
West Indian Manatee *(Trichecus manatus*)	Historically observed within the Portland Bight	Historically Likely	Historically Likely	None
Magnificent Frigatebirds *(Fregata magnificens)*	Many of the Coral Cays and Parts of the Mainland (e.g. Bowers River, Salt River, Cockpit River, Salt Island Creek, Bower's Gully, Breadnut)	Yes	Yes	None- expected similarity in noise climate to the current state

Sensitive/Endangered Fauna	Occurrence/ Location	Project Area	Zone of Influence	Impacts
Brown Noddies *(Anous stolidus)*	Many of the Coral Cays and Parts of the Mainland (e.g. Bowers River, Salt River, Cockpit River, Salt Island Creek, Bower's Gully, Breadnut)	No	Insufficient Data/Literature	insufficient Data/Literature
Yellow Boa *(Epicrates subflavus)*	Hellshire Hills and Portland Ridge	No	No	
Jamaican Iguana *(Cyclura collei)*	Hellshire Hills provides the last known habitat of the recently rediscovered (1990) endemic Jamaican Iguana (*Cyclura collei*), a globally threatened species and Jamaica's largest native land animal	No	No	None
Thunder Snake *(Tropidophis sp)*	Entirely restricted to Portland Ridge	No	No	None
Blue Tailed Galliwasp *(Celestes duquesneyi)*	Entirely restricted to Portland Ridge	No	No	None
Jamaican Hutia/Coney	Hellshire Hills and Portland Ridge	No	No	None
Jamaican Skink (*Mabouya sloanii)*	Entirely restricted to Portland Ridge	No	No	None
Endemic Cave Frog *(Eleutherodactylus cavernicola)*	Portland Ridge and Jackson Bay Caves	No	No	None
Bahama Mockingbird *(Mimus gundlachii hillii)*	Hellshire Hills and Portland Ridge	No	Insufficient Data/literature	Insufficient Data/Literature
Jamaican Pauraque (*Siphonorhis americanus)*	Last seen more than 100 years ago is rumoured to persist in the Hellshire Hills	No	No	None
West Indian Whistling Duck *(Dendrocygna arborea)*	Within the Portland Bight in particular Salt Island Lagoon, Rocky Point	No	No	None
Fish-eating bat *(Noctilio leporinus)*	Jackson Bay Caves, Jamaica's most extensive cave system	No	No	None

5.3.3 Terrestrial Flora

5.3.3.1 Background and Site Description

The current survey, executed in 2014, revealed a plant community conditioned to endure continuous anthropogenic activity, prolonged drought and some minor flooding. The flora consisted of a mosaic of severely disturbed, secondary-succession vegetation types. These terrestrial communities included a salina that appears to transition into a severely degraded wetland; as well as a patchwork of savannah and thorn savannah flora. However, this sub-section will summarise the relevant findings gleaned from terrestrial surveys conducted in the Portland Bight Protected Area were between 1998 and 2012.

The Hellshire Hills, Brazilletto Mountains, Portland Ridge and Kemps Hill are localities known to possess significant stands of dry limestone forest; however, the two proximal areas, Brazilletto Mountains and Hellshire Hills, are far removed: approximately 4.5 km west and 10.5 km east of the study site respectively. Furthermore, the site is centred on an alluvial plain and not highland, limestone substratum. These factors, combined with the severity of disturbance observed on the current development site, have given rise to vegetation that differs notably in stature, structure and composition when compared to the forest flora in the Brazilletto Mountains and Hellshire Hills (Halcrow and Associates, 1998; C-CAM, 1999).

Approximately 3.0 km to the north of the study site is the New Harbour Housing Development, located on lands which were originally occupied by scrub savannah and abandoned pasture (ESL, 2006); vegetation types similar to those existing on the study site. The flora of the surrounding areas was described by the housing development's EIA as being severely disturbed and incapable of providing an easy source of re-colonising constituents (ESL, 2006a). No threatened or endangered plants were found on that site, which was primarily occupied by African Star Grass (*Rhynchospora* sp.) and trees such as Guango (*Samanea saman*) and Cashaw (*Prosopis juliflora*).

The closest industrial infrastructure to the study site is the ethanol processing facility at Port Esquivel, which is located approximately 2.3 km to the southwest of the proposed power plant. Environmental Solutions Ltd. (ESL, 2006b) reported that the vegetation was disturbed and consisted of several types such as, coastal mangrove, coastal thorn scrub, salt flat and residential (cultivated) vegetation. During that expedition, two endemic species were encountered, *Opuntia jamaicensis* and *Hylocereus triangularis* (God Okra).

According to the SJPC EIA (CL Environmental, 2012) the lands could be delineated into three contiguous zones based on the community-types present. This EIA was conducted within a rainy period (May 19 & 23, 2012). The first community type was a degraded Silt Mangrove wetland towards the southern perimeters. *Avicennia germinans* (Black Mangrove) was the dominant mangrove species encountered and was often associated with *Acacia tortuosa* (Wild Poponax) and *Harrisia gracilis* (Torchwood Dildo). The herb, *Eleocharis* sp. was a very common ground-layer constituent during this wet period, as well as the halophytic scrambler, *Sesuvium portulacastrum* (Seaside Purslane) (CL Environmental, 2012).

Further north, there occurred a disturbed Salina, consisting mainly of herbaceous, secondary pioneer species that inhabited an area once used for inland aquaculture (CL Environmental, 2007 & 2012). The halophyte, *Batis maritima* (Jamaican Sapphire) and the grass, *Sporobolus* sp. were primary constituents of former pond basins where there appeared to be an accumulation of clay soil. The occurrence of *Sida acuta* (Broomweed) and *Urena lobata* (Ballard Bush) was also common near the edges and banks of pond-depressions (CL Environmental, 2012).

The northern half of the property was occupied by a Thorn Savannah that consisted mainly of large stands of the thorny leguminous phanerophyte, *A. tortuosa* surrounded by several introduced grass species. Apparently during the wetter months, expansive swards of *Panicum maximum* (Guinea Grass), *Adropogon* sp., *Cynodon dactylon* (Bermuda Grass) and *Paspalum* sp. occur abundantly. Sedges, namely *Cyperus* spp. and *Rhynchospora nervosa* (Star Grass), and weeds, such as *Bidens pilosa* (Spanish Needle), *Sida* spp., *Asclepias curassavica* (Red Top) and *Rivina humilis* (Bloodberry), were common. Where water tended to collect in small or gentle depressions *Typha domingensis* (Reedmace) and *Commelina diffusa* (Water Grass) were frequent (CL Environmental, 2012). The flora of the northern-most sector was found to be notably different from the surrounding flora, where several large stands of *Samanea saman* (Guango) and *Guzuma ulmifolia* (Bastard Cedar) trees were observed. These trees had an average DBH of 52.4 cm and 28.4 cm and an average height of 11.3 m and 6.7 m respectively (CL Environmental, 2012).

Overall, the area appeared to be affected by high levels of anthropogenic influence. This was evidenced especially by coppicing (tree cutting), charcoal burning and grazing by domestic livestock. Paths had also been created through sections of the vegetation, indicating repeated human access.

5.3.3.2 Methodology

An important part of any vegetation survey is determining the most efficient way to effectively sample the plant community. Owing to the highly disturbed and open nature of the area, it was determined that the area could be effectively surveyed using a series of walk-though floral inventories, which were conducted on July 9, 2014. During these walk-throughs, the mean vegetation height as well as species composition was noted; the latter being ranked according to a DAFOR[10] scale. The sorties were concentrated within the footprint of the planned development. However, areas adjacent to the development site and to the existing power plant were also investigated – including Southern Jamaica Power Company (SJPC) delineated lands.

Additionally, information garnered from past environmental assessments in the area was used to assist the survey. In particular, the 2012 SJPC 360 MW Combined Cycle Plant EIA provided the most recent background information (Appendix 7). Virtually all plant species encountered during the field surveys were identified *in-situ* or samples collected and taken to the University of the West Indies Herbarium for later identification.

[10] DAFOR occurrence rank: a subjective scale of species occurrence within an area of study. The acronym refers to, **D**ominant, **A**bundant, **F**requent, **O**ccasional, **R**are.

5.3.3.3 Results and Discussion

Based on the sampling regime, it was felt that the results were best organised into the following sections:

1. The primary development site
2. Surrounding lands
3. Greater SJPC lands

Location for these sections may be seen Figure 5-103.

The most frequent, ecologically important and socially important floras are here presented, along with general descriptions of the area. Overall, the area appeared to be affected by high levels of anthropogenic influence due to the close proximity of a functioning power plant, human communities, scattered dwellings and subsistence agriculture. No endemic species were encountered, except that *Guiacum officinale* (Lignum Vitae) is a tree of national importance. A complete list of species encountered is presented in Appendix 7.

The Primary Development Site

The area delineated as the main development site included a section of the existing power plant that was bordered by a substantially high concrete wall. This section within the existing power plant was restricted in plant-life and diversity. The grounds were apparently kept clear and used to store waste material (as evidenced by the solid waste seen in Plate 5-4. A few stands of the grass *Cynodon dactylon* (Bermuda Grass) were the sole macrophytic representatives present (Plate 5-5)

Plate 5-4 Cleared disposal area of primary site (view towards the south-west)

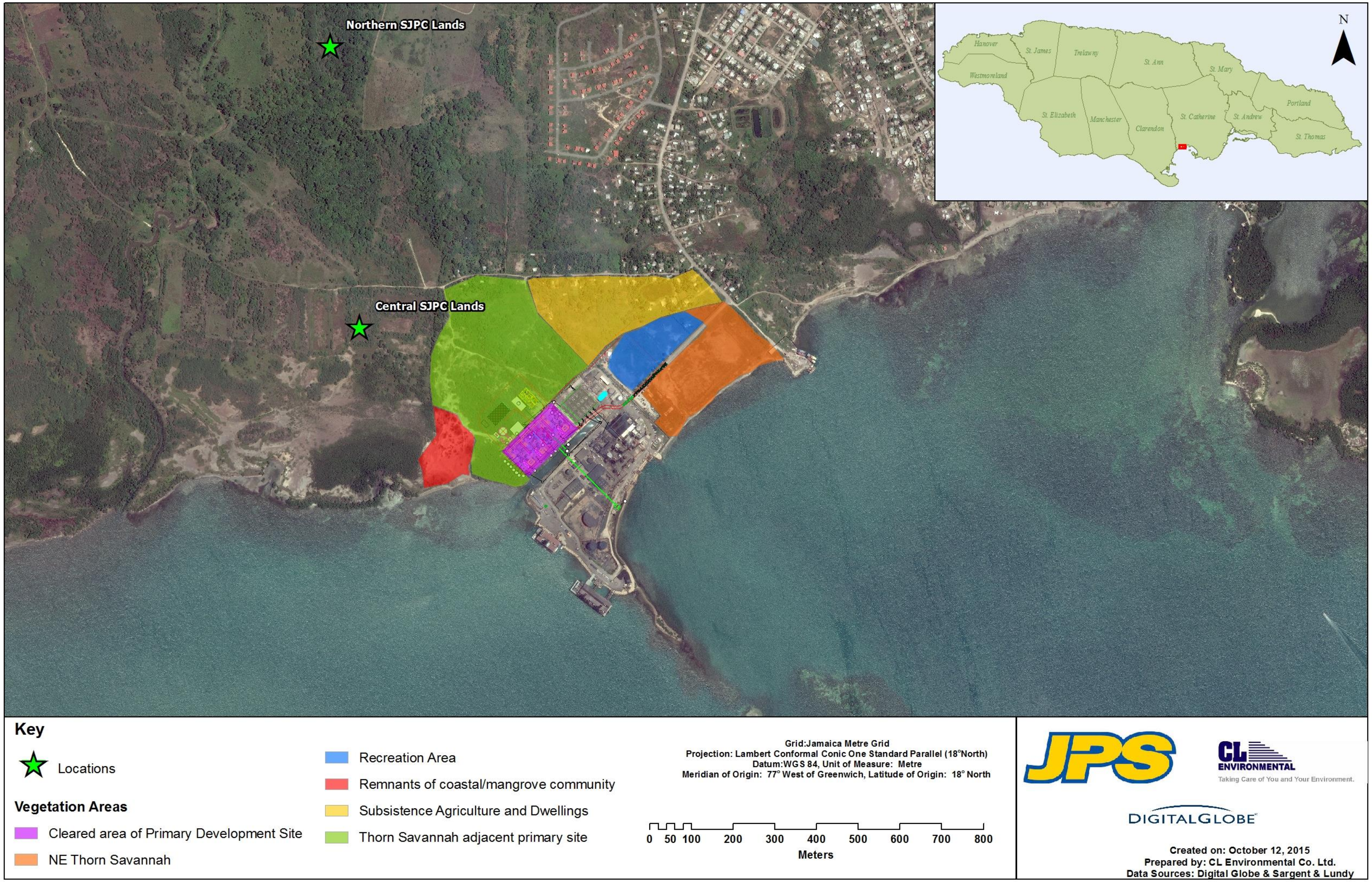


Figure 5-103 Vegetation areas

Plate 5-5 Waste area of primary site (looking north-east) bordered by clusters of *Cynodon dactylon* (Bermuda Grass) in distance

The land external to this walled area (to the northwest and southwest) was significantly richer in flora; although, also quite disturbed. Solid waste derived from the maintenance of nearby power lines was observed nearest to the plant as well as instances of charred vegetation. In several locations the ground cover appeared sparse, with the substrate being exposed regularly (Plate 5-6). This could have been exacerbated by the ongoing drought, which was at the time affecting the region. Several plant species were exhibiting signs of water stress (Plate 5-7).

Plate 5-6 Lands adjacent to primary site dominated by *Acacia tortuosa* (Wild Poponax) and with sparse ground cover provided by *Cynadon dactylon* (Bermuda Grass).

Plate 5-7 Tuft of *Sporobolus indica* undergoing drought stress

The flora was representative of a Thorn Savanna with the herbaceous component dominated by the grasses *C. dactylon* and *Sporobolus indica*. *Acacia tortuosa* (Wild Poponax) was the dominant tree constituent (Plate 5-6), while the nationally important *Guaiacum officinale* (Lignum Vitae) was the only other tree species present. Shrubby herbs, such as *Sida acuta* (Broomweed) and *Urena lobata* (Ballard Bush) were ubiquitous and the cacti *Harrisia gracilis* (Torchwood Dildo) and *Stenocereus hystrix* (Dildo Pear) were conspicuous shrubs. Herbaceous climbers were also common; namely, *Antigonon leptopus* (Coralita) and *Ipomoea* sp. The dominance of *A. Tortuosa* remained relatively constant; however, the grasses tended to give way to *S. acuta*, *Stemodia maritima*, *Gomphrena decumbens* and *G. celosioides* towards the shore and the dominant climber/runner became *Ipomoea* sp (Plate 5-8).

Plate 5-8 View of shore from lands adjacent and to the south of the primary development site

Surrounding Lands

Northeast of the existing power plant, the vegetation was a remnant of the thorn savannah, which was severely influenced by anthropogenic activity. Evidence of grazing and fire damage was present at the time of this survey.

Phanerophyte representation was very poor and was limited to a few *A. tortuosa* representatives. The grasses *C. dactylon* and *Sporobolus spp*. were quite abundant. However, as one progressed southeast, towards the shore, there was a slight change in species composition where the grasses gave way to succulent herbaceous halophytes, namely *B. maritima* (Jamaican Sappire), *Portulaca* sp. and *Sesuvium portulacastrum* (Seaside Purselane). The shrubs *Jatropha gossypifolia* (Belly-Ache Bush) and *W. indica* were common constituents.

Plate 5-9 Overview of flora located north-east of existing power plant. Note charred vegetation just above date stamp

A recreation complex, was also located to the north-east. Here, ornamental/cultivated plants such as *Nerium oleander* (Oleander), *Lantana camara* (Wild Sage), *Durata repens* (Angel's Whisper), *Ixora* sp. and *Ziziphus mauritiana* (Coolie Plum). These plants surrounded a sports field consisting mainly of mowed *C. dactylon*, *Sporobolus* spp. and *S. Portulacastrum*. *Casurina* equisetifolia (Willow), Ficus sp. and Cassia emarginata trees were also found along the perimeter (Plate 5-10).

Plate 5-10 Sports field of recreation complex ringed by tree species and occupied mainly by grasses and succulent halophytes

Greater SJPC Lands

The vegetation here was not expected to be impacted directly by the proposed development. However, it was rapidly assessed so as to provide a drought-period update the SJPC EIA of 2012. The southernmost portion of the property consisted of large areas of bare, sandy-clay soil, occupied by vegetation islands consisting mainly of *B. maritima*, *A. tortuosa* and *S. maritima*. The shoreline itself was occupied primarily by mangrove species *Rhizophora mangle* (Red Mangrove) and *Avicennia germinans* (Black Mangrove).

Plate 5-11 Southern section of Lands occupied by *Batis maritima* (foreground), *Avicennia germinans* (centre) and *Rhizophora mangle* (distance). *Acacia tortuosa* may be seen just left, almost out of frame.

The central areas were also grass dominated; in particular, with the ubiquitous *C. dactylon*. Notably absent from the area (when compared to the CL Environmental SJPC EIA, 2012) were the herbs *Eleocharis* sp. and *Typha domingensis* (Reedmace) due to the dry conditions. Subsistence agriculture was also present with cultivations of Carica papaya (Papaya), Mangifera indica, Musa sapientum (Banana) and Saccharum officinarum (Sugarcane) (Plate 5-12). A. tortuosa was the dominant tree species.

Some northern sections showed severe loss of ground cover due to clearance by fires and drought conditions (also in Plate 5-12). In other northern sections, the vegetation as described in the CL Environmental SJPC EIA (2012) remained intact, but reduced in canopy cover. Of note was the occurrence of a large clearance of vegetation to make an informal roadway (Plate 5-13). A complete list of the vegetation encountered in 2012, in this area, may be found in Appendix 7.

Plate 5-12 Section of land cleared by fire. Note cultivation of *Musa* spp. in background

Plate 5-13 Section of vegetation cleared for vehicular access

5.3.4 Fauna

5.3.4.1 Avifauna

SJPC Site Description

The sample sites for the avifauna survey were zoned according to vegetation and habitat types, which includes acacia woodland, fish ponds, mangrove wetlands, mudflats and salinas which are described below.

FISH PONDS

The old fish ponds on the property were all dried at the time both studies were carried out. The vegetation within the ponds consists of grasses, sedges and small shrubs. In addition, several land crab holes were observed in the ponds. There were also a belt of large acacia trees along the banks of the ponds.

Plate 5-14 Images showing the old fish ponds within the project area.

MANGROVES

The mangroves were seen throughout the area for the proposed power plant. The mangrove density varied throughout the project area, where there was a large patch of dense mangroves found on the coastal sections of the property. As you move from the coast the mangroves gradually become sparse.

Plate 5-15 Representation of the mangroves located near the coast on the property.

ACACIA WOODLAND

A small patch of acacia woodland was located near the present power plant. The vegetation in the area consists of mainly acacia trees and cactus.

Plate 5-16 Small patch of dry acacia woodland.

MUDFLAT AND SALINAS

The mudflats and Salinas were located mainly on the coastal area. A few were located inland within the mangrove wetlands near the mangrove forest. The main mudflat on the property was currently inundated, which was mainly influence by the tide. Most of the other mudflats on the property were dry as a result of the drought in the area.

Plate 5-17 Main mudflat located on the property.

Methodology

A modified line transect bird survey method was used for the study along the established trails on the property. The method entailed walking slowly for a given distance along selected routes and noting all the birds seen or heard in the area (Wunderle, 1994). The trails were used as transects due to the size of the area and the easy accessible trails which pass through the different vegetation types. It should be noted that there was no need to create new trails because there was a network of trails on the property; no area was more than a few meters from a trail. In addition new trails would further disturb the fauna in the area. In additon, addition time were spent at the water bodies and the salinas to note the wetland birds present.

The bird survey was also carried out in the night for the nocturnal bird species. The studies were carried out in August 2012 and July 2014.

Results and Discussion

FISH PONDS, WETLAND, COAST AND SALINA

The old ponds, mudflats, mangrove wetland, coast and the temporary wetland within the study area is an important habitat for wetland birds and several coastal species. Over 26 wetland bird species were observed on the coast, fish ponds, mangrove forest and Salina which include Heron and Egrets (n=7), Pelicans (n=1), Ibises (n=2), Plovers (n=7), Sandpipers (n=4), stilts (n=1),warblers (n=1) and Frigate birds (n=1); 16 residents and 5resident/ migrants ().The most abundant bird present in the area was the Cattle egrets.

Fish ponds

Only a few birds were observed in foraing in the old fishponds, which were mainly herons. It should be noted that the fish ponds were dry when the surveys were carried and this could be the main reason why the weland bird numbers were low.

Mangrove wetland

A few birds were observed in the mangroves, such as the Yellow Warblers and the Black Crowned Night Heron. The Yellow Warbler was the most common bird in the mangroves. No migrant warblers were seen as result at the timeboth survey was carried out.

Coastal birds

On the coast, birds such as the Brown Pelican, Laughing Gull and Frigate Bird were observed. The most common species on the coast was the Frigate Bird. The Semipalmated Plover and the Sandpiper were seen foraging on the coast during low tide and on the coastal mudflats.

Mudflat and salinas

The majority of the wetland birds were observed in the mudflats and the Salinas such as plovers, Herons, and Sand Pipers. The Cattle Egret was the most abundant bird species seen foraging in the mudflats and Salinas. Resident/ migrant wetland birds which can be categorised as mudflat and salina specialist such as the Long-billed Curlew, Semipalmated Plover and the Spotted Sand Pipers were also seen foraging in the mudflats. It should be noted that the mudflats are an important habitat on the property for mudflat and salina species (Table 5-55). In addition, during the rainy reason several areas in the Salina that floods creating temporary ponds.

The Salinas and mudflats provide an important habitat for several crustaceans, and are also an important habitat for the several wetland birds that specialize in foraging on these crustaceans and other arthropods in the area, such as such as plovers, Herons, and Sand Pipers. The mudflats and Salinas are located near the Bowers Gully, where crocodiles were observed. However no crocodiles were observed in the Salinas and Mudflats.

Table 5-55 Wetland birds observed in the study.

Groupings	Proper Name	Scientific Name	Status	DAFOR	Habitat Type
Frigate birds	Magnificent Frigatebird	*Fregata magnificens*	Resident	O	Coastal
Gulls	Laughing Gull	*Leucophaeus atricilla*	Resident	O	Coastal
Herons and egrets	Black-Crowned Night Heron	*Nycticorax nycticorax*	Resident	R	Mudflat/ Salina
Herons and egrets	Cattle Egret	*Bubulcus ibis*	Resident	D	Mudflat/ Salina
Herons and egrets	Great Blue Heron	*Ardea herodias*	Resident / Migrant t	R	Mudflat/ Salina
Herons and egrets	Great Egret	*Casmerodius albus*	Resident / Migrant	R	Mudflat/ Salina
Herons and egrets	Green Heron	*Butorides virescens*	Resident	O	Mudflat/ Salina
Herons and egrets	Little Blue Heron	*Egretta careulea*	Resident	R	Mudflat/ Salina
Herons and egrets	Yellow-Crowned Night Heron	*Nycticorax violaceus*	Resident	O	Mudflat/ Salina
Ibeses	Glossy Ibis	*Plegadis falcinellus*	Resident	R	Mudflat/ Salina
Ibeses	White Ibis	*Eudocimus albus*	Resident	R	Mudflat/ Salina
Pelican	Brown Pelican	*Pelecanus occidentalis*	Resident	O	Coastal
Plover	Black-Bellied Plover	*Pluvialis squatarola*	Resident / Migrant	R	Mudflat/ Salina

Groupings	Proper Name	Scientific Name	Status	DAFOR	Habitat Type
Plover	Piping Plover	*Charadrius melodus*	Resident / Migrant	R	Mudflat/ Salina
Plover	Ruddy Turnstone	*Arenaria interpres*	Resident	O	Mudflat/ Salina
Plover	Sanderling	*Calidris alba*	Resident	R	Mudflat/ Salina
Plover	Semipalmated Plover	*Charadrius semipalmatus*	Resident / Migrant	R	Mudflat/ Salina
Plover	Wilson's Plover	*Charadrius wilsonia*	Resident	O	Mudflat/ Salina
Plover	Kildeer	*Charadrius vociferus*	Resident	O	Mudflat/ Salina
Sandpipers	Least Sandpiper	*Calidris minutilla*	Resident	O	Mudflat/ Salina
Sandpipers	Long-billed Curlew	*Numenius americanus*	Resident / Migrant	R	Mudflat/ Salina
Sandpipers	Solitary Sandpiper		Resident / Migrant	R	Mudflat/ Salina
Sandpipers	Spotted Sandpiper	*Actitis macularius*	Resident / Migrant	O	Mudflat/ Salina
Stilts	Back-necked Stilt	*Himantopus mexicanus*	Resident	O	Mudflat/ Salina
Warbler	Yellow Warbler	Dendroica petechia	Resident	R	Terrestrial

Nb: DAFOR scale used to categorize the birds identified in the study; Dominant (n ≥ 20), Abundant (n= 15 – 19); Frequent (n=10 – 14); Odd (n= 5- 9); Rare (n< 4).

BOWERS GULLY

The riverine system provides a habitat for crocodiles; it is known to be a nesting area for crocodiles, where, the network of mangroves roots protects the hatchlings until they reach maturity. Bowers Gully is the largest fresh water source the area, other than the old fishponds which are usually dry. It is an important refuge for fresh water birds such as Herons, Egret, Common Morehen and Ducks and as such it became a popular spot for birding. It is also an important fish nursery.

Great Egret, Little Blue Heron and Yellow- crowned night Heron were the only birds seen in the river. Birds such as the Coots, Common Morehen or Grebes, which are common in fresh water bodies and rivers, were not seen. It is possible that the flow and the salinity of the river could have been attributing to their absence. It is also possible that crocodile predation in the river is another factor which could attribute to the low numbers of wetland birds in the river.

Overall the number of wetland birds seen was very low and this could be as a result of the time of the year both surveys was carried out. The survey was carried out during the dry season where water levels are low. During the rainy season, the wetland floods and the old fish ponds floods, providing habitats for waterfowls such as ducks, morehens and Coots. It should be noted that both surveys were conducted before the arrival of the migrant wetland birds from North America.

TERRESTRIAL SPECIES

Thirty one (31) terrestrial bird species were observed during the survey of the property. The bird species diversity consisted of 12 endemic birds, 16 residents, and 3 migrants. It should be noted that four of the twelve of endemic birds identified in the study are forest specialist. The dominat terrestial species in the area was the white wing dove. In addition, most of the teresrtrial birds in the study were observed in the acaica woodland. A few terrestrial birds were observed in the trees along the old fish ponds and alo in the mangrove trees.

Only a few migrant warblers were seen in the study as this was as a result of the time of the year the study was carried out before the arrival of the migrants form North America. Studies have shown that dry forest, acacia forest, and scrubland vegetation are prime habitat for migrant warblers (Douglas, 2002). Of the 200 bird species found on the island, there are 74 winter visitors (Downer & Sutton, 1990). Overall, the migratory birds account for a large number of Jamaica's avifauna, which is almost doubled during winter season from August to May. Both bird surveys were not conducted in the winter migratory season and the bird species present in the area can only be carried out in a survey. In addition, due to the limited size of the acacia woodland only a few bird species which are typical of dry limestone forest were observed during the study (Table 5-56). There were also a few acacia trees along the banks of the abandoned fish ponds that provide a habitat for the terrestrial bird species encountered on the property.

Table 5-56 Terrestrial birds observed during the survey of the property.

Proper Name	Code Used	Scientific Name	Status	DAFOR
American Redstart	AMRE	Setophaga ruticilla	Migrant	R
Antillean Palm Swift	APSW	Tachornis phoenicobia	Resident	F
Bananaquit	BANA	Coereba flaveola	Resident	O
Black-Whiskered Vireo	BWVI	Vireo altiloquus	(Summer) Migrant	O
Common Ground Dove	COGD	Columbina passerina	Resident	O
Greater Antillean Bullfinch	GABU	Loxigilla violacea	Resident	R
Greater Antillean Elaenia	GAEL	*Elaenia fallax*	Resident	R
Jamaica Tody	**JATO**	**Todus todus**	**Endemic**	**O**
Jamaican Euphonia	**JAEU**	**Euphonia Jamaica**	**Endemic**	**R**
Jamaican Lizard-cuckoo	**JALC**	**Saurothera vetula**	**Endemic**	**R**
Jamaican Mango	**JAMH**	**Anthracothorax mango**	**Endemic**	**O**
Jamaican Oriole	**JAOR**	**Icterus leucopteryx**	**Endemic**	**O**
Jamaican Pewee	**JAPE**	**Contopus pallidus**	**Endemic**	**R**
Jamaican Vireo	**JAVI**	**Vireo modestus**	**Endemic**	**O**
Jamaican Woodpecker	**JAWO**	**Melanerpes radiolatus**	**Endemic**	**O**
Loggerhead Kingbird	LOKI	Tyrannus caudifasciatus	Resident	F
Northern Mockingbird	NOMO	Mimus polyglottos	Resident	F
Jamican Parakeet	**JAPA**	**Aratinga nana**	**Endemic**	**F**
Red-billed Streamertail	**RBST**	**Trochilus polytmus**	**Endemic**	**O**
Sad Flycatcher	**SAFL**	**Myiarchus barbirostris**	**Endemic**	**R**
Smooth-Billed Ani	SBAN	Crotophaga ani	Resident	F
Stolid Flycatcher	**STFL**	**Myiarchus stolidus**	**Endemic**	**R**
Turkey Vulture	TUVU	Carthartes aura	Resident	O
Vervain Hummingbird	VEHU	Mellisuga minima	Resident	O
White Crowned Pigeon	WCPI	Columba leucocephala	Resident	F
White-Collared Swift	WCSW	Streptoprocene zonaris	Resident	O
White-Winged Dove	WWDO	Zenaida asiatica	Resident	D

Proper Name	Code Used	Scientific Name	Status	DAFOR
Yellow Warbler	YEWA	Dendroica petechia	Resident	R
Yellow-faced Grassquit	YEFC	Tiaris olivacea	Resident	F
Zenaida Dove	ZEDO	Zenaida aurita	Resident	O

Limitations

- The study was carried out in the dry season. Fauna species composition with emphasis on birds and arthropods will change significantly in the wet season.
- The survey was conducted before the arrival of the migrants; hence the bird survey does not represent all the species which could be present in the area.

5.3.4.2 Bats (Chiroptera)

There are 27 different species of Bats found in Jamaica, some more common than others and some more easily detected. Habitat and feeding requirements vary greatly, insectivores, nectivours, frugivours, and combinations of these. There is also a fishing bat (*Noctilio leporinus*). Bats may utilize dense or cluttered forest, open spaces, forest edges, low lying vegetation or the understory for feeding and or travel and the usage of a particular area changes. Some species may roost in trees while others prefer caves, buildings and other more sheltered and humid environments. Bats utilize a diverse habitat range, even amongst species with similar feeding habits, showing deliberate niche portioning. Insect feeding bats for example may utilize open spaces, cluttered spaces or even prefer the edge of a forest and they may also hunt at different times of night.

Bats have historically been documented in the Clarendon and St Catherin area, including sections of the PBPA (Table 5-57). The proposed project site may therefore be used by a variety of bat species. Occasional flora constituents, such as columnar cacti, (*Harrisia gracilis* and *Stenocereus hystrix)* and ornamental shrubs (namely *Nerium oleanrder*) may be pollenated by bats, these have been document on or near the proposed site. It is therefore possible that nectivourous, insectivoursous and frugivours use the surrounding vegetation and land area for both hunting and travel.

Table 5-57 Historical Occurrence of Various Bat Species in the Parishes of St. Catherine and Clarendon.

Species	Feeding Habit	Historical Occurrence
Noctilio leporinus	Piscivore	Hellshire Hills Sisters Cave
Pteronotus macleayii	Insectivore	Douglas Cave Castel , S.t Clair Cave
Pteronotus parnellii	Insectivore	Hellshire Hills and two sisters cave, Douglas Cave Castel, St. Clair Cave, Jackson's Bay Cave
Pteronotus quadridens	Insectivore	Portland Point Lighthouse, St Clair Cave
Mormoops blainvillei	Insectivore	Douglas Cave Castel, River Sink Cave, St. Clair Cave, Jackson's Bay Cave, Riverhead Cave
Macrotus waterhousii jamaicensis	Insectivore	Portland Cave, Portland Cottage, Portland Ridge Cave, Portland Ridge, Portland Point, Portland Point Lighthouse, Colbeck Castel, Fort Clarence, Hellshire Hills,
Glossophaga soricina	Nectarivore	Mason River, Portland Cave, Mahoe Gardens, Portland Cottage, Portland Point, Portland Ridge, Portland Ridge Cave, Portland

Species	Feeding Habit	Historical Occurrence
		Point, Portland Point Lighthouse, Portland Cave, Riverhead Cave, River Sink and Two Sisters Cave
Monophyllus redmani redmani	Nectarivore	Douglas Cave, Mason River Research Centre, St. Clair Cave, Hellshire Hills, Jackson's Bay, Jackson's Bay Cave, Portland Cave, Skeleton Cave
Erophylla sezekorni syops	Frugivore	Kemps Hill, Portland Cave, Portland Ridge, Portland Point, Portland Point Lighthouse, Hellshire Hills, St. Clair Cave, Jackson's Bay
Phyllonycteris aphylla	Frugivore	St. Clair Cave, River Head Cave, Pedro Cave
Ariteus flavescens	Frugivore	Kemps Hill, Portland Ridge, Ferry Cave, Hellshire Hills, Riverhead Cave, Jackson's Bay, Portland Cave
Artibeus jamaicensis jamaicensis	Frugivore	Mason River Research Centre, Portland Ridge, Skeleton Cave, St Clair Cave, Ferry, Ferry Cave, Hellshire Hills, Drums Cave, Jackson's Bay, Jackson's Bay Cave, Portland Cave, Riverhead Cave, River Sink Cave
Natalus micropus micropus- (Chilonatalus micropus)	Insectivore	Jackson's Bay, St. Clair Cave,
Natalus stramineus jamaicensis	Insectivore	St Clair Cave, Portland Cave
Eptesicus fuscus (lynni)	Insectivore	Portland Point Lighthouse, Jackson's Bay, Riverhead Cave

Bat behaviour, biology and historical occurrence; Bats of Jamaica- Hugh H. Genoways, Robert J. Baker, John W. Bickham, Carlton J. Phillips Special Publication, Museum of Texas Tech University.

5.3.5 Marine Benthic Community

A detailed description of the benthic community will include previous studies along with current data. Special emphasis was placed on the recording and identification of rare, threatened, endemic, protected, endangered, and economically important species. Additionally, identification and descriptions of each marine habitat was also included.

5.3.5.1 2012 Study

Introduction

A previous benthic assessment was conducted in May 2012, the study area extended approximately 2 kilometres, from the shoreline to the reef area. Two distinct zones were identified during the survey (Figure 5-104).

- Fore Reef and Reef Crest
- Lagoon

The two distinct zones were surveyed using different methods due to both habitat types as well as environmental conditions. The results from this survey were used to guide the surveys conducted in this report. The findings below were reconfirmed in the current study.

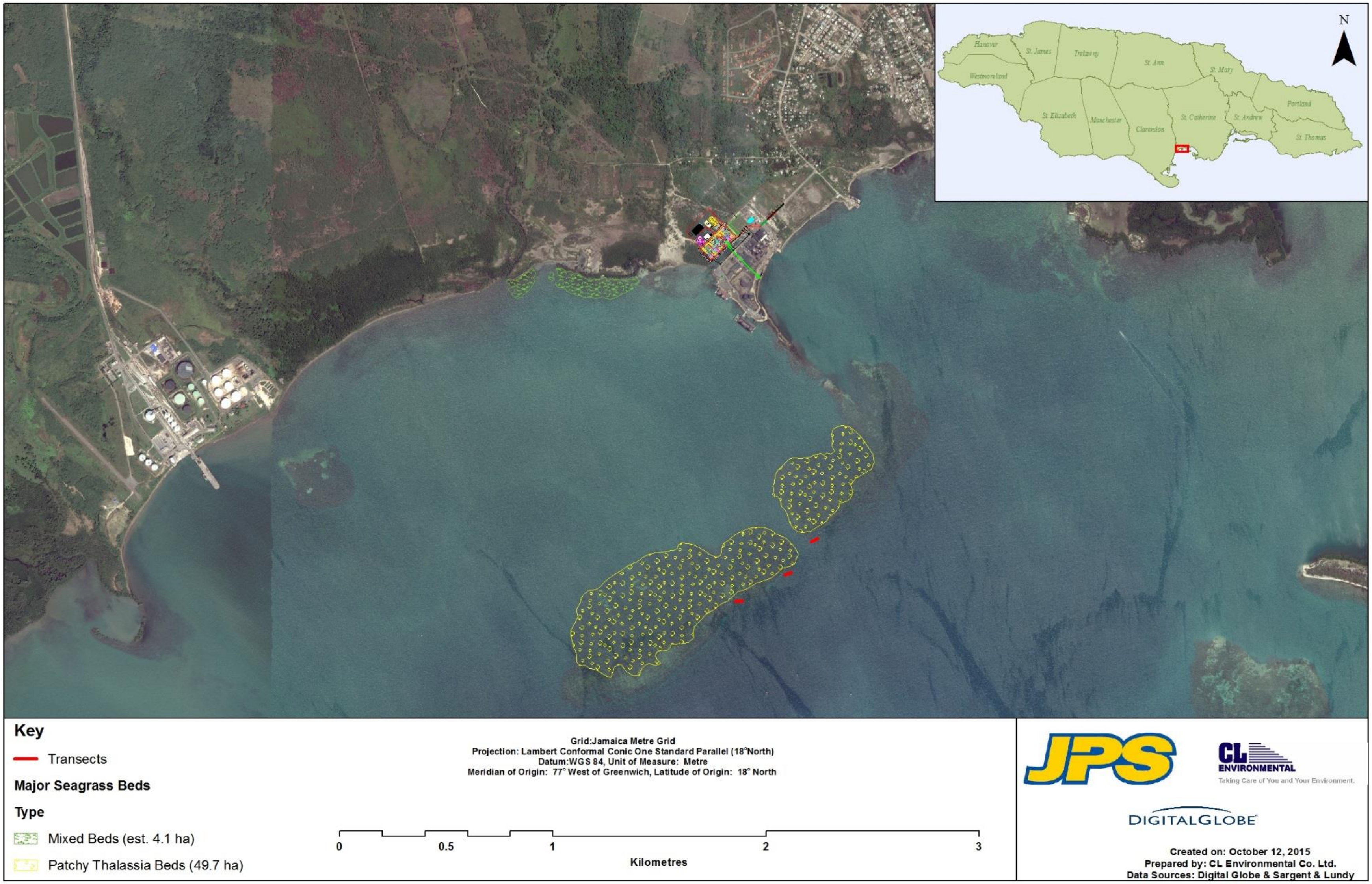


Figure 5-104 Map showing 2012 benthic study area with transect locations as well as seagrass areas

Forereef and Crest

METHOD

Using the results and data from the 2012 study of the area, several surveys and ground truthing activities were conducted in order to describe both the proposed impact areas as well as the surrounding areas of influence.

The study area can be characterised by poor visibility and dominated by soft, silty sediment which is easily disturbed. Several attempts were made to use a transect line survey method for both a benthic and fish assessment, however due to the extremely poor visibility, this was impossible. Various roving surveys and ground truthing exercises were conducted. Survey types included the following:

Roving SCUBA Survey

Roving SCUBA surveys were conducted. Some of these areas found seaward of the barrier (large mounds of unconsolidated material/rubble and rock held together by seagrass and various encrusting and fouling organisms) were previously surveyed. A photo inventory of sensitive species such as coral and seagrass were recorded along with general observations (Figure 5-105).

Grab Sample

Grab samples were used in a ground truthing exercise. This was then used to help describe each environment/sediment type.

ROV Survey

A ROV (VideoRay Remotely operated vehicle) was used when environmental conditions prevented the typical roving survey, such as; extremely poor visibility, shallow, easily disturbed soft sediment hazards (crocodiles). The images and video captured with the ROV were used to help describe the substrate type and conditions.

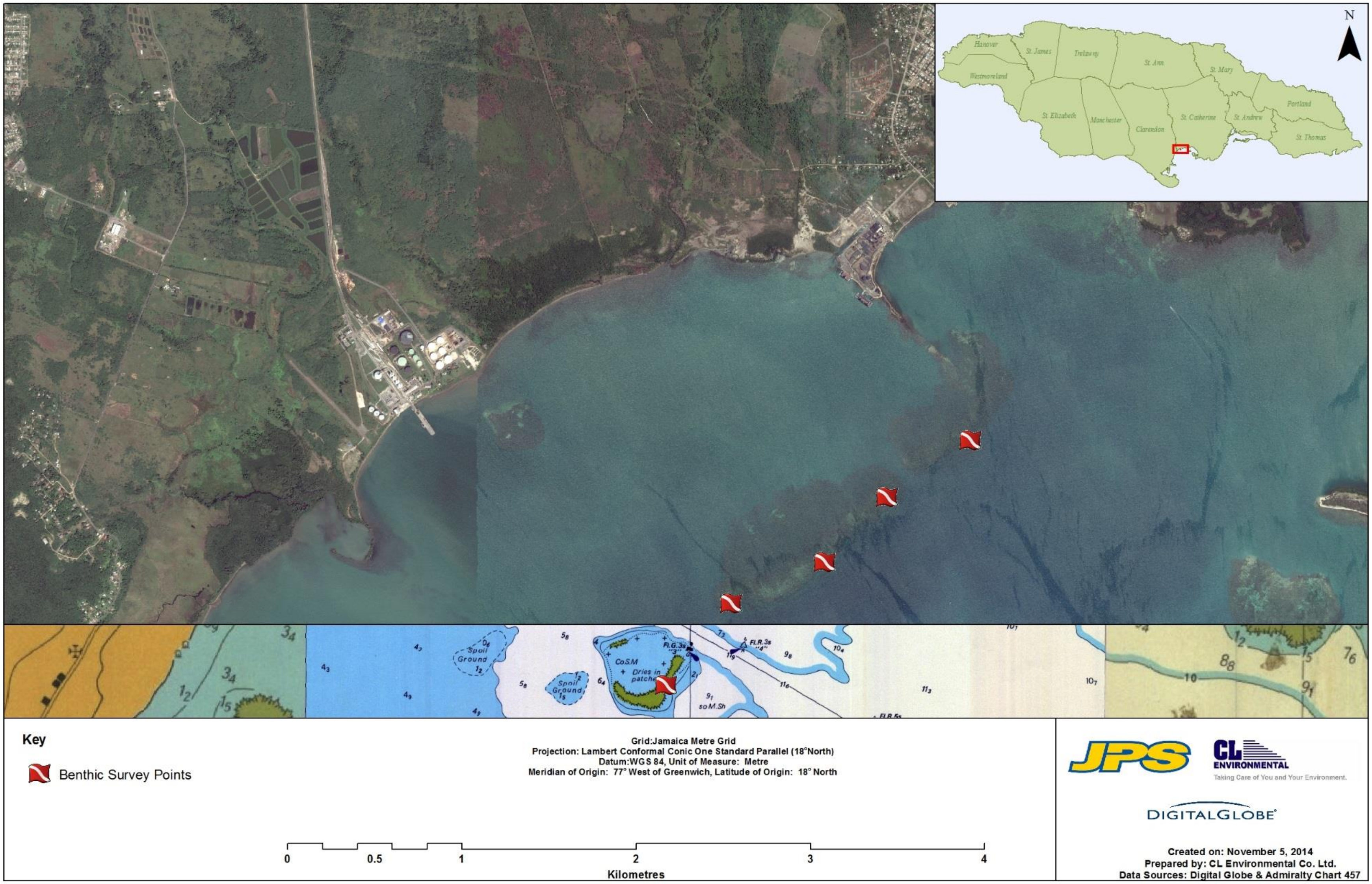


Figure 5-105 Locations of roving SCUBA surveys

RESULTS

During the 2012 study the reef crest was found to be composed of mainly unconsolidated material (coral skeletons/rubble and rocks) and held together by seagrass and various encrusting and fouling species. Diversity was low and the community dominated by macroalgae with few fish and invertebrates.

Directly in front of these patch areas a silty and sandy bottom composed mainly of small patch reefs and dead coral heads. Some live coral was noted in the area along with several sponges and encrusting species and large amounts of macro algae.

This continues to be an accurate description of this area, with even fewer species observed but his may be as a result of the poor visibility.

Coral Community

A fringing reef system was reported approximately 3km from the shoreline (CLE, 2005), but no coral reef communities were observed (CLE, 2005; ESL, 2006b, CLE 2012). The area was dominated by seagrass, Thalassia testudinum, and macroalgae with mounds of coral heads and coral rubble interspersed throughout (ESL, 2006b).

The coral community occurs in an area of rubble, composed of a combination of *Acorpora cervicornis* and *Porites porites* branches dominated by algae. Some small patch reef formations (very low relief) were also observed in the area.

Much of the unconsolidated substrate is dominated by fleshy algae with the main types being *Sargassum sp., Dictyota sp., Caulerpa sp.* Calcareous algae were less dominant and included Halimeda spp. and Galaxura spp. and small amounts of turf algae; shown in Table 5-58 and Figure 5-106.

Table 5-58 Table showing Algae species and Occurrence

Algae	Class	Occurrence
Sargassum sp.	Phaeophycae	25
Caulerpa sp.	Bryopsidophyceae	10
Dictyota sp.	Phaeophycae	19
Halimeda sp.	Bryopsidophyceae	5
Galaxaura sp.	Rhodophyceae	14
Fleshy Algae		5

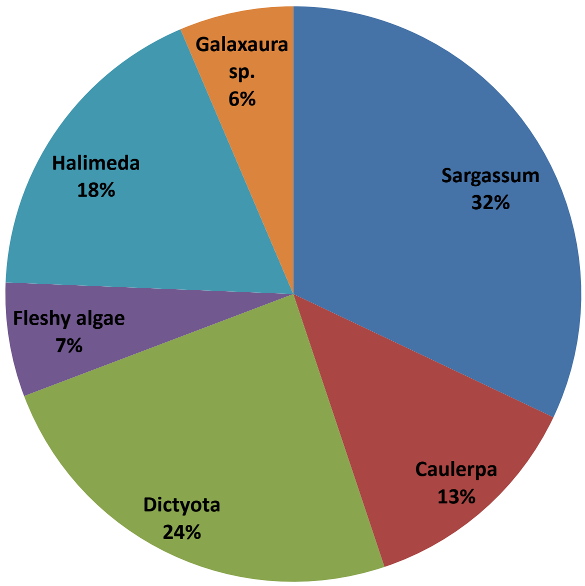


Figure 5-106 Algal Composition of the Backreef Area

Plate 5-18 - Plate 5-19 show the general reef conditions including the dominant algal species. Some sponges were also seen holding the substrate together (Plate 5-20) however the typical nuisance sponges such as the 'chicken liver' (*Chondrilla nucula)* were not observed.

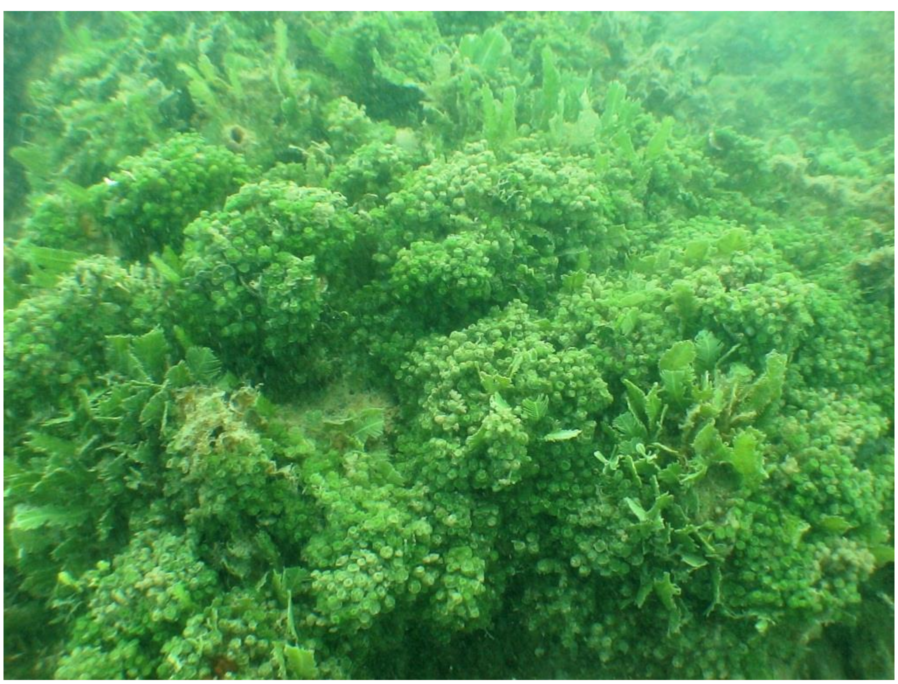


Plate 5-18 Photo showing Algae covering the substrate (*Caulerpa sp.*)

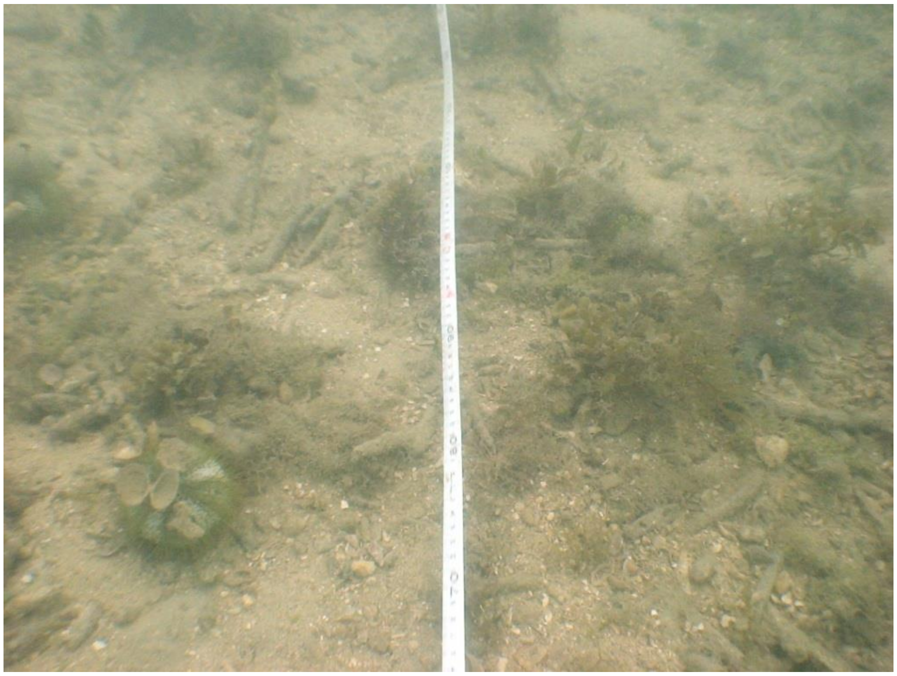


Plate 5-19 Photo showing a sandy/rubble substrate with some macro algae.

Plate 5-20 Photo sowing sponges and algae holding the substrate together

A total of seven hard coral species were observed (Table 5-59). These include *Colpophyllia natans*, *Oculia sp*., *Porites asteroides sp*.,*Stephanocenia intersepta* and *Mancinia areolata* and *Montastrea annularis* which was the largest live, hard coral colony observed in the area Gorgonians (Sea whips) along with some seagrasses (*T. testudinum*) were also observed in the backreef area (Plate 5-21 - Plate 5-25).

Table 5-59 Table showing the hard coral species observed in the area

Species	Family	Frequency	Relative abundance (%)
Oculina sp.	Oculinidae	5	11.36
Porites asteroides	Poritidae	5	11.36
Stephanocoenia sp.	Astrocoeniidae	8	18.18
Favia sp.	Favidae	1	2.27
Mancinia sp.	Favidae	21	47.72
Montastraea annularis	Favidae	3	6.82
Colophyllia natans	Favidae	1	2.27

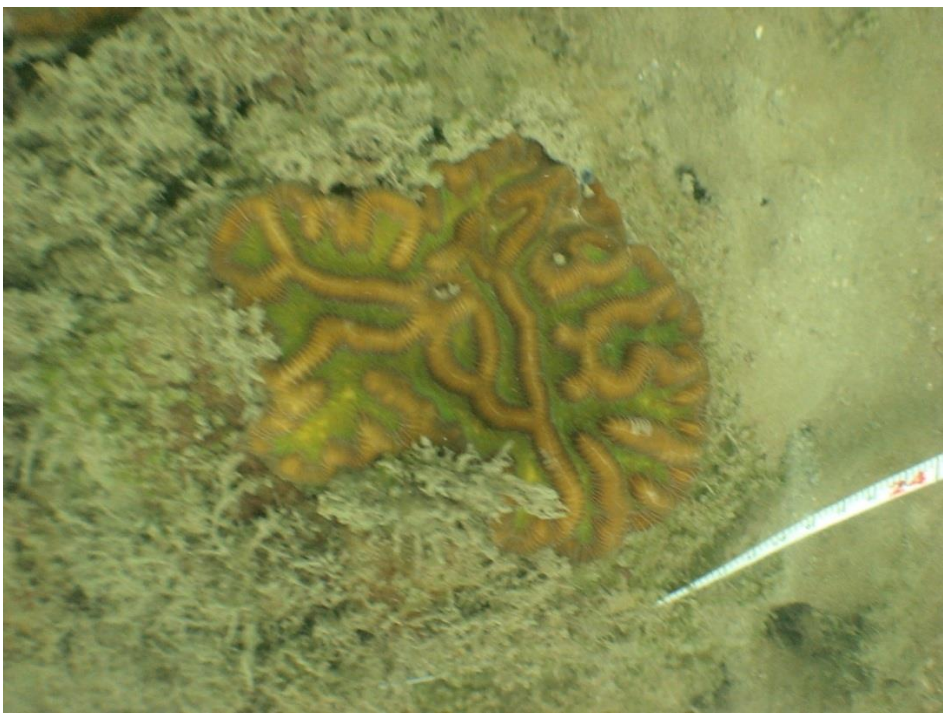


Plate 5-21 Photo showing *Colophyllia sp.*

Plate 5-22 Photo showing *Oculina sp*.

Plate 5-23 Photo showing *Porites asteroides*.

Plate 5-24 Photo showing *Stephanocenia sp*. and *Mancinia sp*.

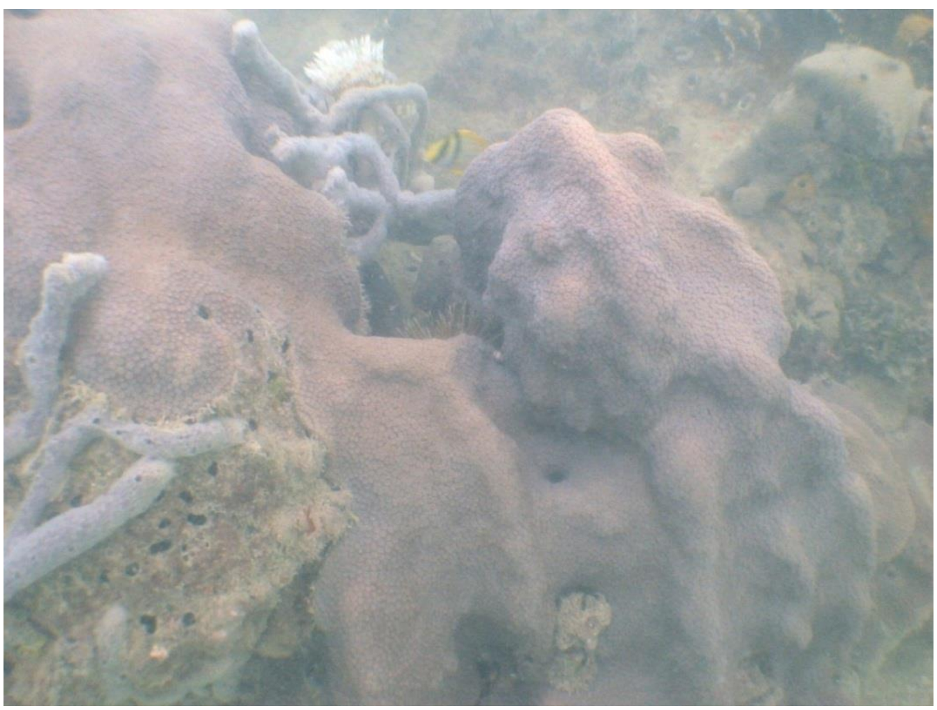


Plate 5-25 Photo showing *Montastrea annularis* colony

The sample area was found to be sufficient as shown in Figure 5-107.

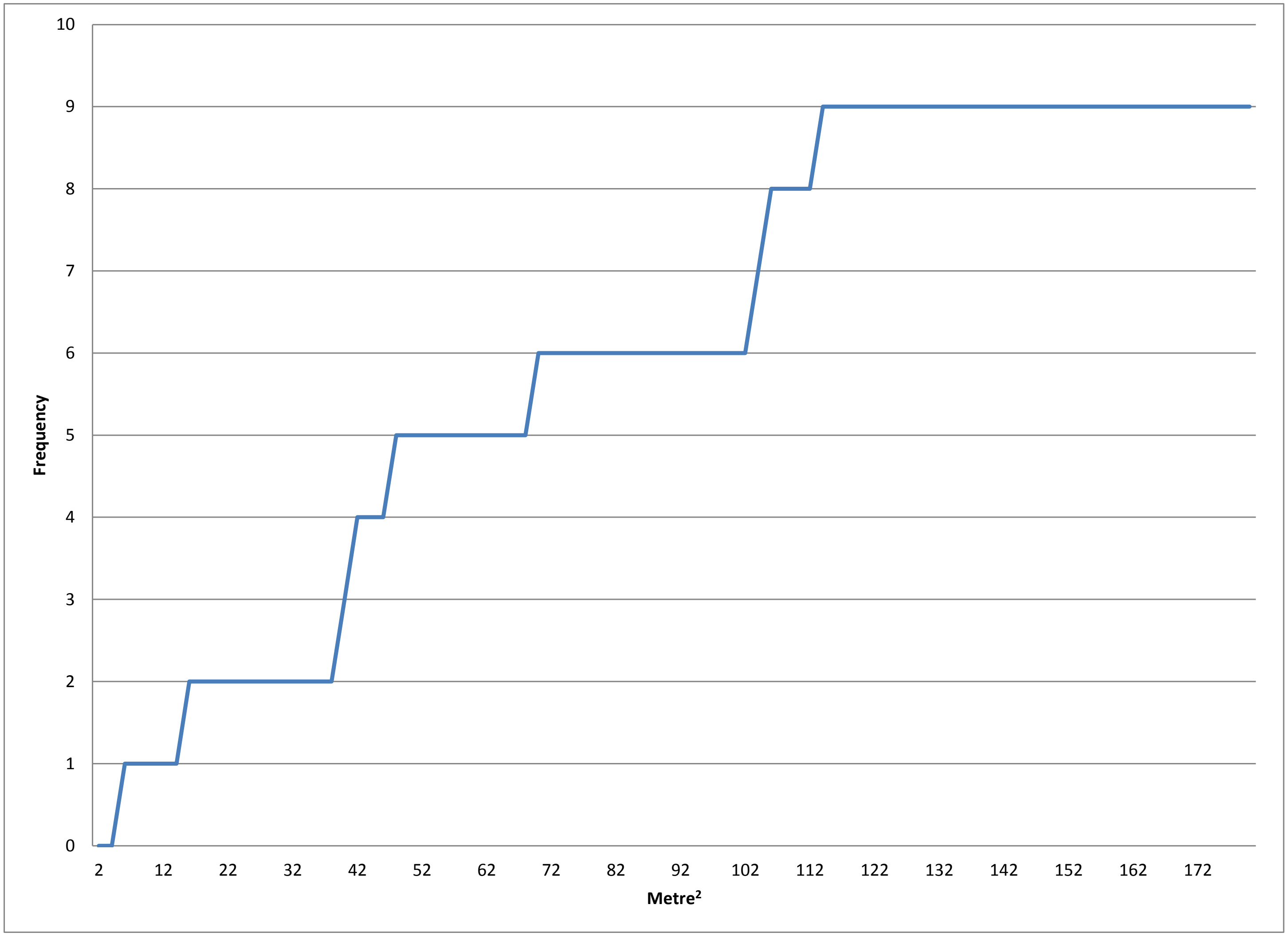


Figure 5-107 Species Area Curve for Hard Coral Species in the Study Area

The results are similar to other surveyed reefs in the area. According to the 2005 JCRMN[11] (Jamaica Coral Reef Monitoring Network) report, The Portland Bright Protected Area (PBPA) consists of a marine area (approximately 70% of the PBPA) and has widespread coral reefs associated with the 16 cays and several shoals (Linton et al., 2003). Extensive surveys were conducted by the JCRMN in conjunction with CCAM during 2004 and 2005 at nine sites associated with the cays and shoals. The results from these assessments showed variable hard coral cover ranging from 0% to 34% with a mean of 20%. Between 8 and 13 coral species were identified and the most common species were those of *Porities spp* and *Montastrea spp*. At the site with no hard coral present the substrate was dominated by algae (48%). These results are similar in the study area which is an algal dominated reef with low hard coral cover and diversity.

The reef appears to have suffered severe damage as a result of natural and anthropogenic impacts, including wave damage during storms and hurricanes, possible dynamiting, nutrient loading and unsustainable fishing practices. The reef has shifted from a coral dominated reef to an algal dominated reef, resulting in the low coral cover and low species diversity. No disease or bleaching was observed during the survey. The poor substrate condition makes the settlement/recruitment of coral larvae difficult; that is unconsolidated substrates are not ideal for coral recruitment compounded by the large algal mats, sponges and other encrusting organisms which prevent the settlement of larvae. Crustose coralline algae were observed but the occurrence was low. Encrusting coralline algae makes a more suitable environment for coral recruitment.

Fish Community

In 2001, a Preliminary Assessment of Nearshore Fishable Resources of Jamaica's Largest Bay, Portland Bight was conducted. Samplings of mangrove, seagrass *(Thalassia, Syringodium* and *Halodule*) and nearshore sandy habitats over 13 months in Jamaica's largest bay, which included Galleon Harbour (and its associated Fishing Sanctuary established in 2010), were conducted. A total of 98 species were found within the Bight with sites in the east having higher species richness than the sites in the west of the Bight, despite nearly identical ecology and physio-chemical characteristics. This was confirmed with the Jaccard coefficient of similarity, with Manatee Bay and Galleon Harbour on the east side being most similar in diversity and the western sites being similar. Manatee Bay westward through to Galleon Harbour had a mean species number of 32 (±2.4) species, whereas the Cays sites had only 8 species. Sites along the east side of the Bight had relatively less diversity with 15 species being found (Aiken et al., 2002).

[11] 2005, JCRMN Report

Table 5-60 Species found at Manatee, Coquar, and Galleon Harbour 12 months apart, indicating nursery role (Aiken et al., 2002)

Species	Common Name
Anchoa lyolepis	Dusky anchovy
Archosargus rhomboilalis	Sea bream
Sparisome chrysopterum	Redtail parrot
Eucinostomus gula	Silver jenny
Selene vomer	Lookdown jack
Gerres cinereus	Yellowfin mojarra
Caranax latus	Horse-eye jack
Ocyurus chrysurus	Yellowtail snapper
Haemulon sculurus	Bluestriped grunt
Sphyraena barracuda	Great barracuda
Lutjanus apodus	Schoolmaster snapper
Odontoscion dentax	Reef croaker
Bothus lunatus	Peacock flounder
Lutjanussynargis	Lane snapper
Acanthurus chirurgus	Doctorfish
Sphoeroides spengleri	Bandtail puffer
Penaeus spp	Marine shrimp

Portland Bight has been identified as a nursery along the mangrove-seagrass interface due to the presence of juveniles at all times during a 12 month period. Galleon Harbour was identified as a Critical Habitat and as a nursery, with a special note being made of the fact that the muddy areas near Galleon Harbour had adult and juvenile marine commercial shrimp in larger numbers than elsewhere in this study (Aiken et al., 2002).

Environmental Solutions Limited reported the presence of juvenile fish at their offshore sites which comprised mainly of damselfish and parrotfish. These sites were characterized as seagrass meadows comprised solely of *Thalassia testudinum*, with interspersed macroalgae and are used for feeding, and as nursery grounds for juvenile development (ESL, 2006b).

In the present study, the reef fish diversity was also low and several small fish were observed. Table 5-61 shows the species present, the size class, developmental stage and the feeding habit. Figure 5-108 shows the trophic level distribution of the fish types observed.

Table 5-61 Table showing a summary of the fish survey

Fish	Genus/Family	Frequency		Adult/ Juvenile	Feeding Habit
		≤5cm	≥10cm		
Dusky damselfish	Stegastes adusus	8		A	Herbivore
Threespot damselfish	Stegastes planifrons	1		A	Herbivore
Surgeon Fish	Acanthuridae	1		A	Herbivore
Parrot fish	Scaridae	4	4	J	Herbivore
Wrasse	Labridae	5		A	Omnivore
Remora	Echeneis neucratoides		1	J	Planktivore

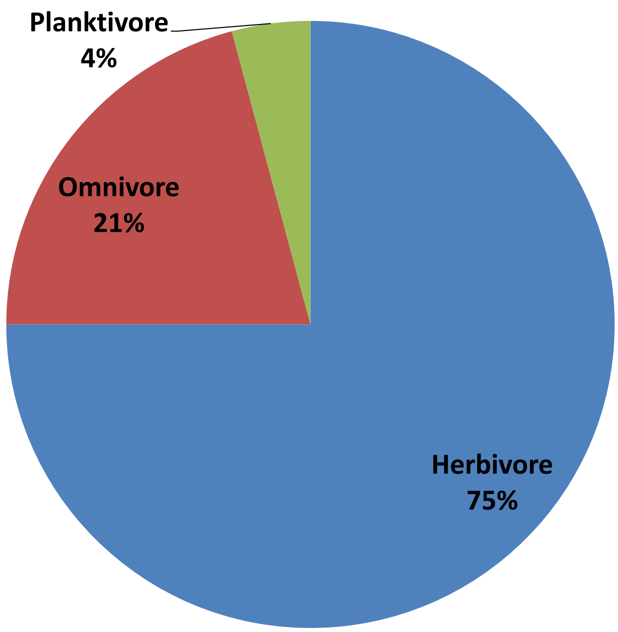


Figure 5-108 - Trophic level composition of the fish community

The numbers of fish observed were very low and most of these were small adult herbivores suggesting that the reef and surrounding areas are heavily fished and much of the nursery function of the habitat is either gone or severely reduced. Damselfish were the most abundant while surgeonfish and wrasses were the least abundant.

Invertebrate Community

Invertebrates were surveyed along with the substrate survey belt transect. Invertebrates seen in the backreef include brittle stars and star fish (*Oreaster sp.)* Plate 5-26 - Plate 5-28*)*, sea cucumbers such as Donkey Dung *(Holothuria mexicana)* and sea urchins (*Echinometra sp and Lytechinus sp.).*

Table 5-62 Invertebrate frequency and classification

Invertebrates	Frequency	Characteristics	Class	Main Diet	Frequency in Thalassia dominated areas
Lytechinus sp	78	Collector Urchin	Echinoidea	Algae, Seagrass	11
Echinometra sp	65	Rock Boring Urchin	Echinoidea	Algae	3
Starfish	16	Predators	Asteroidea	Slow moving organisms	1
Sea Cucumber	4	Scavengers	Holothuroidea	Organic Debris	0
Brittle Star	1	Scavengers	Ophiuroidea	Organic Debris	0

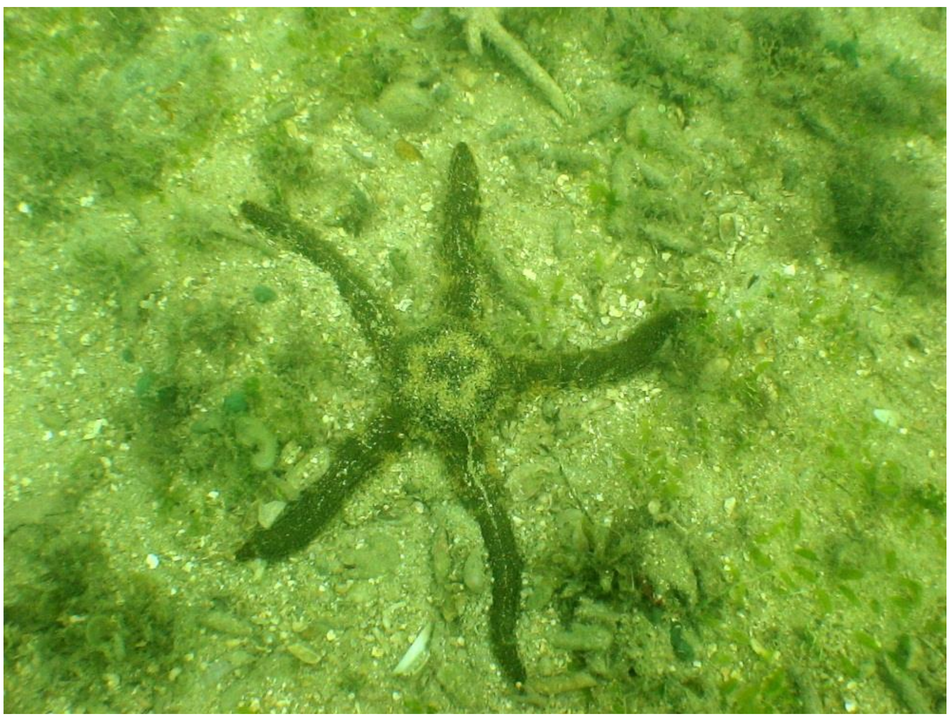


Plate 5-26 Photo showing Brittle Star

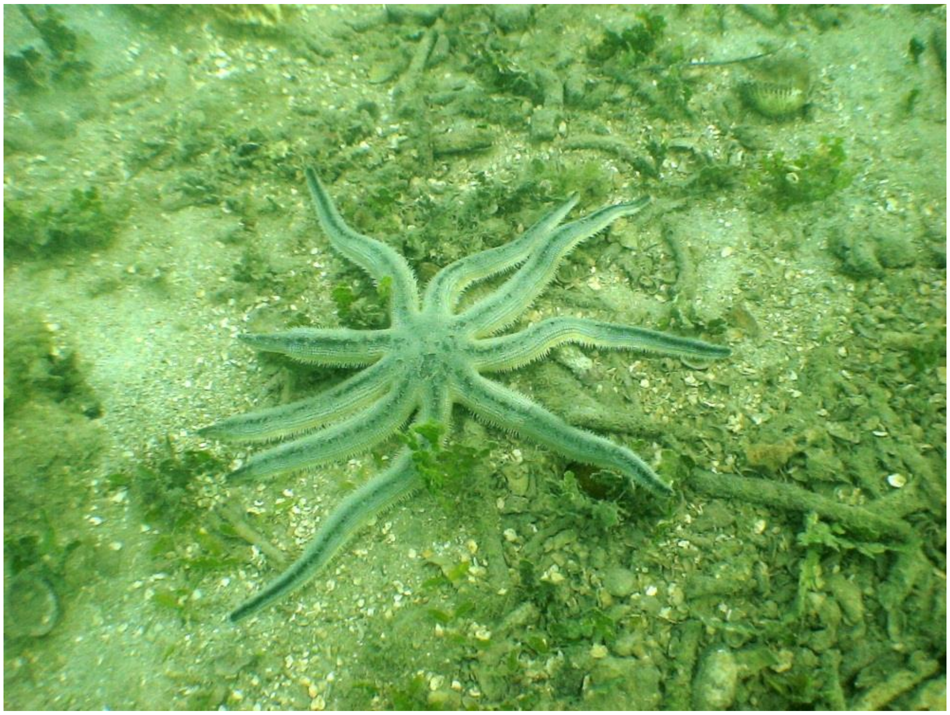


Plate 5-27 Photo showing Starfish

Plate 5-28 Photo showing Starfish

Sea urchins (*Lytechinus and Echinometra)* were the most abundant invertebrate observed (Figure 5-109), followed by starfish, sea cucumbers and brittle stars which had the lowest occurrences. No commercially important species were observed (lobster or conch) and no *Diadema antillarium* were seen in the study area. Jones (2006) reported that invertebrate diversity is generally low but parrotfish were abundant at most sites in the Reef Check surveys of 2004-2005.

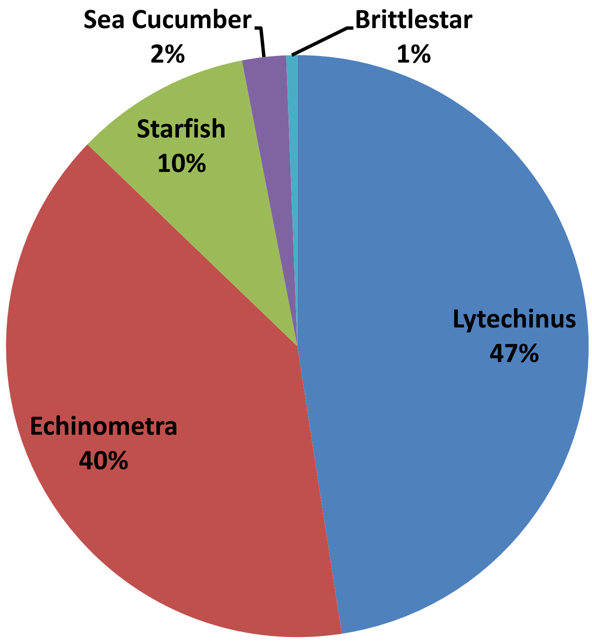


Figure 5-109 Invertebrate community composition (relative invertebrate presence along transect)

Reefs play an important structural role in shoreline protection as well as providing habitat, nursery and foraging ground for fish and many other animals. However the reef community and structure in the study area is severely affected. With low diversity in all communities (corals, fish, invertebrates), the reef has experienced a phase shift from a coral dominated community to an algal dominated one. Coral colony size was generally small with some typical backreef species present. The substrate is also largely unconsolidated, making coral recruitment very difficult. The fish and invertebrate communities have both very low population sizes along with very low diversities. The functionality of the reef system is significantly reduced and the recovery reef community would require drastic changes.

No commercially important fish or invertebrate species were observed. No invasive species were seen (*Pterois volitans/miles* - Lionfish or *Perna viridis* – Green Mussel).

Lagoon

The lagoon area lies directly behind the reef. A patchy distribution of seagrass was observed, extending towards the shoreline. This area is characterised by low visibility and soft/muddy substrate with mixed seagrass types.

METHOD

Surveys were conducted on 17 May, 2012 between 11 am and 3 pm, using a VideoRay Remote Operated Vehicle (ROV) and visual surveys. The ROV was used in the lagoon area due to the low visibility caused by siltation from the Bowers Gully and other operations in the area. This area is also known to have large crocodiles, making diving or snorkelling unsafe.

The ROV was used to estimate both the limits of the seagrass beds as well as the composition. Visual surveys were conducted along the shoreline; estimating the limits of each bed and the species composition. Anecdotal information about the location of other patches of seagrass was also used during the survey. This was useful when visual confirmation was impossible.

The ROV was allowed to sit on the bottom of the sea floor for short periods of time in-order to capture video and or images of any possible fauna in the area.

RESULTS

Seagrass Communities

The mixed bed area of seagrasses along the shoreline of the proposed site was identified with an estimated area of 4.1 hectares. In contrast, ESL found very small patches of seagrass *(Thalassia testudinum and Syringodium filiforme)*, approximately 1.5km west of the present study site. The patchy distribution of *Thalassia testudinum* seagrass immediately behind the reef area had an estimated area of 49.7 hectares.

Directly behind the reef, *T. testudinum* occurs in a patchy distribution on a rockier substrate (Plate 5-29). Moving northwest, towards the shoreline the sediment type changes becoming more muddy and silty. The mud-flat area consists of very small patches of algae but shows signs of several burrowing animals, mainly worms (Plate 5-30). It was unclear as to the full extent of the seagrass as visibility decreases significantly towards the shoreline (Plate 5-31 and Plate 5-32). Using video and images obtained from the ROV, the dominant seagrass observed appeared to be *Thalassia testudinum,* with a smaller percentage of *Syringodium filiforme* also present in the southern beds while mixed beds account for majority of the major beds (Plate 5-33) *S. filiforme* begins to dominate approaching and along the shoreline (Plate 5-34 and Plate 5-35). This poor visibility is possibly due to sediment from the fresh water tributaries along the coastline and the general high turbidity in the area due to wave action.

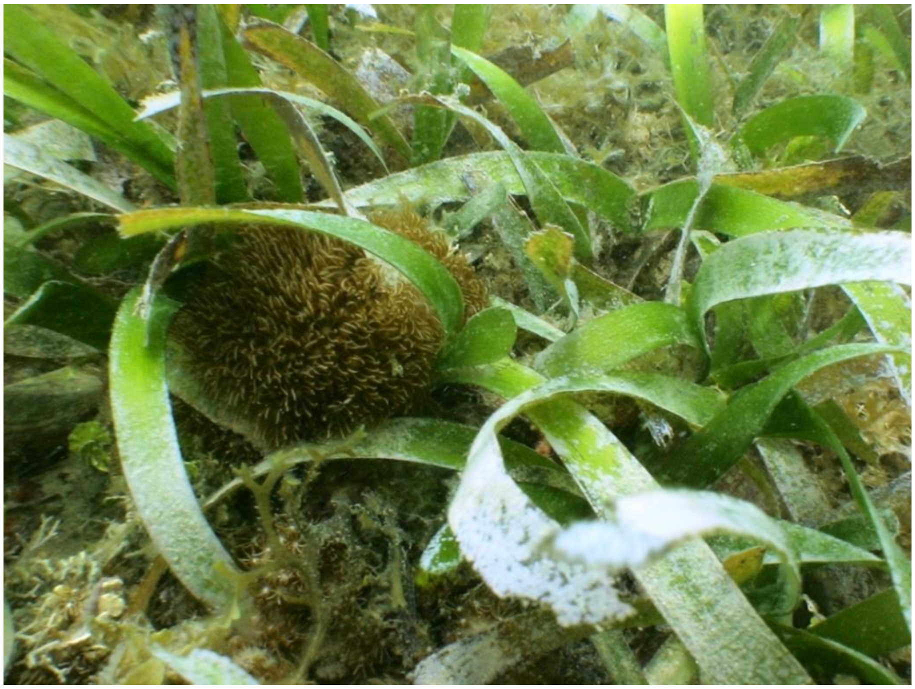


Plate 5-29 Seagrass mixed with Algae and a Soft Coral in the Lagoon

Plate 5-30 ROV Photo of muddy substrate with burrow holes made by animals in a low visibility area

Plate 5-31 ROV Photo of *T. testudinum* in a low visibility area

Plate 5-32 ROV Photo of *S. filiforne* in a low visibility area

Plate 5-33 ROV Photo of a patchy distribution *of T. testudinum and S. filiforme* in a low visibility area

Plate 5-34 Photo of a patchy distribution of *T. testudinum and S. filiforne* along the shoreline

Plate 5-35 Photo of a patchy distribution of *T. testudinum and S. filiforne* along the shoreline

Coral Community

Several coral species were noted on small patch reefs, on sandy sediments and a few in the seagrass beds. Plate 5-36 - Plate 5-40 were photographed in 2014 and show similar conditions (small colony size, low diversity and occurrence) as the 2012 survey. Coral cover in the area was extremely low. While no disease or mechanical damage was noted during the survey, anecdotal information suggests that the area was once heavily dynamited. This may account for the large patches of unconsolidated material as well as the low coral cover and lack of reef structure.

Plate 5-36 Small *P.asteroides* colony

Plate 5-37 Toppled *Millepora sp.*

Plate 5-38 Large *Diploria* colony

Plate 5-39 Large *Montastrea* colony with bleach spots and signs of mechanical damage.

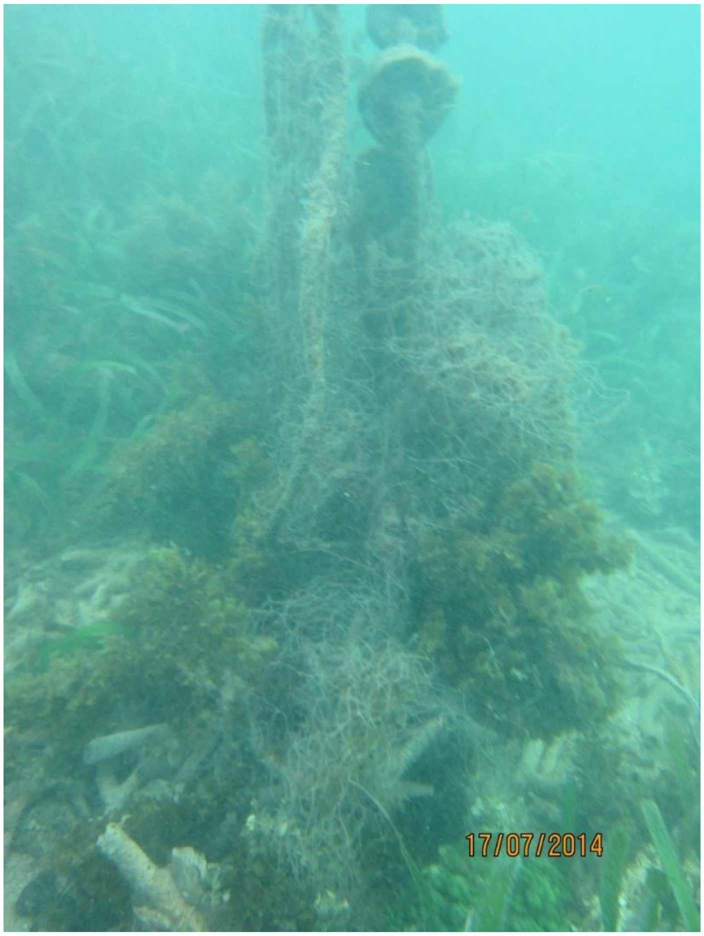


Plate 5-40 Fishnet wrapping around dead coral colony and tangled with sponges and other animals

5.3.5.2 Current Study

Based on 2012 findings, several roving surveys (of previously surveyed 2012 areas) were conducted with special emphasis on sensitive species and fish surveys in the potential areas of influence. The area has exceptionally poor visibility even with good weather conditions.

Thalassia testudinum was the dominant grass seen in all survey areas, similar to previous studies. Several algal species were also seen in dense patches in seagrass areas. Seagrass distribution remains patchy with the densest beds occurring on mounds of unconsolidated reef material/rubble. This included coral skeletons (*Porites and A. cervicornis* skeletons most likely), rock and other rubble.

These mounds of rubble act as a fringing barrier reef system and provide coastal protection to the bay. Although not a true reef system (and system under large amounts of degradation and stress), the loose material provide ecological volume for several species. Due to the intense over fishing and other harmful practices in the area (some ongoing and others restricted), none of these structures or ecosystems can function properly or to their full potential.

The benthic community also includes several invertebrate species including starfish, sea cucumbers, urchins and most notably large clumps of bivalve muscles. Although no commercially important species were seen during the survey, local fishermen have also begun harvesting sea cucumbers, which they say are harvested for export.

The Forereef and Crest

A fringing reef/ barrier reef system remains intact composed mainly of seagrass and coral skeletons with an extremely sparse coral community and large amounts of macroalgae (as with previous studies).

Seagrass beds are dominated by *Thalassia testudinum* and occur in patches, mainly on mounds of coral skeleton and rock but also in the lagoon areas towards the shoreline. Plate 5-41- Plate 5-44 show small coral colonies occurring in the seagrass beds of the reef crest.

Plate 5-41 Starfish in seagrass bed

Plate 5-42 *Solonastrea* sp. In seagrass bed

Plate 5-43 *Oculina* sp. in seagrass bed

Plate 5-44 *Diploria strigosa* in rubble/seagrass area at the base of the crest

The forereef was composed mainly of small patch reef with a sandy and silty substrate. A few larger coral colonies were seen in these area (Plate 5-45), the area has poor visibility, very few live corals were seen on each patch, instead these were dominated by macroalgae and some encrusting species (sponges and bivalves) (Plate 5-46). Some soft corals were also seen in this area (Plate 5-47).

Plate 5-45 Large *Montastrea* colony seen in front on the forereef

Plate 5-46 Encrusting bivalve

Plate 5-47 Soft Coral and Macroalgae in poor visibility

Fish Community

Fifteen (15) different taxa of fish were identified from the five survey areas. Five (5) taxa were identified from Site 1, one (1) from Site 2, three (3) from Site 3, five (5) from Site 4 and ten (10) from Site 5. Fish abundance was generally low, ranging from a maximum (24 individuals) at Site 5 to a minimum (2 individuals) at Site 2 (Table 5-63). As expected, the majority of fish observed were in the smaller size classes (≤6-10cm) with damselfish, foureye butterflyfish or surgeonfish present at most sites.

Table 5-63 Abundance of fish species at each site.

Generic name	Taxon or scientific name	No. of individuals				
		Site 1	Site 2	Site 3	Site 4	Site 5
Dusky Damselfish	*Stegastes fuscus*	-	2	1	-	3
Blue Tang	*Acanthurus coeruleus*	-	-	-	-	1
Banded Butterfly	*Chaetodon striatus*	-	-	-	-	1
Foureye Butterflyfish	*Chaetodon capistratus*	1	-	-	2	4
Grey Angelfish	*Pomacanthus arcuatus*	2	-	-	-	-

Generic name	Taxon or scientific name	No. of individuals				
		Site 1	Site 2	Site 3	Site 4	Site 5
Parrotfish	Scaridae	-	-	1	-	4
Surgeonfish	*Acanthurus bahianus*	3	-	6	2	1
Squirrelfish	Holocentridae	1	-	-	-	-
Schoolmaster Snapper	*Lutjanus apodus*	-	-	-	2	-
Yellowtail Snapper	*Ocyurus chrysurus*	-	-	-	1	-
Hogfish	*Lachnolaimus maximus*	-	-	-	1	-
Porgy	Sparidae	-	-	-	-	6
Porcupine fish	Diodontidae	-	-	-	-	2
Spotted drum	*Equentus punctatus*	-	-	-	-	1
Remora	Echeneidae	1	-	-	-	1
Total		**8**	**2**	**8**	**8**	**24**

Figure 5-110- Figure 5-113 show the size class frequency of all fish observed at each site (Site 2 had a single fish and therefore no graph was generated). Most fish fell within the 6-10 cm size range with low abundance. The lack of major grazers (larger parrot fish) and the general low abundance and diversity suggest a very poor fish community, heavily overfished and suffering from intense anthropogenic influences and pressure.

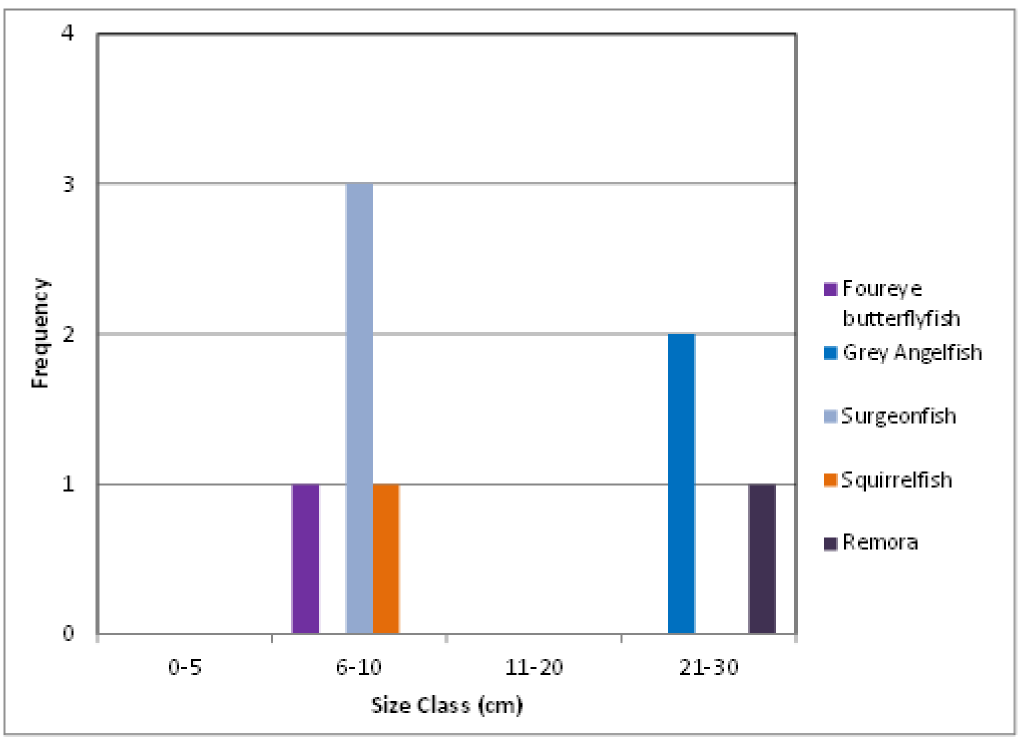


Figure 5-110 Size class and quantities of fish observed at Site 1

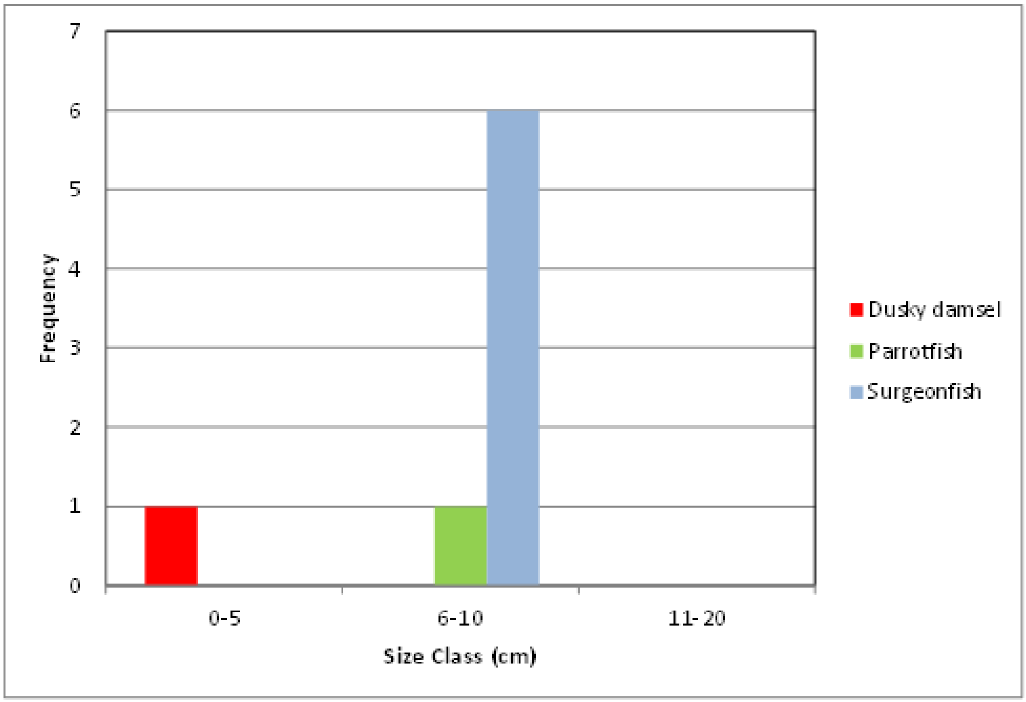


Figure 5-111 Size class and quantities of fish observed at Site 3

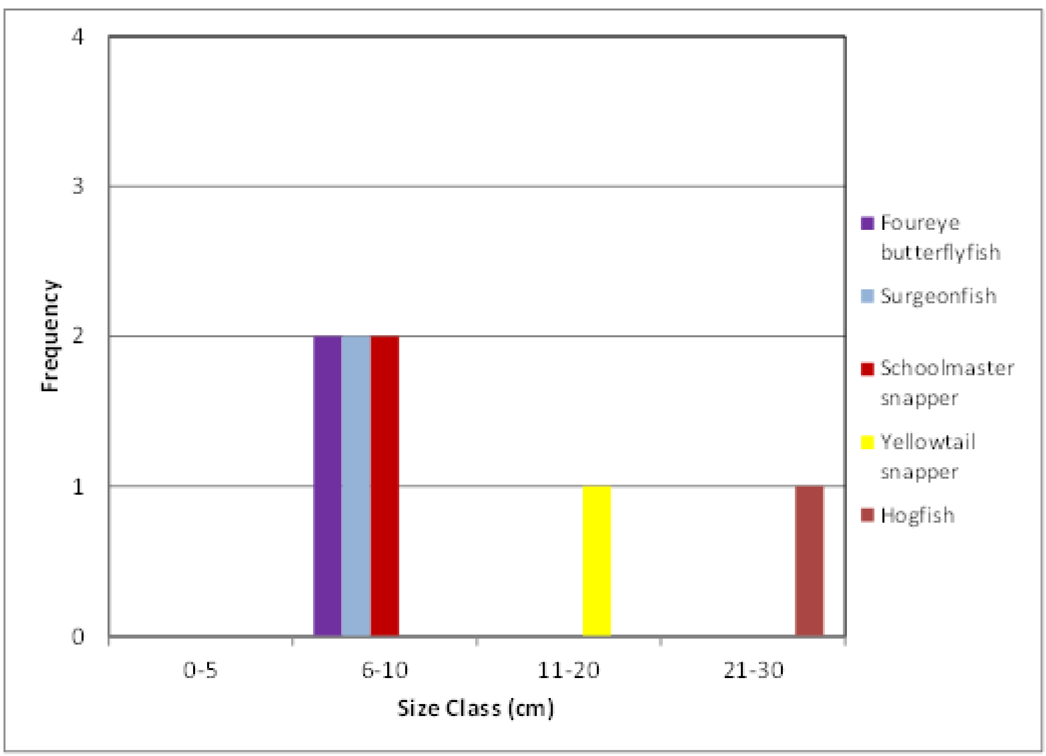


Figure 5-112 Size class and quantities of fish observed at Site 4

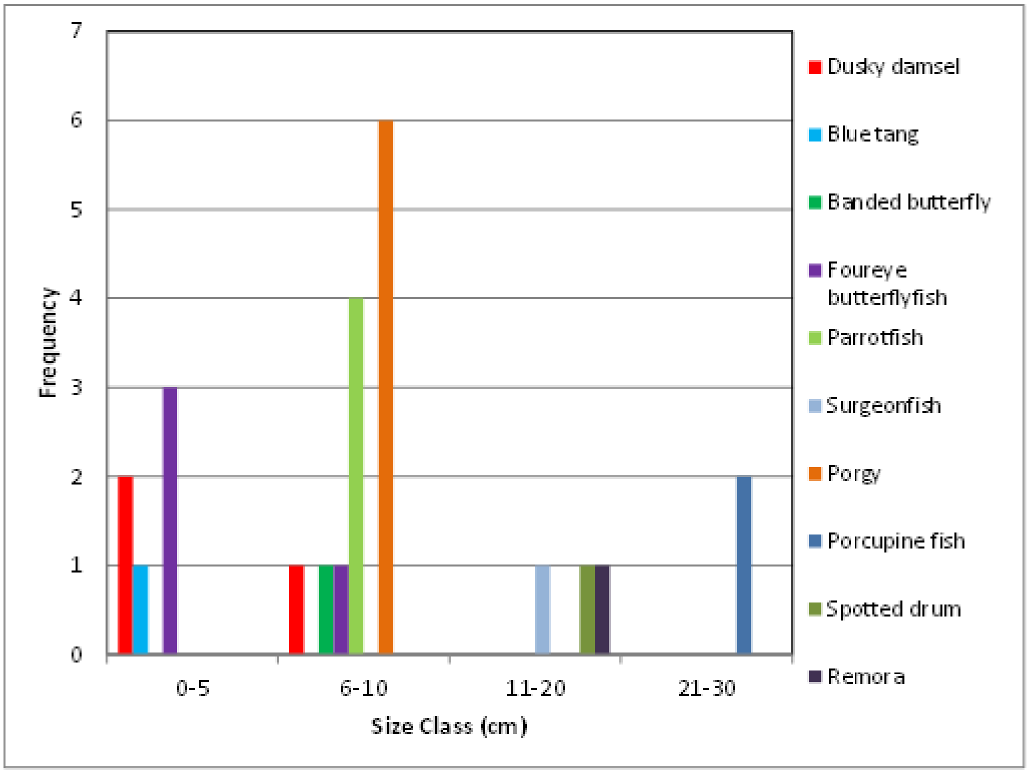


Figure 5-113 Size class and quantities of fish observed at Site 5

Portland Bight represents a unique area the proposed project areas falls within the industrial zone of the protected area. Both the terrestrial and nearby surrounding marine environment have been heavily degraded and modified. Sensitive and protected species include, some mangroves along the river bank, seagrass and a sparse coral community. Most ecosystem functions have been heavily reduced.

The dynamics of such a large area include; the industrial activities, anthropogenic pollution, a very large fishing community, the occurrence rare, endemic and protected species all combine to give Portland Bight Protected Area a unique social and environmental atmosphere. The area needs thoughtful and careful management in order to integrate further developments, environmental awareness and responsibility, rehabilitation of severely degraded areas and conservation of highly sensitive and unique ecosystems.