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Draft

Environmental Impact Assessment

for

Geothermal – Drilling of the 3rd Exploratory Production Well

Prepared and Submitted by

ATOM
Solutions Incorporated

If there are any comments, questions or suggestions they can be submitted in writing to esale@caribsurf.com

Government of Montserrat

DRAFT

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November 2015

Executive Summary

This EIA seeks to assess the Environmental and Social impacts of a suite of variables identified in the TOR and the Scoping Report. The assessment includes a baseline for each variable followed by a discussion on impacts on the physical, natural, human and social environments. However, since the drilling is taking place in an elevated area on St. George's Hill, in Zone V, which was evacuated after the 1995 eruption and has remained a restricted area, there are limited human and environmental impacts expected from the drilling of MON-3. Most of the vegetation is secondary forest and scrub. No sensitive or endangered flora and fauna are at risk. The hillside vegetation was once covered in ash. The Belham Valley forms a low lying area north of St. George's Hill. This has been heavily inundated with volcano muds left over from lahars. Importantly, the drill site was selected not only for its geothermal potential, but also because it's elevated provides protection from lava flows which may arise from future eruptions.

Based on the assessment made, the principle concern is the health and safety of the drill crew and the need to deploy precise and well prepared emergency response and management plans should volcanic activity put human activity at risk. Upset conditions at the well also present risks to health and safety. How these concerns are managed will be the responsibility of the Drill Contractor. Impacts will be monitored in a subsequent Environmental and Social Impact Management Plans (EMP & SMP) documents. The plans include management, monitoring and mitigation measures to address any upset conditions and accidental discharge of chemicals and fuels and any other impact which may occur.

Drilling will encounter groundwater. Our assessment finds that limited impacts are expected once the integrity of the well casing is maintained. The thrust of the assessment supports the use of best practices in the choice of drill lubricants and other materials introduced into the well.

The TOR identified the discharge of liquid effluent as a major concern. This is because the site drains north towards Belham Valley which is the source of groundwater for domestic consumption. The assessment supports the intention of

the Public Works Department to direct liquid effluent away from Belham Valley through a surface drain to be constructed on the new site access road. This will connect with and flow down the existing drain on Weekes' Road, pass through a culvert under Cork Hill Main Road and discharge into an existing water course which heads west to the coastline meeting it at Hot Water Pond. This was the disposal route for effluents discharged from MON-01 and MON-02. No groundwater is used in this drainage area for any purpose. Impacts along the path towards Hot Water Pond are expected to be temporary on the surface and limited underground as evidence in those areas today after the previous drilling.

Presently there is day time trucking of sand through the area of study primarily to the Plymouth Jetty. This is loaded onto barges for export. Belham Valley is being quarried. There are also several quarry pits on either side of Cork Hill Main Road. The MON-03 Site is accessed via Weekes' Road which runs uphill and eastward, off Cork Hill Main Road, just south of MON-02. While no significant impact on mining activity is anticipated there should be direct communication with truckers to reduce speed and take extra caution when passing Weekes' Road intersection. During transport of drill equipment to and from the Jetty, quarry trucking activity should cease.

The Social Impact Study was designed to evaluate the potential social impacts which were identified in the Geothermal TOR and the Scoping process. The scoping exercise used during the drilling of MON-01 and MON-02 was extensive, employing questionnaires, interviews, community surveys, literature reviews, public meetings and individual structured meetings to identify stakeholder concerns. Stakeholders included both surrounding communities of Friths/Flemmings and Happy Hill and interest groups including various government ministries and agencies and the sand miners who operate in the nearby Belham Valley. Much of the data gathered is still relevant. Social impacts for MON-03 were determined through discussions with key stakeholders and reviewing updates to data gathered previously. Positive impacts are expected especially from the provision of commercial services (food, transport and possibly accommodation). Occupational health and safety concerns are raised in the event that local persons routinely access the site.

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Acronyms

Acronym	Description
BID	Background Information Document
DfID	Department for International Development
DMCA	Disaster Management Coordination Agency
EIA	Environmental Impact Assessment
EMP	Environmental Impact Management Plan
GoM	Government of Montserrat
GEPSC	Geothermal Energy Project Steering Committee
MALTHE	Ministry of Land, Agriculture, Trade, Housing and Environment
MMSA	Montserrat Motor Sports Association
MUL	Montserrat Utilities Limited
MVO	Montserrat Volcano Observatory
NL	Not Likely
PPE	Personal Protective Equipment
SIA	Social Impact Assessment
SMP	Social Impact Management Plan
TOR	Terms of Reference

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1.0 Introduction

1.1 Brief Description

Atom Solutions Inc. has been contracted to provide specialist environmental services to the Government of Montserrat (GoM) for the effective management of geothermal test drilling and related activities on the Island. The assignment comprises of an Environmental Impact Assessment (EIA) for the proposed drilling of a 3rd production well, including the development of a Background Information Document (BID), a scoping study, a baseline condition analysis, an Environmental Impact Assessment document, an Environmental Impact Management Plan (EMP) and a Social Impact Management Plan (SMP). These plans are intended to ensure measures for monitoring the implementation of mitigation measures and impact of the project are undertaken.

1.2 Purpose of Document

This document presents the findings of the Environmental Impact Assessment study which was undertaken for the Geothermal pre-drilling, drilling and post-drilling activity being undertaken by the Government of Montserrat.

1.3 Environmental impact study context and objectives

The Government of Montserrat has legislation requiring that an EIA be undertaken in accordance with the Physical Planning Act. This will form part of the planning application for the proposed project and will be subject to approval

by the Physical Development Authority. The objective of this study is to identify any potential impacts on Montserrat. The consultancy was created to ensure that:

1) Any potential environmental and social impacts associated with drilling activities are clearly identified and any impacts which may occur post-drilling in the event that the well is fully commissioned for production of geothermal energy are also highlighted and considered.
2) All geothermal test drilling activities are managed in order to avoid or minimise negative environmental and social impacts.
3) Opportunities for creating/enhancing environmental and social effects/benefits, which will assist with any mitigation, are identified.
4) Stakeholders have opportunities to contribute to the process of environmental assessment and management and are kept informed of its progress.
5) Any potential impacts on the development caused by environmental conditions are also identified.

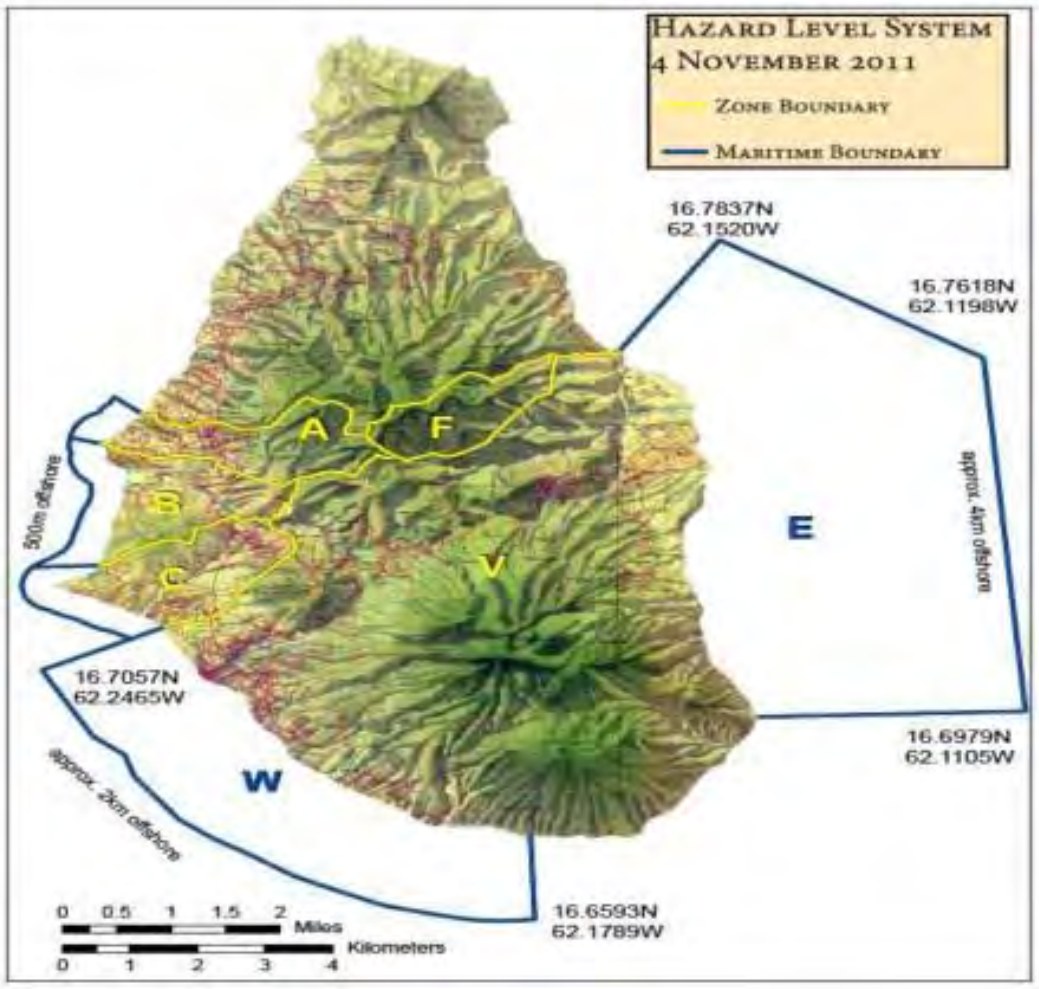
1.4 Natural Hazards and Climatic Change

1.4.1 Natural Hazards

The active volcano continues to be the main source of natural hazard in Montserrat. Hazards from rock falls, pyroclastic flows of limited reach, minor explosions and mudflows remain a possibility. However, if the dome experienced a large collapse, extensive pyroclastic flows would be a possibility even though much less likely than in the past. This would result in activities such as ash

venting and small explosions and it would be unlikely to be hazardous to Zones A, B and C. Zone V is more likely to be affected by such hazards and may include Plymouth and St George's Hill. Hazard levels could rise rapidly if fresh lava reaches the surface. See hazard map in Figure 1.1 below.

Figure 1.1: Hazard Map



The Montserrat Volcanic Observatory (MVO) continuously monitors land deformation, air quality (SO_2) and seismicity. Additionally, using computer models they simulate eruption scenarios and consequent pyroclastic flows in the Belham

Valley. The Observatory functions routinely during work hours in the week but not on weekends.

The MVO publishes Weekly Reports on volcanic activity. For the Period from 30th October to 6th November 2015, activity at the Soufrière Hills Volcano remained minimal. Two volcano-tectonic earthquakes were recorded. Sulphur-dioxide measurements were not possible. The MVO notes that Pyroclastic flows can occur at any time without warning on any side of the volcano, including Gages from where they can travel rapidly into Plymouth. Note that MON-03 is strategically on the north side of St. George's Hill at an elevated location thus protecting it from these flows. The MVO also notes that vehicle tracks across the Belham Valley are frequently destroyed or heavily modified by flash flooding and that caution should be exercised crossing the valley during and after rainfall. The Hazard Level is 1 (more than one year since eruptive activity was recorded). It is noted that during the drilling of MON-01 and MON-02, the hazard Level was 2. There is no public access to Zone V, including Plymouth. Maritime Zones "E" and "W" are daytime transit only between sunrise and sunset (boats may sail through the zone but must not stop). Anyone who ignores these restrictions is liable to be prosecuted.

The following was reported by MVO as of November 5th November, 2015:

During the past year the Soufrière Hills volcano has shown no significant changes in its behaviour. While the major part of the lava dome remains stable

and rock-fall activity continues to decline, the dome still has the potential to become unstable. Temperatures of volcanic gases that escape through fractures and fumaroles have remained high with the hottest fumaroles persistently above 600^0C over the five (5) years since the last major activity. In the last year seismicity has continued to decline to a very low level except for occasional short episodes of volcano-tectonic earthquakes, sometimes accompanied by elevated outputs of sulphur dioxide. Typically sulphur dioxide emissions range between 300 and 400 tonnes/day. Monitoring of ground deformation indicates a slow but continuous lengthening trend over the island as well as a significant amount of uplift of several centimetres over the last five (5) years. When these observations and measurements are taken together we conclude that **the volcano remains in a state of internal unrest** and that lava extrusion is still possible. However, there are no signs that this is imminent. The absence of pyroclastic flows or major rock falls in the last year is an indication that the lava dome continues to stabilise. **The chance that pyroclastic flows will occur within the next year remains low. However, the volcano is still a potential source of hazards, some of which could occur at any time with little or no warning and could pose a threat to people working in or visiting Zone V.**

1.4.2 Climate Change

Global climate change may have contributed to recent droughts in Montserrat. Along with the aftermath of the volcano eruption, this problem has been compounded. A consequence of the eruption was the burial of wells which

supplied the island's water distribution system. The Montserrat Utility Limited (MUL) had to rely on a series of springs which over the last few years, have declined because of the combined effects of drought and deposition of layers of low-permeability clay-rich volcanic ash in the springs' recharge area.

1.5 Project Context

The island of Montserrat is a UK Overseas Territory, located in the Leeward Islands of the Eastern Caribbean, part of the Lesser Antilles Island Chain. Montserrat is approximately 16 km long and 11 km wide, with a total surface area of approximately 40 km^2 and a population of 4,922 (2011 Census). The island is the most mountainous of the Leeward Islands and is dominated by the Soufrière Hills Volcano. In 2010 a DfID funded study assessed the geothermal potential of Montserrat. This built on the findings of other research commissioned since 1997 and concluded that there is high probability that Montserrat has considerable geothermal resources. The most conservative research suggests that there is a 75-80% chance of at least 5 MW of power available.

2.0 Impacts Covered in the Study

2.1 Potential Significant Impacts

The scoping exercise considered the potential impacts provided in the TOR plus additional impact considered to be relevant. After the classification of each potential impact the following variables were selected for this study. Table 2.1 below presents the outcome of the Scoping exercise which identified a total of thirteen (13) environmental impacts requiring further assessment. Accidental discharge of fuels/chemicals and upset conditions are considered to result in significant major impact. Seven impacts were considered significant and moderate. Four impacts were classed as significant but minor. The rating used is:

1 - Significant, major impact (-ve)
2 - Significant, moderate impact (-ve)
3 - Significant, minor impact (-ve)
4 - Insignificant (-ve)
5 - Unknown
6 - Positive impact (+ve)

Table 2.1: List of Potential Environmental Impact Variables

Variable ID#	Impact Variables to be Assessed	Impact Class	Phase
ENV-01	Accidental Discharge of chemicals/ fuels at site	1	Drilling
ENV-02	Well failure /upset conditions	1	Drilling
ENV-03	Discharge of Solid Wastes from drill spoil	2	Drilling
ENV-04	Discharge of Liquid Wastes from drill spoil	2	Drilling
ENV-05	Ground Water	2	Drilling

ENV-06	Soil and land contamination	2	Drilling
ENV-07	Steam Discharge (Temp./SO_2)	2	Drilling
ENV-08	GHG Emissions from on-site diesel generators and well emissions	2	Drilling
ENV-09	Erosion from Water Discharge	2	Drilling
ENV-10	Induced Landslides	3	Pre-Drilling Drilling
ENV-11	Transportation of Infrastructure	3	Pre-Drilling Post-Drilling
ENV-12	Terrestrial Fauna	3	Pre-Drilling Drilling Post-Drilling
ENV-13	Terrestrial Flora	3	Pre-Drilling Drilling Post-Drilling

Table 2.2 below presents the outcome of the Scoping exercise which identified a total of six social impacts requiring further assessment. Of these, three are positive impacts. The remaining three impacts were considered significant enough to merit further assessment with Occupational Health and Safety being the greatest concern.

Table 2.2: List of Potential Social Impact Variables

Variable ID#	Variables to be Assessed	Impact Class	Phase
SOC-01	Occupational Health and Safety	2	Pre-Drilling Drilling Post-Drilling
SOC-02	Employment Opportunities	6	Pre-Drilling Drilling
SOC-03	Demand for commercial services	6	Pre-Drilling Drilling
SOC-04	Tourism	6	Drilling Post-Drilling
SOC-05	Residential water supply levels	3	Drilling
SCO-06	Transport/Road use conflicts	3	Pre-Drilling Drilling Post-Drilling

2.2 Assumed Insignificant Impacts

A number of impacts were considered as low or insignificant and will therefore not be analysed further in the EIA. These are listed below.

Table 2.3: List of Assumed Insignificant Environmental Impact Variables

Insignificant Impact Variables
Atmospheric Heat Pollution
Induced Seismicity from Drilling
Subsidence
Land Take
Surface Water
Air Quality
Noise and Vibration
Marine
Pipeline Installation

Table 2.4: List of Assumed Insignificant Social Impact Variables

Insignificant Impact Variables
Visual
Public Health & Safety
Archaeological and Cultural Heritage
Land Acquisition & Use Conflicts
Stress on Social Support Systems
Social Context (Disruptions on Community culture, places of worship etc.)
Damage to road infrastructure
Economic Disruptions

2.3 Methodology

The methodology used for the EIA comprises the following key steps.

- Assessment of selected site
- Rapid scoping assessment to identify the key issues and impacts
- Assessment of the legal status of proposed project site with respect to various applicable environmental legislations and international performance standards on social and environmental sustainability
- Stakeholder engagement and consultation to explain the project and EIA process and capture concerns and perceptions
- Baseline studies to define existing relevant physical, biophysical and social conditions
- Environmental Impact Assessment which will evaluate the likely environmental impacts on the physical and biological (Natural) environment but also taking into account inter-related socio-economic, cultural and human health impacts both beneficial and adverse
- Environmental Management Plan which will ensure that all necessary measures are identified and implemented, set to a timeline with specific responsibilities assigned and follow up actions defined in order to protect the environment
- Social Management Plan which will ensure that all necessary mitigation measures are identified and implemented through identifying key strategies for stakeholder management and community participation

3.0 Regulatory Framework

3.1 Legal Framework

The Government of Montserrat has legislation requiring that an Environmental Impact Assessment (EIA) be undertaken in accordance with the Physical Planning Act. This will form part of the planning application for the proposed project and will be subject to approval by the Physical Development Authority.

3.2 Regulatory Framework

Under the existing Physical Planning Act and Subsidiary Legislation an application for development permission in respect of a development specified in the Third Schedule (which includes activities related to geothermal energy) must be accompanied by an EIA of the proposed development. The EIA must include the matters specified in the Fourth Schedule. Under the Conservation and Environmental Management Act 2014, the proposed Conservation and Environmental Management (Certificate of Environmental Approval) Regulations also give further detail on the minimum statutory standards for preparation of an EIA and the review process and public consultation on an EIA.

4.0 Study Area

4.1 Location of Site and its Surrounds

The area between St. Georges Hill and Garibaldi Hill is considered the most practical place to test for a geothermal system from a geologic, logistics and safety perspective. Two major morphological features dominate the prospect area. Garibaldi Hill is located south of the Old Road Bay, filled with mudflows since the last eruption, and north of the Fox's Bay. St George's Hill is located east of Garibaldi Hill, surrounded on its east and south part by the pyroclastic flows of the most recent eruptions. The selected drilling site is in Hazard Level Zone 'V' and will require permission for entry from Disaster Management Co-ordination Agency (DMCA). Figure 4.1 shows the location of MON-03 relative to the previous drill sites.

Figure 4.1: Photos of 3 Drill Sites on St. George's Hill

This area along with the Belham Valley will be a key focus of the EIA, in order to identify the potential environmental and social impacts of the drilling activities and develop appropriate mitigation measures in the form of Environmental and Social Management Plans.

The potential impact zones will be:-

1) The Drilling site and immediate area within Weekes Estate on St. George's Hill including water courses and road access, site preparation, proposed laying of water pipe lines and drainage
2) Belham Valley including all water courses, the aquifer, agricultural land, and road access
3) Fox's Bay area and Hot Water Pond
4) Plymouth including access roads, dredging area around jetty, marine habitats and beach

4.2 Geological Map

An aerial map with the relevant study location information was prepared with the assistance of the GIS Division, Ministry of Agriculture, Trade, Land, Housing and Environment (MALTHE). This is shown in Appendix A which shows the location of MON-03 on St. George's Hill. The black line identifies the limits of the impact Study Area. It encompasses Plymouth Jetty to the south, the access road to the Jetty, Dagenham (considered suitable for final disposal of residual drill spoil), a portion of Cork Main Road including MON-02, Weekes' Road up to the first Zone V entrance gate, the newly reinstated access road up to MON-03, and the drill site itself which is 1.2 acres. See figure 4.1.

From there the Study areas follows the site's natural drainage path down to the base of Belham Valley and includes the valley floor, extending westward up to and including the location of the existing groundwater wells. The Study area also extends westward from the junction of Cork Main Road and Weekes' Road to include the natural drainage of that area and importantly the primary receiving water course which drains towards the Salt Water Pond. St. George's Hill is surrounded on its east and south part by the pyroclastic flows of the most recent eruptions. Belham Valley has been heavily impacted by lahars, volcanic mud, washed through the valley by rainfall. Lahars in the Belham Valley correlate with days when >10 mm rain fell in 24 h, with more events triggered in the late rainy season (see http://jgs.geoscienceworld.org/content/164/4/815.abstract)

The entire study area is uninhabited. Quarrying is the only activity in the general area - in Belham Valley and on the east and west sides of Cork Main Road. Baseline conditions are best contextualized by reflecting on the fact the study area and surroundings are already heavily impacted by the catastrophic eruption of the volcano in 1995 and by the on-going emissions. Overall, this means that the impacts on the surrounding environment from controlled drilling activities for geothermal energy and resultant heat, gas, liquid and solid emissions, while significant, are quite limited.

5.0 Project Justification

5.1 Environmental Criteria

Given the tremendous impacts suffered by the Montserrat people and the environmental, and the invasive nature of the proposed drilling, it is prudent to take every precaution when executing any significant project. A clear definition of potential impacts and related management plans are therefore essentials for pursuing the proposed project.

5.2 Technical Criteria

Technical information for the selected production well as proposed is given below.

Table 5.1: MON-03 Well Information

Well Information		
Location	St George's Hill	
Well 3 Option A Co-ordinates	Eastings 377680.731 Northing 1849.071	
Depth	2,000 to 2,500 m	
Wellhead Completion		**Test Pressure**
13 3/8" 3000 wellhead flange with adaptor spool 10" to 13 3/8"		1,000 psi
10" 900 Master Valve with 2 x 1 3/8" 900 side valves		1,000 psi
Drilling and Casing Programme		
Conductor	36" dia. hole to be drilled to a depth ±24 metres; to be cased with 30" casing back to the surface; this casing to be cemented back to the surface; it is possible that section of the well may be	

	completed as part of the drilling site preparations, and would then not part of the scope of this drilling services contract.
Surface Casing:	26” dia. hole to be drilled to a depth of between 100 and 150 metres; to be cased back to the surface with 20" casing; this casing to be cemented back to the surface.
Anchor Casing	17½” dia. hole to be drilled to a depth of 550 to 750 metres, to be cased back to the surface with 13 3/8” casing; this casing is to be cemented back to the surface.
Production Casing	12¼” dia. hole is to be drilled vertically to a depth of 1400 metres, to be cased back to the surface with 9 5/8” casing. This casing is also to be cemented back to the surface.
Open hole .	8½” dia. hole to be drilled to a nominal total depth of 2,500 metres and cased with 7" perforated liner. This casing shall extend from approximately three joints above the depth of the 9 5/8” Production casing shoe (approximately 1360 metres) to the final well depth.

Wells 1 & 2 had similar characteristics. Their revised coordinates are shown in Table 5.2 below.

Table 5.2: MON-01 & MON-02 Well Information

Well Information	
Location	St George’s Bay Hill
Well 1 Coordinates	Eastings 376464.281 Northings 1848313.976
Well 2 Coordinates	Eastings 376481.214 Northings 1848862.194

5.3 Economic Criteria

The GDP per capita is approximately U$ 11,575 (2010 data). There is limited economic activity on the island including mining and quarrying, construction, financial and professional services and tourism. Volcanic eruptions in 1995 destroyed the capital city and enforced the permanent relocation of inhabitants from two-thirds of the island. Since then the territory has been dependent on UK

aid, with DFID currently providing 60% of Montserrat's recurrent budget in the form of budget support. Montserrat's economy is 100% fossil fuel based. The utility imports the required fuels at a cost of EC$10 Million annually and passes the cost on to the customer through billing. This burden is unsustainable from an environmental, climate change and economic perspective. Given its volcanic origins, Montserrat has the potential for geothermal electrical power generation as an alternative to a power supply based on imported fossil fuels.

The exploration and exploitation of Montserrat's potential geothermal resource is one of the Government of Montserrat's highest development priorities. However, it is an innovative area for energy development with high up front cost.

In 2010 a DFID funded study assessed the geothermal potential of Montserrat. This built on the findings of other research commissioned since 1997 and concluded that there is high probability that Montserrat has considerable geothermal resources. The most conservative research suggests that there is a 75-80% chance of at least 5 MW of power available.

In 2011 DFID commissioned an economic assessment that assessed the commercial viability for resources of different sizes e.g. 2-5 MW, <25 MW and >50 MW. This assessment determined that a 2 MW production capacity had the most favourable economic rate of return and would be sufficient for Montserrat’s immediate and medium-term requirements.

5.4 Social Criteria

Two of the main social pressures currently experienced by the residents of Montserrat are 1) the high cost of electricity and 2) a subdued economy from the impact of the volcanic eruption. As they try to rebuild the country it is hoped that this study will lead to the establishment of a geothermal electricity plant in Montserrat. Such a plant would provide Montserratians with lower electricity costs and provide the economy with enough energy to actively pursue new business opportunities.

6.0 Baselines

6.1 Physical Environment

Description

The study area represents eruptive centres on the lower western flanks of the Soufrière Hills Volcano. Geologically, they are composed of pyroclastic deposits, from pumice and Lapilli falls, and mud flows. Previous geothermal exploration work concluded that there is an active geothermal system underlying this area at depth of around 1,500 to 2,500 metres with water temperatures of the order of 250 – 300 °C. This was considered the most practical location for the 3rd Drill Site from geological, logistical and safety perspectives.

Tectonic movements have caused faulting in this area which has provided conduits to bring hot fluids from deeper areas up to around the 1,500 – 2,000 metres depth. The area has good surface water drainage (some five water courses through the valley). There are also a number of shallow fresh water aquifers of less than 200 metres depth and a few cold and hot springs in the area. The pyroclastic deposits are usually permeable and can be good water bearing rocks.

Methodology

The desk-based assessment previously undertaken was reviewed and updated. Meetings were held with the various stakeholders to collect current and historical

data. Field visits were conducted in order to view and characterize the proposed drill site as well as the study areas. Physical samples were also taken and analysed.

6.1.1 Accidental Discharge of Chemicals/Fuels (ENV-01)

The Site and surrounding area is uninhabited since 1995. It is considered to be currently free of chemicals and fuels. Records kept for drilling MON-01 and MON-02 would indicate if any spills took place and what type of preventative measures, emergency response and remedial action might have been taken. Atom is not aware that there were any accidental spills of fuels or chemicals during the drilling of these wells. Observations during the site visits to MON-03 revealed no sign of land contamination.

6.1.2 Well Failure/Upset Condition (ENV-02)

According to the TOR, the Drill Contractor will clearly specify how he proposes to address well failure and upset conditions and confirm that he carries full insurance for any injury, potential loss or damages to himself, his staff and equipment and the specific volcanic risk insurance being used. The Drill Contractor must also indicate how such risks will be managed as part of drilling operations and what steps would be taken to secure MON-03 at any stage of drilling should unforeseen volcanic activity require shut down and immediate evacuation. A worst case scenario would be an upset condition followed by an

order to evacuate. The Drill Contractor should account for such a scenario though unlikely, in the Emergency Response Plan

6.1.3 Discharge of Solid Wastes from Drill Spoils (ENV-03)

In the drilling of MON-01 and MON-02 drill spoil was discharged and contained in the 960m^3 constructed concrete impoundment ponds. After the top liquid component evaporated, solid material was to be left in the ponds, and the ponds permanently capped. During production testing, drill liquids filled the ponds and overflowed. On completion of testing both ponds were full. According to the Public Works Department, residual solids in the MON-01 and MON-02 ponds are now to be excavated and transported to the Dagenham area near 'Lovers Lane' in Zone V. The same is expected for residual solid drill spoil wastes from MON-03.

The cleared MON-02 pond is to be used to receive and store water from the public supply sources and then be pumped up to the pond which will be constructed at MON-03. The handling and final disposal of solids depends on the constituent characteristics of the solids – whether they could be classified as toxic and pose a risk to public and environmental health.

The use of water based drilling mud is common and assumed to have been used as the drilling fluid for MON -1 and MON-02. Drilling mud typically consists of water mixed with bentonite (natural clay). Additives are used to control the

viscosity and density of the mud. These additives include xanthan gum and starch and cellulose derivatives for viscosity control and solid barium sulphate for density control. The drilling mud is recycled during drilling and the rock cuttings are separated from the mud on shaker boards. Typically, drilling muds are processed with activated carbon, and reused (http://documents.worldbank.org/curated/en/2015/10/25144309/turkey-geothermal-development-project-environmental-social-management-framework).

If the rock cuttings consist of environmentally benign rock types they can be disposed of in municipal landfills. This is a practical and economical way to dispose of solid waste materials that can be used in most cases. However, cuttings may be classified as hazardous depending on the concentration and potential for leaching of silica compounds, chlorides, arsenic, mercury, vanadium, nickel, and other heavy metals. In such cases, cuttings need to be disposed of in isolated cells in a specially constructed landfill. While the above disposal options are recommended, south Montserrat is unique in that it suffered from a catastrophic volcanic eruption releasing magma and ash throughout the Zone V areas. These areas may be suitable for unconfined, below ground disposal of solid drill wastes because they may already be close in chemical composition to the waste material requiring disposal. ***However, a proper study of the impact of the volcanic magma and ash on any proposed area(s) should be done first.***

6.1.4 Discharge of Liquid Wastes from Drill Spoils (ENV-04)

Freshwater will be used as a drilling fluid (circulation water). The purpose of the drilling fluid is to cool and lubricate the drilling equipment and carry rock cuttings out of the well. In some cases synthetic drilling polymers are injected to form high-viscosity polymer slugs to facilitate clean-out. Commonly used drilling polymers include xanthan gum, and starch and cellulose derivatives. Geothermal water extracted during well testing period is also considered a drilling fluid. Water extracted at MON-01 and MON-02 was saline, with characteristics similar to seawater. The 'solid' waste component of the drill spoil occurs in suspension and mobilized and transported in water, forming the liquid waste. As mentioned in the previous section, a 960m^3 concrete impoundment pond, similar to what was constructed for MON-01 and MON-02, will be constructed at the MON-03 Site. Liquid wastes from MON-03 will be directed to this pond. According to Production Well Test Results, MON-01 was produced for "a cumulative total of 35 days and discharged approximately 48,000 m^3 of total reservoir fluid" (page 3 of 27). This was significantly more than the capacity of the constructed pond. A similar discharge is expected of MON-03. While a review of all details of the Drill Reports was not possible, a review of the Executive Summary and Well Completion Report reveals elevated chloride concentrations in the vicinity of [Cl^-] 28,000 mg/kg in the drill effluent, or 2.8%. Salinity is a measure of dissolved salts. Salinity is roughly 1.8 x [Cl-] so effluent salinity could be up to 50,000 mg/kg or 5%

(http://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/). Atom measured seawater salinity at Plymouth Jetty and at Hot Water Pond in the final discharge area of water course and found 3.00% and 2.96% respectively.

Also noted in the Executive Summary is the presence of "trace element concentrations such as elevated boron and arsenic, the result of fluid interaction within the reservoir rocks of the geothermal system". Analyses of scale deposits in the flow test equipment and drainage outflow indicated the material is "primarily silica with minor amounts of iron oxide and sulphur." The Summary also notes that "evaluating potential environmental impacts will depend on additional analyses to determine solubility and mobility".

Available online is a paper presented at the 39th Workshop on Geothermal Reservoir Engineering at Stanford University, California, on February 24-26, titled "Preliminary results of deep geothermal drilling and testing on the Island of Montserrat" by Paul Brophy *et al.*

(https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2014/Brophy.pdf).

Table 1 of his Paper includes a profile of the "brine chemistry" or drill effluent "corrected to reservoir conditions". Chloride concentrations were less than those presented in the Executive Summary of the Well Completion Report. The information provides sufficient information to characterize drill effluents and assess environmental impacts. Table 6.1 is reproduced below:

Table 6.1: Baseline Measurements

ppm	MON-01	MON-02	Seawater
Sodium (Na)	8,660	7,950	10,500
Potassium (K)	761	703	390
Calcium (Ca)	3,757	3,370	410
Magnesium (Mg)	10	8.1	1,330
Boron (B)	16	14	4.5
Silica (SiO2)	383	355	6.4
Chloride (Cl)	20,557	19,080	19,350
Sulphate (SO4)	23	18	2,700
Strontium (Sr)	47	45	8
Arsenic (As)	1.8	1.6	0.003

The information provided suggests that the drill effluent is essentially seawater altered by its prolonged contact with subsurface rocks. The above data came from sampling of liquid effluent. The Executive Summary of the Well Completion Report quotes the Arsenic content of the produced scale material ranging from 86ppm to 140ppm.

There are currently no leaks at MON-01 and MON-02 but there is still the possibility of overflow if heavy sustained rainfall occurs in the area. Our on-site tests of the surface liquid indicated a salinity of 1.00% suggesting that it had become diluted by rainwater over time.

6.1.5 Ground Water (ENV-05)

According to the TOR, groundwater will be encountered at around 200m during drilling. The closest groundwater wells of significance are those in the Belham Valley. A review of available data indicates that six wells were drilled in the Belham Valley in 1996. Like many of the valleys in the south on Montserrat, however, Belham Valley has been inundated with lahars and pyroclastic deposits since the 1995 eruption. In 2007, fill accumulation from lahars in the lower Belham Valley was estimated to be between 10m and 15m (Donnelly, 2007). In 2004, HydroSource Associates managed a project drilling three wells targeting the productive, artesian aquifer in the Belham Valley (HydroSource, 2004). The three wells tap a confined aquifer in reworked gravels and alluvial deposits between 15 and 38 m below mean sea level. The aquifer is confined by a thin (1 m) cap of low permeability clay and lahar deposits beneath a thicker (12 m) lahar deposit. However, since access to these wells becomes limited during times of heightened volcanic activity and extreme rainfall events, the Belham wells are maintained as a back-up source of water supply (http://www.sciencedirect.com/science/article/pii/S2214581814000299).

According to the Water Department of MUL, the 2015 drought required use of this backup source to meet public demand.

6.1.6 Soil & land Contamination from Drill Lubricants and Fuels (ENV-06)

Observations made around the drill sites indicate that no existing industrial contamination. All drill lubricants and fuels will be stored in a secure area on the

concrete platform and will be used in accordance with best industrial practice. No off-site discharge during operations is anticipated.

6.1.7 GHG Emission from On-site Diesel Generators and Well Emission (ENV-08)

GHG emissions in the area may be produced by the volcano. However, data on the release of carbon dioxide or other GHG was not found in MVO Reporting. The combustion of diesel fuel used to operate excavators, loaders and trucks involved in quarry operations operating year round, will contribute carbon dioxide to the atmosphere. Minor contributions will be generated from occasional car racing. The MVO does report on sulphur dioxide emissions but this is not a GHG and may actually cause cooling in the atmosphere. While this is not a GHG it does pollute the atmosphere and is believed to be responsible for several asthma related illnesses.

6.1.8 Erosion from Water Discharge (ENV-09)

This impact refers to erosion that might be caused by rainwater run-off from the site as well as drill effluent. Rain water runoff is expected during and for a period after the rain has ended. Discharge of drill liquids is expected when the well is being ‘produced’, that is tested for its sustained heat delivery capacity. This was done intermittently over a period of 35 days for both MON-01 and MON-02. The combined discharge of rainfall runoff and drill liquids during testing would result in the maximum flows from the site and greatest potential for erosion.

6.1.9 Induced Landslides (ENV-10)

MON-03 is located in the relatively heavily vegetated northern slope of St. George's Hill. Some 1.2 acres will be cleared and levelled. No land slippage is presently occurring since the site is well covered with and surrounded by vegetation. Once cleared, the height of the exposed back-face of the site will be around 5m.

6.1.10 Transportation of Infrastructure (ENV-11)

The transportation of drill equipment and infrastructure to MON-03 will be from the Plymouth Jetty along the same route used by quarry trucks to Cork Main Road. From there it will turn onto Weekes' Road which is paved, up to the Zone V gate and along the newly reinstated access road to the MON-03 Site. The new access road is to be reinforced and upgraded prior to site clearing.

Quarrying activity involves excavation of pits on either side of Cork Main Road and the Belham Valley followed by transport of sand and aggregate to the Jetty and loading onto a barge for export. This activity is expected to be on-going. The same jetty will be used to unload the drilling equipment.

6.2 Natural Environment

Description

The biological diversity (biodiversity) of Montserrat has been impacted by 1) anthropogenic factors: namely the stripping of its original vegetation for cultivation purposes and the introduction of non-native (introduced) species, and 2) natural events: hurricanes, droughts and the eruption of the Soufrière Hills Volcano (1995-2008) and its ongoing activities (Procter and Fleming 1999, Young 2008, Holliday 2009, Pienkowski *et al*. 2015). Despite these impacts, it is estimated that >900 plant (flora) species and >4,000 animal (fauna) species occur on Montserrat (FRA 2005, Young 2008).

Both plant and animal species are categorised by their spatial distribution and conservation status (i.e. likelihood of species persistence in the near future). Table 6.2 identifies the major distribution and conservation categories. According to Young 2008, there are seven species and four subspecies endemic to Montserrat and 12 species that are Vulnerable, Endangered or Critically Endangered (Table 6.2, Appendix C. It has also been reported that there are numerous introduced plant and animal species (Hilton *et al*. 2008, Young 2008), which are of concern as they can outcompete native species, thereby reducing local biodiversity.

Table 6.2: Distribution and conservation categories applied to flora & fauna

Spatial distribution	
Native	occurring naturally
Endemic to Montserrat	only occurring in Montserrat
Non-native/Introduced	not occurring naturally
Conservation status	
Vulnerable	high risk of extinction in the wild
Endangered	very high risk of extinction in the wild
Critically Endangered	extremely high risk of extinction in the wild

Due to the eruptions and ongoing activities of the Soufrière Hills Volcano, the southern two-thirds of the island has been abandoned. As a result, post-eruption biodiversity data for St. George's Hill, the proposed geographic location for the drilling site, is extremely limited. Similarly, the marine environment along the southwest of the island is relatively data deficient with respect to biodiversity (Bovey *et al*. nd).

The forest environments currently present on Montserrat have been described as secondary, naturally regenerated forest tracts (Hilton *et al*. 2008, Holliday 2009). St. George's Hill has been reported as a Mesic forest (i.e. a transitional forest type between dry and wet forests), with previous habitation on the north-western face of the hill and volcanic deposits along the east and northeast (Young 2008, Holliday 2009, Gray 2011).

The marine environment is reported to consist of a narrow coastal shelf which supports small areas of coral reefs (fringing and patch) and pockets of sea grass

beds (Bovey *et al*. nd, Gray 2011). A 1995 survey highlighted a greater abundance of corals with a higher tolerance for sediment smothering and or reduced light levels (Gray 2011). Four species of sea turtles (i.e. hawksbill, green, leatherback and loggerhead) forage and/or nest on Montserrat, with all of the western beaches being identified as significant sea turtle nesting sites (Gray 2011).

The near-shore marine environment at the Plymouth jetty is one that has been repeatedly impacted by the activities of the Soufrière Hills Volcano (i.e. pyroclastic flows, mud flows and ash falls). As a result, there has been expansion of the coastline in the surrounding areas and a significant decrease in the depth of the water column around the jetty (Kelvin White -DMCA, personal communication, November 04, 2015).

The major threats to biodiversity are either as a result of anthropogenic factors (habitat destruction, pollution and invasive species) or natural occurrences (hurricanes, droughts, volcanic activities, climate change, diseases and feral animals).

Methodology

Biodiversity surveys were carried out at four distinct locations (i.e. possible impact areas) during the period November 3rd to 5th 2015. The locations surveyed were:

1) The proposed drilling site (MON-03) and its immediate surroundings

2) Plymouth jetty area and near-shore marine environment
3) Hot Water Pond area near-shore marine environment

A reconnaissance exercise was conducted on November 03, 2015, which included the three above-mentioned sites and the two previous drill sites (MON-01 & MON-02). The three sites to be potentially impacted were visited on November 04, 2015 to allow for in-depth data collection, along with MON-02 to assess previous localised impacts. The proposed drilling site (MON-03) was revisited on November 05, 2015 to complete data collection.

MON-03 was traversed along straight lines from north to south and from east to west to obtain a general overview of the area and to acquire an inventory of flora and fauna species. Random points were chosen along the lines traversed to survey for fauna (i.e. in the canopy, under leaves, in the leaf litter and so on). The immediate surroundings of the proposed site were also surveyed, in a less structured manner, for flora and fauna.

The near-shore marine environment at the **Plymouth Jetty** was assessed by means of a visual survey conducted via a snorkelling exercise. Species observed were recorded. Depth measurements were taken at seven points along the jetty and a water sample, from the southern end of the jetty, was collected and salinity was recorded using a Hanna Instruments 9828 multi-parameter meter.

The **Hot Water Pond** area was visually surveyed by walking along the water course, plant and animal species observed were recorded. Similar to the

Plymouth jetty, the near-shore environment adjacent to the Hot Water Pond was surveyed via a snorkelling exercise. Species observed were recorded and water sampled.

From a biodiversity perspective, the key factors taken into account when determining possible impact levels are:

- Habitat quality
- Species richness – the number of different species in the given area
- Endemicity – the number of species unique to the particular area
- Threat status of species present – highest conservation priority given to species that are Vulnerable, Endangered or Critically Endangered
- Introduced & alien invasive species – non-native species that can have a detrimental effect on local species

6.2.1 Steam Discharge (ENV-07)

Well fluids can be expected to be as high as 250 ^{0}C. In the drilling of MON-01 and MON-02, well fluids were directed into a cone shaped pipe which expanded and discharged into large cylindrical vessel (approximately 3m diameter) resulting in sudden drop in both pressure and temperature. This allowed for the separation of steam and liquid. The liquid was directed to the pond and the steam vented to the atmosphere through the open top of the vessel. This impact refers to potential damage the released steam would have on surrounding flora. The MON-01 and MON-02 Sites were cleared of all vegetation. They are not

surrounded by as much vegetation as is MON-03, being closer to the road and quarry pits. The surrounding vegetation is green and healthy looking.

It is worth mentioning that much higher temperature discharges are taking place at the volcano - outside of the Study Area. Volcanic gases that escape through fractures and fumaroles in the lava dome have remained high, with the hottest fumaroles maintaining 600^0C over the last four and a half years since the last major activity (MVO SAC Report November, 2014).

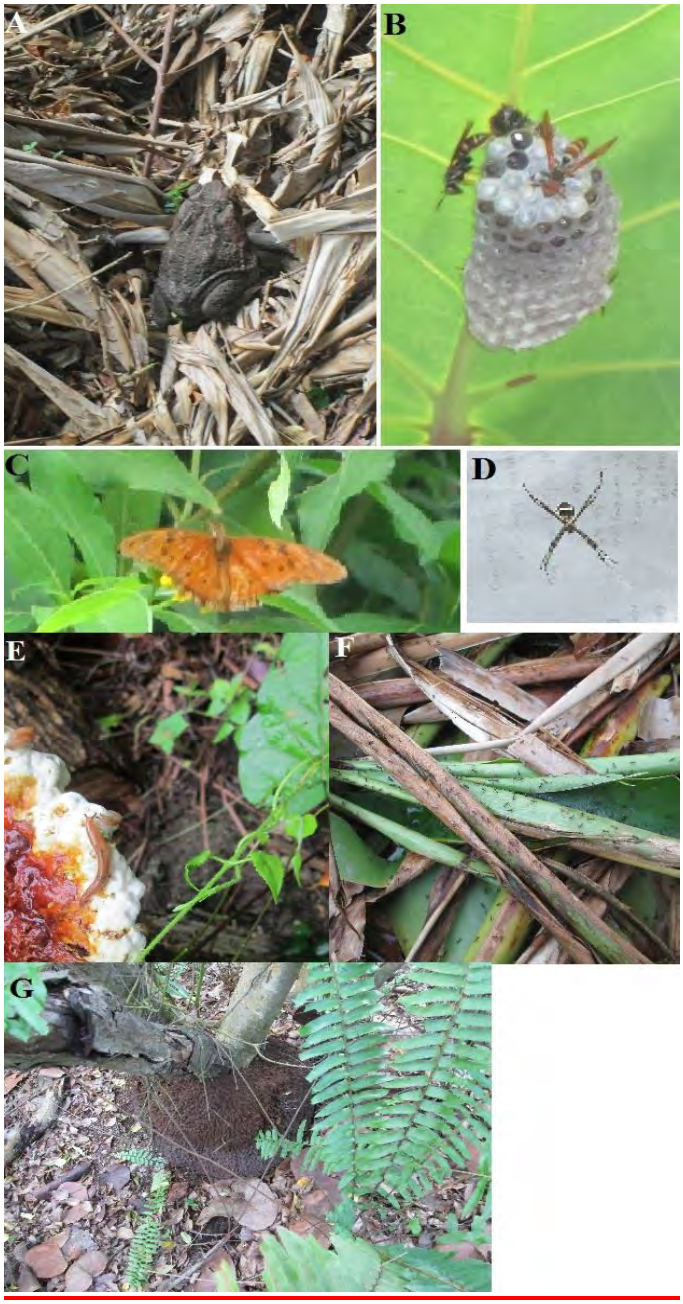
6.2.2 Terrestrial Fauna (ENV-12)

Proposed drilling site (MON-03)

A total of 20 animal species were observed within the proposed site and the immediate surrounding areas (See Appendix C). The species observed included mammals, birds, amphibians and invertebrates (spiders, wasps, butterflies and insects; Figure 6.1).

Figure 6.1: Selection of Drilling Site Fauna

A - marine toad
B – wasp
C – butterfly
D – spider
E – terrestrial slug
F – ants
G – termite mound



Plymouth Jetty

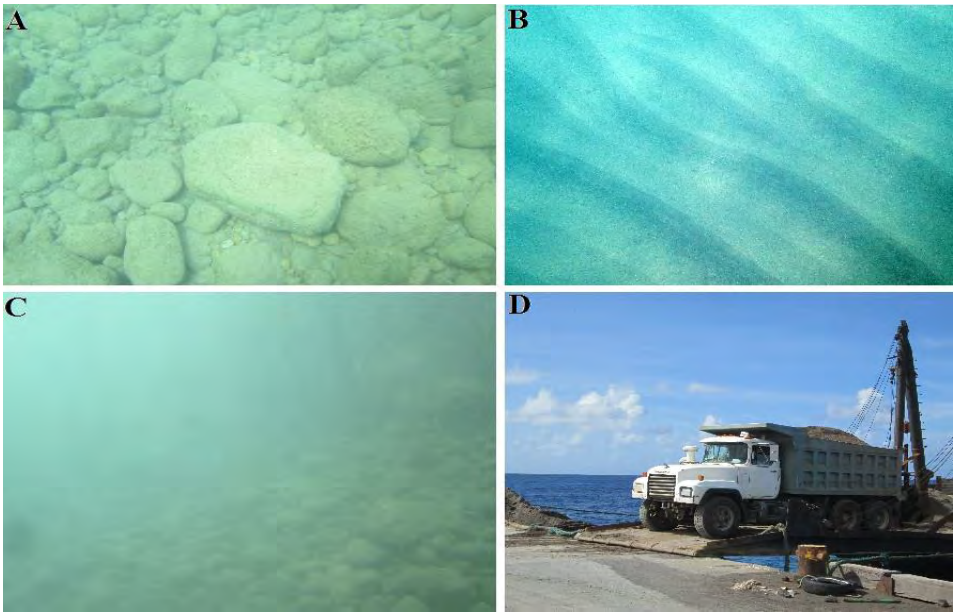
The depths recorded at the jetty were relatively shallow, ranging from 1.5-7 m (5-23ft; Figure 6.2). Travelling offshore, two benthic habitats were encountered. Closer to shore was a band of loose rocks which gave way to bare sand (Figure 6.3 -A & B). Visibility was poor as a result of high turbidity levels. It must be noted that during the time of the survey a barge was docked at the jetty and being loaded with mined sand (Figure 6.3 - C & D). A salinity measurement of 30.23ppt was recorded at site D1.

Figure 6.2: Plymouth Jetty Area (Inset: picture of jetty)

Site	Depth
D1	7m (23ft)
D2	7m (23ft)
D3	4.6m (15ft)
D4	2.4m (8ft)
D5	1.5m (5ft)
D6	2.7m (9ft)
D7	4.9m (16ft)

Figure 6.3: Plymouth Marine Conditions

A – loose rocks close to shore
B – bare sand encountered moving offshore
C – poor visibility
D – barge being loaded with mined sand



The near-shore marine environment was relatively devoid of any fauna. No attached benthic organism, such as corals, sea grasses or algae, were observed. A marine crab was observed in the loose rock habitat and a few mobile fish species were observed in the loose rock habitat and around the jetty pylons (see Appendix C). Magnificent frigate birds (*Fregata magnificens*) were observed flying overhead and brown pelicans (*Pelecanus occidentalis*) were observed resting on the water, just north of the jetty.

Hot Water Pond

The area known as Hot Water Pond presented a dried-out water course, with only a small pool of surface water observed (Figure 6.4 -A & B). Salinity measurements, taken with the Hanna Instruments 9828 multi-parameter meter, indicated the pool of surface water to be rain water (salinity: 0.46ppt). Adjacent to this area is a long stretch of wide, black-sand beach (Figure 6.4 C & D). At the interphase of the watercourse and the beach is a built up sand berm (>2m in height) (Figure 6.4 E).

The near shore fauna observed was quite limited, and included the smooth-billed Ani (*Crotophaga ani*), the spotted sandpiper (*Actitis macularia*) and tadpoles in the pool of surface water (Figure 6.4B, C & D). Crab holes were also observed along the backshore of the adjacent beach.

Figure 6.4: Hot Water Pond Near Shore Flora

A – dried out water course
B – small pool of surface water observed
C – adjacent beach facing south
D – adjacent beach facing north
E – built up sand berm at the interface of the water course and beach

Figure 6:5: Hot Water Pond Fauna

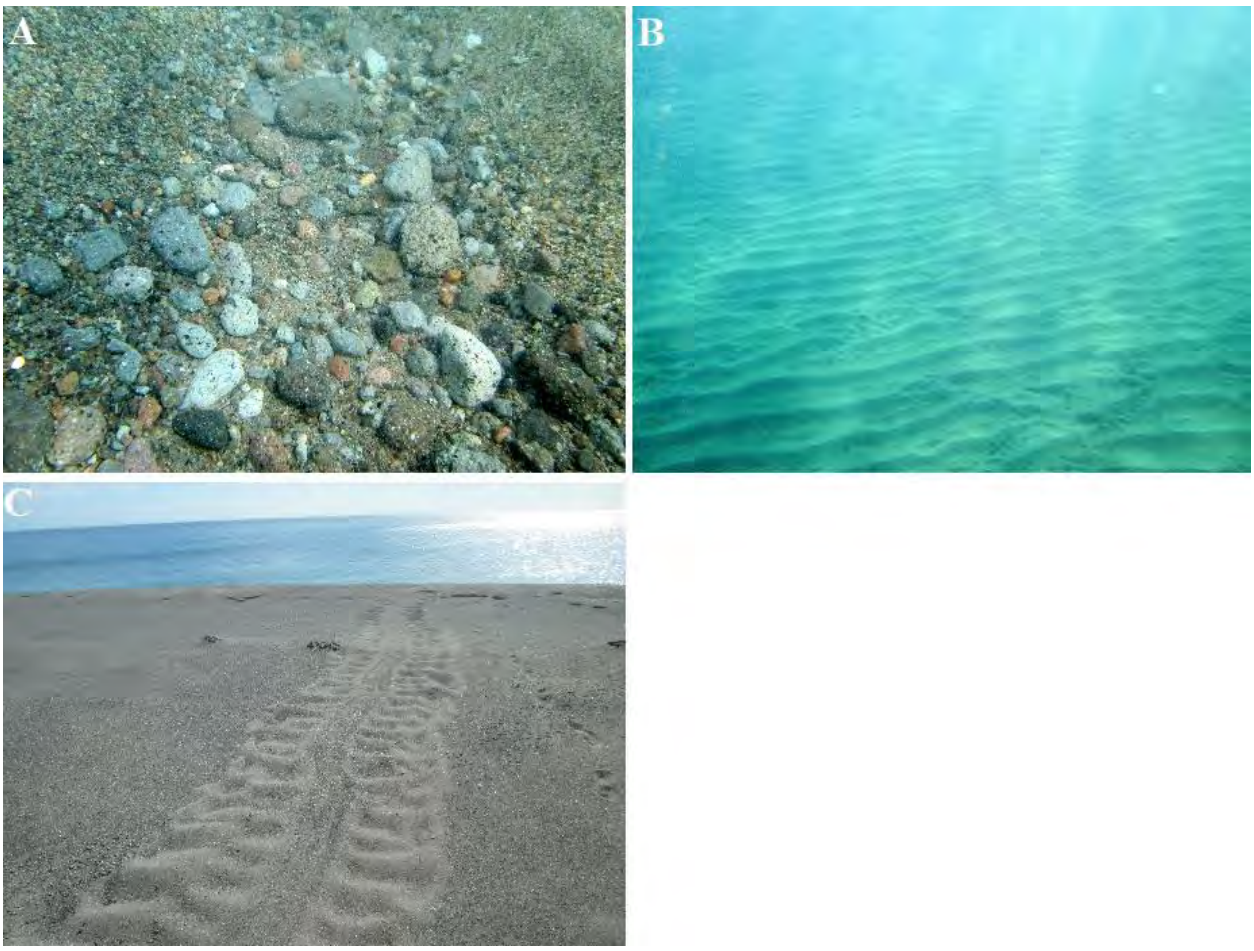
A – dry, low-lying cliff vegetation
B – smooth-billed ani (Crotophaga ani)
C – Spotted sandpiper (Actitis macularia)
D – tadpoles in surface water

Similar to the near-shore marine environment at Plymouth jetty, two benthic habitats were encountered. Closer to shore was a band of loose rocks and sediments which gave way to bare sand (Figure 6.6 A & B). The visibility was significantly improved, from that at Plymouth jetty, due to lower turbidity levels. The salinity was similar to that at Plymouth jetty, with a reading of 29.57ppt.

No attached benthic organism, such as corals, sea grasses or algae, or mobile organisms such as fish or crabs were observed. A fresh track, made by a female of the Critically Endangered hawksbill sea turtle species (*Eretmochelys imbricata*), was observed (Figure 6.6), Magnificent frigate birds (*Fregata magnificens*) were seen flying overhead and brown pelicans (*Pelecanus occidentalis*) were observed resting on the water just to the south.

Figure 6.6: Additional Hot Water Pond Fauna

A – loose rocks and sediments
B – bare sand
C – down track of a nesting hawksbill sea turtle (Eretmochelys imbricata)



6.2.3 Terrestrial Flora (ENV-13)

Proposed drilling site (MON-03)

The proposed site and its immediate surroundings represent a relatively well vegetated secondary forest, made up of a canopy and understory layers. The forest is not continuous, but fragmented, and the environment is not homogeneous, as some areas are comprised of high canopy cover and little understory cover and *vice versa* (Figure 6.7). Overall, canopy cover is estimated at around 70%, with trees making up the canopy in the range of 10-15m in height. No aquatic environments were observed within the proposed site or surrounding areas.

Figure 6.7: Drilling Site Flora

A – area with high canopy cover and little understory cover
B – area with low canopy cover and high understory cover

The site is tree dominated, but also comprised of shrubs, herbs, vines and epiphytes. A total of 35 plant species were observed within the proposed site and the immediate surrounding areas. The most frequently observed canopy species were 'birch gum' (*Bursera simaruba*), 'banyan' (*Ficus sp.*) and 'bread n cheese' (*Pithecellobium unguis-cati*), while the most frequently observed understory species was the fern *Blechnum serrulatum* (Figure 6.3). A full list of all the species observed is provided in Appendix C.

Figure 6.8: Selection of Drilling Site Flora

A – distinctive bark of birch gum
B – bread and cheese,
C – banyan
D – fern

Plymouth Jetty

A small amount of growth was seen on the pylons of the jetty, these included barnacles, chitons and filamentous green algae.

Hot Water Pond

The water course and the backshore of the adjacent beach are populated with dry, low-lying (<4m), scrub vegetation throughout, with *Acacia sp*. and various grasses being the prevalent species. The cliffs adjacent to the beach are also populated with dry, low-lying scrub vegetation which include *Acacia sp*., grasses and cactus species (Figure 6.4 -A). Vegetation appeared healthy and showed no signs of growth impairment (i.e. stunted growth, yellowing of leaves and so on).

6.3 Landscape and Visual including heritage

Description

The proposed site is roughly 1.2 km due east-north-east of MON-02. It is heavily vegetated comprising an area of 1.2 acres of what was Weekes' Plantation. It is in plain sight of the Volcano Observatory. Located on the northern side of St. George's Hill, it has an elevation of approximately 200m. This side of St. George's Hill slopes down towards Belham Valley at a grade of roughly 20%.

Methodology

Multiple visits were made to the drilling site and study area to determine its character, the quality of the landscape and the existing land cover. Photos were gathered and shown below in Figure 6.9.

Figure 6.9: Views of 3rd Drill Site on St. George's Hill

North Western View - Hazy dry day in December 2015 (From MVO - Roderick Stewart)
Northern View - Sunny dry day in 2015 (From Helicopter)

Assessment

In addition to the photos presented an aerial view was used to gauge the visual impact. See Figure 4.1 above. The area being cleared is just 1.2 acres which is small considering the vegetated cover of St. George's Hill is some 770 acres (0.16%).

As it relates to **archaeology** within the immediate surroundings of the proposed drill site three concrete structures were observed. These included a hut, a small tunnel and the ruins of an old sugar mill. The archaeological value cannot be confirmed but the drill site has been shifted to avoid any further damage to the one located adjacent to MON-03.

Having examined landscape, visual and heritage, it is not expected that the associated variables will be impacted in any significant way. Any further comments are included in section 7 under "Assumed Low Impact".

6.4 Human and Social Environment

Description

The TOR document sets the spatial boundaries of the proposed project as the area between Garibaldi Hill and St George's Hill within the Weekes' area. The boundaries are determined by the extent to which there exist both geography-based and interest-based communities in relation to the project. The level of interest of these groups is based upon whether it is believed that their social

practices are likely to be affected by the drilling activity. These practices can be classified as lifestyle, cultural, community, health and quality of life activities.

There are five **Geography-based Communities** located within close proximity of the location. Happy Hill is located in closest proximity 2km to the north-west of the drilling site and Frith, Fleming, Isle Bay and Old Towne are located with 4km in a general northern direction. An exclusion zone runs from the south-west coast of the island and inland in a northward trend through parts of the Belham Valley and somewhat cutting the island in two. This zone now permits public access but still prohibits settlement. Access to Zone V is still restricted and managed by the authorities. Besides this group, there is no need to enter the area in the regular course of their daily activities.

Interest based groups relate to any organised or unorganised group which utilises the area within the exclusion zone or which has utilised it in the past and has some social or economic connection with the area. Just 2km away, within the Belham Valley area, sand mining continues to be one of the main forms of economic activity and contributes to the foreign exchange earnings of Montserrat. The farming community is also gradually returning to the area to pursue their interests again. Car racing is another recreational activity which occurs on the Cork Hill road.

The Montserrat **culture** is predominantly a Christian society with several Christian denominations. All of the island's communities are fairly homogenous

with a majority of persons of Afro-Caribbean origin and a small percentage of non-resident property owners who visit the island occasionally on vacation. Consequently, there are no distinct cultural attributes or values that can be specifically associated with the local communities around the project area.

Methodology

The existing baseline conditions were established through desk-study, interviews and meetings with groups and individuals. The exercise was used to determine the presence of and prioritise the impacts which have been identified in the scoping document. The significance of effects was determined by combining the sensitivity of the identified receptors with the predicted magnitude of change, using a matrix. Data were collected from public documents, inclusive of the three main documents referenced in the TOR.

6.4.1 Occupational Health and Safety (SOC-01)

Exposure to drilling muds, geothermal fluids or steam, and hazardous materials such as petroleum, oils, and lubricants during drilling is natural. Potential human health and safety impacts during the exploration and drilling phase would therefore represent an increased risk of serious injury or accidents, especially to the drilling crew working directly with these materials. However, the potential for these impacts to occur is low if appropriate safety procedures are followed.

Drilling is expected to operating round the clock on two twelve hour shifts over three to four months. Despite the occupational risks greater risk comes from the volcano and its on-going seismic activity.

Even though not in the published TOR, Occupational Health and Safety procedures are expected to form part of the Drilling Contractor's documents in relation to full insurance for any injury, potential loss or damages to himself, their staff and equipment and the specific volcanic risk insurance covered. In their Final Report on Geothermal Exploration (GoM 2010), EGS Inc. identified the ongoing eruption of the Soufrière Hills Volcano as a "major constraint" in completing geothermal exploration and advised "extreme care needs to be taken to ensure that all activities are carried out in a safe and prudent manner and that all risks associated with having personnel in an active volcanic area are minimized to the greatest extent practical".

6.4.2 Employment Opportunities (SOC-02)

Unemployment is currently recorded around 7.5%. Although Montserrat has experienced a small positive growth rate between 2011 and 2013, it is largely an emigration nation and those who have stayed earn a living primarily as civil servants, professionals, involved in mining or the commercial sector. The project will require some additional manpower particularly in the site preparation and drilling. As it relate to the drilling project, it will be temporary.

6.4.3 Demand for commercial services (SOC-03)

Based on 2013 estimates, agriculture contributes 1.6%, industries 23.2% and services 75.1%. While all businesses are small to micro, there is the capacity to absorb the additional potential business. Site preparation, road repairs, drainage and drilling activities are likely to create an increased demand for commercial services like catering, accommodation, courier services, laundry, recreation, etc. These additional services would also be temporary. The needs of the local workers are not expected to exceed their normal levels.

6.4.4 Tourism (SOC-04)

The ministry responsible for tourism has been steadily at work to develop the tourism sector in Montserrat. As Montserrat seeks to rebuild a city in the northern part of the country, Little Bay has been identified to play a critical part. The former capital of Plymouth tours have been re-established in February 2015, with passengers of visiting cruise ships being invited to dock at Little Bay and purchase a Plymouth City tour. This effort still has some challenges with ground swells commonly experienced between December and February; making docking inadvisable at Little Bay. Plymouth jetty has been identified as the backup docking area but some ships do not choose to take the option for safety reasons. The Guadeloupe ferry successfully docked at the Plymouth jetty in July 2015.

This relaunch has however been suspended pending the certification of the taxi drivers who will have a key role to play. This training will be complete to restart in

December 2015. This corresponds to the start of the Montserrat carnival season when most returning nationals choose to return to Montserrat. It is felt that drilling sites past and future, are points of interest. MON-01 and MON-02 sites are easily seen from the Cork Hill main road but MON-03 will not be visible. Tours are currently sold out and some 400 passengers are expected.

A Quad Bike Trail is also being planned for early 2016. The development of a health and wellness product for the tourism sector is also being discussed.

6.4.5 Residential water supply levels (SOC-05)

Demand

The geothermal drilling activities will utilise a significant amount of water for cooling the drill bit and flushing out the drilled cuttings process. It is therefore assumed that this project would place additional demands upon the water resources of Montserrat. The TOR has indicated that the water supply would be sourced primarily from the current water source and supplementary supplies would come from wells within the Belham area.

The maximum drilling water supply requirements were estimated at 3,500 litres per minute with backup storage available through “ponding” at the drilling site. However, data from the MUL during the previous drilling period indicates actual amounts of 418 litres per minute which is well below the projected usage.

Table 6.3: Water Usage during Previous Drilling

Month	Gallons used
Apr-13	2,003,000
May-13	7,026,000
Jun-13	1,794,000
Jul-13	2,875,000
Aug-13	5,112,000
Sep-13	7,266,000
Oct-13	1,781,000
Nov-13	9,000
Dec-13	4,000
Jan-14	7,000

Supply

The water supply capacity was conservatively estimated by the division Manager and is presented below:

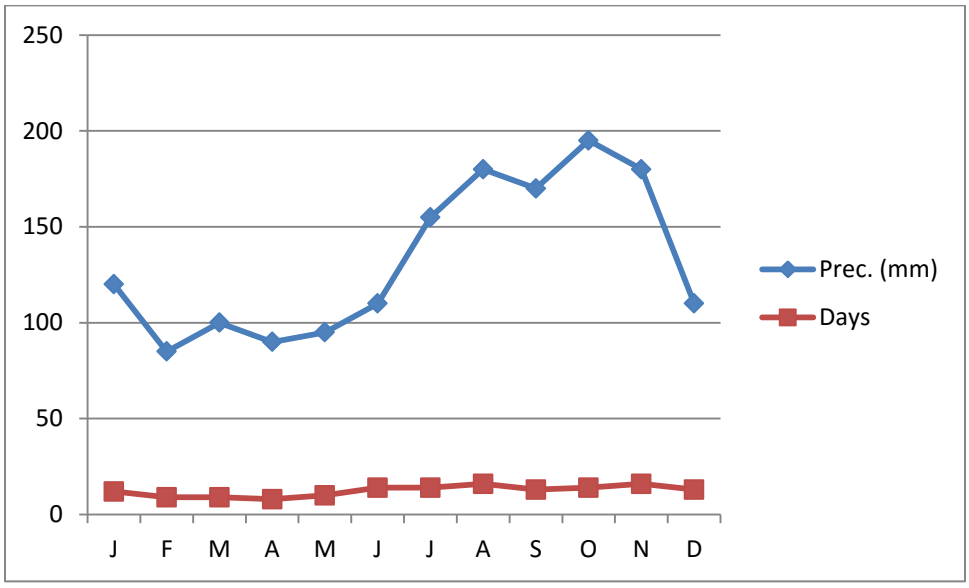
Table 6.4 – Water Usage

Source	Supply (litres/min)	Demand (litres/min)	Note
Killiekrankie Spring	250		No storage
Hope Spring	204		Overflows > supply capacity available
Belham wells	2006		Storage at Hope tank
Drill Sites		418	
Total	**2460**		

Montserrat water availability and supply is almost invariable linked to its rainfall. It experiences a tropical maritime climate with a mean annual temperature of 26°C. The mean low in January is 24°C and in September 28°C. Temperatures rarely fall more than 5°C outside these means. The only long term rainfall data for a

station close to the Belham Valley is for Hope. The mean monthly rainfall for the period 1999-2010 is shown in Figure.6.10 below.

Figure 6.10 – Average Monthly rainfall for Montserrat



Annual average and mean monthly rainfall values at Hope are almost certainly higher than experienced in the Belham Valley itself, which lies some 200m lower than the Hope station. Much of the rainfall occurs as short duration (minutes to hours) high intensity events.

Measurements are higher in the Belham catchment than the project area indicating instantaneous rainfall intensities commonly of the order of 1mm/minute and a maximum of 2.2mm/minute, which are extremely high. Over 50% of heavy rain days are associated with large-scale weather systems, and although there are significant variations in rainfall during the seasonal cycle, nearly all heavy

rainfall days occur during the May-December wet season. Reserves are therefore expected to be at a maximum during the first quarter of 2016.

6.4.6 Transport/Road use conflicts (SOC-06)

Sand mining is one of the main forms of economic activity and contributes to the foreign exchange earnings of Montserrat. This mining is undertaken within the Belham Valley area which is within the exclusion zone. Belham is located approximately 2km away from the drilling site. It has already been observed that mining and drilling activities share a common space and utilise common roads.

When there is an impending shipment of sand, the trucks which transport the material make several trips per hour from the quarry to the holding point where the material is stockpiled just outside the Zone V Jetty area. This activity takes them from the Belham Valley along the Cork Hill road to the Jetty. Consequently, there is the potential for workers on the drilling project to come in contact with the trucks along this portion of this road. In the past, because the road in usually deserted, drivers may traverse these roads at very high speeds.

The miners do understand that there could be potential safety issues for the workers on the drilling project and have indicated a need to caution drivers about safer practices on the road given the multiple uses of the road.

Car racing is another recreational activity which occurs on the Cork Hill road. This is however pre-planned and conducted on weekends when no conflict would occur with the sand miners. However, since the drilling process continued 24 hours a day, drilling staff and racers may be on the same road at the same time.

Residents in the surrounding communities north of the Belham Valley would expect some minor increases in road use within that period but much less activity during the drilling period. The roads located north of the Cork Hill –Weekes' Road intersection would not be affected by the moving of drilling equipment since this part of the road is not traverse on its way to the drilling site.

Access to the site from Cork Hill Main Road is to turn east onto Weekes' Road. This is still within a public access zone and encounters may occur. The most critical road event will be when the large and heavy equipment which would be utilised for the drilling and testing activities would be taken to the drill site from the Jetty at Plymouth to the gate at the entrance to the site. From the gate to the site an old access-way was reinstated reaching it along its northern perimeter, and extending some 40m beyond its eastern boundary. Only transportation related to drilling activities should be on this road.

7.0 Environmental Impacts

7.1 Description of Phases

1) The first phase referred to as “Construction” is more accurately defined as “Pre-Drilling” and may be used interchangeably.
2) The second phase referred to as “Operations” may be defined as “Drilling and Testing”.
3) The third phase referred to as dismantling is more accurately defined and ‘Post-Drilling” and may be used interchangeably.

7.1.1 Construction (Pre-Drilling)

Site preparation is the main activity in this phase along with preparation activities. This will include issues of land; from acquisition to displacement of flora and fauna to the employment of workmen to building of the required platform. It will also include potential dredging at the Plymouth Jetty.

The use of the roads to transport workers and transport drilling equipment or clearing machinery are also included. The installation of new pipelines and the rehabilitation of roads and drains are also pre-drilling activities.

7.1.2 Operations (Drilling & Testing)

Operations include the activities related to actual drilling and all the resulting outputs. It also include supporting activities from the supply of local services, safety, drill spoils solid and liquid management as well as drainage.

7.1.3 Dismantling (Post-Drilling)

Safety issues related to the use of the roads to transport drilling equipment back to the Plymouth Jetty as well as any onsite post drilling activities are included in this phase.

7.2 Impact on Physical Environment

7.2.1 Impacts of the Pre-Drilling phase on the Physical Environment

Preparation of the MON-03 Site will require removal of all surface vegetation and excavating 1.2 acres on the north side of St. George's Hill to provide a flat surface throughout. Vegetation and excavated material is to be transported to a dedicated area adjacent to MON-02. A 6-inch water supply line is to be installed connecting the existing pond at MON-02 with the pond to be constructed at MON-03. An access road of 270m has already been cut from Weekes' Road to the site.

In preparing the site for construction and drilling it is essential to provide adequate drainage for both the access road and the site. Presently the Site drains north into Belham Valley. As previously mentioned, managing rainfall run-off and liquid drill effluents is important. The key objective in preparing for Site clearing and all pre-drilling activity is to ensure the integrity of the access road and to grade and surface this road, and construct a drain into which all runoff will be directed. This drain has to be designed to manage both flows.

7.2.1.1 Induced Landslides (ENV-10)

Site clearing and preparation will expose a roughly 5m high back wall on the southern end of the Site. Slippage may occur due to direct impact of rainfall. It is not expected to happen due to drilling. The land extending upward behind the wall is vegetated throughout, to the top of the Hill. Induced landslides resulting from site clearing and preparation would have a localized minor impact on the landscape but in no way impede the intended use of the Site. The MON-02 Site has a back wall of similar dimension which has remained intact.

7.2.1.2 Transportation of Infrastructure (ENV-11)

Transportation of drill equipment and infrastructure to the Site from the Jetty will be preceded by Site preparation and reinforcement and upgrade of the access roads. Included in the road upgrade will be the need to properly design and construct a drain to take run-off and drill effluent from the Site along the access road, connect this drain with the existing drain on Weekes' Road via culvert and connect this to an existing culvert below Cork Main Road for discharge into the existing earthen water course. The objective is to prevent any damage to the new access road from trucks transporting excavated materials and also to prevent any run-off or effluent discharged during drilling from flowing into Belham Valley. At the time of the Scoping exercise, two points along the access road were noted to require reinforcement.

Clearing and repairs will also have to be done to the drain on Weekes' Road. Where Weekes' Road intersects Cork Hill Main Road the existing culvert which drains to the water course which received discharge from MON-02, will have to be inspected and repaired prior to transport of heavy drill equipment. From our observations the road surface of this culvert needs repair. Once the necessary road upgrades and drainage works are completed, preparation of the site can commence. Unloading and movement from the Jetty to the drill site will require temporary cessation of quarry trucking until all heavy equipment arrives at the Site.

Clearing and preparing the Site and transporting vegetation and excavated material to the laydown area adjacent to MON-02 will not require cessation of quarry activity but will require heightened diligence and awareness to avoid accidents. The impact of transporting heavy equipment is considered significant but minor.

As requested by the MALTHE prior to site clearing the following was recommended:

1) Pave and grade new access road with quarry spoil/aggregate (entire length)
2) Construct U-drain along length of road
3) Repair and reinforce 2 locations on road (approximately 58m and 90m from access gate) where major erosion is evident
4) Make culvert connection with Weekes' Road

5) Clear, repair and reinstate drainage channel alongside Weekes' Road
6) Repair existing culvert below Cork Hill Main Road allowing discharge from Weekes' Road into water course
7) Notify quarry operator and truckers of proposed vehicle activity carrying vegetation and excavated materials to laydown area alongside MON-02
8) Erect new signs signalling vehicle activity

7.2.2 Impacts of the Drilling phase on the Physical Environment

Drilling can commence once all preparations, equipment, infrastructure and personnel are in-place. Information gained from the experience of drilling MON-01 and MON-02 indicates that the 960 m^3 concrete ponds were not sufficient to contain the volume of effluent generated when the wells were being 'produced'. The ponds served as temporary storage and cooling ponds during well testing.

In the operation phase of producing electrical power from the heat energy of pumped fluids, these fluids will be reinjected into one of the other wells – as is standard practice. However, for the purposes of testing the heat capacity and potential of MON-03, the drill effluent it is assumed, will be discharged as was the case for MON-01 and MON-02. At the meeting with the Geothermal Steering Committee, Atom was asked to give an opinion on the suggestion to reinject produced effluent from MON-03 into either MON-01 or MON-02. The implications of this are not fully understood and would require the consideration of a geothermal drill specialist. As such we are assuming in this impact assessment

that drill fluids will be handled as they were in the drilling and testing of wells MON-01 and MON-02.

7.2.2.1 Accidental Discharge of Chemicals/Fuels at site (ENV-01)

Prior to drilling a comprehensive list of all hazardous materials to be used, stored, transported, or disposed of during all phases of activity should be prepared as well as a hazardous materials management plan addressing storage, use, transportation, and disposal (interim and final) for each item in the comprehensive list. The plan will identify specifics regarding emergency response to spills and how hazardous materials will be contained in the event that Site evacuation becomes necessary. It is assumed that the accidental discharge of chemicals would be quickly discovered and cleaned up. This occurrence is classified as significant and major because the Site is within the drainage catchment of the stand-by potable water wells in Belham Valley. The Drill Contractor needs to address the above in the Drill Operations Health and Safety Manual since we do not have this information.

7.2.2.2 Well Failure /Upset Conditions (ENV-02)

The impact of and response to well failure, blowout, fuel explosion or some other catastrophic upset condition is to be addressed by the Drill Contractor. Such an occurrence is considered both significant and major – as damage is likely to personnel, equipment and the surrounding environment. The most critical upset

condition would be an increase in volcanic activity at the same time as an accidental spill or well blow out. The combination of these two, whereas unlikely, should be planned for. In other words, there needs to be a shutdown of rig and containment of chemicals and fuels component, in the Evacuation Plan.

7.2.2.3 Discharge of Solid Wastes from Drill Spoils (ENV-03)

The Drill Crew may generate a variety of solid wastes (general garbage - plastic, paper, cardboard, empty containers, metal scraps, food, etc.). These non-hazardous wastes will be disposed of and stored in containers, to be transported periodically off-site to the landfill for permanent disposal. Containers of hazardous materials like lubricants, oils, chemical additives should be completely empty before disposal. All partially full containers should be retained by Drill Crew and taken off island.

Solids produced by drilling include cuttings, solids separated from drill muds and suspended solids contained in wet sludge from geothermal fluids. These will all be directed to the concrete containment pond to be constructed at MON-03. Drill fluids are hot. When the solids settle and separate, the liquid on top when cool can be mixed with drill water and reintroduced into the well. The 960m^3 pond is designed to accommodate the expected volume of solids removed. As noted previously, the pond will not however, be large enough to contain all the fluids produced when the well is being tested. This testing may take place intermittently over four to five weeks according to the experience gained in testing MON-01

and MON-02. Drill effluent will be discharged into the pond and overflow into two 10-inch PVC lines and directed into the roadside drain.

Because testing takes place for only a very limited time and since the discharge is being drained to an area where groundwater is not being used, handling of drill solids in this manner is satisfactory. The chemistry of the effluent indicates elevated levels of Calcium, Silica, Boron, Strontium and Arsenic. The liquid discharge is expected to disappear underground before reaching the sea because of the high permeability, fractured and unconsolidated nature of the soils in the general area. The handling of the liquid component will be discussed in the next section.

The Works Department has indicated their intention to excavate all ponds, including MON-03 and transport and bury the material at a location near Dagenham in the Zone V (See Map in Appendix). The purpose is two-fold, to be able to reuse the constructed ponds and to find a safe disposal location for the drill solids.

7.2.2.4 Discharge of Liquid Wastes from Drill Spoils (ENV-04)

During testing liquids will be directed to a drain on the access road and allowed to flow via the drain on Weekes' Road into an adjacent water course. While this is not normally a preferred option it would only be for a relatively short time and would have a limited impact due to the presence of ash and lahars which have covered the general area from previous volcanic eruptions. Liquids discharged

into the water course are expected to disappear below ground before reaching the coast at Hot Water Pond. Because the general area has already been impacted by volcanic eruptions the impacts of temporary liquid wastes are classified as “significant but moderate”.

7.2.2.5 Ground Water (ENV-05)

Relatively shallow groundwater is to be encountered during drilling. It is not clear whether the confined aquifer below Belham Valley, the backup potable water source, is part of the same hydrogeological system that exists below MON-03 that will be encountered during drilling. Because of this uncertainty, this impact was considered significant but moderate. However, based on best practice, once the well casing is established and sealed it is unlikely that any further impacts will occur.

According to the Report on geothermal development in Turkey “if geothermal drilling is carried out according to best practices regarding use of drilling fluids and well casing, it is very unlikely that geothermal water can contaminate ground water aquifers”. The Report however, notes that “casing failures in either production or reinjection wells may create pathways for geothermal fluids to mix with groundwater at shallow levels”

(http://documents.worldbank.org/curated/en/2015/10/25144309/turkey-geothermal-development-project-environmental-social-management-framework).

The unlikeliness of groundwater contamination is supported by another Report on exploratory geothermal drilling in north-west Iran which notes that “the construction and drilling operation phase of geothermal development are not expected to have much adverse effect on water quality”. Drilling fluids, including drill mud and chemicals, are used to lubricate the drill bit, stabilize the hole, and remove drill cuttings. When the drill bit hits permeable rocks drilling fluids may be lost into the rock formations. Excessive loss of fluids could result in localized changes to water quality. These changes would be adverse. (http://www.geothermal-energy.org/pdf/IGAstandard/WGC/2005/0210.pdf)

7.2.2.6 Soil & land Contamination (ENV-06)

The discussion on potential for soil and land contamination refers to soils and land areas that the liquid drill effluent will come into contact with once discharged off-site. Much of this has already been discussed previously under the discharge of Liquid Effluents. During our site visit Atom walked the earthen drain which was constructed to receive discharge of effluent from the pond at MON-01. This was some two years after the event. What was striking was the variety of healthy vegetation that had taken root in the constructed drain. The true nature of the impact on soils at the proposed site can only be assessed by taking soil samples within the drain and comparing these with samples up-gradient of the discharge. Given the heavily impacted nature of the surrounding area by volcanic ash and lahars this this impact is considered significant but moderate.

7.2.2.7 Steam Discharge- Temp/SO^2 (ENV-07)

Discharged steam tends to dissipate quickly, rising right away because of its lower density and elevated temperature. This dispersion is influenced by atmospheric conditions. On cooler, humid days, with no wind, the steam is likely to dissipate more laterally and potentially come into contact with surrounding vegetation. Sulphur dioxide present in the steam will discolour and impair the growth of plants.

High concentrations of sulphur dioxide can produce acute injury in the form of foliar necrosis, even after relatively short duration exposure. However, such effects are far less important in the field than chronic injury, which results from long-term exposure to much lower concentrations of the gas and is essentially cumulative in nature, taking the form of reduced growth and yield and increased senescence, often with no clear visible symptoms or with some degree of chlorosis.
(http://www.euro.who.int/__data/assets/pdf_file/0016/123091/AQG2ndEd_10effso2.pdf)

Based on anecdotal evidence, steam discharged during the drilling period at previous drill sites damaged the vegetation immediately surrounding the drill site. Visual inspection of the vegetation immediately surrounding the previous drill sites showed no signs of damage or growth impairment, therefore suggesting that the impacts were short-term rather than long-term and indeed not fatal. The

relatively short length of the drilling period, the spatially limited impacted area and the short-term nature of any effects would suggest that impacts from steam discharge would be minor and reversible over time. Potential damage to vegetation would also be limited to down-wind of release. All vegetation is expected to fully recover once production testing is complete.

7.2.2.8 GHG Emissions from On-site Diesel Generators & Well Emissions (ENV-8)

The impact of GHG from well emissions and on-site diesel generators is considered very limited. Volcanic activity and on-going trucking associated with sand mining render the impact of this activity as 'minor'. According to the US Energy Information Administration, about 22.38 pounds of CO2 are produced by burning a gallon of diesel fuel.

(http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=11). More information would be required to make a direct comparison between GHG produced from burning diesel during drilling and the year round production of GHG from the five to ten diesel trucks and excavation and loading equipment, operating eight (8) hour days year round.

7.2.2.9 Erosion from Water Discharge (ENV-9)

Erosion from water discharge is assessed to be a minor impact. This assumes that the drainage of the site and access road is functional. In the event of an obstruction to the drainage system, it is possible for temporary erosion of the northern bank of the access road to occur. Limited damage can be created by a

one-off event such as this. It is anticipated that if erosion does occur remedial action will take place once the rain stops.

7.2.2.10 Induced Landslides (ENV-10)

The impact of drilling on land stability on and around the site is considered minor. The surrounding land is vegetated and sloping. The perimeter of the drill site could benefit from some reinforcement.

7.2.2.11 Transportation of Infrastructure (ENV-11)

During drill operations all heavy infrastructure will remain on site. Access to the site by operators will be by pick-up truck or similar vehicle. This is expected not to have any significant impact.

7.2.3 Impacts of the Post-Drilling Phase on the Physical Environment

7.2.3.1 Induced Landslides (ENV-10)

Any slippage or landslides caused by the removal of heavy equipment should be remediated right away. This is considered unlikely and minor.

7.2.3.2 Transportation of Infrastructure (ENV-11)

The same procedures for bringing infrastructure to site should be followed returning it to the Jetty and loading it onto the ship. Quarry operations should cease while this is happening.

7.3 Impact on Natural Environment

7.3.1 Impacts of the Pre-Drilling Phase on the Natural Environment

7.3.1.1 Terrestrial Fauna (ENV-12)

Proposed Drilling Site (MON-03)

Admittedly, not all of the animal species utilising the proposed drill site and its surroundings were observed during site visits. This is especially true for species that are nocturnal and those utilising habitats not easily accessible (e.g. canopy species). Despite species richness being moderate, no endemic species or species of high conservation priority were observed. However, a number of introduced/non-native species were observed. Many of the species observed are mobile and thus capable of relocating to suitable habitats within the surrounding area. There are no protected areas within the proposed site or its surrounding and no breeding or nursery areas were observed. The impacts to the fauna of the proposed site and its surroundings should therefore be minor. Potential minor impacts are:

- Localised decrease in species abundance
- Alteration of travel routes/paths utilised by animals

Plymouth Jetty

The impact of the on-going volcanic activities negates this area as a pristine habitat. Many factors at this site, namely the high turbidity levels and low species richness, would suggest that dredging of the area would have low impacts on the

biodiversity present in the near-shore marine environment. The fact that within the near-shore environment no endemic species or species of high conservation priority were observed and no breeding areas were observed would suggest that impacts would be insignificant. Possible impacts could be limited to farther offshore and include increased sedimentation resulting in smothering of any benthic organisms. The use of silt booms during any dredging is therefore highly recommended.

Hot Water Pond

There are no pre-drilling activities which will affect the Hot Water Pond area.

7.3.1.2 Terrestrial Flora (ENV-13)

Proposed Drilling Site (MON-03)

The proposed site and its surroundings, represent a disturbed and not a pristine habitat. The original forest cover was previously cleared for cultivation and the area fragmented for habitation purposes (evident by roads, dwellings and ruins). The secondary/regenerated forest shows moderate species richness, however, no endemic species were observed while a number of introduced species were. In addition, the threat status of the observed species is low as none fit into the high conservation priority categories. The above-mentioned, in conjunction with the absence of any protected areas and observable breeding or nursery areas would suggest that the impacts to flora within the proposed site and its surrounding would be minor. Such potential minor impacts are:

- Localised decrease in species abundance
- Potential landslides during periods of heavy rains, which can contribute to alteration of habitats down-slope

Plymouth Jetty

The impact of the flora at the jetty are as described in the previous section.

Hot Water Pond

There are no pre-drilling activities which will affect the Hot Water Pond area.

7.3.2 Impacts of the Drilling Phase on the Natural Environment

7.3.2.1 Terrestrial Fauna (ENV-12)

Proposed Drilling Site (MON-03)

The impacts due to pre-drilling site clearing remain relevant for the drilling phase. With the start of the 24 hour work schedule, there will be an increase in noise and vibration levels, along with a significant increase in light levels at night. These increases could lead to further displacement of fauna from the point source of disruption. Monitoring measures will be outlined in the Management Plan. The potential impacts during this phase are:

- Alteration of travel routes/paths utilised by animals
- Disruption of nocturnal activities due to light pollution at night

Plymouth Jetty

There are no drilling activities which will affect the Plymouth Jetty area.

Hot Water Pond

The Hot Water Pond, being adjacent to the coast, represents a somewhat harsh environment due to the increased salinity. The fauna species that exist here are extremely hardy and resilient and thus able to cope with the present conditions. Low species richness, no observed endemic or high priority conservation species suggest insignificant impacts from the proposed project.

The use of the beach as a nesting site by a Critically Endangered species (i.e. hawksbill sea turtle) is highly important for the continued survival of the species and highlights the need for monitoring of any alteration of the beach itself. Possible alteration of the beach from the proposed project is not expected.

The near-shore environment adjacent to Hot Water Pond is void of any significant fauna would suggest that impacts would be insignificant. No potential impacts are predicted.

7.3.2.2 Terrestrial Flora (ENV-13)

Proposed Drilling Site (MON-03)

Effects on flora during drilling are addressed in section 7.2.2.7 on steam discharge.

Plymouth Jetty

The impact of the flora at the jetty are as described in the previous section.

Hot Water Pond

This coastal location represents a somewhat harsh environment due to the increased salinity. The flora species that exist here are extremely hardy and resilient and thus able to cope with the present conditions. The lack of visual growth impairment to the plant species, in light of the previous drilling activities (i.e. effluent discharge being directed into the area), would suggest minimal long-term impacts. Low species richness, no observed endemic or high priority conservation species (both in the water course and adjacent beach and near-shore environments) would suggest insignificant impacts from the proposed project.

7.3.3 Impacts of the Post-Drilling Phase on the Natural Environment

7.3.3.1 Terrestrial Fauna (ENV-12)

Proposed Drilling Site (MON-03)

There are no post-drilling activities which will affect Fauna at the drilling site. Once drilling operations have ceases, displaced fauna should begin to re-establish themselves in the available habitats around the site. A potential impact during this phase is the alteration of travel routes/paths utilised by animals.

Plymouth Jetty

There are no post-drilling activities which will affect Fauna at the Plymouth Jetty area.

Hot Water Pond

There are no post-drilling activities which will affect the Hot Water Pond area.

7.3.3.2 Terrestrial Flora (ENV-13)

Proposed Drilling Site (MON-03)

Once testing is completed, the flora in the Mon-03 area which may have been affected by emitted steam is expected to begin to restore, thus reversing the negative impact of the drilling and testing phase.

Plymouth Jetty

There are no post-drilling activities which will affect Flora at the Plymouth Jetty area.

Hot Water Pond

Once testing is completed, any flora in the Hot Water Pound area which may have been affected by liquid spoils directed to that area is expected to begin to restore, thus reversing the negative impact of the drilling and testing phase on the Hot Water Pond area.

7.4 Impact on Landscape and Visual (Heritage)

There are no significant impacts to be assessed under this category but comments are provided under section 7.6.3 for insignificant impacts.

7.5 Impact on Human and Social Environment

7.5.1 Impacts of the Pre-Drilling Phase on the Social Environment

7.5.1.1 Occupational Health and Safety (SOC-01)

With regards to general health and safety of the contractors for pipeline installation, site clearing, road repairs, drainage repairs, dredging, transportation of excavation and drilling equipment and the maintenance of the integrity of equipment, we recommend shared responsibilities of all parties involved in the operation. Furthermore, best industrial practices should be followed at all times, consistent with the Management Plans which form part of this EIA.

Loss control will be achieved through the following.

1) Safety procedures, occupational health, environmental conservation, fire protection and security programmes to prevent undesirable occurrences
2) Communication and training to provide workers with the necessary knowledge and skill to execute their tasks safely
3) Application and enforcement of safety standards for work methods and workplace conditions

4) Emergency response plans to minimise adverse effects when accidents occur; analysis of accidents and close-call incidents to prevent their recurrence.

Managers and supervisors are accountable for the job safety and occupational health of every person under their authority. All levels of management must be aware of any dangers associated with the work they supervise, and be able to direct and control such work to maintain a safe, healthy and environmentally clean operation.

Employee also has a duty to protect the environment, work safely, promote safe working practices and conditions, and to prevent substandard conditions and practices at all times. Company's personnel, contractors to Operator and their employees, and any authorised visitors are required to comply with applicable safety and environmental regulations, and with applicable Operator safety and loss prevention requirements while in the Operator's service or on Operator's premises.

The successful future of Operator's operations depends upon thorough integration of these responsibilities into all Operator activities. Active participation by all employees to identify and eliminate unnecessary risk is essential to satisfy the intent of this policy. This will be addressed further in the EMP.

7.5.1.2 Employment Opportunities (SOC-02)

Depending on the dimensions of the vessel bringing the drilling equipment to Montserrat there may be the need to dredge the Plymouth Jetty area. The assessment of the jetty area indicates a maximum depth of 7 meters on the western side of the jetty where the sand barge docks. Based on the vessel requirements, it may be necessary to dredge. This will be done by a private contractor thus creating employment for a few persons.

For the Drilling Site preparation and the construction of concrete tanks phases, all local employment would be involved. Manual labourers and mason are expected to find work under the directions of the MALTHE. Given the 20° slope of the land, some site securing will be necessary.

General road works will be required for the Cork Hill road near the entrance to the Weekes' area and the emergency road between the Drill Site and the Zone V gate. Since the community identified employment opportunities as having moderate significance to them, it would be monitored in the SMP to determine the opportunity for community employment on the project.

7.5.1.3 Demand for Commercial Services (SOC-03)

The opportunities for work apart from direct employment in the project are expected to be local. This being the case there is no expected increase in the need for commercial services outside of the subcontractors. There will however

be the need for supplies and materials to do repairs on the road and at the Drill Site. The needs of the local workers are expected in the same manner as would be expected in the baseline.

7.5.1.4 Transport/Road Use Conflicts (SOC-06)

During the pre-drilling phase there will be three sections of road to be concerned about. They are:-

1) From the Zone V gate near the drilling site to the intersection on Cork Hill road
2) From the Cork Hill intersection to the Plymouth Jetty
3) From the Cork Hill intersection towards the Belham Valley area

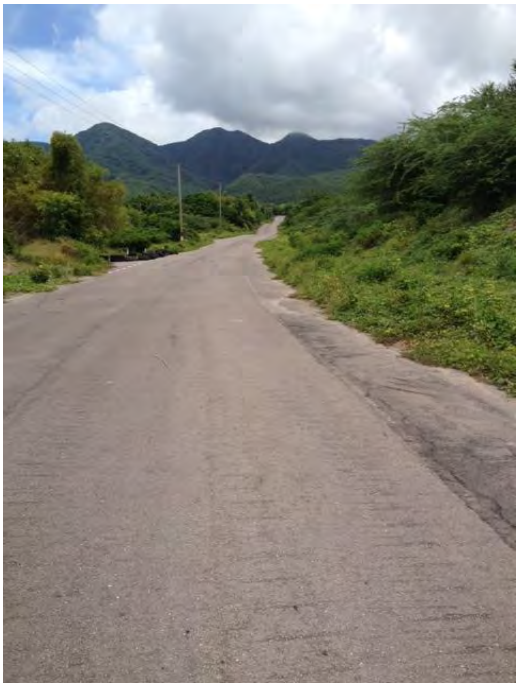
Only traffic related to drilling is expected to be on the emergency road since it is inside Zone V and the drilling site is the only used location in that area.

Between the Zone V gate near the drilling site to the intersection on Cork Hill road, only a moderate amount of conflict is expected to occur since there are no properties in use along that road. However, several activities will be occurring over a short period of time. The site clearing and construction teams along with the pipe installation and drainage rehabilitation teams will all use this road to complete their tasks. The latter two teams will actually be working on the sides of the road while the former two will simply pass by. After the platform is constructed, the drilling equipment will need to be transported to the drilling site along this road. Some tasks may overlap. Additionally, this area may now be

accessed by the public; creating a more likely conflict. This period will require coordination between contractors to keep the area safe while allowing all parties to conclude their work.

From the Cork Hill intersection to the Plymouth Jetty is a road used by the sand miners and the general public at any time of the day. From 2016, Plymouth tours are expected to also use this road. Prior to the arrival of the drilling rig, the dredging team will be using this road to get to the jobs. However, drilling equipment will be transported from the jetty to the site once. Outside of these occasions, the road conflict is expected to be at the baseline level since all other road users currently use the road. See road in Figure 7.1 below.

Figure 7.1: –Cork Hill Road



The road between Cork Hill intersection and the Belham Valley area will be used by those employed at the drilling site, the public, the sand miners, rally drivers and Plymouth tours.

Access through Belham and Flemmings will experience a negligible increase in traffic after the drilling has commenced. The road crossing the Belham Valley may however pose a problem for workers if there is significant rainfall to cause flooding. See pictures below.

Figure 7.2: –Belham Valley Road

7.5.2 Impacts of the Drilling Phase on the Social Environment

7.5.2.1 Occupational Health and Safety (SOC-01)

All the measures discussed in the pre-drilling phase are applicable to the drilling phase. However, there are a number of other considerations when working at a live drilling platform.

In general the potential for these impacts to occur is low if appropriate safety procedures are implemented and maintained. These procedures include proper protection equipment for workers, including safety glasses, gloves, hard hats, respirators, or other personal protective equipment (PPE) used to protect against injuries and illnesses. The provision of appropriate safety gear and officers proficient in first aid practices would reduce the incidence of injuries and accidental occurrences.

In the event of accidental occurrences, the only public health facility with the capability to respond to mass casualties is located in St John's which is approximately a half-hour drive away. The facility however has limited capacity and could not adequately respond to a casualty situation involving more than three individuals. Any incidents which are too large in scale would result in the injured being evacuated to the nearest island with adequate medical response facilities. This is likely to be Antigua. Measures to address occupational health and safety are addressed in the SMP.

7.5.2.2 Employment Opportunities (SOC-02)

While geothermal projects may be more capital intensive than labour intensive, the specialised nature of employees makes it difficult for locals to find employment with these projects. It is therefore estimated that local employment during drilling would be negligible due to the highly specialised nature of the project.

7.5.2.3 Demand for commercial services (SOC-03)

In addition to the number of supporting contracts required during the pre-drilling phase, the drilling phase will require an increasing number of services including short-term rental accommodation, dining and entertainment. There is also likely to be a small increased demand for some equipment and industrial services as well as other miscellaneous services. While not very significant in absolute dollars, any injection of funds into the economic is welcomed. It will be difficult to link increased economic activity with specific injection from the drilling operations but the Statistical Department is able to compare performance across similar periods. This is not available within the time period of the project but it can be reviewed when the data becomes available. Any sector which grows should reflect a larger percentage of its contribution to the economy. Current figures are agriculture 1.6%, industries 23.2% and services 75.1%.

7.5.2.4 Tourism (SOC-04)

Even if the tour group travels along the Weekes road to the Zone V gate, MON-03 would still not be visible. However, some on-site outcomes like steam expulsion may be seen from the nearby road while other on-site activities may be observed from the MVO. Some site observations may also be seen from a distance particularly during testing.

With the limited viewing opportunity, the impact may be low particularly since it will be for a limited time. How this may be maximised will be indicated in the SMP.

7.5.2.5 Residential Water Supply Levels (SOC-05)

Drilling activities by nature require large amounts of water. Water resources are quite well managed by the Montserrat Utilities Limited (MUL), a statutory body which produces 2,434lpm for consumption. 74% of this is for residential use. This is confirmed by the drilling of MON-01 and MON-02 where no issues arose. The actual daily consumption was just 418lpm, well below the daily production capacity in Montserrat (17%).

While there is no doubt that the additional requirements of this project would place additional burden upon MUL, they are confident that the additional demand will not affect the citizens negatively. The current sources of water and the additional reserve wells located near the Belham River area should be adequate given the short-term life of the project.

7.5.2.6 Transport/Road Use Conflicts (SOC-06)

During the Drilling phase there will be two sections of road to be concerned about. They are:-

1) From the Zone V gate near the drilling site to the intersection on Cork Hill road
2) From the Cork Hill intersection towards the Belham Valley area

Only traffic related to drilling is expected to be on the emergency road since it is inside Zone V and the drilling site is the only used location in that area.

Between the Zone V gate near the drilling site to the intersection on Cork Hill road, minimum conflict is expected to occur since there are no properties in use along that road and all pre-drilling work would have been completed including the site clearing, construction of platform, pipe installation and drainage rehabilitation. The main road activity will be for drilling staff and any personnel performing monitoring or maintenance to the drainage system.

From the Cork Hill intersection to the Plymouth Jetty is a road used by the sand miners and the general public at any time of the day. Starting in December 2015, Plymouth tours are expected to also use this road. No traffic resulting from drilling is expected on this road. Road use and conflict are expected to be at the baseline minimal level.

The road between Cork Hill intersection and the Belham Valley area will be used by those employed at the drilling site, the public, the sand miners, rally drivers

and Plymouth tours. A minimum amount of increased traffic is expected since Rallies are well planned for weekends to avoid trucks and each tour to Plymouth last just 45 minutes.

7.5.3 Impacts of the Post-Drilling Phase on the Social Environment

7.5.3.1 Occupational Health and Safety (SOC-01)

Once the well is capped after drilling and testing is complete there no risk to persons since no work would be ongoing at the site. It is within a managed area so no unauthorized persons are expected there.

If the well is placed in production there may be some additional risks since the well would again be opened and connected to a network to either allow the release of steam or the injection of used hot water. The exact configuration is unknown at this time but since the network is likely to be a closed one, no significant risks will exist.

7.5.3.2 Tourism (SOC-04)

Once drilling and testing are complete MON-03 will be as dormant as Mon-01 and MON-02. There will be no effects to observe.

7.5.3.3 Transport/Road use conflicts (SOC-06)

In the Post-Drilling phase the drilling machinery will be transported:-

1) From the Zone V gate near the drilling site to the intersection on Cork Hill road

2) From the Cork Hill intersection to the Plymouth Jetty

Only traffic related to drilling is expected to be on the emergency road since it is inside Zone V and the drilling site is the only used location in that area.

Between the Zone V gate near the drilling site to the intersection on Cork Hill road, any conflict is expected to be minimal. After the platform is dismantled, the drilling equipment will need to be transported to the Jetty along this road.

Road use from the Cork Hill intersection to the Plymouth Jetty will be the same as for Pre-Drilling. There will be little need to visit the site except to cap the well. Its future will be determined by the GEPSC hence its final configuration. The road use situation should return to its baseline at this time.

7.6 Insignificant Impacts

7.6.1 Physical Environment

7.6.1.1 Atmospheric Heat Pollution

Atmospheric heat generated from drilling is considered very limited, compared to localized active volcano impacts. The temperatures of volcanic gases that escape through fractures and fumaroles in the lava dome have remained high, with the hottest fumaroles maintaining 600^0C over the last four and a half years since the last major activity (MVO November 2014).

7.6.1.2 Induced Seismicity from Drilling

Real-time contact between drill operations and the MVO during the drilling of MON-1 and MON-2 allowed real-time correlation between drill activity and any resulting seismic activity to be monitored. It was noted that reinjection of drill fluids into the well produced a minimal but measurable vibrational response on the surface, (in the order of 1.5 on the Richter scale according to the MVO).

7.6.1.3 Subsidence

It is improbable that substructure would alter due to drilling and extraction of spoil. The well casing penetrates and remains stable in the formations below. Extraction and reinjection of fluids is taking place too far below the surface to cause any subsidence around the well.

7.6.1.4 Land Take

The 1.2 acre land take is small considering the vegetated cover of St. George's Hill is some 770 acres (0.16%).

7.6.1.5 Surface Water

There is no standing surface water in the vicinity of the site other than perhaps seasonally in the Belham Valley area. The high permeability of the ground and unconsolidated fractured sub-surface provide quick downward mobility of rainwater run-off. This prevents any surface water from accumulating.

7.6.1.6 Air Quality

The air quality on and off site is not expected to be impaired due to drilling. Spoils are a liquid mixture which is deposited in the pond. Mostly steam and gases escape into the air but not in concentrations to affect the air quality in an open elevated environment.

7.6.1.7 Noise and Vibration

With residences over one Kilometer away noise and vibration is unlikely to be a problem. Rotational drilling should not create vibrations that would affect the mill remains; the closest one completely trapped by plant roots

7.6.1.8 Pipeline Installation

The pipeline will bring water from MON-2 to MON-3 through a 6-inch HDPE line laid close to the road. Small vegetative clearance may be required. Any impact is expected to be minimal.

7.6.2 Natural Environment

Very limited flora and fauna were observed in the near-shore **marine** environment (at the jetty and adjacent to Hot Water Pond). The jetty area is influenced by mud and ash flows from the volcano. The turbidity level is high, there are constant deposits of sand when loading the barges and the near-shore environment was predominantly bare sand (with no corals, sea grasses or macroalgae). Dredging should therefore not impact the near-shore environment.

No impacts are predicted at the near-shore environment adjacent to Hot Water Pond where the environment is very similar.

7.6.3 Landscape and Visual including Heritage

7.6.3.1 Visual

With a land take of 0.16% of St. Georges' Hill, there will be no significant alteration to the view from MVO or other sites.

7.6.3.2 Archaeological and Heritage

Small historic mills have been observed on both sides of the emergency road. The archaeological value cannot be confirmed but the drill site has been shifted to avoid any further damage to the one located adjacent to MON-03. Rotational drilling should not create vibrations that would affect these mill remains; the closes one completely trapped by plant roots.

7.6.4 Human and Social Environment

7.6.4.1 Public Health & Safety

With the 3rd drilling well within the Exclusion Zone V where access is managed by the DMCA, there would be little risk or chance for members of the public to venture into this area. The main threat continues to be the volcano. The MVO,

DMCA and the local police provide adequate daily analysis and updates on the activity associated with the volcano.

7.6.4.2 Land Acquisition & Use Conflicts

The process of acquiring the Land for the intended use is well in progress and should be completed before the preparation work starts.

7.6.4.3 Stress on Social Support Systems

This particularly pertains to the health care system in the event of an accidental on-site occurrence. If a major event did occur and involve more than three persons it would result in the injured being evacuated to Antigua where there are adequate medical response facilities.

7.6.4.4 Social Context (Disruptions on Community Culture, Worship etc.

Major community social and commercial activity lies outside of the exclusion and impact zone.

7.6.4.5 Damage to Road Infrastructure

Equipment is expected to enter the area prior to the project to construct a platform. The main road from the Plymouth Jetty into the location will also have to carry heavy equipment at the beginning of the project and at the decommissioning stage. Roads will be rehabilitated where necessary to take the expected loads before the project.

7.6.4.6 Economic Disruptions

Mining represents the only significant economic activity currently undertaken in the area. The proposed drilling site is 1,000m from the main roadway used to transport sand from the quarry to the storage area and the Jetty. Truck transporting sand should not be affected except for two small windows used to transport the drilling equipment to and from the site.

8.0 Proposes Management Plan

8.1 Management Plan Outline

The EMP and the SMP will be used to ensure measures of monitoring the implementation of mitigation measures and impacts of the project are undertaken. An essential purpose of the plans is to manage the project's environmental performance. The environmental performance measures the compliance with the legal and contractual obligations of the Drill Contractor and the efficiency of the plans to manage significant environmental aspects.

The information generated by environmental monitoring will be used by the Public Works Department and other key GoM stakeholders to make decisions and inform discussions with the Drill Contractor and to prepare the periodic reports. Monitoring and control contribute to identifying the progress of the social impacts and to incorporate continuous improvement into the environmental management process.

The overarching objectives will be to monitor, mitigate, minimise and manage the potential and expected environmental impact of the project activities. These will be presented as a separate document; an EMP and a SMP.

8.2 Oversight of Measures

The management plans will be managed by the (GoM) through MALTHE and will engage other ministries, Drilling Contractor, Sub Contractors, GEPSC and all other related agencies as deemed necessary. The responsibility matrix being developed by MALTHE will identify all parties and determine their responsibilities throughout all phases of the project.

The project is expected to be without any major adverse long-term effect on the environment in Montserrat. Strict implementation of the EMP and SMP should result in this expectation becoming a reality.

Only social gains are expected. And while some may be short-lived over the duration of the project, economic gains in Tourism and the foundation for potential new businesses in Montserrat are expected to be long-term and accrue to the benefit of all Montserratians. While many social factors may have remained constant over the recent past, the optimism and hope expressed in relation to this project is very encouraging

9.0 Non-Technical Summary

9.1 Physical Environment

The proposed drill site is located on the northern face of St. George's Hill, in the Weekes' Area. This location was chosen as a result of its geothermal potential, as well as for logistical and safety reasons. Its physical environment was assessed and analysed via a desk-based assessment, stakeholder meetings and field visits. It is relatively well vegetated forested area which is uninhabited and free of land contamination (from industries, chemicals and fuels). Groundwater is believed to occur below the proposed site at a depth of 200m. Several potential environmental impacts were identified, the most significant of these being accidental discharge of chemicals or fuels at the site and well failure or upset conditions.

The Plymouth jetty is linked to the proposed drill site via the Cork Hill Main Road, while natural drainage from the site flows to the Belham Valley. The Plymouth Jetty (and its surroundings), Hot Water Pond and the Belham Valley have been impacted by the on-going Soufrière Hills volcanic activities (i.e. pyroclastic & mud flows and ash falls). The coastline in the area of the jetty has been progressively extended and the depth of water column decreased (due to build-up of volcanic material). The near-shore environment is comprised of a narrow band of loose rocks and bare sand. Hot Water Pond has been filled in, and no significant water body persists. The adjacent near-shore environment resembles that at Plymouth jetty.

9.2 Natural Environment

Despite volcanic eruptions and hurricane Montserrat still boasts a relatively high level of biological diversity. Unfortunately, biodiversity data for the proposed site, Plymouth jetty, Hot Water Pond and the marine environment is very limited (owing in large part to them generally being uninhabited). The natural environment was therefore primarily assessed via field visits to the study areas and through stakeholder meetings.

The proposed drill site represents a tree-dominated area with regenerated (i.e. secondary) growth. A moderate level of biodiversity (plants and animals) was observed, however, numerous introduced species were among these. The biodiversity at Hot Water Pond was consistent with the harsh conditions present (i.e. increased salinity) while the marine environment displayed low levels of biodiversity. The major potential environmental impacts are to the land plants and animals during the clearing of the site.

9.3 Landscape and Visual including Heritage

The proposed drill site and its surroundings comprise a portion of what was known as the Weekes' Plantation. This area was previously under cultivation, and used for sugar production. Landscape and visual assessment was conducted via multiple visits to the study area and photos from different angles under conditions. The proposed site has an elevation of approximately 200m and

slopes at a grade of 20% down to the Belham Valley. The site is clearly visible from the MVO, but not the Cork Hill Main Road.

Within the immediate surroundings of the proposed drill site three concrete structures were observed. These included a hut, a small tunnel and the ruins of an old sugar mill. Based on the assessment, no significant potential impacts are predicted.

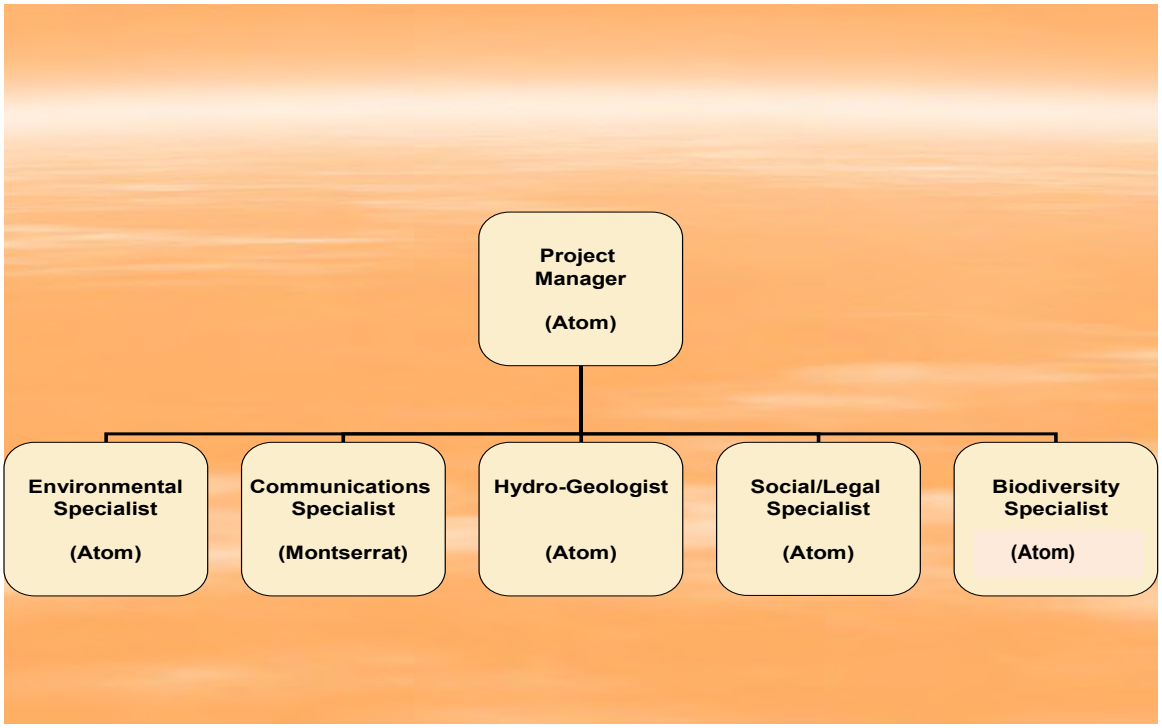
9.4 Human and Social Environment

The activities of the Soufrière Hills Volcano has resulted in the southern two-thirds of the island, which includes St. George's Hill, being uninhabited. The proposed site is situated in Zone V, where access is limited and regulated by authorities. The human and social environment was assessed through a desk-study, stakeholder meetings and interviews. Six potential social impacts were identified for consideration with three being negative and the others positive. The most significant negative social impact would be that of occupational health and safety. The potential positive impacts include increases in employment opportunities, demand for commercial services and tourism opportunities. They have been identified to occur throughout all three stages of the drilling operation.

10.0 Consulting Team

The team structure for this project is shown below. The resources utilized in the execution of such roles are shown in the table.

Figure 10.1 – Team Structure



Resources	Roles
Dr. Erwin Edwards (EE)	Project Management Energy/Climate Change Specialist Socio-economic Specialist Legal Advisor
Mr. Cathal Healy (CH)	Environmental Impact Specialist
Ms. Nerissa Golden(NG)	Communications Specialists
Mr. Leslie Barker (LB)	Hydro-Geologist
Ms. Cindy Downes (CD)	Project Coordinator/Administrator
Dr. Julian Walcott (JW)	Biodiversity Specialist

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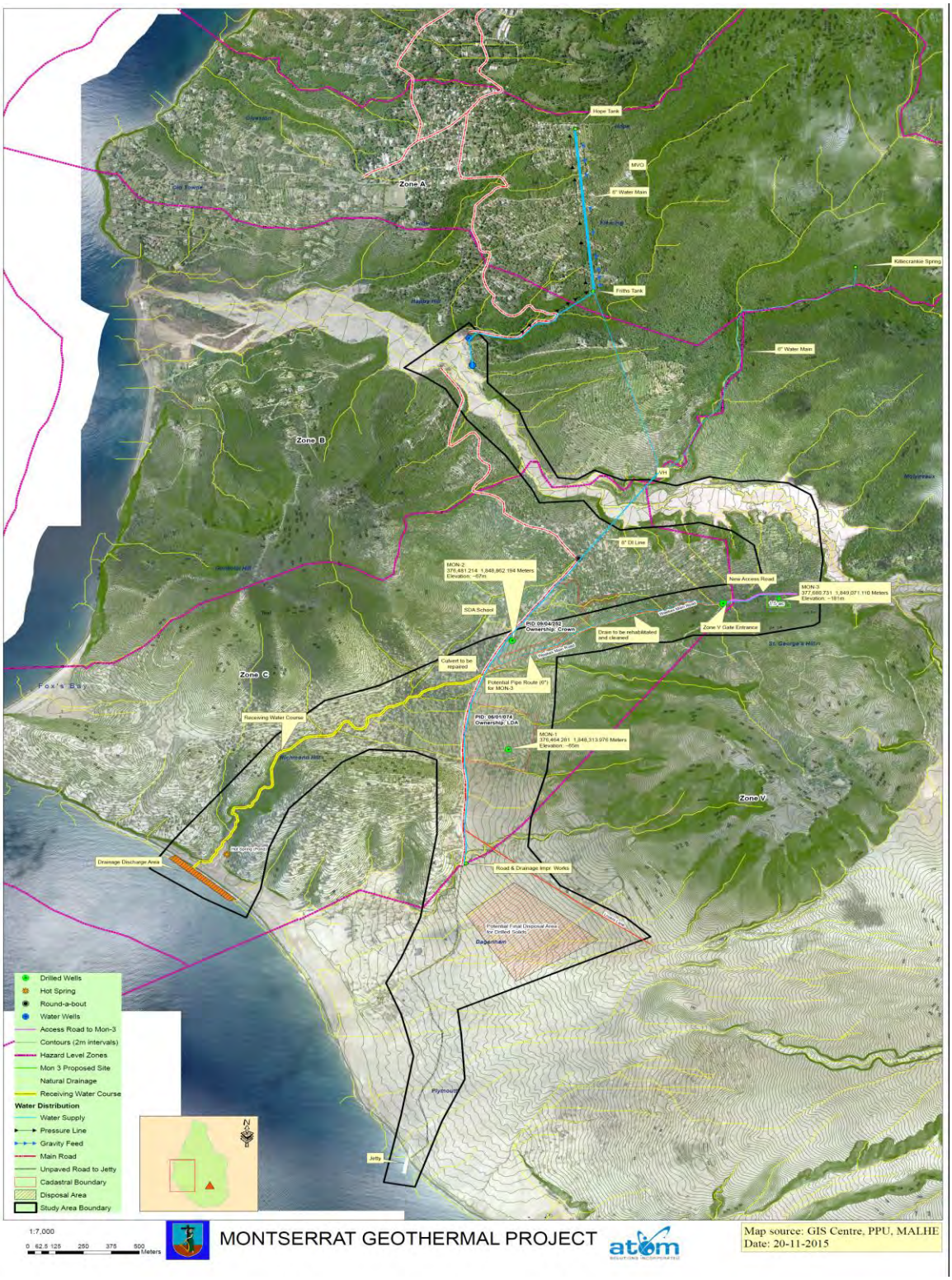
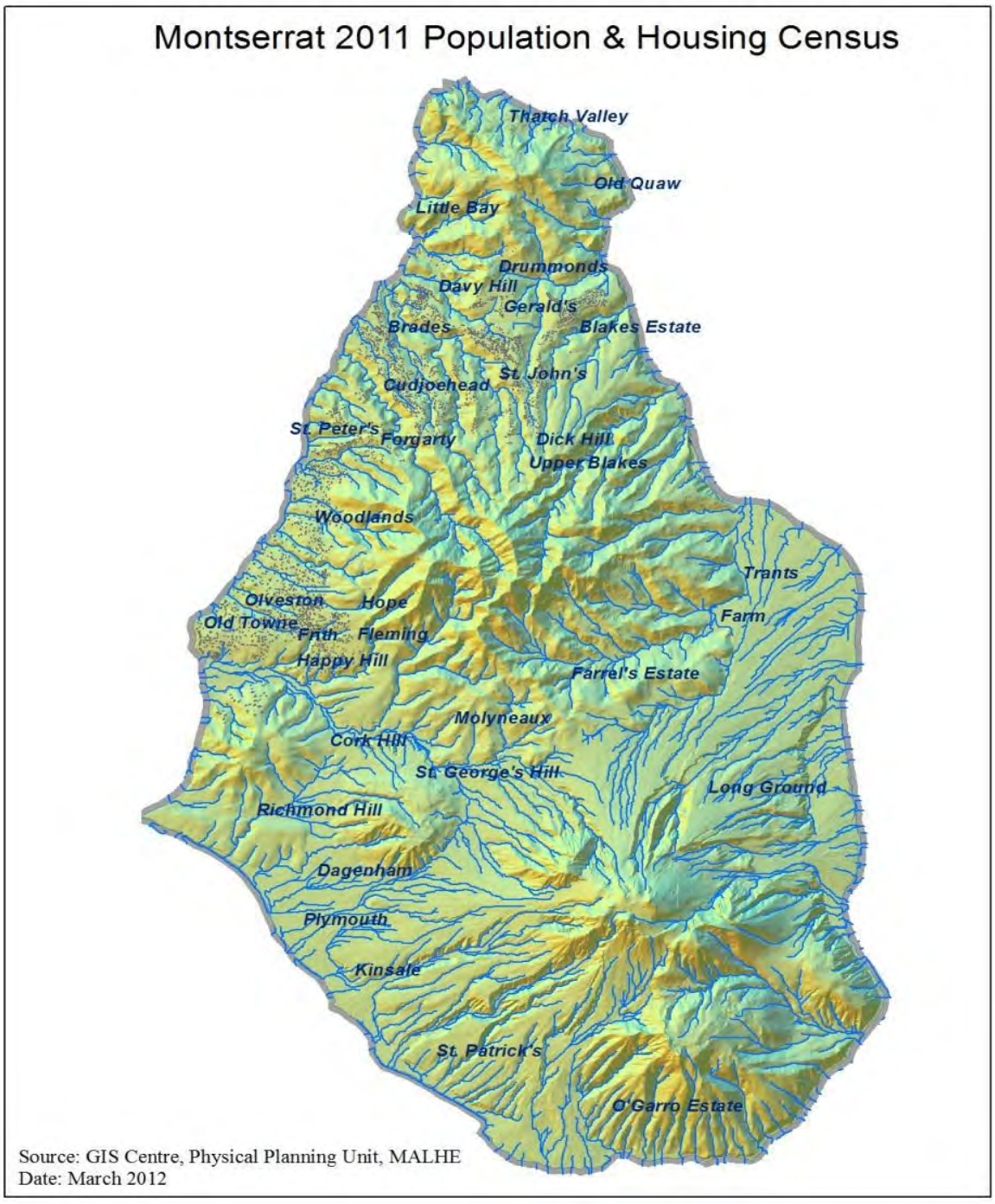
Appendix A – Aerial Map of Montserrat



Appendix B– Map of Montserrat



Appendix C – Natural Environment Data

(Endemic, Vulnerable, Endangered and Critically Endangered species of Montserrat)

Category	Species group	Common name	Scientific name
Endemic	Plants	n/a	*Xylosma serratum*
		n/a	*Epidendrum montserratense*
		Pribby	*Rondeletia buxifolia*
	Reptiles	Montserrat amelva	*Ameiva pluvianotata*
		Montserrat anole	*Anolis lividus*
		Montserrat galliwasp	*Diploglossus montiserratt*
		Southern leeward dwarf gecko*	*Sphaerodactylus fantasticus ligniserulus*
		Leeward racer*	*Alsophis antillensis manselli*
		Blind snake; warm snake*	*Typhlops monastus monastus*
	Birds	Montserrat oriole	*Icterus oberi*
	Bats	Yellow-shouldered volcano bat*	*Sturnira thomasi vulcanensis*
Vulnerable	Plants	Red Cedar; Stinking Cedar	*Cedrela odorata*
	Reptiles	Leatherback sea turtle	*Dermochelys coriacea*
		Loggerhead sea turtle	*Caretta caretta*
	Birds	Forest thrush	*Cichlherminia lherminieri*
Endangered	Plants	Lignum vitae	*Guaiacum officinale*
		West Indian mahogany	*Swietenia mahagoni*
	Reptiles	Green sea turtle	*Chelonia mydas*
	Bats	Yellow-shouldered bat	*Sturnira thomasi vulcanensis*
		White-lined bat	*Chiroderma improvisum*
Critically Endangered	Amphibians	Mountain chicken	*Leptodactylus fallax*
	Reptiles	Montserrat galliwasp	*Diploglossus montisserrati*
		Hawksbill sea turtle	*Eretmochelys imbricata*
	Birds	Montserrat oriole	*Icterus ober*

*Endemic subspecies