Government of Saint Lucia

Scoping Studies Report

Geothermal Resource Development Project
Environmental and Social Impact Assessment

November 2017

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Government of Saint Lucia

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Environmental and Social Impact Assessment

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Prepared for:
Government of Saint Lucia
Department of Sustainable Development
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Saint Lucia

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1 INTRODUCTION

1.1 OVERVIEW

The Government of Saint Lucia (GoSL) proposes a geothermal exploration program to test the geothermal resource and evaluate the feasibility of commercial geothermal power production in Saint Lucia. The geothermal exploration is proposed within the Soufrière, Choiseul, and Laborie regions of Saint Lucia (Figure 1). The geothermal exploration program would include slim-diameter wells to obtain information on the geology and temperature gradient in the area. Deep geothermal wells may be drilled with larger drilling rigs if the initial drilling is successful.

The World Bank requires preparation of an Environmental and Social Impact Assessment (ESIA) in accordance World Bank Operational Protocols prior to approving funding for the geothermal exploration activities. GoSL contracted Panorama Environmental, Inc. to prepare an ESIA for the geothermal exploration program. The Panorama team includes geologists, geothermal experts, resource-specific specialists, and local ESIA and social experts.

The ESIA process includes documentation of baseline environmental and social conditions in order to evaluate potential project impacts. This Scoping Studies Report was prepared by Panorama Environmental, Inc. to document the results of the baseline environmental and social studies conducted by our team members in the potential geothermal exploration areas.

1.2 PROJECT AREAS

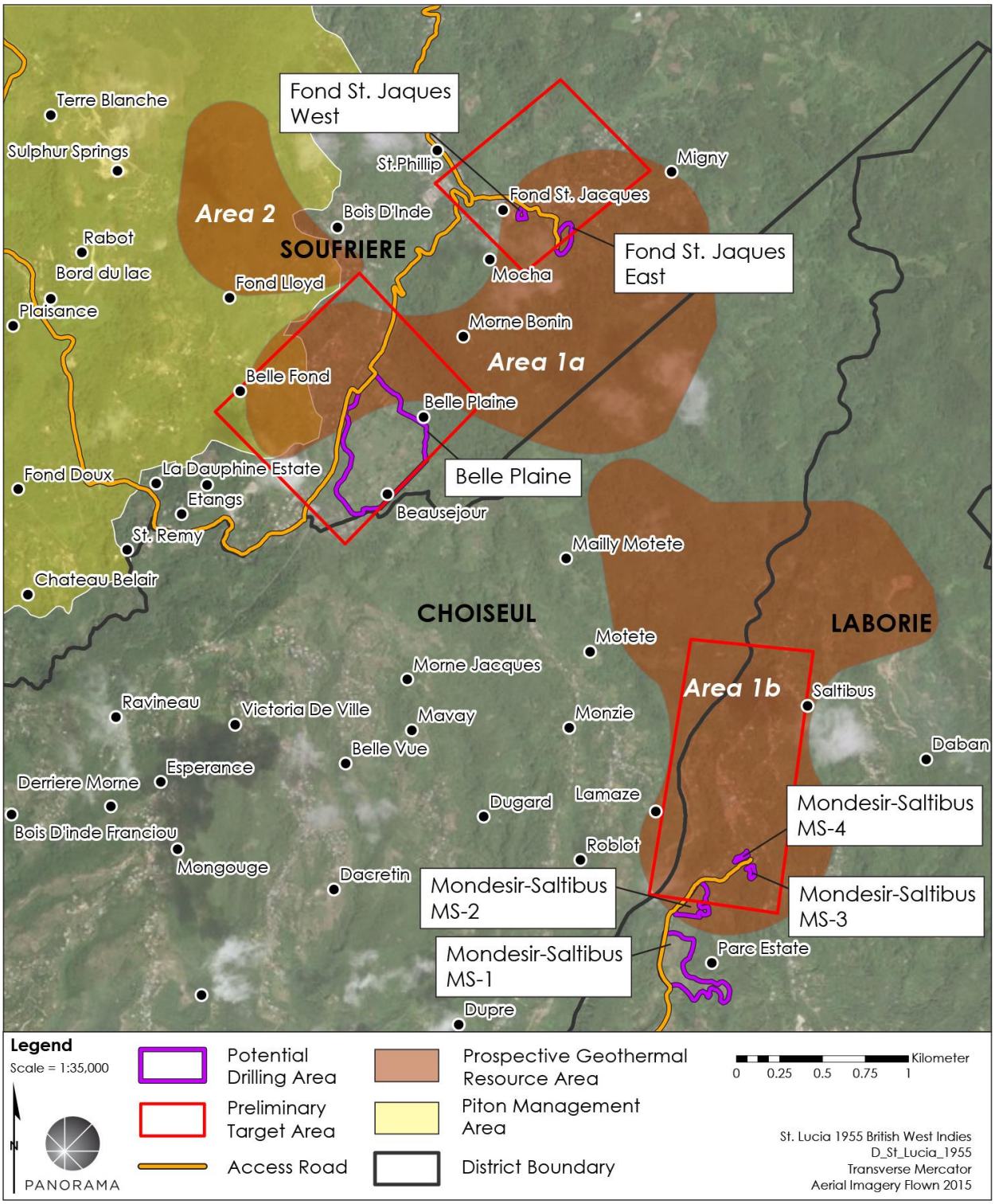
Jacobs New Zealand Limited conducted integrated geoscience investigations in 2015 and 2016 to assess the geothermal resource suitability of Soufrière Volcanic Zone. The results of the investigations and recommendations are presented in the *Soufrière Geothermal Resource - Integrated Exploration Report* (JACOBS - Lovelock & Ussher, 2016). The report authors identified three resource target areas for geothermal exploration to further analyze the suitability for power generation.

The resource target areas were refined by the pre-feasibility contractor, GeothermEx and POWER Engineers, in collaboration with Panorama Environmental, Inc., in order to focus the field baseline data collection. The target areas that were the focus of the baseline data collection activities are shown on Figures 1.1-1 and include:

- Belle Plaine (26.3 hectares [65.1 acres])
- Fond St. Jacques (1.3 hectares [3.3 acres])
- Mondesir-Saltibus (9.0 hectares [22.2 acres])

The 1,200-square-meter (m^2) to 8,400-m^2 (12,917-square-foot [ft^2] to 90,417 ft^2) well pads would be located within the larger study areas.

Figure 1.1-1 Potential Drilling Areas



Source: (McElhanney Consulting Services LTD, 2015)

1.3 SUMMARY OF SCOPING STUDIES

The scoping study requirements are defined the Terms of Reference (TOR) and Panorama's contract with GoSL. Table 1.3-1 provides an overview of the required scoping studies in the TOR and the location of the scoping study results in this report.

Table 1.3-1 TOR Requirements and Scoping Study Reference Location

TOR Requirement	Scoping Study Section(s)
1) Necessary desk reviews of existing reports, maps and field investigations to support the environmental and social assessments;	3.1.1; 3.2.1; 3.3.1; 3.4.1; 3.5.1; 3.6.1; 3.7.1; and 3.8.1
2) Surveys of Water Quality, Groundwater and Hydrology including surface water features and groundwater resources;	3.1.1.2 and 3.1.1.3
3) Literature study of the hydrogeological environment for the project area of influence;	3.1.1.2 and 3.1.3
4) Identify sampling sites based on potential water abstraction sources and potential receptor sites within the project area of influence and agreed to by GoSL and the technical consultant for the pre-feasibility study;	Appendix F
5) A desktop study of published maps including soil classification and land evaluation, soil investigations, soil sampling of locations suspected of contamination through visual assessment;	3.2.1 and 3.2.2
6) A description of water uses and users in the project area of influence and an assessment of surface water and groundwater use and availability	3.1.1.4 and 3.7.2.6
7) A data collection plan for field sampling and streamflow measurements to reflect seasonal variations, that should include: a. Existing hydrological information; b. Flood risk assessment (localized); c. Analysis of physical and chemical parameters (dissolved oxygen, temperature, conductivity, pH, turbidity, TSS, nitrogen, organic material, BOD5, COD, heavy metals, hydrocarbons, sulphur, iron, manganese, uranium, radium, gross alpha and beta) in representative streams/rivers under base flow and seasonally variable conditions. d. Measuring of stream flow (velocity, discharge) at key points under base flow and seasonally variable conditions.	Appendix F
8) Develop a conceptual model of hydrogeology in the project area of influence, specifically focusing on hydraulic interconnections of surface water and springs with groundwater in both the shallow and deep systems;	3.1.3.2
9) Undertake GIS Constraints Mapping highlighting key environmental and social receptors that may influence the topographical survey work and exploratory drilling, using existing data coverage where available, for the following: • Rivers and surface water features; • Significant environmental/ecological features (protected areas such as national parks, conservation areas, UNESCO sites, viewsheds and aesthetic features, wetlands); • Habitat mapping; • Land use mapping;	GIS database to be transmitted electronically 3.1.1; PMA layer in GIS 3.5.2; 3.7.2.9 3.8

TOR Requirement	Scoping Study Section(s)
• Erosion potential; • All sensitive receptors (houses, schools, hotels, communities, touristic sites); • Archaeological/Cultural heritage constraints mapping (over and above PMA requirements). • Areas of high natural hazard potential (landslide, flood, seismic, volcanic)	Sensitive receptors layer in GIS 3.6.2; 3.8
10) Undertake a baseline noise monitoring survey at representative locations/sensitive receptors in the project area of influence including households, hotels, roads and tourism viewpoints, as well as nearby communities which could be affected by noise emissions during drilling. Baseline noise monitoring should be performed in accordance with international standards for noise monitoring and should include daytime and nighttime monitoring at a range of representative dates/times;	3.4.2 and Appendix B
11) Undertake baseline ambient air quality monitoring at potential air quality sources (e.g. surface manifestations) and potential receptor sites within the project area of influence including households, hotels, roads, tourism, viewpoints and potential drilling sites. Baseline air quality monitoring should be performed in accordance with international standards and methodologies for air quality monitoring, taking into account the possible characteristics of the steam from potential geothermal development. Specific tasks to include:	3.3.2 and Appendix A
12) Describe the existing biological, terrestrial and aquatic environment with focus on the flora and fauna (mammals, migratory and resident birds, amphibians and reptiles) and overall biodiversity of the areas to be impacted, based upon existing information and field work (as needed)	3.5.2 and Appendix E
13) Identify important sites and species including local variations and biological diversity "hot spots", including areas of high endemism;	3.5.1 and 3.5.2
14) Prepare habitat mapping of the project area of influence supported by field verification/ walkover surveys to determine the presence or absence of key species, including endangered, threatened, or other protected species;	3.5.2; 3.5.3; and Appendix E
15) Identify designated sites of archaeological importance in the project area of influence;	3.6.2
16)Consult with key archaeological bodies and institutions in St. Lucia and conduct informal community interviews to identify potential grave sites or other unique natural features or tangible objects that embody cultural values, such as Amerindian terraces, sacred graves, rocks, lakes, waterfalls and other forms of non-tangible cultural heritage;	3.6.1 and 3.6.2
17) Perform non-intrusive verification walk-over at any identified potential sites of direct impact in the area of influence to verify any localized risks and issues.	3.6.2
18) Review of existing information and baseline data on the following areas: a. Population and demographic movement; b. Economic environment, livelihoods, employment and labour implications;	3.7.1

TOR Requirement	Scoping Study Section(s)
c. Use of natural resources and agriculture; d. Community organization and local institutions; e. Access to social services and infrastructure; f. Community health, safety and security, including HIV/AIDS prevalence; g. Poverty and vulnerable groups; h. Equity and potential issues related to social conflict; i. Lifestyle, culture and recreation.	
19) Perform field verification survey. The survey should entail identifying occupants that are likely to be affected in the project area of influence, the profile and standard characteristics of these occupants, baseline information on livelihoods and standards of living of the occupants, an understanding of the severity of the impact loss, information on vulnerable groups or persons for whom special provisions may have to be made	3.7.2
20) Prepare map of land ownership and use, supported by desk based profile of the land owners or users (for monitoring livelihood restoration), or land use rights transfer procedures.	3.7.2.9
21) Stakeholder analysis. The study will include an identification and mapping of relevant stakeholder organizations, groups and individuals who have an interest in the project areas or geothermal development in St. Lucia.	3.7.2.9; Appendix C and GIS database
22) Review the geohazard and natural disaster vulnerability of the area of interest, in the context of existing risk to the population and the project infrastructure, and any additional risk imposed by the project activities. Specific tasks may include:	
a. Review of seismic monitoring network and historical data	3.8.2
b. Volcanic hazard analysis based on the University of the West Indies (UWI) studies	3.8.4
c. Potential for increased seismic activity due to drilling or fluid reinjection	4.8.1
d. Vulnerability of population and infrastructure to landslides, floods, high winds, and fire	4.8.1
e. Health and safety precautions and emergency response plans for workers during drilling	4.8.1 and 4.8.2
f. Evacuation plans and contingency plans for potentially affected populations	4.8.2
g. The potential for hydrogen sulfide (H2S) releases and strategy for mitigation measures.	4.3.1, 4.3.2, 4.8.1 and 4.8.2

1.4 USE OF THIS REPORT

This Scoping Studies Report has been prepared on behalf of GoSL to support the assessment of baseline conditions for the ESIA. The Scoping Studies Report also defines the area of influence for the ESIA and provides an initial qualitative assessment of the potential impacts of the project with recommendations for mitigation where impacts are likely significant.

1.5 APPROACH TO ESIA

The literature review and field surveys allowed the Panorama team specialists to identify the existing site conditions, identify data gaps, and understand the resources that could be affected by the geothermal exploration program. The TOR and Inception Report for this ESIA guided the definition of the study methodologies, which are presented in Chapter 2. Chapter 3 presents the results of the literature review and field studies. The data in this chapter defines the areas of influence. Chapter 4 provides an overview of the effects to the resources and identifies recommendations for the mitigation measures that will avoid or reduce significant effects. Chapter 5 provides conclusions and a summary of the scoping studies results.

2 METHODOLOGY

2.1 WATER RESOURCES

2.1.1 Literature Review

Panorama team members from Dewhurst Group L.L.C. (DG) conducted a literature review of existing information related to the water resources in Saint Lucia in accordance with TOR Tasks 1.1, 1.2, 1.3, and 1.6. DG reviewed existing reports and water resource data provided by entities such as the Division of Sustainable Development (DSD) and the Water & Sewerage Company, Inc. (WASCO). DG obtained additional information through online sources. The results of the literature review are presented in Section 3.1

2.1.2 Field Investigation

DG conducted a visual assessment of the streams in the target drilling areas on 7 September 2017. The conditions during the field survey are provided in Section 2.5.2. The visual assessment of water resources included the following process:

1. Identification of existing water sources in the area
2. Determination of the use of water resources and their condition
3. Identification of associated infrastructure

2.1.3 Data Analysis

DG analyzed the information obtained as part of the literature search and field investigation to define water resources within the drilling target area. The data were also used to develop a sampling and data collection plan for future study in accordance with TOR Tasks 1.4 and 1.6. DG also prepared a conceptual hydrogeologic model in accordance with TOR Task 1.8.

The results of the analysis are presented in Section 3.1.

2.2 GEOLOGY AND SOILS

2.2.1 Literature Review

DG reviewed available geological and scientific information relevant to the geothermal project in accordance with TOR Task 1.5, with special emphasis on the volcanic zone of Soufrière. Datasets include geology, geochemistry, water analysis, geophysics (magnetotelluric, magnetic, seismic, gravity surveys), temperature, and Light Detection and Ranging (LiDAR) data. Data were obtained primarily from DSD, WASCO, and online reports. Key studies included:

- Geochemical analysis of fluids by British wells in the 1970s (Bath 1976)

- Studies conducted in the 1980s by Los Alamos National Laboratories (LANL) for the Saint Lucia government (Goff and Vuataz 1984)
- Exploration work conducted by Aquater as part of UN/USAID-funded geothermal exploration campaign in the 1980s, including a hydrogeochemical survey in 1984 (Gandino, Piovesana and Rossi 1985) and subsequent discharge testing of well SL-2 in 1988 (Rivera 1990)
- Various recent chemical studies of the Lesser Antilles archipelago (JACOBS - Lovelock and Ussher 2016)

2.2.2 Field Investigation

DG conducted a visual assessment of the geology and soils of the target drilling areas on 7 September 2017. The visual assessment included an evaluation and documentation of the following conditions:

- Geological context
- Land use
- Condition of facilities (deposits, etc.)

2.2.3 Data Analysis

DG analyzed the data obtained through the literature search and field investigation in order to determine the basic geological setting. The literature review yielded limited information regarding soil contamination; however, land use and agricultural practices were considered in determining areas of potentially contaminated soils.

The results of this analysis are presented in Section 3.2.

2.3 AIR QUALITY

2.3.1 Literature Review

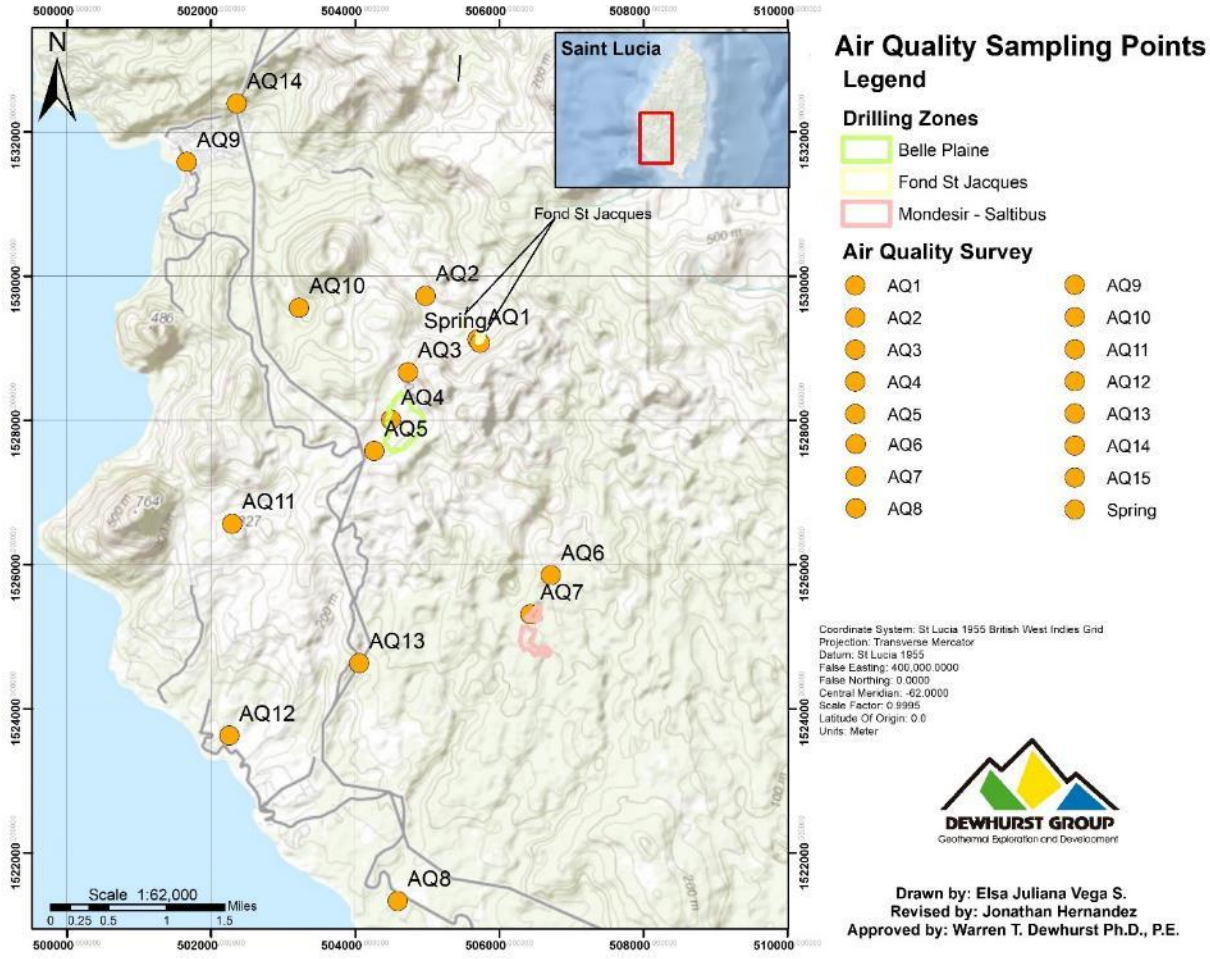
DG obtained and collated existing data on climate in the vicinity of the target drilling areas including wind direction and rainfall in accordance with TOR Task 1.11. Existing climate data and reports were obtained from a meteorological station at Hewanorra International Airport and Caribbean Environmental Health Institute (Caribbean Environmental Health Institute 2006). Air quality data contained in the *Geochemical Monitoring of Sulphur Springs* (Joseph E. , 2004) were reviewed to define ambient air quality conditions.

2.3.2 Field Investigation

DG conducted baseline ambient air quality monitoring in accordance with TOR Task 1.11. The baseline ambient air quality monitoring program included air quality monitoring at 15 air quality monitoring stations near sensitive receptors including households, hotels, tourist sites, and schools around the target drilling areas and near access roads. The sampling points are shown on Figure 2.3-1. Air quality sampling was conducted primarily on the west side of the

target drilling areas because the wind primarily blows in an east–west direction. A control point was also installed in Rodney Bay (at the northern end of the Island) and outside the area of

Figure 2.3-1 Air Quality Sampling Locations



interest. The air-quality survey sheets and photos from the air-quality field survey are included in Appendix A - Air Quality Data.

DG installed air-quality diffusion tubes to passively sample sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and hydrogen sulfide (H_2S). Diffusion tubes measurements were obtained between 6 September and 25 September 2017. Diffusion tubes were installed in trees, light posts, and walls (in lieu of trees or light posts), at heights over to 2 meters (6.6 feet) above ground. Diffusion tubes were secured with zip ties, so that they could not be easily removed by passers-by. Some diffusion tubes were saved, unused, as "blank tubes" to verify the laboratory's analysis; these tubes should not show any percentage of gases when analyzed in the laboratory.

2.3.3 Data Analysis

Air quality sampling data was analyzed in the laboratory by Ormantine USA Ltd., Inc. The existing air quality data and air quality data obtained in the field were evaluated to define the baseline air quality conditions in the vicinity of the target drilling areas.

The results of this analysis are presented in Section 3.3.

2.4 NOISE

2.4.1 Literature Review

DG reviewed the geothermal drilling noise surveys that were conducted in 1987 during the previous geothermal investigation in Saint Lucia. The 1987 survey included noise measurements and house-to-house contact and questionnaires (Associates in Rural Development - Dullin and Hannah 1987).

2.4.2 Field Investigation

2.4.2.1 Noise Survey Timing

DG conducted a baseline noise survey in the target drilling areas and vicinity between 5 September and 7 September 2017. The noise survey was conducted in accordance with TOR Task 1.10. Noise level observations were obtained during daylight hours. Weather conditions during the noise survey were primarily clear with rain showers and an easterly breeze in the late afternoons. Noise observations were avoided during periods of heavy rain and/or significant wind.

2.4.2.2 Noise Survey Locations

Baseline noise sampling locations were located adjacent to the air quality monitoring stations to maximize the use of time available in the field. Noise levels (e.g., observations of sound pressure) were taken at a total of 13 unique locations referred to as NS1 through NS13 as shown in Figure 2.4-1, with multiple readings at sites closest to the target drilling areas. Belle Plaine has three sites with two of those sites having repeat observations at different time periods. Fond St. Jacques has two sites, both with repeat observations at different time periods. Mondesir-Saltibus (Parc Estate) has three sites, two of which have repeat observations at different time periods.

The noise monitoring locations are described in All sound-level meters were calibrated with the REED R8090 Sound Level Calibrator prior to the survey and subsequent to monitoring. The REED R8090 conforms to standard IEC 60942 Class 2. The noise level equipment used to conduct the field survey is identified in Table 2.4-2.

Table 2.4-1. Photos of the noise monitoring locations and data sheets are provided in Appendix B – Noise Monitoring.

2.4.2.3 Noise Survey Instrumentation and Method

Noise measurements were obtained in "A" weighted decibels (dBA), which is equivalent to sound heard by humans with an approximate frequency response of 31.5Hz to 8KHz. The noise level survey was conducted using Type 2 sound-level instruments with an accuracy of +/- 1.5 dBA and precision (resolution repeatability) of 0.1 dBA. Data was logged using a "fast" recording setting to produce 30 data points per minute.

Figure 2.4-1 Noise Sampling Locations

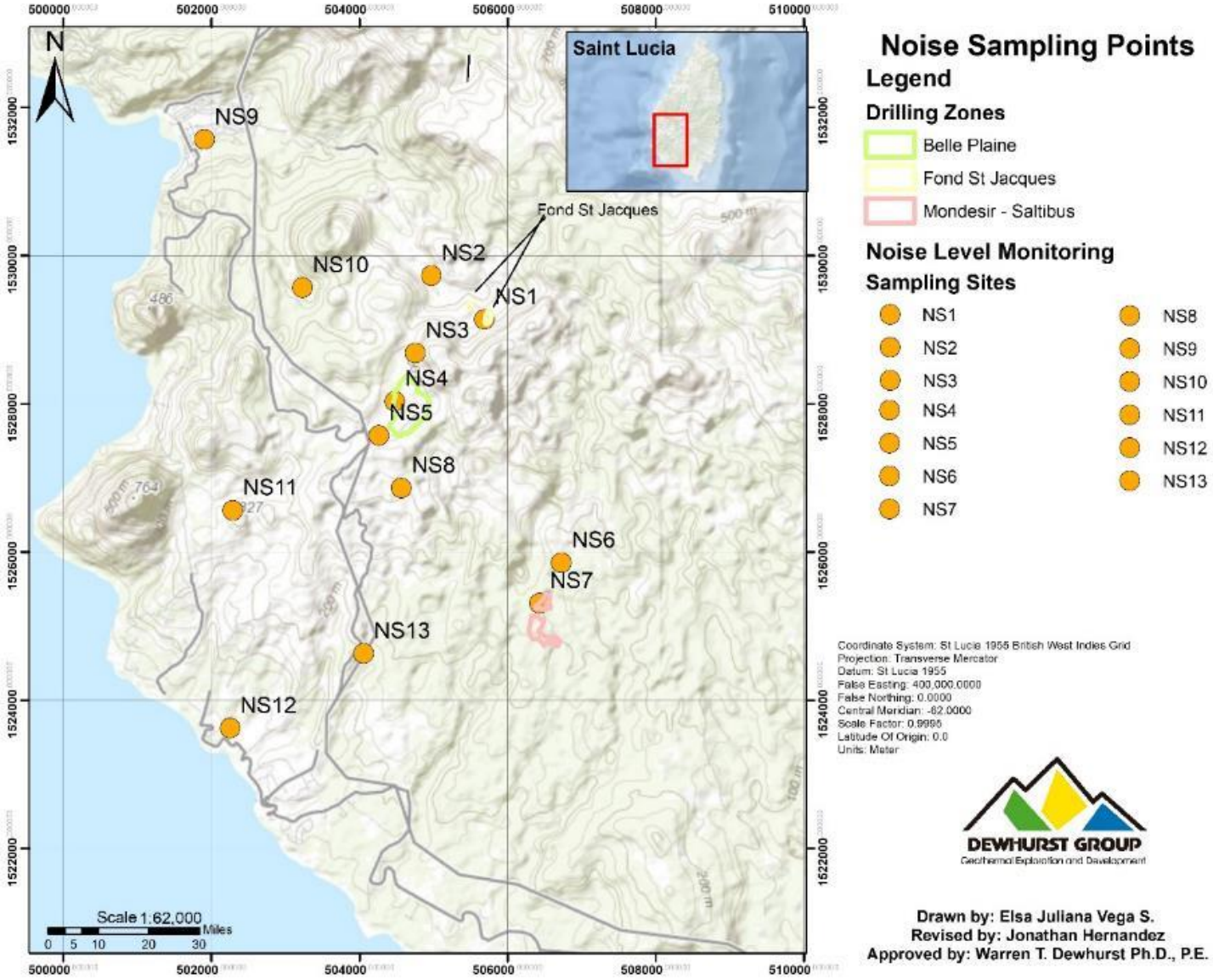


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Table 2.4-1 Noise Monitoring Locations Description

Site Name	X (mE)	Y (mN)	Elevation (m ASL)	Description of Area
NS1	505697,59	1529120,83	298	**St. Jacques** - Drill Site in the field by small structure near unpaved road in the area
NS2	504975,66	1529721,89	250	**St. Jacques** - Primary School Yard near the main road in the area
NS3	504733,32	1528664,69	400	**Belle Plaine** - LUCELEC Generator near the main road in the area
NS4	504497,87	1528007,49	337	**Belle Plaine** - Drill Site Field near the main unpaved road in the area
NS5	504262,91	1527572,65	362	**Belle Plaine** - Greenhouse near the bend on a main Island paved road
NS6	506717,32	1525848,05	292	**Saltibus** - Primary School between local school and the Community Center
NS7	506428,84	1525305,34	261	**Saltibus** - Parc Estate Drill Site (Near a commercial establishment) and soccer field
NS8	504588,74	1521330,67	45	**Saltibus** – At the corner of the local access road (to Parc Estate) corner with Main Road
NS9	501662,68	1531580,77	-6	**Soufrière** – Fire Station Flagpole taken from within southern edge of parking lot
NS10	503220,76	1529558,78	223	**Sulphur Springs** – southern side of main walkway 5m due south of NS10
NS11	502289,70	1526560,38	225	**Union Vale** – About 15m from the main paved road/bridge and within vegetation
NS12	502251,56	1523623,93	53	**Old Mill** - Light Pole # SEQC04444 near main paved road in the area
NS13	504053,18	1524628,25	219	**D'Quitoin** - Off main road - terrace farm - high side/scarp side of the highway

Note:

[a] Sites in Bold represent the target drilling areas.

[b] GPS measurements taken on site with Trimble GEOXH Serial #5138477832.

[c] Projection: Transverse Mercator. Datum: Saint Lucia 1955

Table 2.4-2 Noise Level Survey Equipment

Instrument	Model number	Manufacturer	Serial number
Sound-level meter	MLM02	TACKLife®	17277243
Sound-level meter	MLM02	TACKLife®	17277252
Sound-level meter/logger	SD-4023	REED®	H339634
Sound-level calibrator	R8090	REED®	160324199
Tripod with bracket	BC Master	N/A	N/A
GPS Unit	GeoExplorer 3000 Series GeoXH™	Trimble®	5138477832

Each sound-level meter contains an approximately 13-millimeter (mm) electret condenser microphone. The REED SD-4023 Sound Level Meter/Logger was used to obtain a noise/time series. The MLM02 Sound Level Meters were used for spot observations of low and high sound levels. All three meters were mounted to a tripod with a leveled ball head and proprietary mounting bracket. The mounting bracket permitted the simultaneous use of all three meters. The meters were positioned at an elevation of 1.5 meters (4.9 feet) above ground level (AGL). The MLM02 meters were used to augment time-series observations and to obtain supplemental observations at secondary locations. Observations at these secondary locations was used to characterize "spot" sound levels throughout the areas of impact. Measurements were made over a 15-minute observation period. Time-series measurements and low and high readings were obtained simultaneously. Both high and low sound levels were recorded during monitoring periods.

Key noise level terms are provided in Table 2.4-3.

Table 2.4-3 Noise Definitions

Term	Definition
Ambient	Approximation of the steady-state sound-pressure level in the absence of measurement fluctuation
Continuous	Noise produced without interruption.
High Levels	Absolute maximum values observed above ambient level. High levels may be naturally or culturally induced.
Intermittent	Noise produced on a discontinuous basis (e.g., cyclical equipment, or isolated events such as passing vehicles or aircraft).
Impulse	Brief and abrupt noise of short duration (typically less than one second), the sound pressure of which is significantly higher than the background.
Low Levels	Absolute minimum values observed above 30 dBA but less than ambient level.
Tonal	Noise which contains a clearly audible tone (i.e., a distinguishable, discrete, or continuous note, such as a whine, hiss, hum, screech, etc.).

2.4.3 Data Analysis

Noise data were analyzed to define average daytime ambient noise levels, peak or high noise levels, and minimum noise levels in the community surrounding the project area. Existing stationary and mobile noise sources (e.g., generators and trucks) in proximity to the noise measurement location are described to address variability in the ambient noise levels.

The results of this analysis are presented in Section 3.4.

2.5 BIOLOGICAL RESOURCES

2.5.1 Literature Review

Existing reports and data on flora and fauna in the target drilling areas and vicinity were reviewed by biologists Roger Graveson and Adam Touissant in accordance with TOR Task 1.12.

2.5.1.1 Flora

The floristic literature review included review of Mr. Graveson's records from more than 25 years of experience conducting biological studies in Saint Lucia. The following sources were reviewed:

- Flore Illustree des Phanerogrames de Guadeloupe et de Martinique
- Flora of the Lesser Antilles. (Leeward and Windward Islands), volumes 1-6 (Howard 1974-1989)
- The Classification of the Vegetation of Saint Lucia, National Forest Demarcation and Bio-Physical Resource Inventory Project Caribbean – Saint Lucia (Graveson 2009)
- A Systematic Vademecum to the Vascular Plants of Puerto Rico (Axelrod 2011)
- Plants of Saint Lucia (Graveson 2017)

2.5.1.2 Fauna

Reports on wildlife of Saint Lucia and the target drilling area that were reviewed prior to conducting field studies include:

- Birds of the West Indies (Raffaele et al. 2003)
- Important Bird Areas on Saint Lucia (Anthony & Dornelly 2008)
- Status and Conservation of Saint Lucia Birds (Toussaint et al. 2009)
- Species Accounts, Distribution, Abundance, Ecology, Conservation and Management of St. Lucia's Native and Introduced Wild Mammals (Clarke 2009)
- Biodiversity Assessment of Saint Lucia's Forests, with Management Recommendations (Daltry 2009)
- Field Guide to the Birds of Saint Lucia (Toussaint n.d.)

2.5.2 Field Investigation

A field investigation of the target drilling areas was conducted to define the biological resources in accordance with TOR Task 1.12 and 1.14. Flora and fauna surveys were conducted in early

September 2017. The weather was sunny and dry with temperatures reaching 32 degrees Celsius (°C) (90 degrees Fahrenheit [°F]) during surveys. Flora and fauna surveys were conducted from dawn until early afternoon.

2.5.2.1 Methodology of Flora Study

The target drilling areas were surveyed visually for floristic species by walking around each site. All species observed during the field investigation were documented to enable identification of threatened, endangered, or protected plant species and any areas of high biodiversity and/or high endemism within the survey area.

2.5.2.2 Methodology of Fauna Study

Faunal species within the target drilling areas were documented using an initial site reconnaissance survey and point count surveys. The reconnaissance survey was conducted within the target drilling areas to ground-truth the environmental conditions and establish locations for point count stations.

Twenty-five point count stations were randomly established within the target drilling areas. The survey was conducted by standing at each point station, while scanning in all directions to detect (see and/or hear) as many bird and other faunal species as possible. For each species, the number of individuals detected was noted. Surveys were initially conducted for 10 minutes at each point count station, starting at the surveyor's arrival at the survey point. A 10-minutes survey period was selected to make the data from this survey comparable with data from previous bird surveys. The surveyor then repeated the count of faunal species for an additional two minutes whilst "pishing" (imitating a generalized alarm call) to draw birds in towards the surveyor.

The point count stations were monitored between the hours of 5:30 and 11:30 AM and between 3:30 and 6:30 PM. Point count monitoring was conducted by A. Toussaint, an expert naturalist who possesses great skills and experience identifying by sight and sound birds and other faunal species on Saint Lucia. A pair of binocular was used to aid in the detailed identification of birds and other fauna. Field records were made for all fauna species sighted or heard at each point count station. Photographs were also taken at each point count station using a Canon EOS 7D Mark II camera with Canon EF 400 mm 1:5.6 Lens.

2.5.3 Data Analysis

2.5.3.1 Flora Data Analysis

Habitat mapping (TOR Task 1.13) was not conducted within the target drilling areas because of the absence of native habitat. The target drilling areas are dominated by agricultural vegetation and no native habitats were observed within the target areas. Native forest habitats occur within along within the buffer to the drilling target area; however, this vegetation would not be removed or directly impacted by the project. Land use (e.g., sports field) was indicated on the maps where applicable. Plant species observed were entered into an Excel database and analyzed for the presence of endangered, threatened, or other protected species.

2.5.3.2 Fauna Data Analysis

Records from the point count stations and records from previous studies of the target drilling area and vicinity conducted in the last 5 years were compiled and wildlife lists were prepared. These lists were then compared to information available on endemic, endangered, and protected species in order to identify species of biological importance, if any, present in the target drilling areas and to determine if there were any biodiversity "hotspots".

The results of the biological resources data analysis are presented in Section 3.5.

2.6 ARCHEOLOGICAL AND CULTURAL RESOURCES

An archaeological investigation was undertaken by Dr. Fredrick Smith, Director or Archaeology and History at St. Nicholas Abbey, Barbados West Indies in accordance with TOR Tasks 1.15, 1.16, and 1.17.

2.6.1 Literature Review and Consultations

Dr. Fredrick Smith reviewed published literature on archaeological resources within Saint Lucia. Dr. Smith also spoke with local landowners, farmers, and members of the surrounding villages to gain insights into archaeological findings and gather oral traditions about the sites being investigated during the field surveys. Dr. Smith also spoke at two community forums, including 1) the Region 6 Farmer's Field Coop in Belle Plaine and 2) the Saltibus School. In addition to meeting and speaking with members of the communities near the proposed drilling areas, Dr. Smith met with heritage stakeholders in Saint Lucia.

2.6.2 Field Investigation

2.6.2.1 Field Survey and Data Collection Methods

A pedestrian survey was conducted in the potential drilling areas in Belle Plaine, Fond St. Jacques, and Mondesir-Saltibus (MS-1 and MS-2 only) to identify cultural resources, such as archaeological sites, modified landscapes, ruins, petroglyphs, and other heritage resources that might be impacted by road or well pad construction or geothermal drilling. Surveys were conducted through the process of field walking and visual inspection of artifacts found on the ground surface. Visual inspection was supplemented by the collection of artifacts, referred to as surface collecting. Artifacts collected from each location were placed in bags and labeled with contextual information about their location of recovery.

The main objective of the pedestrian surveys and surface collections was to gain a general knowledge of the location of possible archaeological resources in the potential drilling areas. These methods do not allow for an in-depth understanding of the full potential of archaeological resources; however, they provide information about the chronology and function of different areas of a site. Surface collecting was an appropriate method for this initial phase of survey. It is dependent upon the visual discovery and identification of artifacts on the ground surface.

Much of the potential drilling areas was relatively clear of brush as they were being used for agriculture purposes. The cultivated fields created favorable conditions for finding cultural materials. Plowing and planting break the ground surface and pull lower layers of soil and any artifacts contained therein up to the surface. Plowing and planting drastically move objects vertically but do not greatly alter their horizontal position. Collecting and recording concentrations of artifacts on the surface of fields is an effective means of identifying areas of human occupation and use. Analysis of subsurface stratigraphy was conducted of the road cuts at the Belle Plaine and Mondesir-Saltibus sites, which showed a rich organic layer atop culturally sterile clays. This rich organic layer is the result of human activity, and in both areas, it contained evidence of human occupation and use in both prehistoric and historic periods. Archaeologists typically refer to these rich organic layers as plowzone. All of the artifacts collected during the surveys were washed, catalogued, and photographed at L'Haut Resort in Soufrière.

2.6.2.2 Field Survey Dates

All field surveys were conducted by Dr. Fredrick Smith, Archaeologist. The field survey of the Belle Plaine area commenced on 2 September 2017. Dr. Smith returned to the site for a second survey several days later to reassess the extent of archaeological deposits. Dr. Smith conducted a field investigation of the Fond St. Jacques area on the afternoon of 2 September 2017. Surveys of the Mondesir-Saltibus area were conducted on 3 and 4 September 2017. Gifta Jongué, a community liaison, joined the field survey in Mondesir-Saltibus area to help explain the survey efforts to members of the local community.

The results of the archaeological field survey are provided in Section 3.6.

2.6.3 Data Analysis

The results of the historical and archaeological resource investigation were reviewed to define areas that have a high abundance of resources and data gaps. Section 4 includes recommendations to address these data gaps prior to ground disturbance.

2.7 SOCIO-ECONOMIC ENVIRONMENT

2.7.1 Literature Review

ECMC staff, Egbert Louis and Theresa Louis, reviewed socio-economic reports and data provided by the DSD and other Saint Lucia government and international firms/non-governmental organizations in accordance with TOR Task 1.18. Information reviewed included:

- Population and Housing Census 2010 (Government Statistical Department 2010)
- 2014 - 2025 Mid-Year Population Projections (Government Statistical Department Saint Lucia 2014)
- Analysis of the Saint Lucia Labour Market Needs Assessment Survey 2012 (St. Catherine 2013)
- Economic and Social Review of the Economy (Government of Saint Lucia 2016a)

- Local Economic Development Strategic Plan (Government of Saint Lucia 2016b)
- National Environmental Summary (United Nations Environment Programme 2010)
- Education Statistical Digest 2014 (Ministry of Education 2014)
- National Health Strategic Plan (Regional Health Services n.d.)
- St Lucia Biennial Chief Medical Officer Report 2014-2016 (Ministry of Health and Wellness 2016)
- Saint Lucia National Report submitted in accordance with paragraph 5 of the annex to Human Rights Council Resolution 16/21 (UN Human Rights Council 2015)
- Saint Lucia Annual Surveillance Report for 2014 (Ministry of Health 2015)
- Trade Adjustment and Poverty in Saint Lucia – 2005/06, Volume I: Main Report (Kairi Consultants 2007)
- A "Basic Needs" Index for Saint Lucia at the level of Small Areas for the 2010 Population and Housing Census (Director of Statistics 2011)
- Human Development Report 2016 (United Nations Development Programme 2016)
- Budget, Fiscal Space and Child Well-being Analysis for Children in Saint Lucia (UNICEF 2016)
- Saint Lucia Social Protection Policy (Government of Saint Lucia 2015)
- Final Report on Gender Aware Beneficiary Analysis of Saint Lucia's Public Assistance Programme (Xavier 2015)
- The Changing Nature of Poverty and Inequality in the Caribbean: New Issues, New Solutions (Caribbean Development Bank 2016)

The results of the literature review were verified through the field investigation and socio-economic survey as described below.

2.7.2 Field Investigation

The field investigation was conducted by Panorama team and ECMC in accordance with TOR Task 1.19 and included:

- Field observations
- Community consultations
- Land ownership and use survey

The *Public Consultation Report* included as an appendix to the *Project Inception Report, Geothermal Resource Development Project, Environmental and Social Impact Assessment* (Panorama 2017) prepared for this project provides detailed information on the stakeholder meetings.

The field investigation methods are described below.

2.7.2.1 Field Observations

Panorama, ECMC, DSD, and stakeholder representatives conducted a reconnaissance field tour of the proposed project sites on 3 August 2017. ECMC noted the general socio-economic environmental setting and the existing infrastructure during the field tour.

ECMC conducted a second reconnaissance field investigation on 9 September 2017, to define the number of households within the target areas for geothermal exploration and confirm the land use in the target areas. ECMC documented observations and took photographs during each reconnaissance field investigation.

2.7.2.2 Consultations

A public meeting was held in each affected community (i.e., Belle Plaine, Fond St. Jacques, and Mondesir-Saltibus). Project information was shared with the affected stakeholders and other interested community members during the public meetings. ECMC also documented stakeholder concerns, identified potential impacts, and discussed potential avoidance and mitigation options that will be considered in the project design and ESIA. Community meetings were held between 31 August and 3 September 2017. The notes of public consultation meetings are provided in Appendix C - Public Consultation Questionnaire and Notes.

For each community, surveys were conducted for a sample of the cluster of households near (within about 800 meters [2625 feet]) the target areas for exploration drilling. The purpose of the survey was to collect baseline socioeconomic information from a representative group of potentially affected stakeholders and to solicit their comments and opinions. A list of households was not available; therefore, in view of the time and budget limitations, 10 households in each cluster were randomly selected through house-to-house visits in each of the three communities. In most cases, the respondents (head of household) were present. Where the head of the household was absent, responses were sought from the next responsible adult.

A semi-structured questionnaire was designed to gather the baseline socioeconomic information from households. In developing the questionnaire, several questions were first generated by team members, then reduced and formatted. A few questionnaires were then pretested during the community consultation exercise. The questionnaire was designed to capture aspects of the households' socioeconomic situation including age, gender, family size, education, occupation, income, and land ownership. Respondents were informed about the proposed exploratory drilling and the ESIA process prior to administering the questionnaires.

Individual face-to-face interviews were used to administer the questionnaires for all households except one. A telephone interview was used for one respondent in Belle Plaine who worked in another district. In cases where the head of the household was absent, responses were sought from the next responsible adult.

The interviews were conducted during 5 to 11 September 2017 by Theresa Alexander-Louis who was assisted by the Community Liaison Officer, Ms. Gifta Jongué. The final version of the questionnaire used is attached as Appendix C – Public Consultation Questionnaire and Notes.

2.7.2.3 Land Ownership and Use Survey

ECMC conducted a land ownership and land use assessment to provide information on the ownership and use of lands that are likely to be affected by the project. The assessment included review of Saint Lucia Government land records, existing land legislation, and administrative practices with respect to land acquisition.

The land ownership and use survey was designed to identify potentially affected persons with legal title to land, as well as non-titled persons (family-land tenants, and informal dwellers on privately and publicly owned lands).

A reconnaissance field visit was conducted on 9 September 2017 to physically establish the number of households within the proposed drill site envelope and to confirm the existing land uses (residential, agricultural or commercial) of the communities within the potentially affected areas.

2.7.3 Data Analysis

The data obtained from the literature search and field survey were analyzed in accordance with TOR Tasks 1.20 and 1.21. Responses to the survey questions were coded and transferred from the questionnaires into a spreadsheet for the socio-economic survey. The data entry was checked for accuracy and the data was analyzed using simple database tools. Tables were used to present data.

The Land Registry and Titling Project (LRTP) map sheets and aerial photographs of the proposed location of the drill sites were used to evaluate land use impacts. The aerial imagery was used to provide information on buildings and other structures within the potential drilling areas. The legal identification (i.e., block and parcel number) was established for parcels that are wholly or partially within the boundaries of the potential drilling areas.

The ownership of each parcel on the LRTP map sheet was validated through a record search at the Government Land Registry. The type of land use and legal status of the potentially affected stakeholder was established in cases where the number of land users were more than the number of the sub-divided parcels. Where the boundaries of the proposed drilling sites were near existing or proposed roads as shown on the maps, the configuration and boundaries were realigned to allow the roads to form the proposed drilling site boundary. Similarly, where only a sliver of a parcel was contained within the proposed drilling site boundary, the boundary was realigned to omit that parcel entirely.

The results of this analysis are presented in Section 3.7.

2.8 COMMUNITY RISK ASSESSMENT

2.8.1 Literature Review

Panorama reviewed the geohazard and natural disaster vulnerability of the area in accordance with TOR Task 1.22. The island of Saint Lucia is exposed to multiple natural hazards and

potential adverse natural events that make its population, infrastructure, and economy vulnerable. The major natural hazards that can be anticipated in Saint Lucia include the following geohazard and natural disaster categories:

- Seismicity and earthquakes
- Landslides and slope instability
- Volcanic eruptions
- Geothermal gas emissions
- Hurricanes and tropical storms
- Floods
- Fire
- Health and safety
- Evacuation plans and contingency plans for potentially affected populations

The primary literature reviewed to identify the risk and vulnerability of geohazards and other natural disasters in Saint Lucia included the following:

- Country Hazards and Risk Profiles (United Nations Office for Disaster Risk Reduction n.d., The World Bank 2016, The University of the West Indies 2017)
- Saint Lucia Landslide Inventory Map (Global Facility for Disaster Reduction and Recovery 2017)
- Saint Lucia Landslide Susceptibility Map (Global Facility for Disaster Reduction and Recovery 2017)
- Natural Hazard Mitigation Plan (Government of Saint Lucia 2006)
- Saint Lucia National Flood Plan (Government of Saint Lucia 2006)
- Earthquake Contingency Plan (Government of Saint Lucia 2007)
- Landslide Response Plan (Government of Saint Lucia 2008)
- Hurricane Response Plan (Government of Saint Lucia 2002)
- Volcanic Eruption Response Plan (Government of Saint Lucia 2009)
- Soufrière Geothermal Resource - Integrated Exploration Report (Jacobs New Zealand Limited 2016)
- Volcanic Hazard Assessment for Saint Lucia, Lesser Antilles (Jan Lindsay 2002)

2.8.2 Field Investigation

DG conducted a visual assessment of the geology and soils of the target drilling areas on 7 September 2017. The existing conditions were also reviewed on aerial photographs.

2.8.3 Data Analysis

The existing risk levels were evaluated for each of the natural hazard categories using the data resources described above, and given a general rating of low, moderate, or high. The existing impact vulnerability of regionally applicable populations, infrastructure, or significant economic contributors (i.e., businesses, farms, and tourist attractions) were also evaluated and

rated in this manner. Project factors associated with drilling exploration and future geothermal power plant development were then analyzed to determine if they could:

- Change the existing risk levels;
- Change the existing vulnerability level; or
- Place project workers or project infrastructure at undue risk.

The results of this analysis are presented in Section 3.8.

3 RESULTS

3.1 WATER RESOURCES

The following section contains information pertaining to TOR Tasks: 1.2, 1.3, 1.6, and 1.8. The area of influence includes surface waters downstream of the project area and any water supply infrastructure that could be impacted by the project.

3.1.1 Literature Review Results

3.1.1.1 Watersheds

Regional

Saint Lucia is divided into 37 watersheds (Figure 3.1-1) that are characterized by steep topography due to the geotectonic nature of the island. Within these watersheds, 20 to 25 water catchments are used for domestic water supply (AGRICO Ltd. 2001). Most of the water consumed or used on the island comes from runoff from catchment areas in the upper reaches of seven catchments (also known as watersheds), which have headwaters mainly in the mountainous south-central region (Thomas-Louisy 2014). The most important rivers of the country are Cul de Sac, Canelles, Dennery, Fond d'Or, Piaye, Doree, Canarias, Roseau, Marquis, and Troumassee River (Food and Agriculture Organization of the United Nations, 2015).

Watersheds in the Project Area

The Belle Plaine drilling site is located within the Choiseul/Trou-Barbet watershed. The rivers flow through or adjacent to the potential drilling area from south to north. The drilling area drains to the east and north within the valley.

The Fond St. Jacques drilling site is located within the Soufrière watershed. The river borders the Fond St. Jacques drilling area. Water flows from east to west in the valley.

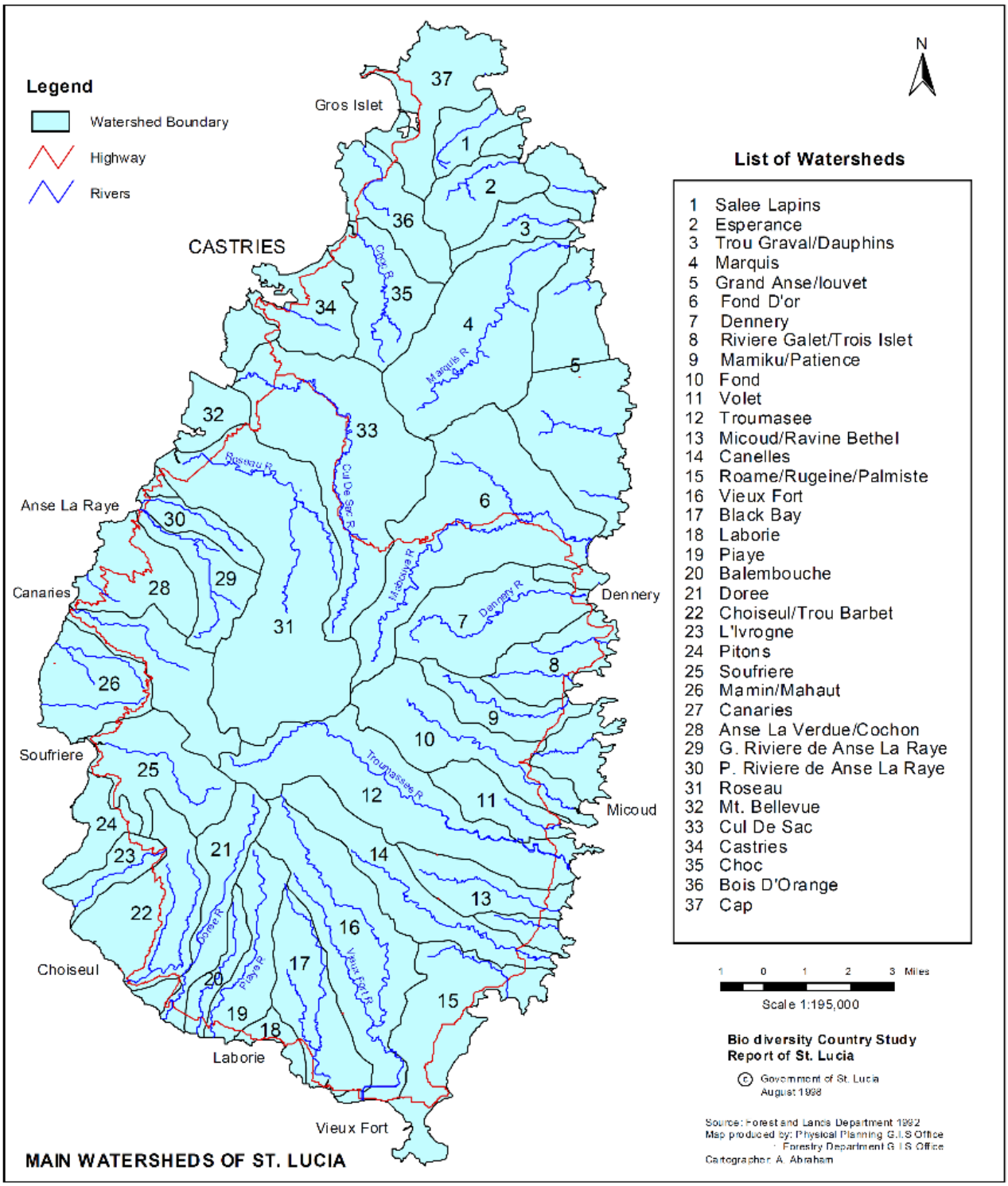
The Mondesir-Saltibus sites are located within the Doree and Balembouche watersheds. The rivers are located to the west and to the east of the potential drilling area. The river located to the west of the potential drilling area maintains perennial flow. The northern drilling area drains to the southwest and the southern drilling area drains to the southeast.

3.1.1.2 Groundwater

Regional Groundwater

Research conducted in the northwest of Saint Lucia in the 1960s indicated that there are good groundwater reserves. The exploration of groundwater began in Saint Lucia by drilling 14 wells in Union (in the northwestern region of the country). Of these wells, only two wells were reported to have produced 7 liters per second (l/s) (Norville and King 2001).

Figure 3.1-1 Saint Lucia Watersheds/Catchments



Source: Forest National Report on Integrating the Management of Watersheds and Coastal Areas in Saint Lucia, 2001

In the Soufrière area near the volcano, pyroclastic deposits are likely to bear good quality water. In addition to the geological context, tectonics have played a fundamental role in Saint Lucia, generating saltwater entrapments in some alluvial plains, especially in the west. These alluvial plains contain productive aquifers. The groundwater resources of Saint Lucia are restricted to the lower alluvial plains with reserves that could be suitable for small-scale uses.

The circulation of groundwater in volcanic islands is linked to more permeable horizons, normally with limited extension and with fault systems. According to the reported geochemical studies by (Aquater 1982), it is possible to say that a large portion of the infiltrated water flows into the sea through shallow aquifers.

The sources of water catchment are relatively small and are characterized by steep terrain with a fast rate of runoff and limited percolation.

Groundwater in the Project Areas
The project areas are located in the southwest region of Saint Lucia and no information about groundwater exploration is available. Most of the rainfall flows to the sea (west) with very little percolation or storage as groundwater due to Saint Lucia's rugged topography, and absence of intermediate collection points such as ponds and lakes (Jacobs 2016).

3.1.1.3 Water Quality and Chemistry

Regional Water Quality
Water quality depends on weather conditions and water uses. In dry times, the quality of the water worsens due to the minimal dilution of the existing chemical constituents in the streams. In times of flooding, the increased water volume helps to dilute the chemical pollution present. Even when such dilution is an advantage, flooding or wet periods cause other issues such as loss of soil surface cover, and increase in sediment load, clogged water-supply systems, causes and water-supply service suspension for habitants. In general, topographically higher areas are contaminated mainly by agricultural activities, while lower lands are polluted by domestic activities (Norville and King 2001).

The water quality of Saint Lucia's rivers has declined considerably in recent years due to an increase in agriculture, especially banana cultivation. Research carried out by the River Surveillance Monitoring Project (Lloyd et al., 1996) concluded that the variable that most affects Saint Lucia's ecosystems is the intensification of agriculture in combination with deforestation near water sources.

Project Area Water Quality
WASCO carried out chemical water studies from 2010–16 in Saltibus, and from 2010–17 in Fond St. Jacques (available data). For Saltibus, WASCO divided the studies into two parts: Upper Saltibus Raw Water (2010–13) and Upper Saltibus Treated Water (2013–16). In Fond St. Jacques, WASCO divided the analytical studies into four parts: Lower Fond St. Jacques Raw Water (2012–16), Lower Fond St. Jacques Treated (2010–17), Upper Fond St. Jacques Raw (2011–16),

and Upper Fond St. Jacques Treated (2010–17). Water quality sampling data in the project areas is provided in Appendix D – Water Quality Sampling and Stream Flow.

The analytical reports for both localities (Fond St. Jacques and Saltibus) included many physical chemical parameters as reported in Appendix D:

- pH
- color
- turbidity
- appearance
- odor
- conductivity
- dissolved oxygen
- residual chlorine
- total alkalinity as calcium carbonate ($CaCO_3$)
- total hardness as $CaCO_3$
- calcium hardness as $CaCO_3$
- magnesium hardness as $CaCO_3$
- chlorides as Cl
- fluorides as F
- free ammonia as NH_3
- nitrates as NO_3
- phosphates as P_2O5 and PO_4
- sulphate as SO_4
- silica as SiO_2
- free carbon dioxide
- nonfilterable residue
- total iron as Fe
- copper as Cu
- Manganese as Mn,
- aluminum as Al,
- total coliform
- fecal coliform
- Streptococci

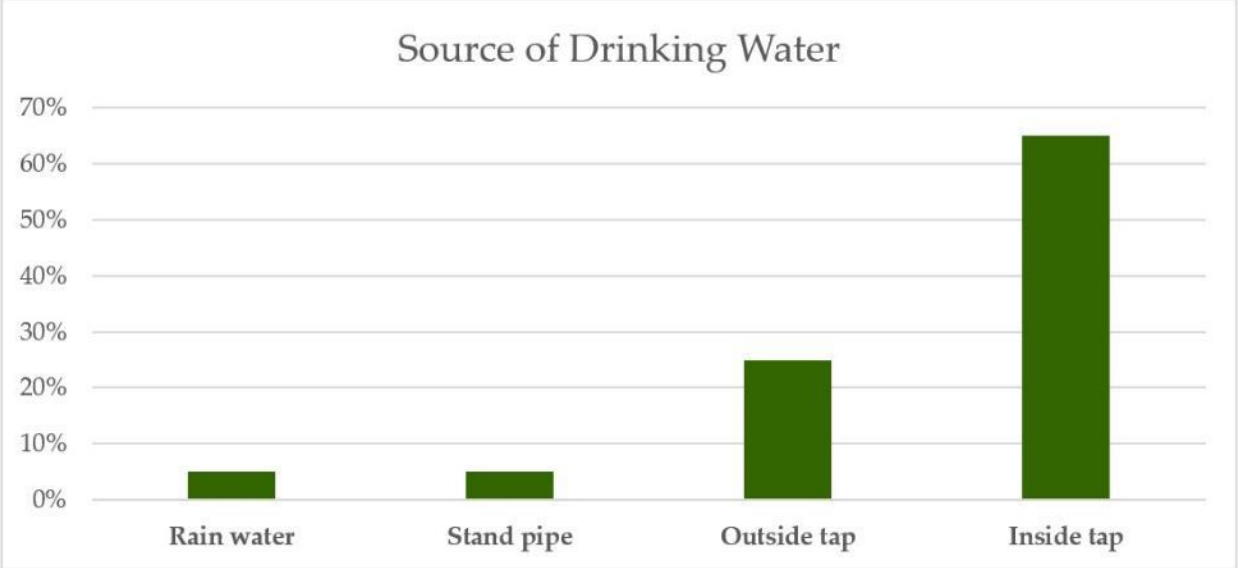
The World Health Organization (WHO) Guidelines for Drinking-Water Quality (World Health Organization 2017) state that "Water intended for human consumption should contain no fecal indicator organisms." Coliform is present within treated waters in Fond St. Jacques and Saltibus according to WASCO water quality analysis reports. Water from both sites is within the WHO allowable range for inorganic constituents.

3.1.1.4 Water Use and Supply

Access to Water

A survey of access to drinking water found that most residents are connected to the public supply (91 percent), with around 66 percent having a private tap inside their home and 25 percent having their tap on the outside (Caribbean Environmental Health Institute 2006). A minority of residents (around 8 percent) use standpipe and rainwater as their primary drinking-water sources. Around 90 percent of residents surveyed have regular water access, while 10 percent indicated intermittent supply (Figure 3.1-2).

Figure 3.1-2 Access to Drinking Water



Source: (CEHI, 2006)

Water Availability

The irregular distribution of rainfall tends to be problematic in the drier period of February to April in the absence of adequate collection and storage facilities (Norville and King 2001). In the dry season, available water comes from river base flows as well as from limited rainfall. The Island tends to experience periods of drought, especially in the southern region, when the stream flows tend to fall below known historic base flows. As a result, the entire residual flow of the sub-catchment is used for water supply, leaving the downstream segment completely dry.

The major concerns with respect to watershed management are uncontrolled agricultural intensification, poor agricultural practices, inappropriate land use, and direct and/or indirect discharge of untreated effluent into waterways (Norville and King 2001). Vieux Fort's water-supply system suffers from water-quality problems, resulting in the intake having to be relocated to the upper reaches of the watershed (ibid). Doing so, however, significantly reduces the available dry-season water supply. Such problems mainly result from inadequate public education and participation in conservation efforts.

Only a small portion of the public received a 24-hour supply of potable water in 2001 (Norville and King 2001). Water service reliability and access have improved in Saint Lucia due to implementation of the northern Water Supply Infrastructure Improvement Project funded by the World Bank and upgrading of the Hill 20 Raw Water Transmission Pipeline together with the new pumping system at Talvern, funded by CDB (WASCO, 2009). The improved water treatment capacity at Grave in Vieux Fort and upgraded intake at Woodlands in Vieux Fort also improved the water supply capacity to serve an additional 20,000 people (*ibid*). Collectively these water supply upgrades have substantially improved the reliability of water supply in Saint Lucia.

The northwestern region is essentially the main tourism belt of Saint Lucia as well as the region of preferred settlement. Around 60 percent of the population resides in the north and the current distribution network is unable to meet the growing demands of this region. In the southern region, the water-supply situation is even more critical (Table 3.1-1). There, raw-water

Table 3.1-1 Water Availability and Supply by Catchment Areas

River and catchment	Catchment area (km^2) from GIS	% Total area in use	Average base flow (l/s)	Average dry season base flow (l/s)	WASCO demand (l/s)
Marquis	30.55	100	240	150	53
Found d'Or	40.12	100	470	225	17 < 25
Dennery	19.25	100	270	137	8 < 10
Fond	18.00	100	285	150	8
Troumasse	32.43	100	285	150	8
Cannelles	16.83	100	300	150	13
Vieux Fort	28.99	100	480	250	75
L'Ivrogne	5.56	100	95	65	10
Soufrière	15.73	100	440	200	8
Canaries	24.24	100	300	175	8
Anse La Raye	8.91	100	175	87	5
Roseau	48.08	100	1050	550	14
Cul de Sac	38.8	100	500	237	25
Choc	13.55	100	100	50	10

Notes:
km^2 square kilometer
l/s = liters per second

Source: Modified from Norville and King, 2001

as well as treated-water storage facilities are inadequate to meet growing demand, especially in the dry season. The southern region of Saint Lucia has the most critical water supply needs because the area has been targeted for extensive development, which depend heavily on the availability of a reliable supply of water (Norville and King 2001).

Saint Lucia is viewed as a water-rich island; however, the drought of 2001 was a reminder that the country is susceptible to droughts. Awareness that drought conditions will reoccur on Saint Lucia spurred the creation of the Water Management Plan for Drought Conditions.

Water in the project area (southern Saint Lucia) is supplied by surface water intakes situated in the upper reaches of the watershed. Water supply is more critical in the southern portion of Saint Lucia (Norville and King, 2001). "…Research concluded that the most significant environmental variable affecting the reduction of diversity of the macro invertebrate (biological)

community of Saint Lucia's streams is the intensification of agriculture in combination with deforestation in the vicinity of the water supply stream intakes. This invariably leads to major deterioration in water supply quality and continuity" (Lloyd et al., 1996 in Norville and King, 2001).

Water Supply

Saint Lucia's water requirements are met through an integrated network of river intakes, treatment plants, transmission pipelines, and distribution systems. These system components are under the operation and control of WASCO. Saint Lucia uses four major potable water supply systems including Roseau Dam and Hill 20 in the north and Grace and Beausejour in the south. Water is supplied to the treatment plants through both gravity- and pump-conveyance systems. These systems treat and then disinfect the raw water in filtration plants.

Groundwater investigations in the 1960s indicated good reserves of groundwater, but due to water quality associated with hardness, salinity, and iron content, these reserves have never been exploited (Norville and King 2001).

Water Use

Water-use estimates from the Water and Sewerage Authority are provided in Table 3.1-2. WASCO does not track water use for agriculture. The WASCO currently allows farmers to withdraw water from raw-water mains for irrigation; farmers also irrigate using water drawn directly from rivers, and some small property holders use the domestic water supply.

Water outages are a common occurrence on Saint Lucia and hotels must truck in water; therefore, WASCO's water-use estimate for hotels does not reflect total hotel consumption.

Table 3.1-2. WASCO Estimated Use of Water Supply

Category	Percentage (%)
Domestic	90
Commercial	3.6
Government	5.64
Hotels	0.19
Boats/Ships	0.17
Agriculture	-
Total	**100**

Source: Modified from (Singh and Clouden 1999)

Water Treatment

Saint Lucia has two sewage systems. The first is a primary sewage collection and disposal system in the city of Castries, which serves approximately 15 percent of the greater Castries population and covers the business area. The second is a sewage system, which includes collection, treatment, and disposal facilities and is located in Rodney Bay on the north end of Saint Lucia, primarily serving residential areas and hotels.

Most of the residents of Saint Lucia use individual on-site systems (pit latrines, septic tanks, and soak ways) for sewage treatment and disposal. Grey water is generally discharged to open drains and has the potential to spread disease since it contains fecal coliforms (Government of Saint Lucia 2009a). "With the exception of areas in the north, all other areas are supplied by surface water intakes located in the upper reaches of the watershed within which these are located. Treatment at the Dennery, Canaries, Micoud and Anse-la-Raye intakes comprise slow sand filtration combined with chlorination while for all the others minimal sedimentation and chlorination is the only treatment provided." (Norville and King, 2001).

Water Use and Availability in the Project Area

Water is typically extracted from run-of-the-river intakes and treated to meet the potable supply requirements in nearby communities. Water from a local spring source is also used as a potable water source for the local community in Fond St. Jacques. Several factors could affect the water supply for a geothermal exploration project. Discussions with Mr. Jim King of WASCO indicated the potential for industrial water wells for large scale use in construction, as well as established tariffs to provide certainty when budgeting the project. In addition, WASCO has pre-approved contractors locally to transport water into on-site storage facilities in order to minimize impact on natural water sources. The only water supplies that may be available near the project area include streams near the drilling areas; however, water availability within the streams could be affected seasonally.

3.1.1.5 Stream Flow Conditions

Stream Flow Monitoring

In 1980, a water-monitoring network was established in 10 Saint Lucia watersheds. The number of monitoring stations by type are summarized in Table 3.1-3. All stations were discontinued for reasons such as shifting of the channel away from gauges, washing away of some gauges by Tropical Storm Debbie in 1995, and a lack of specialized local professionals (Flether-Paul n.d.).

Flow Rate Data

The Water Resources Management Agency of Saint Lucia provided stream flow data for 30 watersheds from 1985 to August 2017. The stream flow measurements were obtained during the dry and wet season. These data are provided in Appendix D. This information was not consistently obtained in a manner that allows for calculation of peak discharge under a 1 in a 100-year event; however, the data were analyzed to describe variability in stream flow conditions during the wet and dry seasons.

Table 3.1-3 Water Monitoring Stations in Saint Lucia

Type	Streamflow	Rainfall
Recording	2	25
DCP loggers	0	13
With telemetry	0	0
Manually read	0	6

Spot measurements	12	
Total	**14**	**44**

Source: Fletcher-Paul, w.d

Seasonal Flow Rate in the Project Area
The project areas drain to four watersheds:

- Choiseul/Trou Barbet (Belle Plaine)
- Soufrière (Fond St. Jacques)
- Doree (Mondesir-Saltibus)
- Balembource (Mondesir-Saltibus)

There is no stream flow measurements data for the Belle Plaine watersheds during the wet season. The Choiseul River downstream of the Belle Plaine area had a measured flow rate of 0.027 cubic meters per second (m^3/s) during the dry season in 2014.

The Soufrière River downstream of the Fond St. Jacques project area had a measured average wet season flow rate is 0.47 m^3/s and an average dry season flow rate of 0.42 m^3/s. These flow rates indicate the potential for low seasonal variability in stream flow in the Fond St. Jacques area.

The Doree watershed (Mondesir-Saltibus) has an average wet season flow rate of 0.44 m^3/s and an average dry season flow rate of 0.22 m^3/s indicating that the flow is seasonally affected. Stream flows are expected to be perennial in all area streams.

3.1.1.6 Drought Susceptibility

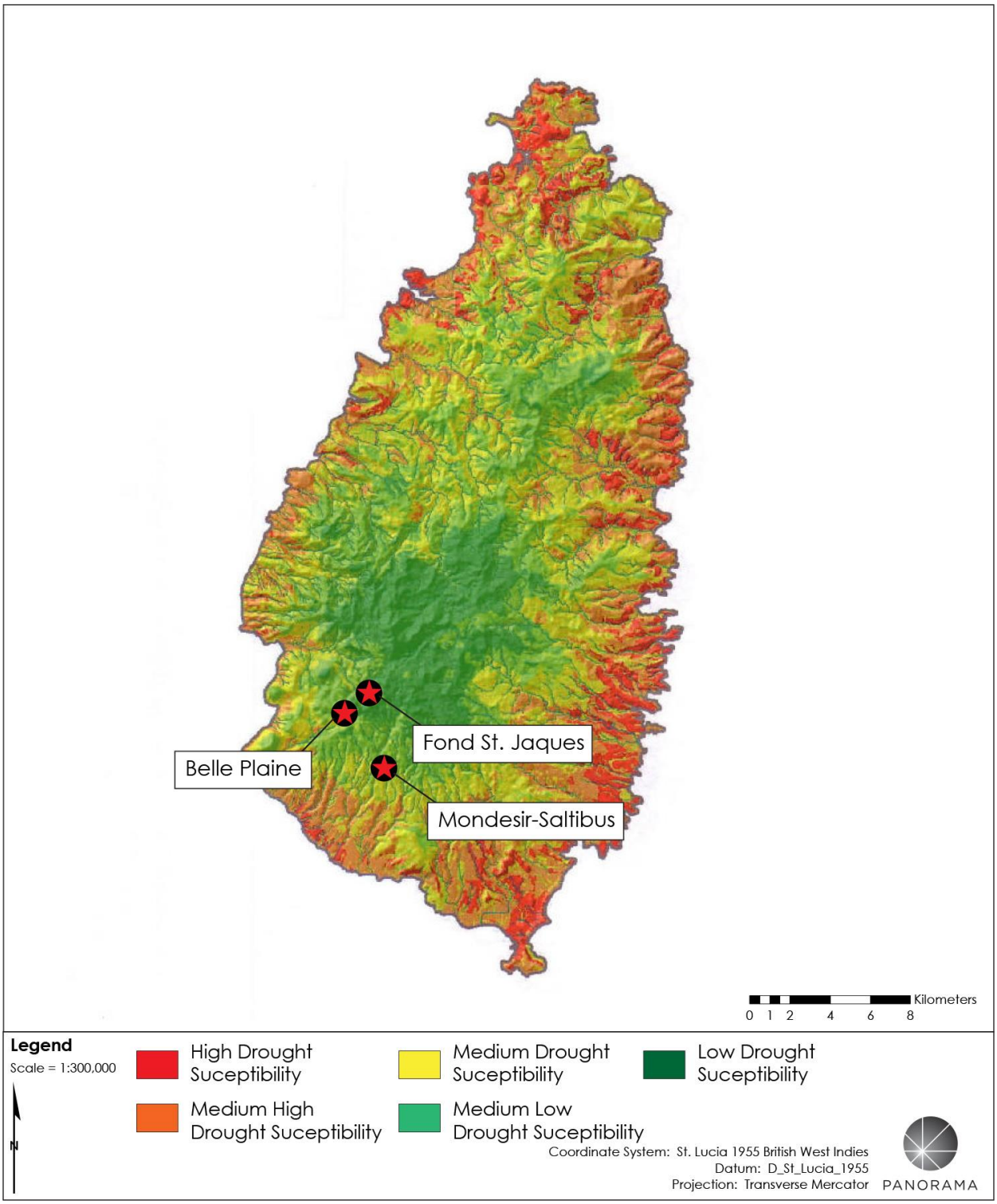
Drought Susceptibility Map
The Government of Saint Lucia produced the Drought Susceptibility Map under the Government of Saint Lucia Disaster Management Project II (Government of Saint Lucia, 2009). The Drought Susceptibility Map is based on:

- Annual water balance
- Flow accumulation
- Mean annual temperature
- Soil drainage
- Moisture supply capacity

In the map, drought susceptibility is given five orders, with red representing "High Susceptibility" and green representing "Low Susceptibility" (Figure 3.1-3).

Project Area Drought Susceptibility
The project areas are located in a region of classified as medium-low susceptibility to drought. Areas downstream of the project and along the coast are characterized as medium to medium-high drought susceptibility.

Figure 3.1-3 Drought Susceptibility Map



Source: (GOSL 2009)

3.1.1.7 Flood-Risk Assessment

Regional

Flooding is a risk in Saint Lucia, particularly flooding associated with hurricanes and tropical depressions. The Saint Lucia National Flood Plan (Government of Saint Lucia 2003) identifies five types of flooding:

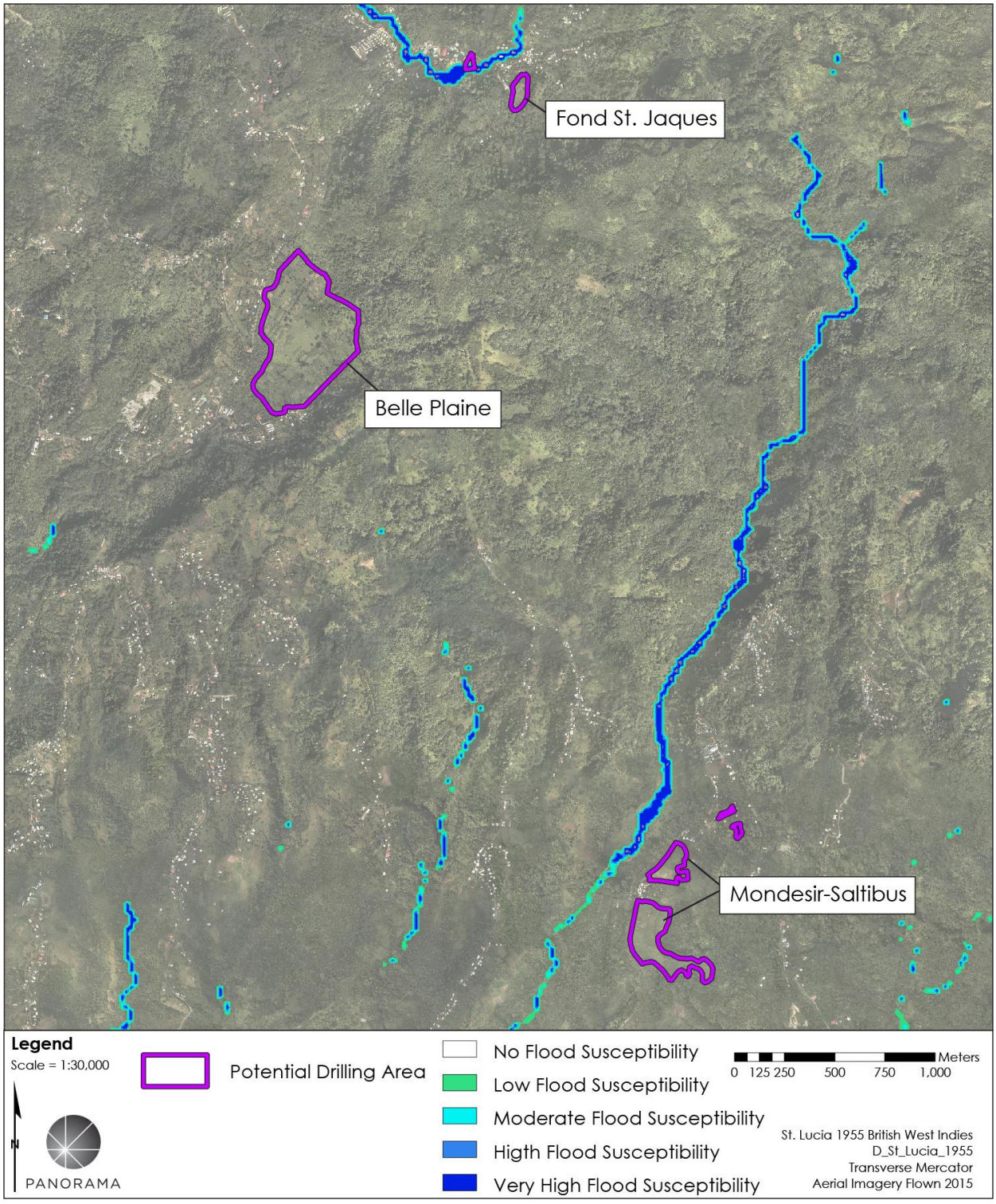
- **Flash floods**. Flash floods are the result of heavy rainfall over a relatively small drainage area. Flash floods carry highly destructive flood waves and are most common in mountainous areas or in steep places that have streams flowing through narrow canyons.
- **Riverine floods**. Riverine floods occur when a large amount of rain falls in river systems with tributaries that drain large areas containing many independent river basins. Riverine floods may last a few hours or many days, depending on the intensity, amount, and distribution of rainfall.
- **Land-based floods**. Some states are subject to relatively large amounts of rain in relatively short periods of time. Land-based floods can result, especially when such sudden rains are combined with steep terrain, porous soil, river basins, siltation, compromised (e.g., deteriorated, insufficient, or blocked) drainage systems, and unregulated deforestation of upland areas.
- **Coastal/tidal floods.** Coastal/tidal floods occur during high tides, hurricane rains, storm winds (which create a "suction effect" of reduced atmospheric pressure along a coastline), and tsunami waves produced by earthquakes or volcanic eruptions at sea.
- **Ponding.** Ponding results from a slow build-up of water in depressions, sinks, and areas with clay-base soil and slow percolation rates. Ponding may persist for many days because of poor drainage.

Flood hazard maps are used to define flood risk/susceptibility. Precipitation initially results in runoff in developed areas (e.g., roads and paved surfaces). Areas of clay soils with little vegetation and forested areas also contribute to runoff. The average Saint Lucia runoff from a 1 in 5-year event is 15 percent, increasing to 20 percent from a 1 in 50-year event. All major valleys in Saint Lucia are capable of creating floods, which is a danger for settlements along riverways (Jetten 2016).

Project Area Flood Risk

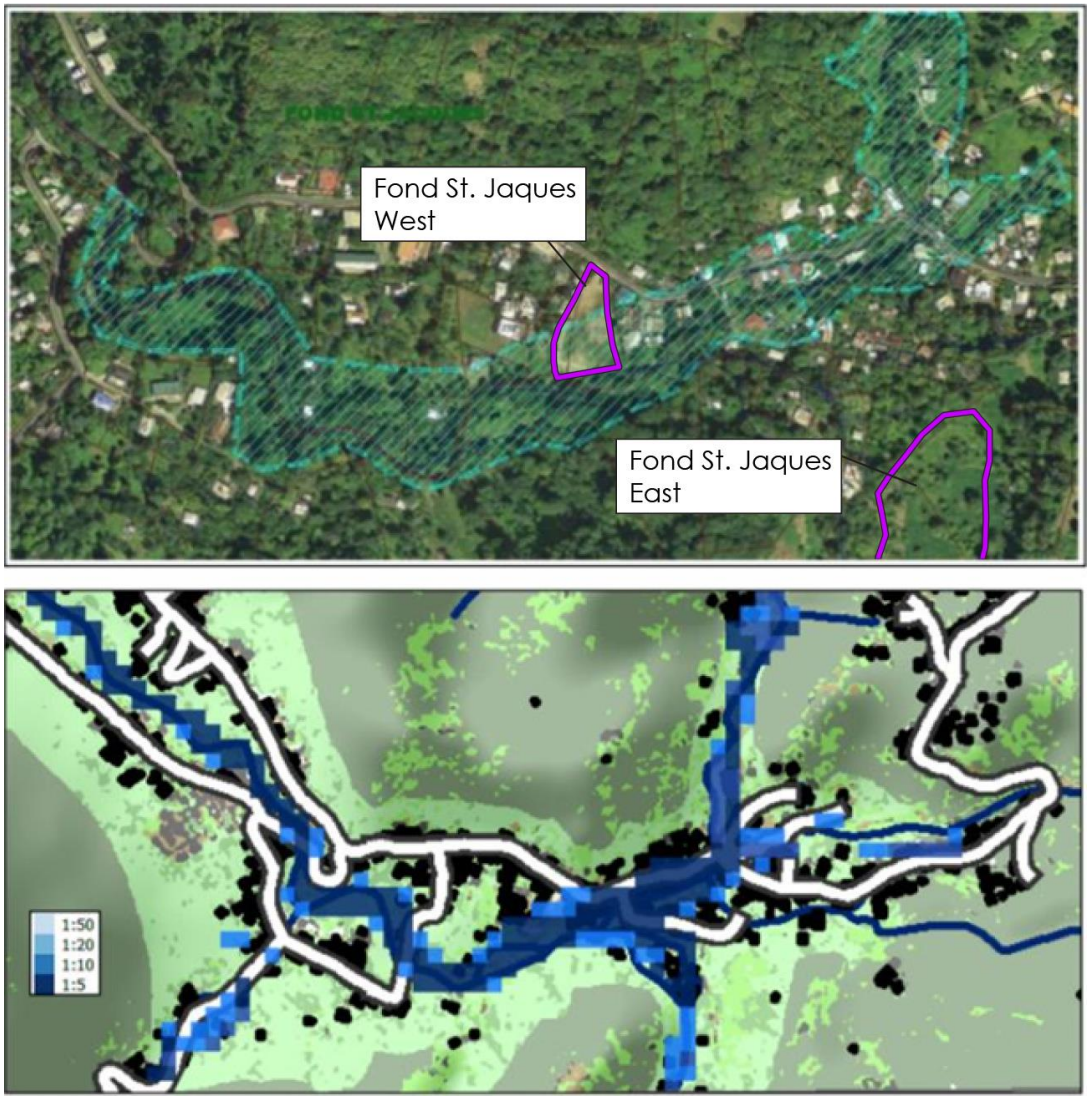
The flood-hazard assessment for the is shown in Figure 3.1-4. Fond St. Jacques has a greater risk of flooding due to the presence of steep terrain and narrow valley surrounding the river (Figure 3.1-5). Only the southwestern segment of MS-2 is located in the flood plain. The Belle Plaine area and the remainder of the Mondesir-Saltibus areas are not located in flood-prone areas and no flood risk mapping has been conducted for these areas.

Figure 3.1-4 Flood Risk Areas



Source: GFDRR 2016

Figure 3.1-5 Fond St, Jacques 2013 Flood-Hazard Assessment (top) and National Flood-Hazard Image (bottom)



Source: (Jetten 2016)

3.1.2 Field Survey Results

3.1.2.1 Belle Plaine

No water resources were identified within the drilling target area in Belle Plaine. Two streams have been identified in proximity to the drilling area. One stream flows towards the project area from south to north along the western edge of the valley. The stream may supply irrigation water to the site intermittently. The second stream is downgradient of the project and flows around the potential drilling area along the eastern border of the site. The potential drilling area generally drains toward the north and east. Storage tanks that are mainly used for runoff water were observed during field surveys. Water use in Belle Plaine is primarily managed for agricultural activities. Several greenhouses are located at the southern edge of the valley and just south of the potential drilling area. Streams along the western flank of the valley contained minimal flow during field investigation and these streams likely run dry for portions of the year. No springs or ponding of surface water was observed within the valley. There is limited potential for groundwater storage in the area due to the small size of the basin and surrounding drainage area.

3.1.2.2 Fond St. Jacques

Surface water resources in the Fond St. Jacques area includes two water courses. One of the water courses is a third-order stream that flows across the area from northeast to southwest and contains few visible floating solids. The second water course is a first-order stream flowing from southeast to northwest that has a considerable amount of visible floating solids and associated residues. These streams do not provide water to the local community. The water courses could not be accessed during field surveys due to recent rainfall and unsafe access conditions (i.e., loose slippery soils).

An unpaved road provides access from the main access road to the Fond St. Jacques East area. The Fond St. Jacques East area is characterized by a shallow water table (e.g., swamp like conditions) with an intermittent canopy of vegetation. A chain of steep hills bound the valley to the east of the potential drilling area. Dense vegetation and a stream are located south of the Fond St. Jacques East area. The stream supplies water to a local water storage tank that serves as the primary water source for the Fond St. Jacques community. Buried pipelines convey water from the water storage tanks to the community.

Two springs are located in the foothills on the southeastern flank of the potential drilling areas. The water that comes from these springs is stored in tanks (see Figure 3.1-6) and supplies the adjacent communities of Fond St. Jacques and Soufrière with freshwater. The water storage tanks are located approximately 40 meters (130 feet) west of the foothills and 25 meters (80 feet) from the local access road.

The main storage tank (Figure 3.1-6, left) is made of concrete and most of its volume is installed underground. This unit is connected to the spring by means of a pipe buried at shallow depth. The relative distance between the spring and the storage tank ranges from 8 to 10 meters (25 to

Figure 3.1-6 Water Storage Tanks in Fond St. Jacques Area (left and top right) Crops that use surface water (bottom right)

30 feet). An irrigation system was observed at the base of the foothills during field investigation filled.

Two plastic water storage tanks, which collect surface water, were observed in proximity to the drilling area. These plastic water storage tanks are used primarily for agricultural purposes (Figure 3.1-6). The water storage tanks have an estimated capacity of 189 liters (50 gallons) based on visual assessment.

3.1.2.3 Mondesir-Saltibus

The Mondesir-Saltibus area is primarily used for agricultural production including bananas, cocoa, coconuts, and vegetables. Water in the area is primarily used for agricultural production.

The primary water sources in the area include a third-order stream flowing in a north-northeast to south-southwest (NNE–SSW) direction, and a secondary, first-order stream flowing in a north-northwest to south-southeast (NNW–SSE) direction. Due to the high vegetation cover and the steep topography, only the valleys through which these streams flow were identified visually. The recent rains and slippery soil conditions during the field investigation prohibited any access and assessment of the water courses near the potential drilling areas. There is limited water supply infrastructure other than cemented roadside drainage ditches and pipes that supply water to the population.

3.1.3 Conceptual Hydrogeological Model

3.1.3.1 Regional Hydrogeological Conditions

Shallow groundwater aquifers within Saint Lucia are fed primarily by streams and river recharge. Deeper groundwater aquifers are limited in extent due to the low permeability and existence of aquitards (clay layers) created from hydrothermal alteration.

The deeper groundwater aquifers are expected to contain high levels of heavy metals, including manganese, due to the volcanic nature of the region. The geothermal aquifer is naturally separated from the groundwater aquifer by aquitards, which limit infiltration and cross-contamination of geothermal resources with surface water or shallow groundwater resources.

The overall geology of St. Lucia (due to volcanic activity and provenance) provides limited sedimentary basins, such as sandstone or limestone, which are common for groundwater basins. The steep topography along with fracture networks and streams lend to drainage as opposed to ponding and groundwater storage.

Preliminary assessments identified three main catchment areas, or sources of groundwater, on Saint Lucia associated with the surface features:

1. Grande Riviere du Vieux Fort,
2. Troumassée River, and
3. A third, slightly smaller catchment area associated with Anse la Reye.

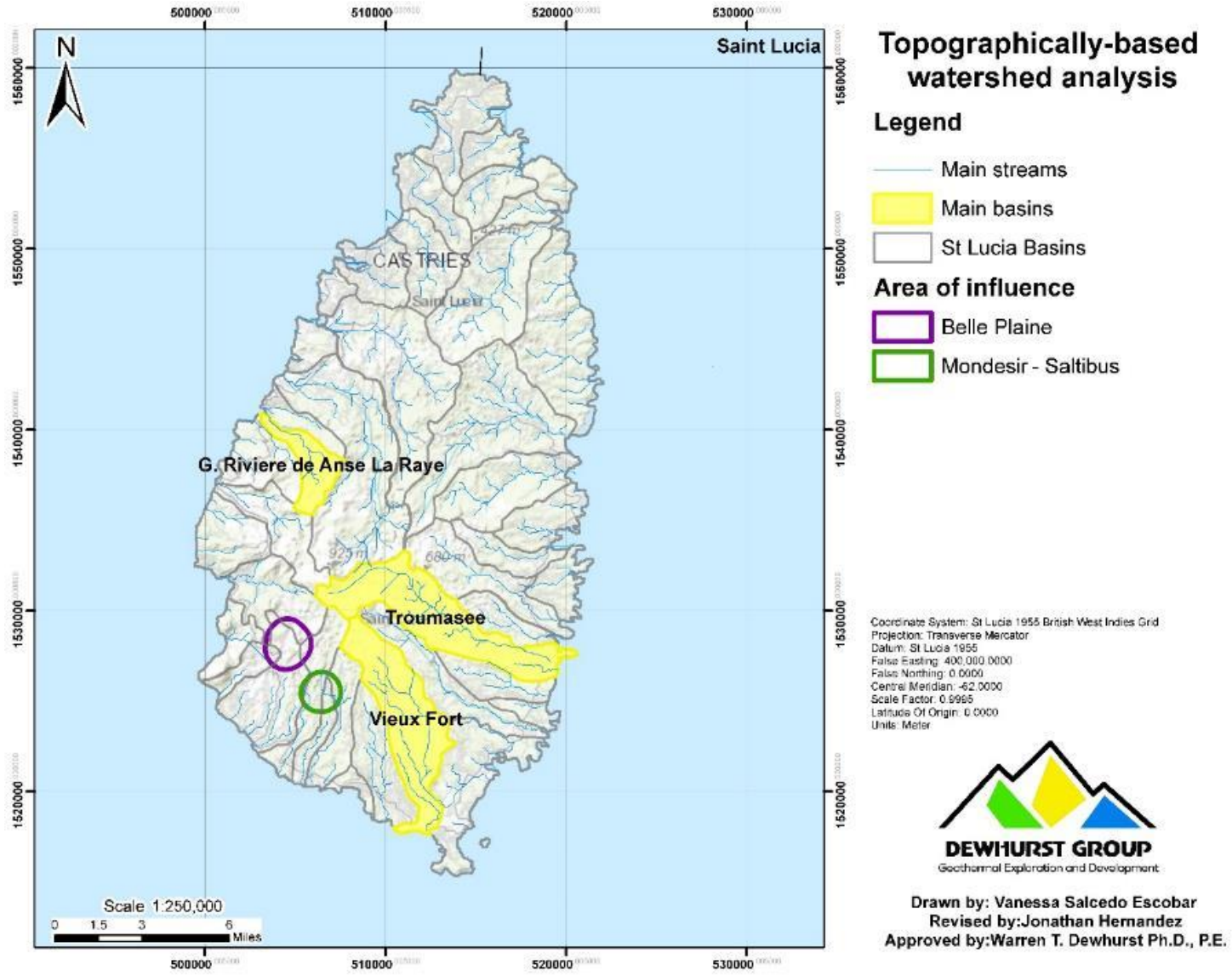
The surface area within each catchment is provided in Table 3.1-4 and Figure 3.1-7. None of these sources of groundwater are within the areas of influence for the project.

Table 3.1-4 Summary of Major Catchment Areas

Catchment Name	Surface Area (approximate) km^2
Grand Riviere du Vieux Fort	27
Troumassée River	29
Anse La Reye	5.8

Previous hydrogeological studies document the presence of structural controls possibly associated with the Qualibou Depression through which many of the surface hydrothermal manifestations occur in New Jerusalem, Cresslands, Spike Falls, and Diamond. All of these manifestations are in the deposits of blocks and ashes at the base of the Qualibou Depression. This geologic unit could serve as the aquifer that controls the shallow outflow of fluids from the Sulphur Springs, with manifestations of this outflow breaching the surface where vertical permeability structures are intersected (JACOBS - Lovelock and Ussher 2016).

Figure 3.1-7 Saint Lucia Groundwater Basins



Source: After Morgan, 2007

A study carried out in 1986 (Flynn et al., 1998) indicates that the fractured and jointed lavas can serve as transmissive aquifers. There may be an impermeable zone over the geothermal resource consisting of altered old rocks of basaltic composition and andesitic pyroclasts that are composed mainly of clays.

3.1.3.2 Hydrogeological Environment/Conceptual Hydrogeological Model

Groundwater Resources/Storage in the Project Area

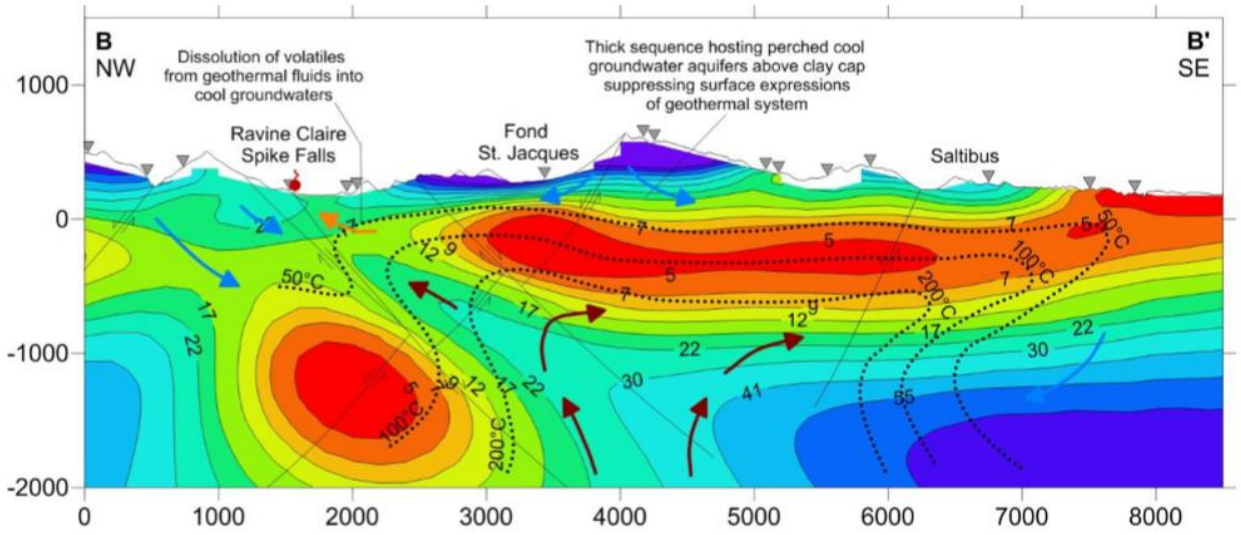
Rainwater runoff from topographically high areas, including the mountains surrounding Belle Plaine and Fond St. Jacques, recharge groundwater aquifers in the valleys. The groundwater aquifers in the project areas are expected to be limited in size/volume due to the volcanic nature of the geology in the project areas and the small basin and alluvial area that could contribute to the groundwater system. Groundwater aquifers typically occur in areas with underlying sedimentary soils; volcanic bedrock is not conducive to groundwater storage.

Belle Plaine is located in a valley. Runoff from the surrounding mountains could contribute to groundwater recharge in the Belle Plaine Valley. The Belle Plaine drainage area is limited in size resulting in limited potential for groundwater recharge and storage. Mondesir-Saltibus is located on a hill slope where some shallow groundwater may occur due to proximity to nearby streams and stream recharge. The topography of the Mondesir-Saltibus area is not expected to support substantial groundwater resources because groundwater would runoff the hill slope rather than collect in the area. There is currently no data available to support the presence of cool groundwater in either Belle Plaine or Mondesir-Saltibus. A perched groundwater aquifer was observed in the Fond St. Jacques drilling area where a spring discharges from the hill slope.

Jacobs of New Zealand (2016) developed a conceptual hydrogeological model of the area of influence (shown in Figure 3.1-8) using the results of the seismic study (refer to Section 3.2.1 and Figure 3.2-1). The conceptual model shows the presence of a clay layer, which suppresses surface expression of the geothermal system. The cool groundwater aquifer is perched above the clay layer. The hydrothermal alteration appears to occur at relatively shallow depths just at or below sea level. Surface manifestation of the geothermal resource occurs along fractures where there is upflow, such as in the vicinity of Ravine Claire Spike Falls.

Fond St. Jacques shows evidence of perched cool groundwater aquifers above the clay cap, which suppresses surface expressions of the geothermal system (Jacobs 2016). This perched cool groundwater aquifer was observed during field investigation. A spring and and shallow groundwater/saturated soils were observed at Fond St. Jacques. The presence of a perched groundwater aquifer/spring indicates that the clay caps of the geothermal system are a factor in groundwater storage, providing high impermeability at lower depths, allowing for storage within the subsurface—likely within fracture networks as opposed to porosity. Similar scenarios of groundwater storage above geothermal clay caps could exist in Belle Plaine and Mondesir-Saltibus; however, no subsurface investigation has been conducted in these areas.

Figure 3.1-8 Schematic Conceptual Hydrogeologic Model



Source: Jacobs, 2016

Potential Mixing of Groundwater and Geothermal System

Recent geophysical studies (JACOBS - Lovelock and Ussher 2016) of the project area indicate the presence of a geothermal upflow zone between Belle Plaine, Fond St. Jacques, and Mondesir–Saltibus (Parc Estate), with a northwest - southeast trend. The Jacobs (2016) study also concludes that the outflow of deep geothermal fluids starts from this zone of upflow and moves toward zones topographically lower, west and southeast of the zone of interest. The outflow of shallow steam-heated waters occurs east of Fond St. Jacques. No heated springs were observed in the project areas indicating that the water resources in the project area are isolated from the geothermal system by an impermeable layer.

Water quality sampling and analysis was conducted on the shallow groundwater system in the vicinity of Sulphur Springs (Aquater 1982). The water quality analysis indicates that, except for tiny admixtures of geothermal steam causing geochemical anomalies for ammonia, boron, and carbon dioxide, no extensive mixing of shallow water with either the underlying reservoir brine or its steam takes place. This condition strongly suggests that impervious or self-sealed rocks intervene between the geothermal reservoir and the surface.

3.1.4 Data Gaps

The water quality and geology field investigation took place in Saint Lucia during the end of the summer months and encountered conditions that limited access. Safety is always prioritized over data acquisition during field surveys. The steep terrain and rainfall during the field visits provided hazardous conditions at times restricting access to area streams and other water bodies. The best possible visual assessment was made in good faith, and provided within this report. Other hazards included livestock and other wildlife on private property, such as the farm lands of the Belle Plaine drilling site. Fond St. Jacques also contained livestock as well as

swampy terrain that made passage difficult to the east, and to the west of the site. Mondesir-Saltibus is bounded by rivers, which were visually assessed in the field; however, access to the rivers was not possible due to previous rain and steep topography.

A detailed conceptual hydrogeological model for the area of interest could not be developed at this time due to the absence of key data on the aquifers in the area of interest. The current conceptual model is based on assumptions and inference from the remote sensing data. The conceptual model is speculative and additional data would be required to validate the conceptual hydrogeological model including:

- The geometry of the hydrogeological units and their hydraulic properties (e.g., hydraulic conductivity, storage coefficient, and porosity)
- Piezometrics, temporal variability, direction of groundwater flow, and hydrochemical characteristics and variations
- The recharge and discharge mechanisms of the system
- Classification of aquifers
- A preliminary water balance
- The hydraulic interconnections of surface water and springs with groundwater, in both shallow and deep systems

The preliminary hydrogeological model of the area of influence was developed using topographical data, field investigation, and the results of the magnetotelluric data. Very little is known about the recharge, size, and volume of the shallow cold water aquifer(s) or the deep geothermal reservoir. Geological features within Saint Lucia suggest that the host rock for the deep geothermal reservoir under the clay cap could be heavily fractured lava flows that appear to have structural control in the location of the thermal manifestations. The extent and specific locations of underground connectivity and permeability among the shallow aquifer and deep geothermal reservoir remains uncertain.

3.2 GEOLOGY AND SOILS

The following section contains information pertaining to TOR Task: 1.5. The area of influence includes all soils within the potential drilling area and area of civil works because the exploration areas would only affect soils within the drill sites and areas where grading is conducted.

3.2.1 Literature Review Results

Saint Lucia is volcanic in origin, with rocks that vary in age between the Tertiary and the Quaternary era. The geology of Saint Lucia is divided into three categories (JACOBS - Lovelock and Ussher 2016):

- Eroded basalts and andesites;
- Dissected centers of andesites; and

- Extensive deposits of pyroclastic flows, lava flows, phreatic and phreatomagmaticcraters, domes, and flows of rock and ash from the volcanic center of Soufrière.

Some sedimentary units are located in the northeast section of Saint Lucia formed by the erosion of coral reefs of the lower Miocene.

It is believed that the volcanic activity of the Island's southwestern sector began in the Pleistocene. Structures such as craters and domes have been identified. Surface geothermal manifestations such as fumaroles and hot mud pools are active along faults. The most interesting thermal features are found in the Sulphur Springs area, which is located near the caldera. Other notable locations with geothermal manifestations are located in the north, including Spike Waterfall and Piton falls.

The Qualibou caldera is located in the southwest of Saint Lucia. This main feature was initially identified in 1964 and was formed between 40,000 and 300,000 years. Studies by (Aquater, 1985) concluded that the caldera collapsed 300,000 years ago, while (Goff and Vuataz 1984) estimated the collapse at 100,000 years ago. Subsequent to this collapse, volcanic eruptions that formed domes and deposits of ash filled the caldera. Figure 3.2-1 shows the geology of the Qualibou caldera, which is bounded to the NW and SE by NE-striking normal faults (JACOBS - Lovelock and Ussher 2016).

Saint Lucia is located in an archipelago of volcanic islands, which was formed by the collision of the North American and South American plates under the Caribbean plate (Lindsay 2013) . The data support the notion that the Qualibou Depression is (or has recently been) situated in an extensional regional-stress regime with the principal horizontal stress oriented NW–NNW. Intra-arc environments are known to be favorable settings for geothermal development. The data are consistent with a model of recent magmatic and geothermal activity in the Terre Blanche-Belfond region. The prospective region to the south of the Qualibou Depression is controlled by a NW-striking accommodation zone, with additional secondary permeability perhaps provided by the interaction with large NE-striking structures and faults (JACOBS - Lovelock and Ussher 2016).

3.2.1.1 Geochemistry

Geothermometric calculations of reservoir temperatures from H_2/Ar - CH_4/CO_2 gas ratios give a range of 190–300°C, generally consistent with temperature calculations of 292°C on fluids obtained from borehole sampling (UNRFNRE 1989), and 280°C as estimated from gas geothermometers (GI 1991). The most recent geochemical studies have shown that the geothermal water has not reached chemical equilibrium with the host lithology; geothermometry data are therefore considered unreliable.

3.2.1.2 Water Analysis

Samples of the geothermal reservoir indicate that they are low-chloride, high-boron waters, with a presence of amorphous silica and a relatively low discharge rate, all of which would

indicate a vapor-dominated system. The silica content indicates subsurface temperatures exceeding 180°C (Goff, F. and Vuataz, F. 1984).

3.2.1.3 Geophysics

The following geophysical studies have been carried out in the area of interest:

- Magnetotelluric Surveys
- Seismic surveys
- Magnetic surveys
- Gravity surveys
- Temperature surveys
- LiDAR

The results of these geophysical surveys are discussed below.

Magnetotelluric Surveys

The magnetotelluric/audio magnetotelluric (MT/AMT) resistivity surveys indicate that the northern and northeastern part of the Qualibou Depression has intermediate resistivity values and few clear structures. The survey results are consistent with a resource that was hydrothermally altered in the past, but subsequently cooled, and is not currently thermally

active. Resistivity patterns indicate that the Sulphur Springs system is confined to a relatively small area, but may extend up to 1 kilometer (km) (0.6 mile) to the east and southeast of the thermal area. It is plausible that large NW-striking faults in this region (i.e., those along the Migny River valley and those offsetting drainage to the west of Saltibus) are controls of geothermal upflow (Jacobs, 2016).

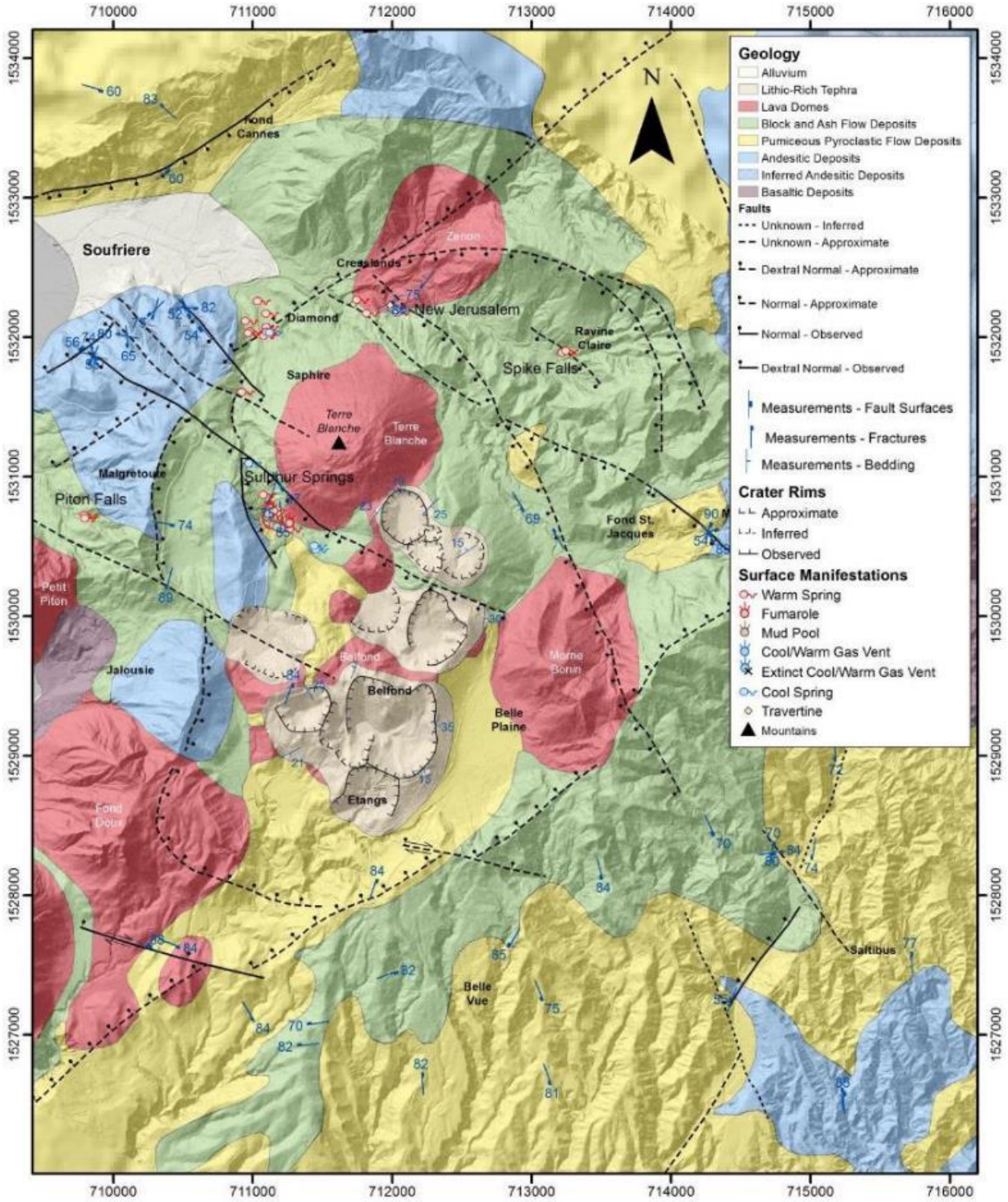
Seismic Survey

(Aspinal, Michael and Tomblin 1976) performed a microearthquake survey at Qualibou caldera. The seismic records are characterized by emergent P-waves and missing or attenuated S-waves, characteristics that denote the presence of fluid bodies (magma or water) at depth. Analysis of the data indicates that the attenuating medium occurs at depths less than 2 km (1.2 miles), extending from Sulphur Springs to the north caldera wall; thus, these researchers conclude that a geothermal system occupies this zone. The distribution of known hot springs inside the caldera is coincident with the attenuating zone (JACOBS - Lovelock and Ussher 2016).

Magnetic Survey

An aeromagnetic survey was performed in previous studies, and is considered extensively within the Jacobs report (JACOBS - Lovelock and Ussher 2016). The strongest feature of the aeromagnetic anomaly map is the broad zone of low magnetic strength surrounding Sulphur Springs and extending over the area encompassing the lower-elevation warm springs and extending further NE into the high terrain west of Mt. Gimie, located approximately 3 km (1.5 miles) northeast of the Fond St. Jacques area. These features may be indicative of a widespread area of hydrothermal alteration that may be caused by some alteration associated with the

Figure 3.2-1 Geological Map of the Qualibou Depression and Surroundings



Source: Jacobs, 2016; Lindsay et al., 2013; and Wohletz et al.,1986

outflows of warm condensate fluids at quite shallow depths from the Sulphur Springs area (Jacobs New Zealand Limited, 2016).

Gravity Survey
(GENZL, 1992) suggests that the most prominent anomaly may be due to a NE-trending down-faulted depression that has been in filled with denser volcanic material. Lindsay et al. (2003) suggest that the gravity high points could be due to the presence of a denser intrusive body which counts against caldera collapse where infill material would comprise less dense pyroclastics.

Temperature Survey
Seven shallow geothermal wells and two deep geothermal wells (SL-1 and SL-2) were previously drilled near Sulphur Springs. SL-2 encountered a geothermal resource and reached a temperature of about 260°C; SL-2 reached a depth of 1408 meters (4619 feet) and showed a very high geothermal gradient (220°C/1000m). Figure 3.2-2 illustrates the different temperatures and depths of each well.

Measures of Deep Resistivity in the Qualibou Caldera
A dipole-dipole resistivity study was made along the N-S trend, through the Qualibou Caldera north of Ruby to the north of Victoria Junction (stations near Sulphur Springs). An apparent low resistivity value was found below the Belfond area indicating that geothermal waters occur at a depth of 600 to 900 meters below ground surface, and locations with low resistivity (<10 ohm-m) corresponded to hot springs. A very low resistivity zone (1ohm-m) was found below the Etangs area, which may be associated with thermal upwelling along a fault zone, perhaps associated with the boiler. Below the Sulphur Springs area, a zone of relatively high resistivity (40-150ohm-m) was found, suggesting the presence of a very hot field of dry steam below Sulphur Springs (Aquater 1982).

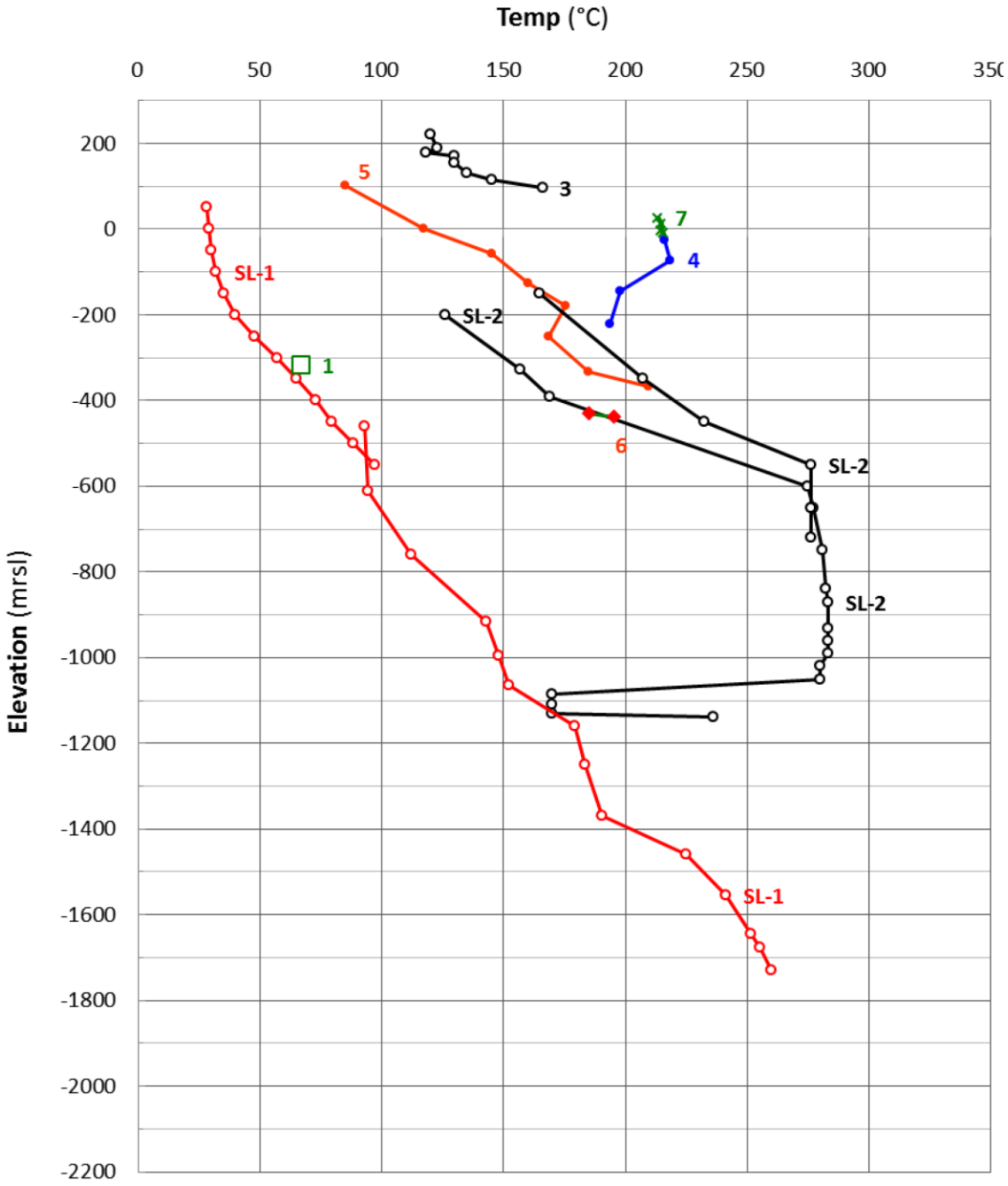
LiDAR
In 2016, McElhanney Consulting Services Ltd. carried out a LiDAR survey with orthophotos in the Soufrière region, covering an area of approximately 75 km^2. The LiDAR data were used to create a digital elevation model (DEM) from the contour data. DG used the DEM data to analyze streams and rivers for the various catchments and their potential flow order (i.e., 1, 2, and 3).

Hydrogeochemical Studies of the Qualibou Geothermal System
Hydrogeochemical data suggest the presence of a geothermal reservoir beneath Sulphur Springs, divided into three layers:

1. An upper zone of condensed steam
2. A two-stage intermediate zone
3. A lower-brine zone

Chemical analysis of Sulphur Springs fluids indicates the presence of an acid-sulphate system, of low pH, high concentrations of SO_4 (sulfate), low Cl (chloride), temperatures of 24°C, and pressures of < 32 ba (barye). These conditions suggest a vapor-dominated system. Gas

Figure 3.2-2 Measured Temperature for Geothermal Exploratory Wells in Saint Lucia



Source: Jacobs 2016

geothermometry for this area indicates a reservoir temperature of 280°C (Goff and Vuataz 1984). The complex brine chemistry suggests a fluid that is not in equilibrium. A detailed conceptual model of the southwest of Saint Lucia is show in Figure 3.2-3.

Heat Origin

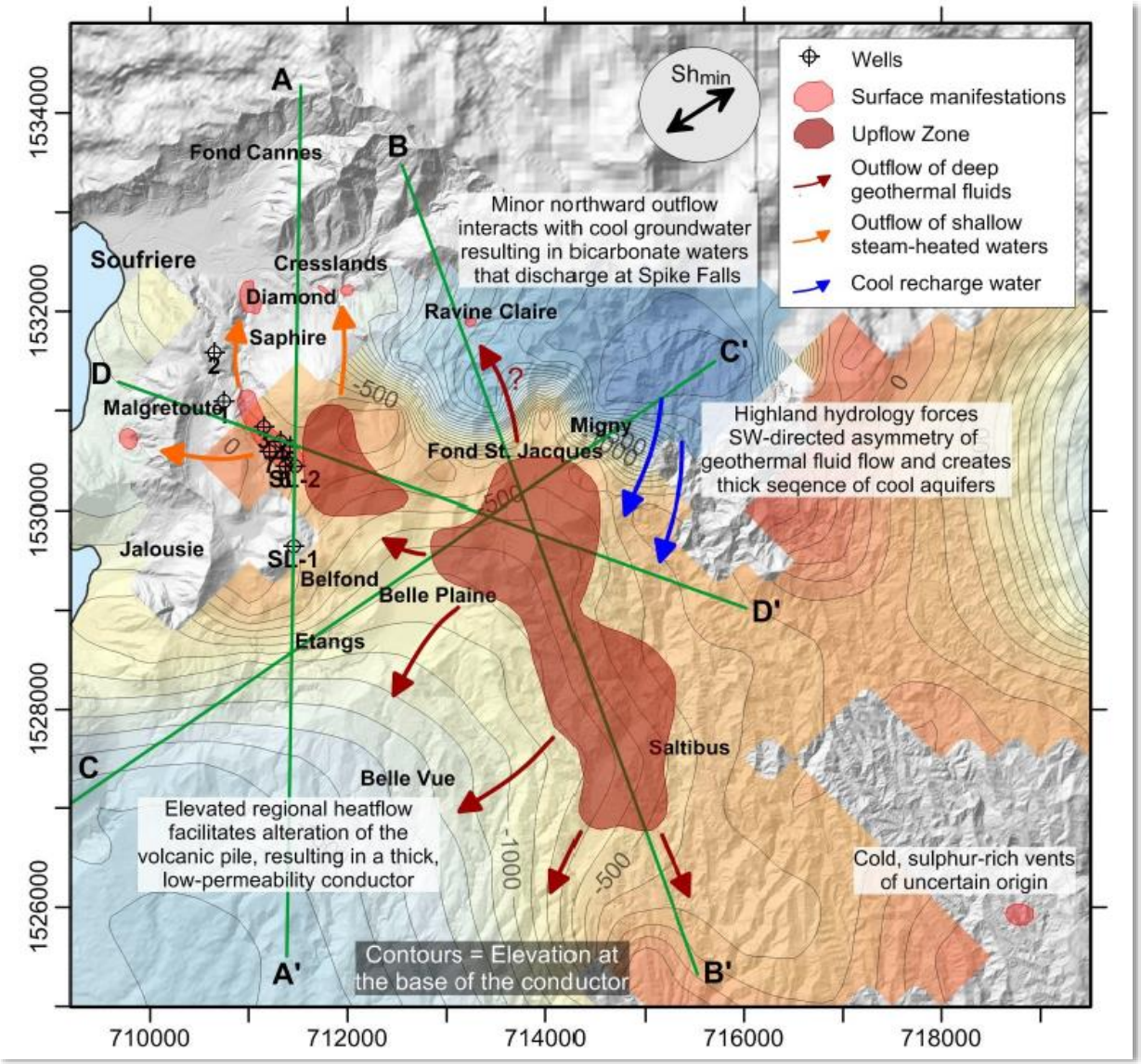
The natural heat of the geothermal resource comes from the cooling of a shallow magmatic chamber below the Sulphur Springs area, the same as the Terre Blanche and Belfond dacitic eruptions of 15 to 20 thousand years ago (JACOBS - Lovelock and Ussher 2016).

3.2.1.4 Soils

Soil Types

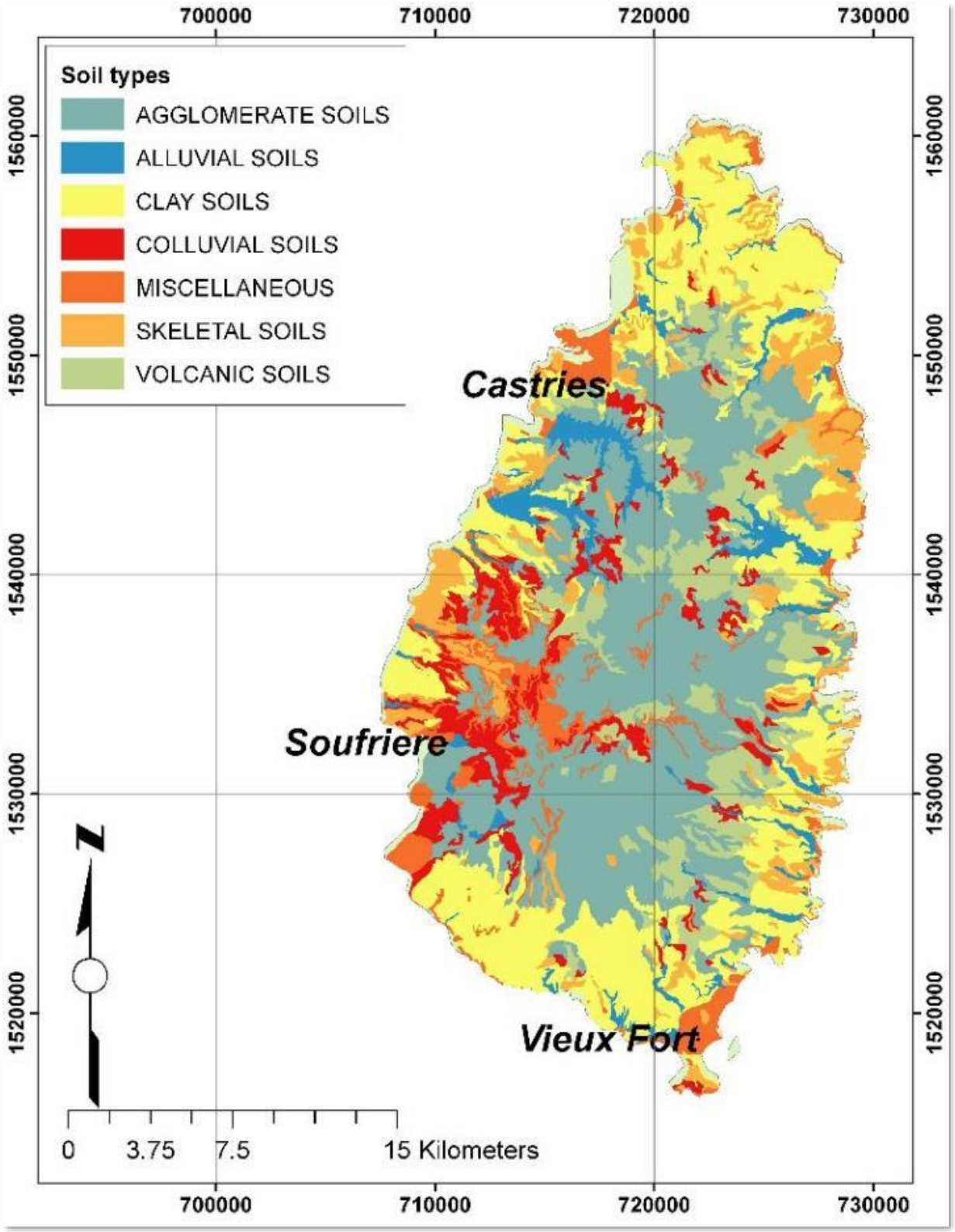
The Soil Atlas of Latin America and the Caribbean generally classifies soil in Saint Lucia as a Cambisol, between Vertic Cambisol (CMvr) and Eutric Cambisol (CMeu). The soil texture class ranges from fine to very fine; the soil has a 30 to 45 percent average grain size of sand without gravel content. The soils are moderately well drained (Gardi 2015). The soils of Saint Lucia are generally kaolinite clays in the center of the Island and montmorillonitic clays in the coastal areas that tend to be drier (Cox, Sarangi and Madramootoo 2006). Microorganisms and plant degradation are the main agents that allow the fertility of the soil, which is typical of tropical soils. The soils are particularly acidic, and generally low in phosphorus (Gonzales and Zak 1994). The high concentration of clayey tropical soils is the result of weathering of the volcanic rocks combined with weathering of soils in river valleys, sedimentation and over-sedimentation, erosion, landslides, and other soils actions. Distribution of primary soil types is illustrated in Figure 3.2-4 (Quinn 2012).

Figure 3.2-3 Conceptual Geothermal Model (Cross sections are shown as green lines)



Source: Jacobs, 2016

Figure 3.2-4 Soil Types in Saint Lucia



Source: (Quinn 2012)

Erosion and Soil Loss

A study of agricultural soils showed that the loss of soil cover is very high as a result of high storm intensity (Cox, Sarangi and Madramootoo 2006). The impact energy of the raindrops during heavy rains breaks the surface energy of the soil aggregates; sediment flow then runs to the macropores and creates a sealing that reduces the percentage of infiltration and generates rapid erosion. The high rate of erosion generates loss of soil fertility and sedimentation of the water systems that are essential in agricultural productivity, especially in the lower valley (Food and Agriculture Organization 2000). According to Saint Lucia's *Initial National Communication on Climate Change* (Tulsie 2001), the following factors relevant to erosional processes are considered major threats to the agricultural sector:

- Loss of vegetation cover in watersheds
- Lack of proper soil conservation practices
- Inappropriate land use, and degradation of soils

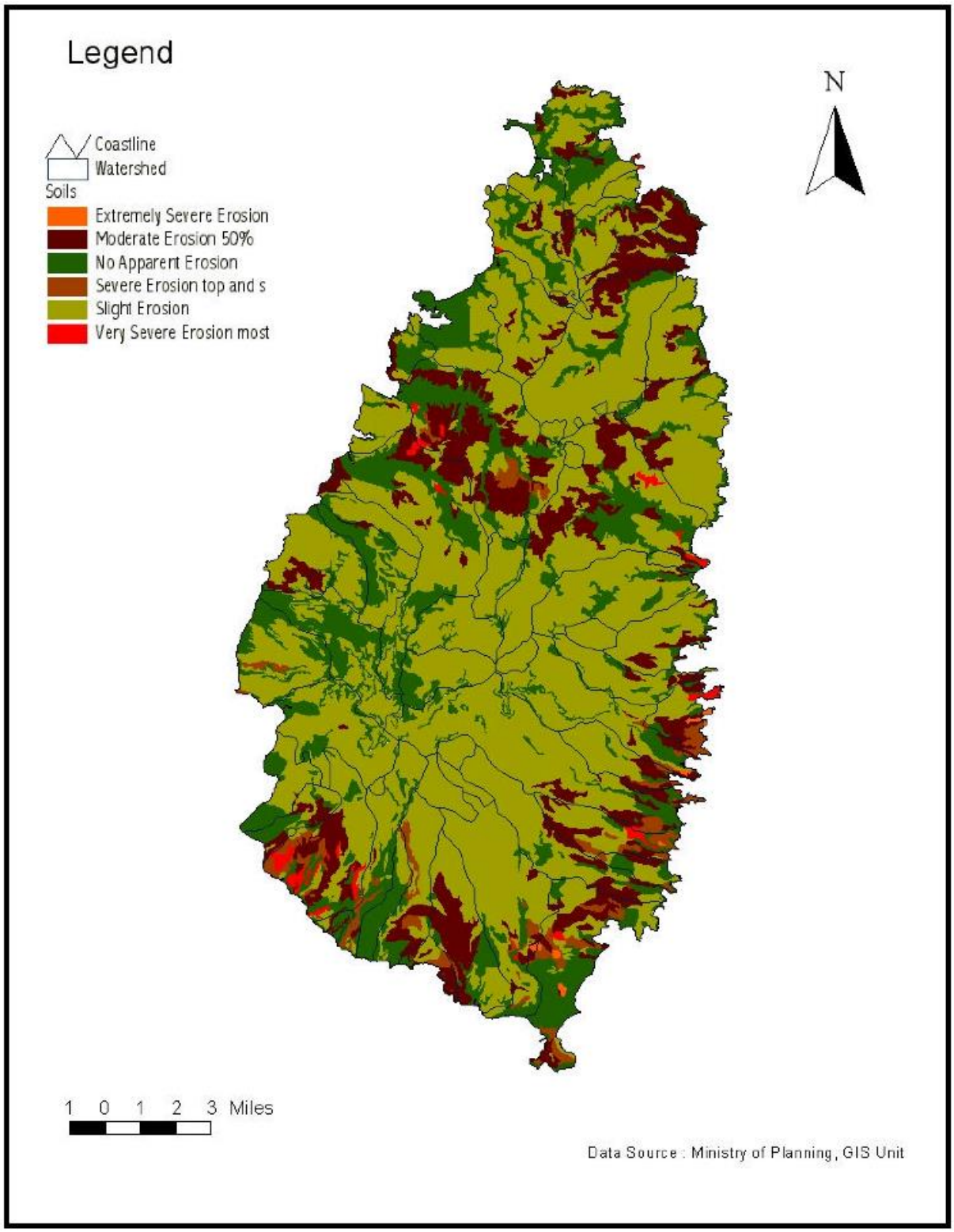
Figure 3.2-5 shows the different levels of erosion throughout Saint Lucia, indicating that the coastline is most susceptible to erosion. The agricultural sector is also very vulnerable to erosion (Reisdorff 2008).

Erosion is the most severe environmental problem in Saint Lucia. Erosion results in chain reactions (e.g., loss of plant land and nutrients, runoff concentration, flooding, and damage to infrastructure) that generate direct and indirect impacts on the economy, tourism, infrastructure, and food supply. More than 90 percent of annual soil erosion is generated in short periods of hours or days (Norville and King 2001). Soil erosion also degrades water quality by causing sedimentation in waterways.

The following factors also contribute to degradation of soil quality in Saint Lucia (Norville and King 2001):

- **Loss of nutrients or imbalances in the soil.** On lands with some degree of inclination, soil tends to lose nutrients by surface runoff, causing agricultural workers to over-feed nutrients.
- **Overfertilization.** Acidification of the soil by overfertilization, which causes pH to drop to values between 4.6 and 5.0.
- **Use of pesticides and herbicides.** The CEHI indicates that the use of pesticides does not affect degradation, however monitoring is needed to evaluate the impact.
- **Disposal of both human and natural waste**.
- **Waterlogging in flat areas**. Waterlogged soils pose problems for agricultural production.

Figure 3.2-5 Erosion



Source: Saint Lucia Department of Physical Planning, 2017

3.2.2 Field Survey Results

Agricultural production was observed in each of the three project areas. Potential sources of soil contamination that are associated with the observed land use include:

- Potential fertilization and acidification of the soil
- Potential application of pesticides and/or herbicides
- Potential disposal of waste

No soil contaminants or application of herbicides or pesticides was observed during the field investigation.

3.2.2.1 Belle Plaine

Belle Plaine is located in a wide, flat valley surrounded by steep mountains. Geologically, this area is characterized by pumice pyroclastic flow deposits. The soil is used for agricultural production, including bananas, cocoa, and coconuts. The area is also used for livestock grazing (cattle and goats). There are no structures associated with water management, but small agricultural shacks for the farm workers are located between the crop rows.

3.2.2.2 Fond St. Jacques

Fond St. Jacques is located in a small valley surrounded by steep mountains. The geology of the area is composed of block and ash flow deposits that possess a high permeability, through which several freshwater springs flow. It is evident that this area has extensive agricultural activity located on both flat and mountain slopes; crops include bananas, coconuts, and cocoa, among others. Some structures are associated with water management, as seen in Figure 3.1-6.

The area around and within the potential drilling area is a shallow, moist valley with scattered vegetation. Saturated soil conditions were observed during field investigation; however, the field investigation was conducted during the rainy season and it cannot be determined whether saturated soil conditions persist year-round due to the nearby spring, or if the saturated soils are a seasonal condition that was reflective of recent rains.

3.2.2.3 Mondesir-Saltibus

Mondesir-Saltibus (Parc Estate) is located on a plateau with water systems nearby. The geology of the area is composed of pyroclastic flows containing pumiceous and andesitic deposits. The outcrops of these units can be found along the road cuts on the eastern side of the main road adjacent to the area. Mondesir-Saltibus is widely used for growing bananas, cocoa, coconuts, and other vegetables, especially toward the hillsides. Some structures associated with water management, such as roadside drainage, were observed in the area.

3.2.3 Data Gaps

No data were available on soil contaminants in the project areas. Potential sources of soil contamination and methods to address any contaminated soils are addressed in Section 4. See Section 3.1.4 regarding field survey limitations due to inclement weather conditions.

3.3 AIR QUALITY

The following section contains results pertaining to TOR Task 1.11. The area of influence for the air quality analysis is areas within approximately 1 km (0.5 mile) of the drilling target areas because air emissions would dissipate over this distance.

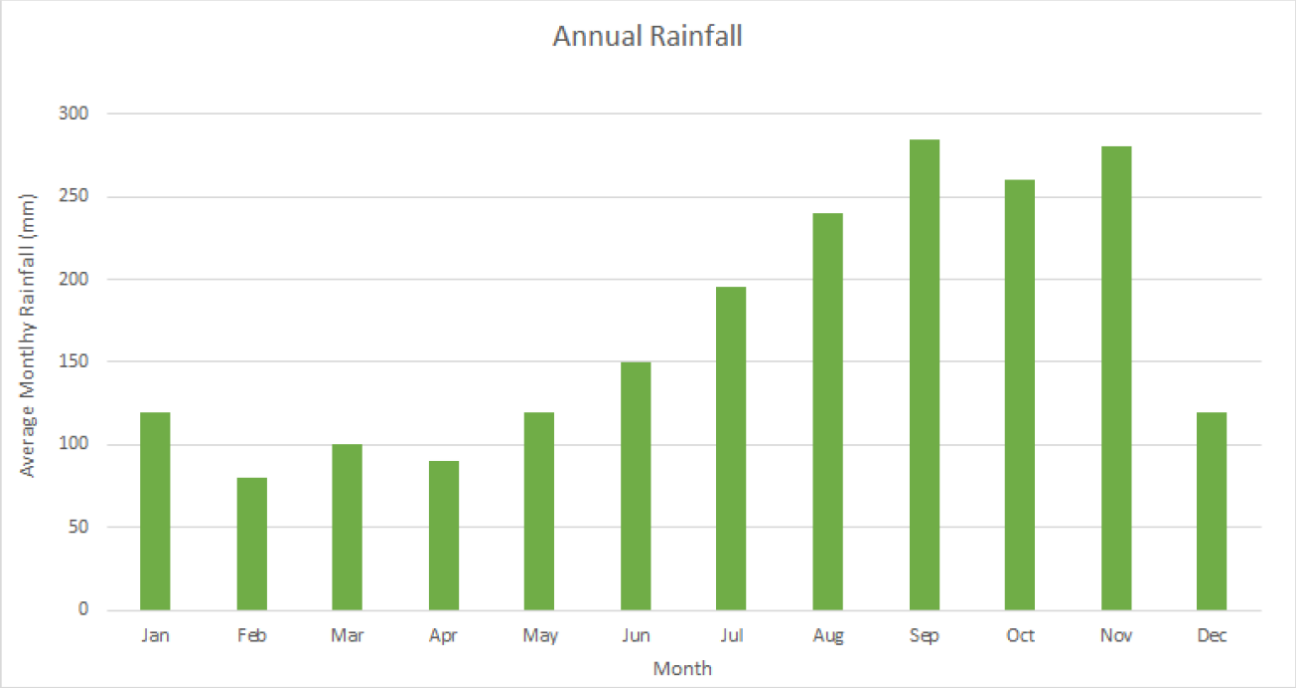
3.3.1 Literature Review Results

3.3.1.1 Precipitation

Saint Lucia's climate is tropical maritime. Most precipitation occurs during August and November; mean annual precipitation ranges from 1,500 mm (59.1 inches [in]) over the coastal areas to approximately 3,800 mm (149.6 in) in the interior of the Island (Caribbean Environmental Health Institute 2006). The average annual rainfall is shown in Figure 3.3-1. The drought seasons are between December and April. Saint Lucia is vulnerable to hurricanes, especially in late summer months.

The average daytime temperatures are between 26°C to 32°C, with an average relative humidity around 75 percent.

Figure 3.3-1 Annual Rainfall (Vieux Fort Town, Le Resource, La Retraite, La Tourney, Black Bay, Laborie, Savannes Bay, Augier, Grace, and Joyeux)



Source: Caribbean Environmental Health Institute - CEHI, 2006

3.3.1.2 Meteorological Conditions

Meteorological data from the Hewanorra International Airport for the period of March to December 2014 is presented in Table 3.3-1. This representative dataset shows that the rainy season occurs during the months of July to November. It should also be noted that hurricanes are active this season. The average temperature is 27°C, with a wind direction that runs approximately E-W, with relative humidity at approximately 77 percent.

Table 3.3-1 Meteorological Data March–December 2014 (Hewanorra International Airport)

Month	Wind direction (°s from true North)	Wind speed (knots)	Average temperature (°C)	Average rainfall (mm)	Relative humidity (%)	Average hours of sunshine
March	88.2	15.36	26.4	38.0	73	8.5
April	95.5	16.08	27.2	40.7	73	10.0
May	93.2	15.32	27.6	25.0	74	9.4
June	90.3	17.16	28.3	65.2	76	8.5
July	89.6	16.14	28.1	107.0	77	8.9
August	91.8	13.41	28.0	164.6	81	7.8
September	92.3	11.77	28.3	169.7	79	8.8
October	92.1	9.36	28.1	154.9	80	8.4
November	89.2	14.38	27.8	245.4	80	8.4
December	80.6	12.36	27.2	21.8	76	9.8

Source: (Joseph and Beckles 2015)

3.3.1.3 Air Quality Monitoring

The University of the West Indies completed a study of ambient sulfur dioxide (SO_2) concentrations within and around the Soufrière Volcanic Center to measure emissions from the geothermal hot springs and fumaroles (Joseph et al, 2015). Diffusion tubes were used to collect SO_2 samples at various sites in and around the Volcanic Center. Samples were collected from April to December 2014 to obtain results during different climatic conditions.

The results of the University of West Indies study indicated that "during the dry season period of April to July 2014 concentration at sites closest to the main vents at [the Volcanic Center], which are routinely used by staff and visitors, frequently exceeded the WHO 10-minute AQG for SO_2 of 500 $\mu g/m^3$. However, for sites that were more distal to the main venting area, the average monthly ambient SO_2 did not exceed the WHO 10-minute AQG for SO_2 of 500 $\mu g/m^3$ during the entire monitoring period. The measured concentrations and dispersion patterns of ambient SO_2 at [the Volcanic Center] appear to be influenced by rainfall, proximity to the fumarolic vents, altitude (local topography), local atmospheric circulation and plume dispersion, and anthropogenic sources."

The SO_2 concentrations at the Sulphur Springs site are not representative of the SO_2 concentrations in the project areas because the SO_2 from the springs is expected to disperse at the distance of the project areas. During the ESIA field study a set of NO_2, SO_2 and H_2S diffusion sampling tubes were installed at the same position as the site 6 samples taken during the University West Indies study to evaluate whether there is any relationship between air quality in the project area and air quality at Sulphur Springs. These results are presented in section 3.3.2 below.

3.3.2 Field Survey Results

The results of the SO_2, NO_2 and H_2S diffusion tube sampling over a 20-day period in the project vicinity are provided in Appendix A. The 20-day average concentration results indicate low ambient concentrations of NO_2, SO_2, and H_2S at all sites with the exception of Sulphur Springs. The 20-day average concentrations were well below the World Health Organization (WHO) Guidelines. WHO guidelines specify 10-minute maximum concentrations of 500 $\mu g/m^3$ for SO_2, a 1-hour average of 40 $\mu g/m^3$ for NO_2 and a 30-minute average of 7 $\mu g/m^3$ for H_2S.

The Sulphur Springs site was installed next to the main hot spring area within the Soufrière Volcanic Center. The results from the Sulphur Springs site showed significantly higher concentrations of SO_2 and H_2S. H_2S concentrations exceed WHO guidelines of 7 $\mu g/m^3$. It should be noted that the WHO guidelines are for annoyance, with potential eye irritation likely not caused until concentrations reach 150 $\mu g/m^3$ or above. A 20-day SO_2 average concentration of 292 $\mu g/m^3$ was measured at the Sulphur Springs site. This average SO_2 concentration was below WHO guidelines and in line with concentrations measured during the University of West Indies Study, which showed monthly average concentrations ranging from 177 to 623 $\mu g/m^3$ between April and December 2014. The higher concentrations measured at this site should be excluded when evaluating baseline conditions for proposed drilling sites because they are not representative of ambient conditions away from the hot spring area and closer to population centers.

3.3.3 Data Gaps

Ambient air quality monitoring was conducted over a three-week period during the rainy season. Sample tubes at 3 of the 15 sampling locations (Fond St. Jacques, Castries base station and the Soufrière Fire Station) were affected by vandalism or lost due to storms; these data are therefore unavailable for analysis; however, data from other locations were consistent and it is expected that air quality at these stations would be similar to locations other than Sulphur Springs. The air quality data also represent a snap-shot in time and the data could be somewhat affected by seasonal weather conditions such as tropical storms during the monitoring period.

Fine particulate matter <10 microns (PM_{10}) data were not be collected at the time of field survey because PM_{10} cannot be collected with diffusion tubes and rain conditions would have affected the results. PM_{10} measurements should be collected during the dry season when the agricultural fields could generate dust emissions Recommendations regarding future air quality monitoring are provided in Section 4.3.2.

3.4 NOISE

The following section contains results pertaining to TOR Task 1.10. The noise area of influence includes areas within 1 km (0.5 mile) of the drilling sites because drilling noise would attenuate over this distance.

3.4.1 Literature Review Results

Noise monitoring took place during drilling of SL-1 and SL-2 geothermal exploration wells with dosimeter readings around the pumping stations on a regular basis to create iso-decibel maps (Associates in Rural Development - Dulin and Hannah, 1988). Infrastructure and drilling operations were heard within a 1 km (0.5 mile) radius of the drilling sites based on resident surveys (Associates in Rural Development - Dulin and Hannah, 1988). Mufflers were recommended, but not used during operations, resulting in high noise levels during drilling (Associates in Rural Development - Dulin and Hannah, 1988).

3.4.2 Field Survey Results

Noise levels measured in the project area of influence are provided in Table 3.4-1. The highest maximum peak noise level (119.5 dBA) was recorded at NS8-A. The high peak noise level was caused by a passing dump truck approximately 20 meters (65.6 ft) from the data logger. The lowest noise level (30.0 dBA) was measured in the Belle Plaine area near the local generator when the generator was not running.

The noise data was generally consistent during the monitoring period with the exception of intermittent interruptions such as traffic, children, wildlife, livestock, and light rainfall. The weather conditions did not substantially affect the noise monitoring results because noise monitoring was not conducted during periods of heavy rain or high winds. Peak noise measurements and causes for the peak measures are noted in this section as well as on the graphs found in Appendix B - Noise Monitoring.

The noise levels documented in the project area of influence are consistent with a rural environmental where the noise sources are predominantly natural (e.g., wind, water, wildlife, and farm animals). Other noise sources included mobile (e.g., traffic) and stationary sources encountered along roadways.

Table 3.4-2 provides the extreme high and low noise levels measured within each area of influence during daytime noise surveys. Noise levels at night are lower than during the daytime due to reduced vehicle activity.

Table 3.4-1 Noise Monitoring Results

Date	Site	Time Start (HH:MM:SS)	Time End (HH:MM:SS)	Min (dBA)	Max (dBA)	Average (dBA)	Mean (dBA)	Std. Dev.
5-Sep-17	NS1	10:40:58	10:56:06	38.1	58.5	44.9	44.9	2.0
5-Sep-17	NS2	11:18:30	11:34:02	43.5	91.2	63.7	63.4	5.9
5-Sep-17	NS3	11:49:08	12:04:58	30.0	81.1	48.4	48.1	5.2
5-Sep-17	NS4	12:29:09	12:44:29	32.9	67.0	44.5	44.3	4.7
5-Sep-17	NS5	13:03:25	13:19:03	44.7	80.1	55.6	55.3	5.7
5-Sep-17	NS6	15:12:19	15:27:31	42.7	85.3	58.4	58.1	5.7
5-Sep-17	NS7	15:52:09	16:07:35	43.1	84.5	52.9	52.7	4.1
5-Sep-17	NS8	16:43:57	16:59:03	46.0	109.3	59.6	59.2	7.1
5-Sep-17	NS9	17:50:42	18:06:06	58.5	90.7	63.1	62.9	4.3
6-Sep-17	NS10	11:25:43	11:44:21	41.2	79.1	52.0	51.9	3.4
6-Sep-17	NS11	12:27:01	12:45:57	37.1	86.0	48.3	48.2	4.1
6-Sep-17	NS12	13:36:13	13:50:59	36.0	85.0	48.2	48.1	3.7
6-Sep-17	NS13	14:20:27	14:35:45	32.0	85.0	52.1	51.5	8.2
7-Sep-17	NS8-A	10:22:57	10:39:59	30.9	119.5	49.9	49.1	9.9
7-Sep-17	NS7-A	11:05:56	11:22:20	30.2	69.7	42.6	42.4	4.3
7-Sep-17	NS1-A	14:22:12	14:42:40	32.4	68.8	46.6	46.3	5.2
7-Sep-17	NS2-A	14:59:42	15:16:10	41.0	104.7	70.7	70.3	7.2
7-Sep-17	NS3-A	15:28:35	15:44:27	51.0	88.0	60.2	60.2	1.6
7-Sep-17	NS4-A	15:56:20	16:13:28	30.8	71.8	46.3	46.1	4.7

Notes:

dBA = A-weighted decibel scale.

Sampling times are GMT-4. Sites followed by "-A" are repeat measurements at the same location. GPS measurements taken on site with Trimble GEOXH Serial #5138477832

Table 3.4-2 Extreme Noise Levels by Project Area

Area of Impact	Noisiest/ Quietest	Site	Ambient Avg. (dBA)	High (dBA)	Low (dBA)
Belle Plaine	Noisiest	NS3-A	60.2	88.0	51.0
Belle Plaine	Quietest	NS3	44.5	64.7	30.0
Fond St. Jacques	Noisiest	NS2-A	70.7	104.7	41.0
Fond St. Jacques	Quietest	NS1	44.9	46.0	38.1
Mondesir-Saltibus	Noisiest	NS8	59.6	119.5	46.0
Mondesir-Saltibus	Quietest	NS8	42.6	65.0	30.2

The high noise levels shown above are attributed to the following factors:

- **NS2-A**. The high noise level was measured in the courtyard of the Fond St. Jacques primary school at the end of the school day at approximately 3:00 PM when children were present and yelling and interacting a short distance from the microphone equipment.
- **NS3-A.** The high noise measurement at Belle Plaine was recorded within 20 meters of a running diesel engine flatbed 4-axle truck that was idling throughout the duration of the noise measurement.
- **NS8.** A Large diesel engine truck on the main road near the noise monitoring station passed by during the recording.

3.4.3 Data Gaps

Noise monitoring was conducted during daylight hours exclusively. Night time transportation was not available and night time field work was not advisable due to security reasons. During the data acquisition, rain was noted within the noise data and may have had a minor effect on the recorded ambient noise levels.

3.5 BIOLOGICAL RESOURCES

The following section contains results pertaining to TOR Task: 1.12, 1.13. and 1.14. The area of influence includes the drilling sites and a 300-meter (1,000-foot) buffer for consideration of potential noise effects on birds. Biological surveys were not conducted within MS-3 or MS-4; recommendations for future surveys of these areas are provided in Section 4.5, below.

3.5.1 Literature Review Results

Numerous biological resource investigations have been conducted for the PMA, which is located to the west of the Belle Plaine and Fond St. Jacques areas. The steep slopes of both Pitons and Piton Mitan are home to a rich and unique flora. Gros Piton is one of the few areas left in the Caribbean where native dry and moist forest remains more or less unmodified. Roger Graveson has recorded 254 indigenous flowering plant species on the Pitons (this excludes common weedy herbaceous plants and plants only found on the flatter areas between and

around The Pitons and alien plant species) including three Saint Lucian endemic, twenty-two Lesser Antillean endemics and thirty-five Caribbean endemics. Forty-six plant species are only found in the PMA. Many species are extremely rare throughout their Caribbean range. Two new indigenous tree species were discovered during surveys of the PMA by Melvin Smith, *Crateva tapia* and *Erythroxylum oxycarpum*. Two endangered species, *Tradescantia zebrina* and *Callisia fragrans*, recently established in the PMA and threaten the biological diversity of the PMA. The PMA is listed as an Important Bird Area and is recognized for its diversity of avian species (Tha Landmark Practice 2013).

3.5.2 Field Survey Results

Flora and fauna species observed within the project area of influence are listed in Appendix E – Flora and Fauna Species Observations and Photographs, Tables E-1 through E-8. Photos of each project area and the surrounding habitat are also provided in Appendix E.

3.5.2.1 Vegetation Communities/Habitat Characteristics

The dominant land use/vegetation types in each drilling area are shown on Figures 3.5-1 through 3.5-3. The dominant vegetation types and habitat characteristics of each project area are summarized in Table 3.5-1, below. The drilling areas were characterized by a lack of native habitats or vegetation communities. Belle Plaine, Fond St. Jacques East, and the Mondesir-Saltibus areas are subject to widespread agricultural production. The Fond St. Jacques West area has been developed/disturbed and generally lacks vegetation or habitat. Native forest habitat occurs along the border of the Belle Plaine and Mondesir-Saltibus project areas.

3.5.2.2 Fauna

Table 3.5-2 provides a summary of the common faunal species documented in each project area and surrounding area of influence (i.e., habitat areas within approximately 300 meters [1,000 feet] of the potential drilling sites). The drilling areas were characterized by a lack of native habitats. Belle Plaine, Fond St. Jacques East and West, and MS-2 were very similar in composition of faunal community with many of the same bird, mammalian, herpetofauna, and insect species due to similar habitat conditions within and surrounding the drilling areas. The drilling areas were characterized by a lack of suitable habitat; however, the surrounding forested edge provides natural habitat for bird species.

Figure 3.5-1 Belle Plaine Habitat/Land Use

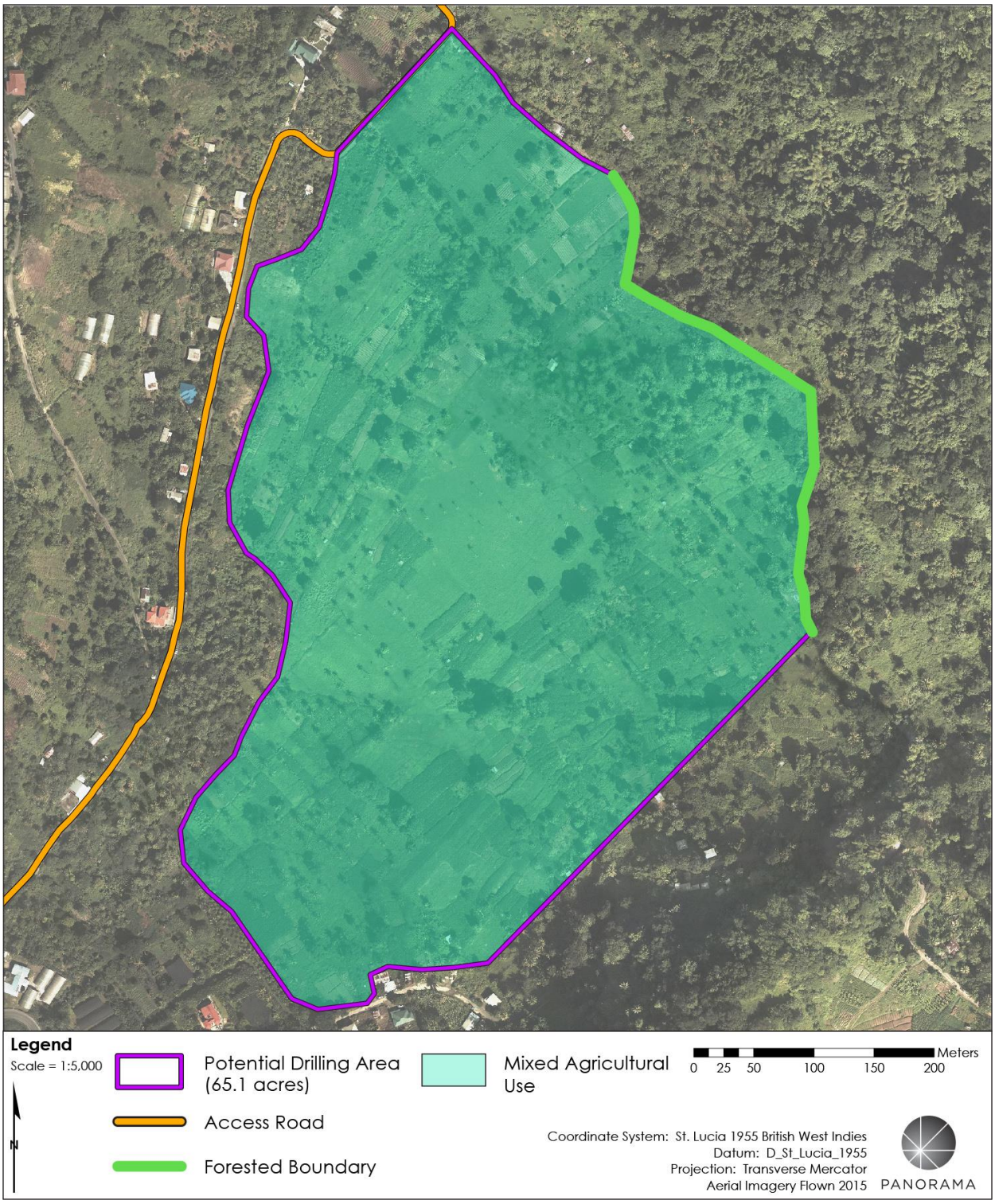


Figure 3.5-2 Fond St. Jacques Habitat/Land Use

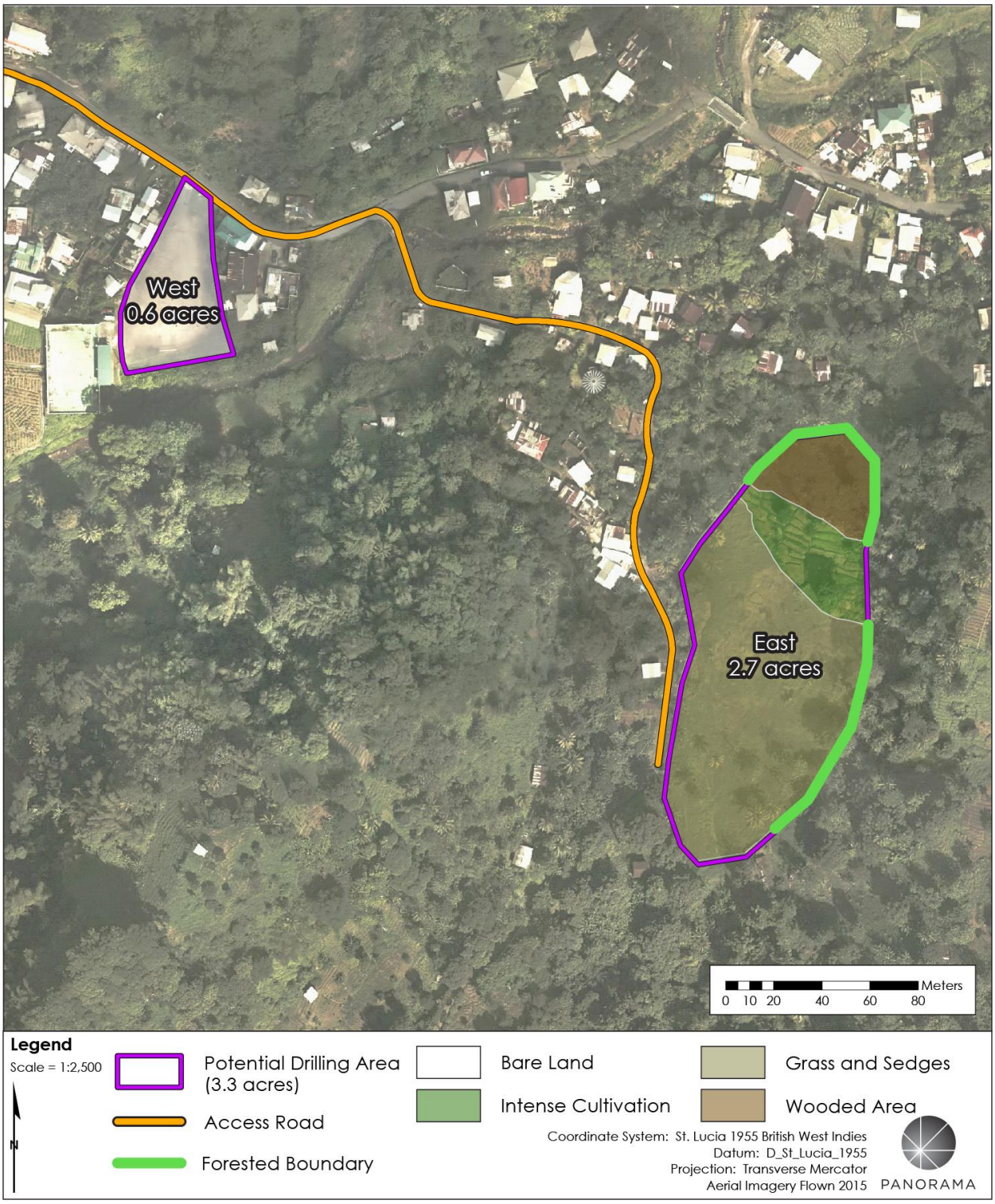


Figure 3.5-3 MS-1 and MS-2 Habitat/Land Use

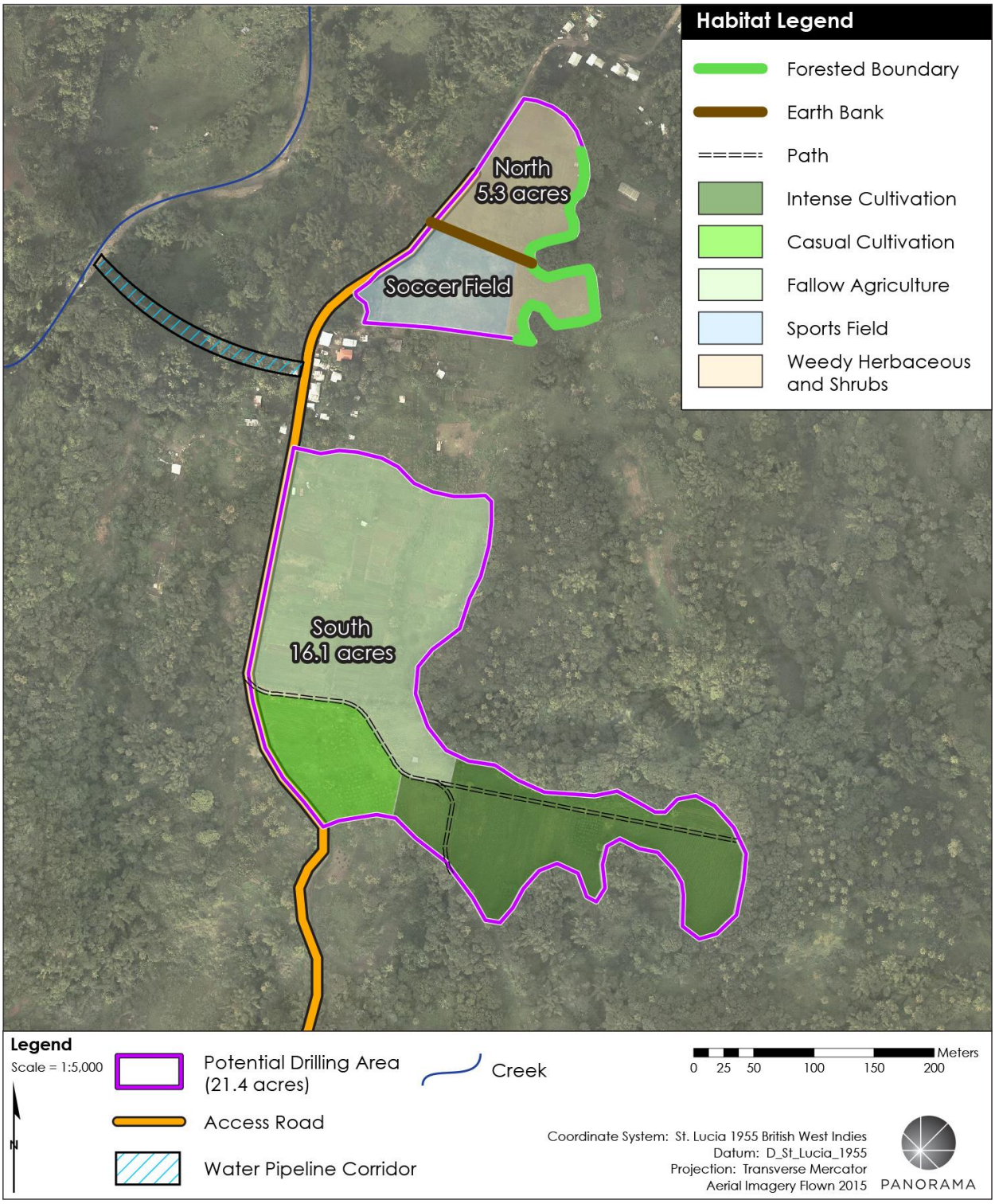


Table 3.5-1 Habitat and Dominant Floristic Species by Area

Area Name	Description of Vegetation/Habitat Conditions	Dominant Vegetation
Belle Plaine	The Belle Plaine area has been cleared of all natural forest and replaced by agriculture. The area was previously intensively farmed with bananas and is now largely abandoned with open herbaceous areas punctuated by remnant *Musa* cultivars (bananas and plantains) and mature fruit trees. Small plots with a market gardening type of agriculture are located in small areas. Cows graze on the site and several substantial wall houses are under construction in the area. The area is bordered on the western side by a steep forested hill	The area is covered predominantly by weedy flora of grasses, herbs and shrubs. The majority are native species, but many are naturalized species. Widely spaced throughout the open areas are cultivated fruit trees including *Erythrina poeppigiana,* Gmelina and pines, and mahogany. There are also many clumps of Musa cultivars (bananas and plantains). A few ornamental trees occur on the site including Ficus bejamina, Bougainvillea, Saman trees and *Heliconia wagneriana* which have become naturalized.
Fond St. Jacques West	Fond St. Jacques west is a small cleared site with a river on the lower end of the site. There is almost no vegetation on the site.	The area is developed/disturbed and generally lacks vegetative cover.
Fond St. Jacques East	The Fond St. Jacques east area is very swampy and most of the site is saturated. The area is covered by an herbaceous flora of mainly grasses and sedges, with some weedy shrubs and scattered fruit trees. The area is bordered by some large trees except where it forms a boundary with the road. There are patches of cultivated dasheen (*Colocasia esculenta*), a crop that thrives in swampy conditions. Crows graze in the area.	The area is dominated by the grass *Paspalum paniculatum* and large areas covered by the sedge *Fuirena umbellata.*
MS-2	The MS-2 area is a formerly intensive agricultural area that is now limited to sparse cultivation. There are many common weedy herbs and shrubs found on the site.	The area is dominated by herbs and shrubs including *Andropogon bicornis, Urena lobata* and *Ipomoea tiliacea* along with grasses such as *Andropogon bicornis, Cenchrus purpureus, Chloris ciliata* and *Eragrostis pilos.* Additional cultivated vegetables and fruit trees are present.
MS-1	The MS-1 area is a formerly intensive agricultural area that is now limited to sparse cultivation. There are many common weedy herbs and shrubs found on the site.	The area is dominated by herbs and shrubs including *Andropogon bicornis, Urena lobata* and *Ipomoea tiliacea* along with grasses such as *Andropogon bicornis, Cenchrus purpureus, Chloris ciliata* and *Eragrostis pilos.* Additional cultivated vegetables and fruit trees are present.

Table 3.5-2 Faunal Species and Conditions in the Area of Influence

Area Name	Birds	Mammals	Herpetofauna	Insects
Belle Plaine	A total of 36 species were detected in the Belle Plaine area and surroundings. The majority of the detected species are resident species, with the exception of two, the Sand spotted sandpiper and the barn swallow. Five endemic birds occurred in the area; two of the Saint Lucian endemics were uncommon for the site. Nine priority species were found occurring in the forested area adjacent to the site, four of which are classified as endangered species of birds. The priority species observed include: • Saint Lucia Parrot (*Amazona versicolor*) • Saint Lucia Black finch (*Melanospiza richardsoni*) • Saint Lucia Oriole (*Icterus laudabilis*) • House Wren (*Troglodytes aedon mesoleucus*) • Saint Lucia Warbler (*Dendroica delicata*) • Saint Lucia Pewee (*Contopus oberi*) • Lesser Antillean Saltator (*Saltator albicollis albicollis*) • Lesser Antillean Flycatcher (*Myiarchus oberi sanctaeluciae*)	Mongoose (*Herpestes suropuntatus*) was recorded in the area. Mongoose was introduced to Saint Lucia and is classified as invasive wildlife. Two species of bats were observed in the study area including: • Fruit bats (*Monophyllusplethodon* • Insectivorous bats (*Bracyphylluscavernum* These species are not considered endangered.	Five reptile species were recorded in the study area, including the endemic Saint Lucia anolis lizard (*Anolis luciae*). Other reptiles included: • Common house gecko (*Hemidactylus mabouia*) • Slipperyback skink, known as Zandoli tarre (*Gymnopthalmus pleei*)	Butterflies, dragonflies, and bees were common insects observed in the study area. Common butterfly species included: • Southern great white • White peacock • Common long tail skipper • Tropical chequered skipper • Ocola skipper • Fiery skipper • False barred sulphur • Spreadwing skipper • Caribbean buckeye • Southern broken dash • Hannos blues

Area Name	Birds	Mammals	Herpetofauna	Insects
	• Grey trembler (*Cinclocerthia gutturalis macrorhyncha*)			
Fond St. Jacques West	There were very few faunal species on the Fond St. Jacques West site due to the lack of vegetation to provide habitats for these species. Bird species encountered included: • Carib grackle • Lesser Antillean bull finch • Common ground dove • Zenaida dove These species are very common on the island and are adapted to open areas.	None	None	None
Fond St. Jacques East	A total of 29 bird species were detected in the Fond St. Jacques east area. The majority of the detected bird species are resident species. Five Saint Lucia endemic species were observed during surveys. Three priority species were observed including: • Saint Lucia parrot (*Amazona versicolor*) • Saint Lucia black finch (*Manospiza richardsoni*) • Saint Lucia oriole (*Icterus laudabilis*)	Seven mammal species were recorded in the study area. These include, the small asian mongoose (*Herpestesou ropuntatus*) the opossum (*Didelphis marsupialis*), rats, and mice. All species are introduced to Saint Lucia and are classified as alien invasive wildlife. Two species of bats, a fruit bat (*Monophyllus plethodon*) and an insectivorous bat (*Bracyphyllus cavernum*) were found in this study area. These species are not considered endangered.	Three reptile species were recorded in the study area including • Saint Lucia anolis lizard (*Anolis luciae*) • Common house gecko (*Hemidactylus mabouia*) • Slipperyback skink, known as Zandoli tarre (*Gymnopthalmus pleei*) One amphibian, the cane toad (*Rhinella marina)* was encountered in the study area. The habitat is ideal for this species, which is considered an invasive species.	Butterflies, dragonflies, and bees were the most common insects observed in the study area. Dragonfly species were the most common insect group. The presence of a wet surface provides ideal habitat for the majority of dragonfy species.
MS-2	A total of 15 bird species, which include two priority species,the	None	None	An abundance of butterflies was found on this

Area Name	Birds	Mammals	Herpetofauna	Insects
	Saint Lucia warbler and Lesser Antillean saltator, were observed in the MS-2 study area. The Saint Lucia warbler (*dendroica delicata*), is classified as endemic to Saint Lucia, but is considered of *Least Concern* in accordance with the IUCN Red List Category & Criteria (2016).			study site, belonging to eight (8) species, none of which found are known to be endangered or of concern. The common species include: • Southern great white • Caribbean buckeye • White peacock • Common long tail skipper • Tropical chequered skipper • Fiery skipper • False barred sulphur • Southern broken dash
MS-1	A total of 20 species of birds were recorded in the MS-1 study area. The bird species encountered were very similar to Belle Plaine and Fond Saint Jacques East, owing to the similar biodiversity and rich ecotone in the forest edge surrounding the potential drilling sites, which provide an ideal habitat. Four of these species are classified as priority species, two of which are Saint Lucia endemic species: Saint Lucia pewee (*Contopus oberi*) and Saint Lucia warbler. Both Saint Lucian endemics were common for the site, which is consistent at the national level.	None	Three reptile species were recorded in the study area, including: • Saint Lucia anolis lizard (*Anolis luciae*) • Common House Gecko (*Hemidactylus mabouia*) • Slipperyback Skink, known as Zandoli tarre (*Gymnopthalmus pleei*)	Very few insects were observed and none were identified to a species level.

3.5.2.3 Endangered and Priority Species

No endangered or priority floristic, mammalian, herpetofauna, or insect species were encountered during surveys of the project areas and adjacent area of influence. Several endangered and priority birds were encountered in the forest habitat adjacent to Belle Plaine and Mondesir-Saltibus. Description of each species status and presence in the project area of influence are provided in Table 3.5-3. These species are also among the suite of sixteen "priority bird species" listed in the 2009 Status and Conservation of Saint Lucia Birds (Toussaint et al. 2009).

Table 3.5-3 Endemic and IUCN Listed Birds

Species Name	Endangered or Priority Status	Threats	Status in Project Area
Saint Lucia Parrot *Amazona versicolor*	Vulnerable, according to the IUCN Red List Category & Criteria Priority Listed in Saint Lucia	Major threats to the parrot includes urban sprawl and agriculture, increasing pressure on the forest and resulting in habitat loss. Selective logging of mature trees may significantly reduce breeding sites (Juniper and Parr 1998), and hurricanes, hunting and trade pose further threats.	The Saint Lucia parrot was encountered in two of five study areas, Belle Plaine and in Fond Saint Jacques East. Birds were heard and seen flying in small groups and as single individuals. No evidence of individual nesting or roosting was observed. There was only one case of a perched pair of birds near the Fond Saint Jacques East area. It appears that the adjacent forested areas and the ecotones provide very important foraging habitat.
Saint Lucia Oriole	Near Threatened, according to the IUCN Red List Category & Criteria Priority Listed in Saint Lucia	The Saint Lucia Oriole is susceptible to brood parasitism by the shiny cowbird (*Molothrus bonariensis minimus*, a species found in both sites where the Oriole occurs, which are predominantly in cleared areas and hence likely to increase with increasing human impacts on the landscape (Keith 1997). Keith (1997) also mentions the possibility of harassment by the bare-eyed thrush (*Turdus nudigenis nudigenis*), sighted at both sites mentioned. Secondly, it has been speculated that the oriole may also be susceptible to secondary poisoning from agrichemicals.	A total of five oriole were found across study sites at the edge of agriculture areas at Bell Plaine and Fond Saint Jacques East. The general habitat at these two sites appears to be very favorable for the oriole, due to the prevalence of abandoned agricultural plantations.
Saint Lucia black finch	Endangered, according to IUCN Red List	The decline in habitat through clearance for agriculture, urban and tourism	The Saint Lucia black finch were found in two of the five study areas, Belle Plaine and Fond St

Species Name	Endangered or Priority Status	Threats	Status in Project Area
	Category & Criteria Priority Listed in Saint Lucia	development can impact its range. This species has a broad habitat range. However, the total population level remains extremely low.	Jacques east. The black finch was encountered only four times in two study areas.
Saint Lucia wren	Least Concern, according to IUCN Red List Category & Criteria Priority Listed in Saint Lucia	While common in the Americas, the Saint Lucia population is very small with birds rarely seen and with extremely limited range. Threatened by habitat lost, wildfires, predation by alien invasive species including by mongoose and brood parasitism by the shiny cowbird.	The Saint Lucia wren was encountered in one of the five study areas, Belle Plaine.
Saint Lucian warbler	Least Concern, according to IUCN Red List Category & Criteria Priority Listed in Saint Lucia	Habitat modification may threaten populations due to limited habitat range within riparian areas.	The Saint Lucia warbler was found in four of the five study areas. It was more common in the forest habitat of Belle Plaine and Fond Saint Jacques East and less common in the agricultural area in the Mondesir-Saltibus area
Lesser Antillean saltator	Least Concern, according to IUCN Red List Category & Criteria Priority Listed in Saint Lucia	No known threats	The lesser Antillean saltator occurred in four of the five study areas, absent only in Fond St Jacques West.
Gray trembler	Least Concern, according to IUCN Red List Category & Criteria Priority Listed in Saint Lucia	Highly endemic species limited to Saint Lucia and Martinique. Population is currently stable.	Grey trembler occurs in three of the five study areas. They were encountered around forests edges, woodlands, scrubs and agricultural areas.
Saint Lucia pewee	Least Concern, according to IUCN Red List Category & Criteria Priority Listed in Saint Lucia	No known threats	The Saint Lucia pewee was encountered in three of the five study areas: Belle Plaine, Fond Saint Jacques East and MS-1.

3.5.3 Data Gaps

The biological resources survey was conducted over a one-week period in early September in between a period of tropical storms. The results of the fauna survey may be affected by seasonal use of the project sites and surrounding forested buffer. Other wildlife species may use the site seasonally. Recommendations for pre-construction surveys are provided in Section 4.

3.6 ARCHEOLOGICAL AND CULTURAL RESOURCES

The following section contains results pertaining to TOR Task: 1.15, 1.16, and 1.17. The area of influence includes all areas that may involve grading or soil disturbance during exploration activities.

3.6.1 Literature Review and Consultation Results

There is a long tradition of archaeological research in Saint Lucia beginning in the mid-twentieth century. Among the more renowned Caribbean archaeologists to conduct investigations in Saint Lucia was (McKusick 1960), whose research in the 1950s identified distinct Amerindian pottery traditions on the island, which helped refine Irving Rouse's (Rouse 1992) elaborate cultural sequencing for the broader Caribbean region.

In the 1970s, Ripley Bullen, Adelaide Bullen, and Eric Branford conducted extensive archaeological investigations at the Giraudy site in the quarter of Vieux Fort, which shed new light on the settlement patterns and subsistence strategies of the Amerindians peoples of Saint Lucia dating back to the earliest Saladoid occupations around A.D. 150 (Bullen 1973).

In the 1980s, a group of Austrian archaeologists from the University of Vienna conducted a series of archaeological surveys in southern Saint Lucia, which added new insights into the cultural practices of indigenous peoples of the island (Friesinger 1986).

Perhaps the most extensive and detailed archaeological analysis of Saint Lucia's archaeological assets was conducted in the early 2000s by an international group of Caribbean archaeologists from Holland and the United States, including Corrine L. Hofman, Menno L.P. Hoogland, and William F. Keegan (Hofman, Hoogland and Keegan 2004). Working with local members of the Saint Lucia Archaeological and Historical Society, the international team identified and inventoried numerous archaeological sites, conducted extensive tests on known sites, and recorded ethnographic and ethnohistorical information that supported archaeological findings and interpretations (Hofman and Bright 2004, Hofman, Hoogland and Keegan 2004, W. C. Keegan 2003, Keegan, Hofman and Hoogland 2004).

The archaeological studies conducted by these professionally trained researchers have been augmented by the important contributions of self-trained experts and avocational archaeologists from Saint Lucia, including Reverend Charles Jesse (Jesse 1968), a founding member of the Saint Lucia Archaeological and Historical Society, who published the first systematic inventory of Amerindian archaeological sites in the island in 1960. Other Saint Lucians, such as Robert Devaux and Winston Phulgence, are among the aficionados and

collectors who have helped save archaeological sites and materials from destruction by development. Moreover, Archaeological Secretary Laurent Jean Pierre and First Vice President Francis Pappin of the Saint Lucia Archaeological and Historical Society, as well as Bishnu Tulsie, Director of the Saint Lucia National Trust have done much to raise local awareness of Saint Lucia's archaeological resources. Despite the pioneering and insightful research of these notable Caribbean scholars and resident collectors, Saint Lucia has not received the same level of archaeological attention as other parts of the Caribbean, especially the nearby Windward Islands of Barbados and Martinique, where ongoing archaeological research programs have been regularly pursued for many decades. Moreover, the archaeological studies in Saint Lucia have focused exclusively on prehistoric archaeological sites.

Archaeological Secretary Laurent Jean Pierre and First Vice President Francis Pappin of the Saint Lucia Archaeological and Historical Society highlighted the challenges of protecting heritage resources and developing ongoing archaeological research programs. I met with Margo Thomas, the Director of the Saint Lucia Archives, who has published extensively on heritage issues in the island. She noted the absence of resources for heritage assessments, but was pleased to see a growing appreciation for heritage assets in Saint Lucia. Bishnu Tulsie, the Director of the Saint Lucia National Trust discussed the need for greater structure and government support for heritage protection. I also met with members of the Ministry of Education, including Deputy Permanent Secretary Michelle Charles, about heritage education initiatives and the potential for developing long term heritage education efforts in Saint Lucia. These discussions provided important insights into the challenges and opportunities that may result from the geothermal project.

3.6.2 Field Survey Results

The archaeological and cultural resource investigation field survey results are described by drilling target area below. Areas within Belle Plaine and MS-1 and MS-2 with a higher sensitivity and density of historic resources are shown on Figure 3.6-1 and Figure 3.6-2. Recommendations for archaeological monitoring and survey within sensitive areas and MS-3 and MS-4 are provided in Section 4.6, below.

3.6.2.1 Belle Plaine

Historic Resources

Ceramics

The pedestrian survey of Belle Plaine revealed a sizeable amount of early colonial ceramics. These included a piece of late seventeenth- or early eighteenth-century English tin-enamel glazed earthenware (delft), as well as what appears to be a piece of seventeenth century French tin-enamel glazed earthenware (faience). The site also contained a large number of English refined earthenware ceramics dating from the last quarter of the eighteenth century to the mid-nineteenth century. Among the refined earthenware ceramics were creamware and numerous shards of blue and green shell-edge pearlware. There was a paucity of imported and locally made low-fired unglazed coarse red earthenware ceramics, which are frequently found in plantation settings.

Figure 3.6-1 Belle Plaine Historically Sensitive Areas

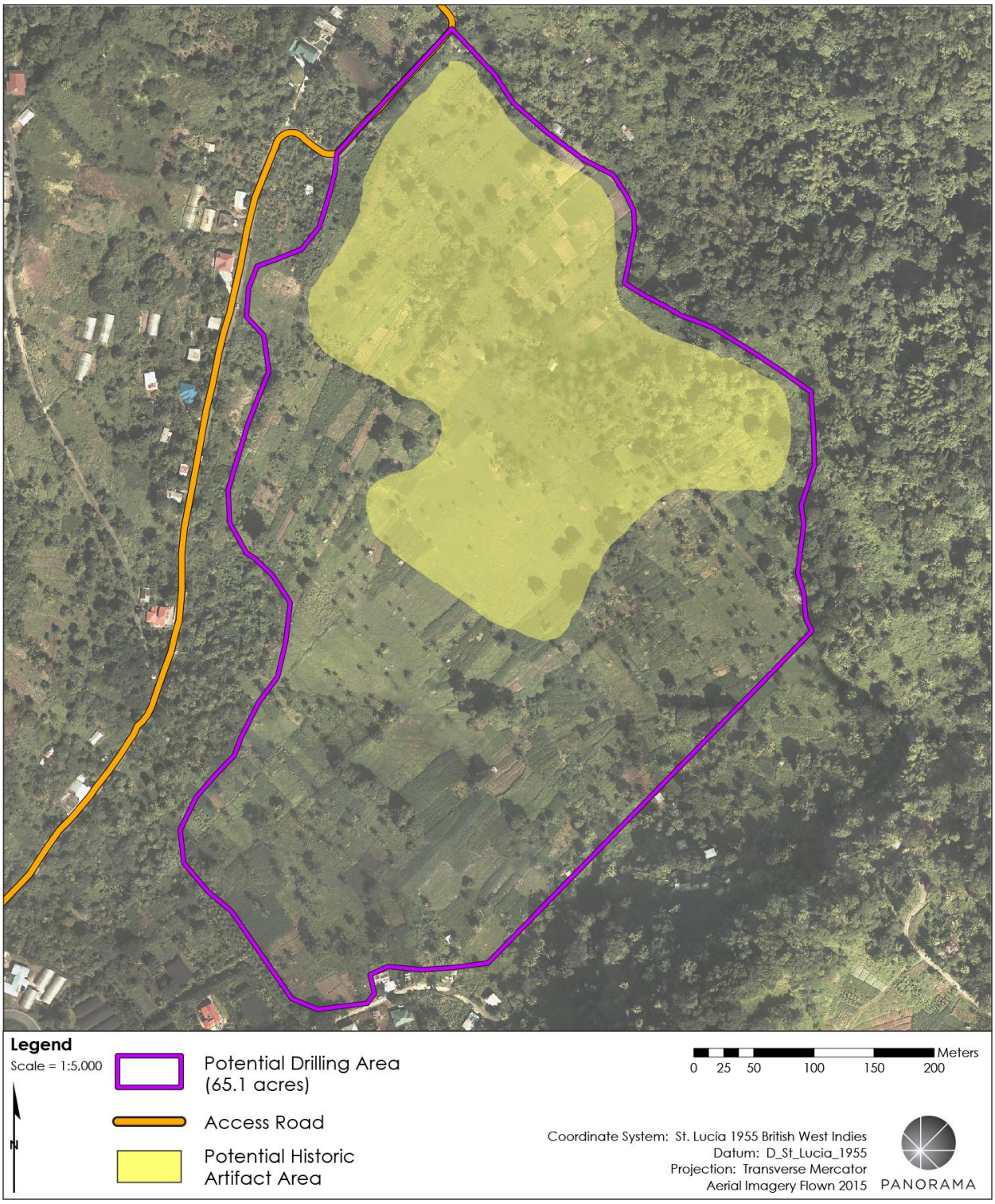
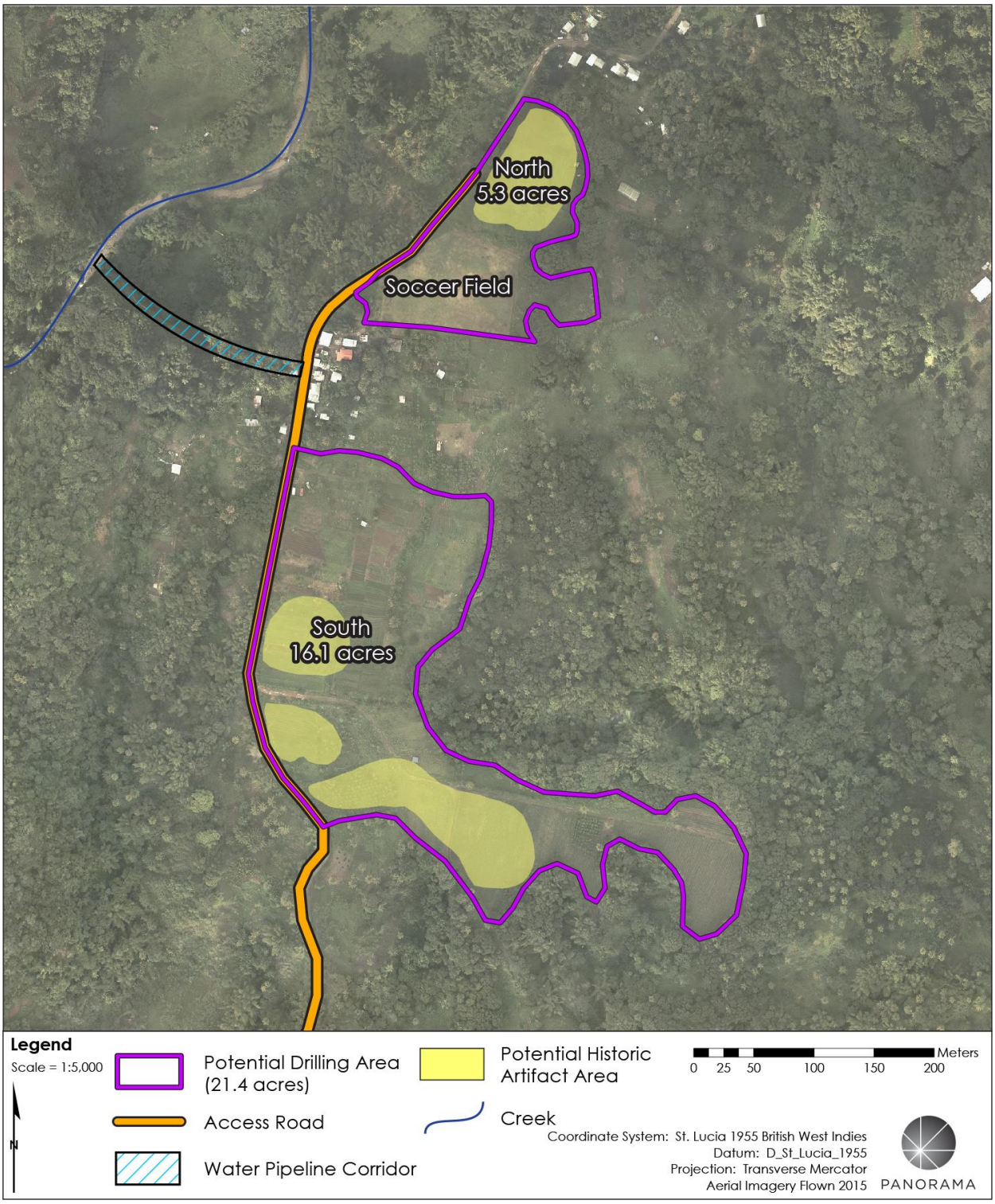


Figure 3.6-2 MS-1 and MS-2 Historically Sensitive Areas



The sizeable amount of refined ceramic types indicates an extensive amount of domestic activity at the site in the eighteenth through the mid-nineteenth centuries. The almost complete absence of either imported or locally made coarse red earthenware ceramics at the site may be an indication of the relative wealth of the inhabitants. Coarse red earthenware pottery is often found in association with industrial practices, such as a sugar making, or the domestic sites of enslaved peoples. The near absence of coarse red earthenware ceramics and the heavy presence of refined earthenware at Belle Plaine, therefore, suggest that individuals who deposited the materials were of a relatively wealthy socio-economic standing, such as a planter and his family.

Rabot Estate

The potential drilling area at Belle Plaine is located on or near the locations of two early plantations, Rabot Estate and Belle Plaine Estate. In 1795, British military forces, along with French Royalist planters in Saint Lucia, attempted to oust the French Republican-inspired "brigands" from their strongholds in Choiseul and Soufrière. The brigands were a company of former slaves, freed people of color, and French republican soldiers whose aim was to institute French Republican ideals of liberté, égalité, fraternité in Saint Lucia. They were known as the L'Armée Française dans les Bois, but they were more commonly called "brigands." In April of 1795, British and French Royalist forces attempted to destroy L'Armée Française dans les Bois. The brigands lay in wait for the British and French Republican forces in Belle Plaine. The conflict that ensued that April was known as the Battle of Rabot, and it was a major brigand victory that served as a symbol of brigand resilience and a rallying cry of against British colonial rule. The victory would sustain the spirits of brigand forces for many years. Local farmers called the large and well-maintained stone structure near the potential drilling site "Rabot," and it may have been the location of Rabot Estate's great house (the home of the planter and his family) during the early colonial period. Rabot remained a productive estate well into the nineteenth century. At the time of slave emancipation in 1834, Rabot was a sugar-producing estate owned by Colonne Doufsard. It had around 46 enslaved workers on the estate and the factory had a watermill. It remained a sugar-producing estate well into the nineteenth century. In the 1890s, however, the estate was abandoned when global overproduction of sugar, especially European beet sugar, glutted world markets and led to a sharp decline in sugar prices.

Belle Plaine Estate

Belle Plaine Estate was a coffee estate owned by Antoine Taurin Bernard Drivon in the 1820s and 1830s. The number of enslaved peoples on the estate ranged from between 65 and 102. In the later nineteenth century, Belle Plaine was also a sugar estate producing about 50 hogsheads of semi-refined muscavado sugar annually in its cattle-driven mill. However, as with the nearby Rabot Estate, Belle Plaine fell victim to declining sugar prices and it was abandoned by 1896 (Hamsen, Ellis and Devaux 2014).

The refined historic-period ceramic materials recovered during the pedestrian survey at Belle Plaine are likely from the planter's family in the great house, a manager's dwelling, or some

other domestic high-status residence or outbuilding associated with Rabot Estate and/or Belle Plaine Estate.

Prehistoric Resources
A few sherds of Amerindian pottery were recovered at the Belle Plaine site. Most of these were small undiagnostic pieces. One relatively thick, flanged bowl rim fragment with a deep incised design was recovered at the site. Another ceramic sherd recovered at Belle Plaine was a finger notched bowl rim. These were thick, unpolished pieces that are most likely associated with the Suazan Troumassoid phase of Amerindian settlement dating to between A.D. 750 and A.D. 1150.

3.6.2.2 Fond St. Jacques

Fond St. Jacques West
The Fond St. Jacques western target area is small and located along a river. The area had been used as a helipad rescue site during the evacuation of residents after tropical storm Tomas, which caused severe flooding and landslides in the area in 2010. The area was heavily disturbed and land was built up for the construction of the helipad. Any potential archaeological deposits have likely eroded away into the river or are buried under the many meters of backfill that were used to construct the helipad. No cultural material was recovered during the pedestrian survey of this area.

Fond St. Jacques East
The Fond St. Jacques eastern target area is located in an area known to local residents as a "swamp." The ground was saturated by a local spring making it unlikely that humans ever settled or occupied the area. No cultural material was recovered during the pedestrian survey of this area. A stone masonry water tank and pumping station were located along the western edge of the potential drilling area, but it does not seem to carry any historical significance.

3.6.2.3 Mondesir-Saltibus

Both MS-1 and MS-2 contained an extensive array of historic and prehistoric archaeological materials. The areas surveyed were under extensive agricultural cultivation at the time of field survey, and farmers were employing the same mounded-earth (conuco) agricultural techniques seen in Belle Plaine. The cleared fields made the pedestrian survey and surface collection easy.

Historic Resources
The artifacts from this area included a wide variety of mid- to late eighteenth-century and early nineteenth-century ceramic types. These artifacts included refined English earthenware ceramics, such as creamware, shell-edge pearlware, and annular-decorated whiteware. Several pieces of stoneware, including a possible tankard, were recovered, along with fragments of early colonial black glass bottles. The most striking difference from Belle Plaine was the large number of low fired, coarse red earthenware ceramics from the early colonial period. These included both imported and locally made varieties of earthenware. Some pieces were industrial wares used in sugar manufacturing, while others were domestic wares, such as locally made bowls and cooking pots known as *kannawis*.

The archaeological assemblage is consistent with the village sites of enslaved peoples found throughout other parts of the Caribbean (Smith 2008, Smith and Bergman 2014, Smith and Bassett 2016, Smith 2017, Smith Forthcoming). In fact, the area was once part of Parc Estate (*La Parc*). Parc Estate was one of the earliest and largest sugar estates in Saint Lucia. It appears on the Jacques Nicolas Bellin map of St Lucia in 1763 and on the Thomas Jefferys map of Saint Lucia in 1775. By the time of emancipation in 1834, Parc Estate was divided between multiple owners who produced cocoa, coffee, and sugar. It had 176 enslaved workers, making it one of the largest slaveholdings in Saint Lucia.

Some of the older farmers from the community with whom the cultural resources specialist spoke believed that the area was once the village for enslaved peoples from Parc Estate. The farmers had also heard of a burial ground in the area, but were not certain of its location. One of the farmers introduced me to his uncle, who was an elderly farmer from the community. Many years ago, the man had found a silver coin while cultivating his fields, which were located within the potential drilling area. The coin depicted a crown on one side and a lion on the other. It had a date of 1779. Although he had sold the coin to a local collector, many members of the community confirmed his discovery. The date of the coin, which was likely British, fits very well with the mid-to late eighteenth century dates of the refined earthenware ceramics recovered from the site.

A long cart road cut along the southern boundary of the potential drilling area revealed the subsurface stratigraphy of the area. It consisted of a rich organic plowzone of dark brown silty clay ranging from 20 cm to 50 cm below the natural ground surface. A wide variety of imported and locally made historic period ceramics were present in this rich organic layer. That organic layer sat atop a subsoil layer of sterile clays that predated human occupation of the island.

Prehistoric Resources

A few sherds of Amerindian pottery were recovered during the pedestrian survey of MS-1 and MS-2, indicating an Amerindian presence at the site. The pottery fragments were small and lacked any distinguishing marks, but the thickness and coarseness of the pottery hint at a Suazan Troumassoid tradition. Several pieces of worked jasper were also recovered during the survey, and these too were likely associated with pre-colonial Amerindian peoples.

An earlier archaeological survey in 2004 noted the presence of prehistoric Amerindian materials at Parc Estate, at the nearby village of Gayabois, and at the nearby Saltibus School (Hofman et al 2004). These sites were dated to the later Suazan Troumassoid period. The Jasper may have come from local outcrops or it may have been collected in other islands and brought to Saint Lucia. In 2004, archaeologists had searched the Saltibus region for jasper sources (ibid; 51-53). Jasper was used by Amerindian peoples of the Caribbean to produce a variety of different tools for cutting, scraping, and splitting. There is evidence of extensive Amerindian activity in prehistoric times in the proposed drilling areas at MS-1 and MS-2.

3.6.3 Data Gaps

The pedestrian surveys conducted for this Scoping Studies report did not include any subsurface investigation (i.e., shovel test pits). Recommendations for further investigation are provided in Section 4.

3.7 SOCIO-ECONOMIC ENVIRONMENT

The following section contains results pertaining to TOR Task: 1.18, 1.19, 1.20, and 1.21. The socio-economic area of influence includes the communities of the potential drilling areas.

3.7.1 Literature Review Results

3.7.1.1 Population and Demographic Profile

The mid-year population of Saint Lucia for 2016 was estimated at 173,966 persons (Government Statistical Department Saint Lucia 2014), reflecting a 0.7 percent growth over the previous year. The latest population and housing census (Government Statistical Department 2010) indicated that about 55 percent of the population resided in two of the country's ten census or administration districts, Castries (the capital) and Gros Islet, both located in the northwestern part of the country. There were an estimated 58,891 households in 2010 with an average household size of 2.8 persons; a significant decline from the 3.3 persons for the previous census.

Females accounted for roughly 51.4 percent of the population. The working age population (15-64 years) represented 71.6 percent of the population. Dependents (people younger than 15 or older than 64 years) comprised 28.4 percent of the population; almost 9.0 percent fall within the age group of 65 years and over. Population trends indicate that this elderly group will form an increasingly larger proportion of the population over time.

The project area spans three contiguous districts or quarters, Soufrière , Choiseul, and Laborie; however, the communities and people potentially affected by the project are located in Soufrière and Laborie. As indicated in Table 3.7-1, the 2010 census estimated that for 2010, these two districts accounted for a total of 15,173 persons, 8,472 in Soufrière and 6,701 in Laborie.

Table 3.7-1 Demographic Profile of Soufrière and Laborie

Demographics	Soufrière	Laborie	Saint Lucia
Population in	8,472	6,701	165,595
Population under 15 years of age	2,296	1,627	43,041
Percentage Females	49.48	50.11	50.36
Percentage Males	50.52	49.89	49.64
Total private dwellings	**2,886**	**2,189**	**58,920**
Population density per square kilometer	1,124	1,189	2,062

Source: (Central Statistics Office 2011)

Between the 2001 and 2010 censuses, Soufrière recorded a 10.7 percent increase in population. Conversely, Laborie experienced the largest decrease (-9.0 percent) in the country. In Soufrière, females accounted for about 49.5 percent of the population, whereas for Laborie, the figure is slightly higher at 50.1 percent, in line with the country's average. Population densities for both districts were well below the national average of 2,062 persons per square km, with Soufrière recording the lowest density island-wide.

The project-affected communities include four settlements, two each located in Soufrière and Laborie. The Belvedere community includes individuals who may be affected by the Fond St. Jacques area and the Parc Estate and Gayabois communities include individuals who may be affected by drilling in Mondesir-Saltibus. Based on the last population census, the two settlements in Soufrière (Belvedere and Belle Plaine), had an estimated 574 persons accounting for approximately 6.8 percent of Soufrière's total population. The two settlements in Laborie (Gayabois and Parc Estate) had 172 persons, which represents only 2.8 percent of Laborie's total population. Table 3.7-2 presents the estimated population of each affected community based on the 2010 Census.

Table 3.7-2 Population of the Affected Communities

Population (2010)	Females	Males	Total
Soufrière			
Belvedere	221	252	473
Belle Plaine	47	54	101
Total	**268**	**306**	**574**
Laborie			
Parc Estate	45	54	99
Gayabois	31	42	73
Total	**76**	**96**	**172**

Source: (Central Statistics Office 2011)

3.7.1.2 Economic Environment, Livelihoods, Employment and Labour Implications

Economic activity and employment in Saint Lucia are driven by three main sectors: tourism, construction and agriculture. Tourism (hotels) accounted for almost 7.8 percent of the gross domestic product (GDP) of Saint Lucia in 2016. Tourism is the single largest economic activity in the country and it is mainly concentrated in the north (Gros Islet) and south (Soufrière). The contribution of tourism to GDP has generally increased over the past 10 years, whereas agriculture's share has gradually declined to 2.0 percent in 2016. Agriculture currently accounts for 11 percent of the total employment.

The unemployment rate remains persistently high at over 20 percent since 2009. However, the most recent Economic and Social Review (Government of Saint Lucia 2016a) reported that the labour market showed signs of improvement. The unemployment rate fell from 24.1 percent in 2015 to 21.3 percent in 2016 largely due to construction as well as the accommodation and food

services sectors. The unemployment rate among youth (15 to 24 years) remains high, reaching a peak of 43 percent in 2016. The declining contribution of the agriculture/banana industry, the 2008 global financial crisis and downturn in economic growth are likely to be some of the main reasons for poor job prospects and overall weak employment trends.

In Soufrière, tourism, followed by agriculture and fisheries are the main economic activities with most of the job openings and new employees being in the accommodation and food service sectors (St. Catherine 2013). Soufrière has several tourist attractions, notably the Pitons a UNESCO World Heritage Site; the Sulphur Springs (drive-in volcano, hot springs); and high-end hotels, such as the multiple award winning Jade Mountain Resort.

Laborie depends on fishing and agricultural production. Data for 2016 (Government of Saint Lucia 2016a) indicates that Laborie has gradually increased fish landings and now accounts for twice the quantity of fish landed in Soufrière. In addition, quarrying/mining by Wilrock Ltd which provides a significant level of employment opportunities in the community. Laborie also has a small tourism sector that comprises a few guest houses within the village and rural areas such as Banse (Government of Saint Lucia 2016b).

Several communities in Soufrière are afflicted by high unemployment, although the unemployment rate recorded in 2010 (Government Statistical Department 2010) for Soufrière was lower (18.6 percent) than the national average of 20.6 percent. The project affected community of Belle Plaine had an unemployment rate of 23.9 percent, albeit less than the Palmiste community which is close to the urban area and had the highest rate (31.8 percent) in Soufrière. Belvedere had a moderate rate of 12.1 percent unemployment. Crop production was a significant form of livelihood in Belvedere. The lowest unemployment rates in Soufrière were recorded in the Sulphur Springs' community (3.5 percent) and Fond Gens Libre (7.3 percent), two areas with tourism-related economic activities.

In Laborie, the average unemployment rate was 8 percent higher than Soufrière's, with rates as high as 48.7 percent along the Laborie/Vieux Fort highway. Unemployment rates in Parc Estate and Gayabois were 30.6 percent and 23.3 percent respectively. Crop production was the main form of livelihood in these two communities.

Females consistently experienced a higher rate of unemployment, countrywide, and at the district and settlement levels. This gender disparity appears to have persisted; whereas the overall unemployment rate for 2016 was estimated at 21.3 percent, unemployment rates for females remained typically higher at 22.9 percent compared to 16.2 percent for males. However, it was found that the difference between the average unemployment rate of females and males decreases as the highest education level attained increases (Government of Saint Lucia 2016a).

3.7.1.3 Use of Natural Resources and Agriculture

Forests

The total land area of Saint Lucia is about 616 square kilometers (238 square miles). About 56 percent of the natural forests are found in forest reserves and 43 percent on private lands

(United Nations Environment Programme 2010). Forest reserves cover about 7,690 hectares (19,002 acres). The Forestry Department is responsible for managing the forest and water resources in Saint Lucia. The Forest, Soil and Water Conservation Act allows for private landowners to enter into agreements with the Government for the management of private lands as forests for conservation purposes, and for private landowner to be compensated accordingly.

Agriculture
The last (2007) agricultural census estimated 12,223 hectares (30,204 acres) to be under agricultural production of which 1,503 hectares (3,714 acres) were under forest and woodland cultivation. Several species of forest trees, particularly mahogany and Blue Mahoe are grown for timber.

Crop and livestock production are the most productive sub-sectors in the agricultural industry. Banana production, which has been on a downward trend, is exported to the United Kingdom and other Caribbean markets. Other crops, fruit and tree crops, roots and tubers as well as vegetables and condiments are produced mainly for domestic consumption and are sold to local supermarkets and hotels. A cocoa revitalization project was implemented to increase production of cocoa particularly in Soufrière. Hotel Chocolat, a luxury chocolate firm located on an old cocoa estate in Soufrière has been promoting the production of cocoa beans.

Soufrière and Laborie recorded a substantial decrease in the area of agricultural lands between the last two agricultural censuses. Soufrière had 455 farms operating on 603 hectares (1,490 acres) while Laborie had 769 farms on 737 hectares (1,820 acres) and the total number of farms in Saint Lucia was 9,972 in 2007. The 2007 census recorded an increase in abandoned banana farms and lands in fallow/resting and a general improvement in the distribution of farm land ownership and an increase in family-lands ownership.

Water Resources
Water resources in Saint Lucia are used mainly for domestic, commercial, and agricultural purposes. The John Compton (Roseau) dam, built in 1995 is the largest water supply with a reservoir capacity of 2.6 million cubic-meters serving the north of the Island. Water is typically extracted from run-of-the-river intakes and treated to meet the potable supply requirements in nearby communities. In some communities, notably Belvedere-Fond St. Jacques, water from spring sources is also used (refer to Section 3.1.1 and 3.1.2 for further details on water resources).

3.7.1.4 Community Organization and Local Institutions
There is a strong tradition of community oriented organizations in Saint Lucia. Several cooperative credit unions, farmers association, mothers' and fathers' groups, youth and sports groups, and other faith-based organizations operate throughout the country. Both Soufrière and Laborie have development foundations – organizations aimed at promoting and facilitating local development initiatives. The community of Fond St. Jacques also has a Development Committee.

The Ministry of Equity has established community/resource centers all over the country. These are public facilities where community members gather for meetings, activities, and other social events. Many of these centers serve as training and emergency shelters. There are community and resource centers in Fond St. Jacques and Laborie that are available to the potentially affected communities.

3.7.1.5 Access to Social Services

Housing and Infrastructure

Based on the 2010 Census, almost 70 percent of Soufrière's households had flushable toilet facilities (linked to a septic tank) and 93 percent used electricity as the main source of lighting; both indicators were higher than the national average. However, 73 percent used public (WASCO's) piped borne water and 72 percent used gas/LPG as fuel for cooking - both were below the national average[1].

Approximately 63 percent of the households in Laborie had flushable toilet facilities (linked to a septic tank) and 94 percent used electricity as the main source of lighting; these indicators were consistent with the national average. About 77 percent of Laborie households used public piped water; this was below the national average but higher than Soufrière's. Although 80 percent of Laborie's household used gas as fuel for cooking, the use of charcoal and wood was higher (11.8 percent) compared to (7.8 percent) and countrywide (5.4 percent).

Education

Primary level education is compulsory for all children between the ages of 5 to 11 years in Saint Lucia. For the past 10 years, primary school enrolment has been steadily declining partly due to a persistent decline in the school-aged population. For the 2013/14 academic year, there were about 97 public schools operating throughout the country, 74 of which were primary and 23 secondary. These schools are organized by eight school districts.

The project affected communities fall within school districts numbers 7 and 8, which have a total of 17 primary and three secondary schools. All 20 schools serving the affected areas have excess capacity[2]. The Parc Estate and Gayabois settlements have access to the Saltibus Combined (primary) school which is about 0.8 km (0.5 mile) away, and the Piaye Secondary schools, which is about 8 km (5 miles) away from the community. The communities of Belvedere and Belle Plaine have access to the Fond St. Jacques Primary (0.5 to 3.2 km [2 miles] away) and the Soufrière Comprehensive Secondary schools, (4.8 to 8 km [3 to 5 miles] away).

Medical Care

Public health care services in Saint Lucia are provided by a network of facilities that comprises 33 health/wellness centers, two general hospitals (Victoria and St. Jude Hospitals), two district

[1] Population and Housing Census 2010; Source: Government Statistical Department, Saint Lucia
[2] Education Statistical Digest 2014, published by the Ministry of Education

hospitals and one polyclinic (in Gros Islet). The health centers provide primary (non-emergency) health care and are dispersed throughout the Island's eight health regions. The health sector policy is that each health center should serve a population within a maximum of 4.8 km (3 miles). Public secondary level (acute) health care is provided by two general hospitals. The largest, Victoria Hospital, is a public hospital located in Castries. St. Jude is a quasi-government facility in Vieux Fort in the south of the Island. A third secondary level health care facility, Tapion Hospital, is privately owned and located in Castries. The National Mental Wellness Centre and a Drug Rehabilitation Centre are the only mental wellness centers in Saint Lucia and both public institutions are located in Castries. Both facilities provide in-patient care and follow-up consultations.

At health centers, routine medical care by a nurse is available 5.5 days per week up to 4:30 PM, after which medical care is available at the hospitals (Regional Health Services n.d.). Doctors are available on selected days and hours. Specialized clinics are held weekly for the management of diabetes, hypertension, birth control, psychiatric disorders and sexually transmitted diseases including HIV. More specialized medical care is available as outpatient services at the general hospitals and medication is accessible at several public health care facilities at a subsidized price to the general public.

The project-affected communities span two health regions (numbers 5 and 6) that contain a total of eight health care facilities. Soufrière Hospital is the main primary care health facility serving the communities of Fond St. Jacques/Belvedere, and Belle Plaine. There are two other health centers in Soufrière that provide general services including visiting specialist and pharmacist services. The Fond St. Jacques health center is less than 4.8 km (3 miles) from the Belvedere community and the Etangs Health Centre is approximately 4.8 km (3 miles) from Belle Plaine. The Soufrière Hospital currently functions as a polyclinic or non-hospital referral facility and is not equipped to provide a high level of acute care. Secondary level medical care for Fond St. Jacques and Belle Plaine communities is available at Victoria and St. Jude hospital, both of which are about 45 km (28 miles) away.

The residents of Mondesir (Parc Estate and Guyabois), have access to the Saltibus health center, which is approximately 4.8 km (3 miles) away. The St. Jude Hospital is about 29 km (18 miles) from Mondesir and is available to the Parc Estate and Gayabois communities for secondary level medical care.

3.7.1.6 Community Health, Safety and Security, and HIV/AIDS Prevalence

Community Health

The Ministry of Health reported that for 2014, the infant mortality rate (deaths per 1000 of the population) was down to 17 and the average life expectancy had decreased to 74.4 years, with females having a higher expectancy (78.7 years) than males (70.3 years) (Ministry of Health and Wellness 2016). Apart from maternal and reproductive conditions, injuries and road accident, non-communicable diseases (including diabetes, hypertension, heart disease and cancer) were the most common causes of illnesses and death in Saint Lucia. Elderly females (65 years and over) were more affected by hypertension whereas older males (45-64 years) were more affected

by diabetes. Females (25-64 years) also accounted more for cancer but the majority of injuries and mental illness were recorded for adult males. In 2013-2014, mortality due to non-communicable diseases was 58 percent of premature deaths and 73 percent of total preventable deaths. In recent years there has been a significant increase in the number of suicides in Saint Lucia. The majority of the cases are due to mental health illnesses or substance abuse problems, such as alcohol and the use of illicit drugs (UN Human Rights Council 2015).

Safety and Security

Indications are that the crime rate has increased in recent years. In May 2017, the Royal Saint Lucia Police Force (RSLPF) reported (St. Lucia Times 2017) that crime in 2016 had increased by two percent over the previous year. The RSLPF indicated that "This rate was the highest experienced over the past four years." It was further reported that for 2016, there were increases in almost all the major crime categories (murders, sexual offences, firearm offences, offences against property, drug offences and summary offences), except crimes against the person (which recorded a slight decrease when compared to 2015). The north of the Island accounted for 40 percent of the total crimes reported in 2016.

An analysis of data obtained from the Central Statistical Office of Saint Lucia revealed that 17,968 crimes were reported for 2016. The major crimes, "crimes against the person" (murder, assaults, wounding etc.); sexual offences; crime against property (robbery, burglary etc.); and firearm offences represented almost 50 percent of all crimes. The official number of reported murders (Royal Saint Lucia Police Force n.d.) for 2016 was 33, of which 30 percent had been cleared up compared to 28 murders in 2015 with a clearance rate of 57 percent. Information obtained on Royal Saint Lucia Police Force indicates that for 2017, a total of 11,454 crimes were reported and accepted; 25 were murders with 68 percent being cleared up (Royal Saint Lucia Police Force n.d.).

In terms of the geographical distribution of crimes, the 2010 Population and Housing Census indicated that of the number of households who recounted being victims of crimes[3], house-breaking represented the largest proportion (66 percent) of crimes at both the national and district levels. The north of the Island accounted for the majority (66 percent) of all households affected, while Soufrière and Laborie accounted for 2.8 percent and 3.2 percent of house-breakings, respectively.

Currently, there are a total of 13 police stations in Saint Lucia with 5 located in the southern half of the island. Soufrière and Laborie have police stations, both within 9.7 and 16 km, (6 and 10 miles) respectively of the communities potentially affected by the project.

[3] Reported and not reported to the police

HIV/AIDS Prevalence

The gradual rise in the numbers of persons testing positive for HIV or dying of AIDS is also of great concern even if the disease is not yet a significant cause of illness and death. The annual HIV/AIDS surveillance report by the Ministry of Health for 2014 (Ministry of Health 2015, Ministry of Health and Wellness 2016) reveals that the prevalence/incidence (number of cases per 100,000 persons) of HIV infection is 35. During 2005 and 2010, the number of new cases of HIV infection had stabilized, but increased again during 2011-2013. The number of new cases of HIV/AIDS in 2014 fell to 61 compared to 63 in 2013. Males, accounted for the majority (62 percent) of these newly diagnosed cases. About two-thirds of the newly diagnosed cases were in the 25- to 49-year old age group, and twice as many males as females had been diagnosed with HIV/AIDS.

Overall, at the end of 2014, there were 674 persons living with HIV out of the total 1029 cases recorded on the national register; males accounted for 50 percent of the cases. About 34 percent of persons living with HIV are enrolled under the Ministry of Health's treatment program.

The majority (81 percent) of the newly diagnosed cases are not recorded by health region or location. For 2010-2014, about 75 percent of newly diagnosed cases lived in the north (Castries, Babonneau and Gros Islet) where almost 55 percent of the population reside. For the 5-year period (2010-2014), HIV/AIDS incidence increased in the north as well as in Micoud, Soufrière and Laborie, as compared with the previous period (2005-2009). In 2014, the incidence in Soufrière was 0.9 whereas Laborie was 0.6.

3.7.1.7 Poverty and Vulnerable Groups

The findings on Poverty and Inequality in Saint Lucia (Central Statistical Office of Saint Lucia 2017)indicates an alleviation in the Island's poverty during the past 10 years. In 2016, it was estimated that 25.8 percent of the population was considered poor, almost 4 percent less than in 2006 (Kairi Consultants 2007). The poverty gap had reduced from 9 percent in 2006 to 7.5 percent in 2016. Although the decline was most noticeable in the rural areas, poverty in Saint Lucia remains a rural phenomenon. Approximately 41 percent of the rural population were poor in 2016, compared to 23 percent for the urban population. Soufrière and Laborie both recorded a significant decline in poverty levels during the 10-year census period. In 2016, it was estimated that approximately 25.5 percent of Soufrière's population were poor, compared with almost 42.5 percent in 2006. Likewise, 23.4 percent of Laborie's population were poor in 2016; a significant improvement from 42.1 percent in 2006.

In 2010, Soufrière and Laborie scored similar poverty levels (13.78 and 13.80 points respectively) out of a maximum of 30 for the "Basic Needs" Index (a proxy for poverty levels) (Director of Statistics 2011). The Belvedere community, although not the poorest, was found to have a higher level of poverty (11.94 points) than Belle Plaine (16.71 points). The highest level of poverty in Laborie was recorded in Parc Estate (10.64 points) while Gayabois was less poor with 12.35 points.

Children make up a substantial (22.5 percent) proportion of those who are in the poorest wealth quintile (UNICEF 2016). The Findings on Poverty and Inequality by the Central Statistical Office of Saint Lucia estimated that the disparity in poverty levels between poor male and poor female household heads in Saint Lucia had worsened from 1.8 percent in 2006 to 9.3 percent in 2016. There was also a gap in employment income between men and women across both poor and non-poor groups.

The Ministry of Education provides assistance in the form of bursaries and the School Feeding Program to needy students in public primary schools. School District 7, which includes Soufrière and Laborie, recorded the highest (79 percent) proportion of students benefiting from the Program (Government of Saint Lucia 2015).

There are other social protection programs, such as the Public Assistance Program (PAP) that are designed to address critical vulnerabilities. The PAP provides aid to almost 3,300 persons who have been deemed needy. The assistance includes monthly cash transfers and waivers on medical care, mainly to vulnerable groups – the elderly, and to a lesser extent, persons with disabilities. In April 2015, PAP provided support to 364 persons in Soufrière (about 11 percent of the total registered needy persons in Saint Lucia) and 329 in Laborie (Caribbean Development Bank 2016).

3.7.1.8 Equity and Potential issues related to Social Conflict

Data on equity or social conflict in Saint Lucia is not readily available at the national or district levels. Information from the Caribbean Development Bank (Caribbean Development Bank 2016) indicates that the level of inequality in Saint Lucia has been declining overall. In 2015, the shares of the wealthiest 20 percent of the population decreased; however, it was estimated that at least one third of the population are multidimensional deprived. Factors used in calculating multidimensional deprivation are poor health, lack of education, inadequate living standard, lack of income, disempowerment, poor quality of work, and threat from violence.

Another measure of inequality is the Inequality-adjusted Human Development Index (IHDI) - an average measure of basic human development achievements in a country. The IHDI value for Saint Lucia is 0.618 for 2015, placing the island in the high (or relatively good) category (Caribbean Development Bank 2016). The highest IHDI was reported for Norway (0.898) and the global average is 0.557.

The Gender Inequality Index (GII) on the other hand reflects gender-based disadvantage in three dimensions: reproductive health, empowerment and the labour market. In 2015, Saint Lucia scored a GII value of 0.354, ranking it 74 out of 159 countries which also places the country in the high GII category. An analysis (by Julie V. Xavier, PhD) on gender beneficiary of Saint Lucia's PAP indicated there are systemic barriers that operate against female beneficiaries and applicants.

Lifestyle, Culture and Recreation

The "kweyol" or patois language forms part of the traditional Saint Lucian culture and lifestyle, and is more prevalent in the rural areas. "Jounen Kweyol" is one of the largest cultural events

that takes place throughout all communities; it is an annual celebration of International Creole Day which is held in October and provides the occasion to support the culture of Saint Lucia as well as a form of recreation. Other cultural activities are the flower festivals (the Lawòz and Lamagwit) which are held in August and October, respectively. These two cultural festivals are promoted at schools, as well as Quadrille – a traditional local dance.

Carnival and Calypso celebrations are held in July each year. Most of the events (Calypso Monarch, Soca Monarch, Panorama/Steel Pan and Carnival Queen competitions) are held in Castries and culminate in the two-day parade. Some communities, including Soufrière town and Fond St. Jacques host their own carnival festivities. Laborie's "Freedom Mas" is a family oriented activity held on Emancipation Day - August 1. Laborie Development Foundation hosts other cultural events such "Festèn Labowi" a fish festival in June and Kolasyon Nwèl, Christmas celebrations in December.

Creole music is played by chak-chak bands that use a violin, guitar, banjo and locally made African style drums (called taboos). Quadrille is danced to the music. "Country and Western" music/dance is also popular throughout the island, especially in the rural areas. This genre of music, reportedly introduced to locals by U.S. military workers who came to build airports in Saint Lucia during the Second World War. Both Soufrière and Laborie have beaches where community members and their families visit for swimming, picnics, and relaxation, especially on weekends and holidays.

"Sou-sou" and "koudmen" are two cultural forms of economic and social collaboration among community members, particularly the poor in rural areas. "Sou-sou" remains popular particularly among poorer women throughout the country. It is a West African form of rotating savings was reportedly brought to Saint Lucia by African slaves. The sou sous operates through an informal group/savings club comprising a small group of people. This form of savings is believed to have diminished with the growth of credit unions. For "koudmen" (lending a hand), community members assist each other by working for free on projects – typically house construction or farm work.

3.7.2 Field Survey Results

This section provides the results of the field verification surveys conducted by ECMC in the potentially affected communities.

3.7.2.1 Age and Gender

The ages of respondents ranged from 20 to 85 years; the youngest being a female from Belvedere and the oldest, a male from Parc Estate. Table 3.7-3 provides a summary of the age and gender distribution of the respondents. The majority of respondents (59 percent) were males.

Table 3.7-3 Age and Gender of Respondents in the Affected Communities

Community	Age Range	% Females	% Males
Belvedere	20-80	55	45
Belle Plaine	25-71	22	78
Mondesir	25-85	46	54

Reported household sizes ranged from 1 to 15 persons. The higher end of the spectrum comprised households with extended families. These types of households were more prevalent in Belvedere and Mondesir settlements. The largest household was an extended family in Parc Estate. It was reported that this settlement basically comprises 7 to 8 families living in separate or extended family households. The average size of all the households surveyed was 3.5 persons.

Males account for roughly 60 percent of the total household population. The working age group (15 to 64 years) was the largest proportion of the population (69 percent). Three disabled (mentally challenged) males, both in the 50 to 55 years age group, are accommodated in households in Belvedere. One physically disabled male was identified in Gayabois. Dependents (residents younger than 15 or older than 64 years) accounted for about 31 percent of the household population with persons 65 years and over representing 13 percent. The youngest (1.5 years) household member was recorded in Belvedere and the oldest was an 89-year-old male in Parc Estate.

3.7.2.2 Education

Approximately 54 percent of the household populations attained primary level education; 28 percent were educated at the secondary and 9 percent at tertiary (community college) levels. Around 9 percent had no schooling; these individual comprised older (73 to 89 years old) persons who live in Belvedere and Mondesir. Belle Plaine's population had the highest proportion of tertiary and secondary level schooling. Respondents in Mondesir had the lowest percentage of tertiary and secondary schooling. The Mondesir community also had the highest percentage of residents with no schooling. Table 3.7-4 summarizes the responses regarding the level of schooling in the affected communities.

Table 3.7-4 Education levels in the Affected Communities

Schooling	Belle Plaine	Belvedere	Mondesir
Tertiary (%)	24	5	4
Secondary (%)	47	23	21
Primary (%)	29	64	61
None (%)	-	9	14
Total (%)	**100**	**100**	**100**

3.7.2.3 Employment, Livelihoods and Income

Based on the survey results, 36 percent of the total working household population are unemployed. A large proportion (39 percent) reported being self-employed, primarily as farmers. The main type of farming practiced is crop production, especially root crops (dasheen and sweet potatoes) followed by vegetables (cucumbers, cabbages, melons and tomatoes). Subsistence cattle, sheep, and goat rearing was also being undertaken by a few households (mainly in Belle Plaine and Belvedere).

In Belle Plaine, 62 percent of the household population were self-employed in farming. Around 50 percent of Belle Plaine's respondents indicated that their employment would likely be negatively affected by loss of land to the project. Compared with Belvedere and Mondesir, full-time employment was relatively higher in Belle Plaine, with 38 percent of household population working in the private or public sector. A few respondents of Belle Plaine also reported being retirees from overseas. Unemployment in Belle Plaine was not reported by any of the households interviewed.

Conversely, 33 percent of the households' working population surveyed in Belvedere (Fond St. Jacques) was unemployed; 39 percent self-employed in farming and 22 percent were employed full-time. Among the three communities, Belvedere had the widest range of livelihoods comprising hotel work, construction, small business/shop owner, and Government work. The majority (64 percent) of Belvedere's respondents were of the view that their livelihoods would likely be negatively affected by loss of land to the project compared with 50 percent in Belle Plaine.

Table 3.7-5 summarizes the employment status of household members in the affected communities.

Mondesir reported the highest level (43 percent) of unemployed persons. Self-employment was around 39 percent and full-time employment, the lowest at 18 percent. About 57 percent of Mondesir's respondents were of the view that their employment would likely be negatively affected by loss of land to the project.

Respondents were generally unwilling to provide information on income. From the data obtained, Belle Plaine reported the highest income levels, followed by Belvedere. Mondesir had the lowest income level, reporting monthly household incomes ranging from less than $500.00 to $1,000.00.

Table 3.7-5 Employment Status of Household Population in the Affected Communities

Employment Status	Belle Plaine	Belvedere	Mondesir
Full-time (% of households)	38	22	18
Part-time (% of households)	*	6	*
Self-employed (% of households)	62	39	39
Unemployed (% of households)	*	33	43
Total (%)	**100**	**100**	**100**
Percentage who perceived employment affected due to loss of land to the project (%)	50	64	57

Notes:
*None reported

3.7.2.4 Land Ownership and Land Use

The respondents indicated that the primary form of land tenure was family-owned land followed by leased, and privately-held land. Among the three communities, private ownership of lands was highest in Belle Plaine, whereas family-owned land was the main form of land tenure in Belvedere. Leasing, primarily from Government/Invest St. Lucia, was the predominant form of land tenure in Mondesir.

Belle Plaine's respondents reported the highest percentage (80 percent) of family-land used for farming. In the Belle Plaine community cluster, members of a family comprising many siblings declared ownership of over 81 hectares (200 acres) of land, which is currently being used to grow a variety of crops for sale. These lands have already been sub-divided and titles are currently being prepared. In Belvedere, family-owned land was the main form of tenure reported for both housing and farming. Leasing from Government/Invest St. Lucia was the primary form of land tenure in Mondesir. Some respondents in Mondesir claimed that they had acquired lands from the Danes' Project in the 1990's. Table 3.7-6 presents the land ownership and use reported by respondents in the affected communities.

Table 3.7-6 Land Ownership Pattern in the Affected Communities

Land Tenure/ Use	Belle Plaine	Belvedere	Mondesir
Housing			
Family (%)	75	89	31
Privately held (%)	25	*	15
Leased/Gov't (%)	*	11	54
Total (%)	**100**	**100**	**100**
Farming			
Family (%)	80	75	25

Privately held (%)	20	*	*
Leased/Gov't (%)	*	25	75
Total (%)	**100**	**100**	**100**

Note:
*None reported

3.7.2.5 Housing Facilities

The houses in the three communities are all detached/individual structures mostly built from masonry (concrete/block-wall) or a combination of masonry and wood. The Belle Plaine community had the highest proportion of houses constructed out of a combination of masonry and wood materials. A higher percentage of wooden houses was observed in Belvedere and Mondesir. All the houses surveyed in the Belle Plaine community reported having septic tank toilet facilities whereas 18 percent and 36 percent in Belvedere and Mondesir, respectively, had pit latrines. Table 3.7-7 shows the type of housing facilities in the sample of households in the affected communities.

In all the potentially affected communities, every house in the sample stated that electricity is their main form of lighting; however, electricity was not used as fuel for cooking. The majority of households used either gas (LPG) or a combination of LPG and charcoal as fuel for cooking. The use of charcoal and wood was reported more frequently in Mondesir and Belvedere.

Table 3.7-7 Type of Housing Facilities in the Affected Communities

Type of Housing	Belle Plaine	Belvedere	Mondesir
Outer walls			
Masonry (%)	33	45	54
Masonry/wood (%)	40	18	15
Wood (%)	17	36	31
Total (%)	**100**	**100**	**100**
Toilet Facilities			
Septic tank (%)	100	82	64
Pit Latrines (%)	-	18	36
Total (%)	**100**	**100**	**100**

3.7.2.6 Water Supplies and Quality

The survey indicated that the majority of households in all the affected communities use mainly public pipe-borne (WASCO's) water as their primary source of water for domestic purposes. A few households in Mondesir reported using public standpipe as their main source of water. Overall, the quality of WASCO's water was rated as good and generally reliable. Rainwater harvesting tanks/containers were also used by most households. Spring "sous" water was

generally used for other non-drinkable domestic purposes and farming in all the communities. A few households in Mondesir also reported using a combination of public standpipe, spring, and river as their sources of water.

Some households were of the perception that spring water was a better and a more natural source of water than the public-piped water, which they believe contains too much chlorine. This view was expressed more frequently in Belvedere where 36 percent of respondents reported using only spring water. It should be noted that a spring is located near the target drilling area; WASCO's water storage tank is also within close proximity to the affected households. Belvedere's respondents indicated that the spring water is extremely important to them as a "back-up" particularly during public water shortages and natural disasters such as Hurricane Tomas when WASCO's supplies had been damaged. Some respondents indicated that their spring water supplies are piped alongside WASCO's pipelines and into their households. One respondent reported that since Hurricane Tomas, spring water, instead of WASCO's water, was now piped to the household for domestic purposes (except drinking).

3.7.2.7 Community Perceptions

In all the communities surveyed, the majority of respondents were of the opinion that the natural environment in their communities was either very good or good. They treasured their community mainly because it was peaceful and quiet. Both Belle Plaine and Mondesir respondents also valued the "pristine" environment and low crime/burglary.

The majority of respondents in all communities surveyed complained about the poor conditions of their roads. Road upgrading and employment opportunities were the most frequent suggestions for improving all communities. The lack of internet services was also identified as a problem in Mondesir. Some residents of Belvedere expressed the need for more support from each other in their community. Others were of the view that the hurricane had destroyed part of their community and now it is "quieter." One respondent was pleased that cable television and internet services had been recently extended further into the community.

Belle Plaine's respondents could not recall the names of any specific community group in their community. A few respondents from Belvedere mentioned that a Fond St. Jacques Youth Group exists; however, persons from their household were not members. Other older respondents recalled there had once been a mothers' and fathers' groups in Fond St. Jacques. In comparison, Mondesir reported having two sports' teams: a women's cricket team and a men's football team. Sporting activities are usually held on the playing field in Parc Estate. A masonry structure/bar "M L Hide Away" located near the playing field is used by the community for recreational purposes.

3.7.2.8 Perceptions of the Project

The majority (75 percent) of respondents from Belle Plaine had some knowledge about the project's history compared with 36 percent for Belvedere, and 42 percent for Mondesir. Overall, respondents had heard that the project was not successful and had to be terminated. Respondents who had heard about this current phase of the project had done so from the radio,

television, and the recent community meetings. Some residents of Belle Plaine had heard about the project from the poster (at the Belle Vue Farmers' Cooperative) or had overheard from a friend.

For all the communities surveyed, the increased noise, especially at night, and the possible health hazards from the drilling were the most frequent concerns reported about the project. Belle Plaine's respondents were extremely concerned about the noise, loss of farmland/livelihoods, and health hazards – *"the heat that would be generated from drilling is too dangerous."* Belvedere respondents were worried about the noise, displacement of homes/residents, and health hazards *"fumaroles, gas leaks and possible radiation into the atmosphere."* In addition to the noise, Mondesir's respondents were concerned about the possible loss of the playing field, loss of croplands, and *"hazardous materials exposed to the atmosphere."*

Few respondents in Belle Plaine envisaged any likely advantages or benefits of the project to their household or the community. Respondents suggested that the project should provide alternative locations or livelihoods for displaced residents and farmers to ensure that the negative effects on their community are minimized. Conversely, some of Belvedere's respondents were of the view that the project might generate employment in their community and *"make Belvedere a landmark."* In order to maximize the benefits and minimize the negative effects, the respondents recommended that their roads should be widened/upgraded; health hazard prevention/mitigation systems introduced in the community; employment opportunities be provided and residents kept informed about the project.

The Mondesir respondents were hopeful that the project would create employment in the community and provide their households with electricity from the project and at a lower rate than LUCELEC. The respondents advised that project should protect the playing field or provide another one nearby; the roads should be improved and health hazard prevention/mitigation systems should be provided in the community to ensure that the project's benefits are maximized and the negative effects minimized.

When asked if they would be seeking a job from the project, the majority of respondents from Belvedere and Mondesir responded "yes," compared with "No" for Belle Plaine. Some of possible jobs mentioned were labourer, mason, road construction/maintenance worker, plant manager, and supervisor.

3.7.2.9 Land Ownership and Use Survey

Belle Plaine

The area of the proposed drill site in Belle Plaine is estimated as 26.3 hectares (65 acres) and is part of an 81-hectare (200-acre) tract of family lands. In recent years, this plot of land has been undergoing a sub-division exercise and smaller parcels are currently being titled to heirs of the original owners.

The site straddles Blocks 0428B and 0427B. A copy of the most recent LRTP map sheet suggests that there are 29 parcels and most likely an equivalent number of persons who own the land

within the proposed drilling site. These parcels appear to be farm lands, some of which are under active cultivation, while the remainder appear to be fallow. Some of the owners of the sub-divided parcels have their residences on the opposite side of road, which essentially borders the site.

A parcel of land (Block 0427B Parcel 123), occupied and owned by the Bellevue Farmers' Cooperative shares part of the drilling site. It is likely that other owners of the lands which are part of the proposed drilling site are part of, or sell their produce to the Cooperative.

A preliminary profile of the ownership and use of the lands that fall within the proposed drilling site is presented in Table 3.7-8.

The combined LRTP map sheet and aerial photograph shown in Figure 3.7-1 indicate that some parcels on the western side of the proposed drilling site will be split into varying proportions by the boundary lines. This potential division significantly reduces the size of affected parcels, thereby reducing the viability of the entire parcel for agricultural purposes.

Belvedere/Fond St. Jacques

Two separate sites have been identified for drilling in the Belvedere/Fond St. Jacques community. The smaller site, which is near the center of the Fond St. Jacques community is being used for recreational purposes by the community. The other site is in Belvedere, about 0.5 kilometer uphill from the first site; it is located at the base of a forested hill which is likely to be at the boundaries of the rain forest. The site is cultivated with a few tree crops scattered on lands which may best be described as being in fallow. A noteworthy feature of the site is WASCO's water storage tank which is being supplied from the nearby spring. The lands occupied by WASCO as a reserve is approximately 256 square meters (2,755 square feet).

The proposed drilling site comprises five parcels; two of which form the majority (2 hectares [5 acres]) of the site, with one of these parcels extending to the adjacent block and hillside. Two other parcels are slivers of the drilling site and are located along the boundaries. The fifth parcel is the land on which WASCO's spring water intake is located.

A preliminary profile of the ownership and use of the lands that fall within the proposed drilling site in Fond St. Jacques is presented in Table 3.7-9. The combined LRTP map sheet and aerial photograph for the proposed drilling sites in Fond St. Jacques is shown in Figure 3.7-2

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Table 3.7-8 Preliminary Profile of Land Ownership and Use – Belle Plaine Drilling Area

Block	Parcel	Area (m²)	Land Ownership and Use
0427B	193	2,152	This parcel is family lands owned by heirs of the original owners. Only a small portion of this parcel falls within the site and should be omitted.
	190	28,000	These 5 parcels are fully within the proposed drill site. These are family lands owned by the heirs of the original owners. The lands appear to have been recently subdivided and allocated to family members. All lands are under active farming.
	188	10,571	
	191	28,708	
	189	26,260	
	156	21,437	
	155	6,781	These 5 parcels are family lands owned by the heirs of the original owners. The lands appear to have been recently subdivided and allocated to family members. All lands are under active farming These areas are smaller than the average as the boundaries of the site do not extend to the road. If the site is used for the proposed project, the owners will not have any access to or use of the rest of the land.
	154	9,374	
	157	2,596	
	158	2,234	
	159	1,225	
	123	22,491	This parcel is fully within the proposed site and is part of lands used by the Belle Vue Farmers' Cooperative for farming. The parcel is most likely owned by the Cooperative.
	103	3,334	These are portions of narrow parcels which fall within the envelope of the proposed site. These parcels are family lands owned by the heirs of the original owners and the lands are being used for farming.
	104	4,532	
	105	4,699	
	106	3,834	
	107	12,601	These 10 parcels are fully within the proposed drill site and are family lands owned by the heirs of the original owners. The lands appear to have been recently subdivided and allocated to family members. The lands are being used for farming.
	108	12,425	
	109	5,444	
0428B	126	5,393	
	127	9,562	
	128	9,580	
	129	9,625	
	130	9,701	
	124	10,188	
	125	30,576	
	117	2,236	These are slivers of family owned lands within the proposed boundaries for the proposed drill site.
	121	394	
	122	251	

Figure 3.7-1 Parcels within the Potential Drilling Area in Belle Plaine

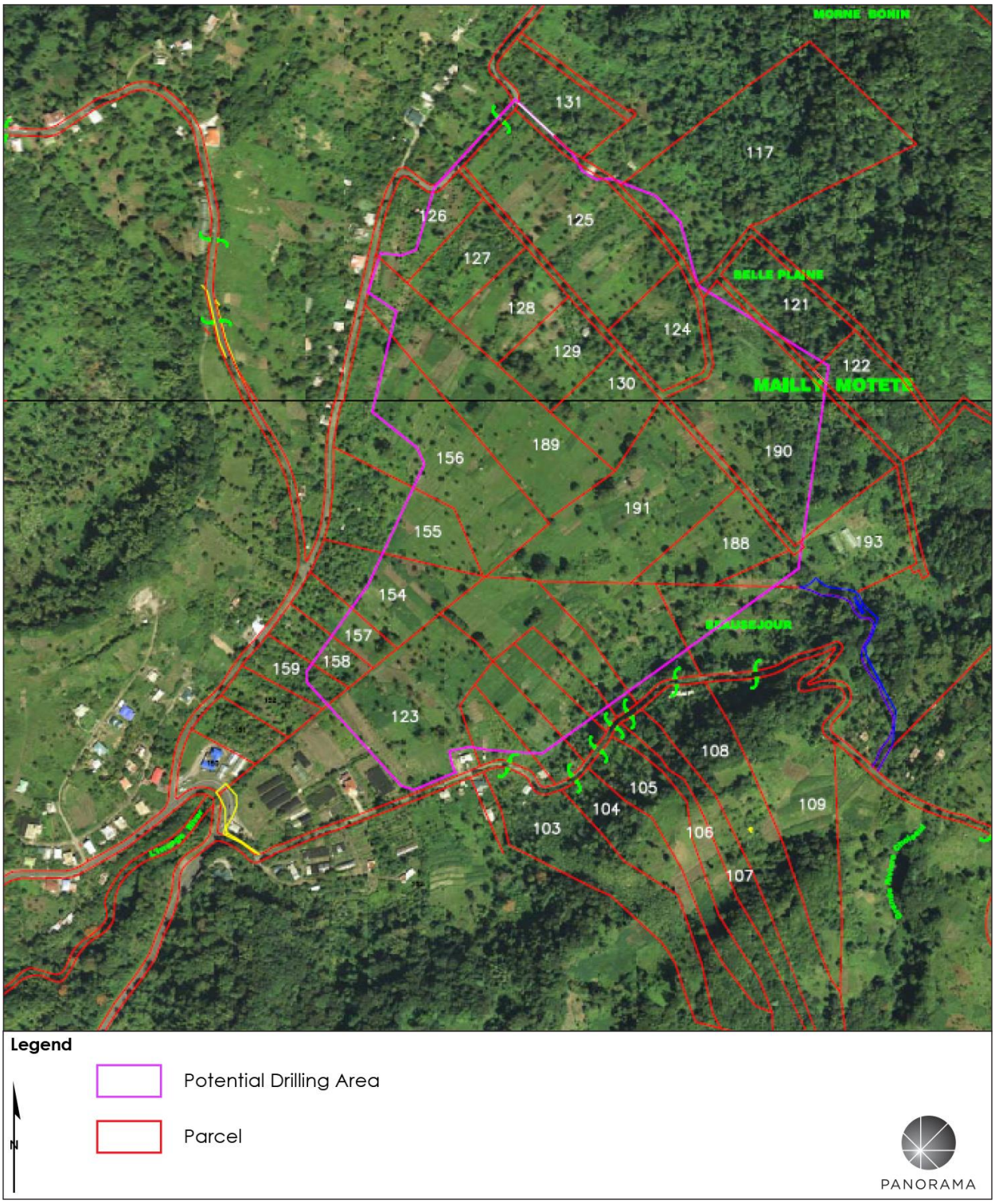
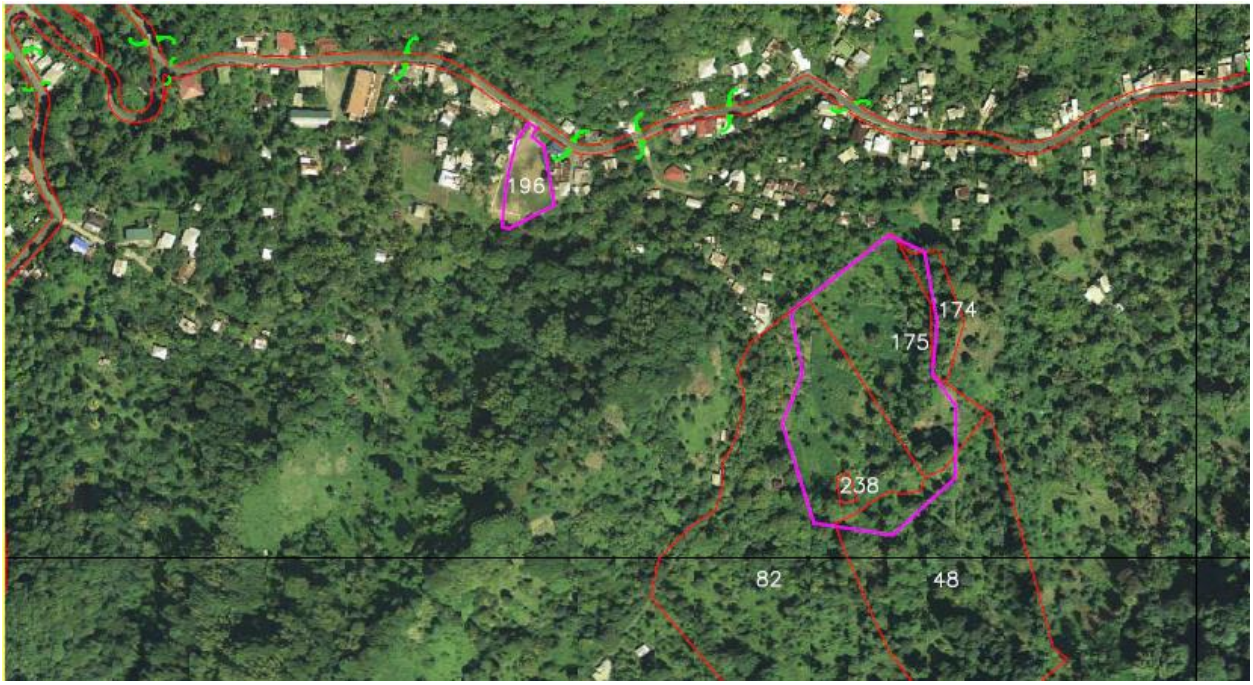


Table 3.7-9 Preliminary Profile of Land Ownership and Use – Fond St. Jacques Area

Block	Parcel	Area (m^2)	Land Ownership and Use
0429B	196	1,897	This parcel is currently being used as a playing field. It is Government owned.
	174	556	This parcel forms part of the proposed drilling site and is privately owned.
	175	10,584	This parcel is under agricultural production and is privately owned
	238	255	This parcel is within the proposed drilling site and is owned by WASCO. It is being used for spring water intake and water storage
0428B	82	9,762	This parcel is under minimal agricultural cultivation and is privately owned.
	48	1,786	This is a peripheral portion of the potential drilling area; it is privately owned

Figure 3.7-2 Parcels within the Potential Drilling Area in Fond St. Jacques



Mondesir

The proposed project area in Mondesir includes four potential drilling sites. MS-2 (2.5 hectares [6 acres]) is near the Parc Estate community and MS-1 is closer to Guyabois; MS-3 and MS-4 are closer to Saltibus and include small sites that would only be suitable for slim-hole wells. MS-1 and MS-2 are being used for agricultural and or recreational purposes. MS-2 is being used for farming and as a playing field. Although the nearest communities (Parc Estate and Gayabois) comprise about 15 to 20 houses clustered between the two segments, the playing field is comparable in size to a standard playing field; therefore, the likely users would also come from the adjacent communities of Saltibus to the north and Balca to the South.

MS-1 is approximately 7.3 hectares (18 acres) and is cultivated with temporary crops such as pineapples, sweet potatoes and vegetables. Information from residents in the community suggested that the lands were earmarked for relocation of farmers who would have been displaced as a result of a major hotel development proposed in the southeast of Saint Lucia. The current level of farming does not reflect intensive cultivation.

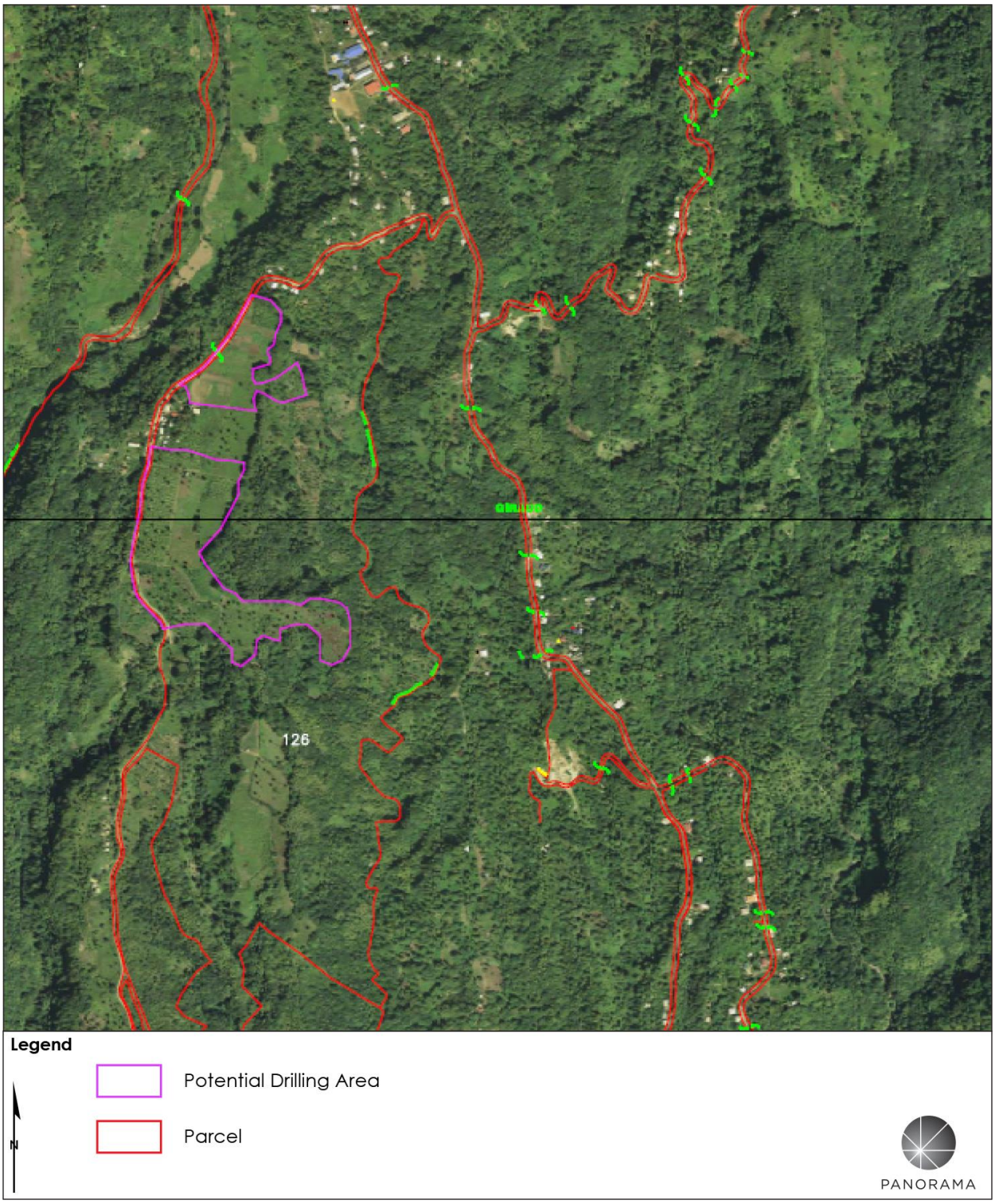
The MS-1 and MS-2 area straddles two blocks (0624B and 0625B); however, both potential drilling sites are located on one large portion of land, legally demarcated as Block 0624B Parcel 140 and is owned by the Crown (Government). MS-3 and MS-4 are located within small residential properties. Table 3.7-10 provides the land ownership for parcels within Mondesir-Saltibus

Table 3.7-10 Preliminary Profile of Land Ownership and Use – Mondesir-Saltibus Area

Block	Parcel	Area (hectares)	Land Ownership and Use
0624B	140	9.7 ha	Crown (Government) in agricultural use
0625B	71		Private land owned by heirs of the original owners; a portion of the parcel is also in a private pedestrian right-of-way
	52	3.6 ha	Privately held parcel
	105	2.3 ha	Privately held parcel
	100	0.70 ha	Crown (Government) in agricultural use

The combined LRTP map sheet and aerial photograph for MS-1 and MS-2 is provided in Figure 3.7-3.Some of the users within MS1 and MS-2 reported having lease agreements with Invest St. Lucia – the quasi-government institution responsible for management of these Crown lands. Comments from other users suggest that portions of the lands are owned by the residents; however, evidence of these claims was not found during our research conducted at the Government Land Registry.

Figure 3.7-3 Parcels within the Potential MS-1 and MS-2 Drilling Areas



3.8 COMMUNITY RISK ASSESSMENT

The following section contains results pertaining to TOR Task 1.22. The area of influence includes areas that could be affected by any slope failure induced by the project or areas exposed to geothermal gas emissions from the project.

3.8.1 Overview

Table 3.8-1 summarizes the results of the literature review and existing natural hazards risk and impact vulnerability ratings for the project region. A description of the findings for each natural hazard category are provided in the sections below.

Table 3.8-1 Existing Natural Hazards Risk and Impact Vulnerability Ratings

Natural Hazards	Risk Rating	Impact Vulnerability Ratings		
		People	Infrastructure	Economy
Seismicity and earthquakes	Low	Moderate	Moderate	Moderate
Landslides and slope stability	High to Low	High	High	High
Volcanic eruptions	Low [a]	High	High	High
Geothermal gas emissions	Low	High	--	Low
Hurricanes and tropical storms	High	High	High	High
Flood hazards	Moderate [a]	High	High	High

Notes:

[a] The risk rating pertains to the area of influence for potential exploration and development areas.

Sources: (Jacobs New Zealand Limited 2016, Jan Lindsay 2002, United Nations Office for Disaster Risk Reduction n.d.)

3.8.2 Seismicity and Earthquakes

Frequent moderate seismicity occurs in the Lesser Antilles island arc because of the crustal plate subduction process and associated volcanic activity (Jacobs New Zealand Limited 2016). The distribution of earthquake activity in the Eastern Caribbean varies, with high levels of seismicity commonly recorded near Antigua, and the lowest levels in the area from Grenada to Saint Lucia (Jacobs New Zealand Limited 2016). In the last 100 years, periodic swarms of shallow earthquakes have been reported in Saint Lucia considered to be triggered by a larger tectonic earthquake (Jan Lindsay 2002). Two substantial earthquakes that caused significant damage in Saint Lucia have been recorded, a magnitude (M) > 7.0 earthquake in 1906 and a M 7.5 to 7.75 in 1953 (Jacobs New Zealand Limited 2016). A more recent M 7.3 earthquake occurred in 2007 off the coast of Martinique, which resulted minor damage to some structures and significant damage to at least one structure (Office of the National Emergency Management Organisation Prime Minister's Office 2008).

Jacobs New Zealand Limited (2016) uses the probabilistic peak ground acceleration (PGA) values listed Table 3.8-2 for the design model to assess earthquakes with a moderate or greater potential to result in structure damage. These assumptions indicate that earthquakes with a moderate or greater potential to result in ground shaking are not expected to occur frequently.

Table 3.8-2 Peak Ground Acceleration

Return Period (years)	PGA (% g)	Perceived Shaking	Potential Structure Damage
475	0.20 – 0.25	Very Strong	Moderate
975	0.30 – 0.35	Very Strong/Severe	Moderate/Moderate to Heavy
2,475	0.45 – 0.50	Severe	Moderate to Heavy

Source: (Jacobs New Zealand Limited 2016)

The potential for ground surface rupture to occur across these faults is largely unknown (Jacobs New Zealand Limited 2016). No faults are known to be active, yet the reconnaissance geological mapping suggests the majority of the fault traces display offsets of Quaternary age (Jacobs New Zealand Limited 2016). There are no records of earthquakes with epicenters on faults in the study area that exceeded a magnitude that would likely result in ground surface rupture (≥M5) (Jacobs New Zealand Limited 2016). The potential for ground surface rupture to occur on known faults in the study is considered low; however, further study would be necessary prior to development to avoid siting structures within 200 meters of any identified fault traces to allow for uncertainties where fault traces are poorly constrained in the landscape and or concealed by vegetation and younger geological deposits (2016).

According to the World Bank, Saint Lucia has an annual average loss (AAL) from earthquakes of US $2.6 million (0.2 percent of the GDP), and a probably maximum loss from earthquakes of US $148 million (10.5 percent of the GDP) over a 250-year return period (2016). These values are less than half of those estimated for loss from hurricanes. Saint Lucia is considered to have a moderate vulnerability to impacts from seismicity and earthquakes in all categories.

3.8.3 Landslides and Slope Stability

The steep slopes and deep soils found on many of the Caribbean islands, including Saint Lucia, are naturally prone to landslides (Jacobs New Zealand Limited 2016). The combination of Saint Lucia's volcanic geology, wet tropical climate, and the rapid decomposition of bedrock in humid conditions has resulted in deeply weathered and relatively weak clayey tropical soils (Jacobs New Zealand Limited 2016). Weak clay-rich soil associated with areas of hydrothermally altered ground are highly susceptible to slips where any topographic gradient exists (Jacobs New Zealand Limited 2016). High-intensity or high-duration rainfall events commonly trigger landslides and slope failures in Saint Lucia, and earthquake-induced landslides have also been documented (Jacobs New Zealand Limited 2016). Numerous damaging landslides have been documented in Saint Lucia; the causes of the most significant

landslides have been attributed to events including hurricanes, tropical storms, and poor farming practices (i.e., mass rainforest canopy removal).

Research indicates that the majority of landslides in Saint Lucia are shallow failures of the soil mass at depths of 2 meters (6.6 feet) or less, the most common landslide types are debris flows, and earth flows, rockfalls, rock slides, and slumps also occur, but are less frequent (Jacobs New Zealand Limited 2016). Most slumps and rotational failures observed are associated with disturbed slopes such as road cuts or unplanned housing developments involving construction, earthworks, and vegetation changes (The University of the West Indies 2017). Roads in Saint Lucia are often susceptible to new slumps and slope failures due to redirected or inadequate drainage, exposed soils, over steepened cut slopes, and/or the removal of support at the toe of slopes (Jacobs New Zealand Limited 2016).

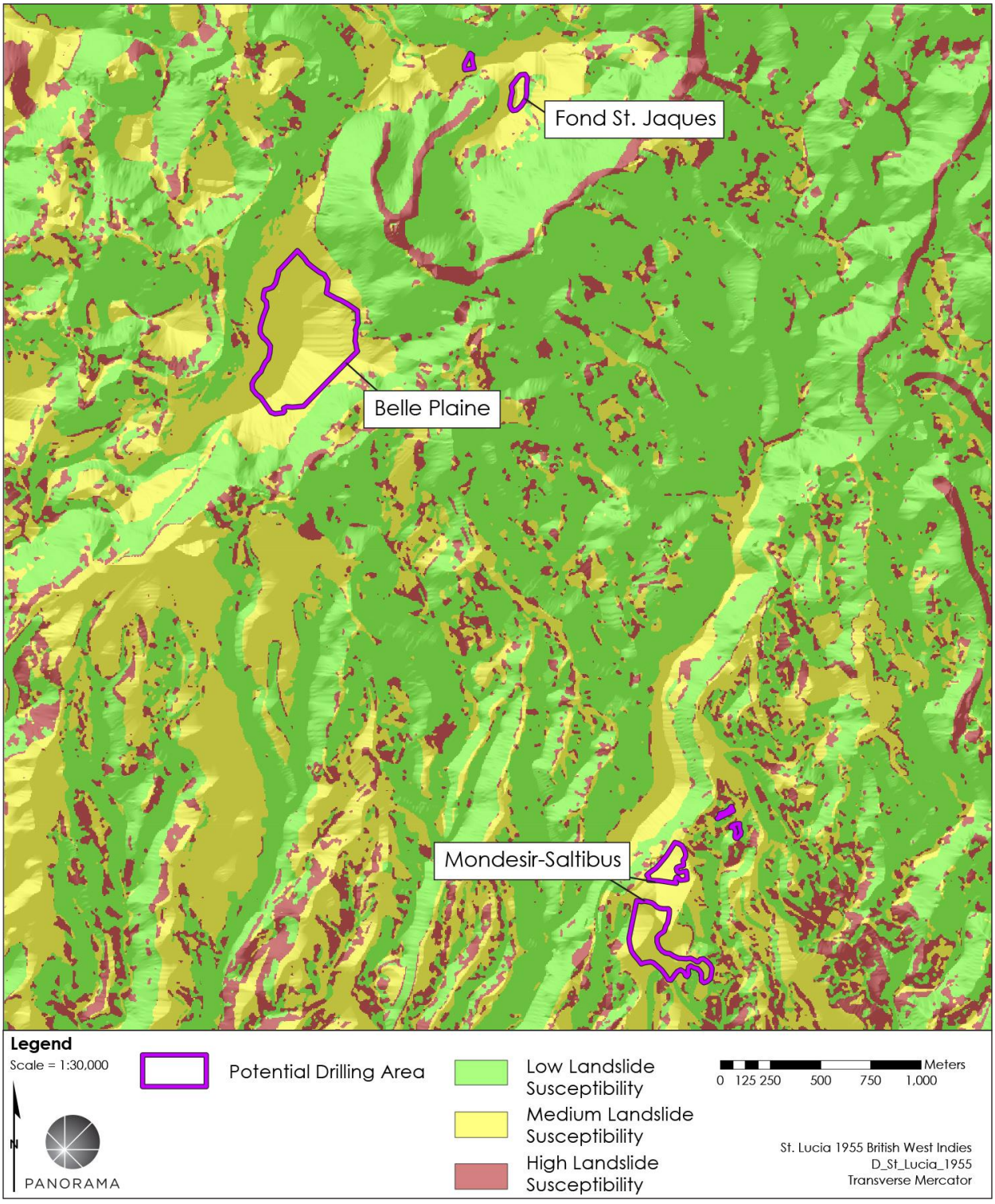
Jacobs New Zealand Limited (2016) conducted a review of numerous studies and mapping for documented landslide locations, susceptibility, and hazards, which indicate that most slopes in the potential development areas have a high susceptibility to landslides (Global Facility for Disaster Reduction and Recovery 2017, Global Facility for Disaster Reduction and Recovery 2017). Areas of landslide susceptibility are mapped on Figure 3.8-1. Jacobs New Zealand Limited also identified several additional landslides in the landscapes that were not documented.

3.8.4 Volcanic Eruptions

The Seismic Research Unit of the University of the West Indies assessed volcanic hazards in Saint Lucia following an increase in shallow earthquakes in 2000. The results of the assessment were published in the *Volcanic Hazard Assessment for Saint Lucia, Lesser Antilles* (Jan Lindsay 2002). The Soufrière Volcanic Zone is the primary focus of the assessment because it displays the youngest volcanic activity on the island and is considered the most likely location of future eruptions. The assessment authors present the following four future eruption scenarios:

1. A steam or hydrothermal eruption from the Sulphur Springs area. This type of event would be the most likely, but the impact would be relatively small (e.g. boulders ejected up to 200 meters [656 feet] from the vent) and would only affect the directly surrounding area for a short timeframe (i.e., days).
2. A small explosive magmatic eruption in the Belfond area forming an explosion crater. This type of event may produce large amounts of ash and projectile rock, but is unlikely to produce pyroclastic flows or lahars. It would be expected to last for a few weeks or months.
3. An effusive magmatic dome-forming eruption within the Qualibou Caldera. This type of event may generate dome collapse pyroclastic flows, pyroclastic surges, considerable airfall, and has a high risk of corresponding lahars being generated.
4. A large explosive magmatic eruption from within the Qualibou Caldera or from the Central Highlands area. This type of event is the least likely and worst-case

Figure 3.8-1 Areas of Landslide Susceptibility



scenario. It may generate large column-collapse pyroclastic flows, basal surges, significant airfall, and has a high risk of corresponding lahars in heavy rainfall events.

Pyroclastic flows and surges down the major valleys (eruption scenarios 3 and 4), and subsequent secondary hazards such as lahars, are the most significant volcanic hazard to personnel and infrastructure developments; however, these events are very unlikely to occur as no recent volcanic activity has been reported in Saint Lucia.

Figure 3.8-2 illustrates the combined hazard zones for three most likely eruption scenarios (1, 2, and 3) from the volcanic hazards assessment report. The worst-case scenario (4) was not taken into consideration in the map because it is considered the least likely to occur (Jan Lindsay 2002). The GoSL's Volcanic Eruption Response Plan (2009) incorporates the same hazards map (Figure 3.8-2) from the volcanic hazards assessment "for planning evacuation scenarios and in-long-term land-use planning in Saint Lucia" (Government of Saint Lucia 2009); however, no land use policies or planning strategies are identified in the plan due to the low likelihood of volcanic activity. Approximately one third of Saint Lucia is within a moderate, high, or very high volcanic hazard zone. The potential development areas near Belle Plaine and Fond St. Jacques are in a 'very high hazard zone.' The potential development area near Mondesir-Saltibus is in a 'high hazard zone.'

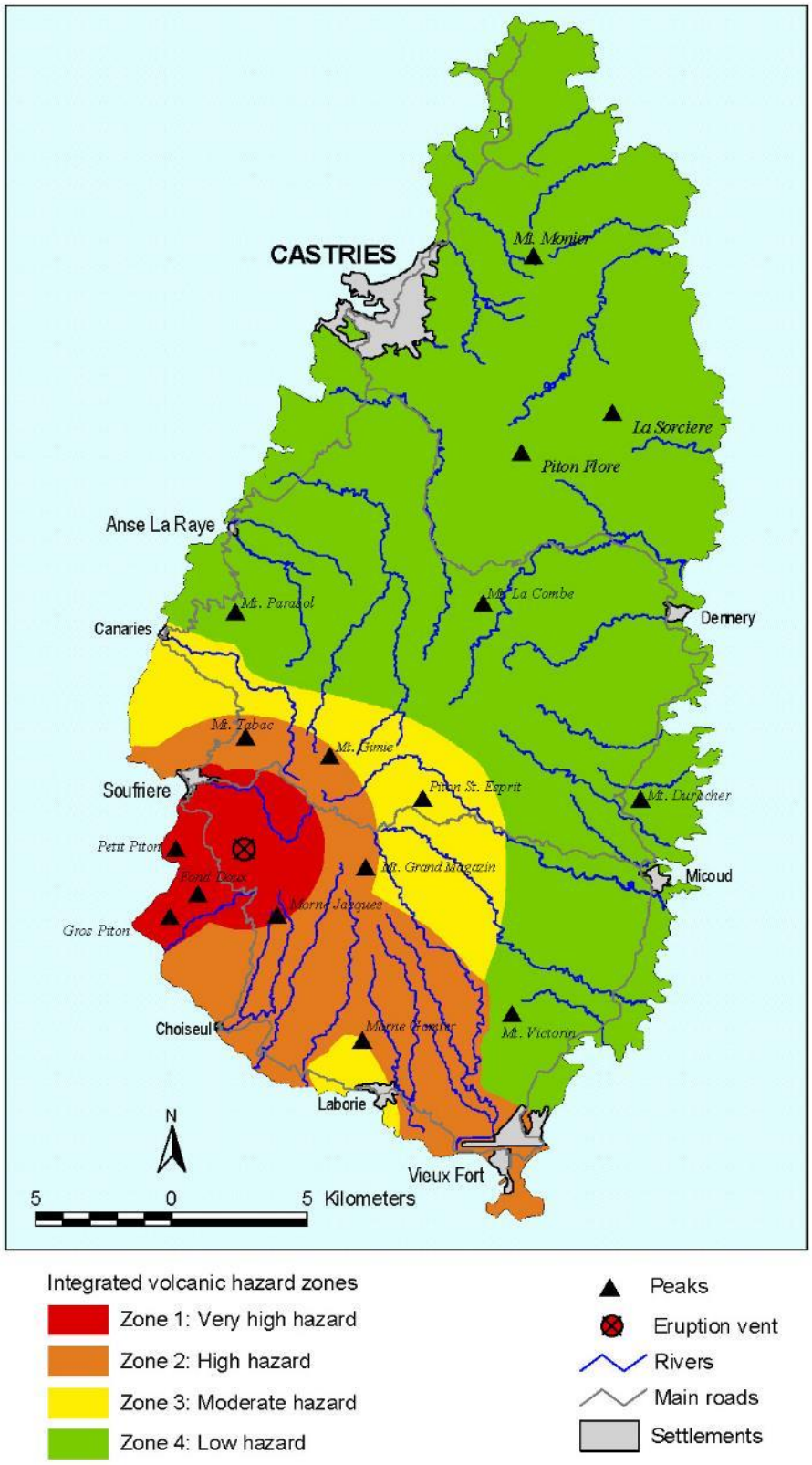
3.8.5 Geothermal Gas Emissions

Geothermal systems contain gases that are potentially hazardous to human health. The most common gases in geothermal systems include: carbon dioxide (CO_2), sulphur dioxide (SO_2), hydrogen sulphide (H_2S), and carbon monoxide (CO). People visiting Sulphur Springs and other areas of fumarolic activity in Saint Lucia are at the greatest risk for exposure to geothermal gas emissions (Jan Lindsay 2002).

CO_2 is an extremely dangerous gas. If inhaled at low levels, it can cause rapid breathing, increased heart rate, headaches, sweating, dizziness, muscular weakness, and drowsiness (Jan Lindsay 2002). At concentrations of 11 percent or more, it can result in unconsciousness in a minute or less, and at concentrations of 20 percent or more, it can cause almost instantaneous death (Jan Lindsay 2002). CO_2 tends to accumulate in hollows in the ground because it is heavier than air, and poses a risk of suffocation to people and animals because it is invisible and has no taste or smell (Jan Lindsay 2002). There have reports of people and animals dying from CO_2 inhalation associated with geothermal systems in the Caribbean, including Saint Lucia (Jan Lindsay 2002).

SO_2 is a gas that has a characteristic pungent odor. It can cause inflammation and burning of the eyes and respiratory tract, and make breathing difficult (Jan Lindsay 2002). When SO_2 is released into the atmosphere, it reacts with air and water particles to form sulfuric acid (H_2SO_4), a constituent of acid rain which can corrode metal, which causes destruction of vegetation and severe irritation to the eyes, nose, and throat (Jan Lindsay 2002). If SO_2 is inhaled, H_2SO_4 is formed in the upper respiratory tract, which over time may cause erosion of the teeth, and chronic irritation of the eyes, nose, throat and lungs (Jan Lindsay 2002).

Figure 3.8-2 Integrated Volcanic Hazard Zones (Eruption Scenarios 1, 2, and 3)



Source: (Jan Lindsay 2002)

H_2S is an extremely toxic gas that has a very strong and unpleasant smell, like rotten eggs. Inhalation of low concentrations of H_2S causes headaches, fatigue, dizziness, excitement, diarrhea, and irritation of the eyes and upper respiratory tract; and is extremely detrimental to the sinus and respiratory system (Jan Lindsay 2002). Inhaling large quantities of H_2S results in paralysis of the respiratory system and death. H_2S is heavier than air and can accumulate in low-lying areas, like CO_2.

3.8.6 Hurricanes and Tropical Storms

Hurricanes have been historically the most likely hazard to impact Saint Lucia; Saint Lucia faces a constant threat from hurricanes and other tropical storms (Government of Saint Lucia 2006). Hurricanes and tropical storms involve extremely high winds and heavy rains that place high levels of stress on buildings, facilities, and people. Hurricanes are also the primary cause of widespread slope failure (Government of Saint Lucia 2006). Recent climate change predictions indicate a future increase in hurricane activity and extreme rainfall events in the region, including an increase in associated landslide failure (Jacobs New Zealand Limited 2016). According to the World Bank, Saint Lucia has an AAL from hurricanes of US $9.5 million (0.7 percent of the GDP), and a probably maximum loss from hurricanes of US $382 million (27.2 percent of the GDP) over a 250-year return period (2016). Saint Lucia has a high vulnerability to impacts from hurricanes in all categories.

3.8.7 Flood Hazards

Inland flooding from heavy rainfall, often associated with hurricanes and tropical storms, is also a significant natural hazard in Saint Lucia. The risk and intensity of flooding in urban areas has increased in recent years due to an increase in development of impervious surfaces, inadequate storm drainage, and inappropriate garbage disposal that blocks storm drains (Government of Saint Lucia 2006). The loss of natural vegetation can also contribute to runoff and flooding problems in both urban and rural environments. Flooding in Saint Lucia has been attributed to tens of thousands of dollars in damage (Government of Saint Lucia 2006).

The Global Facility for Disaster Reduction and Recovery produces a national flood hazard map for Saint Lucia, as part of the Caribbean Handbook on Risk Information Management project (2017). The main areas at risk for flooding in Saint Lucia are narrow zones along river valleys and in the Soufrière Valley. The only flood hazard area identified within the potential development areas is located along the stream corridor through Fond St. Jacques and within a small portion of the Mondesir-Saltibus drilling area as shown in Figure 3.1-4.

4 IMPACTS AND RECOMMENDATIONS

4.1 WATER RESOURCES

4.1.1 Potential Impacts

4.1.1.1 Water Quality

The geothermal exploration project will involve drilling of slim hole wells and potentially full-size geothermal wells to test the geothermal resources. The equipment used during geothermal testing will require use of hydraulic fluids and materials that could contaminate the soil, surface water, or groundwater if the hazardous materials were spilled or not properly stored.

The rock cuttings extracted during drilling geothermal wells could also contain high levels of heavy metals that are potentially hazardous to human health. The geothermal fluid is expected to contain high levels of heavy metals and gases, and could contaminate water resources if the fluid were released to the surface or groundwater. Accidental spill or overflow of the drilling sump could also contaminate soils or surface water.

4.1.1.2 Water Supply

The geothermal drilling operations will use 5 to 30 liters per second of water during well drilling. Water will be obtained from streams near the drilling areas in Fond St. Jacques and Mondesir-Saltibus. A water storage tank would be used to contain water for drilling operations.

Water availability is a key concern to the local community and the streams in the Fond St. Jacques area could run dry during the dry season or periods of drought. Drilling operations in proximity to the spring and WASCO water storage facilities in Fond St. Jacques will need to avoid damage to any water containment or storage infrastructure.

4.1.2 Recommended Water Resource Mitigation Measures

Table 4.1-1 below lists the recommended water resource mitigation measures with the applicable location(s) and timing for implementation.

Table 4.1-1 Water Resource Mitigation Measures

Location	Timing	Recommendation
All areas where hazardous materials will be used or encountered	Develop plan prior to drilling; implement plan during drilling operations	GoSL shall require the drilling contractor to provide a drilling-fluids plan that includes procedures for fluid containment, contingency measures for spills and leaks, and emergency procedures.
Each drill site	During drilling operations	Only non-toxic drilling fluids, such as bentonite drilling mud and other inert additives, shall be allowed as part of the drilling contractors' preliminary drilling plan to protect surface water and groundwater during drilling and testing of the geothermal resource.
Each well	During drilling operations	All cased well segments shall have fully cemented annular volumes except for the production zone. Casing and cementing protect and isolate susceptible geologic formations from any contamination from geothermal production fluids and gases, and maximizes production enthalpy from the reservoir.
Each drill site	During drilling operations	A large sump lined with impermeable high-density polyethylene shall be used to maintain excess drilling fluids on site.
Each drill site	During drilling operations	Drilling muds shall be stored in mud tanks or in lined sumps with sufficient freeboard to prevent overflow (approximately 1 meter).
All work areas	Prior to civil works and throughout drilling operations	Sediment and erosion control best management practices shall be implemented to prevent soil erosion and sedimentation to downstream water bodies.
Vehicle fueling areas and drill sites	During civil works and drilling operations	No vehicle fueling or drilling operations shall be conducted within 15 meters (50 feet) of any surface water resources including creeks, springs, or any public water storage area. Secondary containment shall be provided around the drill rig where any drilling operations are conducted within 300 meters (1,000 feet) of any surface water resources.
Upstream and downstream of drilling areas	During drilling operations	GoSL shall require the drilling contractor implement a water quality sampling and monitoring program (see Appendix F) during drilling operations.
Water storage tanks	Prior to and during drilling operations	The water storage tanks for drilling operations shall be filled during periods when there is surplus water in area streams; the project water use must not affect water downstream water supplies. GoSL shall consider dedicating water storage tanks and water supply infrastructure to the community at the completion of the geothermal exploration activities.
Existing water infrastructure	During civil works and drilling operations	Water containment and storage infrastructure in proximity to drilling operations shall be protected from drilling equipment and site preparation activities. The location of the underground water pipeline at Fond St. Jacques shall be defined prior to drilling operations and drilling operations shall be located to avoid impacts on any water supply infrastructures including buried pipelines.

Location	Timing	Recommendation
Fond St. Jacques East	Drilling operations	Any drilling operations in Fond St. Jacques east shall be conducted downgradient/downstream of area springs
All locations requiring water supply	Water supply	Saint Lucia's approved water supply contractors and industrial water access procedures shall be followed for supply of water to the drilling areas.

4.2 GEOLOGY AND SOILS

4.2.1 Potential Impacts

4.2.1.1 Site Stabilization

Soil behavior pre, during and post drilling operations is an important factor to consider along with weather that can worsen certain soil conditions. Both Fond St. Jacques and Mondesir-Saltibus require transport through unpaved access roads. Depending on the contractor´s rig size, the road turning radius may need to be expanded to accommodate drilling equipment. The road expansion could encounter areas of steep slope, which could result in slope or soil instability. The Belle Plaine site has access via a paved and well-maintained backroad, although there are some instances of blind curves, the main obstacle in soil behavior may be the construction of a well pad within the agricultural land that is well irrigated, of dense use, and within a drainage basin that creates moist and unconsolidated soils. The drilling site within Fond St. Jacques east is located within an area with shallow groundwater and seepage from a nearby spring. The soils may be saturated and require treatment prior to heavy equipment access. The pre-drilling operations of infrastructure for roads, pads, and sumps must account for ´wet season´ conditions for usage and deterioration; conversely, the ´dry season´ conditions are equally important to study for execution of construction operations under maximized sunlight and minimal rainfall.

During drilling operations, subsidence is one of the major concerns due to equipment weight and presence of unconsolidated sediments. Post-drilling operations have limited risk with regards to landslide or unstable soil conditions other than the deterioration over time of the in-place structures (roads, pads, sumps, etc.). Pressure cap build up and formation fracture can occur if there is a build-up of geothermal pressure at the surface.

Productive top soil within the drilling area could be lost as a result of site grading during civil works. The project could also cause off-site erosion or sedimentation due to site grading activities.

4.2.1.2 Soil Contamination

Drill cuttings removed during drilling operations could contain high levels of the following heavy metals due to exposure to the geothermal resource:

- Arsenic
- Boron
- Mercury
- Zinc

- Cadmium
- Chromium
- Nickel
- Uranium
- Radium
- Gross alpha and beta

4.2.2 Recommended Mitigation Measures

Table 4.2-1 below lists the recommended geology and soils mitigation measures with the applicable location(s) and timing for implementation.

Table 4.2-1 Geology and Soil Mitigation Measures

Location	Timing	Recommendation
Roadway Expansion	Before Road Work	The contractor shall conduct a geotechnical investigation of areas of roadway expansion and implement all geotechnical recommendations. The geotechnical investigation shall address potential for landslides and slope failure in areas where roadways will be expanded.
Well Pads	Before pad construction; compaction testing during construction	The contractor shall conduct a geotechnical investigation in accordance with international standards and implement geotechnical recommendations for shallow groundwater and unconsolidated sediments to protect against subsidence. The geotechnical study shall address at a minimum: fracture gradient (via tr-axial or catalog), porosity, compaction, water table, grain size and grain size Subsurface coring or coring logs from previous and close-by areas (CPT) shall be incorporated into the geotechnical investigation as needed. Well pads and areas supporting heavy drilling equipment shall be compacted to a minimum of 90%
Each drill site	Before construction of pad; during reclamation	Stockpile topsoil that is removed during grading of well pads; reapply topsoil during site reclamation
Each drill site	During drilling operations	Sample drill cuttings for the following heavy metals an raidonuclides: • Arsenic • Boron • Cadmium • Chromium • Nickel • Mercury • Zinc • Uranium • Radium • Gross alpha and beta If the sample exceeds toxicity thresholds for any heavy metal, the drill cuttings shall be treated as hazardous waste and either be capped with 1 meter (3 feet) of clean fill material or transported to a landfill that is authorized to accept hazardous waste.
Each drill site	During civil works and drilling operations	Sediment and erosion control best management practices shall be implemented to prevent soil loss on and off-site. Drainage plans shall account for potential heavy rains in the design of pads, roads, sump and other areas where heavy machinery will be located or used
Exploration wells	Post-construction	Monitor wellhead pressure at any wells that are not plugged and decommissioned and depressurize when needed.

4.3 AIR QUALITY

4.3.1 Potential Impact

4.3.1.1 Fugitive Dust

Grading of access roads and well pads could generate emissions of fugitive dust (PM_{10}). The potential dust emissions could affect air quality and visibility in the neighboring communities.

4.3.1.2 Geothermal Gases

Geothermal fluids are known to contain the following gases, or constituents in gases, which are potentially hazardous to human health at high concentrations:

- CO_2
- H_2S
- Boron
- Arsenic
- Mercury

These gases occur naturally in the geothermal resource and the geothermal gases could be released during geothermal testing. Residential areas are located directly adjacent to the Fond St. Jacques west and east drilling sites. These residents could be exposed to high levels of gases if geothermal testing were conducted in the area or if a blowout occurred during drilling.

4.3.2 Recommended Mitigation

Table 4.3-1 below lists the recommended air quality mitigation measures with the applicable location(s) and timing for implementation.

Table 4.3-1 Air Quality Mitigation Measures

Location	Timing	Recommendation
Each drill site	During drilling operations	Conduct air quality monitoring for PM_{10}, CO_2, and H_2S at locations near the drill sites prior to and during geothermal testing activities. If emissions exceed thresholds corrective actions shall be implemented including potential temporary cessation of geothermal testing until air quality levels are below St. Lucia and international air quality thresholds.
Each drill site	During civil works and drilling operations	Apply water to exposed soil surfaces (including drill pads and access roads) during the dry season to control fugitive dust emissions.
All wells	Prepare plan before drilling operations	The drilling contractor shall prepare an emergency evacuation and response plan to address contingencies and procedures in case of well blow-out, loss of control, or other emergencies,
All work areas	Before drilling operations	Implement safety procedures to protect workers and community members from potentially harmful geothermal gases.

4.4 NOISE

4.4.1 Potential Impact

Slimholes would be drilled using a small geothermal drill rig that is capable of reaching up to 2,000 meters (6,562 feet) below ground surface (bgs). Slim holes would be drilled 24 hours per day. Full-size geothermal test wells would be drilled using a large geothermal drill rig and constant drilling, 24-hours per day.

Drilling slim holes would cause a temporary increase in the daytime and nighttime ambient noise level in proximity to the drill rig; the increase in noise could affect people who live in proximity to the drilling. Drilling at night could affect sleep. The level of impact would depend on the proximity of the drill rig to residences.

Drilling full-size geothermal test wells would cause a temporary increase in ambient noise levels. The increase in noise levels from the constant drilling for up to 3 months could be significant.

4.4.2 Recommended Mitigation

Table 4.4-1 below lists the recommended noise mitigation measures with the applicable location(s) and timing for implementation.

Table 4.4-1 Noise Mitigation Measures

Location	Timing	Recommendation
Wells	During project design	Locate deep geothermal wells 150 meters (500 feet) or more from the nearest residence or sensitive noise receptor to the extent feasible.
Areas in Proximity to Well Pad	Prior to drilling	Educate nearby residents about the anticipated noise level and methods to reduce noise levels. Encourage residents near drilling areas to stay in other areas at night to avoid drilling noise.
Each drill site	During drilling operations	Equip all vehicles and equipment with proper noise-reduction parts, such as mufflers, silencers, insulators, and enclosures.
Each drill site	During drilling operations	Install acoustic barriers such as hay bales where drill rigs are located within 100 meters of sensitive receptors.
Each drill site	During drilling operations	Establish a contact person for neighbors to call regarding excessive noise. Install additional noise attenuation measures if noise levels exceed standards.

4.5 BIOLOGICAL RESOURCES

4.5.1 Potential Impact

The geothermal exploration would not directly impact any sensitive plants or habitats because no sensitive plant species or habitat occur within any of the drilling areas. Drilling locations consist of disturbed land or agricultural areas.

The target drilling areas in Belle Plaine and Mondesir-Saltibus are located adjacent to a forested area that provides suitable habitat for birds including Saint Lucia priority species. Noise from geothermal drilling operations could impact bird nesting behavior. Wildlife could also be injured if they were to enter a geothermal drilling site and become trapped in equipment or excavated area. The exploration could indirectly impact sensitive habitats through introduction of invasive plant species to the drilling sites.

4.5.2 Recommended Mitigation Measures

Table 4.5-1 below lists the recommended biological resource mitigation measures with the applicable location(s) and timing for implementation.

Table 4.5-1 Biological Resource Mitigation Measures

Location	Timing	Recommendation
Each drill site	During drilling operations	Enclose the well pad within temporary exclusion fencing to prevent wildlife from entering the work site.
Belle Plaine and Mondesir	Project design	Locate wells at minimum of 75 meters (250 feet) from the forested edge in the Belle Plaine and Mondesir-Saltibus areas and avoid drilling during the peak of bird nesting season (April to June) to the extent feasible. If drilling must take place April to June, conduct a survey to locate bird nests within 30 meters (100 feet) of the drill rig. Install noise barriers to protect the nesting birds, if needed.
Each drill site	Prior to construction	Retain a wildlife biologist to conduct surveys of the drilling site and surrounding 75 meter (250 feet) area prior to construction activities. If any priority species are identified in the area of direct impact, no activities shall be conducted in the area until the priority species leaves the area.
All areas	Civil works and drilling operations	Contain waste within covered containers.
All work areas	Civil works and drilling operations	Clean vehicles and equipment prior to arrival on site to avoid introduction of invasive plants. No pets shall be allowed on the site.
All work areas	Civil works and drilling operations	Implement a worker training program that includes worker training to recognize priority species that could occur in the area and identify measures to avoid those species.

Location	Timing	Recommendation
All work areas	At the completion of construction in each area	The contractor shall remove all construction equipment, supplies, and debris from all work sites including any staging yards and drill areas, and restore all well pads to match undisturbed conditions. Prior to construction the contractor shall prepare a restoration plan that describes the methods for restoration of the well sites and a reference site in an undisturbed area that can be used to define the target restoration conditions. A pre-construction report shall also be filed by the contractor to document the site conditions prior to project disturbance.

4.6 ARCHEOLOGICAL AND CULTURAL RESOURCES

4.6.1 Potential Impacts

The drilling target areas in Belle Plaine and Mondesir-Saltibus include areas that contain historic and pre-historic resources. Areas with a higher sensitivity for cultural resources are shown on Figure 3.6-1 and Figure 3.6-2. Grading of well pads and access roads and drilling geothermal wells could disturb or destroy historical resources in Belle Plaine or Mondesir-Saltibus areas.

4.6.2 Recommended Mitigation

Table 4.6-1 below lists the recommended archaeological and cultural mitigation measures with the applicable location(s) and timing for implementation.

Table 4.6-1 Archaeological and Cultural Resource Mitigation Measures

Location	Timing	Recommendation
Belle Plaine and Mondesir	Prior to project implementation	Retain a qualified archaeologist to conduct shovel test pit investigation to evaluate the potential for subsurface resources in Belle Plaine and Mondesir-Saltibus areas
Grading and excavation areas	During civil works	Avoid grading and drilling operations within historically sensitive areas to the extent feasible. If avoidance is not feasible, a qualified archaeologist shall survey the area (if not previously surveyed) and conduct subsurface testing. Resources should be catalogued and evaluated for their significance.
Belle Plaine and Mondesir	Civil works	Retain a qualified archaeologist to conduct archaeological monitoring during vegetation removal and grading operations in historically sensitive areas and MS-3 and MS-4. Collect and archive any resources that are encountered during archaeological monitoring.
All	Prior to civil works	Conduct worker training to relay the type of resources that might be encountered, procedures to follow if resources are discovered, sensitivity of resources, and the importance of protecting the resources.

4.7 SOCIO-ECONOMIC ENVIRONMENT

4.7.1 Potential Impacts

The project would create temporary job opportunities during civil works and drilling operations, which would have a beneficial impact on employment. Many of the jobs during drilling operations will require specialized skills and workers would come from the international market for specialized jobs. For non-specialized jobs, the project can create an equal employment opportunity for men and women.

The project will involve use of expensive machinery and equipment, which could attract vandalism or theft to the area.

The potential drilling areas include areas that are under agricultural production. Drilling operations could result in temporary loss of livelihood for farmers in the area. Disturbance of playing fields could disrupt the community.

Other key community concerns included noise, geothermal gas emissions, and water supply impacts. These issues, and mitigation measures to reduce the effects, are addressed above under noise, air quality, and water resources, respectively.

4.7.2 Recommended Mitigation

Table 4.7-1 below lists the recommended socio-economic mitigation measures with the applicable location(s) and timing for implementation.

Table 4.7-1 Socio-Economic Mitigation Measures

Location	Timing	Recommendation
Well Pads and access roads	Prior to project implementation	Compensate farmers for temporary loss of livelihood from the geothermal exploration in accordance with the Resettlement Action Plan and Resettlement Policy Framework
Drilling areas and worker camps	During project implementation	Provide fences and security around staging and material storage areas and at worker camp(s) for community safety and to protect from vandalism or theft.
All	Civil works and drilling operations	Comply with the World Bank's social policies regarding age, gender, ethnicity, and religious equality; provide equal employment opportunities for non-specialized labor categories.
All	Civil works and drilling operations	Develop a grievance redress process with an assigned community liaison to address community and worker complaints during project implementation.
Fond St. Jacques and Mondesir-Saltibus	Civil works and drilling operations	Avoid project activities (i.e., drilling, staging, or storage) in recreational areas such as playing fields where feasible to minimize disruption to the communities in the drilling areas.

4.8 COMMUNITY RISK ASSESSMENT

4.8.1 Impact Analysis

4.8.1.1 Seismicity and Earthquakes

Seismicity typically occurs naturally; however, surface and subsurface human activities can also induce seismicity. Geothermal drilling operations are not known to cause seismicity and the drilling operations do not involve any actions that are suspected of inducing seismicity. The geothermal exploration and testing would not increase pressure within a known fault system. Geothermal exploration activities including slim-hole drilling and exploration well construction and testing would not induce seismicity.

The existing risk of earthquakes in the area is considered low. The risk to workers and equipment during geothermal exploration activities would not be considerable.

4.8.1.2 Landslides and Slope Stability

The primary transport roads and potential development areas have a high risk of landslides and slope failure. Activities that destabilize slopes in these areas, such as constructing new roads, expanding existing roads, grading, or removing vegetation could increase the risk of landslides and slope failure. Poor drainage and stormwater runoff practices can also increase the risk of landslides and slope failure.

The drilling areas in Belle Plaine and Mondesir-Saltibus are in areas with low susceptibility to landslides and clearing vegetation or grading for well pads would not impact slope stability because the drilling area is located on flat areas that are stable.

The east Fond St. Jacques potential drilling area is located at the bottom of a slope that exhibits signs of recent landslide; this potential drilling area is susceptible to landslide or mudflow from adjacent hill slopes.

4.8.1.3 Volcanic Eruptions

As stated in Section 3.8.4, approximately one third of Saint Lucia is within a moderate, high, or very high volcanic hazard zone (refer to Figure 3.8-2); however, the risk of a volcanic eruption is considered low. The potential development areas near Belle Plaine and Fond St. Jacques are in a very high hazard zone, and the potential development area near Mondesir-Saltibus is in a high hazard zone.

The project would no effect on the volcanic eruption risk or vulnerability. The geothermal system that is the target of the geothermal exploration drilling project is a result of the volcanic activity in the region. Drilling wells and any future development of the geothermal resource would not change the potential for volcanic eruption.

The risk to workers and equipment from the volcanic hazard during exploration drilling would not be considerable. The risk is similar to other areas in Saint Lucia.

4.8.1.4 Geothermal Blow-outs and Gas Emissions

Well blow-outs (uncontrolled release of geothermal fluids) are a rare occurrence but are a potential hazard. The risk of a blow-out is reduced or eliminated by use of a blow-out preventer and by using drilling personnel who are very experienced with drilling geothermal wells.

Potentially harmful geothermal gases naturally occur in the region (e.g., CO_2, SO_2, H_2S, and CO), such as at Sulphur Springs. There are no known sources of geothermal emissions currently in the project areas.

Geothermal gases could be encountered during well drilling and testing. Steam and hot water produced from the geothermal well could burn employees or animals. If not properly vented. Vented steam could also damage nearby crops and vegetation. Wells should be vented through a silencer to avoid direct venting to vegetation.

Uncontrolled emissions would pose a hazard to workers and adjacent community members who could be exposed to geothermal gases (emitting from well locations. H_2S, which has a rotten egg odor, is the gas of primary concern in geothermal fluids. Workers will be protected by using H_2S monitors at the drill rig to alert workers to dangerous levels of H_2S. The community would be protected by maintaining a buffer between the drilling location and residents. Blow-out preventers and experienced drilling crews would reduce or eliminate the risk of blow-outs and uncontrolled release of gases.

4.8.1.5 Hurricanes and Tropical Storms

Hurricanes and tropical storms present a risk to worker safety and drilling operations. Project activities associated with exploration drilling should be scheduled to avoid the hurricane season (approximately June through November), to the extent possible, to avoid putting workers at significant risk of hurricane and tropical storm hazards.

If the hurricane season cannot be avoided, the relevant policies of the GoSL's Hurricane Response Plan should be adopted to protect workers. Any development associated with the project should comply with the GoSL's Engineering Guidelines for Incorporating Climate Change into the Determination of Wind Forces on Buildings and Other Structures, Appendix to the National Hurricane Plan (Government of Saint Lucia, 2009).

4.8.1.6 Flood Hazards

The drilling areas in Belle Plaine and Mondesir-Saltibus are not within flood hazard zones. The potential drilling area in Fond St. Jacques is located in an area that is at risk of flooding. The primary access corridors for all three of the project areas cross multiple canyons and drainages that have some level of flooding hazard, as shown on the Global Facility for Disaster Reduction's (GFDR's) Flood Hazard Map (2017).

Positioning equipment and workers within a flood hazard area in Fond St. Jacques during heavy rains would be a significant risk to life and property. Project activities should avoid potential flood hazard areas, such as those shown on the GFDR's Flood Hazard Map (2017), during periods of heavy rainfall in the region.

The geothermal exploration drilling program would disturb a limited amount of land for access roads and exploration well pads. The minimal areas of vegetation removal and ground disturbance would not substantially increase offsite flooding.

4.8.1.7 Fire

Workers smoking on the project site could potentially ignite a fire in the project area. In addition, the combustion engines, welding, or cooking at the site could start a fire in trees or brush surrounding the drilling area.

4.8.1.8 Worker Health and Safety

Drilling deep geothermal wells requires working at heights (on drill rigs) and use of equipment that could be hazardous to workers if proper protections were not in place. Geothermal drilling could also expose workers to geothermal gases, such as H_2S.

4.8.2 Recommended Mitigation

Table 4.8-1 below lists the recommended hazard mitigation measures with the applicable location(s) and timing for implementation.

Table 4.8-1 Hazard Mitigation Measures

Location	Timing	Recommendation
All infrastructure in landslide prone areas	Prior to project implementation	Relevant policies of the GoSL's Landslide Response Plan (2008) should be incorporated into Emergency Procedures Plan and project activities to address the general risk of landslides and slope failure on workers, equipment, and infrastructure, as well as to implement appropriate response procedures in the event of a landslide. Site-specific geotechnical analysis should be conducted in areas suspected of having unstable slopes prior to constructing or expanding roads, grading activities, and substantial vegetation removal on steep slopes or channels, to determine if specific design measures are necessary to address the hazard, such as construction of retaining walls, drainage improvements, or other reinforcement structures.
All	During project implementation	Project Emergency Procedures Plan should incorporate the applicable elements of the GoSL's Earthquake Contingency Plan (Government of Saint Lucia, 2007).
Drilling areas	During well drilling	A mitigation plan should be developed to require that proper personal protection equipment and gas detection devices are used during drilling activities
All	Prior to project implementation	Relevant policies of the GoSL's Volcanic Eruption Response Plan (2009) should be included in the Emergency Procedures Plans and implemented to protect workers in the event of volcanic activity during drilling activities and to the appropriate evacuation areas.

Location	Timing	Recommendation
All	Prior to project implementation Civil works and drilling operations	Any roads that are constructed should be designed with proper drainage channels and culverts that avoid substantial impacts to the existing drainage network. No new impervious surfaces, such as paved roads, should established within Fond St. Jacques flood hazard area. The relevant policies and procedures of the GoSL's National Flood Plan for floodplain management and flood response should be included in the Emergency Procedures Plans and adopted to protect workers, construction equipment, and project facilities (Government of Saint Lucia, 2006).
All	Civil works and drilling operations	Smoking shall only be permitted in designated areas.
All	Drilling and testing operations	The drilling contractor shall have extensive experience drilling geothermal wells to minimize the risk of blow-outs and uncontrolled flow of geothermal fluids.
Drilling areas	Drilling operations	All drill rigs that could encounter the geothermal resource shall be fitted with blow-out prevention equipment to avoid uncontrolled discharge of geothermal fluids and potential damage to vegetation, workers, and the surrounding area.

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5 SUMMARY AND CONCLUSIONS

5.1 SUMMARY OF SCOPING STUDY RESULTS

Panorama Environmental, Inc. has completed the scoping studies outlined in the TOR Activity 1 – Baseline Assessment Studies. The scoping studies included reviewing existing literature and field surveys to define the baseline physical, biological, archaeological/cultural and socio-economic aspects of the project area of interest. Data was obtained from the DSD and publicly available sources. Field surveys were conducted in September 2017.

The environmental resources within the project area of influence are summarized in Table 5.1-1:

Table 5.1-1 Summary of Scoping Study Results

Resource	Study Results
Water resources	Streams are located in proximity to the drilling areas in Fond St. Jacques and Mondesir-Saltibus. A spring and water supply infrastructure are located in proximity to the Fond St. Jacques East area. The spring in Fond St. Jacques is the only use of groundwater within the area of influence and the spring is upgradient of the drilling area. Water quality at times does not meet drinking water standards due to the presence of fecal coliform. Drought susceptibility and available water supply are key concerns.
Geology and Soils	There are no known sources of soil contamination within the area of influence. Pesticides may be used within the agricultural properties, but the of pesticides has not been documented. The underlying geology and rock cuttings extracted during drilling could contain high levels of heavy metals due to interaction with the geothermal resource.
Air Quality	Ambient air quality in the vicinity of the project areas is well below WHO guidelines for NO_2, SO_2, and H_2S. Elevated levels of NO_2, SO_2, and H_2S were measured at Sulphur Springs; however, these elevated levels were consistent with previous studies and are not representative of air quality conditions in the project area or vicinity.
Noise	Baseline noise levels in the area of influence are typical for rural areas. Intermittent noise from traffic and stationary noise from generators was detected in the area.
Biological Resources	The drilling sites are characterized by non-native habitats and agricultural land use. Forest habitats along the buffer of the drilling sites in Belle Plaine and Mondesir-Saltibus provide habitat for priority bird species.
Archaeological/Cultural Resources	The potential drilling area at Belle Plaine is located on or near the locations of two early plantations, Rabot Estate and Belle Plaine Estate. The potential drilling area at Mondesir-Saltibus is located within the Parc Estate area. Amerindian resources were present within the Belle Plaine and Mondesir-Saltibus potential drilling areas.

Resource	Study Results
Socio-economic Environment	The potential drilling areas at Belle Plaine and Mondesir-Saltibus are currently used for agricultural development. The Belle Plaine and Fond St. Jacques areas are primarily owned by families. The Mondesir-Saltibus area is primarily government owned land that is leased to farmers.
Natural Hazards	The Fond St. Jacques area is located in an area that is prone to flooding and landslides. The other drilling areas are not in flood prone or landslide prone areas. Other hazards that could affect the areas include hurricanes, seismic activity, flooding, and wildfires.

5.2 DATA GAPS

Several data gaps were identified in this study including:

- No data was available on groundwater aquifer properties sufficient to support a detailed hydrogeological model
- Insufficient data were available to calculate seasonal discharge on area streams
- The buried water line from the spring in Fond St. Jacques was not located
- Air quality data were collected during a short time period in the rainy season and data may not be characteristic of conditions during the dry season
- The biological surveys were conducted during a one-week period in September; the surveys may not reflect species use of the area during the spring when nesting is more likely to occur
- The archaeological pedestrian survey did not include any subsurface investigation and the presence of subsurface resources cannot be determined

Panorama provided recommendations for filling data gaps in situations where the geothermal exploration project would result in potentially significant social or environmental impacts. Subsequent evaluation and baseline study may be required prior to development of a geothermal power plant. Development of the geothermal resources is beyond the scope of this Scoping Study and ESIA.

5.3 PRELIMINARY IMPACT CONCLUSIONS AND RECOMMENDED MITIGATION

Panorama identified preliminary impact conclusions and recommended mitigation measures to avoid, minimize, and compensate for significant impacts (refer to Section 4). All potentially significant impacts could be mitigated to avoid significant impacts on the community.

The impacts of the geothermal exploration program would be temporary and most impacts would be limited to the duration of the drilling activity. There would be no long-term or lasting significant impacts if a geothermal resource is not identified. Well pads would be reclaimed through grading to match the natural contours and revegetation of the site. The wells would be plugged and abandoned according to industry standard if a viable geothermal resource is not indicated through the results of drilling and well testing.

If a viable geothermal resource is identified, the well pads would be a long-term feature. Full-size well at Belle Plaine and Mondesir-Saltibus wells, if successful, could potentially be used for geothermal production or injection. The slim holes could be used as monitoring wells or could be redrilled as larger, production-size wells. Large wells and production drilling is not expected at Fond St. Jacques.

The preliminary impact conclusions and mitigation in this Scoping Studies report will be evaluated further during preparation of the ESIA and detailed procedures for implementing the mitigation will be provided in the Environmental and Social Management Plan.

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APPENDIX A

Air Quality Data

APPENDIX A. AIR QUALITY SURVEY PHOTOS

DAY 1- SEPTEMBER 5TH, 2017

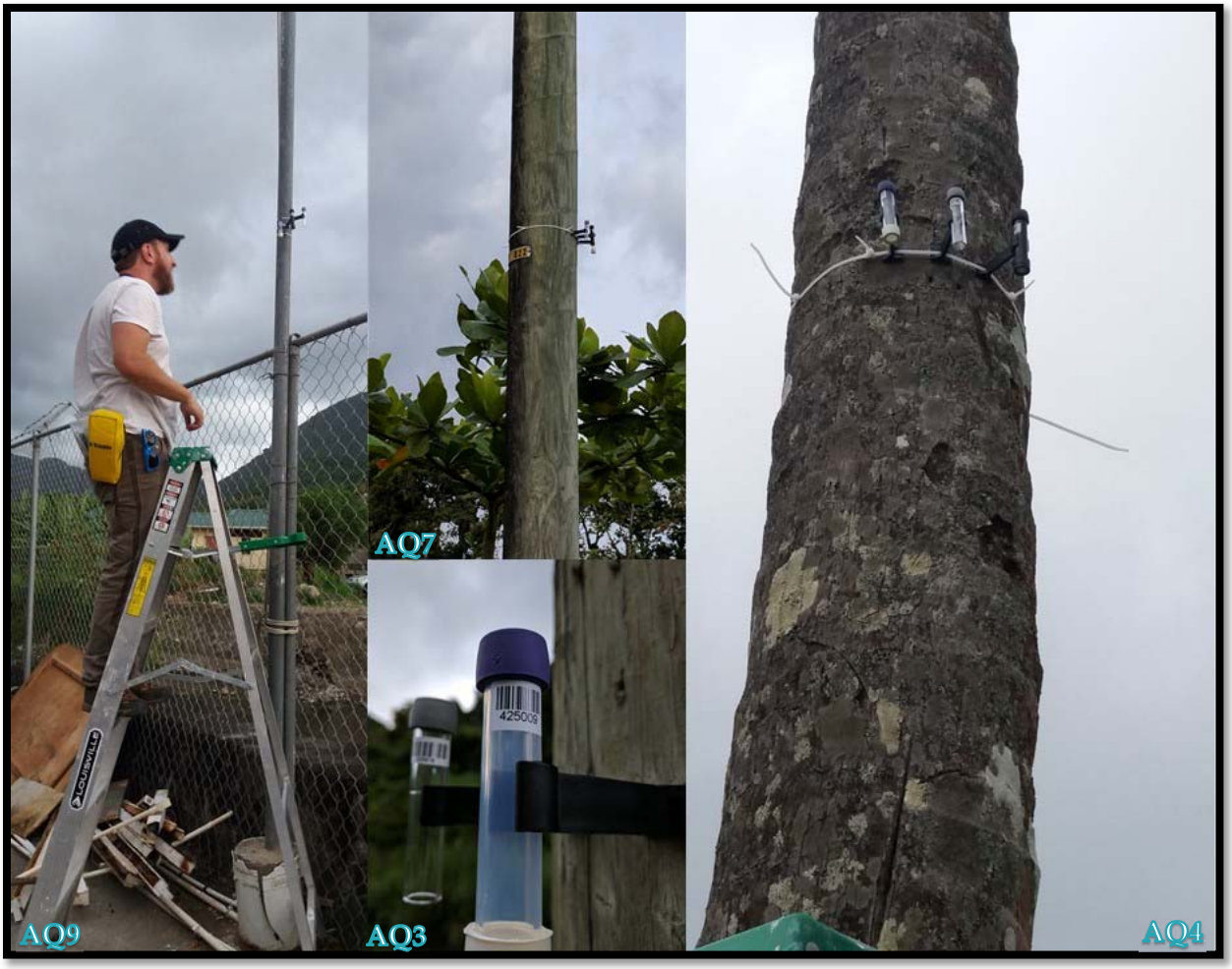

Illustration 1. Air Quality Survey - First Day.

DAY 2 - SEPTEMBER 6TH, 2017

Illustration 2. Air Quality Survey - Second Day.

Sample H_2S Protocol Sheet

Customer: ORMANTINE USA		**Contact:** Michael Willmont	
Address:		**Contact email:**	
		Contact Tel. No:	**Account No:** Y2000
Email			**Lab Ref:**
Type of Tube: H_2S	**Lot No:** 51161/4	**Bar Codes:** 1010223-1010245	
Purchase Order No: 18662	**SOR number:** 38804	**Date of dispatch:** 08/10/2017	
TO BE COMPLETED BY CUSTOMER			
Email address for reports to be sent to:			
Contact Name:	**Customer Reference/Job Number:**		

Inorganics – Analysis Required:

- ☐ Nitrogen Dioxide (NO_2)
- ☑ Hydrogen Sulphide (H_2S)
- ☐ Chloride (Cl)
- ☐ Sulphate (SO_4)
- ☐ Nitric Oxide (NO)
- ☐ Ammonia (NH_3)
- ☐ Bromide (Br)
- ☐ Nitrogen Dioxide/ Sulphur Dioxide
- ☐ Tubes returned – Analysis not required
- ☐ Ozone (O_3)
- ☐ Phosphate (PO_4)
- ☐ Sulphur Dioxide (SO_2)
- ☐ Fluoride (F)
- ☐ Nitrate (NO_3)

Fast Track Analysis – An additional charge will apply

- ☐ Fast Track Analysis & Report 5 working days – Must be pre-arranged.
- ☐ Premium Fast Track – Must be pre-arranged. Contact diffusionradko.com

Number of tubes returned: ☐

Sampling and Monitoring Record - Black

Bar Code label	Location Coordinates (X; Y) (Projection: Transverse Mercator. Datum: St. Lucia 1955)	Sampling		Exposure time (Hours)	Other information
		Start date and time	Finish date and time		
1010223	Travel Blank	09/05/17 8:48 am	9/25/17 7:00	-	-
1010224	Travel Blank	09/05/17 8:48 am	9/25/17 7:00	-	-
1010225	Travel Blank	09/05/17	9/25/17	-	-

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		8:48 am	7:00		
1010226	Travel Blank	09/05/17	9/25/17	-	-
		8:48 am	7:00		
1010227	Travel Blank	09/05/17	9/25/17	-	-
		8:48 am	7:00		
1010228	La Haut (502354.16; 1532392.58)	09/05/17	9/25/17	479	AQ14 - Tubes installed near the registration building for the La Haut Hotel outside of Soufriere.
		9:21	8:20		
1010229	Fond St. Jacque 1 (505697.59; 1529120.83)	09/05/17	9/25/17	No trace of tubes	AQ1-B - Initially the tubes were installed on an abandoned house (south side of the house), next to a trail; however, to ensure the stability of these tubes, they were relocated to a tree next to the initial house. There are crops (bananas, cocoa). The main road is very narrow for the displacement of larger vehicles.
		10:29	9:01		
1010230	Fond St. Jacque School (504975.66; 1529721.89)	09/05/17	9/25/17	477.5	AQ02 - The tubes were installed on a wall (west) of the Fond St. Jacques Primary School. This is located next to the main road.
		11:15	8:46		
1010231	Belle Plaine Generator (504733.32; 1528664.69)	09/05/17	9/25/17	477.5	AQ03 - The tubes were installed on a light pole at 3m above ground between the local road and the LUCELEC generator.
		11:50	9:13		
1010232	Belle Plaine Drill Site (504497.87; 1528007.49)	09/05/17	9/25/17	476	AQ04 - The tubes were installed on a coconut tree at 3.50m above ground. Windy day (NE-SW). The area is flat surrounded by steep mountains. There is a presence of agriculture interests (banana, coconut, cocoa), as well as livestock, goats, and domestic pets.
		12:25	9:30		
1010233	Belle Plaine Nursery (504262.91; 1527572.65)	09/05/17	9/25/17	476.5	AQ05 - Tubes were installed on wall gutter at a 2,10m above ground. Windy day (E-W). There are 4 greenhouses located near the
		13:05	9:40		

					samplings site, as well as a main road.
1010234	Saltibus School (506717.32; 1525848.05)	09/05/17 15:10	9/25/17 10:46	475.5	AQ06 - Tubes were located on a pipe between the local school (Saltibus) and community center, 5m above ground.
1010235	Parc Estate Drill Site (506428.84; 1525305.34)	09/05/17 15:50	9/25/17 10:37	475	AQ07 - Tubes were installed on a light pole at 4m above ground. The area has a soccer field. There is an unpaved road.
1010236	Parc Estate/Tete Morne Main Road Entrance (504588.74; 1521330.67)	09/05/17 16:45	9/25/17 10:10	473.5	AQ08 - Tubes were located 3m above ground, at the intersection of the main road with two secondary unpaved roads.
1010237	Rodney Heights - Base Station (513548.93; 1554903.44)	09/05/17	9/19/17 8:50	n/a	AQ15 (Blown into garden)
1010238	Soufriere - Fire Station (501662.68; 1531580.77)	09/05/17 17:30	9/25/17 8:29	471	AQ09 - Tubes were installed next to the fire station (west side) on a light pole 3m above ground. Next to the main road. Next to a drainage.
1010239	Sulfur Springs (503220.76; 1529558.78)	09/06/17 11:25	9/25/17 11:45	456	AQ10 - Tubes were on a pole where previous air quality studies were made. Area with geothermal manifestations (hot springs, mud pools). Tourist area.
1010240	Union Vale (502289.70; 1526560.38)	09/06/17 12:25	9/25/17 11:28	455	AQ11 - Tubes were installed on a cocoa tree 2.10m above ground. The area is surrounded by a river, a main road and some crops (cocoa, coconut).
1010242	Fiette (502251.56; 1523623.93)	09/06/17 13:30	9/25/17 11:15	453.5	AQ12 - Tubes were installed on a light pole across the road from a historical ruin of a colonial windmill, 3m above ground.
1010241	Dacretin (504053.18; 1524628.25)	09/06/17 14:25	9/25/17 9:35	451	AQ13 - Tubes were installed on a tree at 2.10m above ground. Next to a house. Crops: onions.

Sample NO_2 Protocol Sheet

Customer	Dewhurst Group	**Account**	E1071
Address	13617 Anndyke, Pl.		
	Germantown		
Email	k.mccallum@dewhurstgroup.us	**Phone**	301 916 8996

Lot No.	DIF100-20WA	**Type of Tube**	NO_2
SOR number		**Date of dispatch**	08/17/2017

Inorganics – Gray

☑ Nitrogen Dioxide (NO_2)	☐ Nitric Oxide (NO)	☐ Ozone (O_3)
☐ Hydrogen Sulphide (H_2S)	☐ Ammonia (NH_3)	☐ Phosphate (PO_4)
☐ Chloride (Cl)	☐ Bromide (Br)	☐ Sulphur Dioxide (SO_2)
☐ Sulphate (SO_4)	☐ Nitrogen Dioxide/ Sulphur Dioxide	☐ Fluoride (F)
		☐ Nitrate (NO_3)

Sampling and Monitoring Record – Gray

Bar Code label	Location Coordinates (X; Y) (Projection: Transverse Mercator. Datum: St. Lucia 1955)	Sampling		Exposure time (Hours)	Other information
		Start date and time	Finish date and time		
005627	Travel Blank	09/05/17 8:41	9/25/17 7:00	-	-
005626	Travel Blank	09/05/17 8:41	9/25/17 7:00	-	-
005625	Travel Blank	09/05/17 8:41	9/25/17 7:00	-	-
005624	Travel Blank	09/05/17 8:41	9/25/17 7:00	-	-
005623	Travel Blank	09/05/17 8:41	9/25/17 7:00	-	-
005622	La Haut (502354.16; 1532392.58)	09/05/17 9:21	9/25/17 8:20	479	AQ14 - Tubes installed near the registration building for the La Haut Hotel outside of Soufriere.

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005621	Fond St. Jacque 1 (505697.59; 1529120.83)	09/05/17 10:29	9/25/17 9:01	No trace of tubes	AQ01-B. Initially the tubes were installed on an abandoned house (south side of the house), next to a trail; however, to ensure the stability of these tubes, they were relocated to a tree next to the initial house. There are crops (bananas, cocoa). The main road is very narrow for the displacement of larger vehicles.
005620	Fond St. Jacque School (504975.66; 1529721.89)	09/05/17 11:15	09/25/17 8:46	477.5	AQ02 - The tubes were installed on a wall (west) of the Fond St. Jacques Primary School. This is located next to the main road.
005619	Belle Plaine Generator (504733.32; 1528664.69)	09/05/17 11:50	09/25/17 9:13	477.5	AQ03 - The tubes were installed on a light pole at 3m above ground between the local road and the LUCELEC generator.
005618	Belle Plaine Drill Site (504497.87; 1528007.49)	09/05/17 12:25	09/25/17 9:00	476	AQ04 - The tubes were installed on a coconut tree at 3.50m above ground. Windy day (NE-SW). The area is flat surrounded by steep mountains. There is a presence of agriculture interests (banana, coconut, cocoa), as well as livestock, goats, and domestic pets.
005617	Belle Plaine Nursery (504262.91; 1527572.65)	09/05/17 13:05	09/25/17 9:40	476.5	AQ05 - Tubes were installed on wall gutter at a 2,10m above ground. Windy day (E-W). There are 4 greenhouses located near the samplings site, as well as a main road.
005616	Saltibus School (506717.32; 1525848.05)	09/05/17 15:10	09/25/17 10:45	475.5	AQ06 - Tubes were located on a pipe between the local school (Saltibus) and community center, 5m above ground.
005615	Parc Estate Drill Site (506428.84; 1525305.34)	09/05/17 15:50	09/25/17 10:37	475	AQ07 - Tubes were installed on a light pole at 4m above ground. The area has a soccer field. There is an unpaved road.

005614	Parc Estate/Tete Morne Main Road Entrance (504588.74; 1521330.67)	09/05/17 16:45	09/25/17 10:10	473.5	AQ08 - Tubes were located 3m above ground, at the intersection of the main road with two secondary unpaved roads.
005613	Rodney Heights - Base Station (513548.93; 1554903.44)	09/05/17 20:10	09/19/17 8:50	n/a	AQ15
005612	Soufriere - Fire Station (501662.68; 1531580.77)	09/05/17 17:30	09/25/17 8:29	471	AQ09 - Tubes were installed next to the fire station (west side) on a light pole 3m above ground. Next to the main road. Next to a drainage.
005611	Sulfur Springs (503220.76; 1529558.78)	09/06/17 11:25	09/25/17 11:45	456	AQ10 - Tubes were on a pole where previous air quality studies were made. Area with geothermal manifestations (hot springs, mud pools). Tourist area.
005610	Union Vale (502289.70; 1526560.38)	09/06/17 12:25	09/25/17 11:28	455	AQ11 - Tubes were installed on a cocoa tree 2.10m above ground. The area is surrounded by a river, a main road and some crops (cocoa, coconut).
005609	Fiette (502251.56; 1523623.93)	09/06/17 13:30	09/25/17 11:15	453.5	AQ12 - Tubes were installed on a light pole across the road from a historical ruin of a colonial windmill, 3m above ground.
005608	Dacretin (504053.18; 1524628.25)	09/06/17 14:25	09/25/17 9:35	451	AQ13 - Tubes were installed on a tree at 2.10m above ground. Next to a house. Crops: onions.

Sample SO_2 Protocol Sheet

Customer	Dewhurst Group	**Account**	E1071
Address	13617 Anndyke, Pl.		
	Germantown		
Email	k.mccallum@dewhurstgroup.us	**Phone**	301 916 8996

Lot No.	12865	**Type of Tube**	SO_2
SOR number		**Date of dispatch**	08/17/2017

Inorganics – Purple

☐ Nitrogen Dioxide (NO_2)	☐ Nitric Oxide (NO)	☐ Ozone (O_3)
☐ Hydrogen Sulphide (H_2S)	☐ Ammonia (NH_3)	☐ Phosphate (PO_4)
☐ Chloride (Cl)	☐ Bromide (Br)	☑ Sulphur Dioxide (SO_2)
☐ Sulphate (SO_4)	☐ Nitrogen Dioxide/ Sulphur Dioxide	☐ Fluoride (F)
		☐ Nitrate (NO_3)

Sampling and Monitoring Record – Purple

Bar Code label	Location Coordinates (X; Y) (Projection: Transverse Mercator. Datum: St. Lucia 1955)	Sampling		Exposure time (Hours)	Other information
		Start date and time	Finish date and time		
425002	Travel Blank	09/05/17 8:09 am	9/25/17 7:00 am	-	-
425003	Travel Blank	09/05/17 8:09 am	9/25/17 7:00 am	-	-
425004	Travel Blank	09/05/17 8:09 am	9/25/17 7:00 am	-	-
425018	Travel Blank	09/05/17 8:09 am	9/25/17 7:00 am	-	-
425005	Travel Blank	09/05/17 8:09 am	9/25/17 7:00 am	-	-
425006	La Haut (502354.16; 1532392.58)	09/05/17 9:21	9/25/17 8:20 am	479	AQ14 - Tubes installed near the registration building for the La Haut Hotel outside of Soufriere.

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425007	Fond St. Jacque 1 (505697.59; 1529120.83)	09/05/17 10:29	9/25/17 9:01 am	No trace of tubes	AQ01-B - Initially the tubes were installed on an abandoned house (south side of the house), next to a trail; however, to ensure the stability of these tubes, they were relocated to a tree next to the initial house. There are crops (bananas, cocoa). The main road is very narrow for the displacement of larger vehicles.
425008	Fond St. Jacque School (504975.66; 1529721.89)	09/05/17 11:15	9/25/17 8:46 am	477.5	AQ02 - The tubes were installed on a wall (west) of the Fond St. Jacques Primary School. This is located next to the main road.
425009	Belle Plaine Generator (504733.32; 1528664.69)	09/05/17 11:50	9/25/17 9:13 am	477.5	AQ03 - The tubes were installed on a light pole at 3m above ground between the local road and the LUCELEC generator.
425010	Belle Plaine Drill Site (504497.87; 1528007.49)	09/05/17 12:25	9/25/17 9:30 am	476	AQ04 - The tubes were installed on a coconut tree at 3.50m above ground. Windy day (NE-SW). The area is flat surrounded by steep mountains. There is a presence of agriculture interests (banana, coconut, cocoa), as well as livestock, goats, and domestic pets.
425011	Belle Plaine Nursery (504262.91; 1527572.65)	09/05/17 13:05	9/25/17 9:40 am	476.5	AQ05 - Tubes were installed on wall gutter at a 2,10m above ground. Windy day (E-W). There are 4 greenhouses located near the samplings site, as well as a main road.
425012	Saltibus School (506717.32; 1525848.05)	09/05/17 15:10	9/25/17 10:45 am	475.5	AQ06 - Tubes were located on a pipe between the local school (Saltibus) and community center, 5m above ground.
425013	Parc Estate Drill Site (506428.84; 1525305.34)	09/05/17 15:50	9/25/17 10:37 am	475	AQ07 - Tubes were installed on a light pole at 4m above ground. The area has a soccer field.

					There is an unpaved road.
425014	Parc Estate/Tete Morne Main Road Entrance (504588.74; 1521330.67)	09/05/17 16:45	9/25/17 10:10	473.5	AQ08 - Tubes were located 3m above ground, at the intersection of the main road with two secondary unpaved roads.
425015	Rodney Heights - Base Station (513548.93; 1554903.44)	09/05/17 20:10	9/19/17 8:50	n/a	AQ15 (Blown Into garden)
425016	Soufriere - Fire Station (501662.68; 1531580.77)	09/05/17 17:30	9/25/17 8:29	471	AQ09 - Tubes were installed next to the fire station (west side) on a light pole 3m above ground. Next to the main road. Next to a drainage.
425017	Sulfur Springs (503220.76; 1529558.78)	09/06/17 11:25	9/25/17 11:45	456	AQ10 - Tubes were on a pole where previous air quality studies were made. Area with geothermal manifestations (hot springs, mud pools). Tourist area.
425019	Union Vale (502289.70; 1526560.38)	09/06/17 12:25	9/25/17 11:28	455	AQ11 - Tubes were installed on a cocoa tree 2.10m above ground. The area is surrounded by a river, a main road and some crops (cocoa, coconut).
425020	Fiette (502251.56; 1523623.93)	09/06/17 13:30	9/25/17 11:15	453.5	AQ12 - Tubes were installed on a light pole across the road from a historical ruin of a colonial windmill, 3m above ground.
425021	Dacretin (504053.18; 1524628.25)	09/06/17 14:25	9/25/17 9:35	451	AQ13 - Tubes were installed on a tree at 2.10m above ground. Next to a house. Crops: onions.

Sample H_2S Protocol Sheet

Customer: ORMANTINE USA		**Contact:** Michael Willmont	
Address:		**Contact email:**	
		Contact Tel. No:	**Account No:** Y2000
Email			**Lab Ref:**
Type of Tube: H_2S	**Lot No:** 51161/4	**Bar Codes:** 1010223-1010245	
Purchase Order No: 18662	**SOR number:** 38804	**Date of dispatch:** 08/10/2017	
TO BE COMPLETED BY CUSTOMER			
Email address for reports to be sent to:			
Contact Name:		**Customer Reference/Job Number:**	

Inorganics – Analysis Required:

- ☐ Nitrogen Dioxide (NO_2)
- ☑ Hydrogen Sulphide (H_2S)
- ☐ Chloride (Cl)
- ☐ Sulphate (SO_4)
- ☐ Nitric Oxide (NO)
- ☐ Ammonia (NH_3)
- ☐ Bromide (Br)
- ☐ Nitrogen Dioxide/ Sulphur Dioxide
- ☐ Tubes returned – Analysis not required
- ☐ Ozone (O_3)
- ☐ Phosphate (PO_4)
- ☐ Sulphur Dioxide (SO_2)
- ☐ Fluoride (F)
- ☐ Nitrate (NO_3)

Fast Track Analysis – An additional charge will apply

- ☐ Fast Track Analysis & Report 5 working days – Must be pre-arranged.
- ☐ Premium Fast Track – Must be pre-arranged. Contact diffusionradko.com

Number of tubes returned: ____

Sampling and Monitoring Record - Black

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Bar Code label	Location Coordinates (X; Y) (Projection: Transverse Mercator. Datum: St. Lucia 1955)	Sampling		Exposure time (Hours)	Other information	Results	
		Start date and time (MM/DD/YYYY)	Finish date and time (MM/DD/YYYY)			µg/m³	ppb
1010228	La Haut (502354.16; 1532392.58)	09/05/17 9:21	9/25/17 8:20	479	AQ14 - Tubes installed near the registration building for the La Haut Hotel outside of Soufriere.	0.17	0.12
1010229	Fond St. Jacque 1 (505697.59; 1529120.83)	09/05/17 10:29	9/25/17 9:01	No trace of tubes	AQ1-B - Initially the tubes were installed on an abandoned house (south side of the house), next to a trail; however, to ensure the stability of these tubes, they were relocated to a tree next to the initial house. There are crops (bananas, cocoa). The main road is very narrow for the displacement of larger vehicles.	Tubes were missing	Tubes were missing
1010230	Fond St. Jacque School (504975.66; 1529721.89)	09/05/17 11:15	9/25/17 8:46	477.5	AQ02 - The tubes were installed on a wall (west) of the Fond St. Jacques Primary School. This is located next to the main road.	0.09	0.06
1010231	Belle Plaine Generator (504733.32; 1528664.69)	09/05/17 11:50	9/25/17 9:13	477.5	AQ03 - The tubes were installed on a light pole at 3m above ground between the local road and the LUCELEC generator.	0.10	0.07
1010232	Belle Plaine Drill Site (504497.87; 1528007.49)	09/05/17 12:25	9/25/17 9:30	476	AQ04 - The tubes were installed on a coconut tree at 3.50m above ground. Windy day (NE-SW). The area	0.05	0.03

					is flat surrounded by steep mountains. There is a presence of agriculture interests (banana, coconut, cocoa), as well as livestock, goats, and domestic pets.		
1010233	Belle Plaine Nursery (504262.91; 1527572.65)	09/05/17 13:05	9/25/17 9:40	476.5	AQ05 - Tubes were installed on wall gutter at a 2,10m above ground. Windy day (E-W). There are 4 greenhouses located near the samplings site, as well as a main road.	0.05	0.04
1010234	Saltibus School (506717.32; 1525848.05)	09/05/17 15:10	9/25/17 10:46	475.5	AQ06 - Tubes were located on a pipe between the local school (Saltibus) and community center, 5m above ground.	0.06	0.04
1010235	Parc Estate Drill Site (506428.84; 1525305.34)	09/05/17 15:50	9/25/17 10:37	475	AQ07 - Tubes were installed on a light pole at 4m above ground. The area has a soccer field. There is an unpaved road.	0.05	0.04
1010236	Parc Estate/Tete Morne Main Road Entrance (504588.74; 1521330.67)	09/05/17 16:45	9/25/17 10:10	473.5	AQ08 - Tubes were located 3m above ground, at the intersection of the main road with two secondary unpaved roads.	0.04	0.03
1010237	Rodney Heights - Base Station (513548.93; 1554903.44)	09/05/17 	9/19/17 8:50	n/a	AQ15 (Blown into garden)	0.08	0.06
1010238	Soufriere - Fire Station (501662.68; 1531580.77)	09/05/17 17:30	9/25/17 8:29	471	AQ09 - Tubes were installed next to the fire station (west side)	0.17	0.12

					on a light pole 3m above ground. Next to the main road. Next to a drainage.		
1010239	Sulfur Springs (503220.76; 1529558.78)	09/06/17 11:25	9/25/17 11:45	456	AQ10 - Tubes were on a pole where previous air quality studies were made. Area with geothermal manifestations (hot springs, mud pools). Tourist area.	29.24**	20.64**
1010240	Union Vale (502289.70; 1526560.38)	09/06/17 12:25	9/25/17 11:28	455	AQ11 - Tubes were installed on a cocoa tree 2.10m above ground. The area is surrounded by a river, a main road and some crops (cocoa, coconut).	0.31	0.22
1010242	Fiette (502251.56; 1523623.93)	09/06/17 13:30	9/25/17 11:15	453.5	AQ12 - Tubes were installed on a light pole across the road from a historical ruin of a colonial windmill, 3m above ground.	0.11	0.08
1010241	Dacretin (504053.18; 1524628.25)	09/06/17 14:25	9/25/17 9:35	451	AQ13 - Tubes were installed on a tree at 2.10m above ground. Next to a house. Crops: onions.	0.16	0.12

Tubes marked ** were diluted to read within our UKAS accredited calibration range.

Analysed on UV08 Camspec M550

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd. This report is not to be reproduced, except in full, without the written permission of Gradko International Ltd.

Sample NO_2 Protocol Sheet

Customer	Dewhurst Group	**Account**	E1071
Address	13617 Anndyke, Pl.		
	Germantown		
Email	k.mccallum@dewhurstgroup.us	**Phone**	301 916 8996

Lot No.	DIF100-20WA	**Type of Tube**	NO_2
SOR number		**Date of dispatch**	08/17/2017

Inorganics – Gray

☑ Nitrogen Dioxide (NO_2)	☐ Nitric Oxide (NO)	☐ Ozone (O_3)
☐ Hydrogen Sulphide (H_2S)	☐ Ammonia (NH_3)	☐ Phosphate (PO_4)
☐ Chloride (Cl)	☐ Bromide (Br)	☐ Sulphur Dioxide (SO_2)
☐ Sulphate (SO_4)	☐ Nitrogen Dioxide/ Sulphur Dioxide	☐ Fluoride (F)
		☐ Nitrate (NO_3)

Sampling and Monitoring Record – Gray

Bar Code label	Location Coordinates (X; Y) (Projection: Transverse Mercator. Datum: St. Lucia 1955)	Sampling		Exposure time (Hours)	Other information	Temperature °C	Results	
		Start date and time (MM/DD/YYYY)	Finish date and time (MM/DD/YYYY)				mg/m³	ppb
005622	La Haut (502354.16; 1532392.58)	09/05/17 9:21	9/25/17 8:20	479	AQ14 - Tubes installed near the registration building for the La Haut Hotel outside of Soufriere.	20	1.27	0.67
005621	Fond St. Jacque 1	09/05/17	9/25/17			n/a		

DEWHURST GROUP
Geothermal Exploration and Development

	(505697.59; 1529120.83)	10:29	9:01	No trace of tubes	AQ01-B. Initially the tubes were installed on an abandoned house (south side of the house), next to a trail; however, to ensure the stability of these tubes, they were relocated to a tree next to the initial house. There are crops (bananas, cocoa). The main road is very narrow for the displacement of larger vehicles.		Tubes were missing	Tubes were missing
005620	Fond St. Jacque School (504975.66; 1529721.89)	09/05/17 11:15	09/25/17 8:46	477.5	AQ02 - The tubes were installed on a wall (west) of the Fond St. Jacques Primary School. This is located next to the main road.	20	1.23	0.64
005619	Belle Plaine Generator (504733.32; 1528664.69)	09/05/17 11:50	09/25/17 9:13	477.5	AQ03 - The tubes were installed on a light pole at 3m above ground between the local road and the LUCELEC generator.	20	1.13	0.59
005618	Belle Plaine Drill Site (504497.87; 1528007.49)	09/05/17 12:25	09/25/17 9:00	476	AQ04 - The tubes were installed on a coconut tree at 3.50m above ground. Windy day (NE-SW). The area is flat surrounded by steep mountains. There is a presence of agriculture interests	20	0.80	0.42

					(banana, coconut, cocoa), as well as livestock, goats, and domestic pets.			
005617	Belle Plaine Nursery (504262.91; 1527572.65)	09/05/17 13:05	09/25/17 9:40	476.5	AQ05 - Tubes were installed on wall gutter at a 2,10m above ground. Windy day (E-W). There are 4 greenhouses located near the samplings site, as well as a main road.	20	1.06	0.55
005616	Saltibus School (506717.32; 1525848.05)	09/05/17 15:10	09/25/17 10:45	475.5	AQ06 - Tubes were located on a pipe between the local school (Saltibus) and community center, 5m above ground.	20	1.03	0.54
005615	Parc Estate Drill Site (506428.84; 1525305.34)	09/05/17 15:50	09/25/17 10:37	475	AQ07 - Tubes were installed on a light pole at 4m above ground. The area has a soccer field. There is an unpaved road.	20	1.25	0.65
005614	Parc Estate/Tete Morne Main Road Entrance (504588.74; 1521330.67)	09/05/17 16:45	09/25/17 10:10	473.5	AQ08 - Tubes were located 3m above ground, at the intersection of the main road with two secondary unpaved roads.	20	1.97	1.03
005613	Rodney Heights - Base Station (513548.93; 1554903.44)	09/05/17 20:10	09/19/17 8:50	n/a	AQ15 (Blown into garden)	20	1.01	0.53

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005612	Soufriere - Fire Station (501662.68; 1531580.77)	09/05/17 17:30	09/25/17 8:29	471	AQ09 - Tubes were installed next to the fire station (west side) on a light pole 3m above ground. Next to the main road. Next to a drainage.	n/a	Tubes were missing	Tubes were missing
005611	Sulfur Springs (503220.76; 1529558.78)	09/06/17 11:25	09/25/17 11:45	456	AQ10 - Tubes were on a pole where previous air quality studies were made. Area with geothermal manifestations (hot springs, mud pools). Tourist area.	20	1.10	0.58
005610	Union Vale (502289.70; 1526560.38)	09/06/17 12:25	09/25/17 11:28	455	AQ11 - Tubes were installed on a cocoa tree 2.10m above ground. The area is surrounded by a river, a main road and some crops (cocoa, coconut).	20	1.08	0.56
005609	Fiette (502251.56; 1523623.93)	09/06/17 13:30	09/25/17 11:15	453.5	AQ12 - Tubes were installed on a light pole across the road from a historical ruin of a colonial windmill, 3m above ground.	20	1.01	0.53
005608	Dacretin (504053.18; 1524628.25)	09/06/17 14:25	09/25/17 9:35	451	AQ13 - Tubes were installed on a tree at 2.10m above ground. Next to a house. Crops: onions.	20	1.08	0.56

Note: The samples have been tested within the scope of Ormantine USA Ltd., Inc. Laboratory. Quality Procedures calculations. Any inquiries regarding the data in this report are to be directed to the Laboratory manager of Ormantine USA Ltd., Inc. This report is not to be reproduced, except in full, without the written permission of Ormantine USA, Ltd., Inc. Report Approved B. McLeod.

Limit of Detection: 0.037 μgNO_2

Preparation: 20% TEA / Water. Analyzed on UVS04 Camspec M550 equivalent Unico SQ4802.

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Geothermal Exploration and Development

Sample SO_2 Protocol Sheet

Customer	Dewhurst Group	**Account**	E1071
Address	13617 Anndyke, Pl.		
	Germantown		
Email	k.mccallum@dewhurstgroup.us	**Phone**	301 916 8996

Lot No.	12865	**Type of Tube**	SO_2
SOR number		**Date of dispatch**	08/17/2017

Inorganics – Purple

☐ Nitrogen Dioxide (NO_2)	☐ Nitric Oxide (NO)	☐ Ozone (O_3)
☐ Hydrogen Sulphide (H_2S)	☐ Ammonia (NH_3)	☐ Phosphate (PO_4)
☐ Chloride (Cl)	☐ Bromide (Br)	☑ Sulphur Dioxide (SO_2)
☐ Sulphate (SO_4)	☐ Nitrogen Dioxide/ Sulphur Dioxide	☐ Fluoride (F)
		☐ Nitrate (NO_3)

Sampling and Monitoring Record – Purple

Bar Code label	Location Coordinates (X; Y) (Projection: Transverse Mercator. Datum: St. Lucia 1955)	Sampling		Exposure time (Hours)	Other information	Results	
		Start date and time (MM/DD/ YYYY)	Finish date and time (MM/DD /YYYY)			mg/m³	ppb
425006	La Haut (502354.16; 1532392.58)	09/05/17 9:21	9/25/17 8:20	479	AQ14 - Tubes installed near the registration building for the La Haut Hotel outside of Soufriere.	7.25	2.72

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425007	Fond St. Jacque 1 (505697.59; 1529120.83)	09/05/17 10:29	9/25/17 9:01	No trace of tubes	AQ01-B - Initially the tubes were installed on an abandoned house (south side of the house), next to a trail; however, to ensure the stability of these tubes, they were relocated to a tree next to the initial house. There are crops (bananas, cocoa). The main road is very narrow for the displacement of larger vehicles.	Tubes were missing	Tubes were missing
425008	Fond St. Jacque School (504975.66; 1529721.89)	09/05/17 11:15	9/25/17 8:46	477.5	AQ02 - The tubes were installed on a wall (west) of the Fond St. Jacques Primary School. This is located next to the main road.	6.88	2.58
425009	Belle Plaine Generator (504733.32; 1528664.69)	09/05/17 11:50	9/25/17 9:13	477.5	AQ03 - The tubes were installed on a light pole at 3m above ground between the local road and the LUCELEC generator.	7.31	2.74
425010	Belle Plaine Drill Site (504497.87; 1528007.49)	09/05/17 12:25	9/25/17 9:30	476	AQ04 - The tubes were installed on a coconut tree at 3.50m above ground. Windy day (NE-SW). The area is flat surrounded by steep mountains. There is a presence of agriculture interests (banana, coconut, cocoa), as well as livestock, goats, and domestic pets.	5.59	2.10
425011	Belle Plaine Nursery (504262.91; 1527572.65)	09/05/17 13:05	9/25/17 9:40	476.5	AQ05 - Tubes were installed on wall gutter at a 2,10m above ground. Windy day (E-W). There are 4 greenhouses located near	6.46	2.42

					the samplings site, as well as a main road.		
425012	Saltibus School (506717.32; 1525848.05)	09/05/17 15:10	9/25/17 10:45	475.5	AQ06 - Tubes were located on a pipe between the local school (Saltibus) and community center, 5m above ground.	6.36	2.39
425013	Parc Estate Drill Site (506428.84; 1525305.34)	09/05/17 15:50	9/25/17 10:37	475	AQ07 - Tubes were installed on a light pole at 4m above ground. The area has a soccer field. There is an unpaved road.	6.55	2.46
425014	Parc Estate/Tete Morne Main Road Entrance (504588.74; 1521330.67)	09/05/17 16:45	9/25/17 10:10	473.5	AQ08 - Tubes were located 3m above ground, at the intersection of the main road with two secondary unpaved roads.	7.88	2.95
425015	Rodney Heights - Base Station (513548.93; 1554903.44)	09/05/17 20:10	9/19/17 8:50	n/a	AQ15 (Blown Into garden)	6.78	2.54
425016	Soufriere - Fire Station (501662.68; 1531580.77)	09/05/17 17:30	9/25/17 8:29	471	AQ09 - Tubes were installed next to the fire station (west side) on a light pole 3m above ground. Next to the main road. Next to a drainage.	9.10	3.41
425017	Sulfur Springs (503220.76; 1529558.78)	09/06/17 11:25	9/25/17 11:45	456	AQ10 - Tubes were on a pole where previous air quality studies were made. Area with geothermal manifestations (hot springs, mud pools). Tourist area.	292.33**	109.62**
425019	Union Vale	09/06/17	9/25/17	455		6.97	2.61

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	(502289.70; 1526560.38)	12:25	11:28		AQ11 - Tubes were installed on a cocoa tree 2.10m above ground. The area is surrounded by a river, a main road and some crops (cocoa, coconut).		
425020	Fiette (502251.56; 1523623.93)	09/06/17 13:30	9/25/17 11:15	453.5	AQ12 - Tubes were installed on a light pole across the road from a historical ruin of a colonial windmill, 3m above ground.	6.88	2.58
425021	Dacretin (504053.18; 1524628.25)	09/06/17 14:25	9/25/17 9:35	451	AQ13 - Tubes were installed on a tree at 2.10m above ground. Next to a house. Crops: onions.	6.76	2.54

Notes:

**Tubes marked ** were diluted to read within our UKAS accredited calibration range.

The Diffusion Tubes have been tested within the scope of Gradko International Ltd. Laboratory Quality Procedures calculations and assessments involving the exposure procedures and periods provided by the client are not within the scope of our UKAS accreditation. Any queries concerning the data in this report should be directed to the Laboratory Manager Gradko International Ltd. This report is not to be reproduced, except in full, without the written permission of Gradko International Ltd.

Report Checked by J. Farbiszewska-Szulc

Analysed on Dionex ICS3000 ICU5

APPENDIX B

Noise Monitoring

APPENDIX B. NOISE MONITORING PHOTOS

DAY 1 - SEPTEMBER 5TH, 2017

Illustration 1. Noise Survey - First Day.

DAY 2 - SEPTEMBER 6TH, 2017

Illustration 2. Noise Survey-Second Day.

DAY 3 - SEPTEMBER 7TH, 2017

Illustration 3. Noise Survey-Third Day.

APPENDIX B. NOISE MONITORING DATA

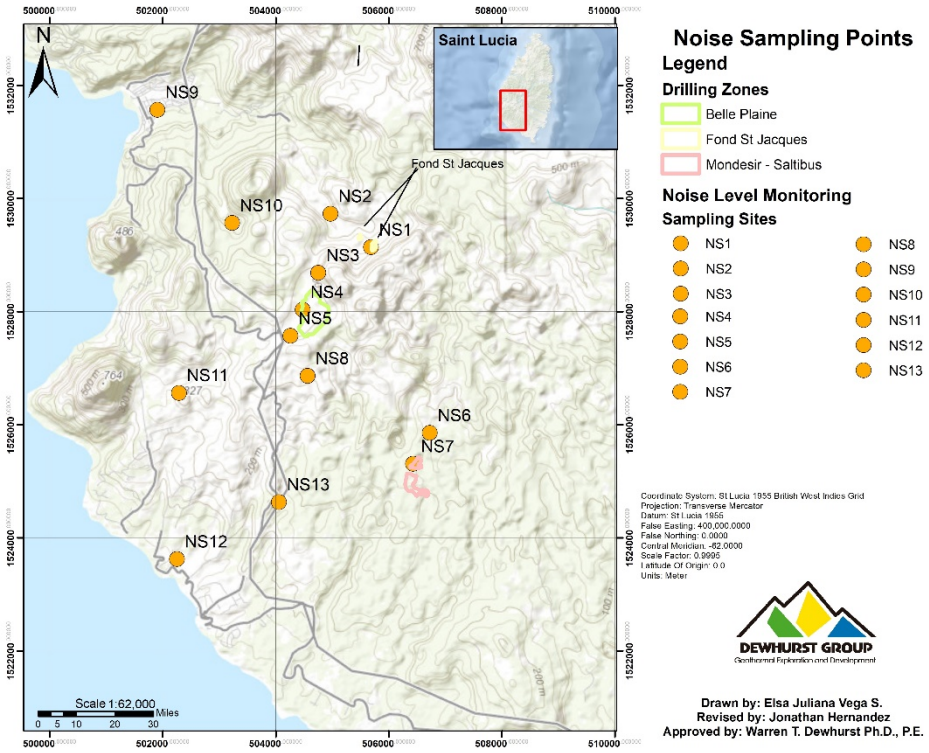


Figure 1. Location map of Noise Monitoring.

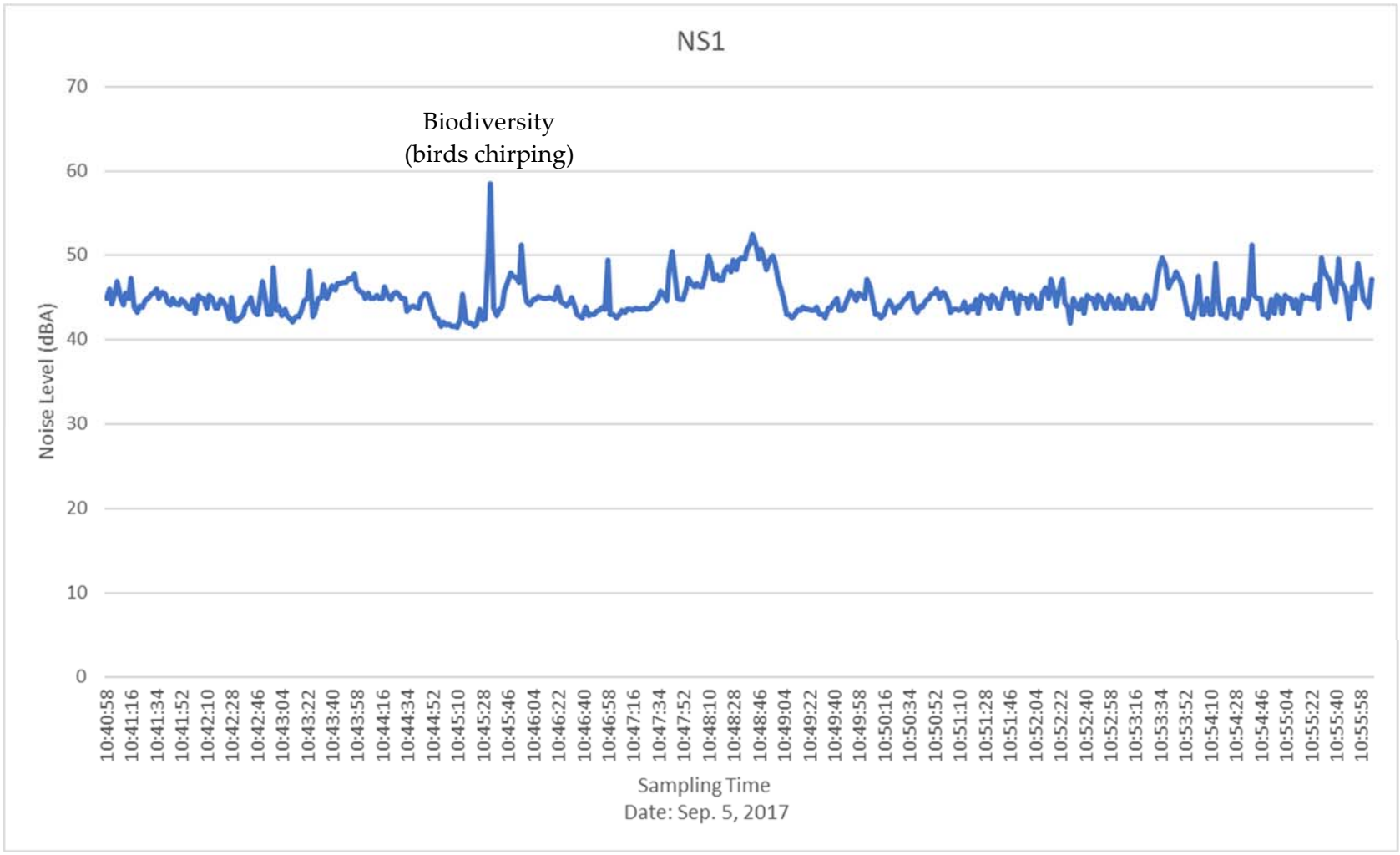
APPENDIX B: NOISE MONITORING

Table 1. Observation sites within each area of influence (Projection: Transverse Mercator. Datum: St. Lucia 1955).

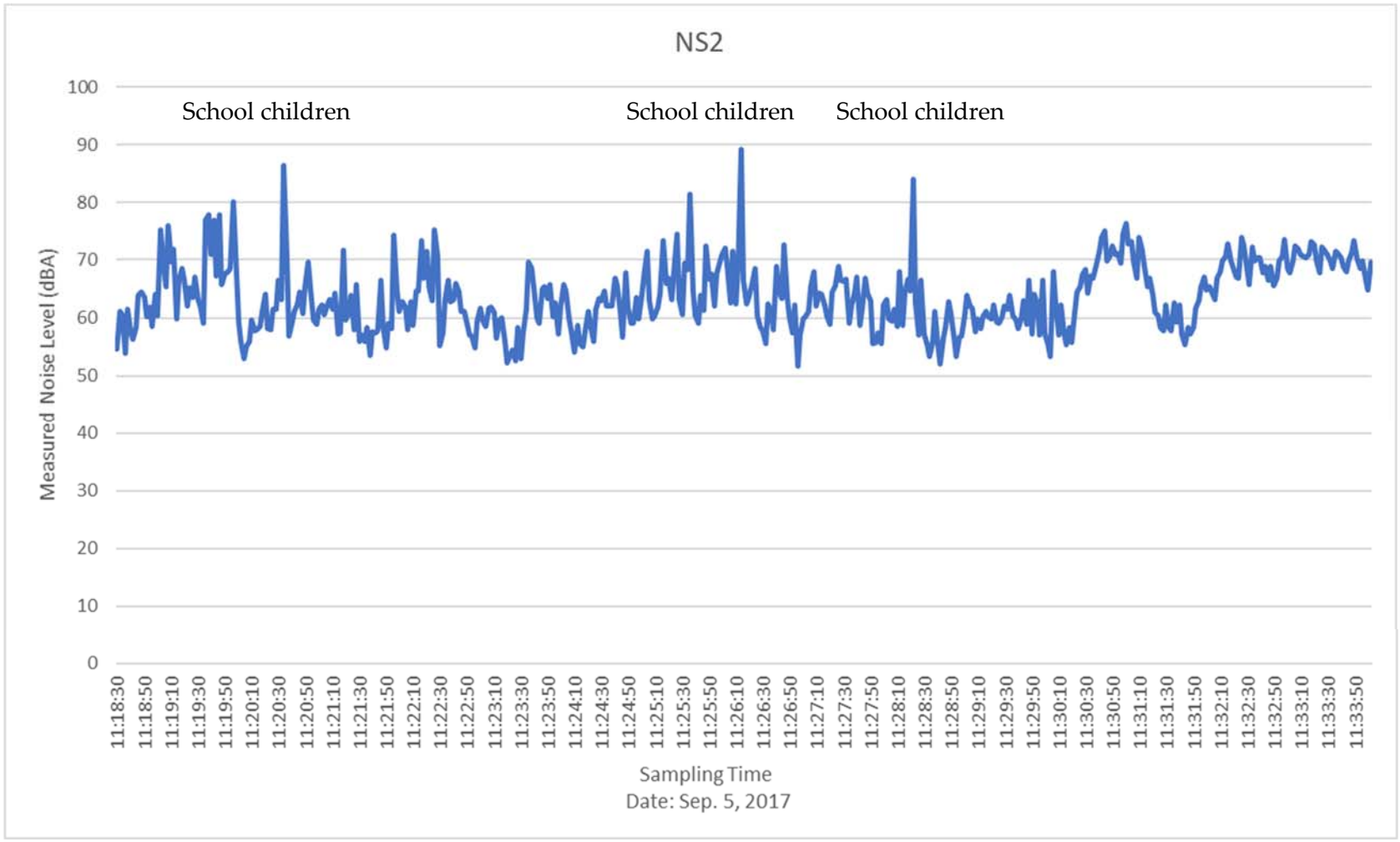
Site Name	X (mE)	Y (mN)	Elevation (m ASL)	Description of Area
NS1	505697,59	1529120,83	298	**St. Jacques** - Drill Site in the field by rundown shack near unpaved road in the area
NS2	504975,66	1529721,89	250	**St. Jacques -** Primary School Yard near the main road in the area
NS3	504733,32	1528664,69	400	**Belle Plaine** - LUCELEC Generator near the main road in the area
NS4	504497,87	1528007,49	337	**Belle Plaine** - Drill Site Field near the main unpaved road in the area
NS5	504262,91	1527572,65	362	**Belle Plaine** - Greenhouse near the bend on a main island paved road
NS6	506717,32	1525848,05	292	**Saltibus** - Primary School between local school and the Community Center
NS7	506428,84	1525305,34	261	**Saltibus** - Parc Estate Drill Site (Near a commercial establishment) and soccer field
NS8	504588,74	1521330,67	45	**Saltibus** – At the corner of the local access road (to Parc Estate) corner with Main Road
NS9	501662,68	1531580,77	-6	Soufriere - Fire Station Flagpole taken from within southern edge of parking lot
NS10	503220,76	1529558,78	223	Sulphur Springs – southern side of main walkway 5m due south of NS10
NS11	502289,70	1526560,38	225	Union Vale – About 15m from the main paved road/bridge and within vegetation
NS12	502251,56	1523623,93	53	Old Mill - Light Pole # SEQC04444 near main paved road in the area
NS13	504053,18	1524628,25	219	D'Quitoin - Off main road - terrace farm - high side/scarp side of the highway

Note: Sites in Bold represent the 3 prospective drilling areas. GPS measurements taken on site with Trimble.

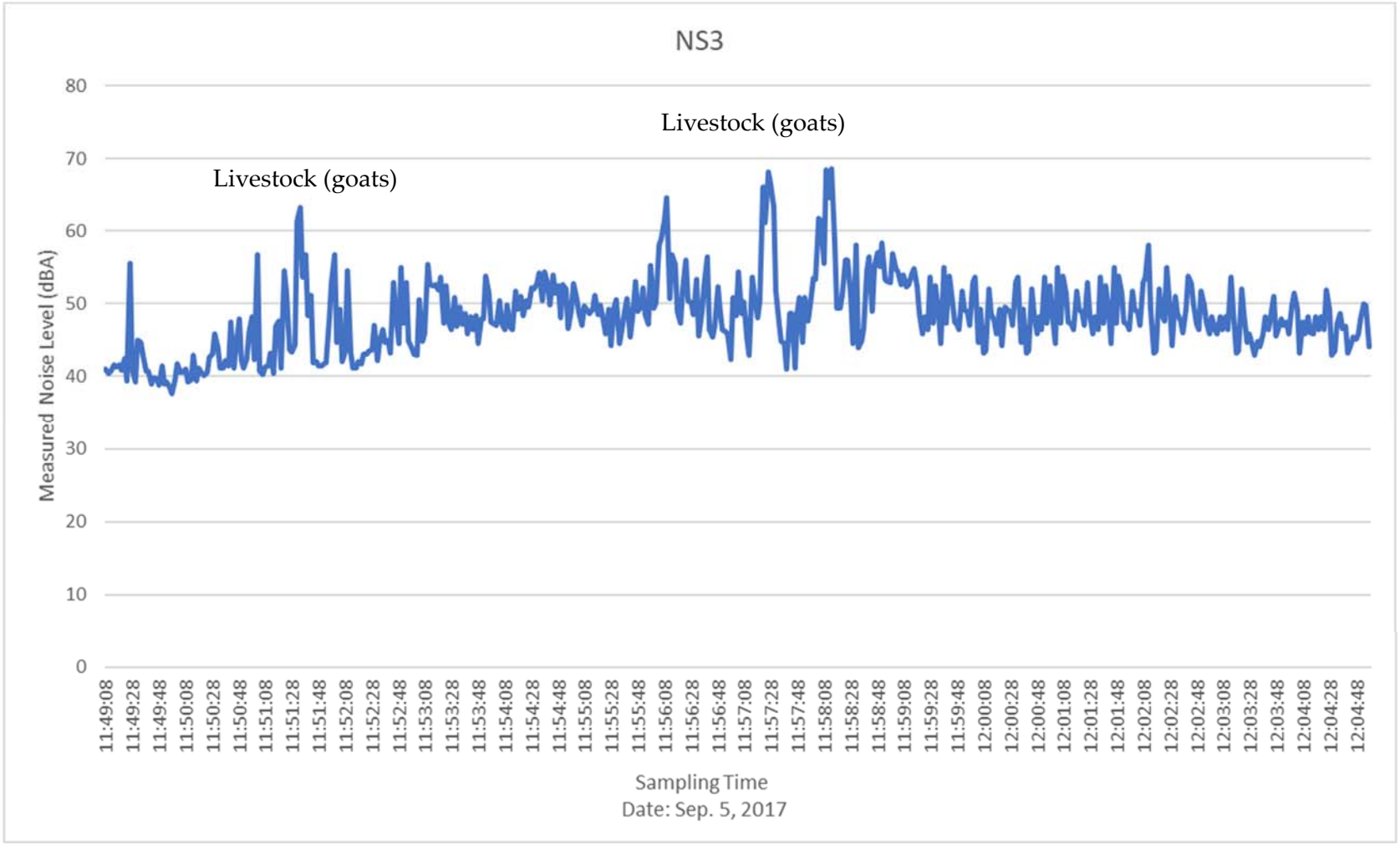
APPENDIX B: NOISE MONITORING



APPENDIX B: NOISE MONITORING



APPENDIX B: NOISE MONITORING



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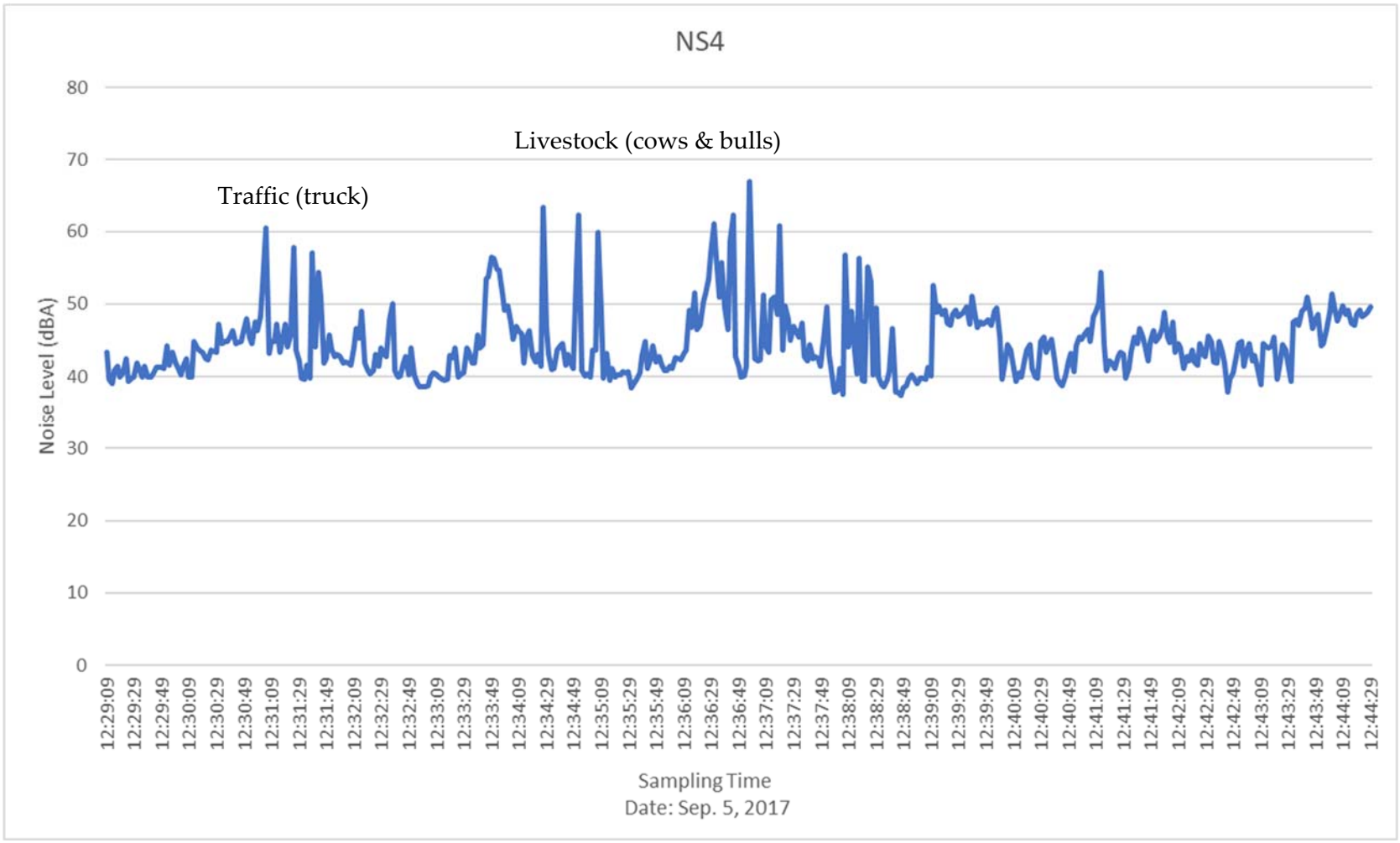
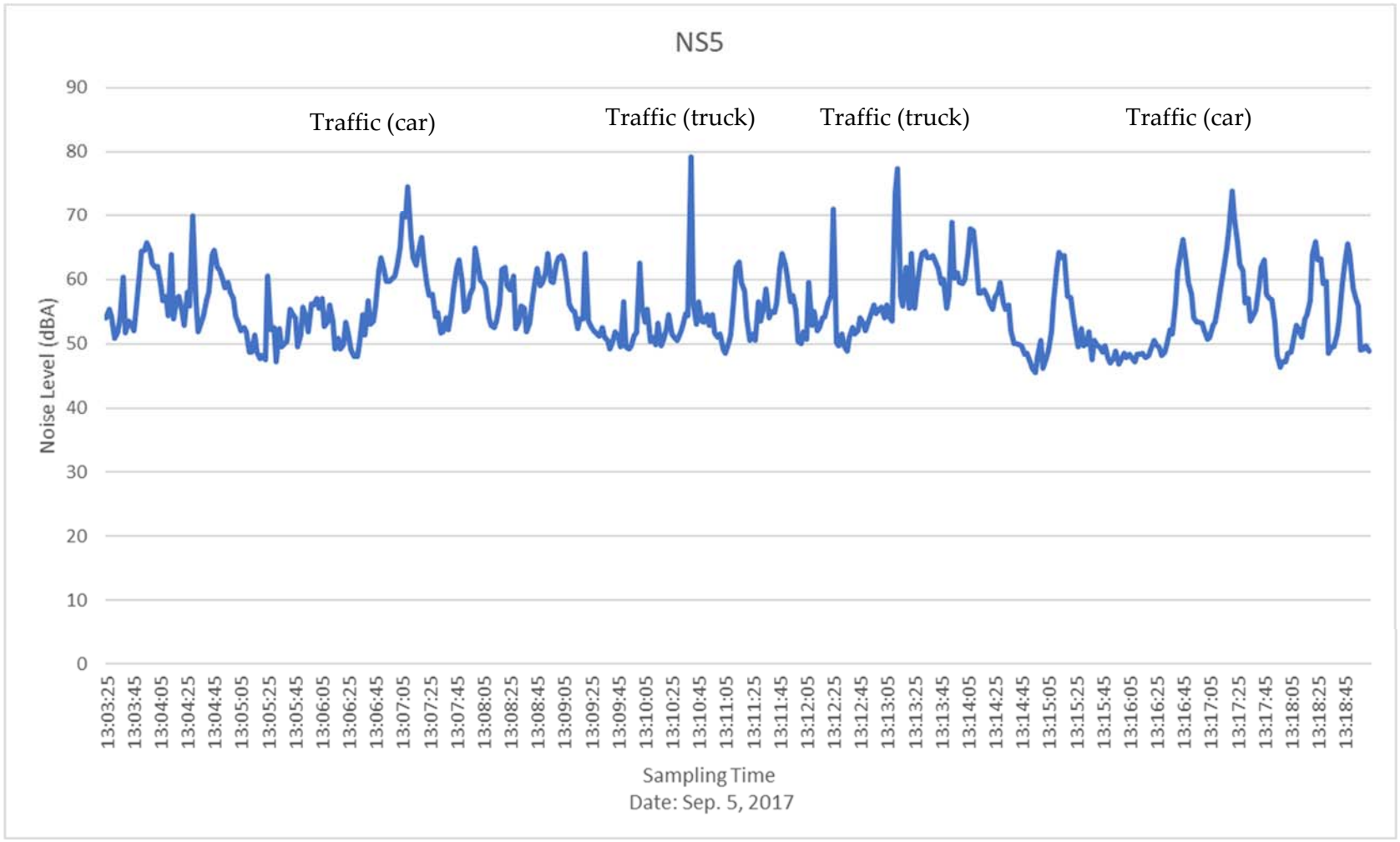


APPENDIX B: NOISE MONITORING



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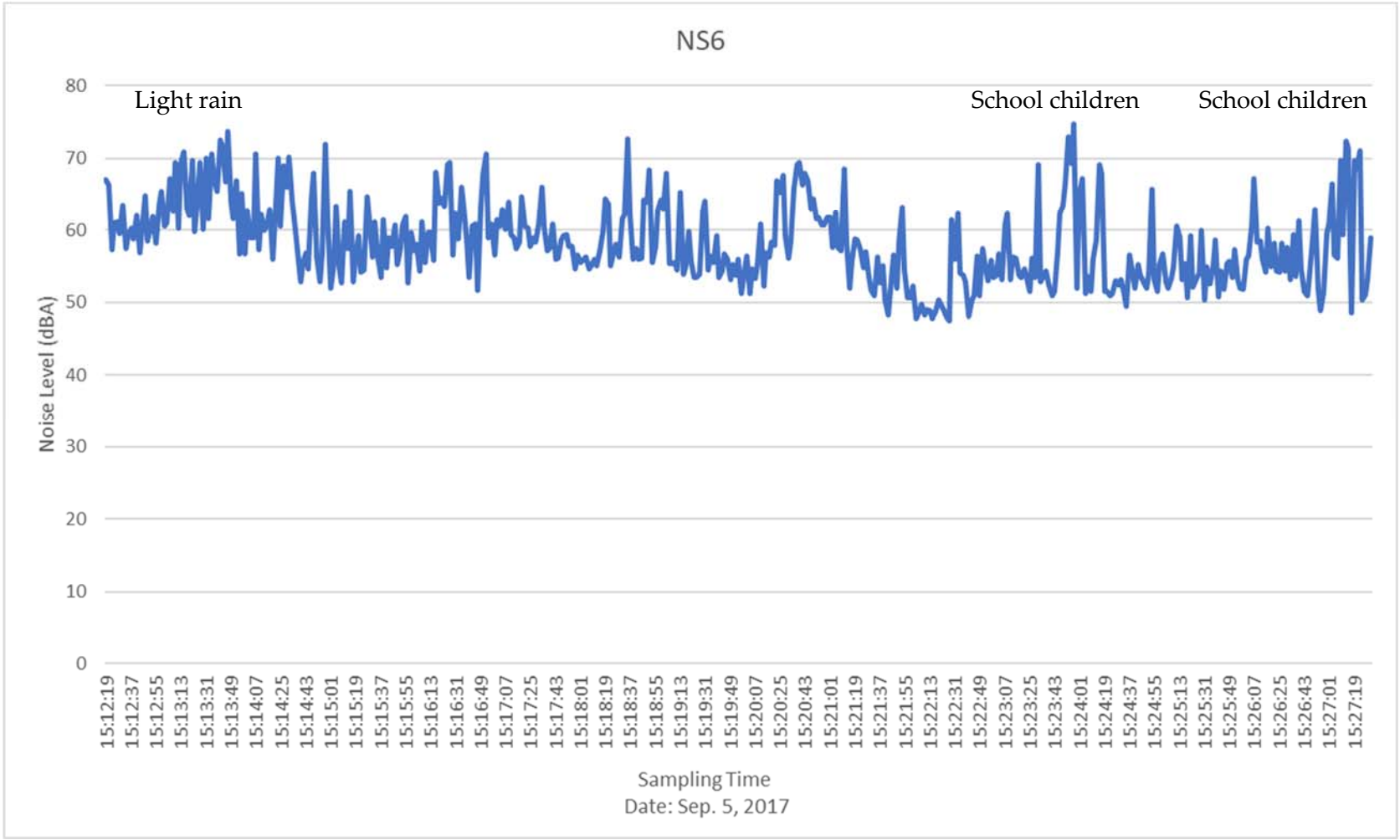
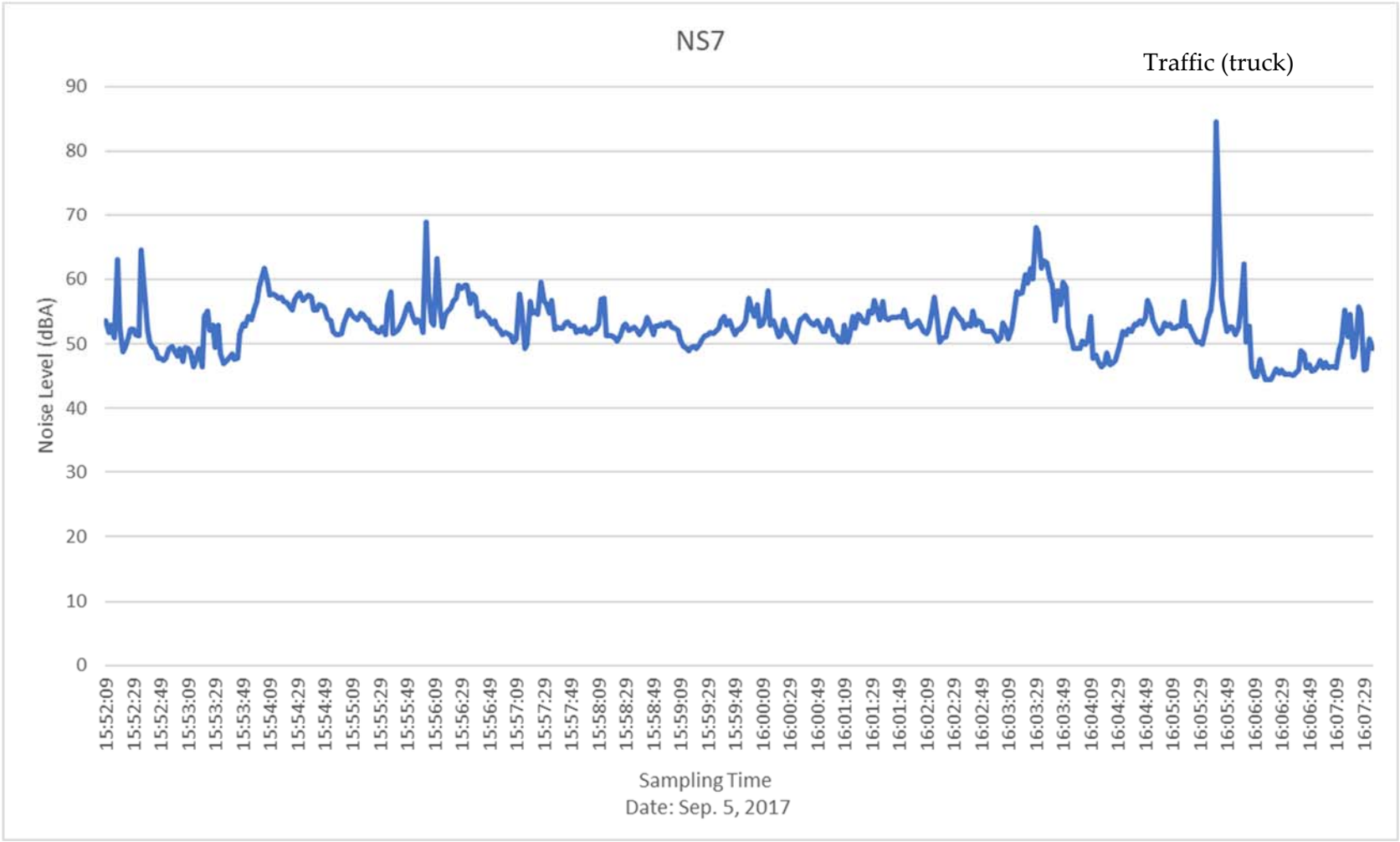


APPENDIX B: NOISE MONITORING



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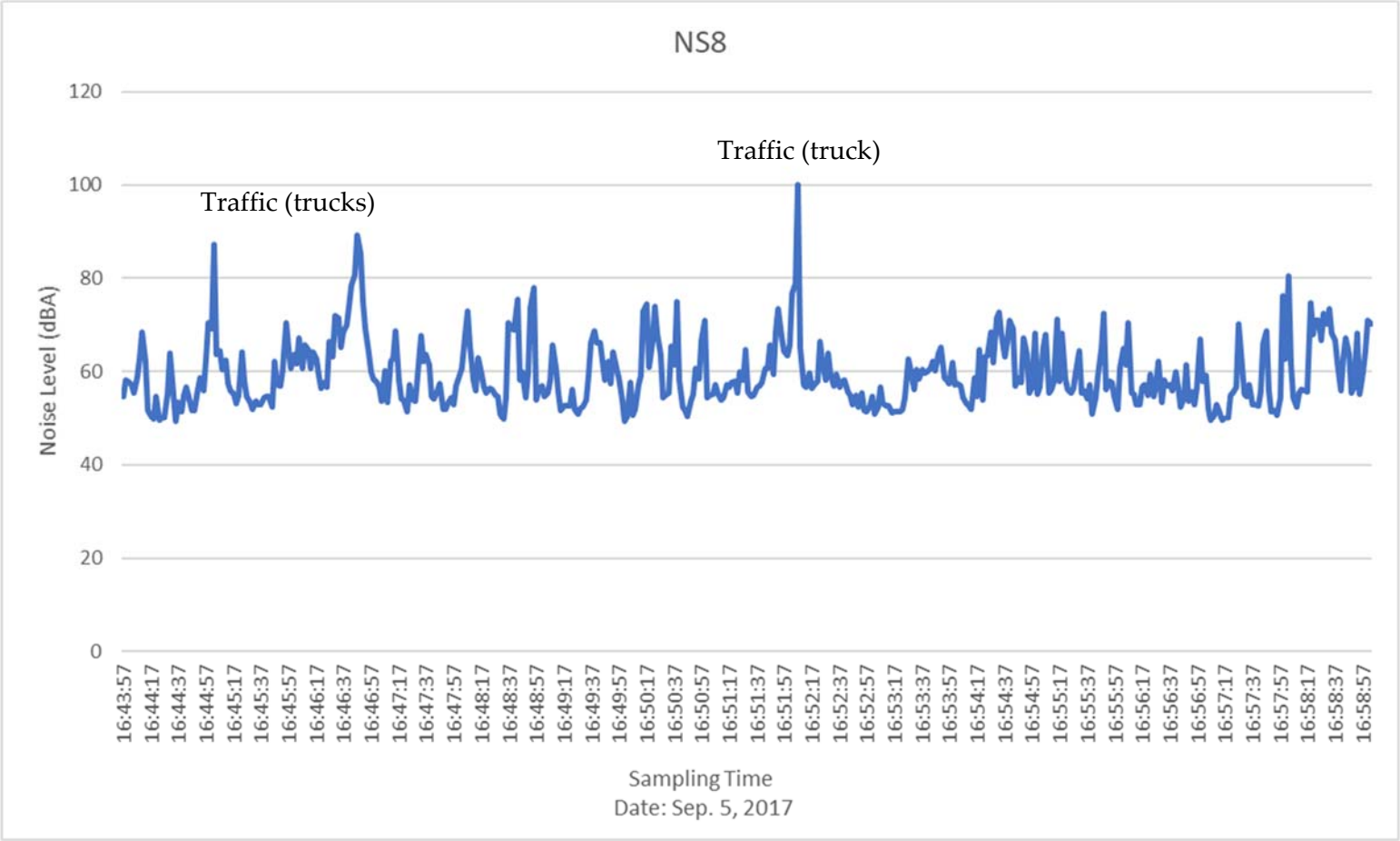

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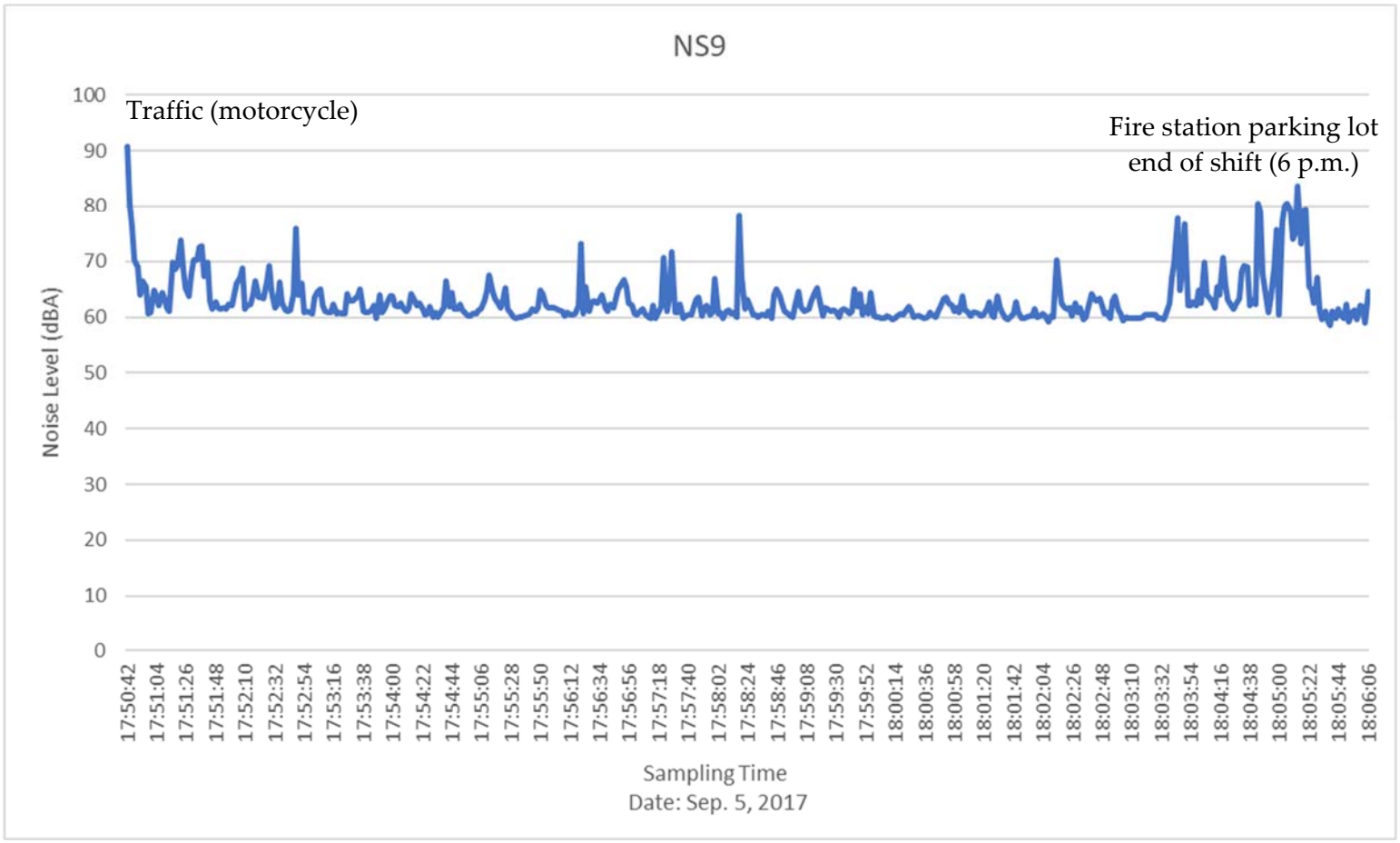

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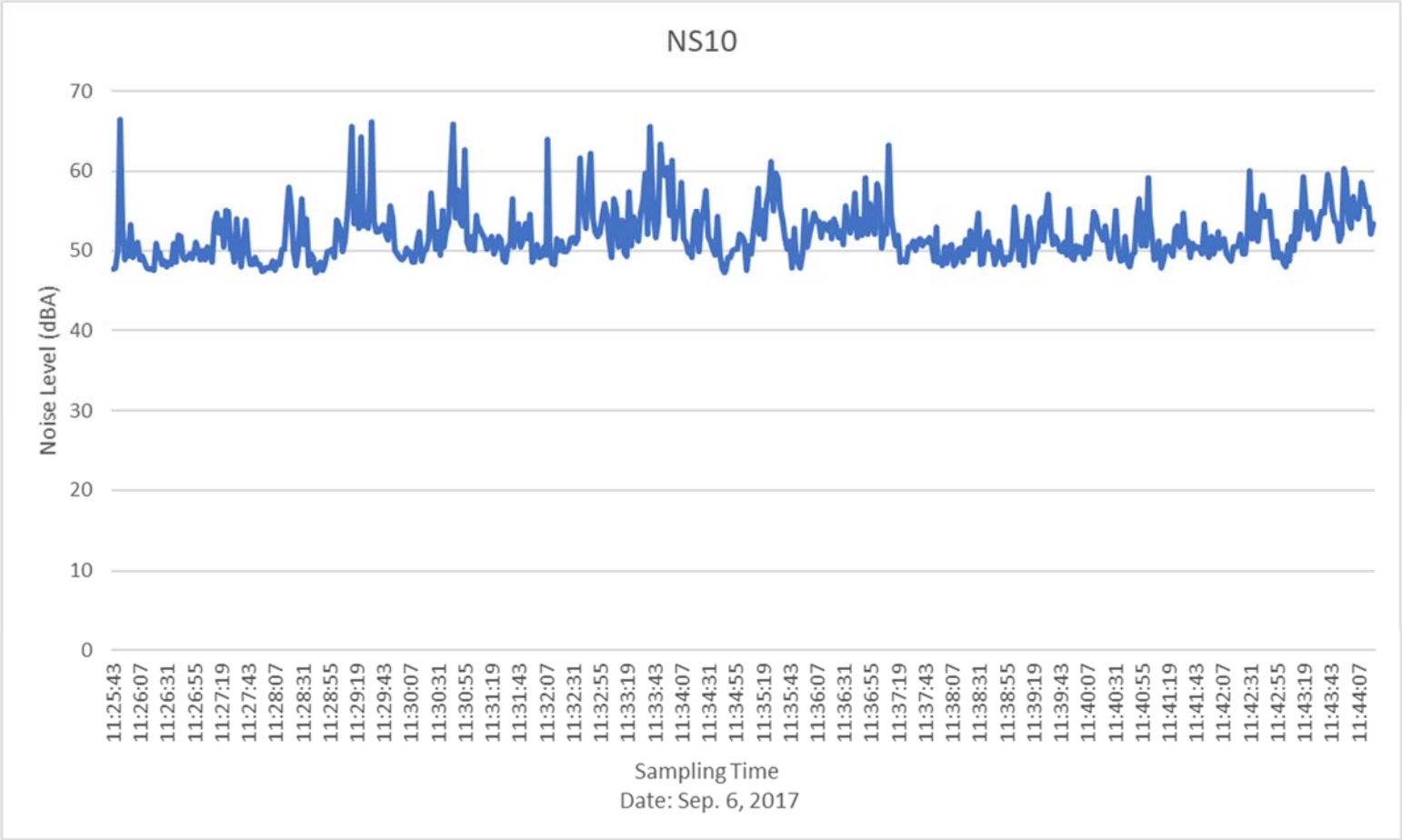

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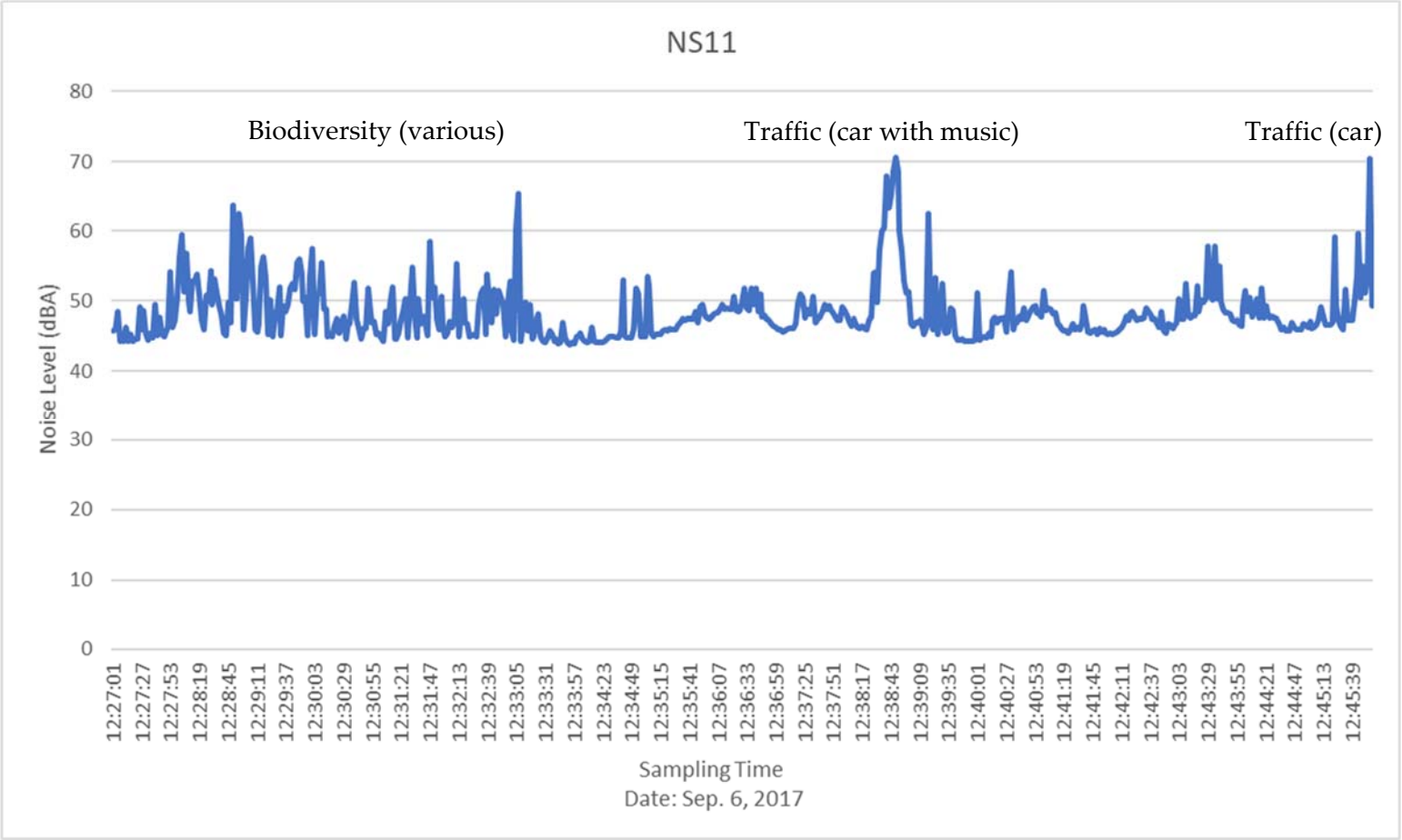

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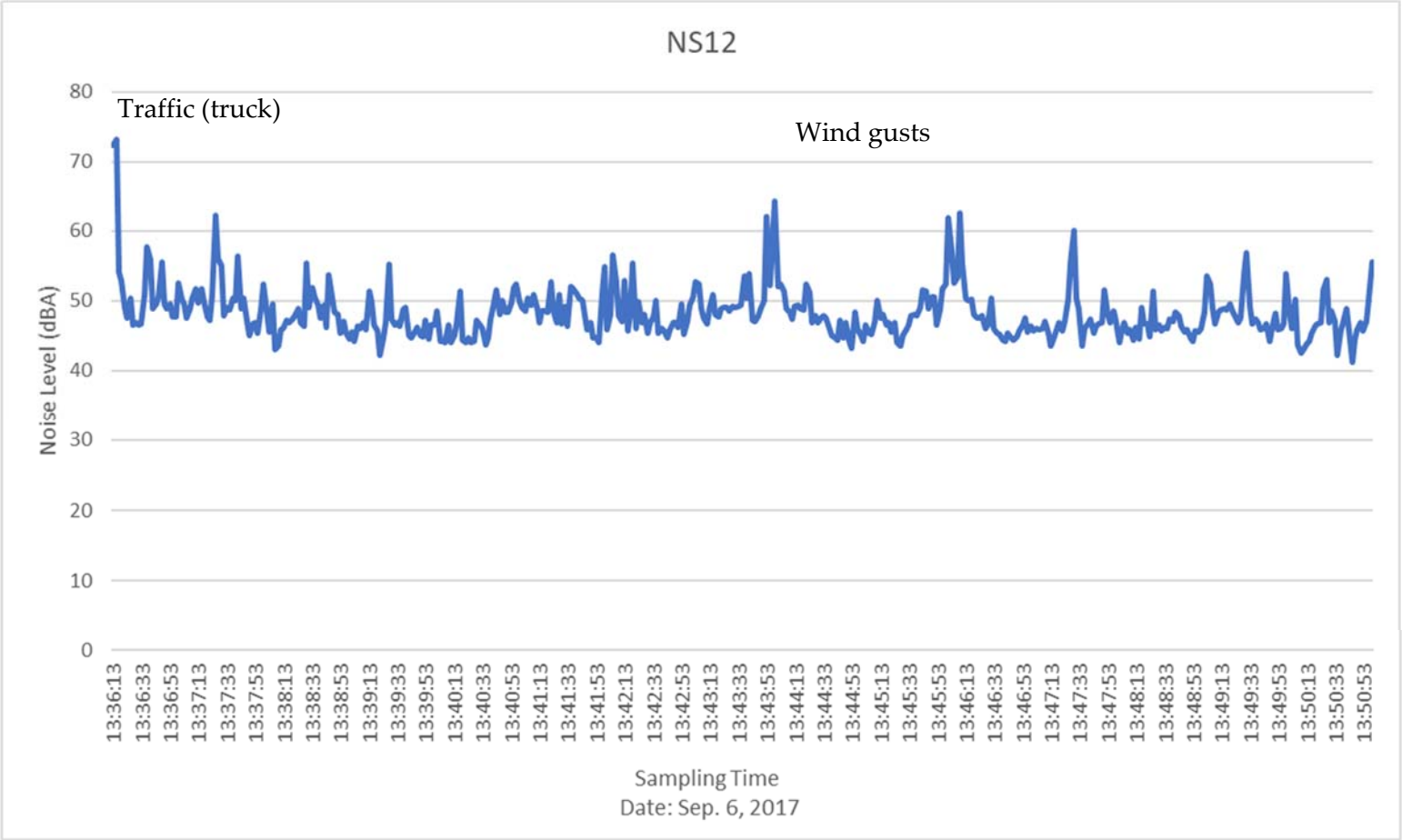

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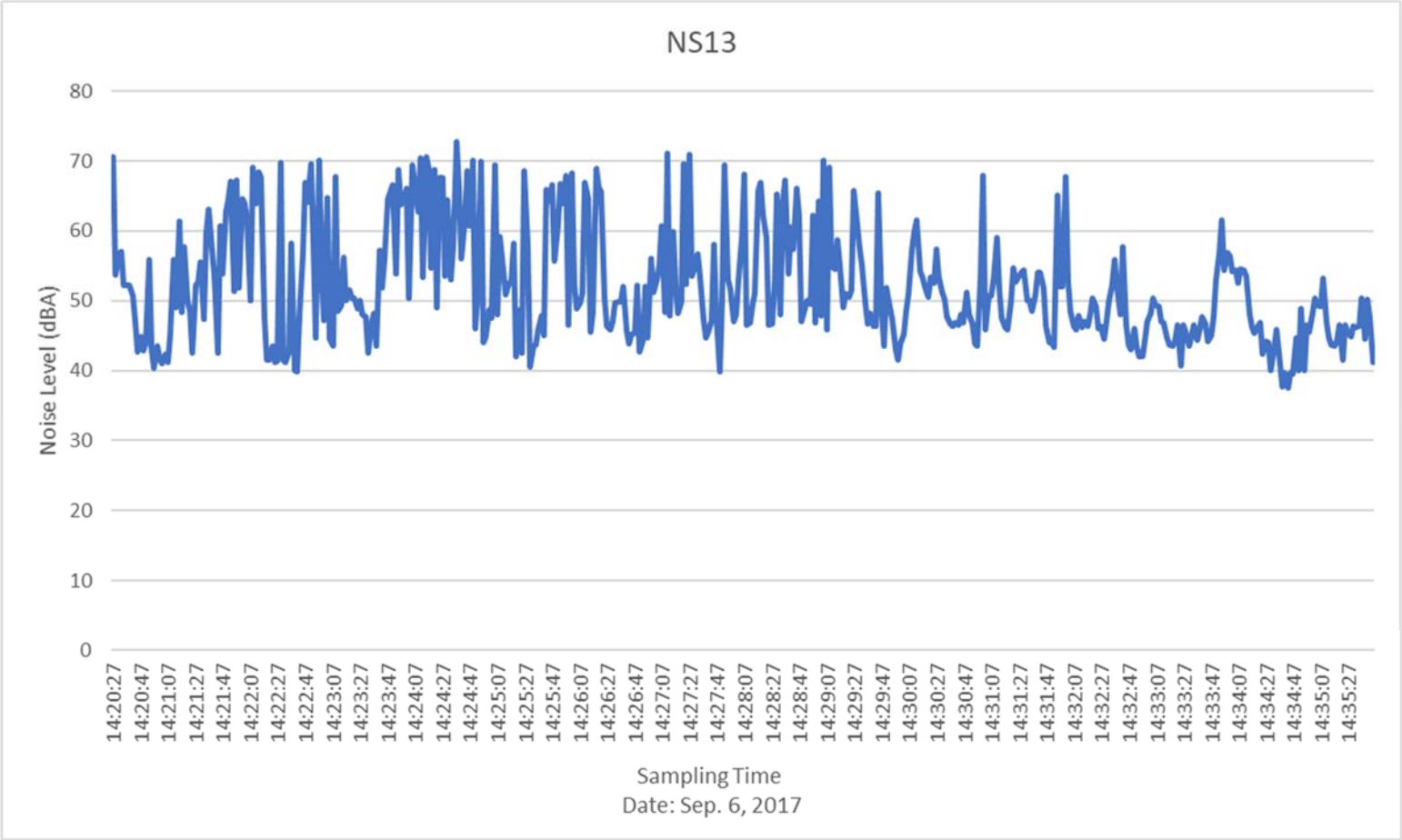

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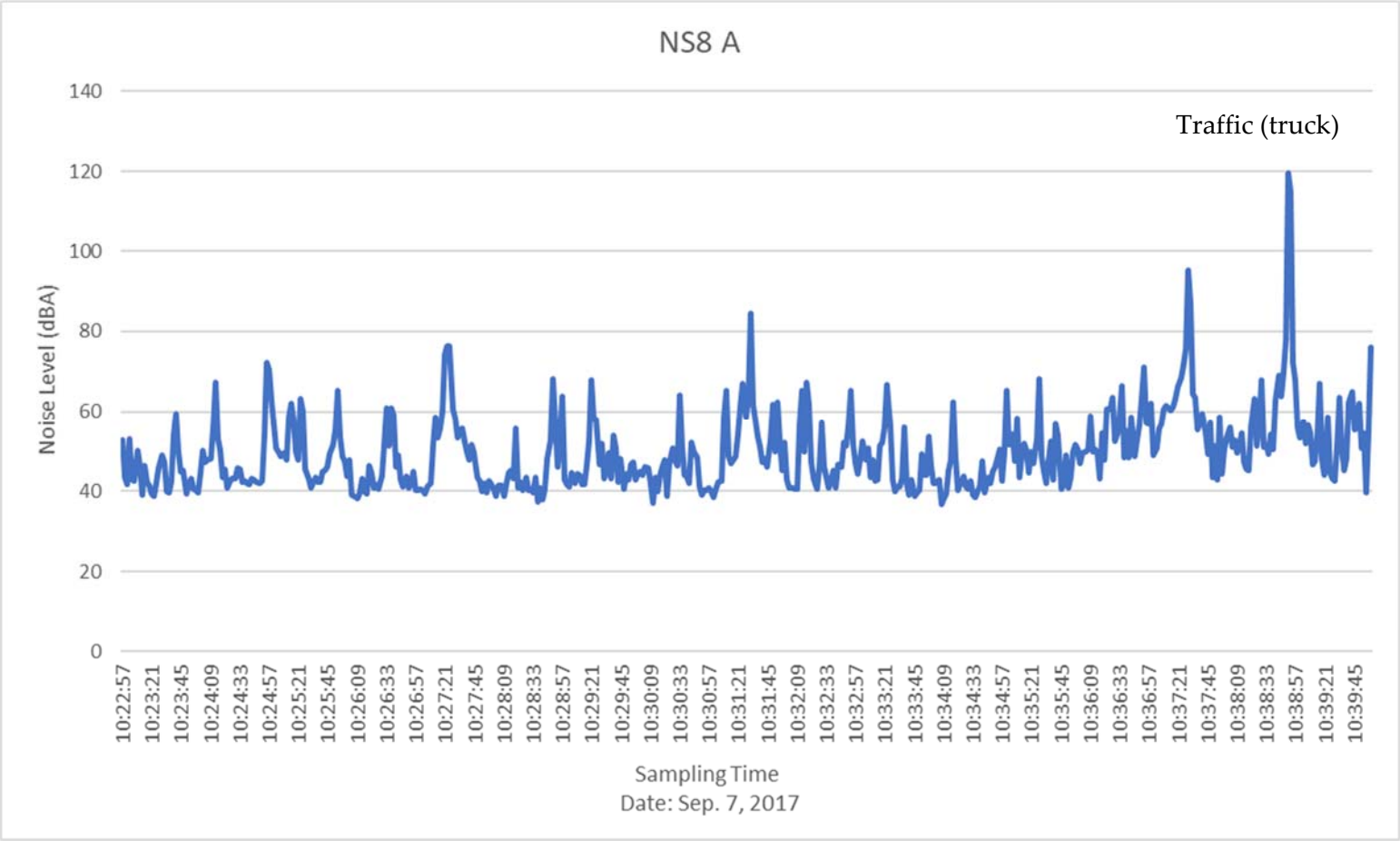

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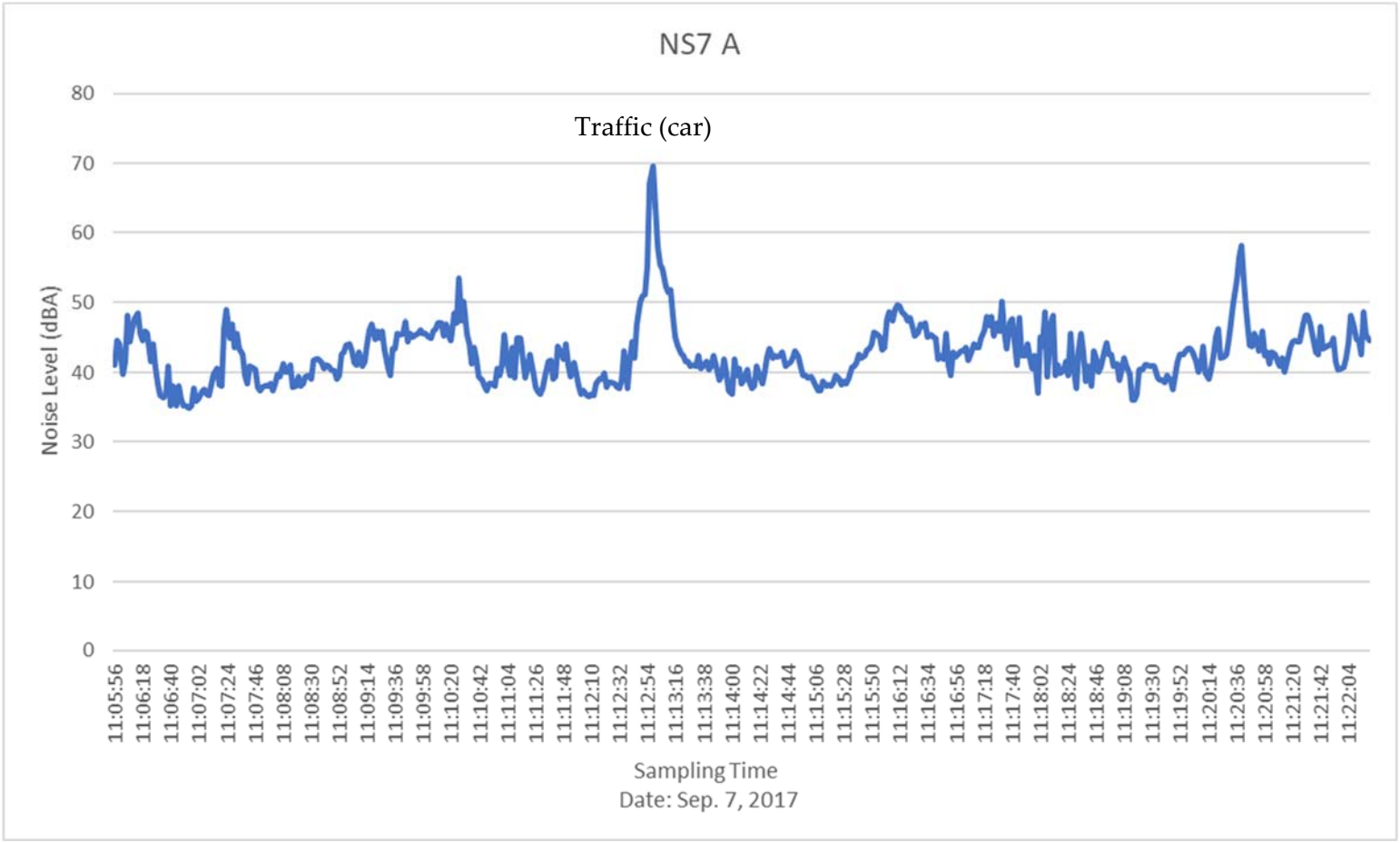

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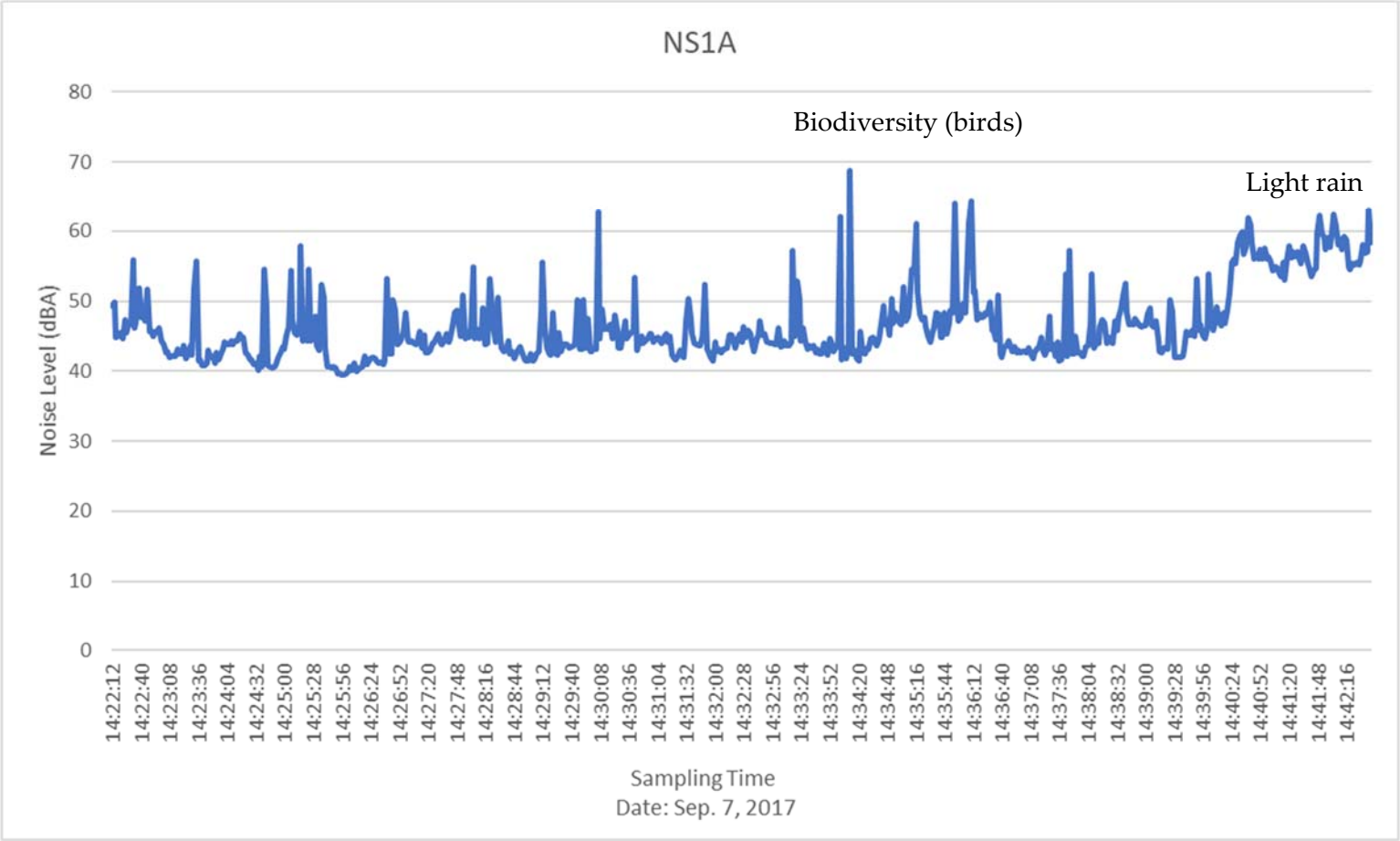

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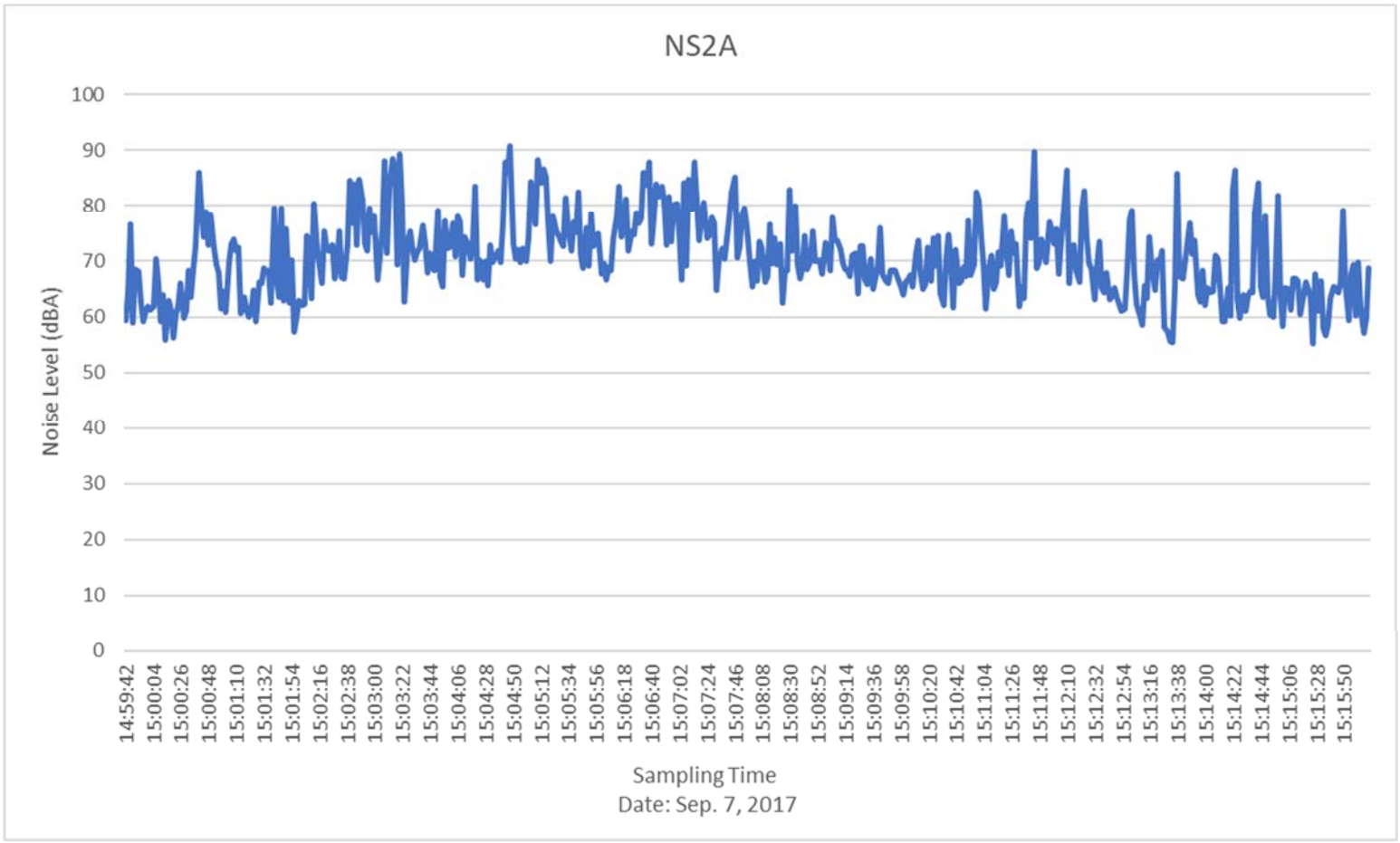

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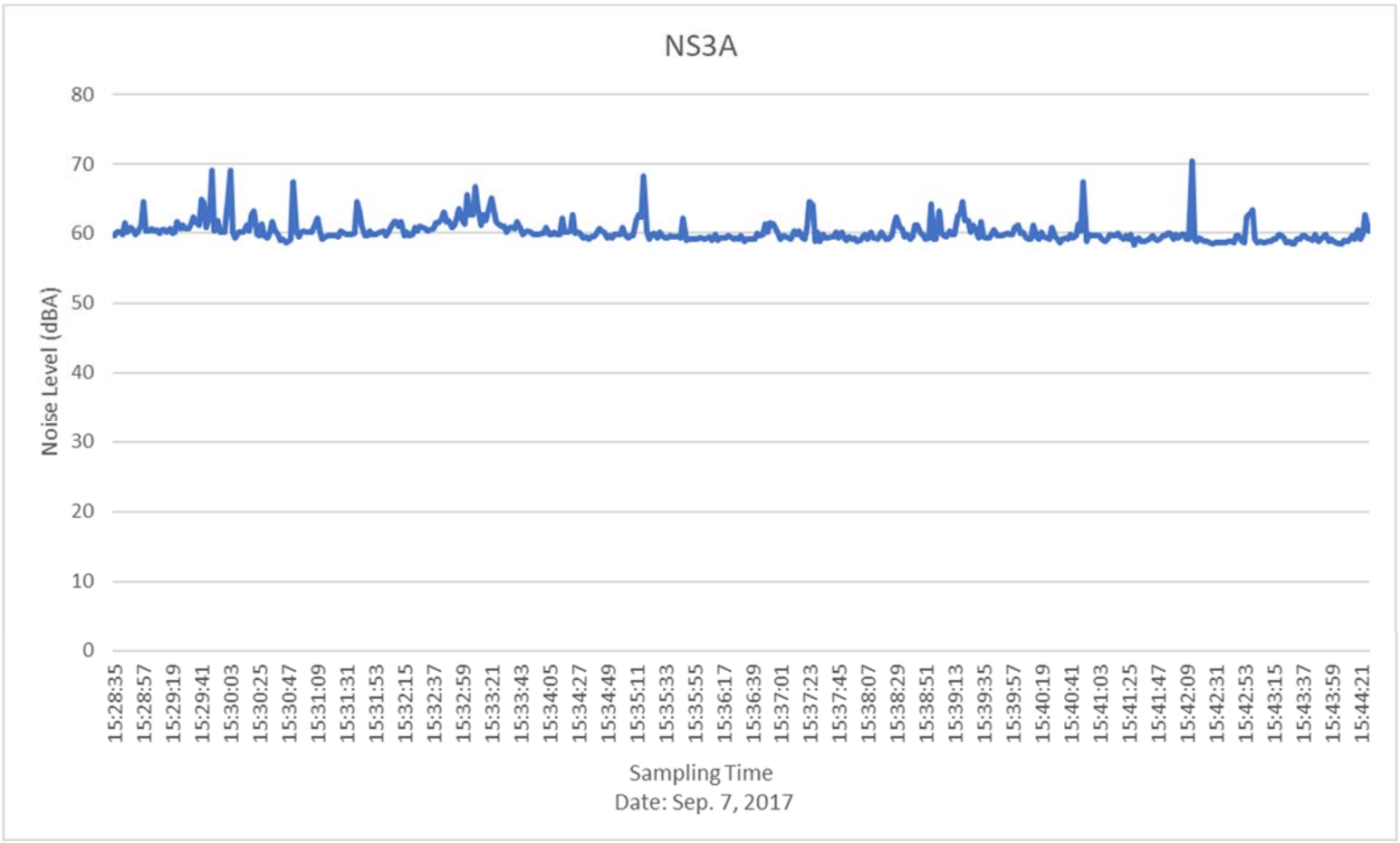

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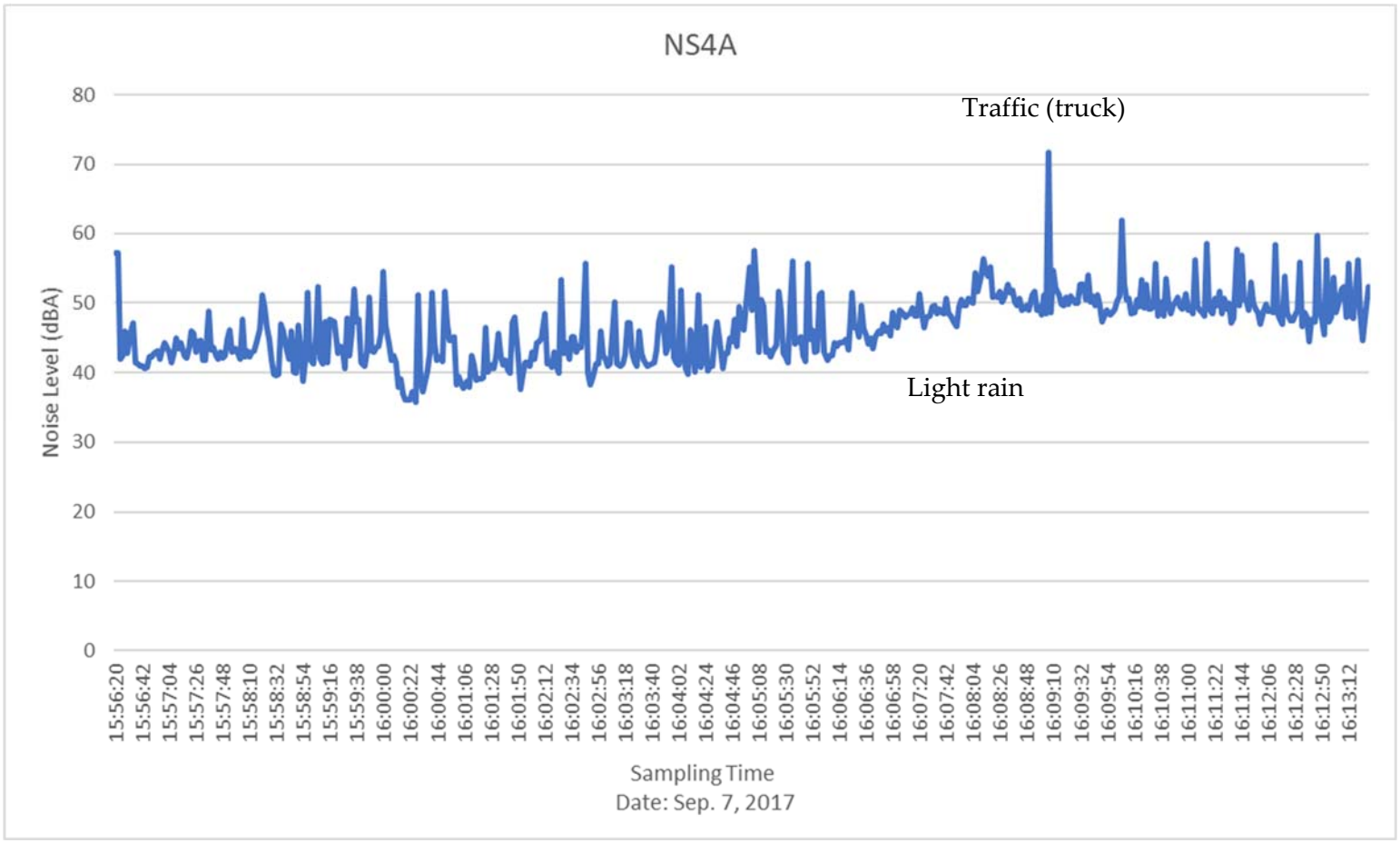


APPENDIX C

Public Consultation Questionnaire and Notes

Appendix C - Questionnaire

ESIA - Geothermal Energy Development Project - St. Lucia

Interviewer Name ---------- Date ----------

Respondent Name ---------- Community ----------

Respondent Mobile No. ----------

1. How long have you lived in this community? --------- years

2. Gender: ☐ Male ☐ Female

3. Age: ------- ☐ 18 - 25 ☐ 26 - 29 ☐ 30 - 39 ☐ 40 – 49 ☒ 50 - 59
   ☐ 60 - 65 ☐ 66 and older

4. Educational Level: ☐ Primary ☐ Secondary ☐ Tertiary

5. Employment Status: ☐ Full-Time ☐ Part-Time ☐ Self-Employed ☐ Unemployed
   ☐ Student ☐ Retired ☐ Disabled

6. For each additional household member, please provide responses to Questions 2-5

Name	**Gender** Male (M) Female (F)	**Age**	**Educational Level** Primary (P) Secondary (S) Tertiary (T)	**Employment Status** Full Time (FT), Part Time (PT), Self-Employed (SE), Unemployed (UE), Student (S), Retired (R), Disabled (D)

7. Household monthly income range: ☐ $0-500 ☐ $501-1000 ☐ $1001-2000 ☐ $2001-3000 ☐ $3001-4000 ☐ >$4000

8. Main economic activities/sources of household income: ☐ farming ☐ fishing ☐ domestic
   ☐ construction ☐ labourer ☐ office ☐ hotel ☐ store/shop
   ☐ teacher ☐ Gov't worker ☐ income from family overseas
   ☐ other _____

9. Is there any work/employment done by household members likely to be affected by the loss of land to the project? ☐ Yes ☐ No If yes, Which ----------

10. Type of house: ☐ wooden ☐ masonry ☐ wood/masonry ☐ other ----------

11. Type of toilet: ☐ Septic tank ☐ Pit Latrine ☐ other ----------Sources of water: ☐ WASCO/pipe borne ☐ RWH tanks ☐ springs ☐ river

12. Quality & reliability of water: ☐ good ☐ not good/muddy/unsafe ☐ WASCO reliable ☐ WASCO unreliable

13. Form of lighting: ☐ electricity ☐ other----------

14. Form of cooking fuel: ☐ electricity ☐ gas ☐ charcoal ☐ wood

15. Land ownership and use

    Housing: ☐ Private ☐ Family Owned ☐ Rented/Private Lease) ☐ Gov't/NDC ☐ Private Leased ☐ Caretaker ☐ Squatting

    Farming: ☐ Private ☐ Family Owned ☐ Rented/Private Lease) ☐ Gov't/NDC ☐ Private Leased ☐ Caretaker ☐ Squatting

16. Type of animals reared/crops grown----------

17. Is there a community group in your community? ☐ Yes ☐ No

    If yes, which group ----------

    If yes does any member of the household belong to a community group? ☐ Yes ☐ No

18. Have there been any changes (good or bad) in the community over the past 5-10 years

    ☐ Yes ☐ No If yes, please explain----------

19. In your opinion, what is your general perception of the natural environment in your community in last 2 years? ☐ 1. Very bad ☐ 2. Not very good ☐ 3. Fair ☐ 4. Good ☐ 5. Very good

20. What do you like/don't like about your community?

    ---

21. What improvement would you like to see in the community?

    ---

22. Where/how did you hear about the Geothermal Project?

    ---

23. What do you know of the history of the past Geothermal Project?

    ---

24. How do you think the project will affect you, your household and the community (problems & advantages)?

    ---

25. Would you be looking for a job with the Geothermal Project? ☐ Yes ☐ No If yes, what type of job?

    ---

26. What should the Project do to make sure that the benefits to your community is maximised and the negative effects minimised?

    ---

27 What is the best way to contact you so that we can provide more information about the project in the future?

ESIA – GEOTHERMAL ENERGY DEVELOPMENT PROJECT - SAINT LUCIA

Notes of Belle Plaine Community Consultation

Date:	Saturday, 2 September 2017
Time:	6:00 pm
Location:	Belle Vue Farmers' Cooperative, Soufriere
Attendees:	Participants/community members
	Valerie Leon – Permanent Secretary (PS), Department of Sustainable Development (DSD)
	Al Barthelmy (AB) – Geothermal Technical Coordinator, DSD
	Charlin Bodley (CB) – Public Utilities Officer, DSD
	Kurt Inglis (KI) – Public Utilities Officer, DSD
	Bethia Thomas – Science and Technology Officer, DSD
	Dr. Frederick Smith - Panorama Sub-consultants/Archaeologist
	Alison King (AK) – Panorama Sub-consultants/ECMC
	Egbert Louis (EL) – Panorama Sub-Consultants/ECMC
	Theresa Alexander-Louis – Panorama Sub-consultants/ECMC

Community Members Profile

19 community members/participants (5 females; 14 males) attended the consultation.

Welcome and Background Information

Charlin Bodley delivered the welcome remarks. Bethia Thomas led the group in prayer. Valerie Leon provided an overview of the Geothermal Energy Development Project, followed by a presentation delivered by Al Barthelmy on the project location and the results of the surface exploration phase recently completed. Dr. Smith gave an overview of the archaeology work he will be doing, and the types of recommendations he would make if he identified any concerns in potential drilling areas.

ESIA of the Planned Exploration Phase

An overview of the geothermal exploration drilling and the ESIA process was provided by Alison King. This was based on the PowerPoint presentation developed by Panorama.

Plenary Discussion

Following presentation of the Permanent Secretary:

Participant Input: If the project fails, are there other options e.g. water and wind? We are surrounded by water.

Response (DSD): The potential for hydro power here is small. Technology for harnessing of tidal energy is still in its infancy, and is not included in the plans of the government at this time. The focus is on the most viable resources, i.e. wind, solar and geothermal.

Participant Input: There used to be a hydro-plant in Soufriere. We have so many rivers, Can't that be an option?

Response: Hydro is not of great significance. The others have more potential. Our rivers are drying up, further reducing the potential for hydro.

Participant Input: The rivers are drying up because of man. We had 2 rivers along the Palmiste road, and they dried up one to do what they wanted, to build a school, etc. But when it rains, the river finds its path, and everywhere floods.

Following presentation of the Technical Coordinator:

Participant Input: Is there any problem with any of the sites?

Response (AB): It is too early to say. This is the reason for the studies.

Following presentation of the ESIA Consultant:

Participant Input: What if when drilling, instead of steam, you get fire?

Response (AB): Given all the data available to us to now, this is very unlikely.

Participant Input: In the last time of drilling in the Sulphur Springs, above the river, steam came up and they were happy. Then they stopped because they got fire coming up and they had to seal it.

Response (AB): It was not fire, they had a blowout. A well is a series of pipes. We must admit it. There was instability at Sulphur Springs. If the job is not done properly and material is coming up under high pressure there is a risk.

Participant input: I physically visited the site during the drilling. I saw fire. Even trees in the vicinity got burnt. Steam was coming off the mouth of the well. I saw gas or fire.

Response (AB): Steam is heat, more than 100 degrees. If it comes into contact with the trees it will destroy them.

Participant input: The fire was under the steam. It came after.

Participant input: In other places, is drilling done in residential areas? Sulphur is hazardous to health. It affects the lungs and the eyes. Persons working at the Sulphur Springs are getting these problems. What does the research show regarding the impacts? I am aware of the energy benefits but what about the health issues?

Secondly, the assessment must be done in a transparent manner. Ensure that community persons are privy to the reports, particularly regarding effects on their health.

Response (CB/AB): We have seen similar projects in similar settings. Government invested in sending a Ministry team to Hawaii where there was a functioning geothermal plant. Government has a developer in mind, the same developer for the Hawaii plant. The feedback from the team was that they were impressed with what they saw and observed no adverse effects. They followed a similar ESIA process to the one being undertaken here, and the ESIA document informed as to how to proceed with the project. Mitigation measures were developed after identifying possible negative effects. At a plant in Iceland, the

pipes are in a residential area. There is a plant operating in Guadeloupe, and explorations are underway in St. Kitts, Grenada, St. Vincent and Dominica. We are not aware of any serious negative effects.

(PS) In terms of transparency, the report will not be hidden. It will be available for public review, although this is not mandatory under the law. It will be online, in libraries and other public places where people can see it. If persons need help in reviewing it, we will send a team to assist. You will see the recommendations, and know whether the project proceeds in the manner recommended.

Participant input: Who is paying the experts?

Response (PS): The Government. The experts are independent and international experts, not involved in other aspects of the work. There are international standards that they are required to meet. ECMC is a sub-consultant to the company in California. This is a reputable company with expertise in this area. There has been no political interference in any way, and the technocrats are being left to do their work. We do not foresee any interference.

Participant Input: Conditions differ in different countries. In drilling we can have migration of gases.

Response (AK): The testing will include testing of the steam to determine what other constituents are in there and the risks they pose.

Participant Input: Geothermal sites usually experience dry spells. Will studies take that into account? Also, when drilling was done before, there were earth tremors in this area. The lands were not stable. Will the ESIA address this?

Response (AB): One well will not last; there must be makeup wells. If a well becomes non-viable, further drilling is needed.

When drilling SL2, the frequency of earthquakes increased, and there was concern that this was caused by the drilling. He visited the site and there was no evidence to support that. In his view, there was no connection.

Participant Input: The literature tells us that there is instability and ground movement. The ESIA must capture that.

Response (AB): Re-injection wells are required to replace the fluid and this largely addresses the stability issue. It is almost like recycling. The pre-feasibility will also examine the possibility of seismic activity in response to the TOR. If it is a concern, measures to address will be recommended.

Participant Input: Can the amount of steam and likelihood of dry spells be measured?

Response (AB): In SL2, the test ran for 2 weeks, and the steam declined thereafter.

Health-wise, we need to ensure that every contract has clauses to ensure that responsible entities comply with specified safety standards, to protect human health and the environment.

Participant Input: A project of this nature has positive and negative impacts. It will cost millions. We are told that it does not mean that the cost of electricity will go down, but this is something we were expecting. If not, is it economically viable in terms of the cost of exploring and drilling? There have been studies in other areas (solar, wind), but have you considered the comparative costs, and whether it is advisable to proceed over the long term? What is the long term sustainability of the project? We need to know how long the geothermal resource will last. Is it 10, 50, 100 years?

Looking at the negative aspects, what are the risks to the environment? Can drilling affect availability of water in streams or underground? Can it cause a volcanic reaction? Our grandparents said that all these valleys (Roblot, Fond St. Jacques, Belle Plaine) were linked underground, and there was “La Tou Noir” (the black hole), where water gets sucked into the ground.

We had higher rainfall before, all the valleys were swamps, and we had a lot of water that fed the hot rocks. What are the implications of the changing rainfall patterns?

What will be the implications for livelihoods? Many of these lands are farmed by Belle Plaine farmers, and this is a major revenue earner.

We must have access to the report.

Response (AB): The pre-feasibility study will include an economic assessment to address these. The national energy transition strategy (NETS) examined and compared the various sources of renewable energy. While geothermal may not guarantee a decrease in price, it provides stability in the price of electricity. The power purchase agreement between the generator and the utility will determine the price to consumers, over the 20 to 30 year life of the plant.

(CB) Although not widely publicized, government over the last three years has investigated the best mix of renewable energies for St Lucia, to achieve the best price for St Lucians. The mix must be stable. The NETS study is to be submitted to Cabinet for approval before the results can be shared. Our peak demand is 60 megawatts. Wind and solar are intermittent sources, especially wind. Geothermal is not a variable renewable energy source. The target is to develop a 30 MW plant, which with availability factors, may yield 28 MW and we would get it consistently. LUCELEC agrees that geothermal works well because our base load is 28 to 30 MW.

(CB) The two main objectives of the pre-feasibility study are to investigate the technical and economic feasibilities of the resource. We are hearing in other countries, a price of 18 US cents per kilowatt hour for geothermal power, but in these instances the developer does the exploration, and includes the cost of the risk associated with that. Government of St Lucia decided to get grant funding to do most of the exploration, so there is an expectation that the cost will be considerably reduced.

Participant Input: The last time they drilled in Sulphur Springs there were 13 strong quakes. Some houses got damaged. If it happens again, would there be compensation? Would the company take that responsibility?

Response (EL): One would have to establish a link between the drilling and the quake. This is difficult to pinpoint. If the property is insured the owner can call on insurance.

Participant input: This reminds me of a situation with LUCELEC. Appliances in Belle Vue were damaged after an electrical storm, and LUCELEC told customers it was their problem. I am hearing the same thing. What you are saying is "brace yourself".

Response (EL, AB): No, but it would have to be established that the quake is associated with the drilling. This would be difficult. The burden of proof is very important. Nobody can predict an earthquake. In the US, they are considering whether fracking may cause an earthquake.

Dr. Smith noted during his later comments that fracking is a big problem in the USA now, and the impacts are still being studied.

Participant Input: Are we saying that people need to get insurance for their houses? Who would pay for that?

Participant Input: I (KI) am wearing a resident's hat and have three concerns:

1. The access to the two sites in Belle Plaine. This is not truck friendly and would need to be upgraded, and reinstated after use.

2. The risk of contamination of farmlands to be used for drilling. If these are to be leased and returned to owners after two to three months, they must not be contaminated and made unusable.

3. Drilling along a fault or crack may cause these to widen. Residents are advised to photograph their homes before drilling starts, so that they may produce evidence of damage in the event of tremors.

A complaints board or some other facility should be established where community members may bring their concerns and not be turned away. Person conducting the investigation into such complaints should be independent of the project.

Participant Input: I am a resident of Etangs. When they were drilling there, they did not notify us. The generator used to pump water was making noise all the time. I could not hear my wife. We could not sleep at night.

Participant Input: Will the noise be bearable?

Response (AK, EL): There are measures that can be put in place to reduce noise. A baseline survey of noise will be undertaken, and noise standards will have to be complied with to ensure that the noise is bearable.

Participant Input: We have an issue now at Belle Plaine with LUCELEC generators. They were put there when work was being undertaken on the Soufriere feeder, but were not removed and are occasionally used since then. There is a siren that goes off on most weekends (late nights and early mornings).

Participant Input: If you have to drill on my property, can I refuse?

Response (PS): The government hopes to engage persons in negotiation, but compulsory acquisition for the national good can be a last resort.

Participant Input: My concern is the noise. I am an insomniac. I do not sleep well. How will it affect my health?

Response (AB): We do not know for sure where drilling will take place. We must select a developer with a good work record in environmental and health issues. The developer under consideration now is good. That developer has a proprietary technology that is environmentally friendly.

Participant Input: The permanent secretary mentioned a US$22 million grant. What is it to be used for?

Response (PS): It will be used for the drilling exploration and well testing.

Participant Input: We have a target for 35% renewables by 2025. What is it now?

Response (PS): Less than 1%.

Participant Input: Why did you stop the wind project?

Response (PS): It has not stopped. We are still in discussion with the developer. It is on hold for now. There are issues with land acquisition. We hope we will not have these issues with the geothermal project, and people will support for the good of St Lucia.

Participant Input: How will livelihood issues be addressed? If lands are acquired, how is this affect farmers and persons rearing animals?

Response (PS): These social aspects must be considered as part of the ESIA and will inform the decisions, including for compensation. The World Bank has safeguard measures that must be applied if we are to access the funding.

Participant Input: If residents live in close proximity, will they be relocated?

Response (AB): If we do not address these things we do not have a project.

Participant Input: The project has long term benefits. Consultation and feasibility studies are good. We do not want chaos like the DSH Project. You must present what will affect us. Our children stand to benefit.

Response (PS): There will be no chaos. When we get the results of the studies we will come back.

Participant Input: What about water quality?

Response (PS): Hydrologists will gather baseline information over next week, and the impact on water will be assessed. They will look at issues like when water disappeared as we heard in the last consultation, and what caused that to happen.

Participant Input: After completion, will geothermal energy be reliable and sustainable?

Response (AB): It has been factored into the NETS, which looked at improving energy security. We will reduce consumption of fossil fuels. We know roughly what the geothermal potential is, about 75 MW, more than we need.

(PS) The persons conducting the study will be in the area asking questions. They will have ID badges provided by our department.

Participant input: We are not against the project but we have genuine concerns based on past experiences, as well as current experiences, for example in relation to noise pollution. We want to see our concerns taken into consideration. We need to see what is being recommended, for example would it be advisable to take out insurance?

Response (PS): We will be surveying households close to the sites, to understand land ownership, land use etc., to ensure persons are not put in a worse situation.

Participant input: You mentioned consideration of including a requirement for the drillers to adhere to standards. There must be penalties for non-compliance.

Response (AK): The monitoring plan will set up a system, and identify who is responsible for monitoring and enforcement.

Closing Remarks

The Permanent Secretary noted that experts will be in the field for the next three weeks. She requested a volunteer from the community who would ensure that instrumentation is not tampered with. She requested that interested persons contact the DSD. The equipment is expensive, and loss of data can affect the progress of the project adversely.

Bethia Thomas closed the meeting at 9.30 pm, thanking all for their participation, and inviting them to share some refreshments.

ESIA – GEOTHERMAL ENERGY DEVELOPMENT PROJECT - SAINT LUCIA

Notes of Community Consultation

Date: Thursday, 31 August 2017

Time: 7:00 pm

Location: Fond St Jacque Resource Centre, Soufriere

Attendees: Participants/community members
Valerie Leon – Permanent Secretary, Department of Sustainable Development (DSD)
Al Barthelmy – Geothermal Technical Coordinator, DSD
Charlin Bodley – Public Utilities Officer, DSD
Kurt Inglis – Public Utilities Officer, DSD
Alison King – Panorama Sub-consultants/ECMC
Egbert Louis – Panorama Sub-consultants/ECMC
Theresa Alexander-Louis – Panorama Sub-consultants/ECMC

Community Members Profile

Twenty-five participants comprising six females and nineteen males attended. Their ages ranged from 30 – 70 years.

Welcome and Background Information

Charlin Bodley made the welcome remarks. Kurt Inglis lead the group in prayer. Valerie Leon provided an overview of the Geothermal Energy Development Project, followed by a presentation delivered by Al Barthelmy on the project location and the results of the surface exploration phase recently completed.

ESIA of the Planned Exploration Phase

An overview of the geothermal exploration drilling and the ESIA was provided by Alison King. This was based on the PowerPoint presentation developed by Panorama.

Plenary Discussion

Spring Water Supplies

There are several springs in the Fond St. Jacques area (from Migny, down towards the community), that a significant number of persons in the community harness for drinking water. There is concern that the project will affect these very important water sources. The example of the disappearing lake at Robot after drilling was cited. The community members are very passionate about these springs.

One participant indicated that this has been his drinking water supply for more than 30 years. This water is all that some people in the Fond St. Jacques and surrounding communities drink. Although most people have a WASCO supply, many still use the local spring sources for drinking, and other surface supplies for washing.

When the WASCO water supply is interrupted, this is the only source of water for the community. They were forced to rely on this source for a protracted period after the passage of Hurricane Tomas.

Provision of increased storage of WASCO water in the community to improve water security would not be an acceptable mitigation measure, as:

- This is chlorinated water, and
- Where would the water come from if not the same source that would be affected by the project?

When asked to indicate the importance of this water supply to the community on a scale of 1 to 10, the community members were unanimous in rating it at 10.

Another participant noted that the WASCO supply to the community is unreliable, even though the area is an important source of raw water for WASCO (there are 3 WASCO intakes in the area) that is used to serve communities as far afield as Choiseul, Cresslands and Hotel Chocolat. As a result, some people have no choice but to go to the springs.

Impact on Agriculture

DSD must work hand in hand with Ministry of Agriculture. This is an agricultural community, and cultivated areas will be affected.

An undertaking was made by the Permanent Secretary to collaborate.

Impact of Noise

One participant indicated that he was a child during the first drilling project, and the noise was very intense. He is very concerned that persons would not be able to live next to the proposed well location shown, within the community. They would have to be moved.

ECMC and DSD representatives noted that the technology has advanced since then, and it is possible to reduce noise. It is also possible use directional drilling to set back the pad from the community.

DSD noted a need to include environmental standards in every contract, to protect against such impacts, with proper enforcement by the supervising entity.

One participant enquired whether there would be penalties in the contract for non-compliance with such clauses.

Cynicism

A participant noted that often the end justifies the means, and politicians often have their own agenda. Is the primary objective to reduce Saint Lucia's carbon footprint? The community is in great need of jobs, infrastructural development, and all the possible benefits of such a project. People can come in with a nice smile and big words that lay people do not understand, and only afterwards do the people understand that things are not what they expected. He recalled an experience with WASCO where the community was opposed to tapping into a water source, and this project was only aborted after significant expense had been incurred by the company.

After Hurricane Tomas, the geological report touted by technocrats was never shared with the community, as it was thought that it was something they would not understand. The people need to be provided with information and equipped to make informed decisions for themselves.

ECMC noted, confirmed by the Permanent Secretary, that the ESIA report will be made public. It will be placed on a website and in community libraries and resource centres such as this one in Fond St. Jacques. ECMC also noted that the funding agencies that support this project are very concerned about environmental and social issues and will not disburse any money unless the issues are properly addressed.

Aesthetics

After the drilling near Sulphur Springs, some 50 pipes were left all about the place, and the holes are still there. Another participant noted that aesthetics are important as they sell the area as an attraction.

DSD conceded that this did occur with one of the previous exploration projects. ECMC noted that it will be a requirement of contractors to properly remediate after completion.

Land Availability

The community is deprived of land space that is arable and/or flat. The demarcated potential drilling areas fall within such spaces. These lands are used for homes, recreation and farming by the community. (*Note that there was some uncertainty about the exact locations being proposed).*

The smaller portion of land identified does not appear to be large enough for the size of well pad described in the presentation. There would be no playing field anymore if this area was to be used.

Impacts of Weather on Drilling

A participant enquired whether drilling would continue, rain or shine. ECMC noted that work would likely be halted if a storm was approaching.

Impact on Telephone and Electricity Lines

A participant enquired about the impact of large trucks on low hanging lines.

ECMC responded that the access routes would be reviewed in the ESIA to ensure these would not be impacted.

Employment

A participant enquired whether priority will be given to persons in the area for jobs. Politics often becomes a factor.

The Permanent Secretary responded that once persons from the area have the required skill sets, they will be given priority. There are some things beyond the control of technocrats, but they would do all within their purview. Consideration may be given to placing in the contract, the need to use persons in the area for labour, and to also engage in knowledge transfer for a specified number of persons.

DSD is also presently reviewing the possibility of requesting that relevant training be included on the government's training priority list, in anticipation of future jobs in this field. Such persons could find work across the globe as the world goes green.

One participant asked where the drilling company would come from.

The Permanent Secretary noted that the project is not at the stage where she can confirm that there is a viable resource for drilling. More information will be available in early 2018 after the studies are complete. Although government has a preferred developer, if that negotiation process is not successful, the project will be opened up to international and unrestricted tender through a transparent and open process.

Cost of Electricity

One participant noted that if electricity costs will be reduced, he is in 100% support of the project. This positon was supported by most others present, with the proviso that all mitigations required are put in place, so that they are not negatively impacted.

The Permanent Secretary noted that government has secured grant support to do much of the exploratory work, reducing costs to local tax payers, significantly de-risking the project for a power plant investor, and placing the government is a stronger position to negotiate. This should redound to the benefit of the consumer in terms of cost.

A participant noted that the NURC will regulate the pricing, not LUCELEC.

Another noted that everyone in the country pays for the dam remediation although not all benefit from the dam supply.

Level of Participation in the Meeting

One participant was of the view that participation was low.

The Permanent Secretary responded that no effort was spared in informing the community about the meeting and it is up to persons to take an interest in matters that can affect them. This is the 4th community meeting in relation to this project.

Closing Remarks

Charlin Bodley closed the meeting at 9 pm, thanking all for their participation, and inviting them to share some refreshments. Contact numbers were provided for DSD so that participants may continue to engage project personnel.

ESIA – GEOTHERMAL ENERGY DEVELOPMENT PROJECT - SAINT LUCIA

Notes of Mondesir Community Consultation

Date:	Sunday, 3 September 2017
Time:	3:00 pm
Location:	Saltibus Primary School, Choiseul
Attendees:	Participants/community members
	Valerie Leon – Permanent Secretary, Department of Sustainable Development (DSD)
	Al Barthelmy – Geothermal Technical Coordinator, DSD
	Charlin Bodley – Public Utilities Officer, DSD
	Kurt Inglis – Public Utilities Officer, DSD
	Bethia Thomas – Science and Technology Officer, DSD
	Dr. Frederick Smith - Panorama Sub-consultants/Archaeologist
	Mr. Kerry McCallum - Panorama Sub-consultants/Dewhurst Group
	Alison King – Panorama Sub-consultants/ECMC
	Egbert Louis – Panorama Sub-consultants/ECMC
	Theresa Alexander-Louis – Panorama Sub-consultants/ECMC

Community Members Profile

23 (10 female; 13 males) community members/participants attended.

Welcome and Background Information

Curt Inglis made the welcome remarks. Bethia Thomas lead the group in prayer. Permanent Secretary Valerie Leon provided an overview of the Geothermal Energy Development Project, followed by a presentation delivered by Protect Coordinator Al Barthelmy on the project location and the results of the surface exploration phase recently completed.

ESIA of the Planned Exploration Phase

Dr. Fred Smith gave an overview of the archaeological work he will be doing, and the types of recommendations he would make if he identified any concerns in potential drilling areas. He informed the meeting that he had spent some time before the meeting on the Parc Estate site, north of the playing field, which is earmarked for possible geothermal exploration. He found ceramic pottery dating back to the mid 18th century to the 1830's, which suggests that people were living there at those times. It is possible that there may be other discoveries to be made there, and more research is required.

Mr. Kerry McCallum informed the meeting about the air quality sampling tubes that will be placed at various locations around Soufriere and Choiseul, and left for about 3 weeks, at which time they will be collected.

An overview of the geothermal exploration drilling and the ESIA process was provided by Alison King. This was based on the PowerPoint presentation developed by Panorama.

Plenary Discussion

Participant Input: The area is agricultural flat land. The top soil will have to be removed to prepare for drilling. If the exploration is not successful, what will become of the area? Will they replace the topsoil? Secondly, what becomes of the pit/plug to ensure it does not become a hazard? Thirdly, what is the minimum distance that houses should be from the drill pad?

Response (DSD): The site must be restored to its previous condition. We had a situation in the 1970s where this did not happen, but this should be a requirement of the contract, with implications for non-payment if it does not occur satisfactorily. We will also need to require under the contract that the wells are plugged (with concrete) appropriately after the work is completed. This also has not been satisfactory under previous programmes, and we must ensure that it is done. The pipes will remain in the ground.

Participant Input: I was a taxi and truck driver before, and had work to supply the previous project. The area was left in the same way, top soil was not replaced.

Response (ECMC): We will recommend that top soil be set aside during site preparation, and spread back over the site as part of the site restoration works.

Participant Input: Mr. Barthelmy mentioned 6 miles to drill the well. How far down is the rock?

Response (DSD): From the moment you start drilling, you encounter rock.

Participant Input: I am born in Choiseul, resident in Gros Islet. What benefits will be derived by the population from this activity? Will there be competition? We only have 1 supplier, LUCELEC. What is the cost benefit for Saint Lucians?

Response (DSD): Our peak load is 60 MW. Geothermal can generate 30 MW, or 50% of our electricity. This is an indigenous resource, reducing our need for imported oil. Electricity prices will be less volatile because of fluctuations in oil prices. Geothermal brings added stability, which is attractive to investors. A lower cost power supply is also possible, which would benefit all residents.

Because we are a small island, it is not feasible to have multiple companies. We are 99% electrified and have very good infrastructure. LUCELEC will continue to provide the transportation infrastructure. Power generated by independent power producers will be sold to LUCELEC at a price lower than it costs LUCELEC to produce power from oil.

Although there is no guarantee, hopefully the price of power will go down.

Participant input: I work with the Ministry of Agriculture, based in this area. I am concerned as this area is a water catchment area and a farming area. It feeds water to the pineapple area. There is an intake at the Gia Bois. Mr. Ferguson John (past MP for the area) has three fish ponds with water fed from there. There is spring water lower down. When there is no water in the mains, the people go there for water. The Ministry of Agriculture may have more information on these water sources.

Participant input: Will members of the community be trained to help with equipment deployment?

Response (PS): The project is not in full force. We are just doing testing and analysis, and these experts have been contracted for that. The work is so specialised, but there may be some limited opportunity for young people to observe.

The contract will require the drilling company to employ persons from the community.

If there is a viable resource, there will be a power plant. Once the power plant is opened, there is a world of opportunities for young people.

Participant input: I have read that they have been different feasibility studies, and drilling. Will this be another failure?

Response (PS): A number of drilling programmes have been conducted. That is why the pre-feasibility consultant is required to analyse existing information, to guide next steps.

Of 7 wells, two were producing, but SL2 was acidic. It would corrode equipment. Now, we are not drilling in the same place. More drilling is needed to capture the quality of the resource. We hope this is the last go, and we will discover a commercially viable resource.

(AB): Geothermal is very challenging and complex, even for countries with more resources than us, such as the British and the Americans, who do not always succeed.

(PS): By the second half of next year we will know if we can drill production size wells.

Participant input: This is a very fertile area. From here to Tete Morne, you can grow anything. We would have to gain big time because there is a lot to lose.

In the past, lands here have been identified here for relocation of farmers from the water catchment area (upper Saltibus) and Black Bay. This is prime agricultural land. Speak to Invest St Lucia. Some of these lands are leased by farmers from the Crown/ Invest St Lucia.

Participant input: If you develop that area, what would be the buffer zone for farmers?

Response (DSD): The studies will advise.

Participant input: Will there be a follow up?

Response (PS): Yes, we will have a public review. The public will have access to the document.

Closing Remarks

Ms. Charlin Bodley noted that experts will be in the field for the next three weeks. She requested a volunteer from the community who would ensure that instrumentation is not tampered with. She requested that interested persons contact the DSD. The equipment is expensive, and loss of data can affect the progress of the project adversely.

Mr. Curt Inglis closed the meeting, thanking all for their participation, and inviting them to share some refreshments.

APPENDIX D

Water Quality Sampling and Stream Flow

WASCO

THE WATER AND SEWERAGE COMPANY INC.

LABORATORY ANALYTICAL REPORT

SOURCE	Upper Fond St. Jaques Raw	
Date of sample	9.11.11	
Time	17:23	
Sampled by	D.Remy	
pH	6.92	
Colour	<1	
Turbidity [NTU]	0.21	
Appearance	Clear	
Odour	Odourless	
Conductivity [µS/cm]	169	
The following are in mg/l		
Dissolved Oxygen	6.91	
Residual Chlorine		
Total alkalinity as $CaCO_3$	58.4	
Total hardness as $CaCO_3$	65	
Calcium hardness as $CaCO_3$	47	
Magnesium hardness as $CaCO_3$	18	
Chlorides as Cl	23	
Fluorides as F	0.15	
Free ammonia as NH_3	0.054	
Nitrates as NO_3	1.76	
Phosphates as P_2O_5	25.13	
Phosphates as PO_4	0.249	
Sulphates as SO_4	1.7	
Silica as SiO_2	38.6	
Free Carbon Dioxide	19	
Non-filterable residue		
Total iron as Fe	0.064	
Copper as Cu	0.032	
Manganese as Mn	<0.001	
Aluminum as Al	0.071	
REMARKS		

BACTERIOLOGICAL REPORT	count per 100ml	
Total Coliform	120	
Faecal Coliform	20	
Faecal Streptococci	20	

SOURCE	Upper Fond St. Jaques Raw	
Date of sample	26.03.12	
Time	14:55	
Sampled by	D.Remy	
pH	7.3	
Colour	<1	
Turbidity [NTU]	0.593	
Appearance	clear	
Odour	odourless	
Conductivity [µS/cm]	169.4	
The following are in mg/l		
Dissolved Oxygen	10.02	
Residual Chlorine	<0.1	
Total alkalinity as $CaCO_3$	56	
Total hardness as $CaCO_3$	53.5	
Calcium hardness as $CaCO_3$	35.4	
Magnesium hardness as $CaCO_3$	17.9	
Chlorides as Cl	16.5	
Fluorides as F	<0.01	
Free ammonia as NH_3	0.02196	
Nitrates as NO_3	0.88	
Phosphates as P_2O_5	26.25	
Phosphates as PO_4	0.391	
Sulphates as SO_4	4.9	
Silica as SiO_2	48.8	
Free Carbon Dioxide	18	
Non-filterable residue		
Total iron as Fe	0.126	
Copper as Cu	0.08	
Manganese as Mn	0.007	
Aluminum as Al	0.013	
REMARKS		

BACTERIOLOGICAL REPORT	count per 100ml	
Total Coliform	1550	
Faecal Coliform	470	
Faecal Streptococci	20	

SOURCE	Upper Fond St. Jaques Raw	
Date of sample	26.8.13	
Time	15:34	
Sampled by	D.Remy	
pH	7.33	
Colour	<1	
Turbidity [NTU]	0.602	
Appearance	Clear	
Odour	Odourless	
Conductivity [µS/cm]	171	
The following are in mg/l		
Dissolved Oxygen	5.18	
Residual Chlorine	<0.1	
Total alkalinity as $CaCO_3$	24.8	
Total hardness as $CaCO_3$	53	
Calcium hardness as $CaCO_3$	36	
Magnesium hardness as $CaCO_3$	17	
Chlorides as Cl	17.25	
Fluorides as F	0.11	
Free ammonia as NH_3	0.0366	
Nitrates as NO_3	2.64	
Phosphates as P_2O_5	9.48	
Phosphates as PO_4	0.46	
Sulphates as SO_4	1	
Silica as SiO_2	58	
Free Carbon Dioxide	27	
Non-filterable residue		
Total iron as Fe	0.22	
Copper as Cu	0.03	
Manganese as Mn	0.007	
Aluminum as Al	<0.001	
REMARKS		

BACTERIOLOGICAL REPORT	count per 100ml	
Total Coliform	TNTC	
Faecal Coliform	70	
Faecal Streptococci	0	

SOURCE	Upper Fond St. Jaques Raw	
Date of sample	27.05.14	
Time	15:53	
Sampled by	B.Fontenelle	
pH	7.46	
Colour	1	
Turbidity [NTU]	0.325	
Appearance	Clear	
Odour	Odourless	
Conductivity [µS/cm]	182.6	
The following are in mg/l		
Dissolved Oxygen	5.65	
Residual Chlorine	<0.1	
Total alkalinity as $CaCO_3$	27.2	
Total hardness as $CaCO_3$	55	
Calcium hardness as $CaCO_3$	35	
Magnesium hardness as $CaCO_3$	20	
Chlorides as Cl	24	
Fluorides as F	0.01	
Free ammonia as NH_3	<0.01	
Nitrates as NO_3	3.08	
Phosphates as P_2O_5	14.64	
Phosphates as PO_4	0.49	
Sulphates as SO_4	3	
Silica as SiO_2	53	
Free Carbon Dioxide	21	
Non-filterable residue		
Total iron as Fe	0.04	
Copper as Cu	0.27	
Manganese as Mn	<0.001	
Aluminum as Al	0.023	
REMARKS		

BACTERIOLOGICAL REPORT	count per 100ml	
Total Coliform	1000	
Faecal Coliform	150	
Faecal Streptococci	90	

SOURCE	Upper Fond St. Jaques Raw	
Date of sample	16.08.16	
Time	14:45	
Sampled by	D.Remy	
pH	7.12	
Colour	8	
Turbidity [NTU]	0.586	
Appearance	Clear	
Odour	Odourless	
Conductivity [µS/cm]	146.2	
The following are in mg/l		
Dissolved Oxygen	5.61	
Residual Chlorine	<0.1	
Total alkalinity as $CaCO_3$	26.4	
Total hardness as $CaCO_3$	65	
Calcium hardness as $CaCO_3$	33	
Magnesium hardness as $CaCO_3$	32	
Chlorides as Cl	21	
Fluorides as F	0.12	
Free ammonia as NH_3	0.0122	
Nitrates as NO_3	3.52	
Phosphates as P_2O_5	14.4375	
Phosphates as PO_4	0.7	
Sulphates as SO_4	2	
Silica as SiO_2	37	
Free Carbon Dioxide	18	
Non-filterable residue		
Total iron as Fe	0.49	
Copper as Cu	<0.01	
Manganese as Mn	<0.001	
Aluminum as Al	0.029	
REMARKS		

BACTERIOLOGICAL REPORT	count per 100ml	
Total Coliform	510	
Faecal Coliform	250	
Faecal Streptococci	40	

WASCO

THE WATER AND SEWERAGE COMPANY INC.

LABORATORY ANALYTICAL REPORT

SOURCE	**Upper Saltibus Treated Water**		
Date of sample	20.08.13	11.11.13	
Time	13:50	16:25	
Sampled by	D. Remy	D. Remy	
pH	7.9	7.6	
Colour	61		
Turbidity [NTU]	14.7	6.88	
Appearance	Clear	hazy	
Odour	odourless	odourless	
Conductivity [µS/cm]	132	127.2	
The following are in mg/l			
Dissolved Oxygen	4.68	5.11	
Residual Chlorine	0.5	0.4	
Total alkalinity as $CaCO_3$	17.6	20.8	
Total hardness as $CaCO_3$	45.5	39.5	
Calcium hardness as $CaCO_3$	27	21.5	
Magnesium hardness as $CaCO_3$	18.5	18	
Chlorides as Cl	23.5	30.25	
Fluorides as F	0.16	<0.01	
Free ammonia as NH_3	0.134	0.183	
Nitrates as NO_3	14.08	<0.01	
Phosphates as P_2O_5	3.27	1.68	
Phosphates as PO_4	0.14	0.34	
Sulphates as SO_4	<1.0	2	
Silica as SiO_2	32	26	
Free Carbon Dioxide	1	14.5	
Non-filterable residue			
Total iron as Fe	0.47	0.16	
Copper as Cu	<0.01	<0.001	
Manganese as Mn	<0.001	0.047	
Aluminum as Al	0.01	0.046	
REMARKS			

BACTERIOLOGICAL REPORT	count per 100ml		
Total Coliform	0	0	
Faecal Coliform	0	0	
Faecal Streptococci	0	0	

SOURCE	**Upper Saltibus Treated Water**			
Date of sample	24.03.14	13.05.14	09.09.14	
Time	17:13	15:50	17:40	
Sampled by	D. Remy	B.Fontenelle	D. Remy	
pH	7.98	14:24	7.55	
Colour	17	10	149	
Turbidity [NTU]	1.44	0.07	21.5	
Appearance	clear	clear	clear	
Odour	odourless	odourless	odourless	
Conductivity [µS/cm]	164	191.4	75.6	
The following are in mg/l				
Dissolved Oxygen	5.07	4.84	4.3	
Residual Chlorine	13	0.8	0.6	
Total alkalinity as $CaCO_3$	25.6	26.4	4	
Total hardness as $CaCO_3$	49	53.5	15	
Calcium hardness as $CaCO_3$	26	28.5	9	
Magnesium hardness as $CaCO_3$	23	25	6	
Chlorides as Cl	36.5	31.75	17.5	
Fluorides as F	0.11	0.14	<0.01	
Free ammonia as NH_3	0.049	<0.01	0.2318	
Nitrates as NO_3	3.96	7.04	12.32	
Phosphates as P_2O_5	12.83	12.06	5.8875	
Phosphates as PO_4	0.36	0.62	0.28	
Sulphates as SO_4	<0.1	2	<1	
Silica as SiO_2	32	35	15	
Free Carbon Dioxide	29	18	21	
Non-filterable residue				
Total iron as Fe	0.22	0.08	0.95	
Copper as Cu	0.1	0.04	0.29	
Manganese as Mn	<0.001	0.022	0.074	
Aluminum as Al	0.039	0.123	0.066	
REMARKS				

BACTERIOLOGICAL REPORT	count per 100ml			
Total Coliform	0	0	0	
Faecal Coliform	0	0	0	
Faecal Streptococci	0	0	0	

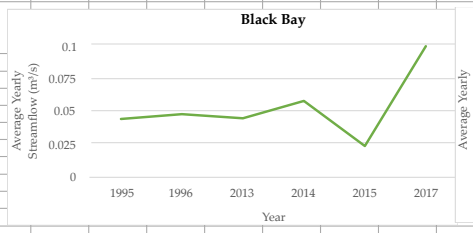
SOURCE	**Upper Saltibus Treated Water**	
Date of sample	24.8.15	
Time	17:17	
Sampled by	D.Remy	
pH	7.23	
Colour	<1	
Turbidity [NTU]	1.18	
Appearance	Clear	
Odour	Odourless	
Conductivity [µS/cm]	169.7	
The following are in mg/l		
Dissolved Oxygen	6.94	
Residual Chlorine	0.5	
Total alkalinity as $CaCO_3$	34.4	
Total hardness as $CaCO_3$	51	
Calcium hardness as $CaCO_3$	35	
Magnesium hardness as $CaCO_3$	16	
Chlorides as Cl	32	
Fluorides as F	<0.01	
Free ammonia as NH_3	0.0244	
Nitrates as NO_3	13.2	
Phosphates as P_2O_5	8.2125	
Phosphates as PO_4	0.5	
Sulphates as SO_4	5	
Silica as SiO_2	40	
Free Carbon Dioxide	16	
Non-filterable residue		
Total iron as Fe	0.22	
Copper as Cu	0.27	
Manganese as Mn	0.056	
Aluminum as Al	0.144	
REMARKS		

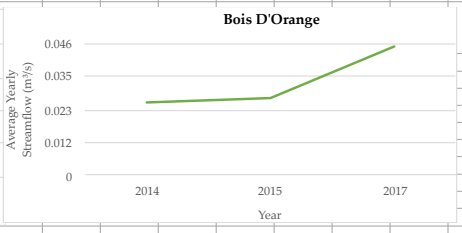
BACTERIOLOGICAL REPORT	count per 100ml	
Total Coliform	12	
Faecal Coliform	0	
Faecal Streptococci	0	

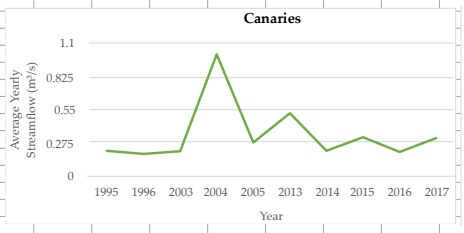
SOURCE	**Upper Saltibus Treated Water**		
Date of sample	17.02.16	12.07.16	
Time	18:38	16:08	
Sampled by	D.Remy	D.Remy	
pH	7.46	12:00	
Colour	25	63	
Turbidity [NTU]	4.26	13.4	
Appearance	clear	clear	
Odour	odourless	odourless	
Conductivity [µS/cm]	84.3	76.6	
The following are in mg/l			
Dissolved Oxygen	5.78	6.07	
Residual Chlorine	0.2	<0.1	
Total alkalinity as $CaCO_3$	10.4	17.6	
Total hardness as $CaCO_3$	30	23	
Calcium hardness as $CaCO_3$	15	12	
Magnesium hardness as $CaCO_3$	15	11	
Chlorides as Cl	20.5	20	
Fluorides as F	<0.01	<0.01	
Free ammonia as NH_3	0.0366	0.061	
Nitrates as NO_3	7.48	3.08	
Phosphates as P_2O_5	6.21	13.9125	
Phosphates as PO_4	0.45	0.74	
Sulphates as SO_4	1	1	
Silica as SiO_2	39	21	
Free Carbon Dioxide	22	44	
Non-filterable residue			
Total iron as Fe	0.26	0.46	
Copper as Cu	0.32	0.01	
Manganese as Mn	0.007	0.035	
Aluminum as Al	0.183	0.036	
REMARKS			

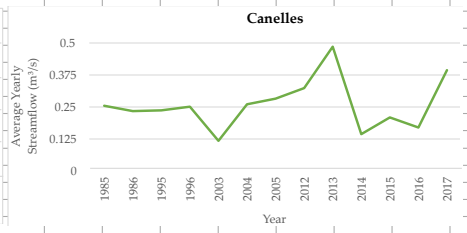
BACTERIOLOGICAL REPORT	count per 100ml		
Total Coliform	8		
Faecal Coliform	4		
Faecal Streptococci	0		

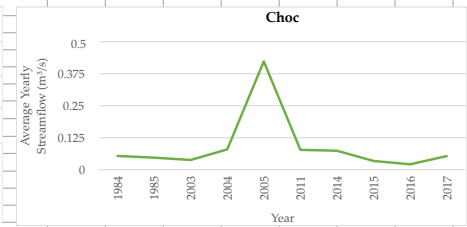
Watershed	Year	Q Average flow rate
AnseLa Raye	2016	0.09
Black Bay	1995	0.0438104
	1996	0.047464
	2013	0.044337
	2014	0.0575
	2015	0.0233095
	2017	0.099
Bois D'Orange	2014	0.02547
	2015	0.027
	2017	0.045
Canaries	1995	0.2091226
	1996	0.18365
	2003	0.2059238
	2004	1.011115166
	2005	0.2784
	2013	0.5217982
	2014	0.2094115
	2015	0.322509333
	2016	0.1998
	2017	0.315444444
Canelles	1985	0.251875
	1986	0.23075
	1995	0.23369575
	1996	0.24816
	2003	0.113405
	2004	0.2576528
	2005	0.279913
	2012	0.32155077
	2013	0.484994068
	2014	0.139756166
	2015	0.20577125
	2016	0.166
	2017	0.3924
Cap	2014	0.007314
Castries	2014	0.041786
	2017	1.455125
Choc	1984	0.05192925
	1985	0.045314444
	2003	0.036084666
	2004	0.07797775
	2005	0.426215
	2011	0.076240833
	2014	0.072642
	2015	0.032198
	2016	0.019
	2017	0.0515
Choiseul/ Trou Barbet	2014	0.027
Cul de Sac	1985	0.642
	1986	0.425
	1987	0.521464833
	1989	0.421545454
	1990	0.481783333
	1991	0.285966666
	1992	0.155971428
	1993	3.30145
	1995	0.16285
	1996	0.2963
	1998	0.122138363
	1999	0.241298
	2000	0.278760285
	2001	0.249828230
	2002	0.3117514
	2003	0.262966666
	2004	0.384273333
	2010	0.036323428
	2012	0.3950735
	2013	0.515187251
	2014	0.268601526
	2015	0.1978845
	2016	0.146416666
	2017	0.195416666
Dennery	1995	0.16717275
	1996	0.110256
	2003	0.074076333
	2004	0.1316346
	2005	0.3257415
	2015	0.041202
	2016	0.057
	2017	0.065
Doree	1995	0.1260266
	1996	0.117417
	2003	0.563333
	2004	0.28711
	2014	0.15619
	2015	0.1980774
	2016	0.12825
	2017	0.1884
Fond	1995	0.22868
	1996	0.21242
	2015	0.337259333
	2016	0.27625
	2017	0.285166666
	1990	0.293311111
	1991	0.14542
	1992	0.454584888
	1994	0.1407
	1995	0.183333333
	1996	0.1869
	1998	0.0627264
	1999	0.0753
	2000	0.157925
	2001	0.150756090

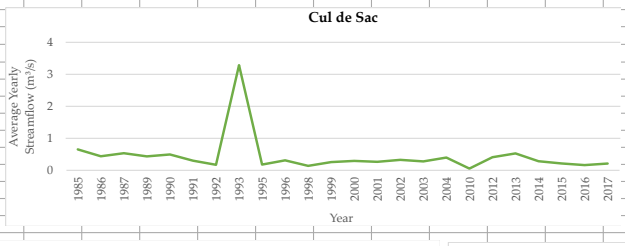


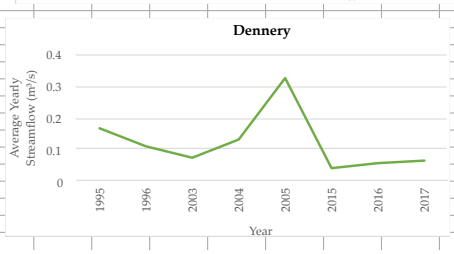


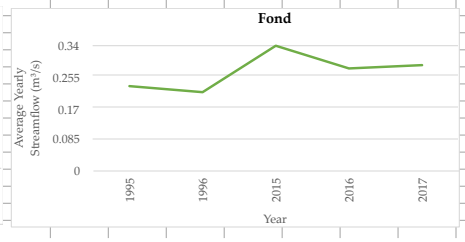


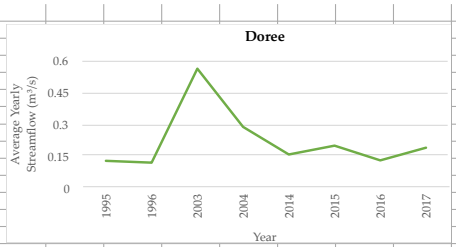


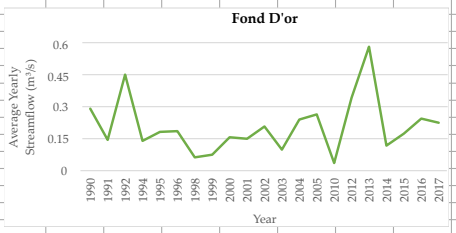




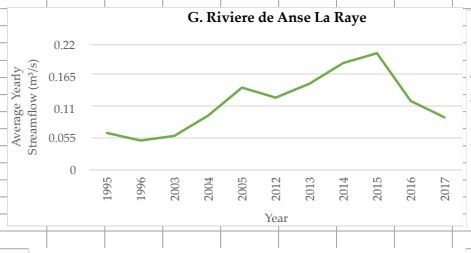


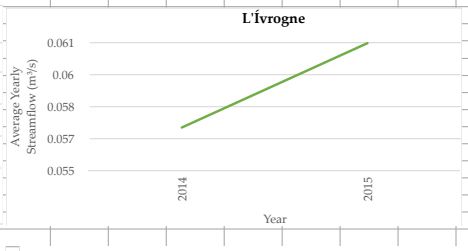


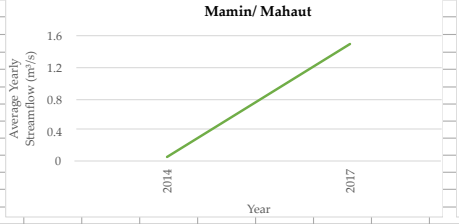


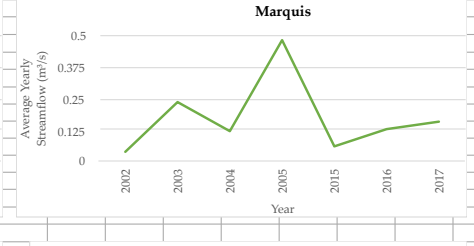


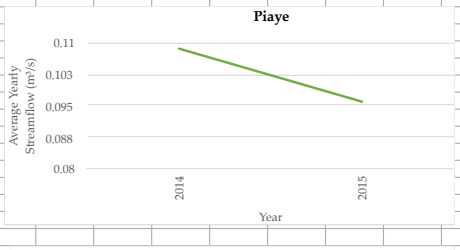
Fond D'or	2002	0.208920666
	2003	0.099286666
	2004	0.2417802
	2005	0.266078692
	2010	0.035925
	2012	0.345252
	2013	0.586685738
	2014	0.118307428
	2015	0.1751225
	2016	0.246285714
	2017	0.226692307
G. Riviere de Anse La Raye	1995	0.0646525
	1996	0.0515
	2003	0.059624
	2004	0.09489925
	2005	0.143436666
	2012	0.125985
	2013	0.1502317
	2014	0.1860855
	2015	0.203175428
	2016	0.120166666
	2017	0.09175
L'Ívrogne	2014	0.057
	2015	0.061
Mamiku/Patience	2015	0.021573
Mamin/ Mahaut	2014	0.06
	2017	1.492
Marquis	2002	0.0390785
	2003	0.236171666
	2004	0.120969571
	2005	0.481514
	2015	0.060750416
	2016	0.129
	2017	0.1586
Piaye	2014	0.1085545
	2015	0.096
Roseau	1992	1.846818333
	1994	0.11706
	1995	0.52153875
	1996	0.31039
	2001	0.316279833
	2002	0.6976775
	2003	0.262347
	2004	0.6925
	2005	0.7576
	2012	0.420255
	2013	0.851198330
	2014	0.450277181
	2015	0.548228611
	2016	0.308642857
	2017	0.237285714
Soufriere	1995	0.1924636
	1996	0.221894
	2003	0.3909916
	2004	0.6160168
	2005	0.906427
	2013	0.5230108
	2014	0.2750968
	2015	0.2989283
	2016	0.309
	2017	0.5152
Troumassee	1990	0.7925818
	1991	0.4115
	1992	0.4365667
	1994	0.33735
	1995	0.54135
	1996	0.5105
	1998	0.2346
	1999	0.4259393
	2000	0.556225
	2001	0.42985
	2002	0.5452172
	2003	0.3799733
	2004	1.1200823
	2005	1.1627335
	2013	4.93591
	2014	0.420858
	2015	0.6095417
	2016	0.721375
	2017	0.844125
Vieux Fort	1984	0.2586875
	1985	0.28332
	1986	0.4205
	1987	0.3657
	1988	0.3362
	1995	0.1708
	1996	0.161
	2003	0.1412942
	2004	0.3012032
	2005	0.4769615
	2006	0.168732
	2010	0.059668
	2013	0.3570249
	2014	0.1741665
	2015	0.189817
	2016	0.11225
	2017	0.3135
Volet	2015	0.010797

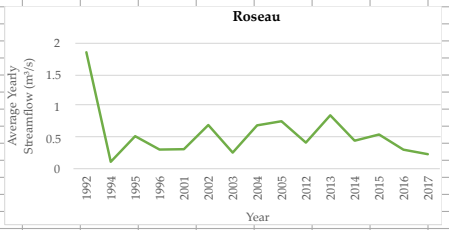


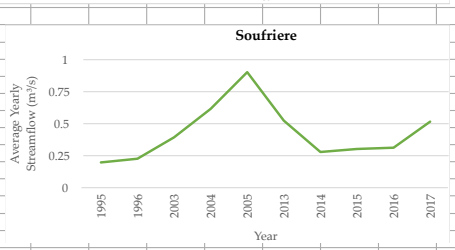


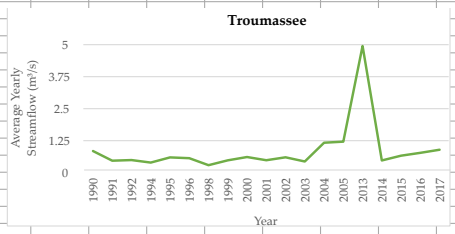


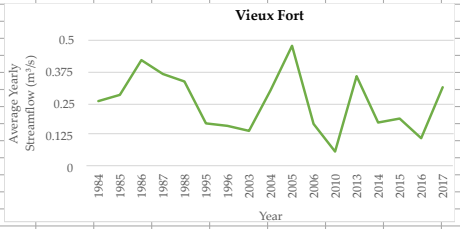




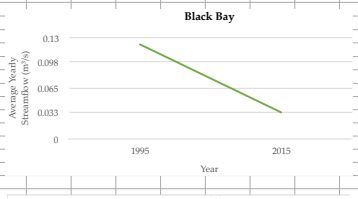


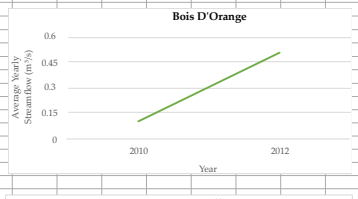


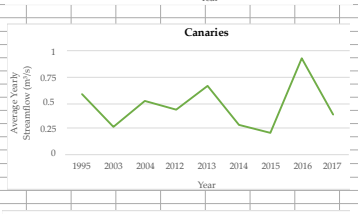


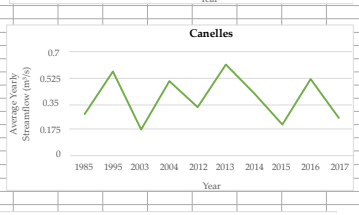


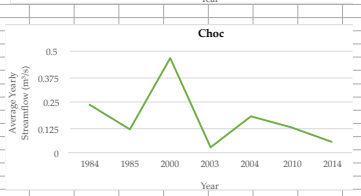
Watershed	Year	Q Average Flow Rate (m³/s)
Anse la Raye	2015	0.067
Anse La Verdue/Cochon	2014	0.023
Black Bay	1995	0.120819833333333
	2015	0.034
Bois D'Orange	2010	0.0995
	2012	0.504298
Canaries	1995	0.584465833333333
	2003	0.2635555
	2004	0.5178412
	2012	0.432322
	2013	0.66553875
	2014	0.2828486
	2015	0.204550272727273
	2016	0.936375
	2017	0.3842
Canelles	1985	0.279130434782609
	1995	0.57156
	2003	0.17308625
	2004	0.505553
	2012	0.3263155545
	2013	0.61938225
	2014	0.422269333333333
	2015	0.207200571428571
	2016	0.5196
	2017	0.2525
Castries	2017	0.076
Choc	1984	0.240369473684211
	1985	0.119586071428571
	2000	0.468767
	2003	0.031459
	2004	0.1832552
	2010	0.129319222222222
	2014	0.058421
Cul de Sac	1985	1.628775
	1986	0.896625
	1987	0.979421823529412
	1988	0.740171
	1990	1.819142857142857
	1991	0.568385714285714
	1992	0.444644444444444
	1994	0.1054
	1995	0.652871428571429
	1999	0.293005454545455
	2000	0.53663825
	2002	0.4369795
	2003	0.4549415
	2004	0.772497
	2012	1.354932
	2013	0.495297071428571
	2014	0.261650909090909
	2015	0.100287909090909
	2016	0.311333333333333
	2017	0.287
Dennery	1995	0.303271125
	2003	0.057490555555556
	2004	0.4397064
	2014	0.265
	2015	0.0625526
	2016	0.210333333333333
	2017	0.068
Doree	1995	0.196002333333333
	2003	0.227698
	2004	0.161976
	2013	0.395853
	2014	1.431228
	2015	0.129083333333333
	2016	0.7994
	2017	0.182666666666667
Esperance	2014	0.123
Fond	1995	0.474604833333333
	2014	0.5015
	2015	0.225525714285714
	2016	0.9975
	2017	0.312
Fond D'or	1990	1.51595
	1991	0.319894666666667
	1992	0.328
	1993	3.3523
	1994	0.0793
	1995	0.40315
	1998	0.0835
	1999	0.215911111111111
	2000	0.421771428571429
	2001	0.154633333333333
	2002	0.32514725
	2003	0.143617666666667
	2004	0.598740571428571
	2012	0.541127333333333
	2013	0.6482274
	2014	0.275029333333333
	2015	0.151404076923077
	2016	0.6245555555555556
	2017	0.29
G. Riviere de Anse La Raye	1995	0.160181
	2003	0.0818158
	2004	0.231701
	2013	0.163004666666667
	2014	0.0917238333333333
	2015	0.069689
	2016	0.477
	2017	0.2155
Grand Anse/ Louvet	2016	0.13
L'Ívrogne	2013	0.08737
	2015	0.024
Mamiku/ Patience	2014	0.105
Marquis	2002	0.0617608333333333
	2003	0.053619
	2004	0.244006333333333
	2014	0.727671
	2015	0.0316037777777778
	2016	0.208833333333333
	2017	0.1698
P. Riviere de Anse La Raye	2013	0.192
	2014	0.011
Piaye	2014	1.621881
	2015	0.0776965
Roseau	1992	1.2401165
	1994	0.185475
	1995	1.184661
	2002	1.156118333333333
	2003	0.908178
	2004	1.080211111111111
	2006	0.4466
	2012	1.418932
	2013	1.411673142857143
	2014	0.5471461
	2015	0.2587145
	2016	0.444333333333333
	2017	0.5945
Salee Lapins	2014	0.068
Soufriere	1995	0.417311333333333
	2003	0.449403833333333
	2004	0.52078125
	2013	0.667148
	2014	0.3586672

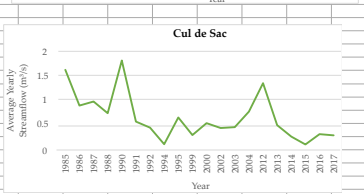


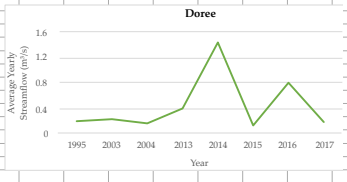


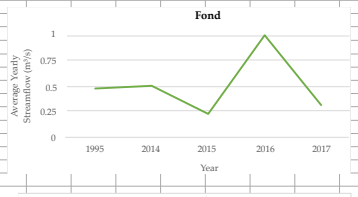


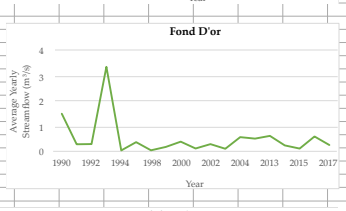


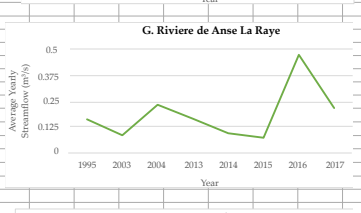


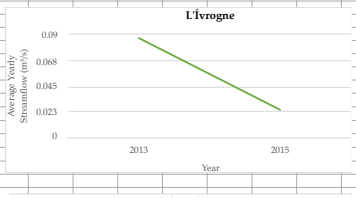


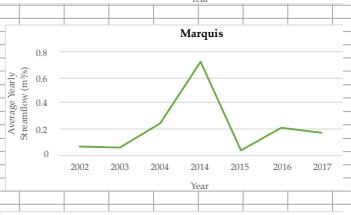


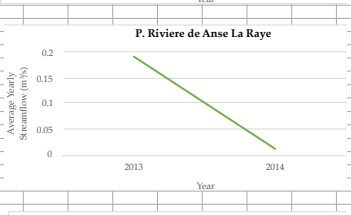


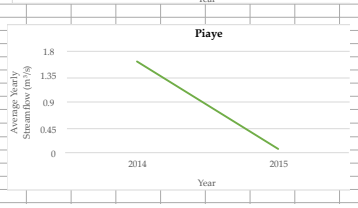


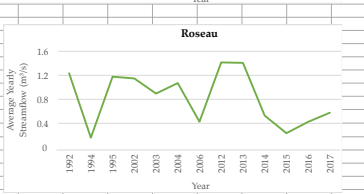




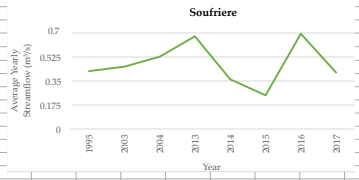


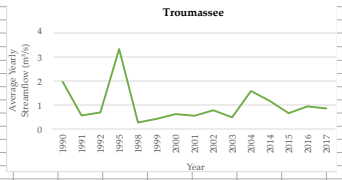


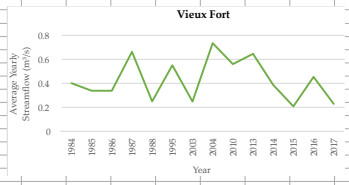




		2015	0.244162
		2016	0.6855
		2017	0.40633333333333
	Trou Graval/ Dauphins	2010	0.024851
	Troumassee	1990	1.95076
		1991	0.5677727272727727
		1992	0.690166666666667
		1995	3.290116666666667
		1998	0.2805
		1999	0.430255555555556
		2000	0.6243
		2001	0.5561
		2002	0.780809
		2003	0.49226
		2004	1.57050675
		2014	1.163358
		2015	0.661107
		2016	0.9393
		2017	0.85475
	Vieux Fort	1984	0.403458333333333
		1985	0.341782608695652
		1986	0.34128571428571 4
		1987	0.660307692307692
		1988	0.254447
		1995	0.55
		2003	0.253487
		2004	0.731396
		2010	0.559649
		2013	0.643828
		2014	0.389337571428571
		2015	0.213591416666667
		2016	0.454888888888889
		2017	0.23375
	Volet	2014	0.6







APPENDIX E

Biological Resources Supporting Information

FLORA AND FAUNA WITHIN THE PROJECT STUDY AREAS

Table E-1 Flora within the Belle Plaine Project Study Area

Common and Scientific Names	Family
Cultivated Vegetables	
Gonbo, Okra *Abelmoschus esculentus (Linnaeus) Moench*	Malvaceae
Ti lonyon, Chives *Allium species*	Amaryllidaceae
Pineapple *Ananas comosus (Linnaeus) Merrill*	Bromeliaceae
Selwi, Celery *A[ium graveolens Linnaeus*	Apiaceae
Zèpina, Spinach *Basella alba Linnaeus*	Basellaceae
Broccoli, Cabbage *Brassica oleracea Linnaeus*	Brassicaceae
Pwa angòl, Pigeon pea *Cajanus cajan (Linnaeus) Millspaugh*	Fabaceae-Faboideae
Toloman, Malobi *Canna glauca Linnaeus*	Cannaceae
Sweet, seasoning, hot peppers *Capsocum species*	Solanaceae
Watermelon *Citrullus lanatus*	Cucurbitaceae
Dasheen *Colocasia esculenta (Linnaeus) Schott*	Araceae
Jonmou, Pumpkin *Cucurbita moschata Duchesne*	Cucurbitaceae
Jenjanm dou, Kashibou *Curcuma zanthorrhiza Roxburgh*	Zingiberaceae
Carrots *Daucus carota Linnaeus*	Apiaceae
Chadon beni	Apiaceae

Eryngium foetidum Linnaeus	
Lanni, Fennel *Foeniculum vulgare Miller*	Apiaceae
Lettuce *Lactuca species*	Asteraceae
Manyòk, Cassava *Manihot esculenta Crantz*	Euphorbiaceae
Bazilik, Oktansya, Basil *Ocimum basilicum* Linnaeus	Lamiaceae
Parsley *Petroselinum crispum (Miller) A. W. Hill*	Apiaceae
Rosemary *Rosmarinus officinalis Linnaeus*	Lamiaceae
Sugar cane *Saccharum officinarum Linnaeus*	Poaceae
Tomato *Solanum lycopersicum Linnaeus*	Solanaceae
Thyme *Thymus vulgaris Linnaeus*	Lamiaceae
Salad bean *Vigna unguiculate (Linneaus) Walpers*	Fabaceae-Faboideae
Chou, Calalou *Xanthosoma species*	Araceae
Corn, Maize *Zea mays Linnaeus*	Poaceae
Bitter ginger *Zingiber zerumbet (L.) Roscoe ex Smith*	Zingiberaceae
Wild Herbs and Shrubs	
Acalypha aristata Kunth	Euphorbiaceae
Aeschynomene americana Linnaeus	F.Faboideae
Labonn fanm, Latifi *Ageratum conyzoides Linnaeus*	Asteraceae
Malanga, Fiant (upright) tayo *Alocasia macrorrhizos* (Linnaeus) G. Don	Araceae
Alternanthera tenella Colla var. *tenella*	Amaranthaceae
Alysicarpus vaginalis (L.) de Candolle	F.-Faboideae
Zèpina (blan) *Amaranthus dubius* Martius ex Thellung	Amaranthaceae

Zèpina wouj *Amaranthus spinosus* Linnaeus	Amaranthaceae
Axonopus compressus (Swartz) Palisot de Beauvois	Poaceae
Begonia humilis Dryand	Begoniaceae
Zèb a zédjwi, Needle grass *Bidens pilosa Linnaeus*	Asteraceae
Koko shak *Caladium bicolor (Aiton) Ventenat*	Araceae
Calathea lutea (Aublet) Schultes	Marantaceae
Callisia repens (Jacquin) Linnaeus	Commelinaceae
Pwa blé *Calopogonium mucunoides Desvaux*	F.-Faboideae
Zèb kolan, Burr grass *Cenchrus echinatus Linnaeus*	Poaceae
Elephant grass *Cenchrus purpureus (Schumacher) Morrone*	Poaceae
Fléwi Nwèl *Chloris radiata (Linnaeus) Swartz*	Poaceae
Godmò *Chromolaena odorata L.) R. M.King and H. Rob*	Asteraceae
Cissus verticillata (L.) Nicolson & C. E. Jarvis	Vitaceae
Cleome rutidosperma de Candolle	Cleomaceae
Clerodendrum chinense (Osbeck) Mabberley	Lamiaceae
Clerodendrum paniculatum Linnaeus	Lamiaceae
Kaka mèl *Clidemia hirta (Linnaeus) D. Don*	Melastomataceae
Zèb gwa, Water grass *Commelina diffusa Burman f.*	Commelinaceae
Conyza laevigata (Richard) Pruski	Asteraceae
Job's tears *Croix lacryma-jobi Linnaeus*	Poaceae
Cyanthillium cinereum (L.) H. Robinson	Asteraceae
Diverse small sedges *Cyperaceae species*	Cyperaceae
Desmanthus leptophyllus Kunth	F.-Mimosoideae
Sweetheart, Kòd-a-vyèlon *Desmodium species*	F.-Faboideae
Digitaria setigera Roth	Poaceae
Echinochloa colona (Linnaeus) Link	Poaceae
Pyé poul *Eleusine indica (Linnaeus) Gaertner*	Poaceae

Various Emilia species *Emilia species*	Asteraceae
Various low/prostrate species *Euphorbia species*	Euphorbiaceae
Zèb sèk *Flemingia strobilifera (L.) W. T. Aiton*	F.-Faboideae
Spanish shawl *Heterotis rotundifolia (Smith) Jacques-Félix*	Melastomataceae
Hyptis atrorubens Poiteau	Lamiaceae
Lyenn dous *Ipomoea tiliacea (Willdenow) Choisy*	Convolvulaceae
Jiwòf flè, Bwa wa tou *Lantana strigocamara R. W. Sanders*	Verbenaceae
Gwo ponpon *Leonotis nepetifolia (Linnaeus) R. Brown*	Lamiaceae
Leptochloa species	Poaceae
Jiwòf dlo *Ludwigia species*	Onagraceae
Macroptilium lathyroides (Linnaeus) Urban	F.-Faboideae
Zèb djiné, Guinea grass *Megathyrsus maximus (Jacq.) B. K. Simon & Jacobs*	Poaceae
Melochia nodiflora Swartz	Malvaceae
Mawi hont, Ti mawi *Mimosa pudica Linnaeus*	F.-Mimosoideae
Konmonm kouli *Momordica charantia Linnaeus*	Cucurbitaceae
Bwa gazon, (Mal) fonbwazen *Ocimum gratissimum Linnaeus*	Lamiaceae
Oxalis barrelieri Linnaeus	Oxalidaceae
Oxalis corniculata Linnaeus	Oxalidaceae
Panicum pilosum Swartz	Poaceae
Panicum trichoides Swartz	Poaceae
Paspalum conjugatum P. J. Bergius	Poaceae
Paspalum paniculatum Linnaeus	Poaceae
Paspalum virgatum Linnaeus	Poaceae
Phenax sonneratii (Poiret) Weddell	Urticaceae
Gwenn anba fèy *Phyllanthus species*	Phyllanthaceae
Malenbé, Bwa mal lèstomak *Piper dilatatum Richard*	Piperaceae
Koupyé *Portulaca oleracea Linnaeus*	Portulacaceae
Ti dayi *Priva lappulacea (Linnaeus) Persoon*	Verbenaceae
Setaria barbata (Lamarck) Kunth	Poaceae

Balyé wonzè *Sida acuta Burman f.*	Malvaceae
Balyé wonzè *Sida rhombifolia Linnaeus*	Malvaceae
Béléjenn djab *Solanum torvum Swartz*	Solanaceae
Ti makònèt *Spermacoce remota Lamarck*	Rubiaceae
Venvenn kawayib *Sphagneticola trilobata (L.) J. F. Pruski*	Asteraceae
Vèvenn latjé wat *Stachytarpheta jamaicensis (Linnaeus) Vahl*	Verbenaceae
Black-eyed Susan vine *Thunbergia alata Bojer ex Sims*	Acanthaceae
Tridax procumbens Linnaeus	Asteraceae
Tèt nèg *Triumfetta species*	Malvaceae
Pikan kouzen *Urena lobata Linnaeus*	Malvaceae
Ponm kannél, sugar apple *Annona squamosa Linnaeus*	Euphorbiaceae
Cultivated Trees	
Bwapen, breadfruit *Artocarpus altilis (Parkinson) Fosberg*	Annonaceae
Neem *Azadirachta indica A. Jussieu*	Moraceae
Papapya *Carica papaya Linnaeus*	Meliaceae
Kannèl, Cinnamon *Cinnamomum verum J. Presl*	Caricaceae
Citrus species	Lauraceae
Coconut *Cocos nucifera*	Rutaceae
Kalbas, Calabash *Crescentia cujete Linnaeus*	Arecaceae
Mòtèl *Erythrina poeppigiana (Walpers) O. F. Cook*	Bignoniaceae
Indian laurel tree *Ficus benjamina Linnaeus*	F.-Faboideae
Glory cedar *Gliricidia sepium (Jacquin) Kunth ex Walpers*	Moraceae
Gmelina *Gmelina arborea Roxburgh ex Smith*	F.-Faboideae
Mango *Mangifera indica Linnaeus*	Lamiaceae
Chennèt, Ginep, Ackee. *Melicoccus bijugatus Jacquin*	Anacardiaceae
Nutmeg *Myristica fragrans Houttuyn*	Sapindaceae
Caribbean pine *Pinus caribaea Morelet*	Myristicaceae

Guava *Psidium guajava Linnaeus*	Pinaceae
Saman *Samanea saman (Jacquin) Merrill*	Myrtaceae
Ponmsité., Golden apple *Spondias dulcis Solander ex Parkinson*	F.-Mimosoideae
Honduras mahogany *Swietenia macrophylla King*	Anacardiaceae
Ponm danmou, Love apple *Syzygium malaccense (Linnaeus) Merrill & Perry*	Meliaceae
Tanmawen, Tamarind *Tamarindus indica Linnaeus*	Myrtaceae
Cocao *Theobroma cacao Linnaeus*	F.-Mimosoideae
Wild Trees	
Bwa mou limou *Acnistus arborescens (Linnaeus) Schlechtendal*	Solanaceae
Bwa kòtlèt, Bwa kawé *Citharexylum spinosum* Linnaeus	Verbenaceae
Sip blan *Cordia sulcata* A. de Candolle	Boraginaceae
Kalbas, Calabash *Crescentia cujete* Linnaeus	Bignoniaceae
Fijé, Strangler fig *Ficus insipida* Willdenow	Moraceae
Kakoli *Inga ingoides* (Richard) Willdenow	Fabaceae-Mimosoideae
Leucaena *Leucaena leucocephala* (Lamarck) de Wit	Fabaceae-Mimosoideae
Kòsòl chyenn, Noni *Morinda citrifolia Linnaeus*	Rubiaceae
African tulip tree *Spathodea campanulata Palisot de Beauvois*	Bignoniaceae
Mouben, Hog plum *Spondias mombin Linnaeus*	Anacardiaceae
Maho nwè *Varronia martinicensis Jacquin*	Boraginaceae

Table E-2 Fauna within the Belle Plaine Project Study Area

Common and Scientific Name	Abundance	Status
Bird Species		
Cattle Egret *Bubulcus ibis ibis*	Common	Resident
Green Heron *Butorides virescens virescens*	Common	Resident
Spotted Sandpiper *Actitis macularius*	Common	Aug-May
Scaly-naped Pigeon *Patagioenas squamosal*	Common	Resident
Zenaida Dove *Zenaida aurita aurita*	Common	Resident
Common Ground-Dove *Columbina passerine antillarum*	Common	Resident
Ruddy Quail-Dove *Geotrygon montana marinica*	Common	Resident
Saint Luica Parrot *Amizona versicolor*	Uncommon	Resident
Mangrove Cuckoo *Coccyzus minor*	Common	Resident
Lesser Antillean Swift *Chaetura martinica*	Common	Resident
Purple-throated Carib *Eulampis jugularis*	Common	Resident
Green-throated Carib *Eulampis holosericeus holosericeus*	Common	Resident
Antillean Crested Hummingbird *Orthorhyncus cristatus exilis*	Common	Resident
Caribbean Elaenia *Elaenia martinica martinica*	Common	Resident
St. Luica Pewee *Contopus oberi*	Common	Resident
Gray Kingbird *Tyrannus dominicensis vorax*	Common	Resident
Lesser Antillean Flycatcher *Myiarchus oberi sanctaeluciae*	Uncommon	Resident

Common and Sicentific Name	Abundance	Status
Caribbean Martin *Progne dominicensis*	Common	Resident
Barn Swallow *Hirundo rustica erythrogaste*	Common	Sept-Oct April-May
House Wren *Troglodytes aedon mesoleucus*	Uncommon	Resident
Tropical Mockingbird *Mimus gilvus antillarum*	Common	Resident
Gray Trembler *Cinclocerthia gutturalis macrorhyncha*	Common	Resident
Scaly-breasted Thrasher *Allenia fusca schwartzi*	Common	Resident
Pearly-eyed Thrush *Margarops fuscatus klinikowski*	Common	Resident
Bare-eyed Thrush *Turdus nudigenis nudigenis*	Common	Resident
Black-whiskered Vireo *Vireo altiloquus barbatulus*	Common	Resident
Antillean Euphonia *Euphonia musica flavifrons*	Common	Resident
Saint Lucia Warbler *Dendroica delicata*	Common	Resident
Bananaquit *Palm Warbler*	Common	Resident
Black-faced Grassquit *Tiaris bicolor*	Common	Resident
Saint Lucia Black Finch *Melanospiza richardsoni*	Uncommon	Resident
Lesser Antillean Bullfinch *Loxigilla noctis sclateri*	Common	Resident
Lesser Antillean Saltator *Saltator albicollis albicollis*	Common	Resident
Carib Grackle *Quiscalus lugubris inflexirostris*	Common	Resident
Shiny Cowbird *Molothrus bonariensis minimus*	Common	Resident
Saint Lucia Oriole	Uncommon	Resident

Common and Sicentific Name	Abundance	Status
Icterus laudabilis		
Mammals		
Mongoose *Herpestes suropuntatus*	Common	Resident
Fruit Bats *Monophyllusplethodon* *Bracyphylluscavernum*	Common	Resident
Herpetofauna		
Saint Lucia Anolis Lizard *Anolis luciae*	Common	Resident
Common House Gecko *Hemidactylus mabouia*	Common	Resident
Zandoli Tarre *Gymnopthalmus pleei*	Common	Resident
Insects		
Southern Great White Butterfly	Common	Resident
White Peacock Butterfly	Common	Resident
Common Long Tail Skipper Butterfly	Common	Resident
Tropical Chequered Skipper Butterfly	Common	Resident
Ocoloa Skipper Butterfly	Common	Resident
Fiery Skipper Butterfly	Common	Resident
False Barred Sulphur Butterfly	Common	Resident
Spreadwing Skipper Butterfly	Common	Resident
Caribbean Buckeye Butterfly	Common	Resident
Southern Broken Dash Butterfly	Common	Resident
Hannos Blues Butterfly	Common	Resident

Table E-3 Flora within the Fond Saint Jacques Project Study Area

Common and Scientific Names	Family
Wild Herbacious Species	
Acalypha aristata Kunth	Euphorbiaceae
Malanga, Giant tayo *Alocasia macrorrhizos (L.) G. Don*	Araceae
Zèb a zédjwi, Needle grass *Bidens pilosa Linnaeus*	Asteraceae
Dasheen *Colocasia esculenta (Linnaeus) Schott*	Araceae
Zèb gwa, Water grass *Commelina diffusa Burman f.*	Commelinaceae
Cuphea carthagenensis (Jacq.) J. F. Macbride	Lythraceae
Cyanthillium cinereum (L.) H. Robinson	Asteraceae
Diverse small sedges *Cyperaceae species*	Cyperaceae
Sweetheart species *Desmodium species*	Fabaceae-Faboideae
Emilia species	Asteraceae
Epidendrum difforme Jacquin	Orchidaceae
Fuirena umbellata Rottbøll	Cyperaceae
Lavann, Lavender *Hedychium coronarium J. König*	Zingiberaceae
Hyptis atrorubens Poiteau	Lamiaceae
Nephrolepis brownii	Fern
Oxalis barrelieri Linnaeus	Oxalidaceae
Paspalum paniculatum Linnaeus	Poaceae
Pilea nummulariifolia (Swartz) Weddell	Urticaceae
Tèt nèg *Pseudelephantopus spicatus*	Asteraceae
Balyé wonzè *Sida acuta Burman f.*	Malvaceae
Balyé wonzè *Sida rhombifolia Linnaeus*	Malvaceae
Ti makònèt *Spermacoce remota Lamarck*	Rubiaceae

Thelypteris dentata (Forsskål) E. P. St. John	Fern
Tillandsia fasciculata Swartz	Bromeliaceae
Wild Herbs and Shrubs	
Kaka mèl *Clidemia hirta* (Linnaeus) D. Don	Melastomataceae
Zèb sèk *Flemingia strobilifera (*Linnaeus) W. T. Aiton	F.e-Faboideae
Jiwòf dlo *Ludwigia* species	Onagraceae
Sleeping hibiscus *Malvaviscus penduliflorus* de Candolle	Malvaceae
Malenbé, Bwa mal lèstomak *Piper dilatatum* Richard	Piperaceae
Anho bwa *Psittacanthus martinicensis (Presl) Eichler*	Loranthaceae
Pikan kouzen *Urena lobata* Linnaeus	Malvaceae
Fruit Trees	
Zabwiko, Apricot *Mammea americana* Linnaeus	Clusiaceae
Mango *Mangifera indica* Linnaeus	Anacardiaceae
Guava *Psidium guajava* Linnaeus	Myrtaceae
Ponmsité, Golden apple *Spondias dulcis* Solander ex Parkinson	Anacardiaceae
Cocoa *Theobroma cacao* Linnaeus	Malvaceae

Table E-4 Fauna withinin the Fond Saint Jacques East Project Study Area

Common and Scientific Name	Abundance	Status
Bird Species		
Cattle Egret *Bubulcus ibis ibis*	Common	Resident
Green Heron *Butorides virescens virescens*	Common	Resident
Scaly-naped Pigeon *Patagioenas squamosal*	Common	Resident
Saint Luica Parrot *Amizona versicolor*	Uncommon	Resident
Mangrove Cuckoo *Coccyzus minor*	Common	Resident
Lesser Antillean Swift *Chaetura martinica*	Common	Resident
Purple-throated Carib *Eulampis jugularis*	Common	Resident
Green-throated Carib *Eulampis holosericeus holosericeus*	Common	Resident
Antillean Crested Hummingbird *Orthorhyncus cristatus exilis*	Common	Resident
Caribbean Elaenia *Elaenia martinica martinica*	Common	Resident
St. Luica Pewee *Contopus oberi*	Common	Resident
Gray Kingbird *Tyrannus dominicensis vorax*	Common	Resident
Caribbean Martin *Progne dominicensis*	Common	Resident
Tropical Mockingbird *Mimus gilvus antillarum*	Common	Resident
Gray Trembler *Cinclocerthia gutturalis macrorhyncha*	Common	Resident
Scaly-breasted Thrasher *Allenia fusca schwartzi*	Common	Resident
Pearly-eyed Thrush	Common	Resident

Bird Species		
Margarops fuscatus klinikowski		
Bare-eyed Thrush *Turdus nudigenis nudigenis*	Common	Resident
Black-whiskered Vireo *Vireo altiloquus barbatulus*	Common	Resident
Antillean Euphonia *Euphonia musica flavifrons*	Common	Resident
Saint Lucia Warbler *Dendroica delicata*	Common	Resident
Bananaquit *Palm Warbler*	Common	Resident
Black-faced Grassquit *Tiaris bicolor*	Common	Resident
Saint Lucia Black Finch *Melanospiza richardsoni*	Uncommon	Resident
Lesser Antillean Bullfinch *Loxigilla noctis sclateri*	Common	Resident
Lesser Antillean Saltator *Saltator albicollis albicollis*	Common	Resident
Carib Grackle *Quiscalus lugubris inflexirostris*	Common	Resident
Shiny Cowbird *Molothrus bonariensis minimus*	Common	Resident
Saint Lucia Oriole *Icterus laudabilis*	Uncommon	Resident
Mammals		
Small Asian Mongoose *Herpestesou ropuntatus*	Common	Resident
Opossum *Didelphis marsupialis*	Common	Resident
Herpetofauna		
Saint Lucia Anolis Lizard *Anolis luciae*	Common	Resident
Common House Gecko *Hemidactylus mabouia*	Common	Resident
Zandoli tarre *Gymnopthalmus pleei*	Common	Resident

Bird Species		
Cane Tode *Rhinella marina*	Common	Resident

Table E-5 Flora Within the Mondesir North Project Study Area

Common and Scientific Names	Family
Herbs, Shrubs, and Vines	
Malanga, Giant tayo *Alocasia macrorrhizos (L.) G. Don*	Araceae
Alysicarpus vaginalis (Linnaeus) de Candolle	Fabaceae-Faboideae
Zèpina wouj *Amaranthus spinosus Linnaeus*	Amaranthaceae
Andropogon bicornis Linnaeus	Poaceae
Zèb a zédjwi, Needle grass *Bidens pilosa Linnaeus*	Asteraceae
Patagon *Boerhavia diffusa* Linnaeus	Nyctaginaceae
Bothriochloa pertusa (L.) Camus	Poaceae
Pwa blé *Calopogonium mucunoides* Desvaux	Fabaceae-Faboideae
Zèb kolan, burr grass *Cenchrus echinatus* Linnaeus	Poaceae
Elephant grass *Cenchrus purpureus* (Schumacher) Morrone	Poaceae
Chloris radiata (Linnaeus) Swartz	Poaceae
Fléwi Nwèl *Chromolaena odorata* (L.) R. M.King and H.Rob	Asteraceae
Cleome rutidosperma de Candolle	Cleomaceae
Kaka mèl *Clidemia hirta (Linnaeus) D. Don*	Melastomataceae
Zèb gwa, Water grass *Commelina diffusa Burman f.*	Commelinaceae
Condea verticillata (Jacq.) Harley & Pastore	Lamiaceae
Job's tears *Croix lacryma-jobi Linnaeus*	Poaceae
Sweetheart species *Desmodium species*	Fabaceae-Faboideae
Digitaria setigera Roth	Poaceae
Tèt nèg *Elephantopus mollis Kunth*	Asteraceae
Pyé poul	Poaceae

Eleusine indica (Linnaeus) Gaertner	
Various Emilia species	Asteraceae
Eragrostis pilosa (L.) Palisot de Beauv.	Poaceae
Euphorbia heterophylla Linnaeus	Euphorbiaceae
Euphorbia species	Euphorbiaceae
Hyptis atrorubens Poiteau	Lamiaceae
Kakoli *Inga ingoides* (Richard) Willdenow	Fabaceae-Mimosoideae
Lyenn dous *Ipomoea tiliacea* (Willdenow) Choisy	Convolvulaceae
Jiwòf flè, Bwa wa tou *Lantana strigocamara* R. W. Sanders	Verbenaceae
Gwo ponpon *Leonotis nepetifolia (L.) R. Brown*	Lamiaceae
Macroptilium lathyroides (L.) Urban	Fabaceae-Faboideae
Zèb djiné. Guinea grass. *Megathyrsus maximus*	Poaceae
Oxalis corniculata Linnaeus	Oxalidaceae
Panicum pilosum Swartz	Poaceae
Paspalum paniculatum Linnaeus	Poaceae
Paspalum virgatum Linnaeus	Poaceae
Gwenn anba fèy *Phyllanthus species*	Phyllanthaceae
Porophyllum ruderale (Jacq.) Cassini	Asteraceae
Koupyé *Portulaca oleracea Linnaeus*	Portulacaceae
Ti davi *Priva lappulacea (Linnaeus) Persoon*	Verbenaceae
Balyé wonzè *Sida acuta Burman f.*	Malvaceae
Balyé wonzè *Sida rhombifolia Linnaeus*	Malvaceae
Béléjenn djab *Solanum torvum Swartz*	Solanaceae
Ti makònèt *Spermacoce remota Lamarck*	Rubiaceae
Ti makònèt *Spermacoce verticillata Linnaeus*	Rubiaceae
Sporobolus jacquemontii Kunth	Poaceae
Tridax procumbens Linnaeus	Asteraceae
Pikan kouzen *Urena lobata Linnaeus*	Malvaceae
Fruit and Vegetable Species	

Gonbo, Okra *Abelmoschus esculentus (Linnaeus) Moench*	Malvaceae
Ti longyon, Chives *Allium species*	Amaryllidaceae
Pineapple *Ananas comosus (Linnaeus) Merrill*	Bromeliaceae
Kòsòl. Soursop. *Annona muricata Linnaeus*	Annonaceae
Ponm kannél, Sugar apple *Annona squamosa Linnaeus*	Annonaceae
Papaya *Carica papaya Linnaeus*	Caricaceae
Watermelon *Citrullus lanatus*	Cucurbitaceae
Citrus species	Rutaceae
Coconut *Cocos nucifera Linnaeus*	Arecaceae
Dasheen *Colocasia esculenta (Linnaeus) Schott*	Araceae
Bandja *Dioscorea alata Linnaeus*	Araceae
Sweet potato *Ipomoea batatas*	Convolvulaceae
Mango *Mangifera indica Linnaeus*	Anacardiaceae
Bananas, Plantains *Musa × paradisiaca*	Musaceae
Tabak, Tobacco *Nicotiana tabacum Linnaeus*	Solanaceae
Guava *Psidium guajava Linnaeus*	Myrtaceae
Salad pea *Vigna unguiculata (Linnaeus) Walpers*	Fabaceae-Faboideae
Chou, Calalou *Xanthosoma species*	Araceae
Corn, Maize *Zea mays Linnaeus*	Poaceae
Wild Trees	
Neem Tree *Azadirachta indica*	Meliaceae
Leucaena leucocephala	Fabaceae
Citharexylum spinosum	Verbenaceae
Tabebuia heterophylla	Bigoniaceae
Ficus insipda	Moraceae
Inga ingoides	Fabaceae

Table E-6 Fauna within the Mondesir North Study Area

Common and Scientific Name	Abundance	Status
Birds		
Purple-throated Carib *Eulampis jugularis*	Common	Resident
Green-throated Carib *Eulampis holosericeus holosericeus*	Common	Resident
Antillean Crested Hummingbird *Orthorhyncus cristatus exilis*	Common	Resident
Caribbean Elaenia *Elaenia martinica martinica*	Common	Resident
Gray Kingbird *Tyrannus dominicensis vorax*	Common	Resident
Caribbean Martin *Progne dominicensis*	Common	Resident
Tropical Mockingbird *Mimus gilvus antillarum*	Common	Resident
Scaly-breasted Thrasher *Allenia fusca schwartzi*	Common	Resident
Saint Lucia Warbler *Dendroica delicata*	Common	Resident
Bananaquit *Palm Warbler*	Common	Resident
Black-faced Grassquit *Tiaris bicolor*	Common	Resident
Lesser Antillean Bullfinch *Loxigilla noctis sclateri*	Common	Resident
Lesser Antillean Saltator *Saltator albicollis albicollis*	Common	Resident
Carib Grackle *Quiscalus lugubris inflexirostris*	Common	Resident
Shiny Cowbird *Molothrus bonariensis minimus*	Common	Resident
Insects		
Southern Great White Butterfly	Common	Resident
Caribbean Buckeye Butterfly	Common	Resident
White Peacock Butterfly	Common	Resident

Birds		
Tropical Chequered Skipper Butterfly	Common	Resident
Fierty Skipper Butterfly	Common	Resident
False Barred Sulphur Butterfly	Common	Resident
Southern Broken Dash Butterfly	Common	Resident

Table E-7 Flora within the Mondesir South Project Study Area

Common and Scientific Names	Family
Herbs and Shrubs	
Alysicarpus vaginalis (L. de Candolle	Fabaceae-Faboideae
Zèpina wouj *Amaranthus spinosus Linnaeus*	Amaranthaceae
Zèb a zédjwi, Needle grass. *Bidens pilosa Linnaeus*	Asteraceae
Pwa blé *Calopogonium mucunoides Desvaux*	Fabaceae-Faboideae
Zèb kolan, burr grass *Cenchrus echinatus Linnaeus*	Poaceae
Fléwi Nwèl *Chromolaena odorata (L.) R. M.King & H.Rob*	Asteraceae
Cleome rutidosperma de Candolle	Cleomaceae
Kaka mèl *Clidemia hirta (Linnaeus) D. Don*	Melastomataceae
Zèb gwa, Water grass *Commelina diffusa Burman f.*	Commelinaceae
Job's tears *Croix lacryma-jobi Linnaeus*	Poaceae
Sweeheart species *Desmodium species*	Fabaceae-Faboideae
Tèt nèg *Elephantopus mollis Kunth*	Asteraceae
Emilia species	Asteraceae
Euphorbia species	Euphorbiaceae
Hyptis atrorubens Poiteau	Lamiaceae
Lyenn dous *Ipomoea tiliacea (Willdenow) Choisy*	Convolvulaceae
Jiwòf flè. Bwa wa tou *Lantana strigocamara R. W. Sanders*	Verbenaceae
Gwo ponpon *Leonotis nepetifolia (L.) R. Brown*	Lamiaceae
Macroptilium lathyroides (L.) Urban	Fabaceae-Faboideae
Oxalis corniculata Linnaeus	Oxalidaceae
Gwenn anba fèy	Phyllanthaceae

Phyllanthus species	
Koupyé *Portulaca oleracea Linnaeus*	Portulacaceae
Ti dayi *Priva lappulacea (Linnaeus) Persoon*	Verbenaceae
Balyé wonzè *Sida acuta Burman f.*	Malvaceae
Balyé wonzè *Sida rhombifolia Linnaeus*	Malvaceae
Ti makònèt *Spermacoce remota Lamarck*	Rubiaceae
Ti makònèt *Spermacoce verticillata Linnaeus*	Rubiaceae
Tridax procumbens Linnaeus	Asteraceae
Pikan kouzen *Urena lobata Linnaeus*	Malvaceae
Fruit and Vegetable Species	
Pineapple *Ananas comosus* (Linnaeus) Merrill	Bromeliaceae
Papaya *Carica papaya* Linnaeus	Caricaceae
Citrus species	Rutaceae
Coconut *Cocos nucifera* Linnaeus	Arecaceae
Sweet potato, Patat *ipomoea batatas*	Convolvulaceae
Mango *Mangifera indica* Linnaeus	Anacardiaceae
Bananas, Plantains *Musa × paradisiaca*	Musaceae
Guava *Psidium guajava* Linnaeus	Myrtaceae

Table E-8 Fauna in the Mondesir South Study Area

Common and Scientific Name	Abundance	Status
Bird Species in Mondesir South		
Mangrove Cuckoo *Coccyzus minor*	Common	Resident
Purple-throated Carib *Eulampis jugularis*	Common	Resident
Green-throated Carib *Eulampis holosericeus holosericeus*	Common	Resident
Antillean Crested Hummingbird *Orthorhyncus cristatus exilis*	Common	Resident
Caribbean Elaenia *Elaenia martinica martinica*	Common	Resident
Saint Lucia Pewee *Contopus oberi*	Common	Resident
Gray Kingbird *Tyrannus dominicensis vorax*	Common	Resident
Caribbean Martin *Progne dominicensis*	Common	Resident
Tropical Mockingbird *Mimus gilvus antillarum*	Common	Resident
Gray Trembler *Cinclocerthia gutturalis macrorhyncha*	Common	Resident
Scaly-breasted Thrasher *Allenia fusca schwartzi*	Common	Resident
Bare-eyed Thrush *Turdus nudigenis nudigenis*	Common	Resident
Black-whiskered Vireo *Vireo altiloquus barbatulus*	Common	Resident
Saint Lucia Warbler *Dendroica delicata*	Common	Resident
Bananaquit *Palm Warbler*	Common	Resident
Black-faced Grassquit *Tiaris bicolor*	Common	Resident
Lesser Antillean Bullfinch *Loxigilla noctis sclateri*	Common	Resident

Common and Scientific Name	Abundance	Status
Lesser Antillean Saltator *Saltator albicollis albicollis*	Common	Resident
Carib Grackle *Quiscalus lugubris inflexirostris*	Common	Resident
Shiny Cowbird *Molothrus bonariensis minimus*	Common	Resident
Herpetofauna		
Saint Luica Anolis Lizard *Anolis luciae*	Common	Resident
Common House Gecko *Hemidactylus mabouia*	Common	Resident
Zandoli tarre *Gymnopthalmus pleei*	Common	Resident

REPRESENTATIVE PHOTOGRAPHS

Figure 1 Belle Plaine Cultivated Beds and Forested Edge

Figure 2 Belle Plaine Neglected Fields, Coconut Palms, and Forested Edge

Figure 3 Belle Plaine Open Weedy Area with Bananas/Plantains and Forested Edge

Figure 4 Fond St. Jacques West Bare Soil

Figure 5 Fond St. Jacques East Grasses, Sedges, Dasheen, and Forested Edge

Figure 6 Mondesir-Saltibus North Fallow Area with Bananas

Figure 7 Mondesir-Saltibus North Cleared Plot Ready for Planting and Mango Trees

Figure 8 Mondesir-Saltibus North Sweet Potato Beds Near Playing Field

Figure 9 Mondesir-Saltibus North Sports Field with Mown Grass *Eragrostis pilosa*

Figure 10 Mondesir-Saltibus North Weedy Growth Next to Sports Field

Figure 11 *Andropogon bicornis* on Side of Sports Field

Figure 12 Mondesir-Saltibus South Fallow, Some Sweet Potato Beds, Coconuts, Bananas

Figure 13 Mondesir Saltibus South Mature Sweet Potato Beds

Figure 14 Mondesir-Saltibus South Intensive Pineapple Cultivation

Figure 15. Saint Lucia Anolis

Figure 16. Great Southern White

Figure 17 White Peacock

Figure 18. Caribbean Buckeye

Figures 19. From top left: Saint Lucia Parrot, Saint Lucia Oriole, Saint Lucia Black Finch male/female

Figure 20. Saint Lucia Warbler

Figure 21. Lesser Antillean Saltator

APPENDIX F

Water Resource Sampling and Monitoring Plan

1 OVERVIEW

This appendix to the Scoping Studies Report for the Geothermal Resource Development Project Environmental and Social Impact Assessment details the water resource sampling and monitoring approach to be implemented during project construction. The following section contains information pertaining to the project TOR, Tasks 1.4 and 1.7.

1.1 PURPOSE

The purpose of the water sampling and testing program is to define the methods for water quality monitoring in potentially affected water resources during project implementation. The water quality sampling and testing program will support an evaluation of potential impacts of the geothermal exploration on water quality. The program will also provide baseline water quality data for assessment of future geothermal development. If water quality monitoring data indicates that the project is causing water quality to exceed acceptable levels, corrective actions will be implemented to protect downstream water quality.

1.2 WATER SAMPLING APPROACH

Water samples will be collected at designated locations; one upstream and one downstream of the project areas. Samples will be transported to a laboratory that is certified to perform the appropriate biological and chemical analysis. Sampling may also be conducted in the field using hand-held meters and visual observations.

1.3 DATA ANALYSIS

Water quality data will be compared relative to Saint Lucia and international water quality standards. If an exceedance of water quality standards or increase in downstream constituent loading is detected, an evaluation will be made to define the potential cause of the water quality conditions and corrective actions will be implemented to avoid degradation of water quality, where needed.

2 SAMPLING LOCATIONS

2.1 LOCATION OF SAMPLING POINTS OVERVIEW

Samples must be taken from locations that are representative of the water source (e.g., rivers or streams). One sampling point will be located upstream of the drilling site and one downstream of the drilling site on adjacent streams to allow for a comparison of data prior to potential project impacts (upstream sample) and after potential project impacts (downstream sample). The geothermal drilling locations are designated as Belle Plaine, Fond St. Jacques, and Mondesir/Saltibus.

2.2 BELLE PLAINE

Two streams are located in proximity to the Belle Plaine area. Proposed sampling locations on each of these streams are shown on Figure 1 below. The two sampling points south of the Belle Plaine target drilling area (BP-1 and BP-3) will provide data on baseline or pre-project water quality. The western stream appears to terminate at the agricultural area where drilling is proposed and the BP-1 sampling location may be eliminated in the future if the stream does not flow through or continue past the drilling site. The northern sampling point (BP-2) will be located downstream of the drilling area to represent post-project water quality. The sampling locations may be adjusted after selection of the final drilling site to better approximate water quality conditions upstream and downstream of the project site.

2.3 FOND ST. JACQUES

Two streams are located adjacent to the Fond St. Jacques potential drilling areas. Proposed sampling locations are shown on Figure 2. FS-2 is representative of water quality conditions upstream of the Fond St. Jacque west area and FS-1 is representative of water quality conditions downstream of the Fond St. Jacques west drilling area. The southern stream that flows adjacent to Fond St. Jacques east is tributary to the northern stream. FS-3 represents water quality conditions upstream of Fond St. Jacques east. A downstream sampling location may be selected downstream of the target drilling area and depending on the final drilling location and direction of drainage from that area.

A spring in the Fond St. Jacques east area is used to provide water for the Fond St. Jacques community. A shallow groundwater monitoring well should be installed in proximity to the spring to monitoring water quality at the spring during drilling operations. FS-4 shows an approximate location for the shallow groundwater monitoring well. The location of FS-4 may be adjusted in the field to approximate the spring area. The shallow groundwater monitoring well should be installed using 1″slotted PVC pipe and clean sand backfill.

Figure 1 Belle Plaine Recommended Sampling Locations

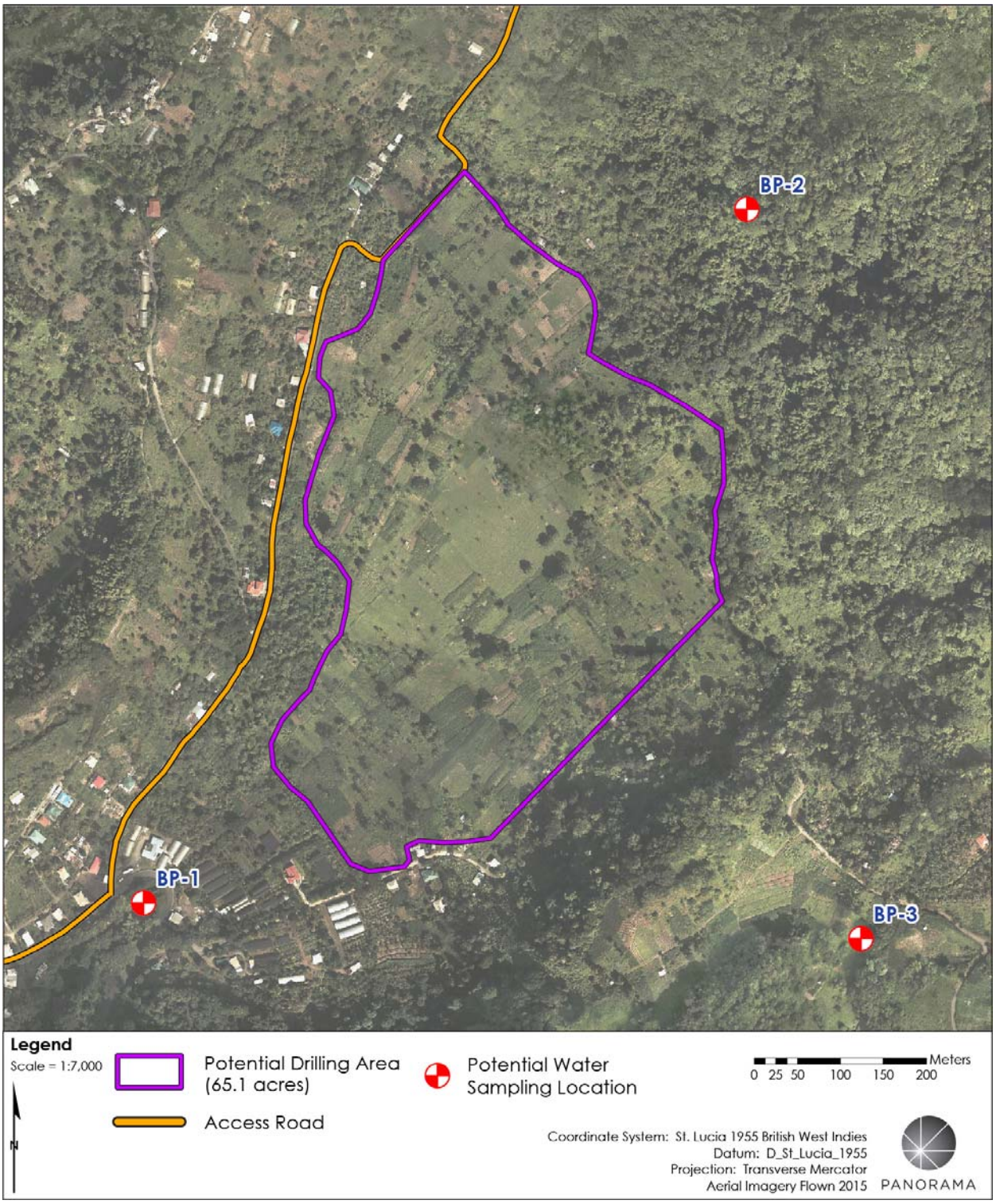


Figure 2 Fond St. Jacques Sampling Locations

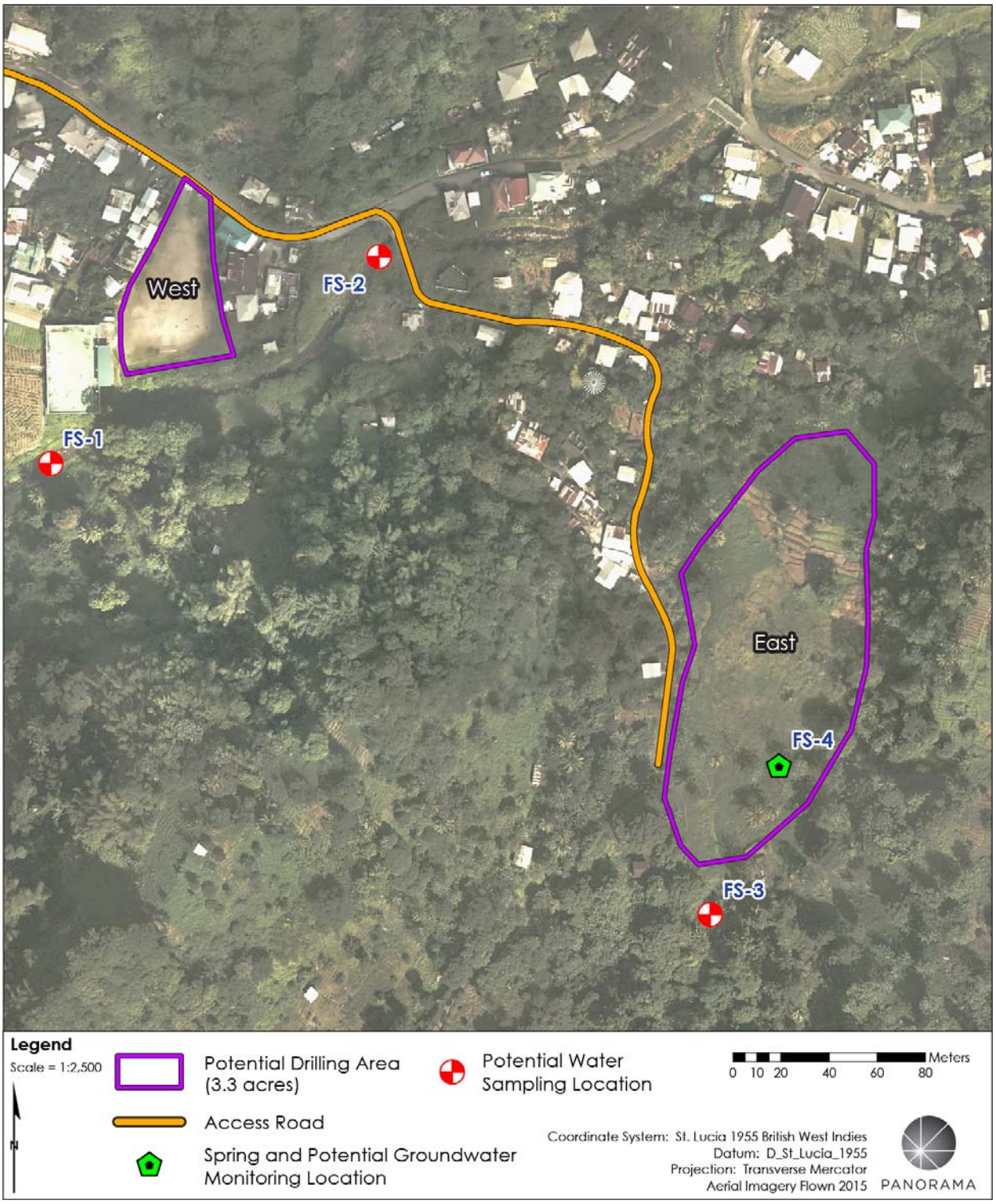
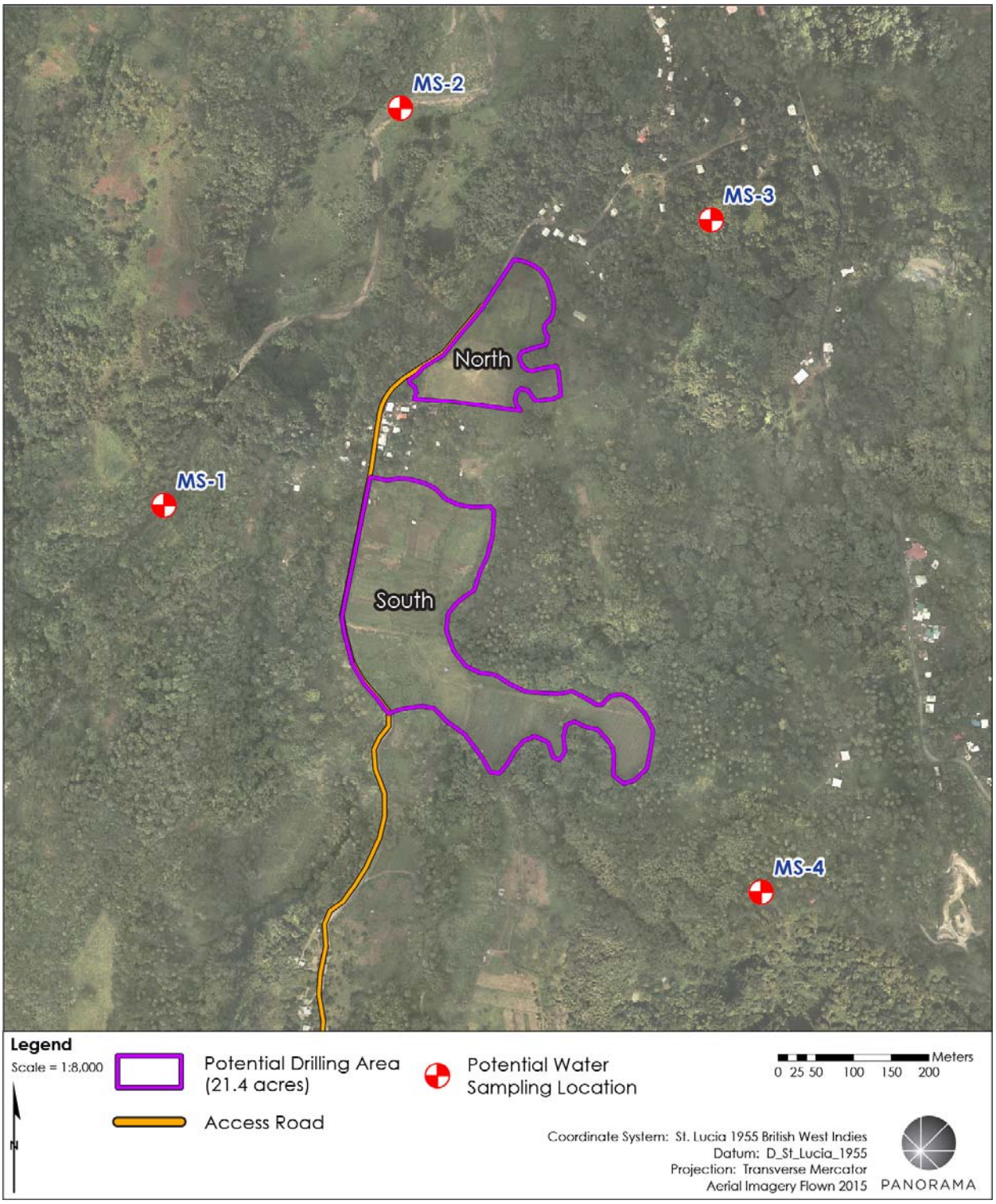


Figure 3 Mondesir-Saltibus Sampling Locations



2.4 MONDESIR-SALTIBUS

Two streams are located adjacent to the Mondesir-Saltibus potential drilling areas. The stream located to the west of the project area may be used for a water supply intake and a portion of the Mondesir-Saltibus north site may drain towards the west. Suggested sampling locations are shown on Figure 3. Depending on the final drilling location and water supply uses, one sampling location should be located upstream of the intake and one sampling location located downstream of the intake and potential discharge area. The Mondesir-Saltibus south potential drilling area drains toward the eastern stream. One sampling location should be located upstream of the drilling area and one downstream to represent pre- and post-project conditions. The sampling locations may be adjusted to reflect the final drilling sites and water supply intake location.

3 SAMPLING AND STREAM FLOW MEASUREMENT METHODS

3.1 FREQUENCY OF SAMPLING

Surface water monitoring/sampling should be conducted weekly during drilling and testing operations at sampling location in proximity to the drilling site. Groundwater monitoring/sampling should be conducted monthly during drilling and testing operations. Sampling shall also be conducted prior to and immediately following any rain storms and immediately following any suspected discharge to area streams.

3.2 PHYSICAL AND CHEMICAL SAMPLING METHODS

Water quality sampling methods are described below and include:

- Visual observation
- In-situ measurement
- Stream grab samples
- Groundwater samples

3.2.1 Visual Observations

Visual observations will be recorded for color, oil and grease, and visible solids, and erosion during water quality sampling. Photographs will be taken at each sampling location to record visual observations. Any observed project-related water quality discharge such as erosion, discharge of oil and grease, or other fluids, will be noted on field data sheets.

3.2.2 In-situ Measurements

The following measurements will be recorded in-situ using a hand-held meter:

- pH
- Dissolved oxygen
- Turbidity
- Conductivity
- Temperature

In-situ sampling equipment and the sensors must be calibrated prior to sampling events. The type of sampling equipment used and the sampling location shall be noted on field data sheets. Samples shall be recorded from the pre-defined sampling locations to provide consistency in data collection and analysis.

3.2.3 Grab Samples

Grab samples will be used to collect water samples for the following chemical analyses:

- Total suspended solids (TSS)
- Nitrogen (N)
- Organic material (e.g., fecal coliform)
- Biological oxygen demand-5 (BOD5)
- Chemical oxygen demand (COD)
- Heavy metals including:
  - Arsenic (As)
  - Boron (B)
  - Cadmium (Cd)
  - Chromium (Cr)
  - Nickel (N)
  - Mercury (Hg)
  - Zinc (Zn)
- Total petroleum hydrocarbons (TPH)
- Sulphur (S)
- Iron (Fe)
- Manganese (Mn)
- Uranium (U)
- Radium (Ra)
- Gross alpha and beta

Grab samples will be collected in an open container at the defined monitoring location. Grab samples may be collected in a suspended or handheld 5-gallon container, disposable bailer, or open-mouth bottle. The grab sample shall be stored and transported to the lab following proper chain-of-custody procedures. Grab sampling methods including allowable containers and maximum storage time for each analyte is provided in *National Field Manual for the Collection of Water Quality Data* (U.S. Geological Survey, n.d.). The height and depth of sample and staff obtaining the water sample shall be recorded on filed data sheets. All bottles must be marked individually, with key information such as project name or code, location, date, sample number, sample name, and type of analysis to be performed; this information must also will also be contained in a field notebook and in the sample-collection data sheets.

3.2.4 Groundwater Samples

Prior to obtaining a groundwater sample, the groundwater well should generally be purged. Exceptions to the groundwater purge method may be made in situations where the well is located in clay soils and the well fills very slowly. Once the groundwater well has refilled, a sample should be extracted using a pump. Data on the depth to groundwater shall be recorded on field data sheets. Methods for groundwater sampling shall follow *National Field Manual for the Collection of Water Quality Data* (U.S. Geological Survey, n.d.). Groundwater quality analysis will include the same analytes as the grab samples, listed above.

3.3 CHEMICAL WATER QUALITY ANALYSIS

Stream and groundwater grab samples will be transported to a laboratory that is certified to conduct the water quality analyses indicated. Water samples shall be properly stored and transported following proper chain-of-custody procedures.

3.4 MEASURING STREAM FLOW AT KEY POINTS UNDER BASE FLOW AND SEASONALLY VARIABLE CONDITIONS

The USGS splits stream gaging into a three-step process of measuring stream stage, measuring discharge, and determining the stage-discharge relation (Buchanan and Somers, 1969; https://water.usgs.gov/edu/measureflow.html). This is the process recommended for streamflow measurement. Stream flow measurements should be obtained upstream of any project water supply intake and downstream of the water supply intake. The Government of St. Lucia should determine the end use of any stream flow data collected under base flow and seasonally variable conditions prior to conducting measurements. The approach to measurement should reflect the end use of the data.

3.4.1 Measuring Stream Stage Procedures and Equipment

A variety of methods are currently used to measure streamflow. One of the most common is a stilling well located on the riverbank or attached to a bridge pier. Its operation consists of:

- Entry and exit of the water from the stilling well through underwater pipelines, allowing the surface of the water in the stilling well to be at the same height as the water surface in the river.
- The stage is measured inside the well by means of a float or an optical or acoustic pressure sensor.
- The measured phase value is stored in an electronic data recorder at a regular interval (usually every fifteen minutes).
- A telemetry system may also be present in a stilling well, allowing data to be transmitted remotely to a host computer in real time (Fundamentals and Environment Measurements, n.d.).

Depending on the budget and the field, it is not always possible to install a stilling well where stream gaging is necessary. For these cases, the following procedures can be performed:

- Stage can be measured with a vented pressure transducer installed within a PVC or metal pipe along the stream bank. In locations where a bridge or overhead structure is available for instrument mounting, a noncontact radar or ultrasonic water-level sensor can also be used (Fundamentals and Environment Measurements, n.d.).
- Stage can be determined by measuring the pressure required to maintain a small flow of gas through a tube and bubbled out at a fixed location underwater in the stream. The measured pressure is directly related to the height of water over the

tube outlet in the stream. As the depth of water above the tube outlet increases, more pressure is required to push the gas bubbles through the tube.

Choice of equipment will depend on recognition of conditions in the field as well as available budget. Stage must always be measured relative to a constant reference elevation, or datum. Since the present project seeks to consider seasonal variations, it is necessary to routinely survey the elevation of the stream gage structure and its datum, to ensure that elevations have not shifted due to seasonal variations.

It is not practical for a stream gage to continuously measure discharge. Fortuitously, however, there is a strong relation between river stage and discharge and, as a result, a continuous record of river discharge can be determined from the continuous record of stage. Determining discharge from stage requires defining the stage-discharge relationship by measuring discharge at a wide range of river stages.

3.4.2 Measuring Discharge and Equipment

River discharge is computed by multiplying the area of water in a channel cross-section by the average velocity of the water in that cross-section. Subsection width is best measured with a cable or steel measuring tape, while depth can be measured by a wading rod in shallower channels and suspended sounding weights in deeper waters (Fundamentals and Environment Measurements, n.d.).

One of the most common methods for discharge-velocity measurements is through a current meter. The current-meter method employs commercial equipment such as:

- Price® AA current meter
- Price® AA current meter attached to a wading rod
- Price® AA current meter suspended above a heavy weight

3.4.3 Determining the Stage-Discharge Relation and Equipment

Stage-discharge relation is a dynamic variable that is determined by comparing stage at a stream gage to discharge at the same point (Fundamentals and Environment Measurements, n.d.).

Prior to any estimation of stage and discharge and seasonal measurement, the end use of this data should be determined to evaluate the requirement for the data and the appropriate method to obtain the data.

4 WATER QUALITY STANDARDS AND CORRECTIVE ACTIONS

4.1 EFFLUENT STANDARDS

The IFC and World Bank Group Environmental, Health, and Safety General Guidelines (IFC and World Bank Group 2007a) have developed guidelines for effluent discharge to waters such as lakes, streams, rivers, or the ocean. The IFC and World Bank effluent threshold standards for mining, which has similar processes to geothermal drilling, are presented in Table 4.1-1 for informational purposes. The temperature threshold standard is a differential of less than 3 degrees Celsius (C).

Table 4.1-1 Threshold Standards for Effluent Discharge

Parameter	Threshold Standards (mg/L)
Total suspended solids	50
pH	6 to 9
Chemical oxygen demand	150
Five-day biological oxygen demand	50
Oil and grease	10
Arsenic	0.1
Cadmium	0.05
Chromium (hexavalent)	0.1
Copper	0.3
Cyanide (total)	1.0
Cyanide (free)	0.1
Cyanide (weak acid dissociable)	0.5
Iron	2.0
Lead	0.2
Mercury	0.002
Nickel	0.5
Phenols	0.5
Zinc	0.5

Source: (IFC and World Bank Group 2007b)

4.2 CORRECTIVE ACTIONS

Corrective actions will be implemented if downstream water quality exceeds indicates a 10 percent or greater increase in any constituent relative to upstream water quality or any constituent in the downstream water quality exceeds IFC thresholds for effluent discharge (see Table 4.1-1) and the upstream water quality does not exceed those thresholds. The corrective actions should be specified by a qualified hydrologist or hydrogeologist. Prior to implementing any corrective action, the source of the discharge should be identified so that the source may be properly treated. Potential project-related sources of water quality degradation include discharge of sediment to area streams, discharge of oil or grease from leaky equipment, discharge of water from overflow of sumps or mudpits. These effluent sources can be treated with proper best management practices including:

- Properly maintaining all equipment and only maintaining and fueling equipment in designated areas
- Providing secondary containment around the drill rig
- Installing sediment control barriers such as silt fence, straw bales, straw waddles, of functional equivalent along the downstream side of the project area to control erosion
- Controlling site run-on
- Designing mud pits and sumps with sufficient freeboard (1 meter)
- Ensuring proper location and use of toilets
- Proper storage of any hazardous materials
- Proper control of any geothermal fluids encountered to avoid surface water exposure