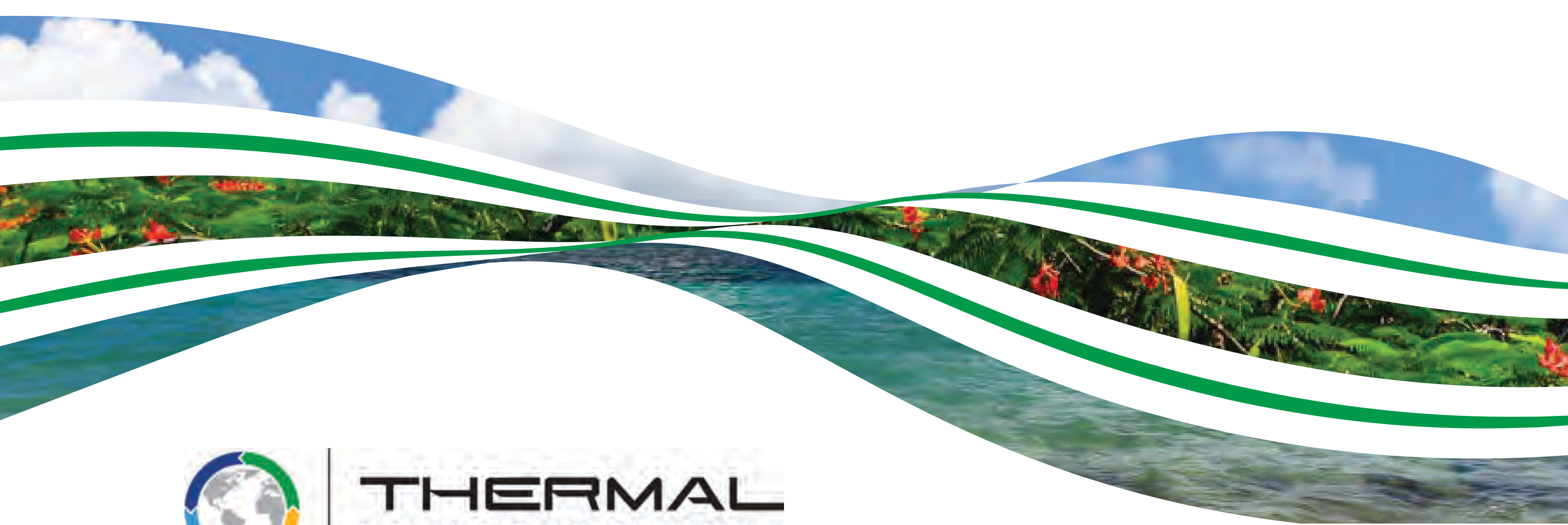
ENVIRONMENTAL IMPACT ASSESSMENT

PREPARED BY POINT IMPACT ANALYSIS, LLC & MIG

MAY 2, 2017

## Prepared For Nevis Renewable Energy International, INC.

# NEVIS BINARY GEOTHERMAL DEVELOPMENT PROJECT



THERMAL ENERGY PARTNERS

# Nevis Binary Geothermal Development Project

# Environmental Impact Assessment

**Prepared for**
**Nevis Renewable Energy International, Inc.**

**Prepared by**
**Point Impact Analysis, LLC and MIG**
**May 2, 2017**

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# 1. EXECUTIVE SUMMARY

Nevis Renewable Energy International, Inc. (NREI), a subsidiary of Thermal Energy Partners, LLC, plans to develop a nominal 10-megawatt (MW) (gross) binary geothermal power plant and related well field facilities at the Hamilton Estates on the Island of Nevis (Nevis). Nevis is part of the inner arc of the Leeward Islands chain of the West Indies in the Caribbean Sea. The proposed project would use local geothermal resources to provide a sustainable source of power that would replace the existing diesel-fired generation at the Prospect Power Plant. The Federation of St. Kitts and Nevis has adopted a goal of supplying nearly 100 percent of its electricity from renewable resources. The proposed NREI project would enable the island of Nevis to achieve this goal. Figure 1-1 provides an aerial image of Nevis.

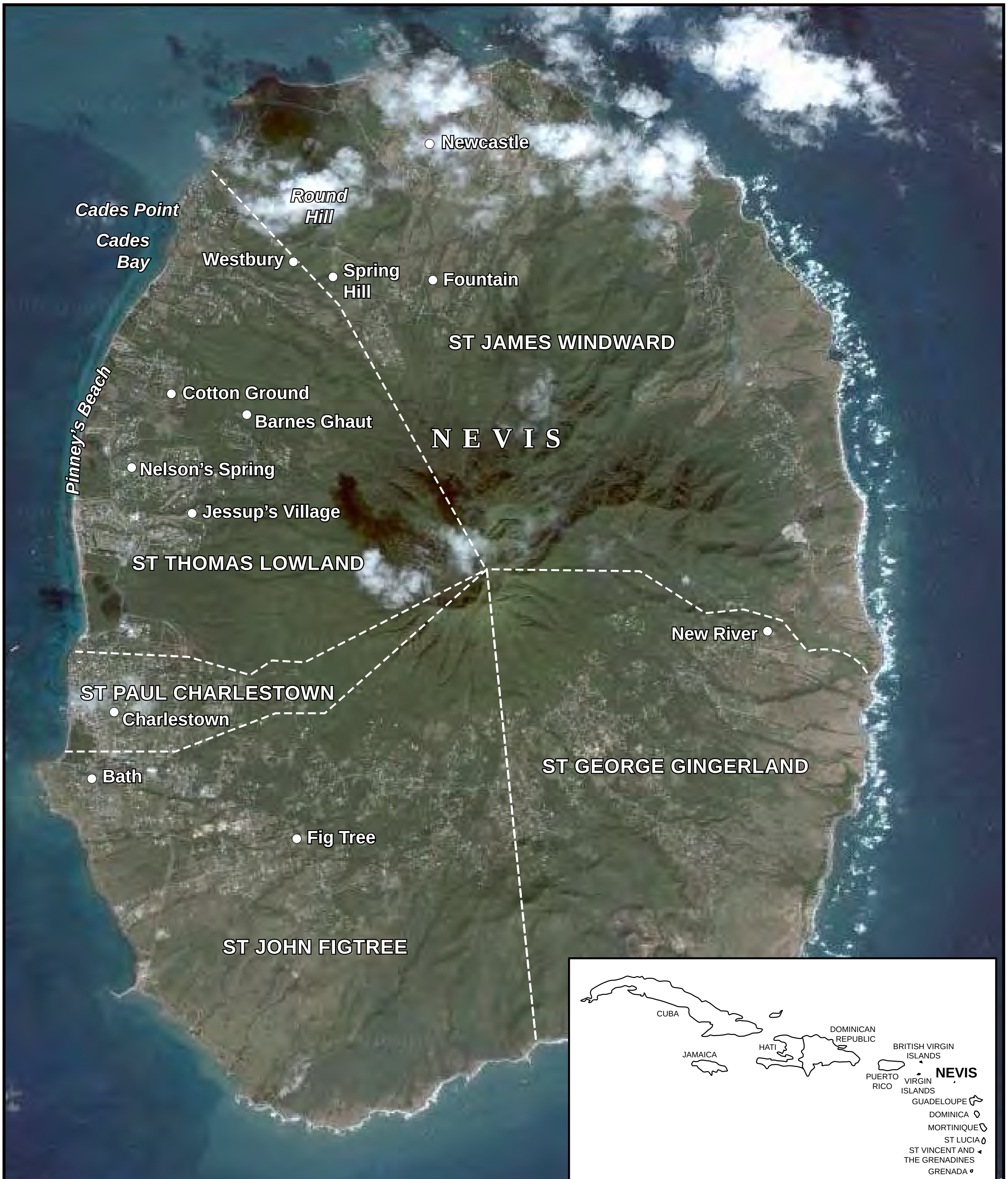
The geothermal resources on Nevis have been under study for over two decades. Previous geothermal investigations had identified areas on the western slopes of Nevis Peak that were promising sites for geothermal development. In 2009, West Indies Power (Nevis), Ltd. (WIPN) conducted exploratory drilling at three sites: N-1 at Spring Hill, N-2 near Jessups, and N-3 at the Hamilton Estate. The N-1 well at Spring Hill encountered high temperature geothermal resources, but suffered a drill string loss in the hole that prevented extensive flow testing. The N-2 well near Jessups was dry, but the loss of drilling fluid indicated highly permeable layers found at depth. The well at Hamilton Estates (N-3) was successfully drilled to 2,950 feet and flowed for approximately 72 hours.

WIPN proposed an 8-MW geothermal plant at Spring Hill in 2010 but failed to obtain financing and develop the geothermal resources under the terms of its agreement with the Nevis Island Administration (NIA). In 2014, the NIA cancelled its agreement with WIPN and awarded the right to the develop the geothermal resources on Nevis to NREI.

NREI has selected the N-3 site at the Hamilton Estate for its geothermal project. The 2009 exploratory drilling showed that the geothermal resources at this location have the appropriate pressure, temperature, and flow for commercial geothermal production. The Hamilton Estate site is close to the electric loads at Charleston, the capital of Nevis, and to the Nevis Electric Company (NEVLEC) substation at the Prospect Power Plant which serves as the central point for the five distribution lines that serve the island.

NREI plans to develop its initial geothermal project at Hamilton Estates using Turboden binary units with air-cooled condensers. The proposed plant would have virtually no emissions during normal operation and no water consumption for cooling. The NREI project includes noise controls, spill containment, and other measures that would reduce or avoid the identified potential impacts to the community and the surrounding environment.

The site for the NREI geothermal development would be on two parcels of rural crown land, approximately 1.5 miles east of Charlestown. The parcels are at the Hamilton Estate, a 580-acre former sugar plantation in St. Thomas Lowlands Parish. The power plant and two production wells would be on a 9.1-acre parcel approximately 700 feet north of the paved public road that runs from Charlestown through the Hamilton Estate to Church Ground. The injection well would be on a 1.2-acre parcel adjacent to the paved road, near the site of the former sugar works. Both parcels are Hamilton Heritage Trust land, crown lands managed by the NIA, which has leased them to NREI to develop the proposed project. Figure 1-2 shows the location of the proposed plant site, production wells, injection well, and pipelines.




Source: Google Earth

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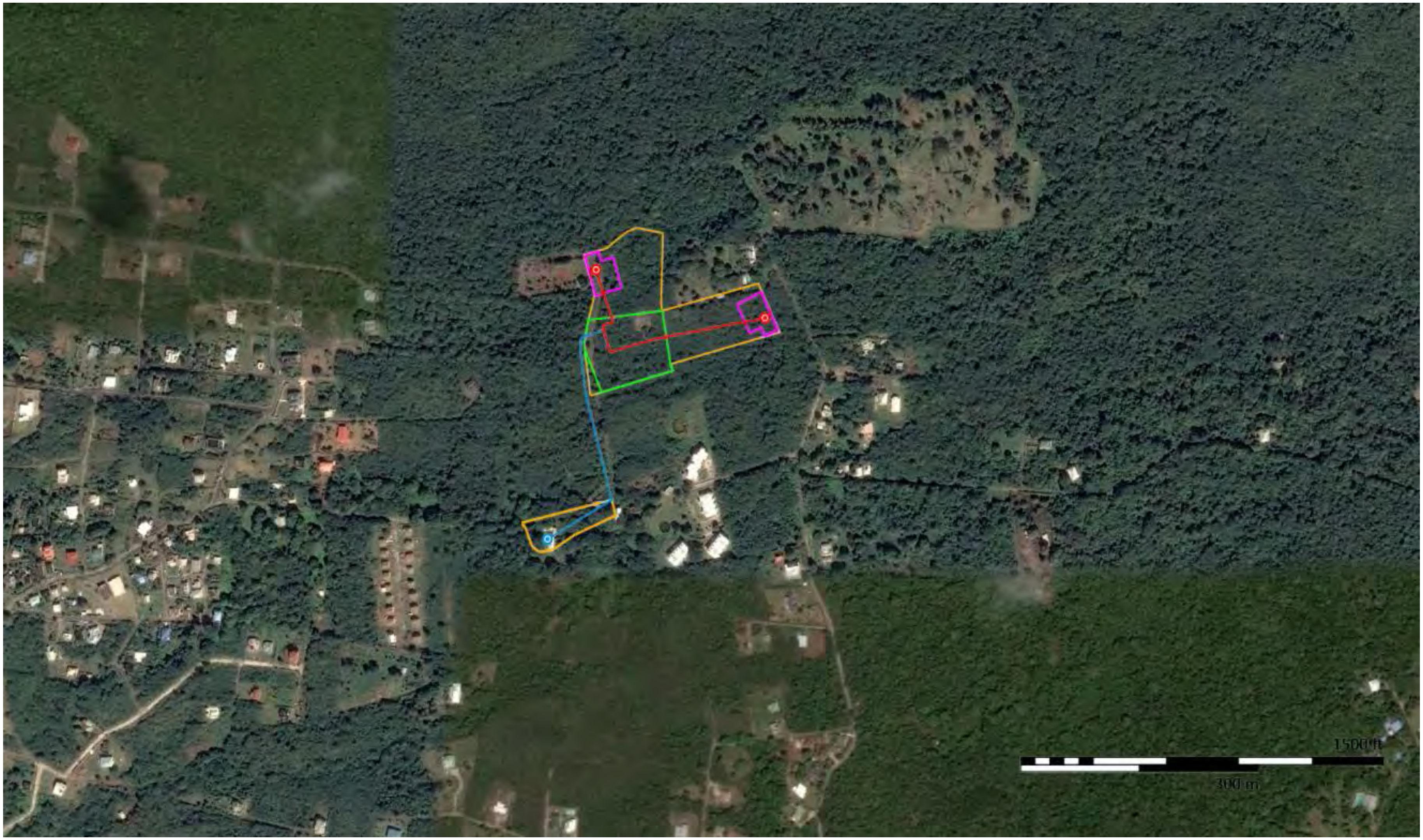
NREI Binary Geothermal Development Project
FIGURE 1.1-1
REGIONAL MAP

POINT IMPACT ANALYSIS, LLC




Source: Thermal Energy Partners LLC

**LEGEND**

- Parcel boundary
- Pad site
- Plant site
- Wells
- Production pipeline
- Injection pipeline

N

NREI Binary Geothermal Development Project
FIGURE 1.1-2
PROPOSED PLANT SITE
AND WELL FIELD

NREI is submitting this environmental impact assessment (EIA) to the NIA and making it available to all interested agencies and the public to provide a description of the positive and negative environmental effects that could occur during the construction and operation of the proposed 10-MW binary geothermal power plant, production wells, injection well, pipelines, and related facilities. Appendix A provides a description and evaluation of the environmental effects of drilling and testing of one well at the Hamilton Estate, planned to begin in May 2017. The EIA is designed to address both local regulations and guidelines of the Federation of St. Kitts and Nevis as well as international funding agencies such as the policies of the Overseas Private Investment Corporation (OPIC), a United State government agency that helps American businesses invest in emerging markets. The EIA follows the International Finance Corporation (IFC) Environmental, Health, and Safety Guidelines for Geothermal Power Generation, IFC Environmental, Health, and Safety General Guidelines, and the IFC Performance Standards for Social and Environmental Sustainability.

## 1.1 Project Summary

The proposed NREI binary geothermal project would provide baseload renewable electricity to the island of Nevis and replace diesel-fired units on the NEVLEC system. The project would involve typical construction activities that could impact local residences and the natural environment. Operation of the binary project would displace nearly all emissions of criteria pollutants and GHGs from the existing diesel units at the Prospect Power Plant. Along with these beneficial qualities of the plant, the plant would be seen and heard by the nearby residents at the Hamilton Estate. NREI has adopted procedures and incorporated measures into the design of the plant and well field to reduce the impacts of project to the community and to avoid impacting the surrounding environment.

## 1.2 Findings

The evaluation of the project found the following impacts to the environment:

**Aesthetics**

- Most nearby residents would have views of plant and well pad construction, drilling, and well testing during the 17- to 18 month construction period.
- The nearby residents east and south of the plant would have direct views of the low-lying geothermal facilities.
- Residents north, southwest, and west of the plant would have mostly obscured views of the plant and injection pipeline.
- Residents of Charlestown, the coastal communities in St. Thomas Lowlands Parish, and tourists would have little or no views of the drilling, construction, and ongoing geothermal operations.

**Biology**

- Project construction would involve clearing and grading of approximately 10.7 acres of mostly scrub regrowth vegetation, on land that has been previously disturbed by sugar cultivation and other agricultural activities, grazing, and geothermal exploration or road

development, does not contain unique or sensitive habitat, and does not contain endangered or threatened plant or wildlife species.

- Project construction would remove common scrub regrowth habitat, but NREI would avoid removing mature trees where possible, minimize the unnecessary clearing of land to preserve existing habitat where feasible, and provide landscaping that would continue to provide habitat for wildlife that use the site and vicinity.
- Project construction would temporary increase in noise levels that could disturb noise-sensitive wildlife, but geothermal operational activities and equipment noise would be controlled and the transmission-intertie line buried underground, so wildlife could continue to use the surrounding areas.

**Climate and Air Quality**

- Construction equipment would create dust and emit criteria pollutants.
- Drilling and testing would have short-term releases of geothermal gases, including hydrogen sulfide, that would be abated, when necessary, to avoid unacceptable odors.
- Binary plant operations would have virtually no emissions during normal operations.
- During power plant emergency shutdowns, geothermal releases from the rock muffler may cause an odor nuisance until the wells are shutdown or the power plant brought back online. This disturbance would be limited to a few hours at most.
- The binary plant would have virtually no greenhouse gas emissions and would displace almost all the diesel-fired electricity generation at Nevis.

**Cultural and Historic Resources**

- The project area does not contain cultural or historic resources, but ground-disturbing activities during construction could encounter buried resources, including human remains.
- Construction and operation of the geothermal plant and pipelines would not degrade the quality of the ruins of the former sugar works at the Hamilton Estate, which are on the opposite side of the road from the injection pipeline would be located.

**Hazards and Hazardous Materials**

- NREI would store hazardous materials in designated areas with secondary containment to prevent accidental spills or releases from contaminating stormwater runoff.
- Storage and use of cyclopentane as a working fluid would increase the risk of fire at the site.
- The geothermal wells have a low risk of well blowout.
- The plant site would be fenced to avoid public risk of electric shock.

**Land Use**

- The binary geothermal project would occur on 10.7 acres of undeveloped land formerly used as a sugar plantation.

- The proposed project would add power generating facilities near residences, as close as 570 feet from the plant site. These residences would experience aesthetic and noise impacts from the proposed project but these impacts would not affect their normal activities.
- The proposed project would be incompatible with future residential development of the parcels immediately adjacent to the proposed power generating facilities.
- The project would not affect planned natural conservation areas.

**Noise**

- Well drilling would occur 24-hours a day in three locations for an estimated 40 days per location and would result in predicted noise levels of up 71 dBA at one residential receptor (Receptor A). NREI NREI would work with local government representatives and residents to reduce and avoid 24-hour drilling noise levels, such as by installing an earthen berm or temporary sound barrier capable of reducing drilling noise by up to 21 dB at Receptor A..
- Well drilling would result in predicted noise levels of up 66 dBA (for up to 40 days) at all other receptors locations. The installation of an earthen berm or temporary sound barrier around drilling locations capable of reducing drilling noise by up to 21 dB would reduce these temporary noise levels to approximately 45 dBA during daytime and nighttime drilling operations.
- Initial well cleanout and venting activities would occur through a diffuser, rock muffler, or otherwise be controlled for noise such that these activities would produce worst-case noise levels in the range of 66 to 71 dBA,) but these worst-case levels would occur for a few hours at each well location, then taper off to noise levels of approximately 40 to 50 dBA.
- Other project construction activities could produce temporary and intermittent daytime noises levels between 50 and 62 dBA at residential receptors near project work areas (non-drilling). NREI would notify these receptors of planned construction activities, provide a construction noise coordinator, and implement mechanisms to resolve construction noise concerns.
- Binary plant operation would not produce noise levels that exceed 55 dBA during the daytime at residential receptors locations.
- Binary plant operation could produce nighttime noise levels of up to 48 dBA, above the IFC 45 dBA nighttime guideline, at two sensitive receptors locations (Receptors A and C), but in the event of a noise complaint, NREI would coordinate with the NIA as necessary to monitor noise levels and identify additional measures and activities that could be undertaken to reduce and avoid potential operational noise levels in excess of 45 dBA during the night as much as possible.

**Public Health and Safety**

- A well blowout could cause a risk to nearby residents.
- Accidental spills could release hazardous materials from the site.
- An earthquake, hurricane, or volcanic activity could disrupt plant operation, damage plant equipment, and cause hazardous conditions at the plant and in surrounding areas.

**Recreation**

- The binary project would be within 0.7 miles of trails used by hikers and mountain bikers but would not affect these natural areas.
- The operation of the plant would not be noticeable from water recreation areas along the coast.

**Socioeconomics and Environmental Justice**

- The proposed project would not displace existing development or require relocation of nearby residences.
- Construction of the binary geothermal plant would require approximately 75 local workers and create 17 permanent jobs.
- The construction and operation of the plant would have little impact on tourism, since the facilities would not have a noticeable aesthetic, air quality, or noise impact on the tourist areas.
- The proposed geothermal power plant would provide more affordable and reliable power, reducing the island's dependence on the volatile prices of diesel fuel.
- The use of geothermal resources would eliminate the need for NEVLEC to buy 4,250,000 gallons a year of imported diesel fuel to provide power to the island.
- The proposed project would not affect indigenous people.

**Soils, Geology, and Minerals**

- Project construction would clear and grade up to 10.7-acres of previously disturbed lands, potentially resulting in top soil loss and exposing bare soil to wind and water erosion.
- The proposed facility would be subject to earthquakes and ground shaking and would be designed to International Building Code (IBC) code requirements for seismic safety.
- The project is not expected to encounter unconsolidated soils that could lead to ground failure and the groundwater in the area is not expected to cause liquefaction.
- The potential for landslides and subsidence in the project area is considered low.
- The risk of settlement is low due to the lack of a high water table and subsurface saturated soils.
- The binary power plant would not result in substantial changes in reservoir pressures or subsurface stress conditions that could lead to structural damage from micro-fracturing of the receiving rock formations.
- Although Nevis Peak has not erupted in more than 100,000 years, it is a "live" volcano and could erupt in the future and damage the geothermal power plant facilities.
- Earthquakes in the region could generate tsunamis, but the propose project area is on the slopes of Nevis Peak at an elevation above 500 feet MSL and would not likely experience tsunami-related structural damage.

- The soils at the project area do not have the potential to shrink and swell.
- The proposed project would site potential septic tanks and leach fields in a flat area of suitable permeability.
- The proposed project would not interfere with or result in the loss of mining activities or resources.

**Transportation and Traffic**

- The propose project would cause a slight to moderate increase in traffic on the main road.
- During construction, workers would be bused to and from the geothermal sites to reduce traffic congestion impacts
- During operation, the plant would have a minimal impact on traffic, plant operators would work in shifts and would not all commute at the same time.
- Transmission line construction equipment would be placed on the side of the road and should not interfere with traffic, but where trenching alongside the road is not possible, ducts would encroach on the road and may partially impede the flow of traffic for a limited amount of time.

**Water Resources**

- Although the natural drainage patterns of the project area have been previously altered, project development would fill two shallow ghauts and further alter existing drainage patters, but would not impede drainage flows or otherwise increase the rate of off-site storm water flows.
- Project construction and drilling activities would not degrade surface or groundwater quality because NREI has designed the project to minimize and control spills, leaks, and other releases of potentially hazardous material via site design and containment systems.
- Drilling would require approximately 10,000 gallons of water per day from the NIA water supply system, approximately 1 percent of the total supply, for an estimated 40 days at each well.
- The proposed project would not require substantial water use during plant operation and have a low potential to affect surface or groundwater resources during production or injection of geothermal fluids because fluids would be contained within well casings and, during emergency shut downs, directed to an on-site lined brine containment pond.
- The project is not anticipated to effect surface thermal manifestations which are more than a mile from the drill sites.
- Project operation would not degrade surface or groundwater quality because NREI has designed the project to minimize and control spills, leaks, and other releases of potentially hazardous material via site design and containment systems.

## 1.3 Recommended Actions

The following design measures have been incorporated into the project to reduce the impacts of the proposed project:

**Aesthetics**

- NREI would use shielding during drilling, construction, and operation to direct lighting toward the ground to reduce the appearance of the facilities at night.
- NREI would paint facilities to blend in with the natural surroundings.

**Biology**

- NREI would avoid removal of trees where possible, minimize the unnecessary clearing of land to preserve existing habitat where feasible, and provide site landscaping that would provide continued habitat for wildlife.
- NREI would fence project parcels to prevent harm to wildlife from direct contact with project facilities
- NREI would screen or place nets over the brine collection pond to prevent wildlife contact with concentrated geothermal fluids.

**Climate and Air Quality**

- NREI would water the plant site as necessary to control dust.
- NREI would limit idling of construction equipment to 15 minutes.
- NREI would use sodium hydroxide and / or hydrogen peroxide injection as necessary to limit hydrogen sulfide emissions during well testing when necessary to avoid odors in nearby residential areas.
- In the event of an unanticipated power plant outage, NREI would shut in the wells within an hour to avoid substantial impacts to downwind receptors.

**Cultural and Historic Resources**

- NREI would stop work in the immediate area, notify the appropriate authorities, and follow recommended procedures if buried cultural or historic artifacts were discovered during site excavation.

**Hazards and Hazardous Materials**

- NREI would place secondary containment around hazardous material storage areas.
- NREI would prepare a Safety Plan for the site and instruct workers in the proper handling of materials.
- NREI would prepare a spill containment plan for the project.
- NREI would install a fire protection system at the site.
- NREI would store flammable hazardous materials in a contained area away from ignition sources.

- NREI would install blowout prevention equipment (BOPE).
- NREI would develop an emergency shut-in plan to stop a well blowout and to contain and clean up any fluids that may be released.
- NREI would fence and restrict access of the public to the facility.

**Land Use**

- NREI would landscape the undeveloped portions of its parcels to be attractive to vistors and adjacent uses.
- NREI include design measure to reduce noise impacts to existing nearby residents.
- NREI would encourage the NIA to limit development of the parcels immediately adjacent to the binary project to compatible uses and restrict potential new residential development within 1,000 feet of the power generating facilities.

**Noise**

NREI has incorporated design measures for general construction activities, well drilling, cleanout and venting activities, and plant operation as follows:

*General Construction Activities*

- NREI would provide receptors within 1,000 feet of the project parcels written notice prior to the start of construction activities, including the name of the NREI staff person responsible for handling construction noise complaints.

*Well Drilling and Initial Cleanout and Venting Activities*

- NREI would provide receptors within 1,000 feet of drilling sites at least one weeks' advance written notice of the start of well drilling, well venting, and well testing activities.
- NREI would install an earthen berm or temporary sound wall between drilling locations and residential receptor locations within 1,000 feet of the drill rig capable of providing up to 21 dB noise reduction.
- NREI would control noise during initial well venting activities, including initial cleanout, through the use of a diffuser, rock muffler, or other engineering solution, as feasible, and determined in coordination with the NIA.

*Power Plant Operations*

- NREI has designed the project to reduce and avoid potential operational noise levels in excess of 55 dBA during the day and 45 dBA during the night as much as possible by maximizing the distance between the condenser units and residential receptors, installing air-cooled condenser units with variable speed drives, reducing the amount of air-cooled condensers operating during the nighttime period (10 PM to 7 AM) to the minimum amount necessary to safely and efficiently provide necessary electrical load requirements, and planting trees and other dense vegetation to increase soft ground cover and potential attenuation of noise levels.

- In the event a noise complaint is received, NREI and the NIA would first conduct ambient noise monitoring to verify noise levels at the affected receptor and then coordinate with the NIA as necessary to identify additional measures and activities that could be undertaken to reduce and avoid potential operational noise levels in excess of 55 dBA during the day and 45 dBA during the night as much as possible.
- Other measures or conditions agreed to by NREI and the NIA would prepare and submit an Operational Noise Complaint Plan to the NIA for review and approval that describes the final site design for the plant and potential noise levels associated with plant operation, the mechanism by which NREI would respond to operational noise complaints, and options available to NREI and the NIA for resolving such complaints.
- NREI would use a silencer or rock muffler to reduce potential noise levels during all plant maintenance activities that require or result in well or pipeline venting or cleanout.

**Public Health and Safety**

- If a well blowout were to occur, NREI would shut in the well, take measures to contain fluids released, and if necessary, notify the public of the release and associated health risks.
- NREI would prepare a Hurricane Response Plan for the project describing shutdown criteria, notification procedures, and safety requirements in the event of a Class III or greater hurricane.
- NREI would design the geothermal facility to be consistent with national and international building codes and capable of withstanding winds of up to 150 mph.
- NREI would prepare an Emergency Response Plan that would address earthquakes, and volcanic activity.

**Recreation**

- See Aesthetics, Climate and Air Quality, and Noise sections.

**Socioeconomics and Environmental Justice**

- NREI would comply with local laws and international policies on worker rights and working conditions.
- NREI would pay royalties and taxes for use of NIA land for the proposed project.
- NREI would share a portion of the net proceeds of the project with the NIA.

**Soils, Geology, and Minerals**

- Prior to construction, NREI would determine the site coefficient and seismic design category for the proposed project area and apply all applicable structural, electrical, and seismic and wind loading design criteria from the IBC code for seismic safety.
- Prior to construction, NREI would conduct a soils analysis and engineering design to mitigate impacts from potentially expansive soils.
- Prior to construction, NREI would site potential septic tanks and leach fields in a flat area of suitable permeability.

- During construction, NREI would berm around the well pads or use standard sediment control methodologies around the power plant site to contain sediment onsite during construction activities. Site grading and vegetation during plant operations would control erosion.
- During construction, NREI would water the disturbed soil if needed to reduce erosion.
- During construction, NREI would save and cover stockpiles of top soil for back-fill or revegetation.
- Prior to plant operation, NREI would prepare a Micro- and Induced-Seismicity Response Plan for NIA review and approval to address the unlikely possibility that such micro- or induced-seismic events occur as a result of plant operation and are perceived by the surrounding community.
- The power plant would have fire suppression devices to reduce fire risks associated with earthquakes and ground shaking.

**Transportation and Traffic**

- NREI would provide vans or buses to bring construction workers to the site.
- NREI would utilize flaggers where necessary to ensure the safety of the workers and passing vehicles during roadside construction.

**Water Resources**

- NREI would avoid removal of trees where possible, minimize the unnecessary clearing of land to preserve existing drainage patterns where feasible and consistent with site access and safety needs, and direct surface flows to new culverts that replace existing drainage features (or re-route upstream flows to new drainage ditches on perimeter of the site).
- NREI would install silt fences between disturbed areas and drainage features.
- NREI would store all fuels, lubricants, and other hazardous materials used in drilling and other construction equipment in appropriate storage tanks and that would be located in bermed areas to provide secondary containment.
- The drilling muds and additives, where possible, would be nontoxic and biodegradable and NREI would grade the well pads to drain into a mud pits that would also collect and store cuttings and water producing during well drilling and testing.
- NREI would train staff in proper handling and prompt clean up procedures measures for hazardous material and chemicals to reduce the likelihood of a spill.
- NREI would case and cement the production and injection wells to prevent contamination of the shallow groundwater system.
- Spilled geothermal fluids would be contained on-site, either at the plant site or in the brine containment pond.
- NREI would install and test blow out prevention equipment (BOPE), which would shut down the well if an uncontrolled flow were to occur. NREI would have independent

contractors inspect the BOPE to ensure that the equipment operates and conforms to industry standards and has redundant features to control unexpected flows.

- NREI would store all fuels, lubricants, and other hazardous materials used in project in appropriate storage tanks and that would be located in bermed areas to provide secondary containment.
- NREI would provide secondary containment with capacity to hold the full volume of the working fluid used in the binary plant's equipment and provide sufficient freeboard for rainfall if uncovered. (these are closed tanks. No freeboard is necessary)
- The proposed project includes a 350,000-gallon brine containment pond that would be able to collect and contain two hours of full geothermal fluid flows during an accident or upset condition.
- NREI would clean up any spills into the brine containment pond to prevent injection of waste into the geothermal reservoir.
- Transporters would carry clean up equipment in the vehicles and follow IFC guidelines for handling of hazardous materials to prevent an accidental spill from occurring.

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# 2. POLICY, LEGAL, AND ADMINISTRATIVE FRAMEWORK

The following section establishes the legal and administrative framework for the NREI geothermal project. The discussion sets forth the purpose and need for the project and identifies the national and international policies, laws, and guidelines that apply to the project.

## 2.1 Purpose and Need

The purpose of the proposed 10-MW (gross) NREI geothermal power plant is to provide a reliable, cost-effective source of electric power to meet the needs of Nevis Island residents and industry while meeting the national goal of removing all reliance on fossil fuels for power generation. Nevis Electricity Company (NEVLEC) currently delivers approximately 55,112,474 kilowatt-hours (kWhr) per year to its customers in Nevis and expects this demand to increase by 3 percent annually (actual growth is less than 1.1 percent annually). Peak demand is 8.7 MW. The proposed project would have a nominal net generating capacity of approximately 9 MW and would be able to provide 60,000,000 kWhr per year to NEVLEC for distribution to its customers.

The need for the project is to displace the existing diesel-fired electrical generation with renewable energy. The current use of diesel fuel is subject to escalation in the price of oil, while the costs of geothermal energy are stabilized under a long-term, 25 year contract. The use of renewable energy would result in environmental benefits for Nevis, reducing emissions of criteria pollutants and GHGs, advancing the country's commitments under the Paris Climate Change Accords, and avoiding the need for continued import of approximately 3,200,00 gallons per year of diesel fuel and the associated risks of accidental spills.

NEVLEC currently generates electrical power for the Nevis at a plant southeast of Charlestown that contains seven diesel generators with an installed capacity of 13.9 MW, not counting the 2.5 MW Wartsila unit added December 2016. Diesel units emit criteria pollutants (oxides of nitrogen, sulfur dioxide, carbon monoxide, and particulates), and GHG (carbon dioxide); diesel particulate matter is carcinogenic. The combustion of fossil fuels, for power generation and for transportation, is the largest source of GHGs globally. Binary geothermal plants have virtually no emissions of GHG during normal operation.

Development of sustainable energy resources has become increasingly important for many nations as the impact of GHGs on global warming and the environmental impact of coal, wood, and petroleum-based energy have become known. Energy resources such as geothermal resources provide a sustainable alternative to fossil fuel power plants. Geothermal power plants have average availability factors of up to 98 percent (reaching 100 percent in some years) (DOE, 2006). Using indigenous renewable resources such as geothermal energy avoids dependence on imported fuels, provides local employment, and provides stability and predictability to the cost of electricity.

## 2.2 Project Guidelines

The following are guidelines that regulate the implementation of the proposed project, including Nevis policies, plans, and programs, OPIC policies, and IFC guidelines.

### 2.2.1 Nevis Policies, Plans, and Programs

The Federation of St. Kitts and Nevis adhere to various national and international conservation activities in addition to national environmental laws that are applicable to the proposed project.

## *International Conventions and Agreements*

The following are conventions and agreements that St. Kitts and Nevis have signed.

### Convention on Biological Diversity

The international legally binding treaty has three goals; conservation of biological diversity, sustainable use, and fair and equitable trading of benefits. St. Kitts and Nevis developed a National Biodiversity Strategy and Action Plan, including an inventory of the biodiversity, evaluation of the causes of biodiversity loss, a gap analysis, proposed projects to safeguard biodiversity, and a framework for implementation (Government of St. Kitts and Nevis, 2004).

### International Plant Protection Convention (IPPC)

The IPPC is an international treaty organization that intends to prevent and control the introduction and spread of pests, plants, and plant products. The convention also aims to protect both cultivated plants and natural flora. It considers both direct and indirect damage by pests, including weeds. The treaty consists of international standard setting, information exchange, and capacity development for implementation (IPPC, 2010).

### MARPOL Convention

The international convention covers the prevention of pollution from ships from oil and exhaust pollution and dumping. The objective of the convention is to preserve the marine environment through the complete elimination of pollution by oil and other harmful substances and the minimization of accidental discharge of such substances (IMO, 2002). St. Kitts and Nevis benefited from regional training workshops provided under the convention, which focused on the St. Christopher Air and Sea Port Authority (Government of Saint Lucia, 2001).

### Montreal Protocol on Substances That Deplete the Ozone Layer

The Montreal Protocol is an international treaty designed to protect the ozone layer by phasing out the production of substances that cause ozone depletion, including chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HFCs). St. Kitts and Nevis comply with the Ozone Depleting Substances consumption data reporting and approved an Ozone Depleting Substances Licensing System (UNEP, 2003). The two components of the protocol consist of refrigeration management and institutional strengthening. One training workshop for refrigeration technicians has taken place within St. Kitts and Nevis, and the government established a public awareness program and national ozone unit under the institutional strengthening component of the agreement (Government of St. Lucia, 2001).

### Stockholm Convention on Persistent Organic Pollutants

The objective of the convention is to protect human health and the environment from persistent organic pollutants, including DDT and polychlorinated biphenyls (PCBs) (UNEP, 2001). The convention requires the parties to develop and apply an implementation plan. The deadline for submittal of the plan from St. Kitts and Nevis was August 19, 2006 (Secretariat of the Stockholm Convention, 2009).

### United Nations Convention to Combat Desertification (UNCCD)

The convention aims to combat desertification and mitigate the effects of drought through national action programs that incorporate long-term strategies supported by international cooperation and

partnership arrangements (UNCCD, 1994). St. Kitts and Nevis submitted a National Action Program in 2007 that sets a framework for addressing the physical, biological, and socio-economic aspects of land degradation. The program includes strategies for poverty reduction, sustainable land management, institutional collaboration, and funding sources for combating land degradation (Government of St. Kitts and Nevis, 2007).

**United Nations Framework Convention on Climate Change (UNFCCC) and Paris Climate Change Agreement**

The UNFCC is an international environmental treaty addressing greenhouse gas emissions and climate change prior to the adoption of the Paris Climate Change Agreement. St. Kitts and Nevis worked on regional projects of the Caribbean Planning for Adaptation to Global Climate Change (CPACC) Project including the establishing an inventory of coastal resources and uses, formulating of initial adaptation policies, establishing of a sea level and climate monitoring network and developing databases and information systems. St. Kitts and Nevis were participated in pilot projects under the CPACC for the formation of economic and regulatory proposals (Government of St. Lucia, 2001; CARICOM, 2009).

The parties of the 21st Conference of the UNFCCC in Paris adopted a long-term goal of keeping the increase in global average temperature to below 2 °C above pre-industrial levels; aimed to limit the increase to 1.5 °C, agreed on the need for global emissions to peak as soon as possible, and pledged to undertake reductions of GHGs in accordance with the best available science. St. Kitts and Nevis signed the Paris Climate Change Agreement on April 22, 2016, committing to 22 and 35 percent reductions by the years 2025 and 2030 and adopting the goal to supply nearly 100 percent of its electricity from renewable sources.

## National Environmental Laws

St. Kitts and Nevis have adopted national environmental laws to protect forests and plants, wildlife, biodiversity, water resources, agriculture, and public health.

**Development Control and Planning Act**

St. Kitts and Nevis adopted the act to reduce vulnerability to disasters following Hurricane Georges in 1998. It created a Board to regulate and monitor the construction industry and ensure that all construction complies with the Building Code St. Kitts and Nevis upgraded the Building Code and increased inspections. St. Kitts and Nevis replaced government building windows with impact resistant windows for protection against future hurricanes (Federation of St. Kitts and Nevis, 2005; St. Kitts and Nevis - Government, 2007).

**Fisheries Act**

The act gives the Minister responsibilities to promote the management and development of fisheries to ensure optimum utilization for the benefit of St. Kitts and Nevis. The act provides for the licensing of fishing vessels, power to enter into agreements on fisheries access, and an institutional framework for the management, planning, development, and conservation of fisheries resources. The Minister may create regulations to manage any fishery, require conservation measures, and control aquaculture development (UNEP, 2007).

**Forestry Ordinance**

The ordinance designates all lands above the 1,000 ft contour as forestry reserves to prevent further deforestation from the sugarcane industry. The ordinance was established to protect soil and water resources (Collier, 2009).

**Forestry Regulations**

The NIA grants permits relating to forestry development, particularly for charcoal burning, fire control, and land clearing (IUCN, 1992).

**Fruit Trees (Destruction Prohibition) Act**

The act gives authority to the Director of Agriculture to enter and inspect land used to grow fruit trees. Destruction of fruit trees requires a license from the Director of Agriculture (Government of St. Kitts and Nevis, 2004).

**National Conservation and Environmental Protection Act of 1987**

The act enables better management and development to conserve natural and historic resources. The act aims to establish protected areas such as national parks, nature reserves, botanical gardens, marine reserves, historic sites, scenic sites, and areas of special concern (Government of St. Kitts and Nevis, 2004). One purpose of act is the preservation of biological diversity of wild fauna and flora species that may be endemic, threatened, or of special concern, designating approximately 90 species for further protection (Collier, 2009).

**Nevis Land Development Ordinance**

The ordinance created a Nevis Land Development Corporation to organize the development division of land for agriculture, industry, and tourism. It established a fund for development on Nevis (Government of St. Kitts and Nevis, 2004).

**Pesticides and Toxic Chemicals Control Act**

The act set up regulation and control of the importation, storage, manufacture, sale, transportation, disposal, and use of pesticides and toxic chemicals. The act established a Pesticides and Toxic Chemicals Control Board.

**Public Health Act**

The purpose of the act is to ensure the maintenance and safety of public health. The act created a Central Board of Health that is delegated the responsibility of preparing, execution, and coordination of actions beneficial to public health (UNEP, 2007). The ministry of health implements the act through two programs, the Institution Based Health Services and the Community Based Health Services. Hygiene and sanitation issues are addressed by the Environmental Health Department (WHO, 2008).

**Solid Waste Management Act**

This act regulates the management of waste and pollution prevention. It gives the Solid Waste Management Corporation responsibility to inventory and characterize solid waste generated and prepare a National Waste Management Strategy. The Corporation designates a list of activities for which an environmental impact assessment (EIA) is required. The Act provides rules governing

storage, handling, importation, dumping, enforcement, and monitoring of waste (St. Kitts and Nevis, 2009).

**Watercourses and Waterworks Act and Ordinance**

The act created a provision for the declaration of specific areas as watersheds and regulation of activities in these areas. The act also prohibits some activities, including cultivation and grazing, within a given distance from watercourses (Federation of St. Kitts and Nevis, 2004).

The ordinance established the Water Board to control, manage, supervise, and maintain watercourses and waterworks. The Water Board is also responsible for providing enough water supply to consumers (Laws of St. Christopher, 1956).

**Wild Bird Protection Ordinance**

The ordinance prohibits the hunting of 18 species of birds. The ordinance established a hunting season for nine bird species (Collier, 2009).

### 2.2.2 Overseas Private Investment Corporation (OPIC)

The NREI binary geothermal project may obtain financing through OPIC. OPIC is a self-sustaining U.S. government agency that helps American businesses invest in emerging markets. Established in 1971, OPIC provides businesses with the tools to manage the risks associated with foreign direct investment, fosters economic development in emerging market countries, and advances U.S. foreign policy and national security priorities. OPIC provides businesses with financing, political risk insurance, advocacy and by partnering with private equity investment fund managers.

OPIC has adopted policies and procedures that implement applicable environmental and social requirements in U.S. law. The OPIC Policy Statement adopts, as a standard for the environmental and social review process, the International Finance Corporation's Performance Standards on Social and Environmental Sustainability and Industry Sector Guidelines**.** OPIC categorizes all projects as Category A, B, C or D based on environmental and social factors, as follows:

- Category A projects are likely to have significant adverse environmental and/or social impacts that are irreversible, sensitive, diverse, or unprecedented and require a full EIA.
- Category B projects are likely to have limited adverse environmental and/or social impacts that are few in number, generally site-specific, largely reversible, and readily addressed through mitigation measures. Category B projects are considered medium risk. For these reasons, the scope of OPIC's environmental and social assessment for Category B projects is narrower than that required for Category A projects. The OPIC Environmental Guidance for Renewable Energy – Geothermal Projects states binary geothermal projects are likely to be screened as Category B projects.
- Category C projects are likely to have minimal adverse environmental or social impacts.
- Category D is reserved for initial approval of guaranties to Financial Intermediaries,

If a project requires mitigation, applicants must submit an Environmental and Social Action Plan to prevent, mitigate, and monitor the anticipated impacts.

### 2.2.3 International Finance Corporation (IFC)

The IFC issues environmental, health, and safety guidelines for geothermal power generation in addition to general health and safety guidelines for all projects. The IFC also adopted performance standards on social and environmental sustainability applied to all investment projects. NREI would follow the guidelines and standards as outlined by the IFC.

The IFC guidelines for geothermal power generation cover environmental, occupational, and community health and safety issues associated with geothermal development. The guidelines provide examples of Good International Industry Practice (GIIP) and performance levels and measures generally considered achievable in new facilities using existing technologies at reasonable costs. These guidelines include effluents, air emissions, solid waste, well blowouts and pipeline failures, water consumption and extraction, geothermal gases, confined spaces, heat, noise, hydrogen sulfide, infrastructure safety, and impacts on water resources. The guidelines also contain performance indicators and monitoring of emissions, effluents, occupational health and safety, and accident and fatality rates.

The IFC designed general guidelines for use with industry specific guidelines. These guidelines cover air emissions and ambient air quality, energy conservation, wastewater and ambient water quality, water conservation, hazardous material management, waste management, noise, contaminated land, general facility design and operation, communication and training, physical hazards, chemical hazards, biological hazards, radiological hazards, personal protective equipment, special hazard environments, monitoring, water quality and availability, structural safety of project infrastructure, life and fire safety, traffic safety, transportation of hazardous materials, disease prevention, and emergency preparedness and response. The IFC has eight performance standards that NREI would follow to minimize their impact on the environment and on affected communities (IFC, 2006). Table 2.2-1 provides detail as to how NREI would comply with the standards.

**Table 2.2-1**
**COMMITMENT TO THE IFC PERFORMANCE STANDARDS**

| IFC Performance Standard | | Comment |
|---|---|---|
| Performance Standard 1 | Social and Environmental Assessment and Management System | Section 4 includes the identification and assessment of potential impact on aesthetics; biology; climate and air quality; cultural and historic resources; hazards and hazardous materials; land use; noise, public health and safety; socioeconomics and environmental justice; soils, geology, and minerals; transportation and traffic; and water resources. Section 6 includes the identification and assessment of potential cumulative impacts. The assessment process is based on current information, including an accurate project description (Section 3) and appropriate social and environmental baseline data reported within each section mentioned above. Mitigation measure and monitoring measure are also included in this EIA report and are summarized in Section 1. Section 8 outlines the Environmental and Social Action Plan that would be further developed over the life of the project. |
| Performance Standard 2 | Labor and Working Conditions | The socioeconomic assessment process under Section 4.11 considered employment creation and income generation aspects. Section 4.9 identifies and assesses the potential impacts that the proposed project could pose to public health and safety. Measures to manage and monitor them are outlined in Section 1 and integrated in the Environmental and Social Action Plan in Section 8. |
| Performance Standard 3 | Pollution Prevention and Abatement | The proposed geothermal power plant would abate hydrogen sulfide emissions if necessary to minimizing significant impact to the environment and the community. |

**Table 2.2-1**
**COMMITMENT TO THE IFC PERFORMANCE STANDARDS**

| IFC Performance Standard | | Comment |
|---|---|---|
| Performance Standard 4 | Community Health, Safety, and Security | Section 4.9 identifies and assesses the potential impacts that the proposed project could have on public health and safety. Measures to manage and monitoring them are outlined in Section 1 and have been integrated in the Environmental and Social Action Plan presented in Section 8. |
| Performance Standard 5 | Land Acquisition and Involuntary Resettlement | Not applicable |
| Performance Standard 6 | Biodiversity Conservation and Sustainable Natural Resource Management | Section 4.3 Biology includes baseline conditions of the project area in regards to biological resources followed by the identification and assessment of potential impact that the proposed project could pose on existing habitats and ecosystems. Recommendations to protect habitat and ecosystems are includes in Section 4.3. |
| Performance Standard 7 | Indigenous Peoples | Not applicable |
| Performance Standard 8 | Cultural Heritage | Section 4.5 includes baseline conditions of the project area in regards to archaeology and cultural heritage followed by the identification and assessment of potential impact that the proposed project could pose of existing archaeological and cultural heritage resources. Measures to avoid or minimize these potential impacts have been outlines through Section 4.5 and summarized with their corresponding monitoring measures in Sections 1 and 8. |

# 3. PROJECT DESCRIPTION

The proposed NREI Nevis Geothermal Development Project at Hamilton Estates would consist of a 10-MW gross (9-MW net) Turboden binary power plant, that includes two 5-MW binary cycle generators, two production wells, one injection well, pipelines, and related facilities. The binary geothermal project would have virtually no emissions during normal operation and would include noise control, spill containment, and other measures that would contain, reduce, or avoid the potential impacts to nearby residences and the surrounding environment. The Nevis geothermal power plant would provide all baseload power for NEVLEC and would be able to meet the peak demands for the entire NEVLEC electrical load for the island of Nevis with only rare exceptions.

## 3.1 Resource Characteristics

The NREI project would generate power using the geothermal resources related to the Nevis Peak volcano and its associated magmatic activity. The proposed NREI project is based on an understanding of the geothermal activity on the island developed after more than a decade of exploratory geological, geochemical, and geophysical studies, as well as slim hole drilling and testing conducted in 2008 and recent reservoir analyses.

Nevis is a relatively young volcanic island. A magmatic source underlying the center of the island produced the numerous volcanic eruptions which created the island and Nevis Peak volcanic cone. This magmatic source also provides the heat which drives the hydrothermal system that constitutes the geothermal resource. The island's volcanic rocks have been fractured by tectonic activity and faulting related to a collapse of the southwestern side of the volcano. Surface manifestations of the hydrothermal system such as warm springs, warm-water wells, gas seeps, sulfuric alterations, and fumaroles occur within this fault-bounded collapse sector, suggesting that the hydrothermal system is focused within this collapse feature and indicate the probable presence of fractured rock and high temperature hydrothermal resources at depth. Surface manifestations include several warm groundwater wells and a fumarole west of the plant site. The Bath hot springs are located near Charlestown, approximately 1.6 miles southwest of the site.

Slim hole drilling at three sites along the western side of Nevis in 2008 indicated appropriate temperatures for geothermal development. NREI would develop the geothermal resources found near the Hamilton Estates Fault Zone, a major fault boundary of the western collapse structures, adjacent to the proposed power plant site. Testing of the slim hole at Hamilton Estate, N-3, found temperatures over 392 °F (200 °C) at a depth of 2,950 feet. Using the data from the other test wells, NREI expects the reservoir temperature to reach over 540 °F (280 °C) at 4,000 feet. NREI plans to drill and test an 8.5-inch well at the Hamilton Estates area in May 2017 and would use the results of production and injection testing to determine the resource temperatures and characteristics for the final design of the Nevis Geothermal Project.

The geothermal resource at Nevis, like all geothermal resources, contains noncondensable gases, including carbon dioxide and hydrogen sulfide. Carbon dioxide is a colorless, odorless gas naturally found in magmas and formed in the subduction zone. . Atmospheric concentrations of carbon dioxide trap heat reflected from the earth's surface, and carbon dioxide is identified as a greenhouse gas (GHG). Hydrogen sulfide is a colorless gas but has a distinctive odor of rotten eggs and, while harmless in small quantities, can be lethal in high doses. Table 3.1-1 provides the noncondensable gas concentrations from the N-1 and N-3 wells, based on the 2008 testing. Although the

concentrations of carbon dioxide and hydrogen sulfide are higher at N-3, these gases would not be released from the proposed binary plant during normal operation.

**Table 3.1-1**
**N-1 AND N-3 GEOTHERMAL GAS COMPARISON**

| Gas | Parts per Million by Weight (ppmw) in Steam | |
|---|---|---|
| | N-1[1] | N-3[2] |
| Carbon Dioxide | 3,046 | 13,111 |
| Hydrogen Sulfide | 134 | 222 |
| Ammonia | 3.34 | 3.70 |
| Argon | 0.29 | 0.84 |
| Nitrogen | 11.4 | 137 |
| Methane | 3.72 | 13.8 |
| Hydrogen | 0.99 | 0.39 |

Source: Thermochem, 2011
[1] Gas from steam sample collected at 16 psia (1.1 bara); gas/steam estimated at 46.1 psia (3.2 bara)
[2] Gas from steam sample collected at 213 psia (14.7 bara); gas/steam estimated at 46.1 psia (3.2 bara)

The volcano at Nevis and has not had a major eruption for 100,000 years and released much of its gases during these events. Table 3.1-2 compares the gas analysis for N-1 and N-3 to the geothermal power plants in Guadalupe, Hawaii, California, New Zealand, and Mexico. At the proposed pressure for the binary plant, the noncondensable gases would be less than 0.2 percent by weight of the produced fluids at the plant.

## 3.2 Project Location

The NREI binary geothermal power plant and production wells would be located on the 9.1-acre Hamilton Heritage Trust land that the NIA has leased to the company for the geothermal project. The injection well would be on the 1.2-acre Hamilton Stable parcel (see Figure 1-2, Proposed Plant Site and Wellfield). The two parcels are approximately 1.6 miles east of Charlestown, the capital of the island of Nevis, in an area formerly used for sugar cane production. The power plant and well field facilities would be on the relatively level site at an elevation of 530 feet. The injection well would be at a lower elevation, approximately 480 feet. The lease has sufficient space for the Turboden binary facilities, air-cooled condensers, two well pads, a lined brine containment sump, tanks for firewater and chemical storage, and a control building. The 9.1 acre-lease has sufficient space for a temporary laydown area and worker parking during construction.

**Table 3.2-1**
**COMPARATIVE GEOTHERMAL GAS CONCENTRATIONS**

| Gas | | Nevis | | Bouillante Field, Guadalupe (Gaudeloupe)[1] | Puna, Hawaii[2] | The Geysers-Southeast, California[3] | The Geysers-Northeast, California[4] | New Zealand-1[5] | New Zealand-2[6] | Cerro Prieto, Mexico[7] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N-1 | N-3 Average | | | | | | | |
| Carbon Dioxide | Mole Percent | 92.90 | 95.95 | 93.00 | 4.20 | 49.00 | 65.00 | 81.2 | 95.90 | 85.44 |
| Hydrogen Sulfide | | 5.26 | 2.10 | 2.80 | 70.36 | 12.30 | 4.94 | 15.6 | 1.85 | 5.11 |
| Ammonia | | 0.26 | 6.99 | - | 0.00 | 6.19 | 7.24 | 0.086 | 0.05 | 1.88 |
| Argon | | 0.01 | 0.01 | 0.04 | 0.60 | 0.06 | 0.01 | | 0.0893 | 0.01 |
| Nitrogen | | 0.05 | 1.57 | 3.50 | 2.23 | 1.66 | 1.04 | 0.6 | | 0.38 |
| Methane | | 0.31 | 0.28 | 0.40 | 0.00 | 5.14 | 6.06 | 0.26 | 1.18 | 3.35 |
| Hydrogen | | 0.66 | 6.29 | 0.30 | 0.06 | 22.30 | 15.90 | 2.17 | 0.01 | 3.50 |
| | | | | | | | | | | |
| Gas->Steam (G/S ppmw) | | 3,759 | 24,661 | 4,000 | 1,500-2,200 | 630 | 21,650 | 12,000 | 23,800 | 15,000 |
| Flash pressure (psia) | | 15-17 | 213 | 90 | 160 | 110-145 | 110-145 | - | 160 | - |

Source: Geologica, Thermochem
1 San Juan, 2010
2 Puna, 1989
3 USGS, 1999
4 Powell, 2010
5 Henley, 1986

## 3.3 Conversion Process

NREI would use a binary geothermal conversion process plant to generate the power from the geothermal reservoir at Hamilton Estates. In a binary process, the produced water from the geothermal resource from the production wells flows through a heat exchanger in a closed loop, heating a working fluid, which is also in a closed loop (see Figure 3.3-1, Schematic Flow Diagram). Once the primary geothermal fluid has passed through the heat exchanger, it is piped to an injection well where it is pumped back into the reservoir. The working fluid absorbs the heat from the heat exchanger, is vaporized and drives a turbine that spins the generator. After passing through the turbine, the working fluid is re-condensed by the cooling system, re-pressurized, and directed back to the heat exchanger. NREI plans to use cyclopentane as the working fluid for the N-3 generating unit. Cyclopentane is a hydrocarbon that is a liquid at ambient temperatures and volatilizes at approximately 122 ºF (50 ºC).

No geothermal gases vent to the atmosphere from the closed geothermal loop. The geothermal resources pass through a separator before entering the power plant, which reduces the variable pressure from the wells to the design point for the plant inlet, flashing some steam and separating the noncondensable gases from the resources. The separated gases are then compressed, piped to the injection line, and entrained in the geothermal fluid that is injected into the reservoir through the injection well. No water is needed for the air-cooled condensers, which transfer the heat in the working fluid directly to the ambient air.

## 3.4 Well Field

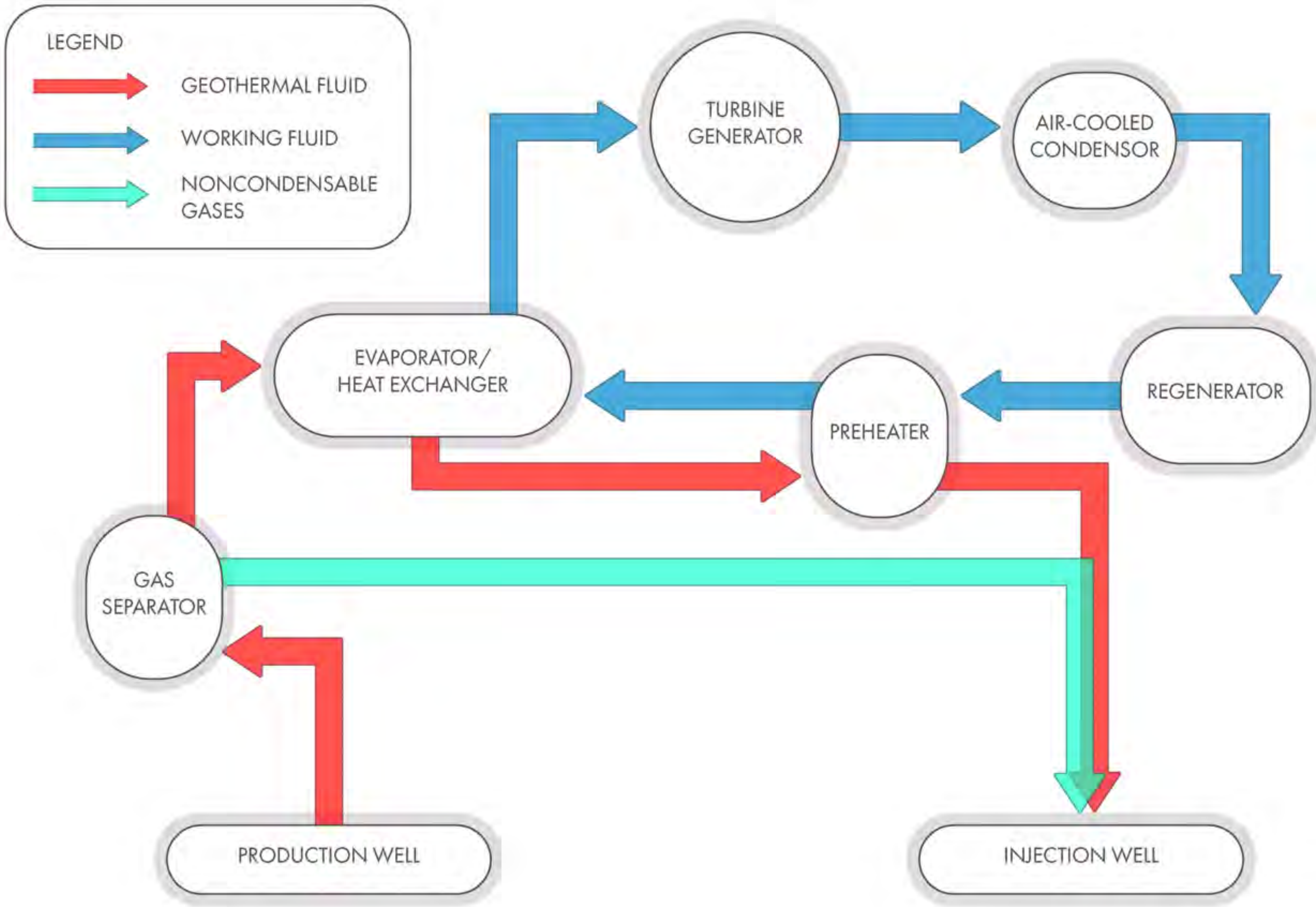
The proposed well field would consist of two production wells, one injection well, and interconnected pipelines.

### 3.4.1 Production and Injection Wells

NREI plans to drill two production wells to obtain the geothermal resources needed for the proposed binary plant at Hamilton Estates. If the test well being drilled in the spring of 2017 provides sufficient flow, it would be used as a production well, and only one additional production well would be needed. NREI expects that one injection well would be sufficient for disposal of the residual geothermal brine from the binary plant.

#### *Well Pads*

NREI would need an area of less than one acre for each production and injection well pad. During drilling, the well pads would accommodate the drill rig, large pipe rack, mud shaker, two 500-barrel water tanks, a generator, air compressor, mud pumps, fuel tanks, an office trailer, and reserve pit to collect the bore cuttings and fluids during testing. The pad must also provide parking for the crew and service and delivery vehicles, have a turnaround area for these vehicles, and have a suitable area available for laydown of the mast. The equipment and tanks would be removed once drilling and testing is complete, but the 350,000-gallon lined drilling mud sump used for the test well at the Hamilton Estate in May 2017, approximately 72 feet by 72 feet, would remain, to be used for additional testing and brine containment during power plant outages. The second production well on the eastern side of the NREI lease would also be connected to the storage pond.




Source: Thermal Energy Partners LLC

NREI Binary Geothermal Development Project

FIGURE 3.4-1
SCHEMATIC FLOW DIAGRAM

### Well Drilling

NREI would drill the production and injection wells at Hamilton Estates using a full size rotary drill rig that would be delivered and erected onsite. Although NREI has not yet selected the drilling company and drill rig, the rig would be larger than the one used for the test well in the spring of 2017. The derrick, or mast, could be approximately 110 feet above ground. The production wells would be drilled to a total depth of approximately 4,000 feet. The geothermal reservoir, based on prior drilling and geophysical exploration, begins at approximately 2,600 feet and extends to an unknown depth. The bottom hole casing is expected to be 8 5/8 inches in diameter. The casing would be fully cemented in place to at least a depth of 3,000 feet to anchor the well to the surface and isolate the geothermal system from any shallow groundwater beneath the site. A perforated liner would be installed in the production zone from a depth of approximately 3,000 feet to the bottom of the well, approximately 4,000 feet below ground surface.

Up to 10,000 gallons of water a day would be used for drilling. The water would be mixed with drilling muds and additives and would circulate down the wellbore and return up the space between the drilling rod and the sides of the well (the annulus), carrying cuttings to the surface. The drill cuttings would be collected in an open container and discharged to the lined drilling sump.

The drilling fluid would recirculate back down the well. Most drilling additives are inert or nontoxic materials, but some additives may be classified as hazardous and require special handling. Geothermal fluids and drill cuttings are exempt from US Environmental Protection Agency regulations regarding hazardous wastes and underground injection.

During drilling in the production zone, some geothermal steam can mix with the drilling fluid and be released to the atmosphere as the return drilling fluid discharges into the mud pit. NREI would monitor for hydrogen-sulfide continuously when drilling at depths below 1,000 feet. Hydrogen sulfide is commonly found in geothermal resources. It has a characteristic odor of rotten eggs at relatively low concentrations (0.005 – 0.008 ppm) and is toxic at substantially higher concentrations (100-350 ppm).

Based on the 2008 sampling, some hydrogen sulfide may be detected at the N-3 site and surrounding area during drilling. The proposed drilling equipment includes three hydrogen sulfide detection sensors for worker safety and a spare, which would be located downwind of the drill site. If the gas is detected at levels that would produce unacceptable odors at downwind residences, NREI would inject abatement chemicals into the drilling rod to reduce hydrogen sulfide emissions to acceptable levels. At no time would hydrogen sulfide levels be allowed to exceed those allowable at other geothermal projects near sensitive receptors.

Diesel used for drilling would be stored in double-hulled diesel storage tanks. Additional diesel from the NEVLEC Prospect Power Plant, approximately 1.1 miles southwest of the site, would be trucked to the site, if needed. The fuel storage tanks and drilling lubricants and additives would be stored in a designated area with impermeable surface. The storage area would be bermed to contain potential spills and any contaminated stormwater.

NREI would install and test blow out prevention equipment (BOPE) at the wells, which would shut in the well if an uncontrolled flow were to occur. NREI would have independent contractors inspect the BOPE to ensure that the equipment operates and conforms to industry standards and has redundant features to control unexpected flows.

Rotary drilling would take place 24 hours per day and may continue for approximately 40 days. Drilling would require two 9-person crews plus NREI supervisors

#### *Well Testing*

Once drilled, NREI would test the production wells to determine their flow rate and to establish the key reservoir properties. During testing of the production wells, NREI may use a separator/muffler that receives two-phase flow through a valve system attached to the wellhead and separates the steam from the water at a set pressure. Orifices, a James Tube, and gauges in the lines that lead to the discharges points would measure the flow rates, temperature, and pressure of the steam and water. During testing, the steam discharges to the atmosphere, and the water discharges through a weir box to measure the flow. Water flow is measured in the weir box while steam flow is calculated based on pressure and temperature. Sample taps would allow for the collection of water, gas, and steam samples. Testing could last for several days up to two weeks, depending on the results of the drilling. During extended testing, the drilling fluids would collect in the sump used for the spring 2017 well testing and be injected into the existing test well or slim hole.

Although the proposed binary technology would avoid emissions of geothermal pollutants during power plant operations, some hydrogen sulfide would be released during well testing. Based on the analyses of the N-3 well in 2008, the hydrogen sulfide emissions during well testing at Hamilton Estates are likely to require treatment. Screening modeling of well testing at Nevis indicates that emissions of 5.5 pounds per hour (lb/hr) result in impacts at downwind locations that are below the odor threshold, at prevailing wind speeds. Injection of sodium hydroxide and hydrogen peroxide into the vented steam can convert the hydrogen sulfide to soluble sulfates that can be injected and reduces the hydrogen sulfide released to the atmosphere. The modeling indicated that abatement would not be needed if the testing were performed when the prevailing wind direction was away from nearby residential areas or if wind speeds were above three meters per second (m/sec) (6.7 miles an hour). Prior testing of the N-3 slim hole well in 2008 did not include any abatement procedures. The well testing in the spring of 2017 would provide additional information on well flow and resource composition for determining the required abatement rates. NREI would have storage tanks with sufficient quantities of 25-30 percent aqueous solution sodium hydroxide and 50 percent hydrogen peroxide on site to abate the potential emissions during any further testing of the production wells.

### 3.4.2 Pipelines

Aboveground 12 to 14-inch pipelines would connect the two production wells to the steam separator at the plant site, and a 24-inch pipeline would connect the separator to the inlet of the Turboden generating equipment (see Figure 3.2-1, Proposed Plant Site and Wellfield).

The production pipelines would be approximately 1,000 feet long and would be within the Hamilton Trust lease boundary. The insulated pipeline would be on supports and would bridge the small drainage that runs through the site. Loops would be installed as necessary to allow for thermal expansion in the pipes.

Approximately 1,700 feet of 24-inch pipeline would carry the return flow from the binary plant to the injection well at the Hamilton Stable parcel. The insulated, aboveground pipeline would be located on crown lands adjacent to the existing estate roads and would have horizontal expansion loops that would extend away from the roadway. The pipeline would be buried or elevated where it

crosses the estate road. Barriers or posts would protect the pipelines from traffic along these public roads.

The piping system would include valves and instrumentation to control and monitor the flow of resource from the production wells to the plant and from the plant to the injection well.

## 3.5 Steam Separator

The two-phase geothermal fluid from the gathering system would flow to the steam separator, which flashes the resource at the inlet pressure for the NREI binary plant. The separator would have a side inlet that induces circular flow, separating the steam and noncondensable gases from the heavier water by centrifugal force.

In the preliminary design for the proposed binary Nevis geothermal project, the two-phase geothermal fluid would flash at a pressure of 141 pounds per square inch absolute (psia), resulting in approximately 234,000 lb/hr of steam and 1,193,000 lb/hr water. At this pressure, the inlet temperature to the binary plant would be 355 °F (179 °C). The actual output from binary plant would depend on the temperature and pressure of the geothermal resource, the flash pressure, the efficiency of the equipment, and the ambient temperature. The final design for the project components would be determined after production and injection testing, when more information is known about the characteristics of the resource.

The noncondensable gases would be pumped from the separator, compressed, and injected into the return flow from the binary plant. The gases would mix and dissolve into the geothermal brine as it travels down the injection well into the geothermal formation at depth.

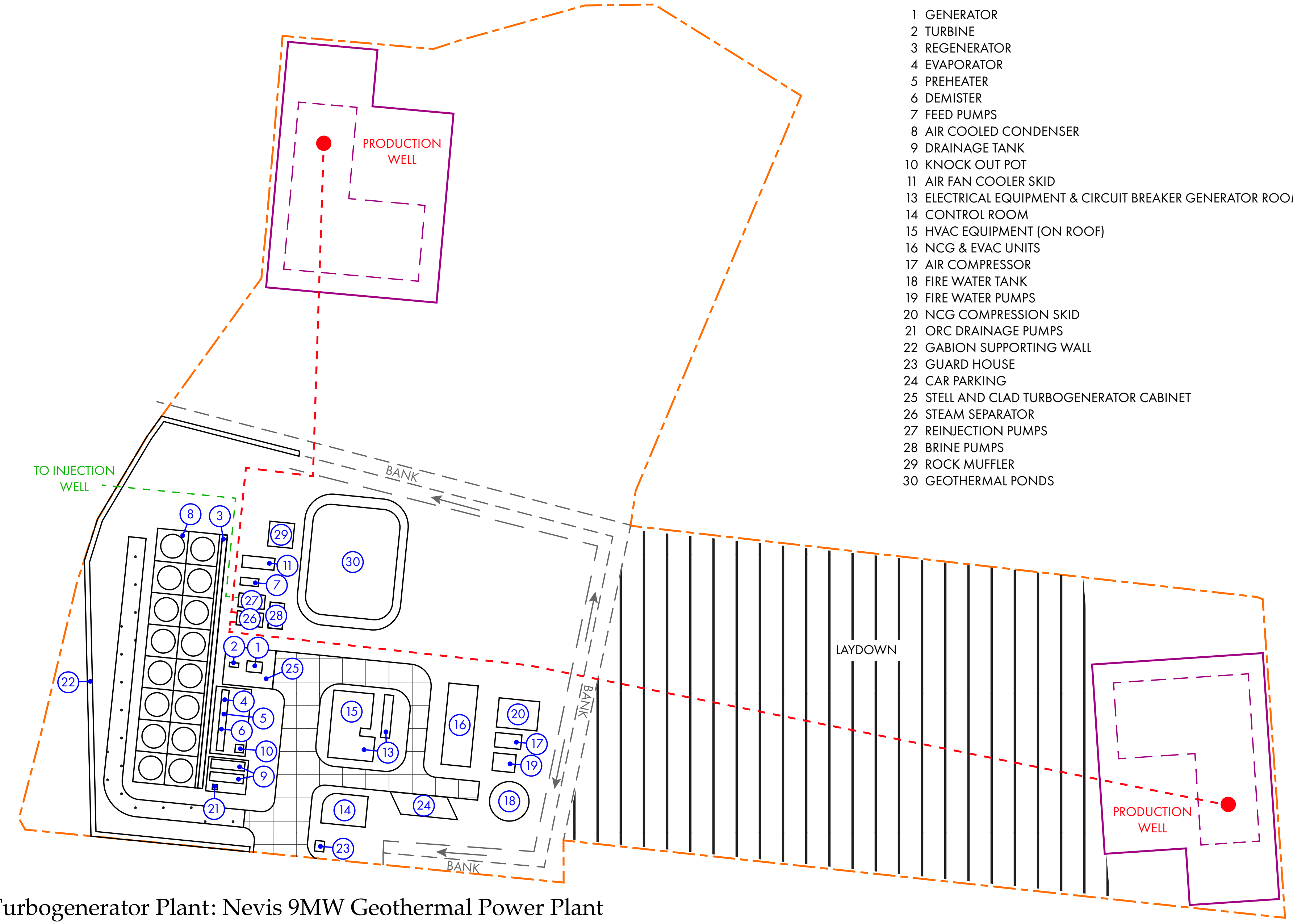
A safety relief valve would protect the steam separator in the event of overpressure. The relief valve would be located upstream of the separator and would vent through a rock muffler (silencer) at the brine containment sump.

## 3.6 Binary Power Plant

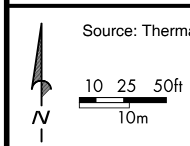
The proposed NREI binary geothermal plant, supplied by Turboden, would consist of an evaporator/heat exchangers, an Organic Rankine Cycle (ORC) turbine-generator, air-cooled condensers, a regenerator, and a preheater, using cyclopentane as the working fluid. The proposed facilities would also include a main control building, a maintenance and spare parts storage building, rock muffler (silencer), fire water system, a parking lot, and a guard shack. The plant and related facilities would occupy approximately 2.9 acres of the 9.1-acre lease (see Figure 3.6-1, Power Plant General Arrangement). A 2.2-acre laydown area would be east of the plant site for temporary storage and parking during construction. The portions of the parcel not used for the well pads, plant site, and pipelines would be landscaped with grasses and native plants. NREI would fence the entire parcel.

The 10-MW geothermal project would consist of two site-by side 5-MW binary units. Each unit would have its own evaporators/heat exchangers, turbine generator, air cooled condenser, regenerator, and preheater.

POINT IMPACT ANALYSIS, LLC




Turbogenerator Plant: Nevis 9MW Geothermal Power Plant




Source: Thermal Energy Partners LLC; GoogleMaps

NREI Binary Geothermal Development Project

FIGURE 3.6-1
POWER PLANT GENERAL ARRANGEMENT

### 3.6.1 Evaporator/Heat Exchangers

Based on the preliminary design, approximately 1,430,000 lb/hr of two-phase geothermal resource would pass through the evaporator, a horizontal tank containing shell-and-tube heat exchangers. The 355 ºF (179 ºC) geothermal fluids would vaporize the working fluid within the heat exchangers. Cyclopentane, the working fluid for the Nevis geothermal project, vaporizes at 122 ºF (50 ºC), a relatively high temperature. The high boiling point allows the binary cycle to take advantage of the high temperature geothermal resource at Nevis. Turboden would develop final design criteria from the testing data acquired during the May 2017 testing.

The geothermal resources at the NREI project would remain within a closed loop. After the geothermal resource passes through the evaporator, it would flow through the preheaters and pumped to the injection well. Other than minor leaks and fugitive releases, if any, no geothermal gases would be released to the atmosphere during operation of the binary system.

### 3.6.2 Turbine Generators

The Turboden ORC turbine-generators would use a high-molecular mass working fluid instead of water, which increases cycle and turbine efficiency. The Rankine cycle has slower turbine rotational speeds and lower pressures than water-based cycles, which reduces maintenance requirements and increases system reliability and online generating time. The lower speed reduces mechanical stress, and the use of an organic working fluid avoids erosion of turbine blades and other metallic parts, which is associated with high-speed deposition of water droplets. The slower turbine speed allows direct coupling to the electric generator without gear reduction, also improving efficiency.

The generators would produce power at 440 volts, which would be stepped up to 33 kV by the onsite transformer for delivery to the NEVLEC underground line to the Prospect Power Plant Substation (see Section 3.15.1, NEVLEC Interconnection).

### 3.6.3 Air Cooled Condensers

The vaporized working fluid would be condensed by air-cooled condensers. A total of 16 condenser cells (two rows of eight cells) would be used for the project. In each cell, large fans would force air across thin fins that contained the working fluid, transferring the waste heat to the ambient air. Each air-cooled condenser would be approximately 26 feet by 26 feet and approximately 20 feet high. The use of air-cooled condensers eliminates consumption of water by the cooling system and the need to discharge effluent from a cooling tower. Turboden has included noise reduction measures in the plant design to reduce noise levels at the property boundaries.

### 3.6.4 Regenerators

The condensed working fluid would collect in the regenerator, where it would be stored for reuse in the close binary cycle.

### 3.6.5 Preheaters

The working fluid would pass through a preheater, where heat exchangers would transfer some of the remaining heat from the geothermal resource to the working fluid through shell-and-tube heat exchangers. The geothermal resource leaving the evaporators would pass through the outside of the tubes before being injected back to the reservoir. The working fluid would be in the inside of the

tubes in the preheaters. The preheated working fluid would be pumped to the evaporator to be vaporized and begin the cycle again.

## 3.7 Plant Control System

The control system would consist of an operator console, control processor, data recording and acquisition cabinets, local instrument links, and an engineering work station. The operator console would allow the operator to monitor all aspects of plant operations as well as to exercise control functions by changing the set points of the individual controllers, operating control valves directly, and turning equipment on and off.

## 3.8 Hazardous Materials Storage

Hazardous materials at the site consist of the working fluid, cyclopentane, and chemicals such as sulfuric acid, sodium hydroxide, and hydrogen chloride that would be used to adjust the pH of the produced geothermal fluids and reduce scale in the wells and heat exchangers. These materials would be stored in designated areas with impervious surfaces designed to contain potential spills. Workers would be instructed in the hazardous properties of these chemicals, required protective clothing, and in the proper procedures for handling, storing, and eventual disposal of these materials.

### 3.8.1 Cyclopentane

Cyclopentane is a highly flammable liquid that can be toxic if swallowed. It needs to be stored in closed containers away from ignition sources such as sparks, open flames, and hot surfaces (Synthesis Material Safety Data Sheet, 2013). Cyclopentane is a liquid at ambient conditions and would not vaporize if spilled. Cyclopentane is not on the Environmental Protection Agency list of regulated flammable substances materials that require an offsite consequences analysis in accident prevention programs (49 CFR Part 68, Table 3 to 68.130).

The cyclopentane system is a closed loop that runs through the evaporators/heat exchangers, turbine, air-cooled condensers, regenerator, and preheater. These vessels would contain a total of approximately 15,000 gallons of cyclopentane. Another 3,000 gallons would be stored as reserve in adjacent drainage tanks. During maintenance on vessels in the cyclopentane loop, the area needing maintenance would be isolated from the rest of the system and drained into the two drainage tanks adjacent to the regenerator. Each tank would contain approximately 9,000 gallons cyclopentane. The equipment in the binary system, including the air-coolers, would be located on an impervious surface with secondary containment designed to hold the entire contents of the vessels and storage tanks plus the expected 10-year, 24-hour rainfall at the site.

### 3.8.2 pH Control

NREI would store sulfuric acid, sodium hydroxide, and hydrogen chloride on site to be able to adjust the pH of the produced water and control scale buildup in the wells and heat exchangers. These chemicals would be stored in tanks in a designated hazardous materials storage area at the plant site, away from the cyclopentane system, and at the well pads. The area would be bermed to prevent spills from entering stormwater runoff.

## 3.9 Fire Protection and Plant Safety Systems

The fire protection system would consist of a fresh-water tank, an electric firewater supply pump and a jockey pump, fire mains, and local hose and spray stations. The main fire pump would deliver water to a distribution loop around the binary plant with spray stations suitable for extinguishing cyclopentane fires. In addition, several hydrants with hose stations, strategically located around the plant perimeter, would be connected to the loop. The fire protection system would also include chemical powder and carbon dioxide extinguishers suitable for extinguishing electrical and small cyclopentane fires.

Cyclopentane detectors would be strategically placed around the binary plant facilities. The plant personnel would be trained on cyclopentane safety. In addition, the binary project would have an evacuation plan, and a wind sock would be mounted so that plant personnel can move up-wind from a leak. An audible alarm would alert the operators if one of the sensors detects more than 600 parts per million (ppm) cyclopentane, the permissible exposure limit adopted by U.S. National Institute for Occupational Safety and Health (NIOSH) for the 10-hour work day (U.S. Department of Health and Human Services, 1995).

Hydrogen sulfide detectors would be placed around the well pads and testing facilities and the rock muffler. An audible alarm would alert the operators if one of the sensors detects more than 10 ppm of hydrogen sulfide in accordance with the U.S. Occupational Safety and Health Administration (OSHA) 8-hour exposure limit.

NREI would prepare a Hurricane Response Plan prior to drilling and the start of power plant construction. The plan would also identify the hurricane response team and responsibilities under each set of predicted conditions. The drilling hurricane response plan would identify the wind conditions that require modification, curtailment, or shut down of drilling operations and the hours of advanced notice needed to implement these responses. The power plant hurricane response plan would identify the design wind loading of the structures and equipment critical to power plant operations, the criteria to be followed to implement modification or curtailment of plant operations, and the procedures and precautions to be implemented when a hurricane is predicted to occur.

## 3.10 Plant Drainage

The 2.9-acre plant site would be at an elevation of approximately 530 feet MSL, with an embankment along the northern and eastern sides of the site and a supporting retaining wall on the western sides of the site below this elevation.

The Turboden equipment including the cyclopentane storage tanks and air-cooled condensers would be within a secondary containment area designed to contain the 18,000 gallons of working fluid at the site, plus precipitation during the 10-year, 24-hour storm. Spills would be captured within this area, separated, if necessary, and reused. Any separated stormwater would be pumped to the brine pond. The hazardous materials such as sulfuric acid, sodium hydroxide, and hydrogen chloride would also be stored in a separate area, also bermed to prevent spills from contaminating stormwater.

The remaining portions of the site would drain to natural drainage. To prevent spills of geothermal fluids within the plant site from discharging offsite, the valves to the natural drainage would be kept shut during normal conditions and would be opened when a storm was approaching. The contained geothermal fluid would be pumped to the 350,000-gallon brine pond that is used to contain releases

of geothermal fluids during emergency shut downs. The contained fluid would either evaporate or be injected back into the reservoir.

The shallow natural drainage the currently flows east-west across the 9.1-acre parcel would be rerouted to a drainage ditch around the eastern well pad, laydown area, and plant site or would be contained within a culvert sized to handle the expected flow during peak storm events.

## 3.11 Water and Utilities

The NREI geothermal project would require water during well drilling and the initial fill of the firewater tank, and utility water for the control room. With the air-cooled condensers, no water would be needed for the binary plant cooling system. A 4-inch water main north of the site would provide up to 250 gallons per minute to fill the drilling sump and would provide most of the water supply for drilling and plant operations. Supplemental water from the Hermitage Heights Tank Farm near Charleston, approximately one mile west of the site, would be delivered by truck.

Table 3.11-1 shows the estimated amount of water needed and the source of the water.

**Table 3.11-1**
**WATER CONSUMPTION**

| Stage | Activity | Amount | Source |
|---|---|---|---|
| *Drilling* | Drilling and Cementing | 10,000 gallons/day (two 5,000-barrel tanks) | NIA |
| *Operation* | Fire System Initial Fill<br>Utility Water (sinks, toilets, landscaping) | 6,000 gallons<br>200 gallons/day | NIA<br>NIA |

The sanitary system for the geothermal project would consist of a septic tank and leach field at the plant site.

NEVLEC would deliver power to the site, which could be used during start-ups and outages. Thus, the proposed project would not need a back-up diesel generator.

## 3.12 Plant Construction

Plant construction would begin by clearing and grading the 9.1-acre development parcel of brush and scrub vegetation. Some large trees would be left on the site. Cut and fill would be needed to provide a level area for the plant, with a bank on the eastern side of the site and a supporting wall on the western side. The cleared vegetation and any excess soil would be taken to the local landfill. Installation of foundations, underground utilities, pipelines, and the proposed plant equipment would follow.

NREI estimates that approximately 18 months would be needed to construct the proposed geothermal development project at Hamilton Estates. During peak construction periods, up to 75 workers would be at the site. NREI would hire from the local workforce, where possible,

particularly during the initial stages of construction. Many of the construction activities would require workers with specialty skills who would live in local hotels and accommodations.

## 3.13 Operation and Maintenance

The proposed NREI binary geothermal plant would operate continuously with little variation in output, relying on the geothermal resources produced from the wells at Hamilton Estates. Binary plants such as the proposed project typically have capacity factors that exceed 97 percent (U.S, Energy Information Agency Annual Energy Report 2016) Output from the geothermal project would vary slightly, as seasonal and diurnal changes in ambient temperature affect the efficiency of the air cooling system.

NREI estimates that it would have 17 employees on site, five operators per shift and a plant manager for two shifts. Most employees would be local or retrained workers from NEVLEC. Turboden may have one or two operators or senior technicians during the first year of operations, but would transition to local hires with remote monitoring.

### 3.13.1 Start-up and Shutdown

Geothermal power plants typically shut down once a year for annual maintenance of the facilities. The proposed NREI project has two production wells and two 5-MW binary cycle generators, so that the required maintenance can be conducted on one well and one binary generator while the remaining well and generator provides power. Thus, the geothermal plant would never be completely off line except for a failure of the transmission line, which would be underground, or some catastrophic event. This configuration allows NEVLEC to decommission the existing diesel generators at the Prospect Power Plant. Each geothermal well is expected to provide up to 14 MWs, based on reservoir engineering calculations. Each generator can, under peak output, provide up to 6.5 MWs. Therefore, the NREI project would not need backup diesel generators. NEVLEC would keep one of its 2-MW generators available for backup, if needed.

During scheduled outages, operators would shut in one of the wells gradually, reducing flow through the plant and requiring little or no releases of steam and water from the separator. The steam and noncondensable gases would vent through the rock muffler; the water would collect in the brine containment pond.

If maintenance were required for the vessels containing working fluid, the area to be repaired would be isolated, and the cyclopentane drained and held in drainage tanks. Cyclopentane is a liquid at ambient temperatures. The working fluids would be contained and stored on site and reintroduced into the system when maintenance is completed.

### 3.13.2 Emergency Shutdowns

During emergency shutdowns, such as a turbine trip or the loss of the transmission intertie line, the binary cycle would shut down. The full geothermal flow, about 2,600 gallons per minute, would vent from the steam separator with the steam released through the rock muffler and the water collecting in the brine pond. The brine pond has the capacity to hold approximately two hours of full flow. If NREI determines that the cause of the outage cannot be corrected within a few minutes, as is often the case, the operators would reduce flows, gradually shutting in the wells as the water collects in the brine pond. Full shut down can be safely accomplished in less than one hour.

Operators would shut in the wells completely before the pond reaches capacity. NREI would have abatement chemicals on site at the rock muffler but does not anticipate needing to abate the emissions during emergency shutdowns, since the release would be temporary and unlikely to result in a significant nuisance to nearby residences.

The proposed plant would have a bypass that would allow the geothermal water to flow directly to the injection line. Since the high temperature fluid from the production well could adversely affect the injection well, NREI would only use this bypass in an emergency.

After the operators determine the cause of the outage and rectify the condition, the flow would be directed back to the plant inlet, and the binary plant would resume normal operation. The use of two production wells, and two generators gives the plant the ability to conduct required maintenance and to address unexpected outages requirements by shifting the load from both production wells to one production well, and from both generators to one generator. This configuration provides for a resilient system capable to responding to required and unexpected operating conditions without adverse impacts to the NEVLEC system or the surrounding environment.

### 3.13.3 Well Workovers

After several years of operation, NREI may need to bring in a "workover" rig to improve the flow of the production wells, remove scale, or replace a downhole pump in a production well. This rig would be smaller than the rotary rig used for the production well, about the size of a 10 ton truck. The mast for the rig would be approximately 20 feet high when erected.

## 3.14 Decommissioning

NREI plans to operate the proposed binary geothermal under a 25-year contract with NREI that may be extended by up to two 5-year increments. Upon completion of the contract, NREI would transfer the project to NEVLEC, which intends to continue operations and expand the plant to meet growth and increasing demand. Continuing operations could require modifications to address future reservoir conditions and equipment requirements. Binary projects inject all the produced geothermal fluids but may experience reservoir temperature decline if the volume of the reservoir is small or if production exceeds the ability of the reservoir to recover from the heat extraction process. NREI's contract terms require that it turn over the plant, wells, and facility grounds to the government and NEVLEC. NIA and NEVLEC would assume all responsibility for continued responsible operations, or, if desired, decommission in accordance with applicable guidance and regulations.

## 3.15 NEVLEC Electrical System

The 9-MW (net) electrical output from the NREI Nevis geothermal project would be sufficient to meet the demand for electricity from residences and businesses on Nevis most of the time. Between January 1 and March 28, 2016, peak demand on the NEVLEC system fluctuated between 6.4 and 8.7 MW. Minimum demand during this period averaged 5.1 MW (NEVLEC, 2017). Currently, 95.2 percent of the installed generation on the NEVLEC system is from diesel units at the Prospect Power Plant in Charlestown (U.S. Central Intelligence Agency, 2017). The proposed project is expected to be able to produce 54,600 to 60,000 MW-hrs a year from renewable sources (maximum output could reach 78,840 MW-hrs, but this is not likely given the present system demand). The electricity from the Nevis geothermal project would allow NEVLEC to cease the operation of its

old existing diesel units. NEVLEC recently installed a 2.5 MW Wartsila unit at the Prospect Power Plant and would maintain one, or perhaps two of the existing diesel generation as emergency standby power. The proposed Turboden binary technology typically has an availability factor of 98 percent (Mitsubishi Heavy Industries, 2016). See section 3.13 above.

### 3.15.1 NEVLEC Interconnection

The present NEVLEC grid system is an 11-kV system that covers the entire island, but NEVLEC intends to upgrade certain portions of the existing system to 33-kV. NREI would install a 33-kV transformer and deliver power to the NEVLEC intertie line at the geothermal plant boundary.

### 3.15.2 Transmission Intertie Line

NREI would install the 33-kV transmission intertie line between the NREI geothermal plant site at Hamilton Estates and the Prospect Substation near Charlestown. Upon completion, NREI would dedicate the intertie line to NEVLEC. NEVLEC has identified the route for the underground line and is establishing the right of way for this circuit. NREI would install the transmission intertie line below ground at depths consistent with international standards for this voltage. The line would be installed in trenches, typically three to five feet deep, in a conduit encased in sand. The planned route to the Prospect Substation would be approximately 1.7 miles (2.8 kilometers) long, as shown in Figure 3.13-1. The underground line would have road crossings and pull boxes along the route. The proposed route would follow existing roads starting at Hamilton Estates, running through Blaziers Estate and Marion Heights before finishing at the Prospect Power Station via upper Stoney Grove. Where trenching alongside the road next to existing utilities is not possible, ducts would encroach on the road. The ducting would consider future development plans to avoid unnecessary soil disturbance.

Stability issues are critical to NEVLEC, given the size of the grid and the possible plans for connection to the larger St. Kitts grid. To ensure that the system is adequately monitored and managed, NEVLEC would install a SCADA system to permit central control of the network. It would also provide valuable information in real time on the system. To facilitate this remote monitoring, NREI would place a communication cable in conduits in the same trench with the transmission cable.

POINT IMPACT ANALYSIS, LLC

Source: Thermal Energy Partners LLC

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LEGEND

- Parcel boundary
- Transmission intertie route
- Plant site
- NEVLEC

NREI Binary Geothermal Development Project

FIGURE 3.15-1

TRANSMISSION LINE

INTERTIE ROUTE

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# 4. BASELINE ENVIRONMENTAL DATA AND EVALUATION OF IMPACTS

This section presents the existing environmental conditions at the Hamilton Estate parcels where the proposed NREI binary geothermal project would be located and evaluates the environmental impacts of the 10-MW (gross) project on the site and surrounding areas of St. Paul Charlestown Parish, St. Thomas Lowland Parish, and St. John Figtree Parish in the island of Nevis. The analysis addresses the impacts of construction, operation, maintenance, and decommissioning of the power plant, production and injection wells, pipelines, transmission intertie line, and support facilities. The analysis includes an evaluation of drilling and testing the wells and of the normal operation, start-up, and shutdown of the binary plant. Appendix A provides additional information on drilling and testing one well at the Hamilton Estate site, which NREI plans to conduct in May 2017.

## 4.1 Assessment Criteria

The evaluation of environmental impacts in this EIA assesses the impact using significance criteria developed in accordance with the International Finance Corporation (IFC) Environmental, Health, and Safety (EHS) Guidelines and the Overseas Private Investment Corporation (OPIC) policies and procedures. The analysis considers the potential positive and negative effects of the project in terms of their frequency, probability, extent, duration, and magnitude and identifies the degree of severity of these effects. Table 4.1-1 defines the terms used in this analysis and presents the terminology used to identify the degree of severity for these factors.

**Table 4.1-1**
**TERMINOLOGY USED TO DESCRIBE IMPACTS**

| | | | | | |
|---|---|---|---|---|---|
| **Frequency** | Rare. *Single event less than once every few years* | Very Infrequent. *Single event less than once per year* | Infrequent. *Less than once every few months* | Frequent. *Once or more per day* | Continuous. *Uninterrupted or on a daily basis* |
| **Probability** | No Impact. *Impact cannot occur* | Low Potential. *Impact unlikely to occur* | Possible. *Impact somewhat likely to occur* | Probable. *Impact likely to occur* | Definite. *Impact certain to occur* |
| **Extent** | Site. *Impacts will occur only on site* | Local. *Impact will occur within one community* | Regional. *Impact will affect more than one community* | National. *Impact will occur throughout Nevis* | International. *Impact will occur outside Nevis* |
| **Duration** | Very Short Term. *Less than a few days* | Short Term. *Less than a few months* | Medium Term. *Less than two years* | Long Term. *For the entire operational phase* | Very Long Term. *For the entire operational phase and after closure* |
| **Magnitude** | Very Low. *Little to no impact detectable* | Low. *Small changes, which are hardly detectable* | Moderate. *Impact measurable, but does not interfere with normal activities* | High. *Many people, animals, and plants affected* | Very High. *Loss of people, biodiversity, property, loss of local livelihood* |

This assessment defines "community" as a cluster of residences within a neighborhood, village, or town that has a local identity, such as the Hamilton Estate. The definition of community does not rely on formal political boundaries and does not include isolated houses. There are several such communities within St. Paul Charlestown Parish.

This environmental analysis rates the potential environmental impacts of the project as of low, medium, or high significance. Table 4.1-2 presents the criteria used to determine the significance rating, based on the degree of severity of the factors in listed Table 4.1-1.

**Table 4.1-2**
**SIGNIFICANCE CRITERIA**

| | |
|---|---|
| Low | Any low or moderate magnitude impact that is confined to the site and is unlikely to occur or, if it occurs, is of short duration. |
| Medium | Any moderate magnitude impact that is certain or likely to occur, but is local and is of medium or long-term duration. Any high magnitude impact that is unlikely to occur and is of short duration or local in extent. |
| High | Any high magnitude impact that is certain or likely to occur, of medium or long term duration, and regional in extent. |

All the impacts of the proposed 10 MW binary geothermal project have "low" or "moderate" significance. The proposed project is in a former sugar cane field with no endangered or threatened species and would not displace or require relocation of the inhabitants at the Hamilton Estate. The binary closed-loop system configuration would have virtually no emissions during normal operation. NREI has proposed air cooling with no water consumption and included noise control, spill containment, and other measures that would reduce or avoid the potential impacts to the community and the surrounding environment. NREI would use local labor during construction and operation and would comply with local laws and international policies on worker rights and working conditions. As such, the proposed project does not require mitigation and can be classified as a Category B project for OPIC review and would not require an Environmental and Social Action Plan.

## 4.2 Aesthetics

The following section describes the aesthetic conditions of the proposed site and surrounding areas on Nevis and assesses the visual impacts of the proposed binary geothermal development project on the nearby sensitive receptors and on the aesthetic resources of the island.

### 4.2.1 Existing Conditions

Nevis is a small, tropical island in the Caribbean with a volcanic peak at its center and sandy beaches along the western and northern coasts. Fertile slopes fall uniformly from the peak toward the ocean and contain natural fresh water and hot springs. Nevis Peak creates micro-climates that vary with

height, location and orientation creating altitude-based biodiversity and various microhabitats; however former sugar cane plantations and current livestock activities have removed and prevented natural vegetation growth in some areas. Per the Beard system of classification, Nevis has six vegetation zones: rain forest, dry evergreen forest, montane thicket, palm brake, elfin woodland, and dry scrub woodland (Lindsay, 1999).

The visual landscape is dominated by the slopes of the volcano, diverse vegetation, and the ocean. From many locations, the views are dramatic and familiar to residents and tourists alike. Visible intrusions or changes in the landscape are particularly sensitive issues for Nevis, where the economy depends on tourism.

The Hamilton Estate is on the lower flanks of Nevis Peak, approximately 1.5 miles from Charlestown and the western side of the island. The Hamilton Heritage Trust land where the binary plant and production wells would be located is relatively level land at elevations between 500 and 610 feet above sea level. The site is part of a former sugar cane plantation that now contains low-lying scrub vegetation. The plant site is approximately 1,300 feet west of the outlying residential areas of Charleston and surrounded by vegetation and a few scattered residences and building.

The injection wells would be at Hamilton Stables at elevation 470 to 490 feet above sea level, near the site of the former sugar production facilities. Acacia trees line the dirt road between the plant site and the injection well. Taller trees are near the site for the injection wells. The areas north and northeast of the project site are completely undeveloped. The summit of Nevis Peak is at elevation 3,343 feet, approximately 1.4 miles northeast of the site.

The main access to the plantation area is an unpaved road that runs past the injection well, former sugar works, and apartment buildings and connects to back roads on the south side of the island. The main road to Church Ground and Stoney Hill on the southern side of the island is approximately 0.8 miles south of the site.

### 4.2.2 Aesthetic Impacts

The following section discusses the impacts of the proposed geothermal development project on aesthetics. Table 4.2-1 summarizes the impacts to aesthetics.

**Table 4.2-1**
**SUMMARY OF IMPACTS TO AESTHETICS**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| Views of Drilling and Construction Activities from Nearby Residences | Frequent | Probable | Local | Short Term | Moderate | Medium |
| Views of Ongoing Geothermal Operations from Nearby Residences | Continuous | Probable | Local | Long Term | Moderate | Medium |
| Views of Drilling, Construction, and Ongoing Operations from Charlestown and Coastal Communities | Very Infrequent | Low Potential | Regional | Long Term | Very Low | Low |

***Aesthetics Impact 1 – Views of Drilling, Testing, and Construction Activities from Nearby Residences***

Drilling and construction activities would involve grading of the well pads and power plant site, operation of drilling and power plant equipment, drilling the production wells, injection well, testing the wells, and installation of power plant equipment, pipelines, and related facilities. Rotary drilling would take place 24 hours per day and could continue for 45 days per well. Testing could last 40 hours. During drilling, the rig and surrounding operational area would be lit at night. NREI would use shielding that directs the light to the ground to reduce the nighttime visibility of the rig masts. Construction at the plant site would last approximately 18 months and would occur during daytime hours. The construction, drilling, and well testing equipment and activities would be visible from the single residence northeast of the plant site, from most of the residences east of the site, and from the Carino condominiums near the former sugar works. These residences are at approximately the same elevation or at slightly higher elevations than the plant site and would be able to see most of the construction and drilling activities. While the single residence would be adjacent to the production well drilling, most of the residences are 570 to 1,300 feet from the drilling and construction sites. The proposed activities would be temporary and would not obscure the long-range views of the ocean and coastline from these residences. Travelers along the public road to the sugar works would have brief views of the injection well drilling and pipeline construction on their way to other portions of the Hamilton Estate.

The downslope residences wests of the plant site would see little if any of the drilling, testing, and construction activities. Trees and other scrub vegetation would obscure the views of the ground-based activities, but portions of the drill mast and the steam plume during well testing would be noticeable above the vegetation.

Residences of Hamilton Estate, Blazier Estate, Marion Heights, and Stoney Grove along the 1.7-mile transmission line route would have short-term views of the trenching and other construction activities for the underground line. This construction would be adjacent to or within the public roadway.

*Aesthetics Impact 1– Medium Significance*

### Aesthetics Impact 2 – Views of Ongoing Geothermal Operations from Nearby Residences

The proposed NREI binary facilities, including the turbogenerator, evaporator, preheater, drainage tanks, and pumps are low-lying horizontal vessels, approximately half the size of the air-cooled condensers. The air-cooled condensers, the tallest features at the site, would be approximately 20 feet high. The guard shack and control room would be single story structures, and the pipelines would be a few feet above the ground. NREI would paint these facilities to blend in with the natural surroundings. Nighttime lighting for safety and security would be directed to the ground to reduce nighttime visibility. NREI would landscape the undeveloped portions of the 9.1-acres parcel in grasses and native plants and plant trees to screen the views of the facilities from nearby residences.

The Hamilton Estate residences southeast of the site and people living in the Carino condominiums would have direct line of sight view of these facilities, from distances of 570 to 1,000 feet. While the power generating facilities would not interfere with the ocean view from these locations, the presence of nearby industrial features and pipelines would detract from the quality of the visual landscape. Travelers along the roads to these residences would also view the injection pipeline.

Vegetation would obscure the views of most of the power generating facilities and pipelines from the single residence to the northeast and from the residences downhill from the site. Some portion of the air-cooled condensers may be visible from these locations. The air-cooled condensers would not have a -vapor plume, and the color of the coolers would reduce the contract with the surrounding vegetation.

*Aesthetics Impact 2– Medium Significance*

### Aesthetics Impact 3 – Views of Drilling, Construction, and Ongoing Operations from Charleston and Coastal Communities

Charlestown and the coastal communities of St. Paul Charlestown Parish and St. Thomas Lowlands Parish are more than 1.5 miles from the proposed binary facilities. Tourists and residents in these locations would have little if any views of the drilling, construction, and ongoing operation of the NREI binary geothermal project. The project would be located on the lower portion of the flanks of the Nevis volcano, which is the dominant visual feature from these areas. The NREI project would be near the edge of the outlying developed areas of Charlestown, surrounded by vegetation. The tops of the rotary drilling mast may be visible from some locations, as would steam during well testing and occasional venting during plant outages. The use of the air-cooled condensers eliminates water vapor plumes that are visible at distances from many geothermal plants, and the natural colors

of the proposed facilities help them blend into the distant landscape. Although the impacts from operation are long term, the distance from the site decreases the visual impact.

*Aesthetics Impact 3– Low Significance*

## 4.3 Biology

The following section describes the biological conditions of the proposed project site and assesses the impacts of the proposed binary geothermal project on these resources. The information on existing conditions and the analysis of potential environmental effects is based on material from Jennifer Lowery, a natural resource consultant who surveyed the Hamilton Estate parcels on which the proposed project would be located (Lowery, 2017; see Appendix B).

### 4.3.1 Existing Conditions

The proposed project would be located on two parcels at the Hamilton Estate. Both project parcels – the Hamilton Heritage Trust parcel and the Hamilton Stable parcel – have a long history of agricultural use, including sugar cultivation until the 1950s. Following the cessation of sugar cultivation, a wide variety of products from cotton to vegetables were grown at the Hamilton Estate. The project parcels were also used for grazing of domesticated animals. As described in more detail below, this grazing has affected the composition of the vegetation at the site, which generally consists of scrub regrowth of varying maturity. The elevations where the project would be located increase from west to east, with the injection well site located at approximately 470 to 490 feet MSL and the power plant and well pad sites located at approximately 530 feet MSL.

#### *Vegetation*

In general, most of the 9.1-acre Hamilton Heritage Trust parcel, where the power plant and production well pads would be located, shows evidence of earlier clearing, where large rocks and topsoil have been pushed into overgrown heaps, possibly from when the estate was surveyed for subdivision, or maintained as farmland and estate roads. Grazing and browsing by goats and wild donkeys, which has intensified over approximately the last 25 years, has affected regrowth at the site and resulted in a higher proportion of toxic or spiny unpalatable species. The few large trees on site are mainly located near the boundaries of the old estate roads, but generally the site vegetation does not exceed 8 to 12 feet in height. Given its history and recent use for grazing, vegetation at the Hamilton Heritage Trust parcel generally consists of regrowth of varying maturity, which can be characterized as areas A, B, and C as follows (see Figure 4.3-1, Vegetation Map):

- Area A generally corresponds to clay soil types present in areas of lower elevation located on the western end of the site. The vegetation in this area forms a dense, almost impenetrable thicket and is characterized by a lower story of grasses, herbs, and vines, and an upper story of shrubs and trees. Grass, herb, and vine species species observed in this area include common vegetative species such as Indigo (*Indigofera suffruticosa and Indigo tinctoria*) and Canker berry (*Solanum racemosum*). Shrub and tree species observed include common species such as wild tamarind (*Leucaena leucophala)* and Casha (*Acacia macracantha*). A single Jamaica caper tree (*Capparis cynophallophora*) was observed in this area. This species normally occurs closer to coastal habitat. While infrequent on Nevis, it is common elsewhere in the Caribbean.

POINT IMPACT ANALYSIS, LLC


Source: Thermal Energy Partners LLC; GoogleMaps

NREI Binary Geothermal Development Project

FIGURE 4.3-1
VEGETATON MAP

- Area B generally corresponds to loamy soils present on the eastern end of the site. Vegetation in this area is similar to that of Area A, but with taller trees and a slightly less dense understory, as well as some ornamental species from nearby residential landscaping. Vegetation observed in this area include common species such as wild jasmine (*Jasminium fluminense*), wild tamarind, and Casha.
- Area C consist of the area recently cleared for the N-3 slim hole boring and the site's entrance road. This area is sparsely vegetated, consisting of a few common pioneering species such as Indigo, wild tamarind, and Spiny cucumber (*Cucumis dipsaceus*).

The approximately 1.2-acre Hamilton Stable parcel, where the injection well would be located, consists of clay soils at a slightly lower elevation than the Hamilton Heritage Trust site. This site was also previously used for agriculture and has vegetation similar to Areas A and B as described above; however, the shrubs and trees present at the Hamilton Stable site are in general slightly taller than those at the Hamilton Trust Heritage.

The proposed production and injection pipelines would run within or adjacent to existing roadways present at the Hamilton Heritage Trust and Hamilton Stables parcels. Similarly, the proposed 1.7-mile transmission intertie route would follow existing roads from the NREI power plant site to the NEVLEC Prospect Power Station. The transmission line would be located in a trench within or directly adjacent to the roadway. Trenching for the transmission line would almost entirely occur within the roadway prism (the area previously disturbed during roadway construction).

### *Water Features*

Both the Hamilton Heritage Trust and the Hamilton Stables parcels lack permanent water features. The Hamilton Heritage Trust parcel contains a small, shallow swale, or ghaut, that crosses the site in an east-west orientation. This feature is typically dry, but would be a watercourse in the rainy season or after a major storm. In general, the natural drainage pattern of both the Hamilton Heritage Trust and the Hamilton Stable parcels have been historically altered by agricultural practices, development and, most recently, levelling for the platform around the N-3 well and its access road (on the Hamilton Heritage Trust parcel). The transmission intertie line would be within or adjacent to existing roads and would not result in new disturbance within or near the bank of any permanent water feature.

### *Wildlife*

In general, historical site activities and recent grazing limit the potential for wildlife to be present in the area where geothermal development facilities would be installed. The only mammalian species native to Nevis are the several species of insect and fruit-eating bats; however, no bats were observed at either the Hamilton Heritage Trust or Hamilton Stables parcels during the survey, and no likely roost sites were seen. Nonetheless, it is probable that the various ruins and abandoned buildings in the estate yard nearby would provide suitable habitat for bats.

Other, non-native mammals observed near the project parcels include the Green Vervet Monkey, domesticated goats and feral donkeys, all of which are detrimental to island's natural vegetation.

Apart from insects, birds are the most common type of fauna found on Nevis. Due to the small size of the island and scarcity of fresh surface water, many of the birds on Nevis are limited in range. The Nevis Ornithological Society has an informal checklist of 165 species sightings in Nevis and

speculates that the true total could be up to 210 species. From informal subjective analysis of various species lists there appears to be a weighting towards the more easily observed birds of more open habitats including waterbirds, shore birds, birds of prey and swifts and swallows, with these making up roughly 60 percent of sightings. Removing a conservative third of records as infrequent visitors, leaves 44 species of woodland and thickets, and a further subjective subdivision of 50 percent being residents of higher denser rainforest leaves a working possible species number of around 20 for lowland dry and sub-humid woodland or scrub typical of the Hamilton Heritage Trust and Hamilton Stable parcels. The dense thickets covering large parts of the project site provide good protection and food for avian fauna. Birds observed during the site survey include: common ground dove (*Columbina passerina*), Zenaida Dove (*Zenaida aurita*), American kestrel (*Falco sparverius*), pearly-eyed thrasher (*Margarops fuscatus*), Lesser Antillean bullfinch (*Loxigilla noctis*), gray kingbird (*Tyrannus dominicensis*), and Carib Grackle (*Quiscalus lugubris*). Of these, all except the grackle are found throughout Nevis. Grackle are uncommon over most of the island, occurring in only a few localities. The grackle observed on site may have been breeding in the dense vegetative cover at the site.

### 4.3.2 Biology Impacts

The following section discusses the impact of the proposed binary geothermal project on biological resources. Table 4.3-1 summarizes these impacts.

The proposed project would result in a total of approximately 10.7 acres of construction disturbance (i.e., clearing and grading of the entire 9.1-acre Hamilton Heritage Trust site, 1.2-acre Hamilton Stables site, and 0.4-acre transmission intertie route) for the proposed geothermal development facilities). The temporary laydown yard would be located on 2.2 acres near the center of the Hamilton Heritage Trust site, between the power plant site and the eastern well pad site. Once constructed, the power plant site (approximately 2.9 acres) and production well pad sites (approximately 0.9 acres each, or 1.8 acres total) would permanently occupy 4.7 acres of land. The injection well site would permanently occupy an additional 0.9 acres of the 1.2-acre Hamilton Stable site. The transmission intertie line would be underground within or adjacent to existing roadways.

**Table 4.3-1**
**SUMMARY OF IMPACTS TO BIOLOGY**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| Vegetation Removal | Rare | Definite | Site | Short Term | Low | Low |
| Wildlife Disturbance | Infrequent | Possible | Site | Short Term | Low | Low |

### *Biology Impact 1 – Vegetation Removal*

At worst case, the proposed geothermal development project would require up to a total of approximately 10.7 acres of clearing and grading for the temporary laydown area, power plant site, production well pads and injection well site, production and injection pipelines, and the 1.7-mile transmission intertie line. This estimate is considered worst-case because portions of the two parcels at the Hamilton Estate and along the transmission intertie route are already devoid of vegetation, and NREI would retain approximately 16 of the largest trees observed on site.

All clearing and grading would occur within areas that were previously tilled for sugar cane cultivation, or disturbed for other agricultural commodities and/or investigative geothermal development. The existing vegetation that would be cleared consists primarily of common, vegetative scrub species that has grown on previously disturbed lands or persists on the side of existing roadways. The proposed production and injection pipelines would be above ground, meaning these pipelines would create a minimal disturbance from the pipeline supports only, and enabling the production and injection pipelines to bridge the small, shallow ghaut present on Hamilton Heritage Trust parcel and avoid disturbing this feature. Similarly, the proposed transmission intertie line would, although not located above ground, would be installed within trenches within or adjacent to existing roadways, and most likely within the existing roadway prism, reducing the possibility for disturbing sensitive habitat features.

The project parcels do not contain endangered or threatened plant or wildlife species and generally consist of scrub regrowth vegetation that is not a unique or sensitive habitat type (Lowery, 2017). NREI would avoid removing trees where possible, minimize the unnecessary clearing of land to preserve existing habitat where feasible and consistent with site access and safety needs (e.g., overgrowth onto facilities would not be permitted), and provide landscaping for the site to provide for an attractive and maintained site appearance. This landscaping would continue to provide habitat for the wildlife species observed on site, including potential bats in the area and the Carib Grackle. In addition, if a sensitive species or habitat were identified at the proposed power plant site, well pad site, injection well site, or transmission intertie route, NREI would call a biologist to assess the habitat and identify appropriate measures to avoid impacting the sensitive species and/or its habitat.

*Biology Impact 1– Low Significance*

### *Biology Impact 2 – Wildlife Disturbance*

The propose project would develop up to 10.7 acres of mostly vegetative scrub habitat. A survey of the Hamilton Heritage Trust and Hamilton Stable parcels did not observe any endangered or threatened species at the parcels. Species observed on and near the site consisted of mostly common bird species and non-native mammal species such as Green Vervet monkeys and domestic animals that do not primarily depend on the scrub vegetation for food and habitat. A Carib Grackle was observed on the Hamilton Heritage Trust parcel, presumably using the dense vegetation for breeding. As noted above, NREI would avoid removing trees where possible, minimize the unnecessary clearing of land to preserve existing habitat where feasible and consistent with site access and safety needs (e.g., overgrowth onto facilities would not be permitted), and provide landscaping for the site to provide for an attractive and maintained site appearance, as well as continued habitat for the wildlife species observed on site, including potential bats in the area and the Carib Grackle.

NREI would also install a brine pond at the site that would temporarily hold geothermal fluids during start up and shut downs before injection back into the reservoir and would cover the pond with netting to ensure that birds and other species not land in the water that could contain constituents that could harm wildlife. NREI would fence the plant site to prevent other species from coming into contact with hazards materials or chemicals, and take measures to reduce the potential for spills into the pond (see hazards and hazardous materials and water resources sections).

As discussed in the noise section, the proposed geothermal development would increase ambient noise levels during construction and operation. Operational noise would be constant and limited to 100 dBA at three feet from the condenser during the daytime, but temporary and intermittent construction noise would be louder than operational noise. Species sensitive to noise could be startled during construction activities and might seek temporary habitat where these impacts are diminished, but would likely return to the project site once construction activities have ceased.

*Biology Impact 2– Low Significance*

## 4.4 Climate and Air Quality

The following section describes the climate and air quality conditions of the proposed site and surrounding areas on Nevis and assesses the impacts of the proposed binary geothermal development project on the nearby sensitive receptors, the climate and air quality resources of the island, and the global accumulation of greenhouse gases.

### 4.4.1 Existing Climate and Air Quality Conditions

Nevis has a tropical maritime climate greatly influenced by the northeastern trade winds. The island has a mean temperature of 81ºF with only small diurnal and seasonal variations. Rainfall varies considerably from month to month and from year to year. In general, the period from January to April is drier than the months from May to December. The immediate project area does not have a weather station, however, the Vance W. Amory Airport, approximately four and a half miles to the north, has been collecting meteorological data during airport operations (typically 7 am to 7 pm), at a 30-foot elevation since 2000. The airport is at the northern tip of the island and is not affected by island terrain. The Mount Palmetum at Jessups also has data on temperature and wind speed, but Nevis Peak appears to reduce the winds peed at this location. Tables 4.4-1 and 4.4-2 summarize the climatic data from these stations.

#### *Temperature*

Some climatic data on temperatures and wind speed is available from the airport at 30 feet and from the Mount Palmetum in Jessups at approximately 385 feet elevation. Airport records provide mean daily or monthly temperatures from 2000 to 2008. Comparable data for mean monthly temperatures is summarized in Table 4.4-1. The temperatures at the higher site were on average approximately 4°F lower than at the airport. Minimum and maximum temperature data from the Mount Palmetum show some inconsistencies, the years 1977-1994 have minimum recorded temperatures in the 60s°F, from 2000 to 2005 the minima were between 72 and 74°F, maxima for all years are between 89 and 92°F. Highest mean temperatures occur during the months of May to September, and lowest between November and February.

**Table 4.4-1**
**MONTHLY MEAN TEMPERATURES**

| | VWA Airport (°F) | | | Mount Palmetum (°F) | | |
|---|---|---|---|---|---|---|
| **Month** | **2003** | **2004** | **2005** | **2003** | **2004** | **2005** |
| *January* | 80.2 | 79.0 | 78.8 | 76.1 | 75.0 | 74.3 |
| *February* | 80.4 | 79.2 | 78.1 | 75.9 | 75.2 | 73.9 |
| *March* | 80.8 | 79.2 | 81.7 | 77.4 | 76.7 | 77.5 |
| *April* | 82.2 | 81.9 | 83.1 | 78.1 | 75.9 | 78.4 |
| *May* | 83.1 | 81.9 | 84.0 | 80.8 | 78.1 | 80.7 |
| *June* | 83.7 | 83.8 | 85.1 | 79.6 | 79.7 | 81.1 |
| *July* | 84.6 | 83.5 | 85.5 | 81.0 | 80.1 | 84.2 |
| *August* | 85.5 | 85.1 | 85.8 | 84.9 | 81.1 | 82.6 |
| *September* | 85.8 | 84.6 | 86.0 | 84.1 | 77.7 | 79.0 |
| *October* | 84.4 | 83.5 | 84.0 | 82.2 | 77.5 | 79.9 |
| *November* | 81.9 | 81.3 | 82.4 | 78.9 | 77.4 | 73.1 |
| *December* | 81.1 | 80.8 | 81.0 | 75.9 | 74.9 | 73.2 |

### *Wind Speed*

Table 4.4-2 summarizes the available data on wind speeds. Data from the airport covers mean monthly wind speed; the Mount Palmetum data also includes maximum wind speeds. All the data is for years that were unaffected by hurricanes or tropical storms, and the wind speeds are moderate throughout the year, highest mean wind speeds are in January and February and again in June and July, the months with lowest wind speeds are September and October.

The frequency with which major storms hit Nevis is extremely variable. In the past century, Nevis experienced a period in which there were no major hurricanes for 60 years and a period in which there were three major storms in a single decade. In the event of a major hurricane (Category 3 and above) passing close to the island, sustained winds exceeding 110 miles per hour (mph) can be experienced, with three second gusts of up to 152 mph (University of West Indies, 2010). Hurricanes and storms are most likely to occur in the months of August to October.

The airport data shows relatively strong, consistent trade winds (average wind speed of approximately 12 mph from the east-southeast, at a location not affected by the steep terrain of Nevis Peak or Round Hill. The Mt. Palmetum data is in the wind shadow of Nevis Peak and has an average wind speed of 4.2 mph.

**TABLE 4.4-2**
**MONTHLY MEAN WIND SPEED DATA**

| 2003-2005 | VWA Airport (mean mph) | VWA Airport (maximum mph) | Mount Palmetum (mean mph) | Mount Palmetum (maximum mph) |
|---|---|---|---|---|
| *January* | 15 | 21 | 4 | 19 |
| *February* | 14 | 19 | 5 | 19 |
| *March* | 14 | 19 | 3 | 13 |
| *April* | 13 | 22 | 4 | 17 |
| *May* | 13 | 16 | 4 | 17 |
| *June* | 15 | 19 | 5 | 18 |
| *July* | 15 | 18 | 6 | 16 |
| *August* | 14 | 23 | 4 | 21 |
| *September* | 10 | 15 | 3 | 16 |
| *October* | 11 | 17 | 4 | 16 |
| *November* | 11 | 20 | 4 | 17 |
| *December* | 14 | 20 | 4 | 18 |

The Vance W. Amory Airport data has limited applicability to Hamilton Estates. The airport is at the northern tip of the island, and the prevailing winds at the airport are from the east, little effected by island terrain. The proposed site is located in a forested area southeast of Charlestown. Project personnel and the Caribbean Guide report the dominant wind direction on the western side of the island as from the east-northeast, probably affected by this terrain.

### *Existing Air Quality*

Nevis has generally very good to excellent air quality with high dispersion from the trade winds and few sources of air pollution on the island. One such source is the emissions from the diesel power plant. Nevis has a small population of approximately 12,000 people with local concentrations of traffic primarily around Charlestown and local sources of pollutants.

### 4.4.2 Impacts on Climate and Air Quality

The following section discusses the impacts of the proposed geothermal development project on climate and air quality. Table 4.4-3 summarizes the emissions impacts to sensitive receptors.

**Table 4.4-3**
**SUMMARY OF IMPACTS TO CLIMATE AND AIR QUALITY**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| Temporary Emissions from Earthmoving and Construction Equipment | Frequent | Definite | Site | Short Term | Very Low | Low |
| Geothermal Emissions during Drilling and Testing | Infrequent | Definite | Local | Short Term | Low | Low |
| Geothermal Emissions from Power Plant Operations and Outages | Rare | Low Potential | Local | Very Short Term | Very Low | Low |
| Greenhouse Gas Emissions | Infrequent | Definite | International | Short Term | Low | Low |

### *Sensitive Receptors*

The sensitive receptors for air quality impacts from the proposed geothermal development include the surrounding residences and residential areas to the west, south, and east. Based on a review of aerial photography, there are approximately 100 residential clusters and potential residential structures within 0.5 miles of the proposed Hamilton Heritage Trust and Hamilton Stables parcels where the proposed binary power plant, production wells, and injection well would be located.

### *Characteristics of Hydrogen Sulfide*

Hydrogen sulfide is a compound that exists in geothermal reservoirs. At room temperature, it is an invisible and foul-smelling gas. Hydrogen sulfide is heavier than air and collects in low places. Low concentrations of hydrogen sulfide cause detectible odors and create a nuisance in inhabited areas; high levels can pose an occupational hazard and pose significant health risks (WHO, 2000).

Table 4.4-4 identifies the health effects associated with various higher concentrations of hydrogen sulfide. WHO has established two guidelines for hydrogen sulfide, one based on nuisance, and one based on health impacts. The lowest observed adverse effect level (LOAEL) for hydrogen sulfide is 15 $mg/m^3$ (10.8 ppm). Given the serious impacts of high doses of hydrogen sulfide, WHO sets a

24-hour guideline based on the LOAEL with an uncertainty factor of 100 and recommends that 24-hour average concentrations of hydrogen sulfide not exceed 150 μg/m$^3$ (0.108 ppm) in order to protect human health (WHO, 2000).

**Table 4.4-4**
**HYDROGEN SULFIDE HEALTH DOSE EFFECTS**

| Effect | Hydrogen Sulfide Concentration | |
|---|---|---|
| | mg/m$^3$ | ppm |
| Eye irritation | 15-30 | 10-20 |
| Serious eye damage | 70-140 | 50-100 |
| Loss of olfactory sense | 210-350 | 150-250 |
| Pulmonary edema with risk of death | 450-750 | 320-530 |
| Strong central nervous system stimulation, hyperpnoea followed by respiratory arrest | 750-1400 | 530-1000 |
| Immediate collapse with paralysis of respiration | 1400-2800 | 1000-2000 |

Source: WHO, 2000

The California Occupational Safety and Health Administration (OSHA) and the American Industrial Hygiene Association (AIHA) require that 8-hour average hydrogen sulfide concentrations in work areas not exceed 10 ppm, just below the LOAEL (AIHA 1989, OSHA, 2010).

To avoid odor annoyance complaints, WHO recommends that hydrogen sulfide concentrations not exceed 7 μg/m$^3$ (0.005 ppm or 5 parts per billion (ppb)) averaged over 30 minutes. WHO explicitly encourages countries to observe guidelines to the extent feasible. The threshold for odor detection varies from person to person. According to WHO, the odor threshold is 7 μg/m$^3$ (5 ppb), according to the California Office of Health Hazard Assessment (OEHHA), it is 11 μg/m$^3$ (OEHHA, 2000), and according to AIHA, it is 13 μg/m$^3$ (AIHA, 1989). The California OEHHA reports that Amoore (1985) analyzed a large number of reports from the scientific literature and found that reported thresholds for detection were log-normally distributed, with a geometric mean of 10 mg/m3 (8 ppb). St. Kitts and Nevis does not have a national ambient air quality standard for public exposure to hydrogen sulfide.

### *Climate and Air Quality Impact 1 – Temporary Emissions of Dust from Earthmoving and Pollutants from Construction Equipment*

The proposed geothermal development project could, at worst case, result in the clearing and grading of approximately 10.7 acres of land, plus well drilling, and facility construction. Exhaust emissions from diesel equipment, trucks, and worker vehicles would be typical for construction projects. Earthmoving activities would also produce dust that would settle close to work areas. The

largest source of emissions would be the drilling rigs. Table 4.4-5 presents the expected level of emissions from the rotary drill rigs.

**Table 4.4-5**
**DRILL RIG EMISSIONS OF CRITERIA AIR POLLUTANTS AND GREENHOUSE GAS EMISSIONS**

| Emission Source[1] | Pollutant (lbs/hour) | | | | | |
|---|---|---|---|---|---|---|
| | $NO_x$ | CO | $SO_2$ | $PM_{10}$ | TOC[2] | $CO_2$ |
| Rotary Drill Rig[3] | 208.8 | 47.9 | 70.4 | 6.1 | 6.1 | 10,092 |

1 Based on three, 2,900 horsepower (hp) engines equipped on the rotary drill rig.
2 As CH4
3 Large Stationary Diesel Engine Emission Factors from U.S. EPA AP-42 Fifth Edition, Volume I, Chapter 3, Table 3.4-1. Assumes 0.5 percent sulfur content.

*Climate and Air Quality Impact 1– Low Significance*

### *Climate and Air Quality Impact 2 – Emissions of Hydrogen Sulfide during Drilling and Well Testing*

Although the proposed binary technology would avoid emissions of geothermal pollutants during power plant operations, some hydrogen sulfide would be released during well testing, which could last for several days to up to two weeks depending on the drilling results. Based on the analyses of the N-3 well in 2008, emissions of hydrogen sulfide emissions during production well testing are likely to require treatment for odor control. Screening modeling of well testing at Nevis indicates that emissions of 5.5 lbs/hr result in impacts at downwind locations that are below the odor threshold, at prevailing wind speeds. Injection of sodium hydroxide and hydrogen peroxide into the vented steam can convert the hydrogen sulfide to soluble sulfates that can be injected and reduces the hydrogen sulfide released to the atmosphere. The modeling indicated that abatement would not be needed if the testing were performed when the prevailing wind direction was away from nearby residential areas or if wind speeds were above three meters per second (m/sec) (6.7 miles an hour).

Well testing in the spring of 2017 would provide additional information on well flow and resource composition for determining the required abatement rates. NREI would install three hydrogen sulfide detection sensors for worker safety and a spare, which would be located downwind (i.e. east) of the drill sites. If the gas is detected at levels that would produce unacceptable odors at downwind residences, NREI would inject abatement chemicals into the drilling rod to reduce hydrogen sulfide emissions to acceptable levels.

*Climate and Air Quality Impact 2– Low Significance*

### *Climate and Air Quality Impact 3 – Impacts of Hydrogen Sulfide and Other Geothermal Constituents during Power Plant Operations*

Operation of the proposed binary geothermal project would not result in the release of hydrogen sulfide or other emissions during normal plant operations. The proposed equipment for the project consists of a Turboden binary geothermal power plant that uses closed loop cycles designed to avoid

emissions to the atmosphere. The geothermal steam and water from the two production wells would pass through the heat exchangers at the binary units and be pumped back into the reservoir through the injection wells. Except for fugitives, no off-gassing or emissions would be released from the closed cycles. Thus, under normal operations, the proposed binary power plant would not release hydrogen sulfide or other geothermal constituents to the atmosphere.

Some emissions could occur during scheduled maintenance and unscheduled emergency situations. The configuration of the proposed NREI project (two production wells and two 5-MW binary cycle generators) is such that required maintenance can be conducted on one well and one binary cycle generator while the remaining well and generator provides power. During scheduled outages, operators would shut in one of the wells gradually, reducing flow through the plant and requiring little or no releases of steam and water from the separator.

During emergency shutdowns, such as a turbine trip or the loss of the transmission line, one or both 5-MW binary cycles would shut down. The geothermal flow, approximately 117,000 lb/hr of steam for each unit, would vent from the steam separator through the rock muffler until the operators could shut in the well or wells, typically within an hour. The water would collect in the brine pond, which has the capacity to hold approximately two hours of full flow from both units. NREI would have abatement chemicals on site at the rock muffler but does not anticipate needing to abate the emissions during maintenance or emergency situations, since the release would be temporary and unlikely to result in a significant nuisance to nearby residences.

*Climate and Air Quality Impact 3– Low Significance*

### *Climate and Air Quality Impact 4 – Greenhouse Gas (GHG) Reduction*

Due to the binary power plant design, the proposed geothermal power plant would not release a substantial amount of GHGs during operation. Some emissions would occur during well testing and plant shutdowns. As described in Section 3.5, up to 234,000 lbs/hr of steam would pass through the steam separator. This steam could be released from the separator during testing or from the rock muffler during emergency well shut in or plant shut down, emitting approximately 1.4 metric tons of carbon dioxide equivalents during this hour. This would occur for no more than a few hours to a few days per year.

The proposed project would, however, eliminate the need to combust diesel fuel for power generation at the Prospect Power Plant in Charlestown, which currently has a generating efficiency of 17.65 kW per gallon of diesel fuel (NEVLEC 2017). As described in Section 3.15, the proposed project would typically generate between 54,600 and 60,000 MW-hrs per year with little to no GHG emissions. At the current generating efficiency of the Prospect Power Plant, the amount of diesel fuel combusted to generate this much electricity would be between 3,059, 490 gallons and 3,399, 430 gallons, which would produce between approximately 3.6 and 4.0 metric tons of carbon dioxide equivalents (MTCO2e) per hour, or between approximately 31,340 and 34,820 MTCO2e per year . The proposed project would result in lower hourly GHG emissions during well testing and plant shutdown and substantially reduce GHG emissions below existing levels.

In addition to this direct reduction in GHG emissions from NEVLEC's Prospect Power Plant, the proposed project would avoid other upstream emissions associated with shipping and transport of diesel fuel to the NEVLEC Prospect Power Plant, and would provide NEVLEC with greater

flexibility and capacity to serve larger, private developments (such as hotels) that may otherwise install their own diesel generators.

*Climate and Air Quality Impact 4 –Medium Significance, Beneficial*

## 4.5 Cultural and Historic Resources

The following section describes the cultural and historic resource conditions of the proposed site and surrounding areas on Nevis and assesses the impacts of the proposed binary geothermal development project on these resources.

### 4.5.1 Existing Conditions

Cultural and historical resources on Nevis include, but are not limited to, buildings and ruins from the colonial era and buildings or structures associated with sugar cane plantations. This analysis is based on a site survey conducted by Jennifer Lowery in March 2017 and discussed in the report, Hamilton Estate: Description, Climate, Soils & Land Use, Biological Resources, Historical & Cultural Resources. Jennifer Lowery is the secretary of the Nevis Historical and Conservation Society (NHCS) Executive Board, editor of *The Natural History of the Island of Nevis,* and a natural resource consultant who lives on Nevis. This section discusses the existing condition of cultural and historic resources at and surrounding the project site.

#### *Historic Context*

Nevis has a rich multi-cultural history. Archaeological excavations reveal that the first inhabitants came to Nevis about 4,000 years ago. Prior to European settlement of the island by the English in 1628, Spaniards, Dutch, and English colonizers visited the island, which was then inhabited by Carib Indians. From Nevis, the English went north and founded Jamestown in the Virginia Colony in 1607

The earliest settlement of the islands is thought to have been around 2000 BC, and there is still some doubt about the origins of these people (Wilson 1985). At around 50 AD and 600 AD, there were successive waves of settlement made up of people of the Arawakan group originating in South America. These people, generally referred to as Carib Indians, still inhabited the islands at the start of European colonization in the late 16th century and early 17th century. Their names for the islands were Oualie (Nevis) meaning "land of beautiful waters" and Liamuiga (St. Kitts), meaning “fertile island.”

There are few historical records of encounters between European settlers and the Caribs in Nevis, but references to settlers constructing fortified camps allow us to infer that such communities existed. One record exists from 1607, when Captain John Smith was on his way to Virginia. His party stopped for five days in Nevis, and in the area of the Bath Stream, they encountered an Indian hunting party. Each group ran from the other, and there were no further encounters (Hubbard, 2010

In St. Kitts, there are more historical records, usually of conflict between the settlers and Caribs. There are records of Sir Thomas Warner, leader of the first English colonists on St. Kitts, meeting the Carib Chief Tegremante. The name of one area, "Bloody Point," commemorates the 1626 massacre of 2,000 Caribs from St. Kitts and Dominica by joint French and English forces. This

seems to have signaled the end of any significant Carib/Arawak presence in the island. Carib petroglyphs have been preserved at two locations.

In the Eastern Caribbean, relict Carib/Arawak communities remain in St. Vincent and Dominica and some mixed Carib/Spanish peoples in north Trinidad. Cultural organizations retain connections between these groups and others farther afield. There have been occasional instances of conflicts between development and traditional Carib sites, most recently over a burial ground in Trinidad. Apart from rare visits for cultural/historic events, there are no current ties between these communities and St. Kitts and Nevis. The project area is an unlikely site for a pre-Columbian settlement and therefore unlikely to be of significance in the heritage of the indigenous peoples of the Eastern Caribbean.

After sugar was introduced in the 1640's, African slaves were brought to the island to harvest the crop. After the American Revolution, African-American slaves who had sided with the British for the promise of freedom resettled in the West Indies, then under English rule. In 1782, the French seized both Nevis and St. Kitts, but governance returned to Britain with the Treaty of Paris in 1783. The islands were part of the colony of the Leeward Islands from 1871 to 1956 and of the West Indies Federation from 1958 to 1962. Nevis, St. Kitts, and Anguilla became a self-governing state in association with Great Britain in 1967. The Federation of St. Kitts and Nevis attained full independence on September 19, 1983.

### *Pre-Columbian*

The project site is an unlikely location for any Amerindian relics because the Hamilton Estate is not recognized as an Amerindian settlement site. Most such sites are coastal and have been found mainly on the eastern and southern areas of Nevis (Lowery, 2017). Typically, the Amerindian sites on Nevis are along the coast and found in the eastern and southern sections of the island, although this may be because west coast sites have been lost to coastal erosion.

### *Colonial Era*

Records of the ownership of the Hamilton Estate are clear going back to 1772, when it was purchased by Andrew Hamilton, a planter, and began to be known as Hamilton's Estate. (There is no known connection between Andrew Hamilton and the family of Alexander Hamilton.) At the time of this purchase, the estate was comprised of 552 acres to which Hamilton later added more land. The estate has a total of 580 acres in three plantations: Hamilton, Upper Paynes or Morgans, and Jerusalem. The lands were worked as a sugar plantation, as were almost all cultivated lands in Nevis at that time, with the center of all activities being the estate yard and the sugar works. (Lowery, 2017).

Sugar cane was grown throughout Nevis from the early 1700s to the mid twentieth century. Wind power was used initially to drive the grinding machinery, but this was eventually succeeded by steam power, probably in the 1860s when the estate was acquired by Thomas Graham Briggs. Sugar production eventually became uneconomical and declined in the latter half of the nineteenth century (Lowery, 2017).

### *Twentieth Century*

In 1900 there were still 10 steam mills and 6 windmills in operation, but by 1921 there were only 3,000 acres of land under sugar cultivation. In 1933, the colonial government bought the Hamilton

Estate, the first of a number of abandoned or nonfunctioning agricultural estates to be purchased. The grinding of sugar finally ended at Hamilton in 1951, the remaining mill at New River closed in 1958. Cultivation of sugar by small farmers continued for a few years, with the cane being shipped to St. Kitts for processing, but this was discontinued as uneconomic (Lowery, 2017).

Due to declining profits in the sugar industry, the government began a program to diversify the agricultural sector and stimulate other sectors of the economy. Tourism has shown the greatest economic growth, and in 1987, it surpassed sugar as the major foreign exchange earner. What still exists of the Hamilton Estate sugar works is of possible interest to tourists, as are the remains at the other sugar estates on Nevis, including the Eden Brown, Golden Rock, Montpelier, Mountravers, Hermitage and New River Estates and the old Manor Plantation (Nevis Historic and Conservation Society, www.vnevisheritage.org, 2017).

The remaining sugar works at the Hamilton Estate lie outside the area of influence of the project, south of Estate Road on Hamilton Heritage Trust land, opposite the proposed site of the injection well. The Hamilton Stables parcel used for the injection well pad contains a recently constructed storage building. Portions of this site have been cleared. The remaining storage building is not historic and would be removed for the construction of the injection well pad.

### 4.5.2 Cultural and Historic Resources Impacts

The following section discusses the impacts on cultural and historic resources from the construction and operation of a binary geothermal power plant at the Hamilton Estate. Table 4.5-1 summarized these impacts. Visual impacts to the Nevis landscape are discussed in Section 4.2, Aesthetics, and impacts to trails on the Hamilton Estate are discussed in Section 4.10, Recreation.

**Table 4.5-1**
**SUMMARY OF IMPACTS TO CULTURAL AND HISTORIC RESOURCES**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| Disturbance of Unidentified Cultural or Historic Resources | Infrequent | Possible | Regional | Long Term | Low | Low |
| Degradation of Nearby Cultural or Historic Resources | Rare | Low Potential | Regional | Long Term | Low | Low |

#### *Cultural and Historic Resources Impact 1 – Disturbance of Unidentified Cultural or Historic Resources*

No pre-Columbian artifacts are likely to be found at the proposed site, as the Hamilton Estate is not a known Amerindian settlement location. The land for the power plant and production wells was formerly cultivated as a sugar plantation, and the remains of the sugar works have been identified as historic resources. The pipeline to the injection well would be aboveground on supports and the injection well would be drilled on the western portion of the Hamilton Stables parcel. The transmission line would be underground, but within or adjacent to the public roadway, on disturbed land.

Drilling the wells and construction of the binary plant, pipelines, and transmission line has the potential to encounter buried resources, including human remains. If NREI were to accidentally encounter buried cultural or historic artifacts during site excavation or construction of the power plant and well pads, it would stop work in the immediate area, notify the appropriate authorities, and follow recommended procedures.

*Cultural and Historic Resources Impact 1 – Low Significance*

#### *Cultural and Historic Resources Impact 2 – Degradation of Nearby Cultural or Historic Resources*

The binary plant and production wells would not be visible from the road to the sugar works. The low-lying injection pipeline would run along the north side of the road, behind a barrier and would not affect the visual or historic integrity of the remains of the sugar works on the south side of the road. These ruins are being maintained by the Nevis Island Administration.

*Cultural and Historic Resources Impact 2 – Low Significance*

## 4.6 Hazards and Hazardous Materials

The following section discusses the existing hazards and hazardous materials near the site and the potential impacts of the hazards and hazardous materials at the proposed binary geothermal project.

### 4.6.1 Existing Conditions

There are no existing significant hazards or hazardous materials in the leased area. The project site consists primarily of former sugar cane fields that are now covered with scrub vegetation. The ruins of the abandoned sugar works are adjacent to the injection well location.

### 4.6.2 Hazards and Hazardous Materials Impacts

The following section describes the hazards and potential impacts from the use of hazardous materials at the proposed binary geothermal project. Table 4.6-1 summarizes these impacts.

| Table 4.6-1<br>SUMMARY OF IMPACTS FROM HAZARDS AND HAZARDOUS MATERIALS | | | | | | |
|---|---|---|---|---|---|---|
| **Impact** | **Frequency** | **Probability** | **Extent** | **Duration** | **Magnitude** | **Significance** |
| Hazardous Material Spill | Rare | Possible | Site | Short Term | Low-Moderate | Medium |
| Fire Impacts | Rare | Low Potential | Local | Long Term | Low-Moderate | Medium |
| Well blowout | Rare | Low Potential | Local | Short Term | Low | Low |
| Electric Shock | Rare | Low Potential | Site | Short Term | Low | Low |

### *Hazards and Hazardous Materials Impact 1 – Hazardous Materials Spills*

The proposed project would use hazardous materials during construction, for well drilling and conditioning, and for operation of the binary geothermal project. NREI would transport hazardous materials to and from the site, store and use them on site, and dispose of them off-site. In addition, the geothermal fluids can contain hazardous substances. Improper handling of hazardous materials and geothermal fluids could result in accidental spills and releases that could expose workers, the public, and the environment to risk of contamination. NREI would reduce risk of exposure to these materials by preparing and adhering to a hazardous materials plan that would detail the proper handling of these materials. Pursuant to the plan, hazardous materials would be stored in designated areas with secondary containment designed to contain the maximum potential spills plus expected rainfall. In addition, berms and plant drainage system would prevent stormwater from carrying spills offset and affecting the surrounding environment.

During construction and maintenance of the binary power plant, production and injection well pads pipelines, transmission intertie line, NREI would use various diesel-fueled vehicles and machines and other construction materials and could lead to potential spills of diesel fuel, lubricating oil, solvents, hydraulic fluid, or anti-freeze. NREI would store an estimated diesel, lube oil, and transformer oil on site in tanks. None of these substances pose a health hazard or reactivity hazard. Diesel requires heating to ignite and lube and transformer oils require preheating. In the event of a spill, the impact would be low. The spill would likely be small, since only small quantities are used at one time, and would be contained to a small area on the project site. NREI would address any spill in accordance with the hazardous materials plan.

During drilling, NREI would use chemicals to lubricate drill bits and prevent scaling in the well. NREI would collect cuttings and water produced during drilling and testing in the lined ponds, and the water in the ponds would evaporate or be injected. Most drilling additives are inert or nontoxic materials, but some additives may be classified as hazardous and require special handling. Geothermal fluids and drill cuttings are exempt from US Environmental Protection Agency regulations regarding hazardous wastes and underground injection.

NREI would use caustic soda, sulfuric acid, and hydrochloric acid for well maintenance. The hazardous materials plan would require that NREI take precautions to reduce the risk of soil or groundwater contamination from these chemicals and would include proper procedure for handling a spill. NREI would store these substances in areas with secondary containment features and include response to spill in the hazardous materials plan.

Geothermal fluids contain hot water, and inert gases, trace amounts of metals, and constituents that can be toxic to plants and animals if released to the environment. Releases of geothermal fluids during well testing would be contained in a lined 350,000-gallon brine pond and either evaporated or injected. Spills of geothermal fluid within the plant site would be contained. The valves in the plant drainage system would normally be kept closed to prevent spills from discharging to the natural drainage. If a major spill were to occur, the contained geothermal fluid would be pumped to the brine containment pond. Were a storm approaching, the valves would be opened to allow the stormwater to discharge to the natural drainage.

The Turboden binary cycle uses cyclopentane as a working fluid. Cyclopentane is a liquid at ambient temperatures. The Turboden equipment, air coolers, and storage tanks would be within a secondary containment area. If there were an accidental spill or release, the liquid would be contained and reused. Any precipitation in the containment area would be removed with an oil-water separator and injected.

With these measures, the impact of hazardous materials spills from the proposed geothermal development would be of medium significance.

*Hazards and Hazardous Materials Impact 1 – Medium Significance*

### *Hazards and Hazardous Materials Impact 2 – Fire Impacts*

The proposed binary geothermal project would increase the risk of fire at the site. The project would introduce people and flammable materials at a remote location that is surrounding by scrub forest. The working for the binary system, cyclopentane, is highly flammable, and would be stored on the site in significant quantities. NREI would design the project to locate electrical equipment and other potential ignition sources at safe distances from the vessels containing cyclopentane. NREI would also install leak detectors at strategic locations around the binary facilities to alert workers to the potential risk of fire.

NREI would develop a fire protection plan for the site that would designate a fire protection team and assign responsibilities in the event of a fire. The plan would include an evacuation plan to protect workers from risk of explosion.

NREI would also install a fire protection system at the site. The fire protection system would consist of a fresh-water tank, an electric firewater supply pump and a jockey pump, fire mains, and local hose and spray stations. The main fire pump would deliver water to a distribution loop around the binary plant with spray stations suitable for extinguishing cyclopentane fires. In addition, several hydrants with hose stations, strategically located around the plant perimeter, would be connected to the loop. The fire protection system would also include chemical powder and carbon dioxide extinguishers suitable for extinguishing electrical and small cyclopentane fires.

The fire protection system, in addition to worker fire prevention training and proper storage and handling of flammable hazardous materials, would reduce the risk of significant impacts from fire at the project site.

*Hazards and Hazardous Materials Impact 2 – Medium Significance*

### *Hazards and Hazardous Materials Impact 3 – Well Blowout*

A geothermal well blowout is an unexpected, sudden release of steam and hot water from a geothermal well. Well blowouts occur when the pressure in the formation exceeds the pressure well mud, casing, or valve exerts upon it. Wells can blow out during exploration or production drilling. Blow outs are dangerous and can release hot and hazardous geothermal fluids, make noise, damage vegetation, and cause injury to workers and animals. Geothermal wells have a lower risk of well blowout than petroleum or natural gas wells, which can encounter volatile and explosive substances.

NREI would further reduce the risk of well blowout and the risk of impacts from potential well blowout by installing blowout prevention equipment (BOPE) which would shut down the well if an uncontrolled flow were to occur. NREI would have independent contractors inspect the BOPE to ensure that the equipment operates and conforms to industry standards and has redundant features to control unexpected flows. If the BOPE fails, NREI could pump cold water into the well to stop the flow of geothermal fluid. NREI would also develop an emergency shut-in plan to stop a well blowout in the case one occurs and to contain and clean up any fluids that may be released.

*Hazards and Hazardous Materials Impact 3 – Low Significance*

### *Hazards and Hazardous Materials Impact 4 – Electric Shock*

The binary plant would connect to NEVLEC at the site by means of an underground 33-kV intertie line. Power lines, electrical devices and equipment all produce electric and magnetic fields. The strength of fields varies based on the power line or equipment and decreases with distance. Although extensive studies of the potential health effects of long term exposure to electric and magnetic fields have been inconclusive, the issue remains a public concern. At the proposed generation and voltage level, exposure to residents along the route would be comparable to routine exposure to household appliances. Workers around electric equipment are, however, at risk of electric shock, and would be trained to follow safety procedures. Fences and restricted access to the facility would prevent members of the public from exposing themselves to risk of electric shock at the project site.

*Hazards and Hazardous Materials Impact 4 – Low Significance*

## 4.7 Land Use

The following section describes the land use conditions of the proposed project site and surrounding areas on Nevis and assesses the impacts of the proposed binary geothermal development project on these land uses.

### 4.7.1 Existing Conditions

The proposed geothermal development would be on two parcels of rural crown land, approximately 1.5 miles east of Charlestown on the western side of Nevis, a 36-square mile island. The parcels are at the Hamilton Estate in St. Thomas Lowlands Parish. Both parcels are Hamilton Heritage Trust land, leased to NREI by the NIA.

The following discussion describes the existing conditions at the concession area, the surrounding areas, and the protected conservations areas in this portion of the island of Nevis.

### Geothermal Project Area

The power plant and production wells would be on a 9.1-acre parcel approximately 700 feet north of the paved public road that runs from Charlestown through the Hamilton Estate to Church Ground. This parcel is on undeveloped land, formerly planted in sugar cane, that was part of the 580-acre Hamilton Estate plantation. The injection well would be on a 1.2-acre parcel adjacent to the paved road, near the site of the former sugar works. The NIA now manages the crown lands at the Hamilton Estates.

### Surrounding Land Uses

The land surrounding the site for the proposed binary facilities is primarily undeveloped open space with secondary growth slowly reclaiming the sugar cane fields that have been fallow since the plantation closed in 1951. Most of the area is private land, but little development has occurred in the intervening years. One residence is on the parcel to the northeast of the plant site, and a cluster of approximately 11 residences are southeast of the site, near where the public road turns south. The Carino condominiums (four two-story buildings and gardens) are directly south of the plant site, approximately 570 to 1,000 feet from the proposed facilities. To the southwest are two rows of government housing, now privately owned. West of the site are the outlying residential areas above Charlestown. The nearest residence is approximately 1,320 feet from the parcel for the plant site. North and east of the site is forest and open space, occasionally used for hiking.

Charlestown, the capital of Nevis, is approximately 1.5 miles west of the site. Charlestown includes a harbor, government buildings, hotels, a retail and commercial center, and surrounding residential areas. St. Paul Charleston Parish has a population of 1,867 in 2011, the last year that data is available (Nevis Island Administration, Department of Finance, 2016 Statistical Digest.

To the north is St. Thomas Lowlands Parish which includes coastal beaches and tourist areas as well as the outlying areas of Charleston, Pinney's Beach, Jessups Village, and Cotton Ground. The Four Seasons Hotel is at Pinney's Beach. The 2011 population of St Thomas was 2,047.

To the south is St. John Fig Tree Parish, with a population of 2,901 in 2011. The Prospect Power Plant and the community of Church Ground are in St. John Parish.

### Planned Conservation Protection Areas

Nevis has a number of natural resources areas that are proposed for protection as called for under the National Conservation and Environmental Protection Act 1987. The proposed areas near the geothermal project include the Nevis Peak Project, Marine Protected Area, and Camps Watershed (see Figure 4.7-1, Protected Areas). The Organization of Eastern Caribbean States (OECS) awarded a grant to the Island Resource Foundation (IRF) to do a study of the feasibility of setting up these protection areas. The study would focus on four areas, defining the boundaries, study the literature on the areas, researching the biological resources, and preparing a management plan (Robinson, 2009).

POINT IMPACT ANALYSIS, LLC


Source: Point Impact Analysis LLC

N

Nevis Peak, above 1000 Feet
Camps Watershed
Marine Protected Area

NREI Binary Geothermal Development Project

FIGURE 4.7-1
PROPOSED PROJECT PROTECTED AREAS

**Nevis Peak Project**

Nevis Peak is a volcanic formation and encompasses rainforests and water resources that drain to the Camps and other watersheds. The proposed Nevis Peak conservation project would prevent the development of buildings above the 1,000-foot contour line to protect the freshwater resources that originate at the peak (Robinson, 2009) and preserve the landscape, natural tranquility, biodiversity, and genetic resources of the area (Potter, 2009). The proposed Nevis Peak conservation area is approximately 0.6 miles from the NREI project area.

**Camps Watershed**

Camps Watershed extends from the northern slopes of Nevis Peak to the ocean. The watershed contains Camps Ghaut, springs, freshwater lagoons, and wetlands that feed into the reef system. The watershed, in addition to the Nevis Peak area above 1,000 feet, contains 25 percent of the land area on Nevis (Robinson, 2009). The planned conservation area includes the communities of Fountain, Rawlins, Mt. Lily, Scarborough, Barnaby, and Camps, on the northern side of the island.

**Marine Protected Area**

The proposed marine protected area would include the marine environment that extends from Colquohouns Estate to Potwork Estate. This marine area contains the largest living reef system in the waters surrounding Nevis (Robinson, 2009). The proposed protection project would aim to maintain reef biodiversity, support ecosystem services, improve fisheries, provide tourism opportunities, and return socioeconomic benefits to local communities (CORAL, 2006). The conservation project would manage the conch nurseries, fish nurseries, coral reefs, water sport activities, and anchorage for boats (SKNVibes, 2006).

### 4.7.2 Land Use Impacts

The following sections discuss the potential impacts to land uses from construction and operation of the proposed binary geothermal power plant at the Hamilton Estate.

#### *Land Use Impact 1 – Use of Trust Land for Geothermal Power Generation*

The proposed binary geothermal project would use two parcels of Hamilton Heritage Trust land for power generation. The power generating facilities and two production wells would be located on a 9.1-acre parcel that was formerly a sugar cane field. The injection well would be located on a 1.2-acres parcel adjacent to the former sugar cane works at the Hamilton Estate. Use of this land for power generation would result in public benefits in the form of reduced costs of power and reduced emissions of air pollutants and greenhouse gases. The land at the Hamilton Estates, a former sugar plantation, was previously used for commercial purposes that had an industrial character. Use of this land for the NREI project would be consistent with these former uses and with public charter for the trust.

*Land Use Impact 1 – Low Significance*

**Table 4.7-1**
**SUMMARY OF IMPACTS TO LAND USE**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| Use of Trust Land for Geothermal Power Generation | Continuous | Definite | Site | Long Term | Low | Low |
| Addition of Power Generating Facilities near Residences | Continuous | Definite | Local | Long Term | Moderate | Medium |
| Addition of Power Generating Facilities near Planned Protection Areas | Continuous | Low | Local | Long Term | Low | Low |

### *Land Use Impact 2 – Addition of Power Generating Facilities near Residences*

The geothermal power plant and related facilities would be located near residences at the Hamilton Estate. The closest residence is approximately 570 feet to the northeast of the generating facilities. Other residences are southeast, south, southwest, and west of the project site. The air-cooled binary geothermal power generating facilities would not have any emissions during normal operations and would not need water for cooling. The proposed project would not be visible to the residences to the west and in the outlying areas of Charlestown, but most of the residents to the north, east, and south of the project would be able to see portions of the low-lying plant and pipelines. The facilities would be painted to reduce contrast with the surrounding vegetation (see section 4.2, Aesthetics). The project would include noise reduction measures so that the noise levels at the nearby residences would meet daytime standards, but could be audible at night (see section 4.8, Noise). The presence of the proposed binary project would be noticeable, but would not interfere with the residential use of the adjacent properties.

The undeveloped open space that surrounds the plant site provides a buffer for visual and noise impacts. The adjacent parcels are privately owned. If these parcels were used for additional residential or condominium development, the new development would experience noise impacts at night. As part of its approval of the proposed geothermal project, the NIA should limit the use of the adjacent parcels to commercial and other compatible uses and restrict new residential development within 1,000 feet of the proposed geothermal plant.

The underground transmission line would follow the existing road past residences in Hamilton Estate, Blaziers Estate, Marion Heights, and Stoney Grove. The lines would be underground and would not affect adjacent uses.

*Land Use Impact 2 – Medium Significance*

### *Land Use Impact 3 – Addition of Power Generating Facilities near Planned Protection Areas*

The binary geothermal project at the Hamilton Estate would not impact the planned protection areas in Nevis. Most of the areas are in the norther portion of the island, but portions of the Nevis Peak Area would be 0.6 miles from the plant. As discussed above, the binary projects would have no air emissions, and plant noise levels would be barely audible at this distance. The power plant could be seen from the areas near the peak, but would have no effect on the vegetation and wildlife and the other natural features in the protected area.

*Land Use Impact 3 – Low Significance*

## 4.8 Noise

The following section describes the existing noise conditions at the Hamilton Estate and surrounding areas on Nevis and assesses the noise impacts of the proposed binary geothermal development project on the nearby sensitive receptors.

### 4.8.1 Existing Conditions

The proposed project would be located primarily on two parcels of land at the Hamilton Estate, a former sugar plantation located on the southern part of the Saint Thomas Lowland Parish, on the western side of the island. The NREI binary geothermal power plant and production wells would be located on the 9.1-acre Hamilton Heritage Trust parcel; the injection well would be located on the 1.2-acre Hamilton Stable parcel (see Figure 1.1-2, Proposed Plant Site and Wellfield). The two project parcels are approximately 1.5 miles east of Charlestown, the capital of the Nevis. The proposed transmission intertie route would follow existing roads for 1.7 miles, past residences to the Prospect Power Plant located southeast of Charlestown.

The area surrounding the project parcels contain the remains of the Hamilton Estate sugar works and individual residences or residential areas, which are located to the east, south, and west (see Figure 4.8-1, Residential Receptor Locations). Residential receptors include:

- Receptor A – A private residence located to the northeast of the plant site.
- Receptor B – A cluster of private residences located to the southeast of the plant site. A restaurant is located just north of this area.
- Receptor C – The Carino Condominium and Gardens Complex located south of the plant site and east of the injection well site.
- Receptor D – A government housing project located to the southwest of the plant site and injection well site.
- Receptor E – A private residence located west of the plant site and northwest of the injection well site.

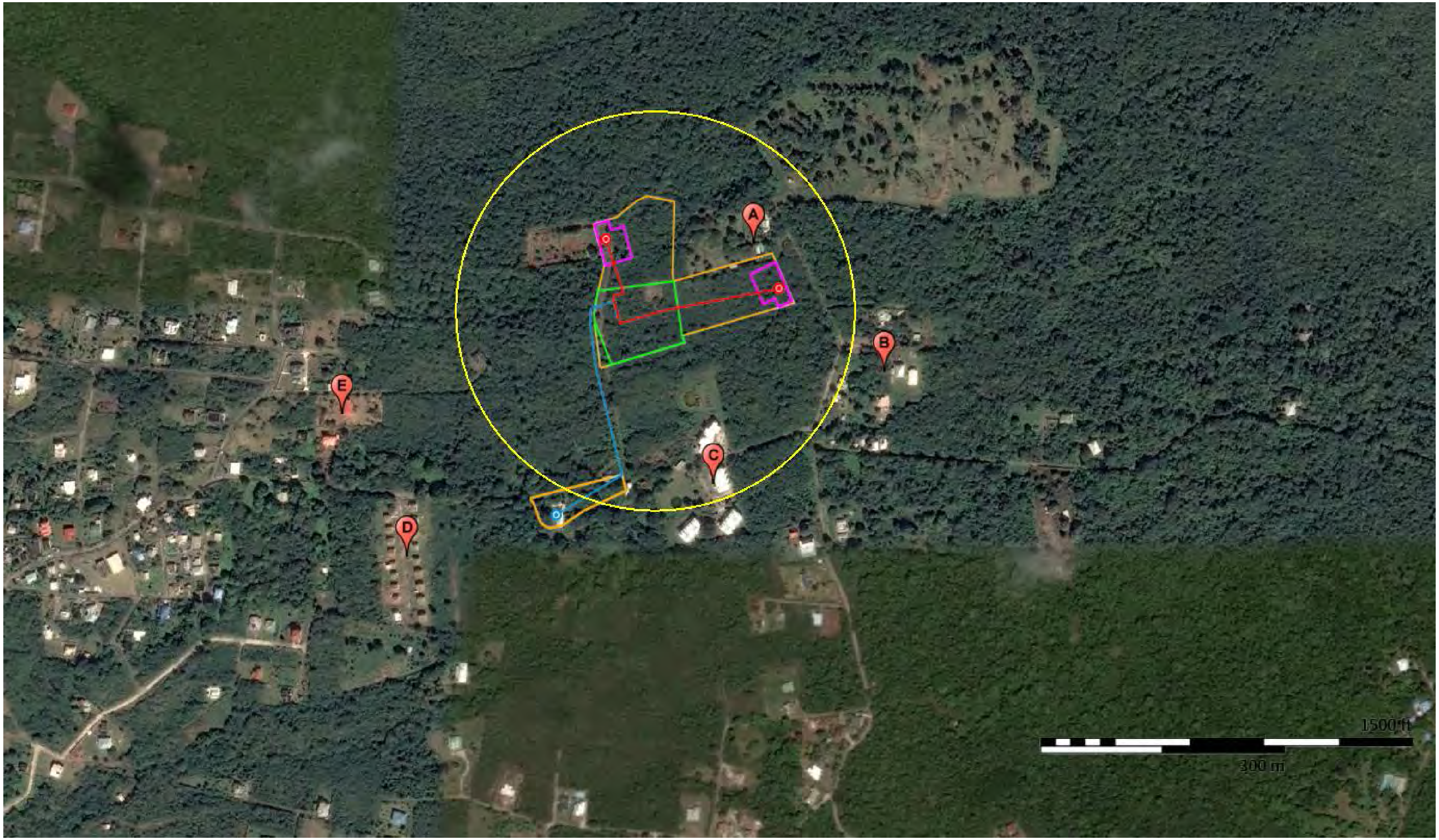
Table 4.1-1 lists the distance between the residential receptors described above and the proposed projects noise sources, including parcel clearing and grading activities, well drilling and venting activities, and the power plant's air cooled condensers, which would be the most substantial source of project noise during plant operation. In general, Receptors A and B are at slightly higher elevations than the project parcels, while Receptors C, D, and E are at slightly lower elevations than the project parcels. While there is no ridge or other topographic feature between the project and surrounding receptors that would shield receptors from project noise, the ground between the project noise sources and Receptors B through E is vegetated and considered acoustically absorptive (i.e., increase attenuation above theoretical estimates).

**Table 4.8-1**
**Nearby Residential Receptors**

| Receptor ID | Distance Between Receptor and Project Noise Sources (Feet)[1] | | |
|---|---|---|---|
| | Parcel Clearing and Grading[2] | Well Drilling and Venting[3] | Plant Air-Cooled Condenser |
| A | 125 | 215 | 575 |
| B | 460 – 760 | 520 – 820 | 920 – 1,220 |
| C | 315 – 475 | 540 – 670 | 575 – 975 |
| D | 400 – 700[(B)] | 600 – 850[(C)] | 1,300 – 1,775 |
| E | 815 | 1,050[(C)] | 1,330 |

1 Distance is based on closest point between the project noise source and the receptor. Where multiple receptors are present in an area, the distance is based on the receptors that are the nearest and farthest from the project noise source.
2 The value provided reflects the distance between the receptor and the closest work area where clearing and grading would occur. Receptors A and B are closest to production well pad clearing and grading activities. Receptors C, D, and E are closest to the injection well site clearing and grading activities.
3 The value provided reflects the distance between the receptor and the closest drill site. Receptors A and B are closest to the eastern production well pad. Receptors C, D, and E are closest to the injection well drilling site.

Existing sources of noise at the Hamilton Estate include local traffic, wind, and other natural sources of noise such as insects and birds. Existing ambient noise levels in the vicinity of the Hamilton Estate are presumed to be low (less than 50 to 55 dBA during the day or lower).




Source: Thermal Energy Partners LLC

**LEGEND**

- Parcel boundary
- Plant site
- Production pipeline
- Pad site
- Wells
- Injection pipeline
- Approximate 45db Contour
- Residential Receptor

N

NREI Binary Geothermal Development Project
FIGURE 4.8-1
RESIDENTIAL RECEPTOR LOCATIONS

### Fundamentals of Acoustics

Noise is generally defined as unwanted sound and is widely recognized as a form of environmental degradation. Airborne sound is the rapid fluctuation of air pressure above and below atmospheric pressure. The frequency (pitch), amplitude (intensity or loudness), and duration of a sound all contribute to the effect on a listener, or receptor, and whether or not the receptor perceives the sound as “noisy” or annoying.

Pitch is the height or depth of a tone or sound and depends on the frequency of the vibrations by which it is produced. Sound frequency is expressed in terms of cycles per second, or Hertz (Hz). Humans generally hear sounds with frequencies between 20 and 20,000 Hz and perceive higher frequency sounds, or high pitch noise, as louder than low-frequency sound or sounds low in pitch. Sound intensity or loudness is a function of the amplitude of the pressure wave generated by a noise source combined with the reception characteristics of the human ear. Atmospheric factors and obstructions between the noise source and receptor also affect the loudness perceived by the receptor. Sound pressure levels are typically expressed on a logarithmic scale in terms of decibels (dB). A dB is a unit of measurement that indicates the relative amplitude (i.e., intensity or loudness) of a sound, with 0 dB corresponding roughly to the threshold of hearing for the healthy, unimpaired human ear.

Sound levels in decibels are calculated on a logarithmic basis. An increase of 10 dBs represents a ten-fold increase in acoustic energy, while 20 dBs is 100 times more intense, 30 dBs is 1,000 times more intense, etc. In general, there is a relationship between the subjective noisiness or loudness of a sound and its intensity, with each 10 dB increase in sound level perceived as approximately a doubling of loudness. Due to the logarithmic basis, decibels cannot be directly added or subtracted together using common arithmetic operations:

$$50\ decibels + 50\ decibels\ \neq 100\ decibels$$

Instead, the combined sound level from two or more sources must be combined logarithmically. For example, if one noise source produces a sound power level of 50 dBA, two of the same sources would combine to produce 53 dB as shown below.

$$10 *\ 10\,log\left(10^{\left(\frac{50}{10}\right)} +\ 10^{\left(\frac{50}{10}\right)}\right)\ = 53\ decibels$$

In general, when one source is 10 dB higher than another source, the quieter source does not add to the sound levels produced by the louder source because the louder source contains ten times more sound energy than the quieter source.

**Sound Characterization and Effects**

There are several methods of characterizing sound. The most common is the A-weighted sound level (dBA). This scale gives greater weight to the frequencies of sound to which the human ear is most sensitive. Representative outdoor and indoor noise levels in units of dBA are shown in Table 4.8-2. Because sound levels can vary markedly over a short period of time, a method for describing either the average character of the sound or the statistical behavior of the variations must be utilized. Most commonly, environmental sounds are described in terms of an average level that has the same acoustical energy as the summation of all the time-varying events. This energy

equivalent sound/noise descriptor is called $L_{Aeq}$. The most common averaging period is hourly, but $L_{Aeq}$ can describe any series of noise events of arbitrary duration.

**Table 4.8-2**
**TYPICAL NOISE LEVELS IN THE ENVIRONMENT**

| Source | Noise level (dBA) |
|---|---|
| Jet fly-over at 300 meters | 120 |
| Pile driver at 20 meters | 100 |
| Gas lawn mower at 30 meters | 70 |
| Active office environment | 55 |
| Quiet rural areas | 30 |
| Wilderness area | 20 |
| Threshold of human hearing | 0 |

Source: Illingworth & Rodkin, Inc. 2010

When considering environmental noise, it is important to account for the different responses people have to daytime and nighttime noise. In general, during the nighttime, background noise levels are generally quieter than during the daytime, and outside noise sources also more noticeable since household noise has decreased as people retire for the day and sleep.

Noise effects on human beings are generally categorized as:

- Subjective effects of annoyance, nuisance, and/or dissatisfaction
- Interference with activities such as speech, sleep, learning, or relaxing
- Physiological effects such as startling and hearing loss

Most environmental noise levels produce subjective or interference effects; physiological effects are usually limited to high noise environments such as industrial manufacturing facilities or airports.

Predicting the subjective and interference effects of noise is difficult due to the wide variation in individual thresholds of annoyance and past experiences with noise; however, an accepted method to determine a person's subjective reaction to a new noise source is to compare it the existing environment without the noise source, or the "ambient" noise environment. In general, the more a new noise source exceeds the ambient noise level, the more likely it is to be considered annoying and to disturb normal activities.

Under controlled conditions in an acoustical laboratory, the trained, healthy human ear is able to discern 1-dB changes in sound levels when exposed to steady, single-frequency ("pure-tone") signals in the mid-frequency (1,000–8,000 Hz) range. In typical noisy environments, changes in noise of 1 to 2 dB are generally not perceptible, but, it is widely accepted that people are able to begin to detect sound level increases of 3 dB in typical noisy environments. Further, a 5-dB increase is generally perceived as a distinctly noticeable increase, and a 10 dB increase is generally perceived as a doubling of loudness that would almost certainly cause an adverse response from community noise receptors.

**Sound Propagation**

The energy contained in a sound pressure wave dissipates and is absorbed by the surrounding environment as the sound wave spreads out and travels away from the noise generating source. The strength of the source is often characterized by its "sound power level." Sound power level is independent of the distance a receiver is from the source and is a property of the source alone. Knowing the sound power level of an idealized source and its distance from a receiver, the sound pressure level at the receiver point can be calculated based on geometrical spreading and attenuation (noise reduction) as a result of distance and environmental factors, such as ground cover (asphalt vs. grass or trees), atmospheric absorption, and shielding by terrain or barriers.

For an ideal "point" source of sound, such as the stationary equipment in a geothermal power plant, the energy contained in a sound pressure wave dissipates and is absorbed by the surrounding environment as the sound wave spreads out in a spherical pattern and travels away from the point source. Theoretically, the sound level attenuates, or decreases, by 6 dB with each doubling of distance from the point source; however, the sound level at a receptor location can be modified further by additional factors. The first is the presence of a reflecting plane such as the ground. For hard ground, a reflecting plane typically increases A-weighted sound pressure levels by 3 dB. If some of the reflected sound is absorbed by the surface, this increase would be less than 3 dB. Soft ground cover such as vegetation may reduce sound pressure levels by approximately 1 or 2 dBs. Other factors affecting the predicted sound pressure level are often lumped together into a term called "excess attenuation." Excess attenuation is the amount of additional attenuation that occurs beyond simple spherical spreading. For sound propagation outdoors, there is almost always excess attenuation, producing lower levels than what would be predicted by spherical spreading. Some examples include attenuation by sound absorption in air; attenuation by barriers; attenuation by rain, sleet, snow, or fog; attenuation by grass, shrubbery, and trees; and attenuation from shadow zones created by wind and temperature gradients. Under certain meteorological conditions, like fog and low-level clouds, some of these excess attenuation mechanisms are reduced or eliminated due to noise reflection.

### 4.8.2 Noise Impacts

This section evaluates the impacts of noise that would result from the development and operation of the project. Noise sources associated with the geothermal power project would include the development of the well pads, construction of the plant site, and operation at the plant site. The potential impacts of the project from noise are summarized in Table 4.8-3.

**Table 4.8-3**
**SUMMARY OF IMPACTS FROM NOISE**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| Temporary Increase in Noise Levels during Construction | Frequent | Definite | Local | Medium Term | Moderate | Medium |
| Increased Ambient Noise Levels during Operation | Continuous | Definite | Local | Long Term | Moderate | Medium |
| Temporary Increase in Noise Levels during Decommissioning | Rare | Probable | Local | Short Term | Moderate | Low |

### Guidelines

The NREI geothermal project would follow the IFC Environmental, Health, and Safety (EHS) guidelines for noise management. The EHS guidelines indicate that project noise levels should not exceed 55 dBA during the day (7:00 am – 10:00 pm) and 45 dBA at night (10:00 pm – 7:00 am) at the property line closest to the geothermal energy system and at residential facilities.

### Construction

Project construction is anticipated to last up to 18 months and would involve the use of heavy equipment to clear and grade project parcels, construct the well pads and plant foundations, drill the two production wells and one injection well, perform well testing, install the aboveground production and injection pipelines, assemble and install power plant equipment and related facilities (e.g., control room), and trench and install the underground transmission intertie line. In general, project construction would proceed in phases in which one activity is finished before the next activity begins (e.g., clearing and grading would be completed before well pads are constructed); however, some phases could overlap slightly.

Project construction could temporarily increase noise levels at residential receptors near the NREI plant site and transmission line intertie route. Potential project construction equipment noise levels were evaluated at these land uses based on published noise data and the information contained in the project description regarding the proposed project's construction activities. Table 4.8-3 lists the typical equipment that could be used during project construction activities and the corresponding noise levels associated with the equipment / construction activity.

**Table 4.8-4**
**TYPICAL CONSTRUCTION EQUIPMENT NOISE LEVELS**

| Equipment / Activity | Reference Noise Level at 50 Feet (Lmax)[2] | Percent Usage Factor[3] | Predicted Noise Levels (Leq) at Distance (in Feet)[1] | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 50 | 125 | 250 | 375 | 500 | 1,000 |
| **General Construction** | | | | | | | | |
| Bulldozer | 85 | 40 | 81 | 73 | 67 | 64 | 61 | 55 |
| Backhoe/Loader | 80 | 40 | 76 | 68 | 62 | 59 | 56 | 50 |
| Excavator | 85 | 40 | 81 | 73 | 67 | 64 | 61 | 55 |
| Pneumatic tools | 85 | 50 | 82 | 74 | 68 | 64 | 62 | 56 |
| Scraper | 85 | 40 | 81 | 73 | 67 | 64 | 61 | 55 |
| Delivery Truck | 85 | 40 | 81 | 73 | 67 | 64 | 61 | 55 |
| Well Drilling (with mud) | 86 | 100 | 86 | 78 | 72 | 68 | 66 | 60 |
| **Well Drilling and Testing** | | | | | | | | |
| Well Drilling (with mud) | 86 | 100 | 86 | 78 | 72 | 68 | 66 | 60 |
| Well Cleanout | 81 | NA | 81 | 73 | 67 | 70 | 61 | 55 |
| Flow Testing | 85 | NA | 85 | 77 | 71 | 68 | 65 | 59 |
| Well Venting (1 hour or less) | 106 | NA | 106 | 98 | 92 | 88 | 86 | 80 |

Sources: Caltrans, 2009; FHWA, 2010;.

1. Estimate does not account for any atmospheric or ground attenuation factors. Calculated noise levels based on Caltrans, 2009: $L_{eq}$ (hourly) = $L_{max}$ at 50 feet – 20log (D/50) + 10log (UF), where: $L_{max}$ = reference $L_{max}$ from manufacturer or other source; D = distance of interest; UF = usage fraction or fraction of time period of interest equipment is in use.
2. $L_{max}$ noise levels based on manufacturer's specifications.
3. Usage factor refers to the amount of time the equipment produces noise over the time period.

### *Noise Impact 1 –Temporary Increase in Noise Levels during Construction*

As shown in Table 4.8-3, the worst-case Leq and Lmax construction noise levels for non-drilling equipment are predicted to be approximately 82 and 85 dBA, respectively, at a distance of 50 feet from the equipment operating area. The magnitude of the project's actual temporary increase in ambient noise levels during construction, however, would depend on the specific construction activity (e.g., clearing and grading or drilling) and the distance between the construction activity and the receptor location, as follows:

- **Site Clearing and Grading / Well Pad and Building Foundation Work:** Clearing, grading, and well pad / plant foundation work would require equipment such as a bulldozer, loader, scraper, compactor and trucks. All clearing, grading, and pad/foundation work would occur at least 125 feet or more from the closest residential receptor (Receptor A) and could produce noise levels of approximately 68 to 73 dBA from a single piece of equipment;

the concurrent operation of two or more pieces of equipment would result in noise levels that are approximately 3 to 4 dBA higher[1]. Most receptors would be located 375 feet or more from clearing and grading work, where the concurrent operation of two or more pieces of equipment would produce noise levels of approximately 62 to 67 dBA.

- **Well Drilling:** Drilling operations would include the actual drilling itself, placing the drill pipe into the hole, and pulling the pipe out. Drilling would continue 24 hours a day for an estimated 40 days at each production and injection well site. Primary noise sources would be the internal combustion engines and motors associated with the drilling equipment. Mud would circulate through the drill pipe using a mud pump. With the exception of Receptor A, which would be located 215 feet from the eastern well pad, all receptors would be located at least 500 feet or more from each drill site. At this distance (500 feet), drilling with mud would generate a noise level of approximately 66 dBA. At a distance of 215 feet, well drilling would generate noise levels of approximately 71. NREI would reduce noise levels at residential receptor locations by installing a temporary sound barrier or earthen berm capable of achieving up to a 21 dB reduction in construction noise.

- **Well Testing:** Once drilling is complete, steam venting would be required to clean out the well. While the wells would be vented for a day or two, the initial cleanout, in which the wells would be vented directly to the atmosphere to clean debris from the well and produce the highest sound levels, would last only a few hours. Following this initial cleanout, the wells would vent through the steam separator, gradually increasing in flow. During the initial cleanout, when the well is vented directly to the atmosphere, the noise level could reach 91 dBA at a distance of 215 feet and 86 dbA at a distance of 500 feet. Several methods are available to reduce noise during this initial well cleanout period, including expansion of the pipe diameter (diffuser), injection of water into the steam, and use of temporary rock mufflers. These methods can reduce noise during well cleanout by 20 – 50 dB. NREI would reduce noise levels from well cleanout by incorporating one or more of these methods into well cleanout operations. With these methods in place, noise levels would be reduced to 71 dBA and 66 dBA at worst case, respectively, for the few hours when well-cleanout would occur. Noise levels during the remaining testing, when venting occurs through the separator, would be much lower.

- **Production and Injection Pipelines:** Production and injection pipelines would carry geothermal fluid from the well pads to the power plant (for the production wells) and from the plant to the injection well). Construction of the pipelines would involve the use of bulldozers, trucks, welding equipment, and other equipment to install the above ground pipelines. In general, this equipment would be slightly quieter than the equipment used to clear and grade the site and conduct the well pad/foundation work. In addition, because the pipeline construction would proceed linearly, concurrent equipment operation is not anticipated (i.e., the route would be cleared and then pipelines welded and installed).

[1] This estimate assumes two or more large pieces of equipment such as a bulldozer operating at the same time. As shown in Table 8-5, a single bulldozer produces a sound level of 62 dBA at 450 feet; when two or more identical sound levels are combined the total noise level increases by 3 dBA.

Pipeline construction noise levels would be approximately 5 to 7 dBA lower than that estimated for clearing and grading due to less load on the equipment, less overall equipment operation, and slightly longer distances between the pipeline route and residential receptors. Thus, pipeline construction would range from approximately 55 to 62 dBA at receptor locations.

Prior to connection of the wells to the plant for the first time the pipes would be cleaned out by venting geothermal fluid to the atmosphere. This one-time event that would generate noise levels similar to the levels that would be generated at the wells during clean-out (71 dBA at 215 feet, which would last only a few few hours).

- **Power Plant Site:** Assembly and installation of the power plant equipment and related facilities would use material lifts, forklifts, pneumatic tools, and possibly a loader or other heavy duty piece of equipment to move materials around the site. This equipment would produce back-up alarm noises; however, equipment assembly and installation is not anticipated to produce noise levels similar to clearing and grading activities. Rather, due to smaller equipment, the intermittent nature of the equipment uses, and the greater distance between the plant site and receptor locations, power plant construction noise is estimated to be 5 to 7 dBA less than that associated with clearing and grading. Thus, power plant construction noise levels would range from approximately 55 to 62 dBA at receptor locations and would typically occur during the day.
- **Transmission Intertie Line:** Installation of the transmission would involve construction equipment to trench and install the transmission line underground. Construction equipment noise would be similar to the construction associated with the production and injection well pipelines (55 to 62 dBA), but would be very short in duration (lasting just a few days at each point along the transmission intertie route).

As described above, project construction would result in short-term and intermittent increases in noise during the 17-month construction period. This increase in noise would be greatest during site clearing and grading and well pad / plant foundation work as well as well drilling venting activities. Due to the proximity of nearby receptors, the noise generated by most construction activities would have the potential to exceed the daytime 55 dBA $L_{Aeq}$ guideline; however, NREI has incorporated the best management practices listed below into the project to reduce potential construction equipment and activity noise level intrusion at nearby residential receptors.

Construction Noise Best Management Practices

- Install an earthen berm or temporary sound wall between drilling locations and residential receptor locations within 1,000 feet of the drill rig capable of providing up to 21 dB of noise reduction.
- Provide receptors within 1,000 feet of the project parcels written notice prior to the start of construction that describes the approximate schedule for the construction activities and a contact name and phone number for the construction contractor and NREI staff person responsible for handling construction-related noise complaints.
- Provide receptors within 1,000 feet of drilling sites at least one week's advance written notice of the start of well drilling, well venting, and well testing activities.

- Use a silencer or rock muffler during all well venting activities, including initial cleanout, as feasible.

Temporary construction noise levels above the 55 dBA guideline would be short-term and intermittent in nature and would only impact local receptors. Most construction activities would be limited to daytime hours only. Drilling activities, however, would occur continuously for an estimated 40 days at each well location and would therefore result in noise levels above both daytime and nighttime guidelines (55 dBA and 45 dBA, respectively). NREI has incorporated practices to reduce equipment noise, provide notification to receptors, and resolve noise-related complaints to address potential project noise levels.

*Noise Impact 1 – Medium Significance*

### Operation

During operation, noise sources would include the power plant equipment, pipelines, and venting during startup and shutdowns. NREI information provided by the plant manufacturer, Turboden, indicates the binary plant would produce noise levels of approximately 100 dB at a distance of 3 feet from the air-cooled condensers, which are expected to be the primary noise generator at the plant, and approximately 71 dBA at a distance of 85 feet from the condenser. This rate of attenuation is consistent with the theoretical calculations for a point noise source, in which sound attenuates at approximately 6 dBA for each doubling of distance from the noise source. The estimates presume maximum plant operation (full gross electrical generation capacity and operation of all 16 air-cooled condenser cells).

#### *Noise Impact 2 – Increased Ambient Noise Levels during Operation*

The magnitude of the project's long-term increase in ambient noise levels from project operation would be as follows:

- **Power Plant Equipment:** As noted, during normal operations the proposed power plant would generate noise from equipment operation including but not limited to the steam separator, turbine-generators, condensers, and various pumps. NREI and Turboden indicate the 16-cell air-cooled condenser, which would use large fans to force air over thin fins containing the binary system's working fluid, would produce the highest equipment noise levels. During peak plant operations, power plant noise is estimated to be 71 dBA at a distance of 85 feet from the condenser. Peak operations would occur during the day time. At nighttime, when electrical demand is lower, NREI may be able to reduce the number of condenser units in operation – as many as 10 of the 16 units may be able to be taken offline, reducing power plant noise to approximately 65 dBA at a distance of 85 feet during nighttime conditions. Table 4.8-5 summarizes the power plant noise levels during normal daytime operations and nighttime operations with potential noise controls.

**Table 4.8-5**
**NOISE LEVELS DURING OPERATION OF THE POWER PLANT SITE**

| Receiver ID | Distance from Air-Cooled Condenser (Feet) | Maximum Daytime / Nighttime Received Level ($L_{Aeq}$) | Excess Above IFC EHS Guidelines (dBA) | |
|---|---|---|---|---|
| | | | Daytime 55 $L_{Aeq}$ | Nighttime(1) 45 $L_{Aeq}$ |
| A | 575 | 54/48 | -- | 3 |
| B | 920 – 1,220 | 50/44 | -- | -- |
| C | 575 – 975 | 54/48 | -- | 3 |
| D | 1,300 – 1,775 | 47/41 | -- | -- |
| E | 1,330 | 47/41 | -- | -- |

Source: Modified by MIG (2017) from Thermal Energy Partners, Turboden 2017
(1) Nighttime noise levels are based on reduced condenser operations and would be approximately 6 dB higher with all condenser units operating.

- **Pipelines:** Pipelines are not a significant source of noise in operation. Noise levels have been measured at 60 dBA at a distance of 10 feet and about 50 dBA at a distance of 100 feet. At the nearest receivers, noise from the resource flowing through the pipeline is calculated to be approximately 40 dBA.
- **Plant Shutdowns:** Shutdowns would occur for overall maintenance of the plant and during upsets. Planned shutdowns would occur approximately every two years. Unplanned shutdowns could occur periodically. Given the configuration of the two 5-MW of binary plants and the two closed system loops, such shutdowns would be rare. If one occurs, steam would vent through the rock muffler until the operators shut in the wells, typically within an hour. In the event the steam separator overpressures a safety relief valve, located upstream of the separator, would vent through a rock muffler at the brine containment sump. Steam venting noise would be less than 40 dBA at noise sensitive receiver locations due to the low velocity of the steam flow.

The operation noise from the geothermal power plant and related facilities would be below the daytime guidelines. The daytime noise estimates are based on maximum plant operating conditions (full power output) during the day. The geothermal plant is unlikely to operate at full capacity under nighttime conditions since demand for electricity drops during the nighttime period. Furthermore, the 2016 fluctuation in peak demand on the NEVLEC System (6.4 to 8.7 MW, see Section 3.15) is less than the NREI plant's net generating capacity (9 MW). During the nighttime hours, when ambient air is cooler and would more efficiently cool and condense the cyclopentane working fluid, NREI may reduce fan speeds which would reduce condenser noise and plant energy consumption. NREI also anticipates up to 10 condenser units could be taken offline during the nighttime period. Nonetheless, even under this scenario, receptors within 900 feet of the geothermal power plan could be exposed to noise level in exceedance of the nighttime guidelines (45 dBA). Receptors A and C could be exposed to nighttime plant noise levels as much as approximately 3 dBA above the

guideline, while Receptors B, D, and E would be exposed to nighttime plant noise levels below the guideline.

NREI has designed the project to reduce and avoid potential operational noise levels in excess of 55 dBA during the day and 45 dBA during the night as much as possible by: 1) maximizing the distance between the condenser units and residential receptors; 2) installing air-cooled condenser units with variable speed drives capable of reducing sound power levels associated with fan operation while safely and efficiently providing daytime and nighttime electrical load requirements; 3) reducing the amount of air-cooled condensers operating during the nighttime period (10 PM to 7 AM) to the minimum amount necessary to safely and efficiently provide necessary electrical load requirements; and 4) Planting trees and other dense vegetation between the plant and residential receptors within approximately 900 feet of the condenser units to increase soft ground cover and potential attenuation of noise levels. In addition, NREI has incorporated the best management practices listed below into the project to resolve any noise related complaints.

<u>Operational Noise Best Management Practices</u>

Following receipt of an operational noise complaint, NREI and the NIA may first elect to conduct ambient noise monitoring to verify noise levels at the affected receptor. Once noise levels are verified, NREI would coordinate with the NIA as necessary to identify additional measures and activities that could be undertaken to reduce and avoid potential operational noise levels in excess of 55 dBA during the day and 45 dBA during the night as much as possible. Such measures and activities may include:

- Installing permanent sound barriers between the plant and receptor locations within 900 feet of the condenser to absorb and/or reflect plant noise away from residential receptor locations.
- Retrofitting occupied buildings to increase interior building attenuation.
- Other measures or conditions agreed to by NREI and the NIA.

*Noise Impact 2 – Medium Significance*

### *Decommissioning*

As noted in Section 3.14, the operating agreement between NREI and NEVLEC calls for NREI to turn the plant over to NEVLEC, which would then have the responsibility to decommission the plant when it is no longer needed.

### *Noise Impact 3 –Temporary Increase in Noise Levels during Decommissioning*

Decommissioning would involve similar equipment and activities as described for the clearing and grading, well pad / plant foundation work, and power plant construction. These temporary activities would produce noise at or just above the 55 dBA guideline; however, decommissioning activities would be shorter in total duration and occur only during the daytime. Potential decommissioning noise is not anticipated to be a substantial intrusion at nearby receptors locations.

*Noise Impact 3 – Low Significance*

## 4.9 Public Health and Safety

The following section discusses the existing public health and safety risks of the site and the potential impacts to public health and safety from the proposed binary geothermal project.

### 4.9.1 Existing Conditions

Nevis is a volcanic island in the Caribbean that is at risk of impacts to public health and safety and property damage from hurricanes, earthquakes, and volcanic activity. Hurricanes are the most common natural disaster to strike the island. Nevis has experienced several severe hurricanes in recent years that have resulted in expensive and widespread damage. Major hurricanes affecting the island in recent years include Hurricane Igor on September 16-20, 2010; category 2 Hurricane Earl on August 30, 2010, Hurricane Omar on October 6, 2008, category 3 Hurricane Georges on September 21, 1998, and category 4 Hurricane Louis on September 4-5, 1995 (NOAA, 2010).

A hazard vulnerability assessment conducted following Hurricane Georges found that Nevis has a ten percent chance, in any 50-year period, of experiencing wind speeds above 145 mph (OAS, 2001a). The project site is located at mid-elevation in the wind shadow of Nevis Peak. Wind speed models show that the site has a lower wind risk than much of the island. The project site is also not at risk for flooding or storm surges. Hurricanes can cause structural failure, disrupt public services, and damage and wash out roads. The Four Seasons Resort, a major employer on the island, has repeatedly closed due to hurricane damage; a closure following Hurricane Omar caused the NIA to declare a national emergency (Coolidge, 2010). Nevis implemented new building codes after Hurricane Georges to decrease the risk and severity of property damage (OAS, 2001b).

Nevis is located within the highest risk zone for earthquakes within the Eastern Caribbean. Major earthquakes in 1950, 1842, and 1690, with estimated magnitudes of 6.3, 6.9, and 6.9 respectively caused widespread damage (OAS, 2001a). Recent earthquakes to affect Nevis include a 7.4 magnitude earthquake in 2007 with an epicenter just north of Martinique about 170 miles away, and a 6.3 magnitude earthquake in 2004 with an epicenter south of Guadeloupe, about 120 miles away (USGS, 2010). See the Soils, Geology and Minerals section for detail on the seismicity of Nevis. Hurricanes and earthquakes can injure or kill people from structural collapse and wind damage. Hurricanes and earthquakes can also disrupt public services and utilities and decrease the response time for emergency services and aid.

Nevis is a volcanic island with active volcanic and geothermal features including fumaroles and hot springs; the most recent volcanic eruption occurred 100,000 years ago (Global Volcanism Program, 2010). An eruption would likely be effusive and dome-forming, like the currently active Soufriere Hills volcano on Montserrat, rather than explosive and magmatic (UWISRC, 2009d). In the event of an eruption, residents and visitors could experience pyroclastic flows, ash fall, ballistic projectiles, and magma flows. Like the eruption of the Soufriere Hills volcano, an eruption of Nevis Peak could destroy urban and rural settlements. Nevis could also experience ash fall from an eruption of Mt. Liamuiga on nearby St. Kitts. See the Soils, Geology, and Minerals section for more detail on the volcanism of Nevis.

### 4.9.2 Public Health and Safety Impacts

The following section describes the potential impacts of the proposed binary geothermal project to public health and safety. Table 4.13-1 summarizes these impacts.

**Table 4.9-1**
**SUMMARY OF IMPACTS TO PUBLIC HEALTH AND SAFETY**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| Risk of Well Blowout | Rare | Low Potential | Local | Short Term | Moderate | Low |
| Risk of Hazardous Materials or Geothermal Fluid Release | Rare | Low Potential | Local | Short Term | Moderate | Low |
| Damage from Hurricanes, Earthquakes, and Volcanic Activity | Infrequent | Possible | Regional | Short Term | High | Medium |

### *Public Health and Safety Impact 1 –Risk of Well Blowout*

Geothermal wells have a relatively low risk of blowout, which would result in an unexpected, sudden release of steam and hot water. NREI would install blowout prevention equipment (BPE) that would shut in the wells automatically if the pressure exceeds the design limits of the valves and casing. Blowouts can occur because of a landslide or other natural geologic event, and an earthquake or volcanic activity could increase the likelihood of well blowout. In the event of a well blowout, the uncontrolled release of steam and gases would be seen and heard in the surrounding areas, but would not affect public health or safety. At the concentrations measured in 2008, an uncontrolled release of hydrogen sulfide from a well could result in odors in downwind communities, but are not expected to reach levels that produce adverse health effects. (See the discussion of hydrogen sulfide in section 4.4, Climate and Air Quality). If a blowout were to occur, workers would shut in the well, take measures to contain fluids, and, if not contained within a few minutes, notify the public of the release and associated risks. The hazards and hazardous materials section describes impacts of well blowouts in more detail.

*Public Health and Safety Impact 1 – Low Significance*

### *Public Health and Safety Impact 2 –Risk of Hazardous Materials or Geothermal Fluid Release*

The NREI binary geothermal project has been designed to prevent risk to the public from accidental release of hazardous materials or geothermal fluids.

Hazardous materials such as sulfuric acid, sodium hydroxide, and hydrogen chloride would be stored in designated areas with impervious surfaces designed to contain potential spills. The cyclopentane used as a working fluid would be stored in drainage tanks adjacent to the Turboden binary equipment. The binary equipment and air coolers would be on an impervious surface with

secondary containment designed to contain the 18,000 gallons of cyclopentane would be in the binary vessels and storage tanks at the plant site. Cyclopentane is a liquid at ambient conditions and would not vaporize if spilled. Thus, cyclopentane does not require an offsite consequences analysis. Thus, if there were an accidental release of cyclopentane or other hazardous materials, the materials would be contained on site and would not pose a risk to the public.

Cyclopentane is highly flammable, and the proposed project includes fire protection equipment that would consist of a fresh-water tank, an electric firewater supply pump and a jockey pump, fire mains, and local hose and spray stations.

The proposed NREI project would also include a lined pond that would be able to contain accidental release geothermal brine at the plant site. The 350,000-gallon pond is large enough to contain two hours of brine at maximum flow rates. If an accidental release were to occur, workers would shut in the binary unit or well causing the accident, typically in less than an hour.

NREI would install cyclopentane and hydrogen sulfide monitors on site to protect workers from accidental releases. These monitors have safety alarms that warn workers if concentrations exceed maximum exposure limits. The proposed binary geothermal project would be more than 570 feet from the nearest public receptors, and any public exposure would be substantially lower than these levels. Thus, the alarms would also serve to protect the public health and safety from any accidental releases of these substances.

*Public Health and Safety Impact 2 – Medium Significance*

### *Public Health and Safety Impact 3 –Damage from Hurricanes, Earthquakes, and Volcanic Activity*

NREI has designed the plant to reduce potential impacts of the proposed project to public health and safety in the event of a hurricane, earthquake, volcanic eruption or other natural disasters. These events could disrupt plant operation, damage plant equipment, and cause hazardous conditions at the plant and in surrounding areas.

NREI would engineer and design the proposed facilities to meet all applicable structural, electrical, and seismic and wind loading design criteria of the latest International Building Code (IBC; currently the 2015 IBC). See the discussion of earthquakes and ground shaking in section 4.12, Soils, Geology, and Minerals.

NREI would design the plant to withstand winds of up to 150 mph. NREI would prepare a Hurricane Response Plan and would train workers to respond appropriately in an emergency. As part of the response plan, NREI would establish criteria for when wells would be shut in and power generation would stop.

The proposed 10-MW NREI binary plant would serve the entire NEVLEC electrical load and loss of power to the island would amplify the effects of a hurricane, earthquake, or natural disaster to the public health and safety. The project has two production wells, two 5-MW binary units, and an underground transmission line. Each binary unit has been designed to operate to withstand the forces of predicted events. If one well needs to be shut down, the maximum flow of geothermal in the other well would be able to provide power for both units. If one unit goes down, NEVLEC has

a backup facility at its Prospect Power Plant. The underground line would protect against outages from hurricane winds and other disasters.

*Public Health and Safety Impact 3 – Medium Significance*

## 4.10 Recreation

The following section describes the recreation conditions at the proposed site and surrounding areas on Nevis and assesses the impacts of the proposed binary geothermal development project on the recreational resources of the island.

### 4.10.1 Existing Conditions

The relatively rural and undeveloped character of Nevis, its verdant vegetation, and unusual wildlife make it a destination for outdoor recreation. The island provides opportunities for tourists and locals alike to enjoy a wide range of outdoor activities, including hiking, biking, horseback riding, site-seeing, wildlife observation, and aquatic sports.

Hiking is a popular way to explore the lush rainforests, green hillsides, and spectacular views of Nevis. The NHCS publishes a hiking guide, which is available for purchase at either of the museums on Nevis. Some of the most popular hikes are to Nevis Peak, Round Hill, Saddle Hill, and the spring that is the source of Nevis' fresh water. Sunrise Tours offers a hike within the Hamilton Estate that includes part of the Upper Round Trail, a trail developed by the Nevis Historical Society at the 1000-foot elevation, also approximately 0.7 miles from the site. The Mountravers Loop from Four Seasons Villas is approximately 0.7 miles north of the plant sites.

Guided tours draw attention to the unique flora and fauna on Nevis, or to historical sites, including churches, springs, and plantation ruins (TravelATW, 2010). Roads and trails all over the island are also well-suited for mountain biking and are lightly traveled. Trail and beach rides are also available for those who prefer to explore the island on horseback (Outdoor Business Group Limited, 2009).

Nevis plays host to some remarkable wildlife. Visitors can watch whales, birds, and other creatures in their natural habitats. There are well over 100 species of birds that can be seen on Nevis, most of which Paul Hilder documents in his guidebook, *The Birds of Nevis*, available at the Museum of Nevis History (Gideon Cardozo, 2009). Visitors may observe land crabs, butterflies, frogs, geckos, and non-native mongooses and vervet monkeys while exploring the island (Jim Johnson, 2010). There are four species of sea turtles that nest on the shores of Nevis and can be found in surrounding waters. Supervised groups can watch the unusual spectacles of sea turtle nesting and hatching. The waters around Nevis also play host to marine mammals. Humpback whales pass by Nevis from January to April, and pilot, sperm, fin, sei and minke whales, bottlenose and spinner dolphins stay year-round. One can explore the ocean and observe the marine life by going snorkeling or SCUBA diving (lessons are available), or by boat. Some whales can also be seen from a telescope installed on Saddle Hill (Gideon Cardozo, 2009).

The island of Nevis has many resources for sports activities. The hotels offer tennis courts and beach volleyball; the internationally-renowned Robert Trent Jones II Golf Course is located near The Four Seasons resort. Many of Nevis's coastal areas are well-suited for water sports. Oualie Beach is the wind-surfing hub of St. Kitts and Nevis, while the sheltered Pinney's Beach is more popular for kayaking, snorkeling, and swimming. Guests can rent snorkel, SCUBA and windsurfing

gear, as well as surfboards, kayaks, and other equipment, at sports shops near Oualie Beach (Outdoor Business Group Limited, 2009).

### 4.10.2 Recreation Impacts

The following section discusses impacts to recreation from the construction and operation of a binary geothermal power plant at the Hamilton Estate. Impacts to the Nevis landscape are discussed in Section 4.2, Aesthetics; impacts to biological resources are discussed in Section 4.3, Biology; and impacts to Cades Bay are discussed in Section 4.14, Water Resources.

**Table 4.10-1**
**SUMMARY OF IMPACTS TO RECREATION**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| Disturbance to Hikers and Mountain Bikers | Frequent | Probable | Local | Short/Long Term | Low | Low |
| Disturbance to Beach Enjoyment and Water Sports | Rare | No Impact | Local | Long Term | Very Low | Low |

#### *Recreation Impact 1 – Disturbance to Hikers and Mountain Bikers*

The proposed project would not result in a disturbance to hikers and mountain bikers. The nearest trails are the Mountravers Loop from the Four Seasons Villas and the Upper Loop Trail, both approximately 0.7 miles from the plant site. At this distance, hikers and mountain bikers could view the landscaped geothermal facilities amid the surrounding vegetation, but would not be likely to hear noise from the operation of the plant. The presence of the binary plant would be an additional developmental feature in the forested area, similar to the few residences at these elevations. The geothermal plant in a former sugar cane field would not affect the wildlife or natural features that draw hikers to these trails. The transmission line would be underground and would not affect recreational uses.

*Recreation Impact 1 – Low Significance*

#### *Recreation Impact 2 – Disturbance to Beach Enjoyment and Water Sports*

The operation of the plant is not likely to be noticeable from the water recreation areas at Charlestown and Pinney's Beach, so there would be little if any impact to beach front recreation activities.

*Recreation Impact 2 – Low Significance*

## 4.11 Socioeconomics and Environmental Justice

The following section describes the socioeconomic and environmental justice conditions of the proposed site and surrounding areas on Nevis and assesses the impacts of the proposed binary geothermal project on socioeconomic and environmental justice resources of the island.

### 4.11.1 Existing Conditions

The following section describes the existing socioeconomic conditions on Nevis, including tourism, agriculture, tax revenue, and employment.

The Federation of St. Kitts and Nevis (combined area: 100 square miles, population: 40,131) is a small island developing state in the Eastern Caribbean (CIA). The citizens of St. Kitts and Nevis enjoy a high standard of living relative to the region. A colony of England until 1983, the Federation of St. Kitts and Nevis is part of the British Commonwealth and adheres to English common law. A unicameral parliament governs St. Kitts and Nevis; Nevis holds three of the 11 seats. As part of a federation, the island of Nevis (area: 36 square miles, 2011 population: 12,277) enjoys a measure of independence and can secede from the country with a two-thirds vote in referendum (Department of Finance, 2017). The local government of Nevis, composed of the Nevis Island Assembly and the Nevis Island Administration (NIA), has autonomy except with regards to foreign affairs, defense and some aspects of economic policy. Informed citizens participate frequently in government (Federation of St. Kitts and Nevis, 2004).

The island of Nevis was inhabited by Amerindians as early as 2000 BC, but their presence on the island ended in the seventeenth century following the arrival of European settlers (Lowery, 2010). In the early colonial period, settlers imported African slaves to work on sugar plantations. Great Britain abolished the slave trade in 1807 and slavery throughout the British Empire in 1833 (Britannia, 2005). As of the 2001 census, 92.5 percent of the population of St. Kitts and Nevis identified as black (Afro-Caribbean), 3.0 percent identified as being of mixed heritage, and 2.1 percent identified as white; 1.5 percent identified as East Indian. Less than one percent identified as Chinese, Portuguese, Syrian, Lebanese, or other. Indigenous people comprise 0.03 percent of the population (CARICOM Secretariat, 2009).

Traditionally, the sugar industry, nationalized in 1975, dominated the economies of St. Kitts and Nevis, but it closed in 2005 after declining for decades (Avameg, 2010). Today, construction, government services, manufacturing, and banks and insurance make the largest contribution to the gross domestic product (GDP), and tourism is the largest foreign exchange earner. On Nevis, The Four Seasons hotel is the largest employer and accounts for approximately 40 percent of the island's GDP. It employs about a fifth of the population directly and 35 to 40 percent indirectly. In addition to The Four Seasons Hotel, many smaller hotels, inns, and recreational centers, including the Robert Trent Jones II Golf Course, also serve tourists. Tourist destinations are concentrated on the coastlines, particularly along the Western shore of the island at Pinney's Beach.

While the economy of St. Kitts and Nevis has shown better than average rates of growth, it is vulnerable to shocks. The country has also been hit by several hurricanes in recent years that have caused hotel closures and extensive property damage.

As the economy of St. Kitts and Nevis transitions towards the service, information, and finance sectors, the government is making a strong commitment to education. The country of St. Kitts and Nevis has a high literacy rate of 97.8 percent (CIA, 2010) and spends 9.3 percent of its GDP on

education. The government aims to transform St. Kitts and Nevis into a highly trained "information society" (Government of St. Kitts and Nevis, 2006). Universal education is free through the secondary level, and children must attend school until age 16 (UNESCO, 2008; CIA, 2010). Nevisians can obtain tertiary education at the Sixth Form College on Nevis or overseas with the assistance of government scholarships (Pan American World Health Organization, 2008).

The health statistics for St. Kitts and Nevis are among the highest in the region. Citizens suffer from the lifestyle and degenerative diseases of the developed world rather than the sanitation-related diseases of the developing world. Circulatory diseases are the leading cause of death, and cancer is the third leading cause of death. As of 2001, 98 percent of citizens had access to piped water, 90 percent to disinfected water, and 97 percent to excreta disposal. Health care is universal (and free for many groups) and highly accessible; every house is within three miles of a clinic. In addition to clinics, the 50-bed Alexandra hospital in Charlestown provides advanced care (Pan American World Health Organization, 2008).

A 2008 study on St. Kitts by the Caribbean Development Bank (not including Nevis, though Nevis likely has similar statistics) found 23 percent of the population living in poverty. However, the government has raised the minimum wage substantially since the data for the report was collected, and officials now estimate the poverty level to be closer to 15 percent. Unemployment in St. Kitts is among the lowest in the region at 6.3 percent and 1.4 percent of the population (both St. Kitts and Nevis) is indigent (Nevis Blog, 2009c; Nevis Pages, 2010).

Unlike St. Kitts, where much of the population lives in the urban area of Basseterre, the population of Nevis lives predominantly in rural areas. The island of Nevis has five parishes: Saint Thomas Lowland; Saint James Windward; Saint Paul Charlestown; Saint John Figtree; and Saint George Gingerland. The largest cities and towns are Charlestown (population: 1,538), Gingerland (population: 493), Newcastle (population: 493), and Cotton Ground (population: 381) (Mongabay, 2009). The project area is in St. Paul Charlestown Parish, near the boundary with Saint Thomas Lowland Parish. St. Paul Charlestown contains the capital city of Charlestown, a harbor, and government offices; Saint Thomas Lowland parish contains the popular tourism and recreation destinations at Pinney's Beach.

### 4.11.2 Socioeconomic and Environmental Justice Impacts

The following section describes the impact of the proposed binary geothermal project on socioeconomics and environmental justice. Table 4.11-1 summarizes these impacts.

**Table 4.11-1**
**SUMMARY OF IMPACTS TO SOCIOECONOMICS AND ENVIRONMENTAL JUSTICE**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| Displacement of Affected People | - | No Impact | - | - | - | - |
| Local Job Creation | Continuous | Definite | Regional | Long Term | Moderate | Medium |
| Economic Effects | Continuous | Definite | National | Long Term | Moderate | Medium |
| Effect on Tourism | Rare | Low Potential | Local/ Regional | Short Term | Very Low | Low |
| Indigenous People | - | No Impact | - | - | - | - |

### *Socioeconomic and Environmental Justice Impact 1 –Displacement of Affected People*

The NREI binary geothermal project would be located on parcels that are not occupied for residential purposes. The power plant and production wells would be in a former sugar cane field, and the injection well as an unused storage site near the abandoned sugar works. No resettlement or displacement would result from the construction of the proposed geothermal facilities.

Isolated residential clusters are within 0.5 miles of the proposed Hamilton Heritage Trust and Hamilton Stables parcels where the proposed binary power plant, production wells, and injection well would be located. Some of these people would have views of the project and would be affected by occasional releases of geothermal gases and by noise from the construction and operation of the proposed facilities. As described in sections 4.2, Aesthetics; 4.4, Climate and Air Quality; and 4.8, Noise, these impacts would not affect the uses of the residential properties, would meet noise standards, and are not expected to result in relocation of the affected population.

*Socioeconomic Impact 1 – No Impact*

### *Socioeconomic and Environmental Justice Impact 2 –Local Job Creation*

NREI anticipates that 75 workers would be needed for the construction of the power plant. Many of these would be local hires. Power plant operations would have 17 employees, most local or retrained NEVLEC operators. In addition, Turboden would have one or two operators during the first year of operation. NREI anticipates that external hires, would stay at hotels in Charlestown and thereby providing support for the local economy. Although most of the diesel units at the Prospect plant would shut down, one or two units would remain operational as standby emergency generators.

NREI would comply with local laws regarding worker rights, working conditions, child labor, nondiscrimination and equal employment, and a safe and healthy work environment. The project would comply with the ICF Performance Standard for Labor and Working Conditions.

There is no recent history of labor-related conflict or other regional vulnerability that would result in the project having the potential to disadvantage or have an adverse disproportionate effect on any at risk worker or other social population.

*Socioeconomic Impact 2 – Medium Significance*

### Socioeconomic and Environmental Justice Impact 3 – Economic Effects

The operation of the binary geothermal power plant at the Hamilton Estate would supply highly reliable power at lower cost than the existing diesel generation. The plant would stabilize electricity rates that have fluctuated with the price of diesel and petroleum products. Low cost power is an important precondition for growth and economic development. The use of geothermal resources would eliminate the need to buy 4,250,000 gallons of imported diesel fuel to provide power to the island.

The NREI geothermal plant would contribute significant revenue to the NIA, which would help the government to provide valuable services to its citizens. NREI and NIA are in partnership to develop and operate the geothermal plant. NIA holds an ownership position in the entire project and would also collect a royalty from all power produced by the plant. The royalty payment to NIA would be collected on the gross proceeds produced by the plant while the ownership share would produce a distribution to NIA from the net proceeds produced by the plant.

*Socioeconomic Impact 3 – Medium Significance*

### Socioeconomic and Environmental Justice Impact 4 – Effect on Tourism

The construction and operation of the plant would have little if any impact on tourism. During initial phases of the project, some drilling and well testing activities may be visible from some tourist areas at Pinney's Beach, but the visual impact would be distant and minor and should not cause any decline in tourism. After construction of the plant, the plant would not have a significant visual or auditory impact on tourist areas. The plant may even attract some tourists interested in renewable generation and would contribute to the progressive image of the island.

*Socioeconomic Impact 4 - Low Significance*

### Socioeconomic and Environmental Justice Impact 5 – Indigenous People and Environmental Justice

The project would not disproportionately affect any minority or impoverished group; the population is homogeneous (94.9 percent Afro-Caribbean) and neither the plant nor the bulk of its effects would be in impoverished areas.

The project would not impact indigenous people. Indigenous people comprise 0.03 percent of the population, and there are no indigenous communities on the island of Nevis. The site does not appear to have archaeological significance or contain artifacts important to indigenous groups located elsewhere.

Most impacts would occur to the nearby residents at the Hamilton Estate, which is not disproportionately impoverished. Charlestown and the communities in St. Thomas Lowlands Parish and St. John Figtree Parish would not be affected.

*Socioeconomic Impact 5 – No Impact*

## 4.12 Soils, Geology, and Minerals

The following section describes the soils, geology, and minerals condition of the proposed site and surrounding areas on Nevis and assesses the impacts of the proposed binary geothermal development project on these resources on the island. Please refer to Section 4.14, Water Resources, for a discussion of the island's water and geothermal resources.

### 4.12.1 Existing Conditions

The soils, geology, and mineral and geothermal resources of Nevis are a function of the island's volcanic past. This section discusses the existing geology, topography, seismicity, volcanic activity, mineral resources, and soil setting at Nevis and the project area.

#### *Regional Geology and Geothermal Resource Systems*

Nevis is an island in the Lesser Antilles, an arc of volcanic islands that lies near the boundary of the Caribbean Sea and the Atlantic Ocean. The Lesser Antilles island arc consists of northern and southern parts. Nevis, along with other islands such as St. Kitts, Montserrat, and Guadalupe lie within the northern part of arc; islands such as St. Lucia, St. Vincent, and Grenada lie in the southern part of the arc.

The Lesser Antilles island arc is a volcanic back arc response to the subduction process associated with regional tectonic plate movements. The island arc lies on the eastern edge of the Caribbean Plate, west of the Lesser Antilles subduction zone, where the North American Plate collides and moves under the Caribbean Plate. The collision and subduction of tectonic plates leads to earthquakes and melting of the subducting plate, which produces magma that rises near to or erupts from the earth's surface, leading to volcanism and mountain building (Tarr, 2010). The northern part of the Lesser Antilles island arc is believed to have formed in the early Miocene period (~20 million years (MY) ago); however, exposed rocks in the island arc are dated to the Pliocene period (~3.4 MY) only (Geothermex, 2005).

The volcanic rocks found in the northern Lesser Antilles primarily belong to the island-arc tholeiite series. Past investigations have concluded that exposed rocks are mostly unfolded, with structural deformation on Nevis and adjacent islands limited to faulting. Faults in the Lesser Antilles trend perpendicular (E-W and NE-SW) to the orientation of the island arc on islands east of the arc and parallel (NW-SE and WNW-ESE) to the arc's orientation on islands west of the arc such as Nevis (Geothermex, 2005; UWISRC, 2009d).

Geothermal systems are commonly associated with volcanic activity since magma produced by tectonic plate collisions heats surrounding rock formations and any fluid they may contain, creating a geothermal resource. Geothermal resources of varying degree can be found throughout the Lesser Antilles, such as the Sulphur Springs on St. Lucia.

#### *Island Geology and Geothermal Resource Systems*

Radiometric dating indicates that the formation of Nevis began with volcanic activity occurring at least 3.4 MY, during the Pliocene period. The island's eruptive centers have shifted over time, with nine discrete eruptive episodes occurring from the mid-Pliocene to the Pleistocene (<2.6 MY) periods. Pre-historic volcanic eruptions have occurred near Round Hill, Saddle Hill, Butler's Mountain, and Nevis Peak. Nevis Peak, which gives the island its conical appearance, is an andesitic

volcano with several volcanic domes. The Peak is an example of one of the island's eruptive centers that have contributed to the formation of the island (Geothermex, 2005; UWISRC 2009d).

The geology of Nevis is characterized by its volcanism and the subsequent weathering and erosion of volcanogenic rocks. The island's petrology is dominated by the past volcanic eruptive centers and debris flows and, to a lesser extent fluvial and lacustrine deposits, and raised beaches (Hutton, 1978). Please refer to Figure 4.12-1 as a Nevis geological reference.

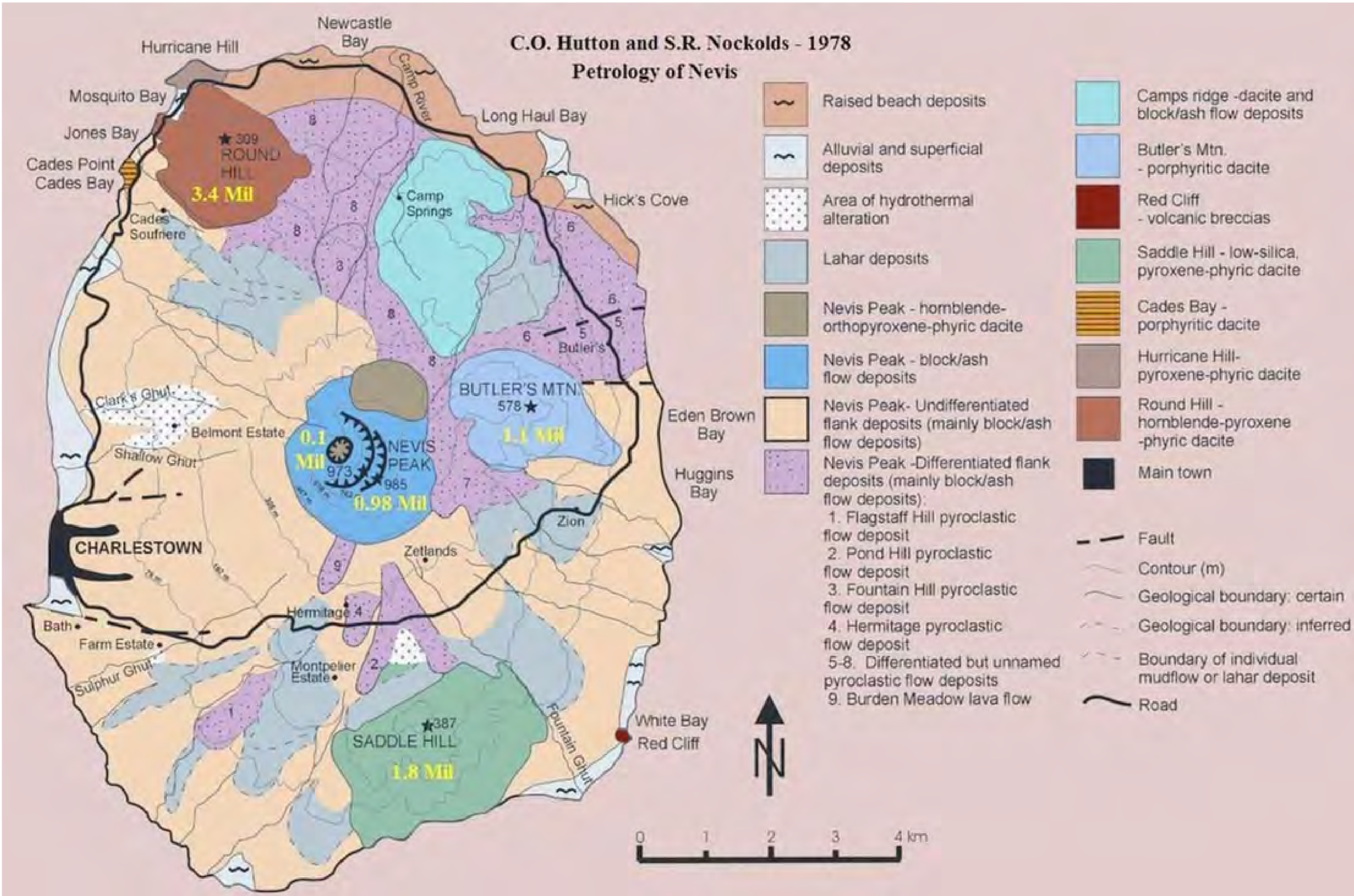
The island's volcanic activity has left behind volcanogenic rocks such as andesitic and dacitic pyroclastics; however, the vast majority of the island consists of undifferentiated pyroclastic deposits. Over time, water has drained in a radial pattern off Nevis Peak and the resulting streams and lakes have deposited sediments in these channels, called ghauts. Raised beaches, the result of alluvial deposits and a possible decrease in sea level since the formation of the beaches, occupy the coast near Charlestown, Newcastle, and other portions of the island's perimeter (DEMHE, 2000; OAS, 2001b; CDB, 2008; UWISRC, 2009d).

Nevis' location near the Lesser Antilles subduction zone creates geologic conditions prime for geothermal resources. Magma generated by the subduction process heats underlying rock and fluid resources, producing a reservoir of geothermal fluids. Over time, geologic events such as earthquakes create faults and cracks that allow geothermal resources to migrate and manifest at the earth's surface in the form of hot springs, mud pots, geysers, fumaroles, and other features indicative of subterranean geothermal resources.

The island's heat source is volcanic activity associated with Nevis Peak. Although Nevis Peak itself has not erupted during recorded history, the Lesser Antilles in general remains volcanically active, indicating magmatic and volcanic activity persists within the region. Specifically, a semi-molten zone of hot rock is likely to exist beneath the central part of Nevis Peak (Young, 2004). This semi-molten zone heats both deep seawater located near the core of the volcano and a shallow, perched aquifer that is the result of infiltration of rainfall (Geothermex, 2005). Previous investigations into Nevis' hydrothermal systems have evaluated the entire island for geothermal potential; however, the islands geothermal indicators (e.g., faults, surface manifestations) are concentrated on the western side of the island, where subsequent detailed exploration activities have occurred in support geothermal development. No surface manifestations of geothermal activity have been identified on the island's eastern half, whereas many existing and historical manifestations of geothermal activity are present on the island's western half, including the Farm Estate and Cades Estate Soufrieres, two areas of active steam vent and fumarole activity, and the Bath thermal springs (Geothermex, 2005).

### *Island Topography*

Nevis, along with St. Kitts and St. Eustatius, is located on a sub-marine bank that has a maximum depth of 180 m. The 36-square mile island is slightly oblong in shape. Nevis Peak rises to a height of 3,231 feet and is the central, dominant peak in a mountain range that includes Saddle Hill (1,230 feet) to the south, Mount Lily to the north (1,250 feet), and Butler's Mountain (1,897 feet) to the east (Lindsay, 1999; DEMHE, 2000).




Source: C.O. Hutton and S.R. Nockolds

NREI Binary Geothermal Development Project

FIGURE 4.12-1
NEVIS GEOLOGY

### Site Geology and Geothermal Resource Systems

The proposed power plant, pipelines, and wells are located on undifferentiated pyroclastic deposits associated with past Nevis Peak eruptions. The proposed site for the geothermal power plant is near the Hamilton Estates Fault Zone, an approximately northwest trending fault zone on the island. There are no surface manifestations of geothermal resources at the project sites, however, testing of the N-3 slim hole in 2008 found groundwater temperatures over 392 °F (200 °C) at a depth of 2,950 feet and NREI expects the reservoir temperature to reach over 540 °F (280 °C) at 4,000 feet.

### Site Soils

Nevis soils are weathered and impoverished with respect to potash. Soils on Nevis Peak are strongly acidic. Surrounding grades are more suitable for agricultural but are littered with rocks, and boulders. Site soils consist of clay, clay loam, and loam soils, known as Charlestown Clay/Clay Loam and Rawlins Gravelly Loam (Lowery 2017). Clay soils have the potential to swell when saturated and shrink as moisture content decreases (Lindsay, 1999; OAS, 2001b; CBD, 2008).

### Seismicity

The eastern Caribbean is a seismically active region due to the subduction of the North American Plate beneath the Caribbean Plate. The Federation of St. Kitts and Nevis Ministry of Finance Planning Unit records that at least 11 earthquakes with magnitudes greater than six have struck Nevis since 1690 (MFDP, 2004). Two earthquakes approximately 8.0 in magnitude struck near Antigua in the $17^{th}$ and $18^{th}$ centuries, and a magnitude 6.3 struck northeast of Dominica in 2004 (UWISRC, 2009a).

Nevis contains a number of fault traces that trend in a predominately northwest to southeast and northeast to southwest directions. In the recent past, Nevis has experienced clusters of earthquakes in 1926, 1947-48, 1950-51, and 1961-63. These earthquakes originated at depths between 3,280 and 36,090 feet (0.6 to 6.8 miles) and produced a maximum 5.1 magnitude earthquake with associated ground shaking intensities of VIII and IX on the Modified Mercalli Scale (UWISRC, 2009d; OAS, 2010).

The Seismic Research Center of the University of the West Indies (UWISRC) maintains three seismic monitoring stations on Nevis: one installed in 1980 at Gingerland, approximately 3 km southeast of Nevis Peak; one installed in 2002 at Round Hill; and one installed in 2002 at Bath House. The U.S. Geological Survey (USGS) and UWISRC estimate that the level of spectral ground acceleration on Nevis that has a 2 percent chance of being exceeded over the next 50 years is 5.6 and 6.1 meters per second squared ($m/s^2$) for 0.2 and 1.0 time periods, respectively (UWISRC, 2009e; Tarr, 2010). This ground acceleration corresponds to Seismic Design Category D, E, or F (formerly Seismic Risk Zone 4), as defined by the International Code (IBC), and could induce severe damage to structures. The UWISCR also maintains a GPS monitoring network that consists of ten stations designed to measure ground deformation associated with Nevis's volcanic and seismic activity.

Micro-seismic activity refers to typically low intensity, recurring events that cannot be felt by humans and can only be detected by sensitive seismic monitoring. Induced-seismicity refers to typically minor seismic events that are believed to be caused, or induced, by human activities. Micro- and induced-seismicity are not phenomena. They can be associated with many types of industrial activities, including reservoir impoundment, mining, oil and gas recovery, and geothermal industries

(EERE, 2010). Micro- and induced seismicity can be associated with hydrothermal systems and geothermal resources, since these systems rely on the fractured nature of the underlying geologic formations to pump and inject hydrothermal fluids. Factors such as reservoir depth and pressure affect play a role in micro- and induced-seismic events, which can occur locally in the region where pumping and injection of geothermal fluids occurs (EERE, 2010).

Finally, seismic activity originating beneath the Atlantic Ocean or Caribbean Sea may trigger local or regional tsunamis. The UWISRC considers the most likely earthquake scenario that could trigger a tsunami to be a shallow earthquake (<50 km depth) greater than magnitude 6.5. In the past 500 years, destructive tsunamis have occurred at the historical rate of one to two per century, with the northeast Caribbean being most susceptible to tsunamis (UWISRC, 2009c).

#### *Volcanism*

The Lesser Antilles island arc is a volcanically active region as a result of the subduction of the North American plate beneath the Caribbean plate, which produces magma that can rise to the surface of the earth and erupt. The UWISRC identifies 19 "live" (i.e., likely to erupt again) active volcanoes, including Nevis Peak, as well as volcanoes on St. Kitts and Montserrat. The 1997 eruption of the Soufriere Hills volcano on Montserrat destroyed the island's capital city, Plymouth, and caused approximately 20 deaths and an estimated $500 million in economic damages the island's economy (UWISRC, 2009b).

There have been no volcanic eruptions from Nevis Peak during recorded history; the last major volcanic eruption on the island occurred from Nevis Peak, approximately 100,000 years ago. Nevis Peak is thought to be formed through effusive lava eruptions creating lava domes, and block and ash flows that produce discontinuous surfaces. Although there have been no recorded eruptions from Nevis Peak, the presence of geothermal resources indicates that magmatic activity associated with Nevis Peak continues. In addition, the Lesser Antilles region in general remains volcanically active (UWISRC, 2009b).

#### *Minerals*

Nevis contains few mineral deposits; other than beach sand mining used for block making and mixed concrete. Beach sand mining, however, was proscribed under the 1987 National Conservation and Environmental Protection Act and is prohibited in many areas of the island (Lindsay, 1999; DEMHE, 2000).

### 4.12.2 Soils, Geology, and Minerals Impacts

Construction of the project would result in soil removal and erosion as well as topsoil loss. Once operational, the project would be subject to seismic-related hazards. The potential construction and operational impacts of the NREI binary geothermal power plant project on soils, geology, and minerals are summarized in Table 4-12.1 and discussed below.

**Table 4.12-1**
**SUMMARY OF IMPACTS TO SOILS, GEOLOGY, AND MINERALS**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| **Construction** | | | | | | |
| Soil removal, erosion and topsoil loss | Frequent | Definite | Site | Medium Term | Moderate | Low |
| **Operation** | | | | | | |
| Exposure to seismic hazards, including: | | | | | | |
| Earthquakes and ground shaking | Rare | Definite | Int’l. | Very Short Term | Very Low to High | Low |
| Ground failure and liquefaction | Rare | Low Potential | Site | Very Short Term | Moderate | Low |
| Landslides and subsidence | Rare | Low Potential | Site | Very Short Term | Very Low to High | Low |
| Settlement | Rare | Low Potential | Site | Very Short Term | Very Low to High | Low |
| Increased microseismicity | Infrequent | Low Potential | Local | Very Long Term | Very Low | Low |
| Volcanic Eruption | Rare | Low Potential | National | Short Term | Very High | Medium |
| Tsunamis | Rare | Probable | Int’l. | Very Short Term | Very Low to Very High | Low |
| Exposure to expansive soils | Rare | Possible | Site | Very Short Term | Low | Low |
| Sanitary waste disposal | Frequent | Definite | Site | Long Term | Very Low | Low |
| Loss of mining resources | - | No Impact | - | - | - | -- |
| **Decommissioning** | | | | | | |
| Soil removal, erosion, and loss | Rare | Definite | Site | Short term | Moderate | Low |

### Construction

Construction of the proposed binary power plant and associated facilities (e.g., production well pads, injection well site, transmission intertie line) would, at worst case, result in the clearing and grading of approximately 10.7 acres of mostly common scrub vegetation and the permanent occupancy of approximately 4.7 acres of the 9.1-acre Hamilton Heritage Trust parcel, and 0.9 acres of the 1.2-acre Hamilton Stable parcel.

#### *Soils, Geology, and Mineral Resources Impact 1 – Soil Erosion and Topsoil Loss*

Project construction activities such as excavation, grading, and foundation installation would expose bare soil to wind and precipitation, increasing potential soil entrainment and surface runoff.

As described in Biological Resources Impact 1, NREI would avoid removal of trees where possible, minimize the unnecessary clearing of land to preserve existing habitat/ vegetative cover where feasible and consistent with site access and safety needs (e.g., overgrowth onto facilities would not be permitted), and provide landscaping for the site to provide for an attractive and maintained site appearance. In addition, as described in Water Resources Impact 2, NREI would install temporary construction berms and silt fences to divert overland flow and contain sediment on site, reducing the potential for soil erosion and off-site sedimentation. NREI would also water the construction site to reduce the potential generation of wind driven erosion. Finally, NREI would save and cover all stockpiles of topsoil for use in back fill or re-vegetation activities, reducing both the potential for wind and water erosion as well as overall soil loss. The significance of this impact is therefore considered low.

*Soils, Geology, and Mineral Resources Impact 1 – Low Significance*

### Operation

Once operational, the proposed power plant and associated facilities would be subject to geologic hazards.

#### *Soils, Geology, and Mineral Resources Impact 2 – Earthquakes and Ground Shaking*

The UWISRC estimates that the proposed power plant, production and injection wells, production and injection pipeline, and transmission intertie line would be subject to a two percent chance of spectral ground accelerations exceeding 5.6 and 6.1 meters per second squared($m/s^2$) for 0.2 and 1.0 time periods, respectively (UWISRC, 2009e). This ground acceleration could induce severe damage to structures; however, the proposed project would be designed to withstand strong ground shaking.

The proposed binary plant would be shipped in several pre-fabricated, heavy-duty steel equipment skids assembly on-site. The skids would be mounted on and anchored to a concrete foundation. The project's air-cooled condensers would be mounted on structural steel beams. Project pipelines would be above ground (except where crossing underneath existing roads), supported by structural steel or iron supports designed to handle the pipeline load. The project also contains fire suppression devices, including firewater loops, sprinklers, and deluge systems to reduce fire risks associated with earthquakes and ground shaking. The transmission intertie line would be buried underground and all support structures would be design to accommodate ground shaking.

NREI would engineer and design the proposed facilities to meet all applicable structural, electrical, and seismic and wind loading design criteria of the latest International Building Code (IBC; currently

the 2015 IBC). A registered professional engineer would determine the project's appropriate IBC site coefficient and seismic design category (e.g., A, B, C, D, E, or F) based on the anticipated ground motion and soil type at the project area, as well as the most-appropriate IBC occupancy category (likely to be Factory Industrial) for the project.

Although the site would be subject to potential strong earthquakes and ground shaking, NREI would identify the site coefficient and seismic design category for the project and adhere to all applicable IBC code requirements for seismic safety, reducing the magnitude of this impact to low.

*Soils, Geology, and Mineral Resources Impact 2 – Low Significance*

### *Soils, Geology, and Mineral Resources Impact 3 – Ground Failure and Liquefaction*

Ground failure is the compaction and settlement of soils during a seismic ground shaking event. The potential for this hazard exists in areas of unconsolidated soils. If unconsolidated soil zones are saturated at the time of ground shaking, water is forced to the ground surface, resulting in a loss of soil supporting capacity known as liquefaction. The potential for liquefaction exists in areas of unconsolidated sediments with a high water table.

The proposed project is located in an area of undifferentiated pyroclastic flows associated with past volcanic eruptions. The project is not expected to encounter unconsolidated soils that could lead to ground failure. Groundwater is located between 6 to 230 feet bgs (USACOE, 2004), in permeable and fractured rock formations, and is not expected to cause liquefaction.

*Soils, Geology, and Mineral Resources Impact 3 – Low Significance*

### *Soils, Geology, and Mineral Resources Impact 4 – Landslides and Subsidence*

A landslide is a result of the liquefaction process on sloped terrain. On flat terrain, the expulsion of water to the surface of the ground results in the settling of soils and the creation of sinks or depressions in the ground. On a moderately sloped surface the liquefaction process results in a lateral movement of the ground surface. On a sloped surface of 15 percent or greater, this settling or movement of soils occurs in a down slope direction, resulting in a landslide.

Acidic geothermal fluids circulating underground have the potential to alter rock formations and result in grounds susceptible to slumps or landslides (Joseph, 2004). Soil slopes at the proposed project, however, are no more than ten percent and the potential for lateral spreading and landslides is considered low.

Subsidence of land surfaces can result from seismic activity, which settles unconsolidated materials located deeper in the earth. Hydrocompaction, which occurs when open-textured soils lose their strength after being saturated for the first time, is another cause of subsidence. Subsidence from geothermal operations is mostly a concern in unconsolidated sedimentary basins and in flat agricultural areas where drainage is important. At Nevis, the reservoir and geologic structures are volcanic rock, but there are unconsolidated layers of volcanic tuffs and clays that could have the potential to shrink if fluid drawdown occurred; however, with the proposed NREI binary plant design, nearly all geothermal fluids produced would be injected back into the geothermal reservoir.

The proposed geothermal development would drill to a depth of 3,000 to 4,000 feet bgs and would not affect geothermal reservoir pressures. The proposed project also would not produce geothermal fluids at rates that substantially exceed injection rates. The potential for landslides and subsidence is considered low.

*Soils, Geology, and Mineral Resources Impact 4 – Low Significance*

### *Soils, Geology, and Mineral Resources Impact 5 – Settlement*

Settlement is the consolidation of the underlying soil when a load, such as a building or fill material, is placed upon it. When soils contain materials that settle at different rates, differential settlement occurs. Saturated, unconsolidated materials are typically subject to settlement. Soils of the project area are composed of weathered pyroclastic flows deposited over time. The lack of a high water table and subsurface saturated soils makes the risk of settlement low.

*Soils, Geology, and Mineral Resources Impact 5 – Low Significance*

### *Soils, Geology, and Mineral Resources Impact 6 – Micro- and Induced-Seismicity*

Micro- and induced-seismicity are phenomenon associated with changes to the subsurface pressures, friction, and stresses of geologic strata either thru the changes to the nature of the resource (e.g., loss of fluid, change in sub-surface stress conditions) or thru the injection of high-pressure fluids that can trigger fractures at depth in the receiving rock formations.

The potential risks associated with micro- and induced-seismicity are considered low. Micro-seismicity is common in applications that inject high pressure fluids into geologic strata, such as hydraulic fracturing, a type of drilling in which water, sand, and other additives are pumped at high pressure into a rock formation to purposefully create micro-fractures in tight rock formations to allow oil and gas to be produced from the formation. The majority of micro-seismic events typically have magnitudes less than 3 on the Richter scale, although magnitude 5.6 and 5.8 events have been recorded in Oklahoma, in the United States, in an area subjected to extensive hydraulic fracturing activities (Oklahoma Secretary of Energy and the Environment, 2017). Similarly, induced seismicity is most commonly associated with enhanced geothermal systems (EGS), which can cause shear or tensile failure in underlying rock formations by injecting very high pressure fluids into the rock formations. This process creates a geothermal reservoir by pumping fluids into a hot dry rock formation where typically only heat exists. The seismic energy generating during the fracturing process depends on the length of the fracture and the stress released during the fracture (EERE, 2010).

The project proposes a traditional binary geothermal system in which nearly all geothermal fluids produced by the project would be injected back into the geothermal reservoir. NREI does not anticipate the binary system would substantially change reservoir pressures or subsurface stress conditions that could lead to structural damage from micro-fracturing of the receiving formation. NREI has reviewed current literature and Congressional Testimony provided by Stanford University Professor Dr. Mark Zobach related to induced seismicity related to standard binary couplet geothermal wells and do not believe there is a realistic likelihood of induced seismic events to be produced by the current NREI plant design and its relatively small capacity in comparison to the reservoirs ultimate assessed capacity (National Research Council, 2012, Zoback, 2012, and Schmittbuhl, 2014). Accordingly, the potential for the proposed project to generate micro-seismic events or induce seismicity is considered very low. Nonetheless, NREI has incorporated the

following best management practice into the project to address potential micro- and induced seismicity effects.

Micro- and Induced-Seismicity Best Management Practices

Following receipt of a micro- or induced-seismicity complaint, NREI and the NIA may first elect to deploy an array of geophones for a period of up to 90 days to detect and measure such events, assess the probability the event is related to the geothermal operations, and, identify whether the event(s) are capable of causing risk or injury to residents and structures, and develop an appropriate response strategy with community input.

*Soils, Geology, and Mineral Resources Impact 6 – Low Significance*

### Soils, Geology, and Mineral Resources Impact 7 – Volcanic Eruptions

Nevis is a volcanic island with evidence of nine discreet disruptive centers associated with volcanic activity, including present-day Nevis Peak (UWISRC, 2009d). Although there have been no volcanic eruptions during recorded history, the NREI conceptual model for the Nevis geothermal resources presumes volcanic activity associated with Nevis Peak provides the heat source for the island's geothermal resource.

There are no government or academic publications that predict volcanic activity in the Caribbean; however, the UWISRC considers Nevis Peak a "live" (i.e., likely to erupt again) volcano, and the Lesser Antilles region is in general volcanically active, as evidenced by the 1997 eruption of the Soufriere Hills volcano on Montserrat that destroyed the island's capital city. The potential risks associated with volcanic activity are therefore considered moderate (UWISRC, 2009b). There is no evidence that the geothermal drilling or power plant operations would induce volcanic activity.

*Soils, Geology, and Mineral Resources Impact 7 – Medium Significance*

### Soils, Geology, and Mineral Resources Impact 8 – Tsunamis

A tsunami is a wave or series of waves generated by the sudden movement or disturbance of the ocean floor that displaces a large amount of water. The UWISRC identifies two types of earthquakes that may generate tsunamis. The first are earthquakes originating in the Lesser Antilles that produce regional or local tsunamis and associated impacts. The UWISRC estimates that there have been 50 such earthquakes in the last 500 years, with 10 to 20 percent of these earthquakes leading to tsunamis that have caused significant flooding. The second type is an earthquake originating outside of the Lesser Antilles, in a distant region, that generates a tsunami. These earthquakes and the resulting tsunamis pose a lower threat to the Caribbean due geographic distance the tsunami must travel to impact the Caribbean (UWISRC, 2009c).

Tsunamis may also be caused by large volcanic eruptions, such as the eruption of the Kic-'em-Jenny submarine volcano located approximately 5.6 miles north of Grenada. Eruptions from this volcano in 1939 and 1965 generated small tsunamis on the north coast of Grenada (UWISRC, 2009c).

Although the frequency with which tsunamis occur is rare, the magnitude of any potential impacts associated with a future tsunami would depend on the location and depth of the earthquake that generates the tsunami, the warning system in place at the time the earthquake strikes, and the response of the threatened community to the tsunami alert or warning.

The proposed project site is located on the slopes of Nevis Peak and is unlikely to experience any direct flooding or structural damage as a result of a tsunami. The project, would, however, experience indirect impacts associated with the temporary loss of Nevis' civil and infrastructure systems and programs that would occur in the event of tsunami.

*Soils, Geology, and Mineral Resources Impact 8 – Low Significance*

### *Soils, Geology, and Mineral Resources Impact 9 – Expansive Soils*

The proposed project would be located in an area of weathered, undifferentiated pyroclastic flows consisting of clay, clay loam, and loam soils that would have the potential to shrink and swell. The higher the clay content the higher the shrink/swell potential of the soil. The site soils pose a potential shrink/swell risk that NREI would control through a site-specific soils analysis and engineering design.

*Soils, Geology, and Mineral Resources Impact 9 – Low Significance*

### *Soils, Geology, and Mineral Resources Impact 10 – Sanitary Waste Disposal*

The proposed project would site potential septic tanks and leach fields in a flat area of suitable permeability and these facilities, therefore, would have no impacts to or from soils or geologic impacts.

*Soils, Geology, and Mineral Resources Impact 10 – No Impact*

### *Soils, Geology, and Mineral Resources Impact 11 – Loss of Mining Resources*

The proposed project would not interfere with or result in the loss of mining activities or resources and would therefore have no impact on mining resources.

*Soils, Geology, and Mineral Resources Impact 11 – No Impact*

### *Soils, Geology, and Mineral Resources Impact 12 – Project Decommissioning*

As noted in Section 3.14, the operating agreement between NREI and NEVLEC calls for NREI to turn the plant over to NEVLEC at the completion of NREI's power purchase agreement, which would then have the responsibility to decommission the plant when it is no longer needed. The binary geothermal power plant would have the potential to produce and deliver renewable energy to the NEVLEC system for several decades, as some binary plants in the U.S. have been in service for 30 years or more. Project decommissioning would result in the breakdown of proposed facilities, well plugging and abandonment, and site restoration work. These activities would have the potential to result in disturbance of bare soils and subsequent soil erosion during decommissioning activities. Although NREI would not be responsible for the decommissioning activities, it is presumed that the implementation of standard construction and erosion management practices such as that NREI would undertake during plant construction (e.g., disturbing the minimum amount of lands, site watering, installing silt fences, etc.,) would render potential soils and geology impacts during decommissioning low (see the discussions under Soils, Geology, and Mineral Resources Impact 1 and Water Resources Impact 2 for additional information on standard practices that would be undertaken by NREI during plant construction). .

*Soils, Geology, and Mineral Resources Impact 12 – Low Significance*

## 4.13 Transportation and Traffic

The following section describes the transportation and traffic conditions at the proposed site and surrounding areas on Nevis and assesses the impacts of the binary geothermal project on the transportation and traffic on the island.

### 4.13.1 Existing Conditions

One major road circles the island of Nevis, called Beach Road in the south, Pinney's Road in the west, and Pump Road when it splits to avoid the Charlestown beachfront (Skyviews, 2009). In addition to this major road, a network of smaller roads also serves the island of Nevis. Roads are well-paved but narrow, poorly lit, and often poorly marked (United States Department of State, 2009). Traffic drives on the left side of the road, and foreigners must obtain a 3-month traveler's license for US$24 from the police departments at Charlestown, Newcastle, Cotton Ground, or Ginger (www.caribya.com/driving/Roadway Guidance to St. Kitts, 2017).

Due to increasing development and income, as well as the increase in jobs outside of the main population centers, vehicle ownership has risen in Nevis. As of 2015, there were 2,139 registered private cars, jeeps, and motorcycles in Nevis and another 314 public service vehicles (Department of Finance, 2016 Statistical Digest). Due to the increase in vehicles, there can be rush hour traffic in the morning, during mid-day, and in the late afternoon. Major gatherings (such as sporting events) and inclement weather can also impede traffic. It is not uncommon for drivers to stop in the middle of the road to visit with one another (United States Department of State, 2009).

#### *Proposed Access Roads*

The access road for the NREI binary geothermal project is via a paved local road with little traffic that runs from Government Road in Charlestown past the sugar works at the Hamilton Estate, turns south, and connects to the main island road in Church Ground. The access road to the parcel where the binary plant facilities are located is via a dirt road that heads north from ruins of the sugar works at the Hamilton Estate.

### 4.13.2 Transportation and Traffic Impacts

The following section describes the impacts to transportation and traffic from the proposed binary geothermal project. Table 4.13-1 summarizes these impacts.

**Table 4.13-1**
**SUMMARY OF IMPACTS TO TRANSPORTATION AND TRAFFIC**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| Traffic Congestion from Drilling and Construction | Infrequent | Low Potential | Local | Short Term | Low | Low |
| Traffic Congestion from Plant Operation | Very Infrequent | Low Potential | Local | Long Term | Very Low | Low |

### *Transportation and Traffic Impact 1 - Traffic Congestion from Drilling and Construction*

Well drilling would require two 9-person crews plus supervisors to work 24 hours a day for up to 45 days for each well. Parking would be provided at the site. The road to the Hamilton Estate has little traffic, and drillers driving to the well pads are not expected to result in significant traffic congestion.

The binary plant would be under construction for approximately 18 months with construction occurring mostly during the daytime. NREI estimated that peak construction would have 75 workers. NREI would provide vans or buses to transport these workers between their temporary residences and the project site. The buses greatly reduce the potential traffic impacts at the beginning and end of the day, particularly on the narrow road between Charlestown and the plant site. Some workers may still choose to drive their own vehicles. With these measures the traffic impacts of worker commutes would likely be minor, but slow-moving construction equipment could cause local traffic delays.

Installation of the transmission line would involve trenching alongside the back roads between the Hamilton Estate and the Prospect Power Plant. Construction equipment would be placed on the side of the road and should not interfere with traffic, but where trenching alongside the road is not possible, ducts would encroach on the road (NEVLEC, 2010). At times, construction may partially impede the flow of traffic. The crews would use flagmen, where necessary, to ensure worker safety from passing vehicles.

*Transportation and Traffic Impact 1 - Medium Significance*

### *Transportation and Traffic Impact 2 - Traffic Congestion from Plant Operation*

During operation, there would be five operators and plant manager per shift. These workers would drive to the plant, probably along the road from Charlestown, but some works may live south of the plant and drive in from Church Ground. These paved roads have little traffic, and the increase in vehicles is not expected to result in traffic congestion.

*Transportation and Traffic Impact 2 - Low Significance*

## 4.14 Water Resources

The following section describes the water resource conditions of the proposed project and surrounding areas on Nevis and assesses the impacts of the proposed binary geothermal development project on the water resources on the island.

### 4.14.1 Existing Conditions

In general, water resources on Nevis consist of fresh water springs, thermal springs, coastal ponds, irrigation ponds, groundwater, and the geothermal reservoir. The proposed project parcels at the Hamilton Estate (the Hamilton Heritage Trust and Hamilton Stable parcels) overly a deep geothermal reservoir and contain two shallow ghauts that serve to transport surface runoff to the island's coastal marine environment, which is located more than one mile away from the power plant site.

This section discusses the existing conditions of the ghaut, coastal marine environment, groundwater, geothermal reservoir, and surface geothermal features in the project parcels and surrounding areas of Hamilton Estates and St. Thomas Lowland Parish.

#### *Rainfall*

Rainfall data from past years is available for the period 1942 to 1988 for the Mount Palmetum at Jessups, which is located approximately 1.8 miles to the northwest of Hamilton Estates (see Table 4.14-1). Total annual precipitation varies, but rainfall distribution is similar, the majority falling August to November with peak rainfall in September, and minima in February to March. A secondary rainfall peak occurs in May. An average of 54.5 inches of annual rainfall occurred for the period 1942 to 1988.

Most recently, Saint Kitts and Nevis have been suffering from drought conditions, with average rainfall in 2015 and 2016 approximately 24 to 31 inches, well below historic averages.

**Storm Maxima**

Based on rainfall maps produced by Devres (1987), the following 24-hour rainfall maxima are expected in the Hamilton Estates area:

| | |
|---|---|
| 10-year | 5.5 inches (140 mm) |
| 20-year | 7.25 inches (184 mm) |
| 50-year | 8.25 inches (210 mm) |

With climate change predictions indicating greater extremes of weather, these figures may be exceeded.

| Table 4.14-1<br>MOUNT PALMETUM AT JESSUPS RAINFALL DATA | |
|---|---|
| Distance from Project (miles) | 1.8 |
| Elevation (feet) | 382 |
| Years of Data (Range) | 45 (1942-1988) |
| Mean Annual Rainfall (inches) | 54.52 |
| Monthly Means (inches) | |
| *January* | 4.11 |
| *February* | 2.98 |
| *March* | 2.64 |
| *April* | 3.24 |
| *May* | 4.71 |
| *June* | 3.56 |
| *July* | 4.97 |
| *August* | 5.90 |
| *September* | 6.41 |
| *October* | 5.34 |
| *November* | 5.62 |
| *December* | 5.03 |

### *Surface Water Resources*

Surface water resources in the area derive primarily from rainfall during the wet season, approximately August to November. Water drains in a radial pattern from Nevis Peak through steep ghauts in ten major drainage basins. The leeward side of the island contains soils that are highly erodible, and numerous ghauts create powerful rivers of rainwater that pour down after heavy rains. The ghauts are ephemeral and typically flow only three to four times a year, after major storms. The steep ghauts channel the stormwater runoff toward the coast where coastal ponds, both freshwater and brackish, can reach capacity and spill over into the sea. Nevis also has non-potable volcanic hot springs, fumaroles, and other surface manifestation of the subsurface geothermal reservoir that rise through faults (ECLAC, 2003).

#### Ghauts

The proposed site for the geothermal power plant at Hamilton Estate is on relatively level terrain. In general, the natural drainage pattern of both the Hamilton Heritage Trust and the Hamilton Stable parcels have been historically altered by agricultural practices, development and, most recently, levelling for the platform around the N-3 well and its access road (on the Hamilton Heritage Trust parcel); however, two shallow ghauts (unnamed) cross the Hamilton Heritage Trust parcel in an east-west direction. The ghauts are typically dry but during the rainy season or after a major storm

the ghauts would transport surface runoff from the upper slopes of Nevis Peak to the islands coastal environment. One of the ghauts is located where the northern well pad would be. This feature does not appear to connect upslope drainage with the island's coastal environment. The other ghaut cuts across the full width of the site, under the proposed eastern well pad, laydown area, and plant site. This ghaut originates further upslope, runs across the Hamilton Heritage Parcel, and continues towards Charlestown.

The transmission intertie line would be within or adjacent to existing roads and would not result in new disturbance within or near the bank of any permanent water feature.

Percolation through the floors of the ghauts is the major source of groundwater recharge on the island. The NIA requires that septic systems be located away from ghauts and prohibits the dumping of trash near the ghauts.

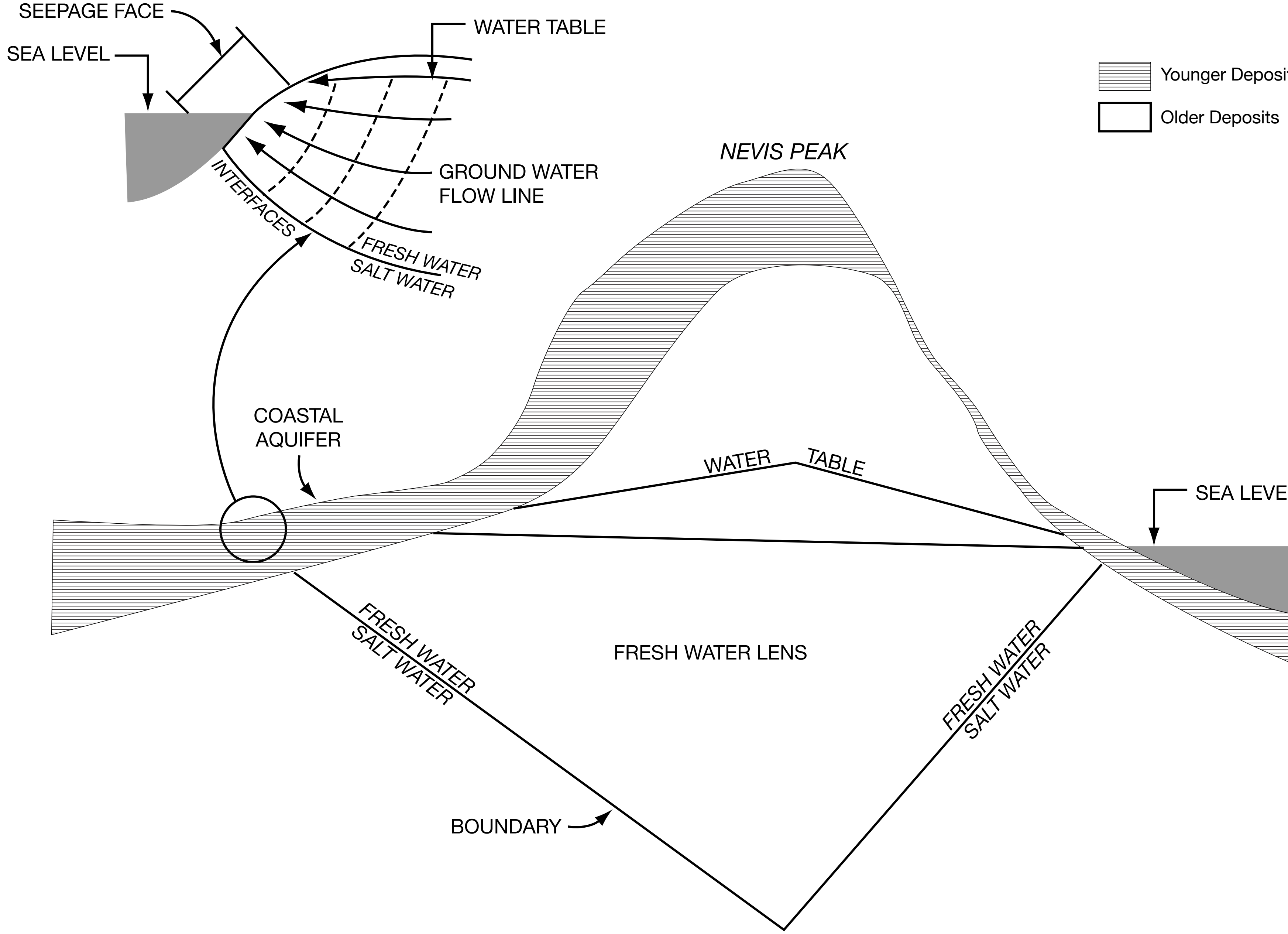
**Marine Environment**

The island's ghauts drain and direct fresh surface water to the coastal environment, but can carry sediment, garbage, and other discharges from residential or commercial developments that can negatively impact the island's renowned coastal marine environment. In particular, Cades Bay (located near Cotton Ground, northwest of the Hamilton Estates area), contains the largest living reef system in Nevis and is a popular tourist destination. The Sea Bridge Ferry to St. Kitts docks at Cades Bay Pier. The federal government proposes to set up a marine protected area that includes Cades Bay; however, the NIA has not yet established formal conservation status for Cades Bay.

### *Groundwater Resources*

Groundwater beneath Nevis consists of freshwater and saltwater aquifers separated by a largely impermeable aquitard (GeothermEx, 2005). The groundwater table rises toward the center of Nevis Peak and reflects the high rates of precipitation on the steep slopes of the volcano. Figure 4.14-1 shows the rise of the water table and a cross-section of Nevis with conceptual boundaries between the freshwater and saltwater lenses. The freshwater lens extends below the peak as an inverted triangle with a boundary separating it from the saltwater lens. Coastal water wells encounter salt water at lower depths producing some brackish wells, which the NIA uses for irrigation (Department of Environment, 2001).

Recharge of the groundwater aquifer from infiltration is poor. Shallow clay soils underlain by a silica pan cover approximately 75 percent of Nevis, severely limiting infiltration. In addition, rapid runoff through the ghauts and exposure to evaporation reduces the amount of groundwater recharge. As the ghauts approach the coast, the slopes decrease, but not enough to allow for substantial recharge (Department of Environment, 2001).




Source: St. Kitts and Nevis Department of Environment

NREI Binary Geothermal Development Project

FIGURE 4.14-1
NEVIS HYDROLOGY

**Water Supply**

Nevis relies on both groundwater and surface water for its water supply. Groundwater accounts for 90 percent of the public piped water supply and surface water accounts for the remaining 10 percent. The islands municipal water distribution system, which is currently undergoing upgrades, provided a total of nearly 2,000,000 gallons per day (gpd) in 2012 -- FAO 2016). Aquifers range in depth from 26 feet along the coast to 230 feet further inland. Water is gravity fed through cast iron and PVC pipes. Residents also use domestic rainfall catchment systems for additional water needs (ACOE, 2004).

Ninety eight percent of the population on Nevis has access to improved water sources (World Bank, 2004). The water department treats the water supply with chlorine to kill bacteria and monitors the system to meet World Health Organization (WHO) water quality standards. The Ministry of Health, however, has reported some water quality problems with heavy metals, such as arsenic (ACOE, 2004). The water department continues to replace the main distribution system with PVC pipes due to the corrosion of the cast iron pipes from high calcium, "hard" water scaling, and corrosion. The water department has not detected salt-water intrusion on Nevis, but some wells are naturally brackish (ECLAC, 2003).

### *Geothermal Resources*

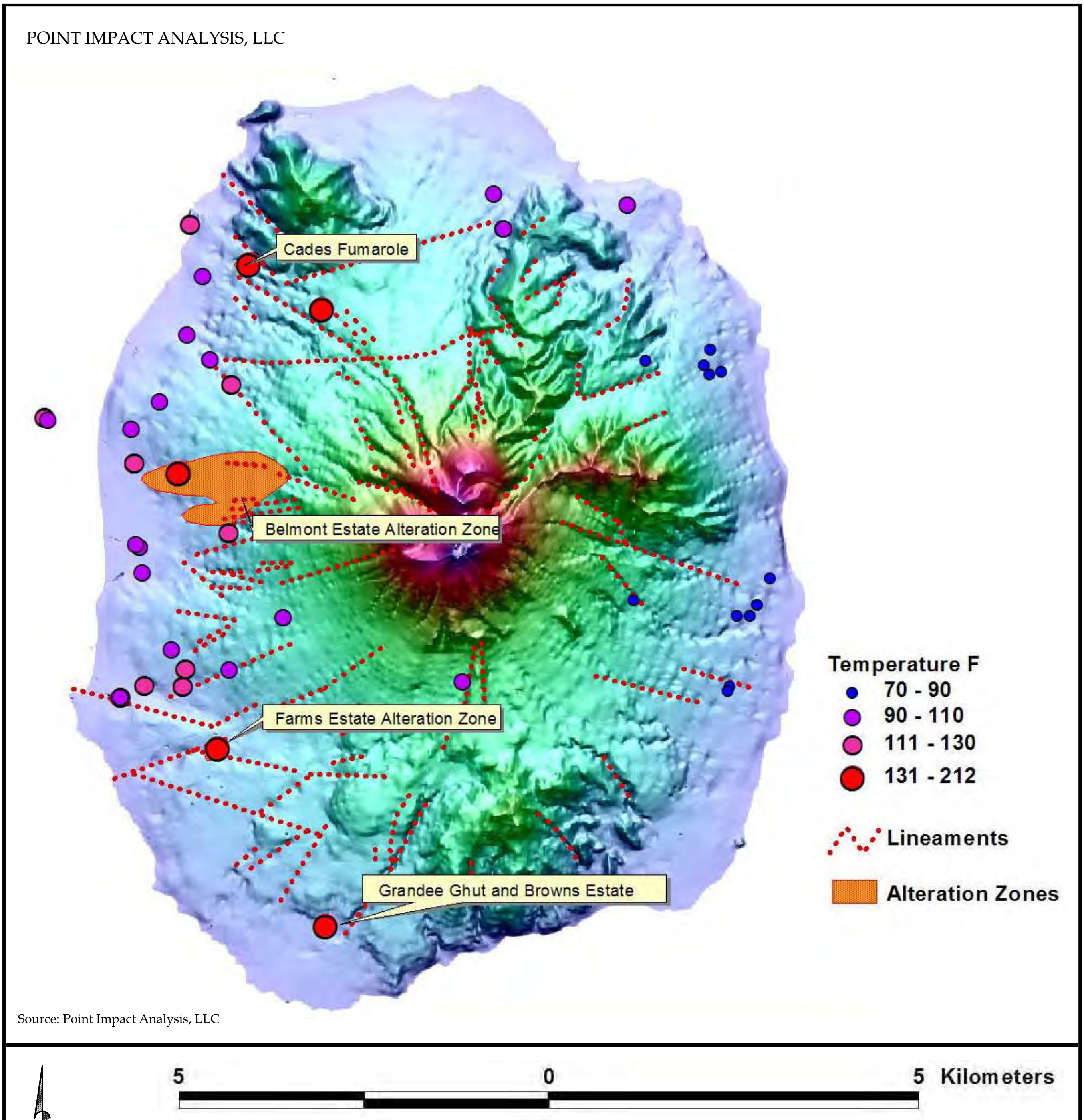
The geothermal resources on Nevis include the deep geothermal reservoir and the surface manifestations of geothermal activity.

**Geothermal Reservoir**

Exploratory geothermal drilling on Nevis and fluid chemistry data indicate that the geothermal system underlies a colder potable water aquifer with leakage occurring along faults. The leakage from the geothermal system mixes with the shallow aquifer, resulting in water chemistry that shows attributes of both the geothermal and shallow groundwater systems. The deeper, higher-temperature system probably consists of thermally altered seawater that circulates near the core of the volcano. The shallower system is perched meteoric water (recharged by rainfall at higher locations). This shallower system is thought to be heated by conduction through the largely impermeable layer of rocks that separate the two systems and by steam that rises through fractures in that layer.

**Surface Thermal Features**

Nevis has existing and former surface thermal manifestations of geothermal activity including fumaroles, thermal springs, gas seeps, and thermal water wells (see Figure 4.14-2). Almost all the thermal features occur on the west side of Nevis Peak, which experienced a large sector collapse event. The apparent collapse feature is bounded by Spring Hill Fault in the north and Grandee Ghaut Fault in the south.




NREI Binary Geothermal Development Project
FIGURE 4.14-2
FAULTS, FUMEROLES AND
HYDROTHERMAL FEATURES

Existing surface manifestations of geothermal activity in St. Thomas Lowland Parish, where Hamilton Estates is located, include the Cades Bay fumarole or soufriere and the Westbury thermal well, both of which are approximately 2.5 miles north of the power plant site. These features indicate the probable presence of highly fractured rock and high temperature geothermal resources at depth. The Cades Bay fumarole developed in the early 1950's from seismic activity beneath Nevis Peak, which provided fracture permeability to the surface. Outflow from the geothermal reservoir feeds the Westbury thermal well and discharges from the sand at Cades Bay with temperatures of 113 °F and 125 °F recorded just south of Cades Point. Sulfur vents, mineral deposits associated with geothermal activity, thermal water wells, offshore bubbles, heated ground surface, and thermal springs also occur near the Four Seasons golf course and Pinney's Estate.

In St. John Figtree Parish, the thermal springs at the historic Baths are a tourist attraction and used by locals for therapeutic healing. The Baths are approximately 1.1 miles southwest from the power plant site. The Farms Estate soufriere is east of the Baths.

Geothermal surface manifestation can be short-lived as the geothermal fluid mixes with the cooler groundwater causing some minerals to precipitate out of solution and seal off the permeability of the channels to the geothermal reservoir.

### 4.14.2 Water Resources Impacts

The following sections discuss the potential impacts on water resources, considering the measures that NREI proposes for the construction, operation, and decommissioning of the proposed geothermal power plant at Hamilton Estates. Table 4.14-2 summarizes the potential impacts to water resources.

**Table 4.14-2**
**SUMMARY OF IMPACTS TO WATER RESOURCES**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| **Construction** | | | | | | |
| Alteration of Drainage Patterns | Continuous | Definite | Site | Long term | Low | Low |
| Degradation of Surface and Groundwater Quality during Construction and Well Drilling | Rare | Low Potential | Site | Very Short term | Very Low | Low |
| Water Consumption during Drilling | Frequent | Definite | Regional | Short term | Low | Low |

**Table 4.14-2**
**SUMMARY OF IMPACTS TO WATER RESOURCES**

| Impact | Frequency | Probability | Extent | Duration | Magnitude | Significance |
|---|---|---|---|---|---|---|
| **<u>Operation</u>** | | | | | | |
| Effect of Geothermal Production and Injection on Surface and Groundwater Resources | Very Infrequent | Low Potential | Local | Long term | Low | Low |
| Drawdown of Geothermal Reservoir and Effect on Surface Thermal Manifestations | Very Infrequent | Possible | Local | Very long term | Moderate | Low |
| Degradation of Surface and Groundwater Quality due to Project Operation | Rare | Low Potential | Site | Very short term | Very Low | Low |
| **<u>Decommissioning</u>** | | | | | | |
| Degradation of Surface and Groundwater Quality during Project Decommissioning | Rare | Potential | Site | Short term | Very Low | Low |

### *Construction*

Construction of the proposed geothermal development would, at worst-case require clearing and grading of up to 10.7 acres of land at the Hamilton Heritage Trust parcel (9.1 acres), the Hamilton Stables parcel (1.2 acres), and the transmission intertie route (0.4 acres). Earthmoving activities, drilling, and use of petroleum-fueled construction equipment and other construction materials would have the potential to alter local drainage patterns and degrade surface and groundwater resources in the area, but NREI would implement measures to minimize any impacts. This estimate of clearing and grading (10.7 acres) is considered worst-case because some of the temporary laydown area, power plant site, production well pads and injection well site, and transmission intertie route would be located in areas that may already be devoid of vegetation, and NREI would retain approximately 16 of the largest trees observed on site.

### *Water Resources Impact 1 – Alteration of Drainage Characteristics*

Although the natural drainage patterns of both the Hamilton Heritage Trust and Hamilton Stable parcels have been historically altered by previous agricultural and investigative geothermal well drilling, the undeveloped project parcels retain a slight slope and two natural ghauts that serve to direct and channel surface water flows from upslope areas down towards the island's coastal environment. The proposed project would clear and level the site to accommodate the proposed geothermal facilities, and the proposed well pads, laydown yard, and plant site would be located in areas where two shallow ghauts are present. Clearing, leveling, and compacting site soils / adding impervious surfaces to the project parcels would have the potential to disrupt natural drainage patterns and slightly increase runoff rates (since a higher volume of water would be directed towards drainage patterns); however, NREI has designed the project to minimize potential impacts resulting from this alteration in the site's natural drainage patterns. First, as described in Section 4.3, Biological Resources, NREI would avoid removal of trees where possible, minimize the unnecessary clearing of land to preserve existing drainage patterns where feasible and consistent with site access and safety needs (e.g., flooding of access roads would be avoided). In addition, as described in Section 3.10, NREI would direct upstream flows to new culverts that replace existing drainage features (i.e., the two ghauts on site) or re-route upstream flows to new drainage ditches on perimeter of the site. Under either scenario, NREI would provide flow dissipaters at discharge points and connect the new drainages to downstream discharge points. In addition, the NREI plant site would include containment in the unlikely event a release of cyclopentane occurs. This hazardous materials containment system would also capture stormwater flows from the plant site that would be directed to valves to allow the uncontaminated storm water to discharge from the site. Surface flows from the remainder of the site would be directed to storm drain inlets that lead to the new culverts or perimeter drainage channels

The proposed transmission intertie line would be installed in a trench in the ground that would be located within or adjacent to existing roadways, reducing the possibility for altering drainage patterns. The same soil removed during trenching for the transmission intertie line would be re-compacted on top of the trench.

Although the project would alter the Hamilton Heritage Trust and Hamilton Stables parcels existing drainage patterns, it would not impede drainage flows or otherwise increase the rate of off-site storm water flows such that the normal activities of people, animals, or plants in the vicinity of the project would be affected.

*Water Resources Impact 1 – Low Significance*

### *Water Resources Impact 2 – Potential Degradation of Surface and Groundwater Quality from Construction and Drilling Activities*

Although unlikely, project construction could potentially degrade surface and groundwater quality during construction and drilling activities in several ways. The clearing and grading of work areas could lead to off-site sedimentation. In addition, the use of heavy, diesel-powered construction equipment to construct the project facilities would require the on-site storage and use of diesel fuel, lubricating oil, solvents, hydraulic fluid and other materials that could leak or accidentally be released to the environment. Finally, well drilling and testing would result in the release of geothermal fluids that contain boron, chlorine, and other constituents that could be harmful to drinking water or the

environment if an uncontrolled release were to occur. There is also an extremely low potential for the release of geothermal fluids during a well blowout, which is a rare occurrence.

NREI has designed the project to minimize and control the potential degradation of surface and groundwater quality during construction and well drilling activities in the following ways:

- As described in Sections 3.10 and 3.12, NREI would avoid removal of trees where possible and minimize the unnecessary clearing of land where feasible and consistent with site access and safety needs. These actions would reduce the potential amount of sediment that could be generated and discharged off site. NREI would also install silt fences between bare work areas (i.e., not vegetated or otherwise stabilized) and inlets to new culvert drainage channels installed by NREI and/or sections of the existing ghauts that may still be present on-site during construction. This would capture and control the amount of sediment migrating off-site during construction. Finally, NREI would landscape the site when construction is finished and direct surface flows to drainage control systems to limit and control potential off-site sedimentation once construction is complete. In addition, as described in Section 3.4, NREI would grade the well pads to drain into a clay-lined reserve pit (north well pad) or the mud sump used for the test well at the Hamilton Estate (the east well pad). Thus, cuttings and geothermal fluids produced during drilling and testing would be directed to impervious containment ponds, and the water in the ponds would evaporate or be injected down the N-3 test well.
- As described in Section 3.8, NREI would store all fuels, lubricants, and other hazardous materials used in construction equipment in appropriate storage tanks and that would be located in bermed areas to provide secondary containment. The berms around these areas would contain spills and prevent them from migrating off-site. NREI would also maintain appropriate and cleanup materials on site so that the spilled material would not leave the well pads or power plant site. Proper handling procedures would ensure the low likelihood of a spill, and spill containment measures would ensure prompt clean up. In addition, as described in Section 4.12, the low permeability of the gravelly and clay loam soils at the site would reduce the potential for spills of these materials to infiltrate into the groundwater.
- As described in Section 3.4, most, if not all, of the drilling muds and additives that NREI would use during well drilling would be nontoxic and biodegradable and diluted by water during drilling. As noted above, NREI would store all potentially hazardous materials in appropriate storage devices. These storage areas would be bermed to provide secondary containment and prevent spills from migrating off-site and NREI would also maintain appropriate clean-up materials on site.

As described in Section 3.4, the proposed production and injection wells would be drilled to a depth of approximately 4,000 feet below the ground surface. To prevent geothermal fluids from coming in contact with the meteoric groundwater near the surface, NREI would case and cement the production and injection wells to at least a depth of 3,000 feet. This would contain the geothermal fluids within the well structure, fill the space between the casing and the surrounding material, prevent leaks from the joints, and isolate the geothermal fluids from the groundwater aquifers. In addition, as described in Section 3.4, NREI would install and test blow-out prevention equipment with redundant shut down mechanisms to stop uncontrolled flows of geothermal fluids in the remote event a blowout occurs.

With the planned control measures, the magnitude of the project's potential degradation of surface and groundwater quality during construction and well-drilling activities would be low.

*Water Resources Impact 2 – Low Significance*

### *Water Resources Impact 3 – Water Consumption during Drilling*

Drilling of the production and injection wells would require approximately 10,000 gallons of water per day to circulate mud through the well and lift the cuttings to the surface. Two 5,000-barrel water storage tanks would be stored onsite for drilling, which would be filled by an existing NIA public water supply line north of the site or, if necessary (for supplemental water supply purposes), via a water truck from the Hermitage Heights Tank Farm near Charleston, approximately one mile west of the site. Drilling would last a maximum of 40 days at each well. The consumption of 10,000 gallons per day would be less than one percent of the total daily water demand on Nevis, which currently has excess water supply for all purposes.

*Water Resources Impact 3 – Low Significance*

## *Operation*

During operation, the proposed geothermal power plant would consume geothermal fluids for electricity production, dispose of spent geothermal fluids, and use and store hazardous materials. This section evaluates the effects of these operational activities on the surface and groundwater resources at the Hamilton Estate.

### *Water Resource Impact 4 – Effect of Geothermal Production and Injection on Surface and Groundwater Resources*

The proposed binary geothermal power plant would generate electricity from the geothermal fluids produced from wells drilled to depths of approximately 4,000 feet below the ground surface. The geothermal fluids brought to the surface would be contained within cased wells, surface piping, and enclosed plant equipment during normal operation. The fluids would then be reinjected to the geothermal reservoir. Reinjection of the geothermal fluids would minimize effects on the quantity and quality of surface and groundwater resources. As described in Section 3.8, NREI would case and cement the production and injection wells to at least a depth of 3,000 feet, which would contain the geothermal fluids within the well structure and isolate the geothermal fluids from the groundwater aquifers. Reinjection would also avoid discharge of geothermal fluids to surface or shallow groundwater resources. Impermeable layers divide the deep geothermal reservoir from the shallow groundwater aquifers. Bringing the geothermal fluid from the deep reservoir to the surface and pumping it back to the reservoir would not affect groundwater levels or quality in the region due to the separation of the deep geothermal resource from the shallow groundwater aquifer and the integrity of the well casing. Surface waters would not be consumed or discharged for the operation of the binary plant.

NREI would connect to an existing NIA water would bring fresh water from the NIA system to plant site for the fire water system and utility water use for drinking, sanitation, and landscaping. NREI estimates that the initial fire water system charging would require approximately 6,000 gallons, while average use for utility purposes would be approximately 200 gallons per day.

During emergencies that shut down both binary units, NREI would need to route the geothermal fluid to the brine containment pond until it can shut-in wells and stop the flow of fluids to the plant.

NREI would pump the water in the storage ponds to the injection system when power resumes. NREI has designed the pond to accommodate two hours of full geothermal fluid flow. As described above, the proposed project would have a low potential to affect surface or groundwater resources during production or injection of geothermal fluids.

*Water Resources Impact 4 – Low Significance*

### *Water Resource Impact 5 – Effects of Geothermal Production and Injection on the Geothermal Reservoir and Surface Thermal Manifestations*

The binary power plant operation would not evaporate the geothermal fluids produced from the wells, but would consume a portion of the heat energy of the geothermal reservoir for electricity production. Potential impacts from geothermal operation on surface geothermal features include potential changes in flow, temperature, and chemistry. Surface thermal features may also exhibit these changes based on natural alterations in the hydrothermal system. A slight change in the deep geothermal reservoir would not prevent the upwelling that contributes to the groundwater aquifer. Therefore, a slight change in pressure or temperature of the geothermal reservoir would likely have little to no effect on the surface thermal manifestations. To help maintain pressure and extend the life of the project, NREI would reinject the spent geothermal fluids to recharge the geothermal reservoir, and this practice would reduce the potential for impacts on the reservoir and surface thermal manifestations.

*Water Resources Impact 5 – Low Significance*

### *Water Resource Impact 6 – Potential Degradation of Surface and Groundwater Quality from Project Operation*

Similar to construction, project operation would have the potential to degrade surface and groundwater quality in several ways. The control of microbiological growth and pH in the wells and heat exchangers would require the storage of additives, and plant equipment would require the storage of fuels and lubricating oil, which have the potential to spill onsite and be conveyed off-site by surface water flows. In addition, the binary plant working fluid, cyclopentane, could leak from equipment or be released during an accident or upset condition. Finally, geothermal fluids could also leak from wells or pipelines during accident or upset conditions.

NREI has designed the project to minimize and control the potential degradation of surface and groundwater quality during project operation in the following ways:

- As described in Section 3.8, NREI would store all potentially hazardous materials used during plant operations in appropriate storage devices that would be located in bermed areas to provide secondary containment. NREI would also maintain appropriate and cleanup materials on site so that spilled materials can be cleaned up immediately and prevented from migrating off-site.
- As described in Section 3.10, the Turboden plant site would include secondary containment with capacity to hold the full volume of cyclopentane held in the plant equipment. This containment system would include valves that would remain shut during normal plant operation to prevent spills of cyclopentane and geothermal fluids from travelling off site. Spills of the cyclopentane from the plant site would be captured in this area and reused to the maximum extent possible. Spills of geothermal fluids would be pumped to the brine containment pond, where the fluids would evaporate or be pumped to the injection well.

- As described in Section 3.13, the proposed plant includes a 350,000-gallon brine containment pond that would be able to collect and contain two hours of full geothermal fluid flows during an accident or upset condition. The brine containment pond would collect and control the release of geothermal fluids from a discharge point after the steam separator, as well as from equipment further downstream in the Turboden plant site (the fluids would be pumped to the containment pond from these downstream points, which would release the fluids to the plant's secondary containment system. Geothermal fluids collected in the containment pond would be allowed to evaporate or be pumped to the plant's injection well.

A pipeline leak upstream of the steam separator is considered remote and unlikely. The proposed binary system maintains geothermal fluids under pressure and a leak is likely to occur at a valve or transfer point, and not from a durable section of pipeline designed to withstand high pressure systems. These valves and transfer points would be located at the well head, where NREI would have blow-out prevention equipment with redundant shut down mechanisms to stop uncontrolled flows of geothermal fluids, or from the valves located within the plant site, which would be controlled by the plant site's secondary containment system. .

The containment of spilled materials onsite and retention of spill cleanup equipment would reduce the likelihood of spills of hazardous materials, geothermal fluids, or waste from affecting surface and groundwater quality.

*Water Resources Impact 6 – Low Significance*

## Decommissioning

As described in Section 3.14, NREI would transfer the project to NEVLEC at the conclusion of the project's contractual agreement. NEVLEC has indicated it intends to continue operations and expand the plant to meet growth and increasing demand. NEVLEC would assume all responsibility for continued responsible operations, or, if desired, plant decommissioning in accordance with applicable guidance and regulations.

### *Water Resource Impact 7 – Degradation of Surface and Groundwater Quality during Project Decommissioning*

Decommissioning activities would include the removal of potentially hazardous materials and waste, and proper handling of the materials and cleanup procedures, as described above, would prevent spills from infiltrating into the groundwater or flowing into the onsite drainage.

Upon decommissioning, the geothermal production and injection wells could be plugged and abandoned. Standard industry practice during well closure currently includes leak testing of the well prior to cementing the well in to prevent potential contamination of the groundwater and removal of the wellhead and casing a few feet below ground surface, and backfilling of the area around the casing.

*Water Resources Impact 7 – Low Significance*

# 5. ALTERNATIVES

The following section discusses the alternatives to the proposed NREI nominal 10-MW (gross) binary geothermal power plant at the Hamilton Estate.

The Federation of St. Kitts and Nevis has adopted a goal of supplying nearly 100 percent of its electricity from renewable resources (Prime Minister Harris, 2016). The NIA plans to meet this goal for Nevis by using the geothermal resources on the western side of the island to replace the existing fossil fueled generation, which provides 95 percent of the current load on the NEVLEC system (US CIA, 2017). NREI has designed the proposed project to meet the NIA objectives.

The NIA issued a Request for Proposals in 2013 for a technically and financially qualified firm to develop a 10 MW geothermal project that would replace the diesel generators at the Prospect Power Plant and serve the peak electric load on the island of Nevis under most circumstances. Although the geothermal resources on the western side of Nevis had been studied since the 1990s, previous plans for developing geothermal resources on Nevis were not able to meet these needs.

NREI considered alternative sites, alternative plant configurations, and design alternatives in developing a geothermal project that would meet these objects.

## 5.1 Alternative Sites

Previous geotechnical investigations had identified areas on the western slopes of Nevis Peak that were promising sites for geothermal development. In 2009, West Indies Power (Nevis), Ltd. (WIPN) conducted exploratory drilling at three sites: N-1 at Spring Hill, N-2 near Jessups, and N-3 at the Hamilton Estate. The N-1 well at Spring Hill encountered high temperature geothermal resources, but suffered a drill string loss in the hole that prevented extensive flow testing. The N-2 well near Jessups was dry, but the loss of drilling fluid indicated highly permeable layers found at depth. The well at Hamilton Estates (N-3) was successfully drilled to 2,950 feet and flowed for approximately 72 hours.

In 2010, WIPN proposed an 8-MW geothermal project at Spring Hill site, which site allowed it to a water-cooled plant with flash technology, the least expensive configuration for a geothermal project. Although the flash plant would release hydrogen sulfide and other gases, the N-1 well has relatively low gas concentrations, and the site had little residential development immediately downwind of the plant. WIPN failed to obtain financing for the Spring Hill project and did not fulfill the terms of its agreement with NIA.

NREI selected the N-3 site at the Hamilton Estates for its proposed project because the 2009 exploratory drilling showed that the geothermal resources at this location had the appropriate pressure, temperature, and flow for commercial geothermal production. The N-3 well, however, has higher noncondensable gas concentrations than the N-1 well (see Table 3.3-1). Moreover, the N-3 site has residential areas and the populated areas of Charlestown, downwind, in the prevailing wind direction, beginning approximately 1,000 feet of the plant location. Thus, use of the N-3 site would require a system that controls hydrogen sulfide emissions.

## 5.2 Alternative Plant Configurations

NREI considered several different geothermal power plant configurations for generating electrical power from the geothermal resources at the Hamilton Estates site. Each conversion process would

use different conversion technology and processes and would have different efficiency, costs, and environmental impacts.

### 5.2.1 Flash Plant

A flash plant would separate the two-phase flow from the wells into high pressure steam and brine. The steam would pass through a turbine and condense it in a direct contact or surface condenser. The brine would be pumped to the injection wells for reinjection. Flash plants circulate cooling water through the condenser to maintain the low pressure that pulls the steam through the turbine. The heat in the circulating water is rejected to the atmosphere as the water in the cooling tower evaporates. In a flash plant, condensate can be used as make up water for the cooling tower although sometimes surface water is used. A flash plant is the most efficient thermodynamic process for high temperature geothermal resources such as is found at Nevis, but flash plants have environmental disadvantages. Noncondensable gases in the steam collect in the condenser and need to be extracted and vented to the atmosphere. Based on the concentrations of gases measured at N-3 in 2009, hydrogen sulfide abatement would be needed at the Hamilton Estates site. Although there are several options for abating hydrogen sulfide emission (see section 5.3, Hydrogen Sulfide Abatement Alternatives, below), all of them add costs and reduce the efficiency of the flash geothermal conversion system. In a flash plant, the carbon dioxide in the geothermal gases would also vent to the atmosphere, but the GHG emissions from a flash plant at Hamilton Estate would be less than 3 percent of the emissions from the diesel units at the Prospect Power Plant. Finally, approximately 75 percent of the steam coming into a flash plant is evaporated in the cooling tower. Over time, the loss of water inherent in using flash technology reduces reservoir pressures and depletes the geothermal reservoir.

### 5.2.2 Backpressure Plant

A backpressure power plant would use a turbine that would release steam directly to the atmosphere and would not have a condenser or cooling tower. Without condensation and cooling, the plant would be able to extract only a fraction of the energy in the resource and would be much less thermally efficient than a flash plant. A backpressure plant would require approximately twice the steam and geothermal resource as a flash project. A backpressure unit would need twice as many geothermal wells, but would occupy less land and would not require cooling water. The backpressure alternative would result in approximately twice the emissions of carbon dioxide, hydrogen sulfide, and other gases. The steam would vent through a stack and would require hydrogen sulfide abatement.

### 5.2.3 Flash Plant with a Binary Bottoming Cycle

NREI could add a binary bottoming cycle to the flash plant to capture some of the heat energy from the brine before it gets injected back into the reservoir. The binary bottoming cycle would increase resource utilization efficiency by extracting additional heat from the condensed steam prior to injection. The binary cycle would need the complete motive fluid loop (evaporator, binary turbine-generator, regenerator, motive fluid condenser, and preheater). A bottoming cycle would not avoid the air emissions of a flash plant and would require fresh water for cooling water, increase parasitic loads, and adds substantial cost to the project.

### 5.2.4 Hybrid Backpressure Plant with Binary Unit

A hybrid unit would combine a backpressure plant with a binary cycle. The steam would exhaust from the turbine at above atmospheric pressure, and the evaporators in the binary would transfer the remaining heat to a motive fluid loop. This configuration would not need a surface condenser, but would require a cooling system and all the equipment of a binary cycle. A hybrid binary unit would extract the noncondensable gases that pass through the turbine and require abatement of hydrogen sulfide emissions. A gas injection abatement alternative, however, could be more feasible for a hybrid unit because the high backpressure reduces the potential for oxidation and corrosion in the noncondensable gas line. The cooling system in a hybrid could use condensate and avoid the need for fresh water. A hybrid unit would cost more than a flash plant and would still require hydrogen sulfide abatement.

### 5.2.5 Binary Power Plant

A binary power plant would use heat exchanges to transfer the heat from the geothermal resource to a motive fluid, typically a hydrocarbon (isopentane or isobutene) or a refrigerant. The geothermal fluid would pass through the plant and be injected without venting to the atmosphere. The plant would have separate loops for the working fluid, each of which would consist of an evaporator, binary turbine-generator, regenerator, motive fluid condenser, and a preheater for storing excess working fluid. Although a binary conversion cycle is less efficient than a flash cycle, NREI decided to proceed with a binary plant for the proposed project at Hamilton Estates because it would avoid virtually all emissions of criteria pollutants and GHGs and would be the most comprehensive way to achieve the NIA objectives for the project.

## 5.3 Hydrogen Sulfide Abatement Alternatives

If NREI were to use a flash plant at the Hamilton Estate site, it would need to have a hydrogen sulfide abatement system, based on the results of the 2009 testing. The following options could be considered for hydrogen sulfide abatement.

### 5.3.1 Caustic Scrubbing

WIPN proposed using a caustic scrubber and with secondary abatement, if necessary, for its flash plant at Spring Hill. WIPN planned to use this system infrequently, when the wind blows in the direction of the sensitive receptors east of the plant instead of the prevailing southwest direction. While caustic scrubbing is a viable short-term method of abating hydrogen sulfide, it produces a residue that builds up in the cooling towers and is not a suitable solution for continuous hydrogen sulfide abatement. At the Hamilton Estates, the prevailing wind direction is expected to be to the west, toward Charleston.

### 5.3.2 Noncondensable Gas Injection

In a gas injection process, the noncondensable gases removed from the condenser would be compressed and injected back into the geothermal reservoir. While gas injection has been used on hybrid systems where the pressurized gases do not come in contact with the atmosphere, it has been unsuccessful at flash projects, where the gases are oxidized. When oxidized, the noncondensable gases become acidic and can damage the injection pumps and injection well casing. Gas injection would also have high parasitic loads and reduce the efficiency of the plant.

### 5.3.3 Thermal Oxidizer

A thermal oxidizer and caustic scrubber system would oxidize the methane, hydrogen sulfide, and other combustible gases present in the geothermal resource. The hydrogen sulfide would oxidize to form sulfur dioxide and sulfur trioxide, which would have to be controlled with a caustic scrubber. The organic hydrocarbons would form nitrogen oxides and carbon dioxide. Because of the low methane and heat content in the noncondensable gases at Nevis, a thermal oxidizer would probably need to use of propane or other supplementary fuel to maintain oxidation temperatures, increasing the emissions of carbon dioxide from the plant.

### 5.3.4 LO-CAT ®

The LO-CAT® process is a patented, wet scrubbing, liquid redox system that uses a chelated iron solution to convert hydrogen sulfide to elemental sulfur, which would need to be reused or disposed of as a waste. The system would have high installation costs and require delivery and continuous use of proprietary chemicals. There is no available process for reusing elemental sulfur at Nevis, and transport and disposal of the sulfur as waste, either on island or at another location, would result in additional environmental impacts.

## 5.4 Cooling Alternatives

NREI considered the following alternatives cooling a geothermal project at the Hamilton Estate.

### 5.4.1 Water Cooling

A water-based cooled system uses a cooling tower to reject waste heat. Water circulates through the condensers, gaining heat that is rejected to the atmosphere as the water evaporates in the cooling tower. A wet cooling tower is the most efficient and cost effective method of cooling a power plant, but it has environmental disadvantages. In a water cooling system, approximately 80 percent of the water coming into the system is evaporated. A water based cooling system could be used for either a flash plant or a binary plant. A flash plant would be able to use condensate as make up water for a cooling tower, but if condensate is used as the makeup water, some hydrogen sulfide would dissolve in the condensate and be emitted through the cooling tower. Use of condensate as a source of make-up water is not an option for a binary plant and fresh or recycle water needs to be used. Using water cooling at a binary plant would require substantial amounts of make-up water to supplement the evaporative losses in the cooling tower. Ground water supplies most of the public piped water supply. Nevis experienced a significant draught in 2015, increasing concerns over water supply issues. The sea level rise anticipated with climate change is expected to increase salt water intrusion into the fresh water acquirers along the coast, further reducing the groundwater supply.

### 5.4.2 Air Cooling

Air-cooling is less efficient than water cooling and results in less power produced during the hottest parts of the day. Air cooling requires a larger site and has more components than a cooling tower, adding to the project disturbance area and project costs. While water cooling is an option for a flash plant that can use condensate for makeup, air cooling is more appropriate for a binary plant., particularly in locations were water supply is an issue.

## 5.5 No Project Alternative

The no project alternative would result in NREI not constructing or operating the proposed project at the Hamilton Estate. None of the impacts associated with the proposed project would occur, and the site would be available for other uses. NEVLEC would continue to use the Prospect Station diesel generators to supply the electricity to the island. The cost of diesel fuel would continue to be subject to price fluctuations, and the generating equipment would continue to emit criteria pollutants and greenhouse gases to the atmosphere.

## 5.6 Selection of the Proposed Alternative

In summary, NREI decided to use a binary conversion cycle with air cooling for its geothermal project at the Hamilton Estate. The use of a binary cycle would avoid virtually all emissions of geothermal gases, and air cooling would avoid the need to use the limited water resources on the island. The use of binary equipment is appropriate for a site that is upwind of populated areas, and the use of air cooling is appropriate for an island with limited water resources. To make up for the lower efficiencies of this these processes, NREI decided to use the highly efficient Turboden Organic Rankin Cycle technology and selected cyclopentane as the working fluid because its high boiling point enables effective use of the high temperature geothermal resources found at the Hamilton Estates.

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# 6. CUMULATIVE IMPACTS

The following section describes the cumulative impacts of the proposed NREI binary geothermal project with past, current, and future foreseeable projects at Nevis.

## 6.1 Past, Current, and Future Foreseeable Projects

The proposed NREI binary geothermal project would be located on leased crown land at the Hamilton Estate that was formerly part of a 580-acre sugar plantation. The abandoned sugar works at the Hamilton Estates are identified as a tourist attraction at Nevis, and the propose binary plant in a landscaped setting is likely to draw visitors to the area. While no other projects are known to be planned for the Hamilton Estates area, the land surrounding the plant site is privately owned, in relatively small parcels. The area has dramatic views of the coastline and the downtown areas of Charlestown. Thus, it is reasonably foreseeable that additional development could be proposed at the Hamilton Estate, including additional residences or perhaps new restaurants and tourist facilities. Any such development, would have to consider the proposed 10-MW binary plant as an existing use and would have to be compatible with this use (see section 4.7, Land Use).

## 6.2 Cumulative Impacts

Most environmental resources would not experience cumulative effects from the project. Most of the impacts of the project are site-specific and would be limited to the immediate area. The impacts of site disturbance would be contained on site not affect the adjacent areas. The proposed project includes erosion controls and containment features that would prevent sedimentation during construction and accidental spills from affecting water resources. The proposed project would not produce any significant impacts to cultural resources, and the geological impacts are site-specific and do not accumulate. The land use and socioeconomics sections already address potential issues in the context of existing and future development and therefore the cumulative land use and socioeconomic impacts of the project would be no more significant than the project-specific land use and socioeconomics impacts already considered in the respective sections.

Any development in the area, including the proposed project, has the potential to remove vegetation and disturb wildlife, change the visual landscape, but the project is not expected reduce recreational use of the surrounding areas. The economy of Nevis depends on tourism, and therefore visible changes in the landscape and decreases in recreational opportunities are particularly sensitive issues. The project would be barely visible from the coastal areas and only seen in the distance from high terrain. Likely future development in the area would consist of residences and small tourist facilities in keeping with the visual character of the area. Development of undisturbed land, however, would reduce land available for hiking or mountain-biking, disturb wildlife, and detract from the natural and rural character of the island that tourists enjoy.

Several planned conservation areas, including the Nevis Peak Project and the Camps Watershed would set aside land where ecosystems would be protected. The proposed nature preserves would constrain development in certain natural areas remain undeveloped and would preserve outdoor recreational opportunities. Disturbance of undeveloped land would contribute cumulatively to the aesthetic, biological, and recreational impacts of the proposed project, but the establishment of conservation areas would prevent cumulative impacts from becoming severe.

Unknown future development would result in some air emissions. The island of Nevis, however, does not have any known air quality problems, and the persistent sea breezes would prevent accumulation of criteria pollutants.

Future development could result in cumulative transportation impacts in the immediate area. The proposed geothermal project would have a small impact on traffic during construction, and a negligible impact on traffic during operation. Cumulative impacts from transportation could be significant if a future project were to increase traffic during the construction stage of the proposed geothermal plant. Future development, however, would most likely occur after construction finished on the geothermal plant and therefore would not result in a cumulative traffic impact.

Additional possible development near the geothermal project site could include residences and tourist facilities. Development projects such as these would increase risk of fire, increase the number of people and amount of property that could be impacted by noise from the geothermal plant, and increase the burden on police and fire protection services.

# 7. IRREVERSIBLE AND IRRETRIEVABLE IMPACTS

The following section evaluates long-lasting or permanent impacts of the proposed project, including materials that would not be recovered, natural resources that would not be restored or replenished over time, and damage to the project site that would not be undone.

## 7.1 Project Site

The proposed project would be located on rural lands, formerly planted in sugarcane. Adjacent land uses include open space, undeveloped drainage, scattered housing, condominiums, government housing, and the outlying residential areas of Charlestown. Following the eventual closing of the geothermal power plant, the plant would be dismantled and removed from the site. In the absence of new planned development, the project site would be allowed to return to its previous state as - habitat of native and nonnative species. The only built evidence of the project at the site would be the wells themselves, which would be properly sealed and abandoned.

## 7.2 Natural Resources

The proposed project does not anticipate any long-lasting or permanent impacts to natural resources. The geothermal resource from which the plant would derive energy is large relative to the amount of fluids and heat that the plant would extract, and, according to the best available data, the resource naturally replenishes with rainwater and seawater. Depletion of the resource over the short term is highly unlikely and permanent or long-term depletion of the resource is more unlikely still.

## 7.3 Materials

Some construction materials would be irretrievable. It may not be cost-effective to recycle some materials, and others may be contaminated by metals and compounds in the geothermal fluid such that they must be disposed of as hazardous waste.

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## 8. ENVIRONMENTAL AND SOCIAL ACTION PLAN

The Nevis Binary Geothermal Development Project would result in potential impacts to the environment and the public. Table 8-1 lists these potential impacts, the measures and best practices NREI has included in the project to avoid and minimize potential impacts, the party responsible for implementing the measure or best practice, and the timing, resources, and monitoring/verification steps associated with the measure/best practice.

As described in Section 4.1, the proposed binary geothermal development project would result in impacts with only a "low" or "moderate" significance. The proposed project would have no substantial adverse impacts. As such, the proposed project does not require mitigation and can be classified as a Category B project for OPIC review and would not require an Environmental and Social Action Plan. The following table has been prepared to demonstrate that NREI has an environmental and social management system commensurate with the significance of the project's potential impacts. The table addresses human resources, environmental management, occupational health and safety management, and community relations, as well as provides the project's mechanisms for implementing and reporting to affected people on the project's performance. NREI would maintain plans, procedures, and other documentation to verify compliance with these design measures and best management practice and would provide this evidence as specified in Table 8-1 or as otherwise requested by the NIA.

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**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| **Aesthetics** | | | | | |
| Views of Drilling, Construction Activities, and Ongoing Geothermal Operations | Shield and direct lighting toward the ground during drilling, construction, and operation | NREI or designated representative/ contractor | During Construction and operation | Engineering plan check | NREI shall provide copies of project plans to NIA |
| | Paint facilities to blend in with the natural surroundings | NREI or designated representative/ contractor | Prior to operation | Engineering plan check | NREI shall provide copies of project plans to NIA |
| **Biological Resources** | | | | | |
| Clearing and Grading of Scrub Vegetation | Avoid large tree removal and | NREI | Prior to and during construction | Site plan review | NREI shall provide copies of project site plan to NIA |
| | Minimize unnecessary clearing of land | NREI | Prior to and during construction | Site plan review | NREI shall provide copies of project site plan to NIA |
| | Provide landscaping | NREI or designated representative/ contractor | Prior to operation | Landscaping plan review | NREI shall provide copies of landscaping plan to NIA |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| Temporary disturbance of wildlife | Fence project area to prevent harm to wildlife from direct contact with project facilities | NREI or designated representative/ contractor | During construction and operation | Site plan review | NREI shall provide copies of project site plan to NIA |
| **Climate and Air Quality** | | | | | |
| Construction would create dust and emit criteria and greenhouse gas pollutants | Water active construction areas twice daily | NREI or designated representative/ contractor | During construction | On-site monitor | Monitoring report |
| | Limit idling of construction equipment to no more than 15 minutes when feasible and consistent with equipment operating procedures | NREI or designated representative/ contractor | During construction | On-site monitor | Monitoring report |
| Geothermal releases from the rock muffler may cause an odor nuisance until the wells are shutdown or the power plant brought back online | Use chemical abatement to limit hydrogen sulfide emissions when necessary to avoid odors in nearby residential areas | NREI | During well drilling, testing, and plant operation | On-site monitor | Monitoring report |
| | Shut in the wells within an hour to avoid impacts to downwind receptors | NREI | During plant operation | Develop plant operating procedures | NREI shall provide copies of operating procedures to NIA |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| Geothermal releases from the rock muffler may cause an odor nuisance until the wells are shutdown or the power plant brought back online | Design brine containment pond to accommodate two full hours of geothermal fluid flow | NREI | Prior to construction | Engineering plan check | NREI shall provide copies of project plans to NIA |
| **Cultural and Historic Resources** | | | | | |
| Ground-disturbing activities during construction could encounter buried resources, including human remains | Notify the appropriate authorities and relocate project facilities if buried cultural or historic artifacts are discovered during site excavation | NREI or or designated representative/ qualified cultural resources contractor | During construction | Develop cultural resources management protocol | NREI shall provide a copy of the protocol to NIA |
| **Hazards and Hazardous Materials** | | | | | |
| Leaks, spills, and other discharges of potentially hazardous materials and/or geothermal fluids | Place secondary containment around hazardous material areas | NREI | During construction and operation | Engineering plan check | NREI shall provide copies of project plans to NIA |
| | Prepare a Safety Plan for the site and instruct workers in the proper handling of materials | NREI | During construction and operation | Develop plant operating procedures / safety plan | Develop plant operating procedures and safety plan |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| Leaks, spills, and other discharges of potentially hazardous materials and/or geothermal fluids | Prepare a spill containment plan for the project | NREI | During construction and operation | Develop plant operating procedures/spill plan | NREI shall provide copies of project plans and procedures to NIA |
| | Monitor geothermal fluid conditions, equipment operation, and pressure in order to detect and repair potential leaks | NREI | During construction and operation | Develop plant operating procedures | NREI shall provide copies of project procedures to NIA |
| Fire impacts | Install a fire protection system at the site | NREI or designated representative/ contractor | During construction and operation | Engineering plan check | NREI shall provide copies of project plans to NIA |
| | Store flammable hazardous materials in non-flammable, flame retardant tanks or buildings | NREI | During construction and operation | Develop plant operating procedures | NREI shall provide copies of project procedures to NIA |
| Well blowout | Install blowout prevention equipment (BOPE) | NREI or designated representative/ contractor | During construction and operation | Engineering plan check; construction and operating procedures | NREI shall provide copies of project plans and procedures to NIA |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| Well blowout | Develop an emergency shut-in plan to stop a well blowout and to contain and clean up any fluids that may be released | NREI or designated representative/ contractor | During construction and operation | Engineering plan check; plant emergency procedures | NREI shall provide copies of project plans and procedures to NIA |
| Electric shock | Fence and restrict access of the public to the facility | NREI or designated representative/ contractor | During construction and operation | Site plan review | NREI shall provide copies of project plans to NIA |
| **Land Use** | | | | | |
| The proposed project would be incompatible with future residential development of the parcels immediately adjacent to the proposed power generating facilities | NREI would encourage the NIA to limit development of the parcels immediately adjacent to the binary project to compatible uses and restrict potential new residential development within 1,000 feet of the power generating facilities | NREI | Ongoing | Information on adjacent property owner plans | NREI shall encourage the NIA to limit development |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| **Noise** | | | | | |
| Temporary increase in noise levels during construction | Install an earthen berm or temporary sound wall between drilling locations and residential receptor locations within 1,000 feet of the drill rig that can provide to 21 dB of noise reduction | NREI and designated representative/ contractor | Prior to and during construction | On-site monitor | NREI shall provide copies of project plans to NIA, including specifications for the earthen berm or temporary sound wall; Construction monitoring report |
| Temporary increase in noise levels during construction | Provide receptors within 1,000 feet of the project parcels written notice prior to the start of construction that describes the project's construction schedule and the name and contact information for the NREI or contractor staff person responsible for handling construction noise complaints. | NREI and designated representative/ contractor | Prior to and during construction | Affected property notifications | NREI shall coordinate with NIA on affected property notifications |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| Temporary increase in noise levels during construction | Provide receptors within 1,000 feet of drilling sites at least one week's advance written notice of the start of well drilling, well venting, and well testing activities. | NREI and designated representative/ contractor | Prior to and during construction | Affected property notifications | NREI shall coordinate with NIA on affected property notifications |
| | Use a silencer or rock muffler during all well venting activities, including initial cleanout, as feasible. | NREI and designated representative/ contractor | During well venting | On-site monitor | Construction monitoring report |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| Increased ambient noise levels during operation | NREI has designed the project to reduce and avoid operational noise by: 1) Maximizing the distance between the condenser units and residential receptors; 2) Installing air-cooled condenser units with variable speed drives; 3) Reducing the amount of air-cooled condensers operating during the nighttime period (10 PM to 7 AM) to the minimum amount necessary to provide necessary electrical load requirements; and 4) Planting trees and other dense vegetation to increase soft ground cover and potential attenuation of noise levels. | NREI and/or designated representative/ contractor | Prior to operation | Site plan, equipment specifications; engineering plan check | NREI shall provide copies of project plans and equipment specifications to NIA |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| Increased ambient noise levels during operation | Following receipt of an operational noise complaint, verify noise levels at the affected receptor and coordinate with the NIA as necessary to identify additional measures and activities that could be undertaken to reduce operational noise levels in excess of 55 dBA during the day and 45 dBA during the night as much as possible (e.g., permanent sound barriers, retrofitting residences, or other measures agreed to by NREI and the NIA) | NREI and designated representative/ contractor | Upon receipt of a noise complaint. | Designated NREI staff person responsible for addressing complaints; noise monitoring results; qualified sound monitoring technician (to verify sound levels) | NREI shall provide the NIA and residences within 1,500 feet of the plant the name and contact information of the NREI staff person to contact regarding plant noise; NREI shall provide copies of the complaint, any noise monitoring, and resolution to the NIA |
| **Public Health and Safety** | | | | | |
| Well blowout | See Hazards and Hazardous Materials | | | | |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| Leaks, spills, and other discharges of potentially hazardous materials and/or geothermal fluids | See Hazards and Hazardous Materials | | | | |
| Plant damage from hurricanes, earthquakes, and volcanic activity | Prepare a Hurricane Response Plan for the project describing shutdown criteria, notification procedures, and safety requirements in the event of a Class III or greater hurricane | NREI | Prior to the start of construction | Plant procedures and plans | NREI shall provide copies of project plans and procedures to NIA |
| Plant damage from hurricanes, earthquakes, and volcanic activity | Design the project to be consistent with national and international building codes and withstand winds of up to 150 miles per hour | NREI | Project design | Engineering plan check | NREI shall provide copies of project plans to NIA |
| | Prepare an Emergency Response Plan that would address earthquakes and volcanic activity | NREI | Prior to start of construction | Plant procedures and plans | NREI shall provide copies of project plans and procedures to NIA |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| **Recreation** | | | | | |
| Disturbance to recreational activities | See Aesthetics, Climate and Air Quality, and Noise | | | | |
| **Socioeconomics and Environmental Justice** | | | | | |
| Job creation and economic effects | Comply with local laws and international policies on worker rights and working conditions. | NREI | Construction and operation | Labor policies and procedures | NREI shall provide copies of project procedures to NIA |
| | Pay royalties and taxes for use of NIA land and resources. | NREI | Project lifetime | Financial resources | NREI shall maintain receipts for payments of royalties and taxes |
| **Soils, Geology, and Minerals** | | | | | |
| Soil removal, erosion and topsoil loss | Minimize the unnecessary clearing of land, water the site during construction, and install silt fences | NREI and/or designated representative/ contractor | Prior to and during construction | On-site monitor | Monitoring report |
| Exposure to seismic hazards, including ground shaking | Design the geothermal facility to meet all applicable structural, seismic, and wind loading design criteria of the latest IBC (currently 2015) | NREI | Project design | Engineering plan check | NREI shall provide copies of project plans to NIA |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| Micro- and induced-seismicity | Following receipt of a seismic complaint, verify seismic activity and coordinate with the NIA as necessary to develop an appropriate response plan. | NREI and | Upon receipt of a seismic complaint. | Designated NREI staff person responsible for addressing complaints; seismic monitoring results; qualified seismic monitoring technicians (to verify seismic activity levels) | NREI shall provide the NIA and residences within 1,500 feet of the plant the name and contact information of the NREI staff person to contact regarding seismic activity; NREI shall provide copies of the complaint, any monitoring, and resolution to the NIA |
| Volcanic activity and tsunamis | See Public Health and Safety | | | | |
| Expansive soils | Perform site-specific soils analysis and engineering analysis | NREI and/or designated representative/ contractor | Prior to construction | Engineering plan check | NREI shall provide copies of project plans to NIA |
| Sanitary waste disposal | Perform site-specific soils analysis and engineering analysis | NREI and/or designated representative/ contractor | Prior to construction | Engineering plan check | NREI shall provide copies of project plans to NIA |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| **Traffic and Transportation** | | | | | |
| Traffic congestion | Provide vans or buses to transport workers between temporary residences and project site | NREI | During construction | Construction procedures | NREI shall provide copies of project procedures to NIA |
| **Water Resources** | | | | | |
| Alteration of existing drainage patters | Direct surface water flows to new culverts or drainage ditches | NREI and/or designated representative/ contractor | Project design | Site plan review | NREI shall provide copies of project plans to NIA |
| | See also Biological Resources and Soils, Geology, and Minerals | | | | |
| Potential degradation of surface and ground water quality (from construction and operation, releases of potentially hazardous materials, and releases of geothermal fluids) | Minimize the unnecessary clearing of land and install silt fences | NREI and/or designated representative/ contractor | Prior to and during construction | Site plan review | NREI shall provide copies of project plans to NIA |

**Table 8-1**
**ENVIRONMENTAL AND SOCIAL ACTION PLAN**

| Topic and Impact Description | Design Measures and Best Practices that Avoid or Minimize Impact | Party Responsible for Measure | Timing of Measures | Resources Needed for Measure | Monitoring / Verification Action |
|---|---|---|---|---|---|
| Potential degradation of surface and ground water quality (from construction and operation, releases of potentially hazardous materials, and releases of geothermal fluids) | Direct surface water flows to new culverts or drainage ditches | NREI and/or designated representative/ contractor | Project design | Site plan review | NREI shall provide copies of project plans to NIA |
| | Grade well pads to drain into well pits or mud pumps | NREI and/or designated representative/ contractor | Project design | Site plan review | NREI shall provide copies of project plans to NIA |
| | Store all potential hazardous materials in appropriate storage vessels in areas with secondary containment systems | NREI and/or designated representative/ contractor | Project design, during construction and operation | Site plan review, construction procedures | NREI shall provide copies of project plans and procedures to NIA |
| | See also Hazards and Hazardous Materials and Public Health and Safety | | | | |

# 9. Consultation, Coordination, and Preparation

The following sections list the persons and agencies consulted and the preparers and reviewers of the Nevis Geothermal Development Project EIA.

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# APPENDIX A

**April 14, 2017**

**Environmental Assessment**

**Drilling and Flow Testing One Geothermal Well at The Hamilton Estate**

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# Drilling and Flow Testing One Geothermal Well at The Hamilton Estate

# Environmental Assessment

**Prepared for**
**Nevis Renewable Energy International, Inc.**

**Prepared by**
**Point Impact Analysis, LLC and MIG**
**April 14, 2017**

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# PROJECT DESCRIPTION

Nevis Renewable Energy International, Inc. (NREI), a subsidiary of Thermal Energy Partners, LLC, is planning to develop the geothermal resources on the Island of Nevis using binary technology to provide a sustainable supply of electric power for Nevis that avoids reliance on the world oil markets and emissions of criteria pollutants and greenhouse gases. Exploratory drilling in 2009 found high temperature geothermal resources at two locations on the west side of Nevis: the Hamilton Estate, approximately 1.5 miles east of Charlestown, and Spring Hill, approximately 2.5 miles to the north. See Figure 1, Regional Map.

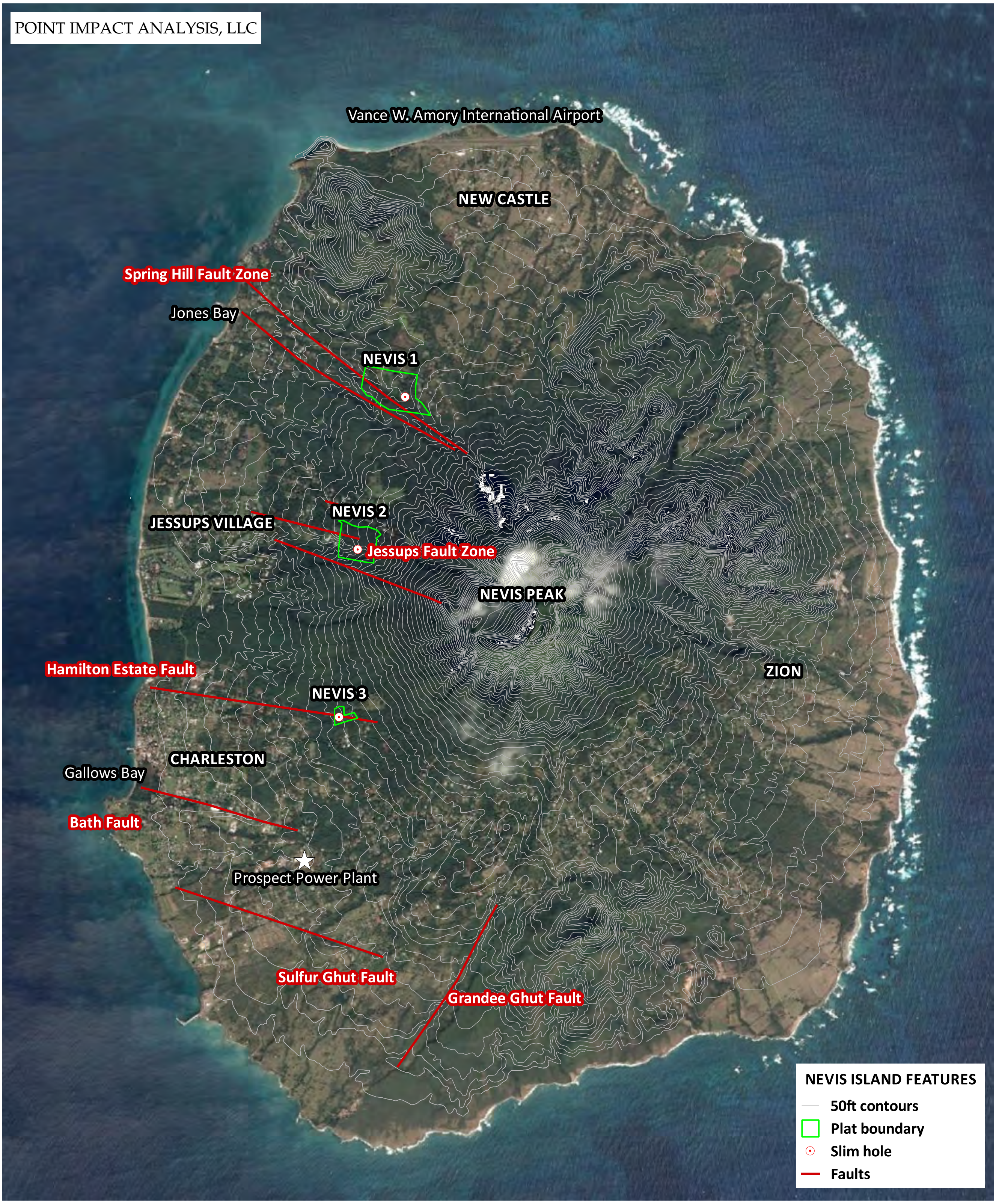
The 2009 testing of the exploratory slim hole at the Hamilton Estate showed that the geothermal resources at this location had the appropriate pressure, temperature, and flow for commercial geothermal production. NREI is proposing to drill and test a larger diameter well at the Hamilton Estate to demonstrate that the production is sufficient for long-term operation of a 9 megawatt (MW) binary geothermal project at the site.

The Nevis Island Administration (NIA) owns the geothermal resources on the Island of Nevis and has granted NREI the rights to develop these resources to supply power to Nevis. These rights include a long-term lease on the 9.07-acre Hamilton Heritage Trust land west of Charlestown that was previously used for exploratory drilling. The Nevis Electric Company (NEVLEC) has contracted with NREI for a 25-year energy supply from geothermal resources, beginning with a 9 MW geothermal project to provide power for the electrical load on Nevis.

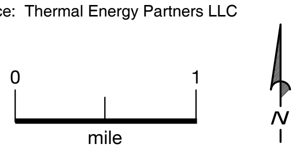
This environmental assessment (EA) evaluates the direct physical impacts and potential environmental effects that could occur during drilling and testing of a new 8.5-inch test well at the NREI the Hamilton Estate site.

Previous geotechnical investigations and the 2009 exploratory drilling at three sites on the western slopes of Nevis Peak were performed by West Indies Power (Nevis), Ltd. (WIPN). The WIPN well at Spring Hill (N-1) suffered a drill string loss in the hole that prevented extensive flow testing. The N-2 well near Jessups was dry, but the complete loss of drilling fluid testified to highly permeable layers found at depth. The well at the Hamilton Estate (N-3) was successfully drilled to 2,950 feet and flowed for approximately 72 hours. WIPN proposed an 8 MW geothermal plant at Spring Hill in 2010 but failed to obtain financing and develop the geothermal resources under the terms of its agreement with NIA. In 2014, the NIA cancelled its agreement with WIPN and awarded the right to the develop the geothermal resources on Nevis to NREI.

Based on the testing to date, NREI plans to develop its initial geothermal project at the Hamilton Estate. The site is close to the electric loads at Charlestown, the capital of Nevis, and to the NEVLEC substation at the Prospect Power Plant.




Source: Thermal Energy Partners LLC




*NREI Geothermal Exploration*

FIGURE 1
REGIONAL MAP

The geologic, geochemical, and geophysical studies conducted at Nevis to date indicate that the present-day Nevis Peak volcano and its associated magmatic activity are the heat source for the current geothermal activity on the island. The fluid chemistry data indicate that the geothermal system underlies a colder potable water aquifer. Geophysical surveys across the western half of the island have shown that the shallow, fresh water aquifer and the deeper, geothermal resource are separated by a low permeability predominantly clayey weathered zone that begins at a depth of approximately 800 to 1,000 feet and extends to approximately 2,600 feet, at least in the Hamilton Estate area and northward to the Jessup Springs area. Lower down on the slopes of Nevis, approaching the coast, and at least one area offshore, there are several areas where hot fluids from the deep subsurface have moved upward along faults through the intervening geologic layers and produced hot springs and thermally altered soils. The 2009 exploratory drilling occurred along the major structural faults on the west flank of Nevis Peak. The N-1 well is adjacent to the Spring Hill Fault Zone. The N-2 well is along the Jessups Fault Zone, and the N-3 well is adjacent to the Hamilton Estate Fault.

## NREI Drilling and Testing Program

The proposed action considered in this EA consists of drilling a test well at the NREI lease at The Hamilton Estate and performing production and/or injection testing of the well for up to 14 days. The test well would have a bottom hole diameter of approximately 8.5 inches and would be drilled to a depth of approximately 4,000 feet, within the production zone. The 2009 slim hole (diameter of 2 and 15/16 inches) drilling encountered high-pressure and high temperature 392$^{o}$ Fahrenheit (200$^{o}$ Celsius) geothermal resources at a depth of only 2,950 feet.

### Well Drilling

The proposed test well would be in the northern portion of the 9.07-acre NREI lease at The Hamilton Estate, approximately 400 feet north of the 2009 slim hole location. The test well would be at an elevation of approximately 538 feet, on the northern portion of the lease. Existing unpaved roads can be used to deliver the drilling equipment to the pad area with only minor improvements. The site for the proposed well was previously used for growing sugar cane, but now contains scrub vegetation. It is approximately 1.6 miles northeast of the harbor in Charlestown, the capital of Nevis.

NREI contractors plan to clear a level drill pad approximately 250 feet by 170 feet, slightly less than an acre. The cleared vegetation and soil would be taken to the local landfill. The well pad would include sufficient area for the drilling equipment, storage tanks, office trailer, and a large drilling sump. The pad would also provide space for parking for the crew and a turnout area for service and delivery vehicles and an area sufficient for laydown of the mast.

NREI plans to use a standard rotary drill rig that would be delivered to the harbor at Nevis in pieces and transported and assembled onsite. The DRILLMEC HH 200 S hydraulic rig has three 1500 horsepower (hp) engines and a mast that would be approximately 78 feet high. The proposed drilling equipment includes large pipe racks, two air compressors, two 1100 kilowatt (kW) generators and an auxiliary 160 kW AC generator, two mud pumps, a mud shaker and suction tank, desalting and desanding equipment, cementing equipment, a water tank, two fuel tanks, an office trailer, fire

extinguishers and blankets, and tanks to collect the bore cuttings. The proposed equipment also includes Washington blowout prevention (BOP) equipment pressure tested to 2,000 psi. See Figure 2, Typical Well Pad Layout.

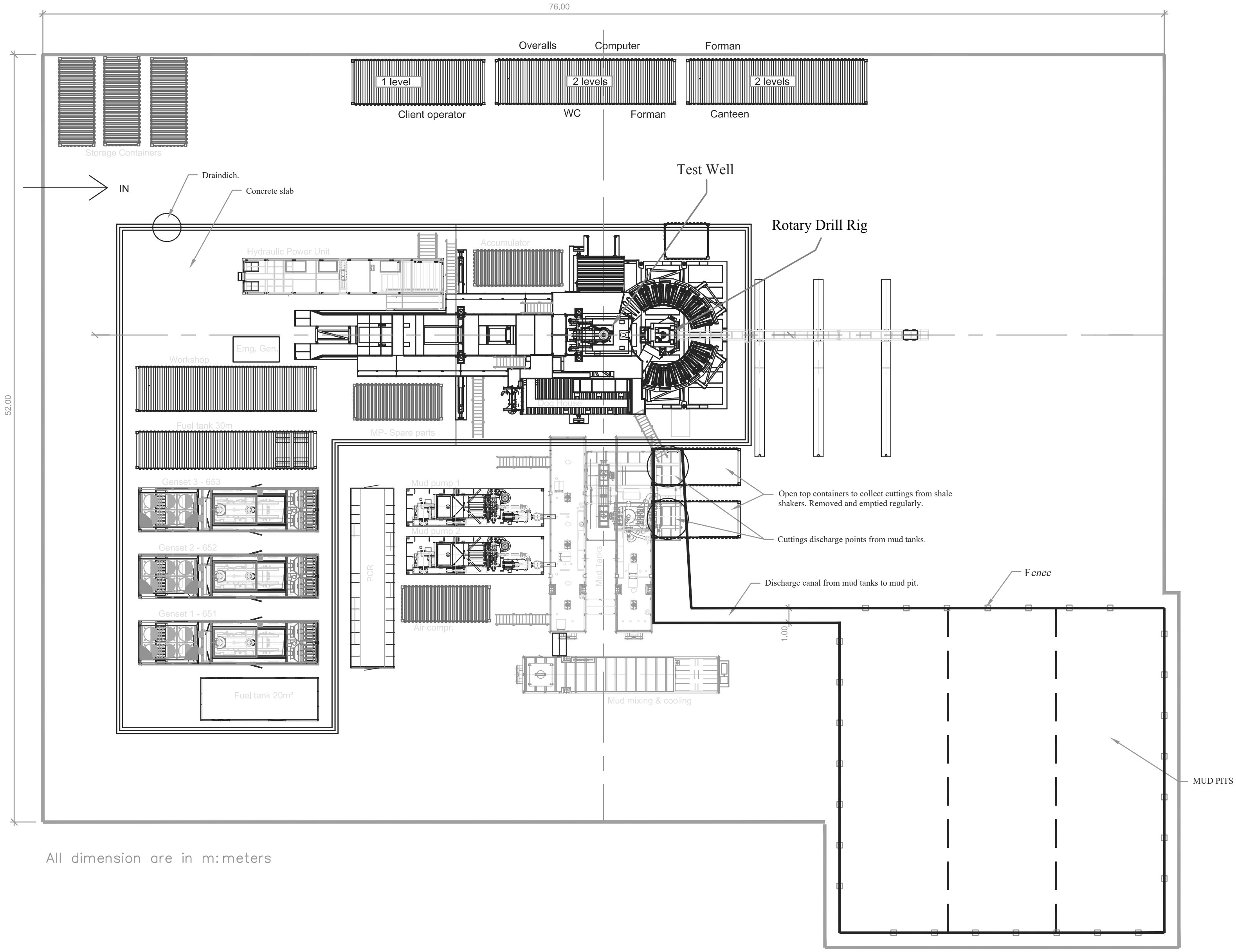
Table 1 shows the drilling interval, drill bit sizes, and casing sizes for the proposed N-3 test well at The Hamilton Estate.

**Table 1: Drilling Interval, Drill Bit Size, and Casing Size for the N-3 Test Well**

| Drilling Interval | Drill Bit Diameter | Casing Type | Casing Diameter |
|---|---|---|---|
| 0-263 ft (0-80 m) | 21 inches | Surface Casing | 18 5/8 inches |
| 0-984 ft (0-300 m) | 17 ½ inches | Anchor Casing | 13 3/8 inches |
| 0-2461 ft (0-750 m) | 12 ¼ inches | Production Casing | 9 5/8 inches |
| 2395-4000 ft (730-1220 m) | 8 ½ inches | Perforated Liner | 7 inches |
| Source: Iceland Drilling Company, Geothermal Development, Nevis St. Paul, Preliminary Drilling Program, N-3 Geothermal Site, (2017). | | | |

Up to 10,000 gallons of water a day would be used for drilling from two sources. A 4-inch water main north of the site would provide up to 200 gallons per minute for drilling operations during non-peak use times. This nearby line would be used to fill the drilling sump and would provide most of water supply for drilling operations. There is a second source of water, if needed available for drilling. This backup or supplemental water would come from the Hermitage Heights Tank Farm near Charlestown, approximately one mile west of the site and would be delivered by truck. The water would be mixed with drilling muds and additives and would circulate down the wellbore and return up the space between the bore and the sides the well (the annulus), carrying cuttings to the surface. The cutting would be collect in the shale shaker while the drilling fluid would recirculate back down the well. Most drilling additives are inert or nontoxic materials, but some additives may be classified as hazardous and require special handling.

During drilling in the production zone, some geothermal steam can mix with the drilling fluid and be discharged from the blooie line when the fluid returns to the surface. NREI would perform sampling when drilling encounters the geothermal resource in the production zone to determine the concentration of hydrogen sulfide ($H_2S$) in the release. $H_2S$ has a characteristic odor of rotten eggs at relatively low concentrations (0.005 – 0.008 ppm) and is toxic at substantially higher concentrations (100-350 ppm).




Source: Iceland Drilling Company 2017

*NREI Geothermal Exploration*

FIGURE 2
TYPICAL WELL PAD LAYOUT

$H_2S$ is commonly found in geothermal resources. Based on the sampling in 2009, some $H_2S$ may be detected at the N-3 site and surrounding area during drilling. The proposed drilling equipment includes three $H_2S$ detection sensors for worker safety and a spare, which would be located downwind of the drill site. If the gas is detected at levels that would produce unacceptable odors at downwind residences, NREI would inject abatement chemicals into the blooie line to reduce $H_2S$ emissions to the levels allowable at other geothermal projects near sensitive receptors. (See the discussion of abatement during well testing.) Most regulatory jurisdictions do not require $H_2S$ abatement during geothermal drilling; at The Geysers, a geothermal area in California, drilling emissions must be less than 5.5 pounds per hour (lbs/hr) $H_2S$.

The drill cuttings would be collected in an open container and discharged to a lined drilling sump. The sump would be approximately 10 feet deep and approximately 72 feet by 72 feet and divided into three sections. The drilling sump would be lined with Bentonite and could contain more than 350,000 gallons of drilling fluids and produced waters.

The proposed drilling plans include two double-hulled diesel storage tanks with a combined capacity of approximately 13,000 gallons. Additional diesel is available from the NEVLEC Prospect Power Plant, approximately 1.1 miles southwest of the site and can be trucked to the site as needed. The fuel storage tanks and drilling lubricants and additives would be stored in a designated area with impermeable surface. The storage area would be bermed to contain potential spills and any contaminated stormwater.

The proposed drilling activities on Nevis would last approximately 10 weeks, with two weeks for delivery and assembly of the drill rig and equipment on site. Actual rotary drilling would take place 24 hours per day and may continue for approximately 40 days. Drilling would require two 9-person crews plus NREI supervisors. Another two weeks would be needed to dismantle the rig and load it at the harbor.

## Well Testing

After the proposed well is completed and cleaned out, NREI would perform production and injection testing to identify the flow rate of the well, the enthalpy (heat content) of its geothermal resource, and injection properties of the reservoir.

Based on the initial flow of the N-3 well in 2009, the geothermal resource at The Hamilton Estate produces two-phase flow (steam and liquid) at the wellhead. The two-phase flow needs to be separated to determine its heat content and the ratio of steam to water in the resource. NREI would flow test the well through a cylindrical separator, which would separate the steam at above atmospheric pressures and would allow use of a James tube to determine the enthalpy of the resource. When separated during testing, the steam would vent to the atmosphere, although during actual plant operations all steam production would be contained and injected back into the geothermal reservoir. The water would collect in the drilling sump and would eventually be injected back into the reservoir, through either the 2009 slim hole well or the proposed test well.

NREI plans to flow test the new well in stages, starting out at 20% of the maximum flow rate and gradually stepping up the flow rate in 20% increments after each stage reaches equilibrium. During geothermal flow testing, the capacity of the drilling sump often determines the length of time that a

well can be tested. The proposed drilling sump has a capacity of over 350,000 gallons. NREI plans to augment this capacity by injecting some of the produced fluids into the existing N-3 slim hole, which can accept 3,000 gallons/hour of flow during testing.

Table 2 shows the expected flows, duration, and injection rates during each test stage. The actual duration of each stage would be determined by the onsite geologist and could be as short as a few hours for the early stages. Use of the N-3 slim hole for injection could extend the time for testing at maximum flow to over 40 hours.

**Table 2: Expected Flow Rates During Well Testing**

| Test Stage | | Hourly Flow (Gallons/Hour) | Duration (Hours) | Total Flow (Gallons) | Flow Injected into N-3 (Gallons) | Flow into Sump (Gallons) |
|---|---|---|---|---|---|---|
| 1 | 20% | 2,158 | 12 | 25,891 | 25,819 | 0 |
| 2 | 40% | 4,315 | 14 | 60,413 | 42,000 | 18,413 |
| 3 | 60% | 6,473 | 16 | 103,565 | 48,000 | 55,565 |
| 4 | 80% | 8,630 | 16 | 138,086 | 48,000 | 90,086 |
| 5 | 100% | 10,788 | 24 | 258,912 | 72,000 | 186,912 |
| **Total** | **--** | **--** | **82** | **586,867** | **246,000** | **350,976** |
| Source: NREI, 2017 | | | | | | |

Although the proposed Turboden binary technology would avoid emissions of geothermal pollutants during power plant operations, some $H_2S$ would be released during well testing. Based on the analyses of the N-3 well during venting, the $H_2S$ emissions during the final three stages of well testing at The Hamilton Estate are likely to require treatment. Screening modeling of well testing at Nevis indicates that emissions of 5.5 lbs/hr result in impacts at downwind locations that are below the odor threshold, at prevailing wind speeds. Injection of sodium hydroxide (NaOH) and hydrogen peroxide ($H_2O_2$) into the vented steam can convert the $H_2S$ to soluble sulfates that can be injected. The required abatement rates depend on the well flow and composition of the resource and would be determined during testing. Abatement would not be needed if the testing were performed when the prevailing wind direction was away from nearby residential areas or if wind speeds were above 3 meters per second (m/sec) (6.7 miles an hour). NREI would have storage tanks with sufficient quantities of 25-30% aqueous solution NaOH and 50% $H_2O2$ on site to abate the potential emissions for 70 hours.

If the produced geothermal waters during testing threatened to exceed the capacity of the sump, NREI would attempt to inject the fluids into the existing slim-hole at the site. If necessary, NREI would stop the flow test and begin injection testing of the new well. Geothermal fluids typically contain constituents that may be harmful to vegetation and aquatic life if discharged to natural drainages. Geothermal fluids and drill cuttings are exempt from US Environmental Protection Agency regulations regarding hazardous wastes and underground injection. Fluids that cannot be injected into the wells would remain in the sump and evaporate. If necessary, the sump would be modified to allow the fluids to infiltrate into the volcanic soils at the site. The sump would remain on site to be used for future operations.

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# ENVIRONMENTAL ASSESSMENT

## Environmental Impacts

Development of the geothermal resources at Nevis would result in environmental and socioeconomic benefits for the island. Nevis Electricity Company (NEVLEC) currently generates electrical power for the Island of Nevis at the Prospect Power Pant southeast of Charlestown. This power plant contains seven diesel generators with an installed capacity of 13.9 MW. (St. Kitts and Nevis Ministry of Finance, 2004). Diesel units emit criteria pollutants (oxides of nitrogen, sulfur dioxide, carbon monoxide, and particulates) and greenhouse gases (GHG) from the combustion of fossil fuels. NREI proposes to use Turboden binary technology which would have no products from combustion, inject all geothermal fluids back into the ground, and produce virtually no criteria pollutants or greenhouse gases during normal operations.

Development of sustainable energy resources has become increasingly important for many nations as the impact of climate change have been further understood. Economic reasons for further development of renewable energy include the fluctuating price of crude oil and greater reliance on local resources. Energy resources such as geothermal resources provide a sustainable alternative to fossil fuel power plants. Geothermal power plants have average availability factors of 90 to 98 percent (reaching 100 percent in some years). Geothermal plants can be built in modular units, with redundant systems to avoid outages during plant maintenance. Using indigenous renewable resources such as geothermal energy avoids dependence on imported fuels, provides local employment, and provides stability and predictability to the cost of electricity.

The site for the proposed test well is approximately 1.5 miles east of Charlestown in an area that was previously used for growing sugar cane, but now contains scrub vegetation. The surrounding area is largely undeveloped. A shallow ghaut (a dry drainage or gully formed during hurricanes and periods of heavy precipitation) crosses the NREI lease, east-west, south of the site for the test hole drilling. One residence is adjacent to the site on the northeast. This residence would not be occupied during the proposed drilling and testing activities. The ruins of the abandoned sugar cane mill are approximately 1,300 feet to the south-southwest, and four apartment buildings are just east of the ruins. The Carino condominiums are approximately 1,750 feet southwest of the drill site. See Figure 3, Proposed NREI Drilling Pad and Surrounding Areas.

NREI contractors plan to clear a level drill pad approximately 250 feet by 170 feet, slightly less than an acre. The cleared vegetation and soil would be taken to the local landfill. The well pad would include sufficient area for the drilling equipment, storage tanks, office trailer, and a large drilling sump. The pad would also provide space for parking for the crew and a turnout area for service and delivery vehicles and an area sufficient for laydown of the mast.

The following sections present the environmental impacts of the planned NREI well drilling and testing, scheduled for spring of 2017.

POINT IMPACT ANALYSIS, LLC


Source: Thermal Energy Partners LLC

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*NREI Geothermal Exploration*
FIGURE 3
PROPOSED NREI DRILL PAD AND SURROUNDING AREAS

## Aesthetics

On Nevis, the slopes of the volcano and the ocean landscape dominate the views from many locations. These views can be dramatic and are familiar to residents and tourists alike. Visible intrusions or changes in the landscape are particularly sensitive issues for Nevis, where the economy depends on tourism.

The proposed test well drilling area at the Hamilton Estate is on the lower flanks of the Nevis Peak volcano, on relatively level land at an elevation of 538 feet above sea level. The summit of the Nevis Volcano is 3,232 feet. The center of the NREI lease is set back more than one mile from the coast, beach, and tourist areas. The site is surrounded by trees and low-lying vegetation. The clearing and grading activity required for pad construction would not be seen from Charlestown or the paved roads to the sugar ruins.

Depending on the viewpoint, the top of the 78-foot drill mast and some steam plumes during well testing may be visible to local residents. During drilling, the drill rig and surrounding operational area would be lit at night. NREI would use shielding that directs the light to the ground to reduce the nighttime visibility of the drilling activities.

Often drilling operations are subjects of curiosity by residents and tourists, but some may see these operations as intrusive. Tourists are usually, but not always focused on the beach and ocean views, and the drilling, if visible, would be seen from a distance and would not dominate the view shed.

## Air Quality

Construction of the well pad and access road, drilling, and other construction activity would result in the temporary release of criteria pollutants. Exhaust emissions from diesel equipment, trucks, and worker vehicles would be typical for construction projects. Earthmoving activities would also produce dust that would settle close to the drill site. The largest source of emissions would be the drilling rig. Table 3 presents the expected level of emissions from the rotary drill rig.

**Table 3: Drill Rig Emissions of Criteria Pollutants and Greenhouse Gases (GHG)**

| Emission Source | Pollutant (lbs/hour)[1] | | | | | |
|---|---|---|---|---|---|---|
| | $NO_X$ | CO | $SO_2$ | $PM_{10}$ | TOC[2] | $CO_2$ |
| Rotary Drill Rig[a] | 108.0 | 24.8 | 18.2 | 3.2 | 3.2 | 5,220.0 |

Source: Large Stationary Diesel Engine Emission Factors from U.S. EPA AP-42 Fifth Edition, Volume I, Chapter 3, Table 3.4-1. Assumes 0.5% sulfur content.

1 Based on three, 1,500 horsepower (hp) engines equipped on the rotary drill rig.

2 TOC is by weight 9% methane and 91% nonmethane.

During exploration with a large rotary rig, geothermal operators typically use air drilling or aerated drilling fluids when drilling in a steam production zone. During air drilling, steam and noncondensable gases mix with the return flow up the annulus in the well bore. It would only be during the well testing that the steam and noncondensable gases would be released to the atmosphere through the blooie line.

Noncondensable gases in geothermal resources typically contain $H_2S$, which has a distinctive odor and can be toxic at high concentrations. The concentration of $H_2S$ varies among geothermal reservoirs and is not anticipated to be a major concern for this project. However, the human nose is a sensitive $H_2S$ detector. Although worker safety becomes an issue at about 10 parts per million $H_2S$, the rotten egg odor is noticeable at a few parts per billion. Based on the analyses of the N-3 well during venting, the $H_2S$ emissions during the final three stages of well testing at the Hamilton Estate are likely to require treatment to avoid noticeable odors at nearby occupied residences (e.g. the apartments located approximately 1,000 feet to the south-southwest). It is noted that $H_2S$ would be released during well drilling and testing, but there would be virtually no $H_2S$ emissions during plant operation. The proposed drilling equipment includes three $H_2S$ detection sensors for worker safety and a spare, which would be located downwind (i.e. east) of the drill site.

Where needed, geothermal operators typically use caustic soda and hydrogen peroxide to convert the gas to sodium sulfate and water. The treated gases are released through the top of the separator, and the soluble sodium sulfate discharged to the mud sump. Screening modeling of well testing at Nevis indicates that emissions of 5.5 lb/hr result in impacts at downwind locations that are below the odor threshold, at prevailing wind speeds[1]. Injection of sodium hydroxide (NaOH) and hydrogen peroxide ($H_2O_2$) into the vented steam can convert the $H_2S$ to soluble sulfates that can be injected. The required abatement rates depend on the well flow and composition of the resource and would be determined during testing. Abatement would not be needed if the testing were performed when the prevailing wind direction was away from nearby residential areas or if wind speeds were above 3 meters per second (m/s) (6.7 miles an hour). NREI would have storage tanks with sufficient quantities of 25-30% aqueous solution NaOH and 50% $H_2O_2$ on site abate the expected emissions for 70 hours, avoiding potential objectionable or nuisance odors from the test well flow testing.

Geothermal resources can also contain small amounts of other constituents such as methane, ammonia, mercury, and arsenic, but assessments at large geothermal projects at other fields show no releases that constitute a public health risk. The temporary releases of these constituents from well drilling and testing at the Hamilton Estate site would not be a concern.

At the completion of flow testing, NREI would shut in the well pending development of a power plant.

## Biology

The proposed test well is located on the Hamilton Estate, which was a sugar plantation until the 1950's. After sugar operation ceased, it became an agricultural farm where a wide variety of products from cotton to vegetables were grown. The test well site is currently undeveloped and not in agricultural use, other than as rough grazing for goats and feral donkeys. Acacia (*Acacia* sp.) scrub is present on the site and is the typical vegetation present on land that has been disturbed by open grazing. A shallow ghaut crosses from east to west to the south of the test well. There are only a few

[1] Data from the Vance W. Amory Airport, located on the northern portion of the island, indicates relatively strong, consistent trade winds from the east-southeast at approximately 12 miles per hour. Given the Hamilton Estate's location, it is likely prevailing wind speed and direction would be similar, as the project location is not in the wind shadow of Nevis Peak or Round Hill (Point Impact Analysis 2010).

species of mammals existing on Nevis, most of which have been introduced. Birds and bats species may occur on the project site.

The project would disturb approximately 0.97 acre for the test well and drill pad (or approximately 11% of the 9.07-acre lease area). The test well location and drill pad would be accessible using existing unpaved roads. The habitat at the proposed project site is mostly disturbed or developed; therefore, no sensitive habitats are anticipated to be impacted. In addition, no sensitive species are expected to occur at the project site; therefore, no impacts to sensitive species are expected. If a sensitive species or species habitat were identified at a proposed pad or road location, NREI would call a biologist to assess the habitat and identify appropriate measures to avoid impacting the species or its habitat.

## Cultural Resources

Nevis has a rich multi-cultural history. Archaeological excavations reveal that the first inhabitants came to Nevis about 4,000 years ago. Prior to European settlement by the English in 1628, the Spaniards, Dutch, and the English colonists who would go on to found the Virginia Colony (Jamestown, Virginia, USA) visited the island, which was then inhabited by Carib Indians. After sugar was introduced in the 1640's, African slaves were brought to the island to harvest the crop. After the American Revolution, African-American slaves who had sided with the British for the promise of freedom resettled in the West Indies, then under English rule. In 1782 the French seized both Nevis and St. Kitts, but governance returned to Britain with the Treaty of Paris in 1783. The islands were part of the colony of the Leeward Islands from 1871 to 1956 and of the West Indies Federation from 1958 to 1962. Nevis, St. Kitts, and Anguilla became a self-governing state in association with Great Britain in 1967. The Federation of St. Kitts and Nevis attained full independence on September 19, 1983.

Typical cultural and historical resources on Nevis include buildings and ruins from the colonial era or buildings or structures associated with sugar cane plantations. The proposed exploration area is currently undeveloped, but is approximately 0.6 miles inland from early settlements and could potentially contain ruins from the colonial or plantation eras.

Records of the Hamilton Heritage Trust land date from 1772, when the land was purchased by Andrew Hamilton, a planter, and began to be known as Hamilton's Estate. There is no known connection between Andrew Hamilton and the family of Alexander Hamilton. At the time of Andrew Hamilton's purchase, the estate was comprised of 552 acres to which he later added more land to a total of 580 acres in three plantations: Hamilton, Upper Paynes or Morgans, and Jerusalem. The lands were worked as a sugar plantation, as were almost all cultivated lands in Nevis at that time, with the center of all activities being the estate yard and the sugar works.

The ruins of the sugar works are still visible along the Hamilton Estate road, approximately 0.25 miles south of the proposed test well location. Tourists visiting the ruins would not see the ground-level drilling and testing activity but may see the top of the drilling mast. The drilling is not expected to affect these historical resources.

## Geology and Land Conditions

Radiometric dating of volcanic rocks on Nevis indicates formation of the island began at least 3.4 million years ago. Nevis Peak is a remnant of one of the ancient eruptive centers that contributed to the formation of the island. Active fumaroles and hot springs on the island are indicative of Nevis' high-level, evolved magmatic center, which maintains a near-surface high heat flux capable of supporting a high-temperature long-lived geothermal system. Though there are no historical accounts of volcanic eruptions on the island, future episodic eruptions could occur given the island's active volcanic past. The last major eruption on the island was of Nevis Peak about 100,000 years ago.

Two main soil series occur within the Hamilton Estate. These are Rawlins Gravelly Loam, (5-10% slopes, characteristic of the steeper slopes surrounding Nevis Peak) and Charlestown Clay Loam (5-10% slopes, boulder phase, the most widespread soil series of Nevis characteristic of the gentler slopes below the main mountain area). Rawlins Gravelly Loam occurs on the eastern portion of the site, gradually transitioning to Charlestown Clay Loam – boulder phase moving west across the site.

The NREI lease area exhibits signs of soil disturbance. However, there is no obvious evidence of soil erosion such as scouring, or gullying (site checked during the dry season only). The location of the proposed test well is not on or near unstable slopes, old landslides, fault scarps or other geologic hazards. NREI contractors would clear and level an approximate one-acre well pad, involving the potential removal of up to 6 inches of topsoil. Soils are anticipated to be balanced on site as much as practical, and substantial cut or fill and associated erosion is not anticipated to occur during clearing activities. The proposed well pad would be designed and built in a manner that provides a stable base for the drill rig and minimizes soil erosion. Grass cover would be left in place where possible.

Dust from volcanic soils can contain silica, which may be a health hazard in dry, windy conditions. Drilling crews would water the roads and drill pads as needed to control dust during construction and well site operations.

Geothermal exploration well drilling does not typically impact other mineral resources in the area.

## Hazards and Hazardous Materials

Drilling and testing operations may require the transportation, storage, and use of hazardous materials, such as fuels and drilling chemicals. Drilling additives, when diluted for use, are nontoxic but can be toxic when delivered in their undiluted form. These materials would be stored and handled following manufacturer's recommendations and covered during storm events.

NREI would maintain Materials Safety Data Sheets for all materials used on site. NREI has developed safety procedures for the proposed drilling activities in a Health, Safety, and Emergency Response Plan. NREI would implement industry standard safe working practices including procedures for working around moving equipment and hot water; for handling hazardous materials; for monitoring and responding appropriately to various levels of hydrogen sulfide, when detected; for responding to spills of produced water, fuel or other materials; and for medical emergencies, vehicle accidents, fire, thunderstorms, and other hazards. The drill rig and their crews also typically operate under the rig owner's or operator's safety plans.

Safety equipment that would be required to be on site includes, but is not limited to, hydrogen sulfide monitoring devices, breathing apparatus for high hydrogen sulfide conditions, earplugs, wind socks or streamers, medical first aid kits, shovels, safety goggles (for use during blowing dust conditions), fire extinguishers, and communications equipment. Such equipment is standard on any geothermal drilling operation. NREI would post emergency response phone lists at several locations around the drill site.

## Hydrology and Water Quality

The Hamilton Estate drilling area is on the leeward side of the island and contains volcanic soils that are highly erodible, with moderate permeability. Most rain falls at upper elevations during the wet season, from June to October. Normal annual rainfall is 54.4 inches per year. Groundwater (wells and springs) accounts for 100 percent of the public piped water supply, and rural communities experience shortages during the dry season. Aquifers range in depth from 26 feet along the coast to 230 feet farther inland (US Army Corps of Engineers, 2004).

A shallow ghaut drains the site, running west toward the coast. The ghaut is typically dry, except after major storms. Access to the drilling area would use the existing access road on the western side of the property roads, which crosses the ghaut.

The locations for the well pads and access roads are relatively flat, and earthmoving activities are not expected to result in significant changes in drainage patterns. Brush would be removed and stockpiled beside the site. About 6 to 8 inches of topsoil would be scraped off and stockpiled at the site. If roads are graded in moderate slopes, the stockpiled vegetation would be placed at intervals beside the road for erosion control.

The well pads would be designed to drain into the drilling mud sump. Most drilling muds are nontoxic, and any toxic compounds would be diluted to nontoxic levels by the other fluids. The sumps that hold the cuttings and produced geothermal fluids can be lined with drilling mud (bentonite clay) or an impermeable liner.

The proposed test well would have conductor casing cemented a few feet into bedrock at a depth of approximately 1,000 feet and is cemented with surface casing to approximately 300 feet (see Table 1 in the Project Description). The wells are then cased and cemented down to near the production zone. The casing would prevent the geothermal fluids from contacting the better quality meteoric water near the surface and would insulate the high temperature geothermal resource from the lower temperature shallow water.

Water produced during testing would be contained in a lined sump that would be able to contain more than 350,000 gallons, sufficient for the proposed testing. The design allows sufficient freeboard to account for rainfall and avoid breaching during storms or overflow with rainwater, the contained fluids could cause local gullying and erosion before entering the natural drainage. Sufficient freeboard would be maintained in the sump to avoid such an occurrence.

At the conclusion of well testing, the contents of the sump would be injected back into the reservoir through the existing N-3 well or the proposed test well. If necessary, the sump would be modified

to allow the fluid to percolate into porous volcanic soils at the drill pad. NREI plans to maintain the sump for future operations at the site.

## Noise

Exploration for geothermal resources would temporarily increase noise levels near the drilling site. Sound is measured using decibels (dB), and for environmental purposes is usually measured in decibels A-weighted (dBA). A-weighting is based on the response of the human ear to the various frequencies comprising sound. A zero on the decibel scale is based on the lowest sound a healthy, unimpaired human ear can hear. Table 4 shows typical sound levels.

**Table 4: Typical Noise Levels in the Environment**

| Source | Noise level (dBA) |
|---|---|
| Jet fly-over at 300 meters | 120 |
| Pile driver at 20 meters | 100 |
| Gas lawn mower at 30 meters | 70 |
| Active office environment | 55 |
| Quiet rural areas | 30 |
| Wilderness area | 20 |
| Threshold of human hearing | 0 |
| Source: Caltrans 2009. | |

Table 5 shows the anticipated noise levels at residences based on the distance from structures visible in aerial photographs to the project area and the farthest distance in the exploration area to those residences. Clearing the project area, as well as construction of the pad and any road construction, would take approximately a few days and occur during normal working hours. The proposed drilling activities on Nevis would last approximately 10 weeks, with two weeks for delivery and assembly of the drill rig and equipment on site. Actual rotary drilling would take place 24 hours per day and may continue for approximately 40 days. The proposed drill rig would be located approximately 660 feet west of the closest residence, which would not be occupied during well drilling and flow testing. The closest occupied residences would an apartment building located approximately 1,000 feet south of the drill rig, and condominiums located approximately 1,750 feet southwest of the drill rig. Dense vegetation can attenuate (reduce) noise levels, and the values in Table 5 do not account for terrain effects, vegetation, and intervening structures.

**Table 5: Anticipated Noise Levels at Given Distances during Geothermal Exploration**

| Activity | Distance from Activity and Estimated Noise Level | | | | |
|---|---|---|---|---|---|
| | 160 ft | 320 ft | 640 ft | 1,000 ft | 1,600 ft |
| Site Preparation[1] | 75 dBA | 69 dBA | 63 dBA | 59 dBA | 55 dBA |
| Rotary Rig Drilling[2] | 59 dBA | 53 dBA | 47 dBA | 43 dBA | 39 dBA |
| Well Cleanout[1] | 71 dBA | 65 dBA | 59 dBA | 55 dBA | 51 dBA |
| Flow Testing[1] | 75 dBA | 69 dBA | 63 dBA | 59 dBA | 55 dBA |
| Sources:<br>1 Final Salton Sea Anomaly Master Environmental Impact Report, Westec Services 1981.<br>2 Drillmec Drilling Technologies, not dated. | | | | | |

As seen in Table 5 above, the loudest periods of noise would be during site preparation and flow testing, not during rotary drilling. Noise resulting from site preparation would be temporary, intermittent, and cease to exist once the rig is set up and operational. Once the site is cleared, and the building pad constructed, the rotary rig would be set up and operate for approximately 40 days. Following the rotary drilling, the well would be cleaned out, and flow testing would begin. As described in Table 2 (Expected Flow Rates During Well Testing) there would be a total of five test stages that would range from 12 to 24 hours each; total time for testing would be 82 hours. Like site preparation noise, the flow testing would be temporary, lasting only 82 hours over a two-week period.

NREI proposes to drill and test only one well at the Hamilton Estate. Operators can reduce noise levels by up to 10 dBA during rotary drilling, well cleanout, and flow testing through the shielding and positioning of trailers and other equipment between the well and noise-sensitive areas. While some project-related noise levels may be audible at the nearest residences, overall drilling noise levels would not be discernable near community centers.

## Socioeconomic

The Island of Nevis had a population of 12,277 in 2011, growing at a rate of 1.05% in the decade from 2001-2011 (Nevis Island Administration, 2016 Statistical Digest). St John's Parish has seen the largest growth in recent years.

Until the 1970s, sugar was the economic mainstay in St. Kitts and Nevis. Due to declining profits in the sugar industry, the government began a program to diversify the agriculture sector and stimulate other sectors of the economy. Tourism has shown the greatest economic growth, and in 1987, it surpassed sugar as the major foreign exchange earner. Government services, wholesale and retail trade, construction, and communications services also contribute significantly to the local economy. According to the 1999 Pan American Health Organization (PAHO) Basic Country Health profiles, unemployment in St. Kitts and Nevis is among the lowest in the Caribbean. The service industry, dominated by tourism, was the largest employer at 37%.

The proposed drilling would require two 9-person crews plus NREI supervisors. NREI plans to hire workers with extensive drilling experience in the project area and augment them with local employees. Typically, the drilling supervisor and perhaps a geologist would stay in a trailer on the site. The remaining workers would stay in motels and hotels in local communities. Drilling operations are small-scale operations that do not add to the cost of maintaining public roads, policing, medical facilities, or fire response.

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# APPENDIX B

**March 2017**

**Report for Environmental Impact Assessment for Thermal Energy Partners**

**Hamilton Estate: Description, Climate, Soils & Land Use, Biological Resources, Historical and Cultural Resources**

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# Hamilton Estate:
# Description, Climate, Soils & Land Use, Biological Resources, Historical & Cultural Resources.

Report for Environmental Impact Assessment for Thermal Energy Partners

Jennifer Lowery

March 2017

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# SECTION 1

## General Site Description

### 1.1 Position & Aspect:

Latitude 17° 08' 30” N Longitude 62° 36' 21” W

The proposed project covers two separate plots of land at Hamilton Estate, the larger site, Plot 1, where the power plant will be situated, is a roughly L shaped plot with an area of slightly over 9 acres. The smaller area, Hamilton Stables Plot, the site of the injection well, is 1.22 acres in area and is situated approximately 750ft SSW of the main plant site.

Plot 1 slopes from East to West, with the highest elevation of 630ft on the Eastern boundary and the lowest of 515ft at the SW corner, it is bounded on four of its' six sides by estate roads. On the remaining sides which make up the inside of the 'L', is a plot of privately owned land with two residential buildings and gardens. The estate roads are nominal and uncleared on the northern and southern boundaries, to the East is a paved concrete road and to the West a cleared unpaved road which is the access road for a private house and small farm close to the NW corner of the site. According to the Ordnance Survey map of Nevis the estate road along the northern boundary delineates the boundary between the parish of St.Paul Charlestown within which Hamilton estate lies, and the adjoining parish of St. Thomas Lowland. A small swale crosses the land E-W which would be a watercourse in the rainy season, the natural drainage pattern of the site has been altered by the levelling for the platform around the N 3 well and its' access road.

Plot 2 slopes from an elevation of around 525ft at its' Eastern boundary to around 475 ft at the lowest NW corner, at the Eastern end the land slopes down steeply from the road to the Northern boundary. The paved estate road which is the main thoroughfare through the estate forms the boundary on the Southern and Western sides, to the North are private lands and a small house is situated close to the boundary, the short Eastern boundary borders on the unpaved estate road which leads to Plot 1.

**Fig.1.1 Overview of Plant Site from Hamilton Road**
arrow shows approximate site of N 3 well.

## 1.2 Land Use

### 1.2.1 Plot 1 Power Plant Site

Currently the project area, excluding the small site of the N 3 well, is undeveloped and not in agricultural use other than as rough grazing for goats and feral donkeys. Adjacent lands to the West and South have been sold or subdivided for private housing and hotel development. Land near the NW corner of the site is currently used for small scale agriculture, and the private land within the 'L' of the site was also in agricultural and horticultural use in the recent past.

Lands to the North, in the parish of St Thomas are part of larger holdings currently undeveloped, on the remaining three sides, beyond the central estate works, are lands which were once part of Hamilton Estate which have been sold off in phases over a 50 – 60 year period. Initially the lands were distributed for small farms, but in the last 20 years many of these, plus more recent subdivisions, have been used for private residences.

### 1.2.2 Plot 2 Injection Site

This area is not in commercial use, but forms part of the entrance to the area of the ruins of the sugar mill and former sugar processing areas. There are more recent wooden buildings on the site which date from the construction of the Carino condominiums, these are constructed next to the remaining walls of much older buildings. The area formed part of the proposed Hamilton Heritage Centre vested in the Hamilton Heritage Trust.

## 1.3 Climate

The general climate is tropical oceanic with small seasonal and diurnal variations in temperature. The elevation of the site at ± 520ft provides some montane cooling effect with additional cooling provided by the prevailing NE trade winds; however Nevis Peak to the North East affords shelter from constant wind exposure, resulting in a more humid moderate climate.

### 1.3.1 Data available

Rainfall data is available for Hamilton Estate for the years 1942-1988, temperature and wind speed records are not available for the exact area, but limited data is available from The Mount Palmetum at Jessups, an area with a comparable climate, located 1.8 miles away at 382 ft elevation.

### 1.3.2 Rainfall

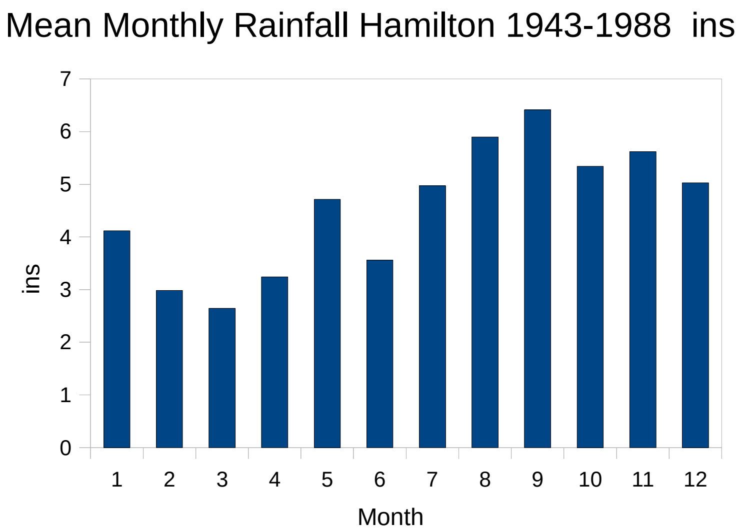
Rainfall data collected for 45 years is given in Table and Fig below. The average annual total rainfall is 54.5 inches, the range of annual rainfall over the recording period is from just over 20ins to 114ins.

Table 1.1: Mean Monthly rainfall

| Month | J | F | M | A | M | J | J | A | S | O | N | D | Annual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall ins | 4.11 | 2.98 | 2.64 | 3.24 | 4.71 | 3.56 | 4.97 | 5.9 | 6.41 | 5.34 | 5.62 | 5.03 | 54.52 |
| “ (mm) | 104.51 | 75.79 | 67.17 | 82.3 | 119.67 | 90.42 | 126.3 | 149.76 | 162.85 | 135.62 | 142.7 | 127.76 | 1384.86 |

Rainfall distribution is in the typical pattern for Nevis, with the highest average rainfall occurring in the months of August to November, September having the highest rainfall, and with a secondary peak in precipitation in May.
The months of February and March are the driest months

**Fig. 1.2**




#### 1.3.2.1 Storm maxima

From the maps produced by Devres 1987 the following 24hr rainfall maxima can be expected in the project area:

| | |
|---|---|
| 10yr | 5.5 inches (140mm) |
| 25yr | 7.25 inches (184mm) |
| 50yr | 8.25 inches (210mm) |

With climate change predictions indicating greater extremes of weather, these figures may be exceeded.

#### 1.3.2.2 Drought Hazard

In drought assessments for Nevis, meteorological drought is defined as when annual rainfall is less than 85% of mean annual rainfall (Jackson 2001), using this criterion, in the years from 1942-1988 where complete data is available, there are 12 years, or more than 25% of the recorded years, which can be classified as drought years.

### 1.3.3 Temperature & Wind Speed

The limited temperature data available from the Mount Palmetum shows a range of monthly means fluctuating by less than 10°F over the year, with maximum temperatures in the months of July and August (81-84°F), and minimum temperatures from December to February (73-75°F). The more

extensive data from the Vance W. Amory Airport , situated closer to sea level, for years 2000 – 2014 show even less fluctuation over the year with the hottest period being from June to October.

**Table 1.2 : Monthly Mean Temperatures yrs 2003-2005**
**The Mount Palmetum**

| Year | | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2003 | °F | 76.1 | 75.9 | 77.4 | 78.1 | 80.8 | 79.6 | 81.0 | 84.9 | 84.1 | 82.2 | 78.9 | 75.9 |
| | °C | 24.5 | 24.4 | 25.2 | 25.6 | 27.1 | 26.4 | 27.2 | 29.4 | 28.9 | 27.9 | 26.1 | 24.4 |
| 2004 | °F | 75.0 | 75.2 | 76.7 | 75.9 | 78.1 | 79.7 | 80.1 | 81.1 | 77.7 | 77.5 | 77.4 | 74.9 |
| | °C | 23.9 | 24.0 | 24.8 | 24.4 | 25.6 | 26.5 | 26.7 | 27.3 | 25.4 | 25.3 | 25.2 | 23.8 |
| 2005 | °F | 74.3 | 73.9 | 77.5 | 78.4 | 80.7 | 81.1 | 84.2 | 82.6 | 79.0 | 79.9 | 73.1 | 73.2 |
| | °C | 23.5 | 23.3 | 25.3 | 25.8 | 27.1 | 27.3 | 29.0 | 28.1 | 26.1 | 26.6 | 22.8 | 22.9 |

**Table1.3 : Monthly Mean Temperatures yrs 2000-2014 VWA Airport**

| | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| °F | 79.4 | 79.1 | 79.8 | 77.9 | 79.1 | 82.7 | 80.6 | 79.4 | 81.1 | 80.3 | 78.8 | 77.5 |
| °C | 26.3 | 26.2 | 26.6 | 25.5 | 26.2 | 28.2 | 27.0 | 26.3 | 27.3 | 26.8 | 26.0 | 25.3 |

The limited wind speed data available from the records of the Mount Palmetum show average maximum wind speeds varying only slightly over the year, the records are for years without hurricanes.

**Table 1.4 Monthly Wind Speed Data (mean & maximum) mph yrs 2003-2005**
**The Mount Palmetum**

| Month | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 4 | 5 | 3 | 4 | 4 | 5 | 6 | 4 | 3 | 4 | 4 | 4 |
| Max | 19 | 19 | 13 | 17 | 17 | 18 | 16 | 21 | 16 | 16 | 17 | 18 |

## 1.4 Soils

### 1.4.1 1.4.1 Plot 1, Power Plant Site

#### 1.4.1.1 Soil Description

According to the soil maps of Lang & Carroll(1966), Hamilton Estate covers two main soil series: Rawlins Gravelly Loam, one of the characteristic soils of the steeper slopes surrounding Nevis Peak; and Charlestown Clay Loam (bouldery phase), the most widespread soil series of Nevis characteristic of the gentler slopes below the main mountain area. The Power Plant site sits across a boundary between the two soils as shown in Fig. below, both series are further classified as situated on 5°-10° slopes, and the Charlestown series varies between erosion class 1 and 2 (see description below) with 2 being dominant. The erosion class of Rawlins Gravelly Loam is not specified. Although the survey depicts the boundary between the two series as a distinct line for the purposes of mapping, the transition would not be as sharply defined, with the greater part of the site being a transition soil from the lighter gravelly soil on the higher east side and the heavier Charlestown clay to the west. Characteristics of the two soil series as described by Lang & Carroll are given below.

*Charlestown Clay/Clay Loam*
*Class: Immature smectoid clay formed on pyroclastic outwash fans*
*Profile Description:*

| *Depth* | *Horizon* | *Description* |
|---|---|---|
| *0-8”* | *A* | *Dark brown clay loam, friable, plastic, slightly sticky consistency.* |
| *0-24”* | *B-C* | *Dark brown, reddish brown or yellowish brown clay, hard, very plastic.* |
| *24”* | *Csi* | *Basement pavement layer of stone & boulders cemented with brown material of sandy appearance.* |

*According to the soil survey, on the upper slopes of the series the clay constituent of the soil is not as apparent as in other regions and is less sticky.*
*Erosion class - 1- slight - up to 50% of topsoil lost*
*2 - moderate - more than 50% of topsoil lost*
*3 - severe - all topsoil lost and some subsoil*
*Drainage through the soil - very slow.*
*Moisture supplying capacity - moderately high but seldom fully Available.*

*<u>Root limiting layer</u> – shallow soil, limited penetration of stiff clay subsoil.*
*<u>Erosion hazard</u> – clean cultivation moderate risk to A Horizon (most gone at present). B Horizon less easily eroded. Risk increases rapidly over 5° slope.*
*<u>Natural fertility</u> – high*
*<u>pH of surface layer</u> 5.8-6.8*

*<u>Rawlins Gravelly Loam</u>*
*<u>Class</u>: Protosol formed on shallow outwash fans of cone derived material*
*<u>Profile Description</u>:*

| *Depth* | *Horizon* | *Description* |
|---|---|---|
| *0-8"* | *A* | *Brown gravelly, gritty, loam; blocky structure; bakes hard in sun but very friable; non plastic, non sticky .* |
| *8-30"* | $C_1$ | *Brown gravelly loam or sandy loam, blocky; non plastic slightly sticky.* |
| *30-60"* | $C_2$ | *Dull yellowish red gravelly sandy loam; poorly developed structure or massive; loose, non plastic, slightly sticky.* |

*<u>Erosion class</u> - 1- slight - up to 50% of topsoil lost*
*2 - moderate - more than 50% of topsoil lost*
*3 - severe - all topsoil lost and some subsoil*
*<u>Drainage through the soil</u> - rapid.*
*<u>Moisture supplying capacity</u> - low.*
*<u>Root limiting layer</u> – base of soil (shoal pavement).*
*<u>Erosion hazard</u> – marked hazard on steeper slopes where not terraced.*
*<u>Natural fertility</u> – moderately low.*
*<u>pH of surface layer</u> – 6.0-6.4*

**Fig. 1.3: Soil Map Plot 1**


Approximate locations of soil pits

### 1.4.1.2 Site Observations

**Fig. 1.4: Soil Pit Charlestown Clay**

**Fig 1.5: Soil Pit Rawlins Gravelly Loam**

Many areas of Plot 1 show signs of soil disturbance. Centrally, around the well site there has been significant cut and fill for levelling, and a track cleared. Immediately East of this area is dense acacia scrub, typical regrowth on disturbed land open to overgrazing. Further into the site are heaps of boulders from some previous clearing. Soil pits were dug in what seemed to be less disturbed areas. The soil on the eastern side proved to be of a loose friable type consistent with the expected Rawlins series, on the lower western side a denser clay was encountered typical of the Charlestown series (see Figs. and above).

**Fig 1.6: Levelled area near N 3**

**Fig. 1.7: Acacia Scrub East of N 3 Area.**

### 1.4.2 Plot 2, Injection Site

#### 1.4.2.1 Soil Description

The soil at this location is mapped as Charlestown Clay, as described above.

#### 1.4.2.2 Site Observations

At Plot 2, the Injection site, there has been more disturbance of the original soil surface. Owing to its' proximity to the sugar works, it has been the site of a number of buildings both recently and historically, the underlying soil type is mapped as Charlestown Clay Loam but is barely accessible on the surface and no soil pits were dug, however as the site slopes steeply roughly from SE to NW, averaging a 10% gradient the risk of erosion in the event of major clearing is high.

**Fig. 1.8: Plot 2 Injection Site Recent Structure**

**Fig 1.9: Plot 2 Injection Site Old Stone Ruin**

### 1.4.3 Erosion Hazards

There was no obvious visual evidence of soil erosion such as scouring or gullying, at either site, however the sites could only be checked in the dry season.

According to Devres 1987 the erosion tolerance of the Charlestown Clay soil series is 3 tons/acre/year and that of Rawlins Gravelly Loam is 5 tons/acre/year. Applying the Universal Soil Loss Equation (USLE) and the data for Rainfall Factor and Erodibility given by Devres, average annual rates of soil loss can be calculated.

Table gives comparative figures for soil loss under current land use which is considered to be broadleaf brush with 25ft length of erodible slopes, and with bare soil, assuming 100ft length of cleared slope. Average slopes were calculated using Google Earth, and were: Plot 1 E 11.0%, Plot1 W 6.5%, and Plot 2 10.5%. Values are approximate for comparison purposes but indicate that erosion levels at Plot 1 under current conditions are close to the tolerance levels of the soil series however under conditions of cleared soil and 100ft of slope, erosion rises by a factor of around 18, Rawlins Gravelly loam on the upper western section of the site is the soil most subject to erosion. At Plot 2 owing to the nature of the surface, figures for current soil loss are less reliable but with the steeper slopes of this site the potential for erosion on clearing is very high.

Reduction of the length of slope of exposed bare soil from 100ft to 25ft during development of the site reduces erosion risks by approximately 50%.

**Table 1.5 : . Calculated soil erosion Tons/acre/year**

| Location | Soil type | Erosion Tolerance | Soil loss | Soil loss |
|---|---|---|---|---|
| | | | Current land use | Cleared land |
| **Plot 1 E** | Rawlins Gravelly Loam | 5 | 6.60 | 120.00 |
| **Plot 1 W*** | Charlestown Clay | 3 | 3.50 | 63.50 |
| **Plot 2** | Charlestown Clay | 3 | 7.14 | 130.00 |

# SECTION 2

## Biological Environment

### 2.1 Natural Vegetation Power Plant Site

Overall, the vegetation cover of the site is regrowth of varying maturity. The well site is the most recently cleared area, with typical pioneer species present. Parts of the remaining lands show evidence of earlier clearing where large rocks and topsoil have been pushed into now overgrown heaps, possibly from when the estate was surveyed for subdivision, prior to that the whole area was maintained as farmland and estate roads.

Grazing and browsing by goats and wild donkeys which has intensified over approximately the last twenty five years has taken its' toll on regrowth and species, and resulted in a higher proportion of toxic or spiny unpalatable species. As a result of these factors, the existing vegetation cover is scrub of varying densities and heights. There are a a few larger trees, mainly located near the boundaries of the old estate roads, but generally the canopy height is around 8-12ft. Beyond these human caused factors is overlaid the natural elevation and soil differences described previously, these give rise to changes in the mix of species along an east to west axis.

Taking the above factors into consideration, the site has been simplified into three areas labelled in Fig. 2.1 as A, B and C, and the most commonly occurring species are listed in the tables below.

Area A corresponds closely to the area of the heavier Charlestown Clay soil type at the lower western end of the site. The vegetation forms a dense almost impenetrable thicket

Area B is in two areas and corresponds to the vegetation occurring on the lighter Rawlins Gravelly Loam soil series which continues up to the eastern higher, more humid side of the site. Near the western boundary there are more taller trees and the understorey is less dense than lower down the slope. Along the boundary of the residential property to the North East some volunteers of the landscaping plants occur occasionally, apart from Xiphidium and a Philodendron species which have become established, these have been omitted from the species list.

There is much overlap between the species of areas A &B, with the reality being more of a continuum than a sharp differentiation.

Area C is the more recently cleared area consisting of the N3 well site and the entrance road where the vegetation is sparse, consisting of a few pioneer species which are listed.


Fig. 2.1 Vegetation Map (Approx.)

The listing of plants in the tables below is meant to give some indication of the relative occurrence of the species, with the most common at the top of the list. The rankings are very approximate and subjective and not based on plant counts.

Table 2.1 Plant Species - Vegetation Area A

| | **Botanical name** | **Common Name** |
|---|---|---|
| Upper Storey Trees & shrubs | Leucaena leucocephala | Wild tamarind |
| | Melicoccus bijugatus | Genip |
| | Acacia macracantha | Casha |
| | Bursera simaruba | Gum |
| | Coccoloba swartzii | Pigeon plum |
| | Randia aculeata | |
| | Citharexylum spinosum | Fiddlewood |
| | Melia azedirach | Chinaberry |
| | Cordia sulcata | |
| | Guettarda scabra | |
| | Gliricidia sepium | Gliricidie |
| | Pimenta racemosa | Bay leaf tree |
| | Ficus citrifolia* | Strangler fig |
| | Hura crepitans* | Sandbox tree |
| | Azadirachta indica* | Neem |
| | Tabebuia rosea* | White cedar |
| | Annona muricata* | Soursop |
| | Capparis cynophallophora** | Jamaica caper |
| Lower Storey Grasses, Herbs & vines | Indigofera suffruticosa | Indigo |
| | I. tinctoria | |
| | Solanum racemosum | |
| | Sansevieria hyacinthoides | Daggerlash |
| | Jasminum fluminense | Wild jasmine |
| | Lantana camara | Tea bush |
| | Pedilanthus tithymaloides | Ladies Slipper, Milky Bush |
| | Erythroxylum havanense | |
| | Croton flavens | Sage bush |
| | Pluchea carolinensis | Cattle tongue |
| | Botriochloa pertusus | Sour grass |
| | Arthrostylidium venezuelae | Climbing bamboo grass |

* Indicates single occurrence ** Single unusual occurrence

Table 2.2 Plant Species - Vegetation Area B

| | **Botanical name** | **Common Name** |
|---|---|---|
| Upper Storey Trees & shrubs | Leucaena leucocephala | Wild tamarind |
| | Randia aculeata | |
| | Acacia macracantha | Casha |
| | Delonix regia | Flamboyant |
| | Melicoccus bijugatus | Genip |
| | Daphnopsis americana | Mountain mahoe |
| | Zanthoxylum monophyllum | Yellow prickle |
| | Pimenta racemosa | Bay leaf tree |
| | Cordia sulcata | |
| | Citharexylum spinosum | Fiddlewood |
| | Ceiba pentandra | Silk cotton |
| Lower Storey Grasses, Herbs & vines | Jasminum fluminense | Wild jasmine |
| | Pedilanthus tithymaloides | Ladies Slipper, Milky Bush |
| | Erythroxylum havanense | |
| | Arthrostylidium venezuelae | Climbing bamboo grass |
| | Botriochloa pertusus | Sour grass |
| | Xiphidium caeruleum | |
| | Philodendron sp. | |
| | Stachytarpheta jamaicensis | Vervain |

Table 2.3 Plant Species - Vegetation Area C

| | **Botanical name** | **Common Name** |
|---|---|---|
| Lower Storey Grasses, Herbs, Low Shrubs & Vines | Indigofera suffruticosa | Indigo |
| | I. tinctoria | |
| | Solanum racemosum | |
| | Leucaena leucocephala | Wild tamarind |
| | Acacia macracantha | Casha |
| | Crotalaria retusa | Shak shak bean |
| | Pluchea carolinensis | Cattle tongue |
| | Croton flavens | Sage bush |
| | Botriochloa pertusus | Sour grass |
| | Jatropha gossypifolia | Belly Ache Bush |
| | Ricinus communis | Castor bean |
| | Antigonon leptopus | Corallita, Bee bush |
| | Cuscuta americana | Dodder, Lub lub |
| | Cucumis dipsaceus | Spiny cucumber |

## 2.1.1 Vegetation Photos

**2.2 Entrance Road 2017 Ref. Area C**

**2.3 Capparis cynophallophora (centre) Ref. Area A**

2.4 **Acacia macracantha pods & spines Ref. All Areas**

**2.5 Erythroxylum havanense Ref. Areas A & B**

**2.6 Dense Mixed Acacia & Wild Tamarind Scrub Ref. Area A**

**2.7 Cleared Rock Pile Ref. Area A**

**2.8 Randia aculeata Ref Areas A & B**

**2.9 Indigofera tinctoria with Seed Pods Ref. Areas A & C**

**2.10 Cordia sulcata Ref Areas A & B**

**2.11 Zanthoxylum monophyllum Ref. Area B**

**2.12 Xiphidium caeruleum, escape from cultivation Ref Area B**

## 2.2 Fauna

### 2.2.1 Mammals

The only mammalian species native to Nevis are the several species of insect and fruit-eating bats. None were observed in the area during the survey and no likely roost sites were seen. It is probable that the various ruins and abandoned buildings in the estate yard nearby would provide suitable habitats for bats and clearing in that area should take that into account.

Other mammals in the area were the Green Vervet Monkeys, domesticated goats and feral donkeys, all of which are detrimental to the natural vegetation.

### 2.2.2 Birds

The Bird Checklist for St. Kitts and Nevis from Avibase lists 224 recorded sightings of species with no differentiation for island location. The Nevis Ornithological Society has an informal checklist of 165 species sightings in Nevis and speculates that the true total could be up to 210 species. From informal subjective analysis of various species lists there appears to be a weighting towards the more easily observed birds of more open habitats including waterbirds, shore birds, birds of prey and swifts and swallows, with these making up roughly 60% of sightings. Removing a conservative third of records as infrequent visitors, leaves 44 species of woodland and thickets, and a further subjective subdivision of 50% being residents of higher denser rainforest leaves a working possible species number of around 20 for lowland dry and sub-humid woodland or scrub typical of the project area.

The dense thickets covering large parts of the project site provide good protection and food for avian fauna. Those observed during the course of this survey were:

Ground Dove

Zenaida Dove

Kestrel

Pearly Eyed Thrasher

Lesser Antillean Bullfinch

Grey Kingbird

Carib Grackle

Of these, all except the Grackle are found throughout Nevis, the Grackle however is quite uncommon over most of the island, occurring in in only a few localities. Continual clearing of 'bush' vegetation reduces the potential nesting sites for many

species, and some attempt should be made to retain or reproduce dense bushy areas to sustain or increase the existing numbers and species of birds.

**Fig. 2.13 Grackle concealed in dense vegetation**

## 2.3 Conservation Issues

The project site does not appear to have unique conservation imperatives. No endangered or threatened plant or animal species were identified. One tree species, Capparis cynophallophora was of note only because it was far outside of its' normal coastal habitat, although infrequent in Nevis, it is not considered endangered. Also one bird species, the Grackle, which is only found in a few localities occurred and was probably breeding in the area. The current situation where there is an abundance of bushy vegetation close by will probably ensure that there will be bird and plant habitats remaining, however continual clearing and development will always put these habitats at risk in the long term, so retention of some part of the natural environment or a re-creation of thickets and nesting sites is advisable.

# SECTION 3:
# Historical & Cultural Resources

## 3.1 Historical

### 3.1.1 Pre Columbian

Hamilton Estate is not recognised as an Amerindian settlement site. Most such sites are coastal and have been found mainly on the eastern and southern areas of Nevis.

### 3.1.2 Colonial Era

Records of the ownership of Hamilton Estate are clear going back to 1772 when it was purchased by Andrew Hamilton, a planter, and began to be known as Hamilton's Estate. There is no known connection between Andrew Hamilton and the family of Alexander Hamilton. Before that time it is known to have been owned by Ralph Payne of St.Kitts and by his son who later became Sir Ralph Payne and prior to that by a Thomas Walker when it was known as Walker's Windmill Estate. At the time of Andrew Hamilton's purchase the estate was comprised of 552 acres to which he later added more land to a total of 580 acres in three plantations; Hamilton, Upper Paynes or Morgans, and Jerusalem. The lands were worked as a sugar plantation, as were almost all cultivated lands in Nevis at that time, with the centre of all activities being the estate yard and the sugar works.

### 3.1.3 The Sugar Industry

Sugar cane was grown throughout Nevis from the early 1700s to the mid 20$^{th}$ century. Up until the abolition of slavery in 1834 the labour for cultivation and processing was provided by slaves imported from Africa and their descendants. The boom years for the Nevis sugar industry were in the late 1700s, records from sale documents in 1785 show Hamilton Estate to have 250 slaves, at that time few estates held more than 100 slaves (N.Wright & A.Wright 1991). At emancipation in 1834 there were 206 enslaved persons, 122 Female and 84 Male , and the estate was owned by Thomas Latham (online, Legacies of British Slave Ownership, University College London)

Hamilton Estate produced Muscovado Sugar, a coarse partially refined sugar with a high molasses content. Wind power was used initially to drive the grinding machinery, this was eventually succeeded by steam power probably in the 1860s when the estate had been acquired by Thomas Graham Briggs

for £15,000. Sugar production in Nevis was becoming uneconomical and declined in the latter half of the 19th century. In 1900 there were still 10 steam mills and 6 windmills in operation but by 1921 there were 3,000 acres of land under sugar cultivation and 3,000 acres of cotton (D.Robinson 1992). In 1933 the colonial government bought Hamilton Estate, the first of a number of abandoned or non functioning agricultural estates to be purchased, in some cases for as little as £3 per acre (D.Robinson 1992). The grinding of sugar finally ended at Hamilton in 1951, leaving only one mill still in operation at New River, which then closed in 1958. Cultivation of sugar by small farmers continued for a few years, with the cane being shipped to St.Kitts for processing, this was discontinued as uneconomic in the 1960s.

The sugar processing machinery remained in situ and :

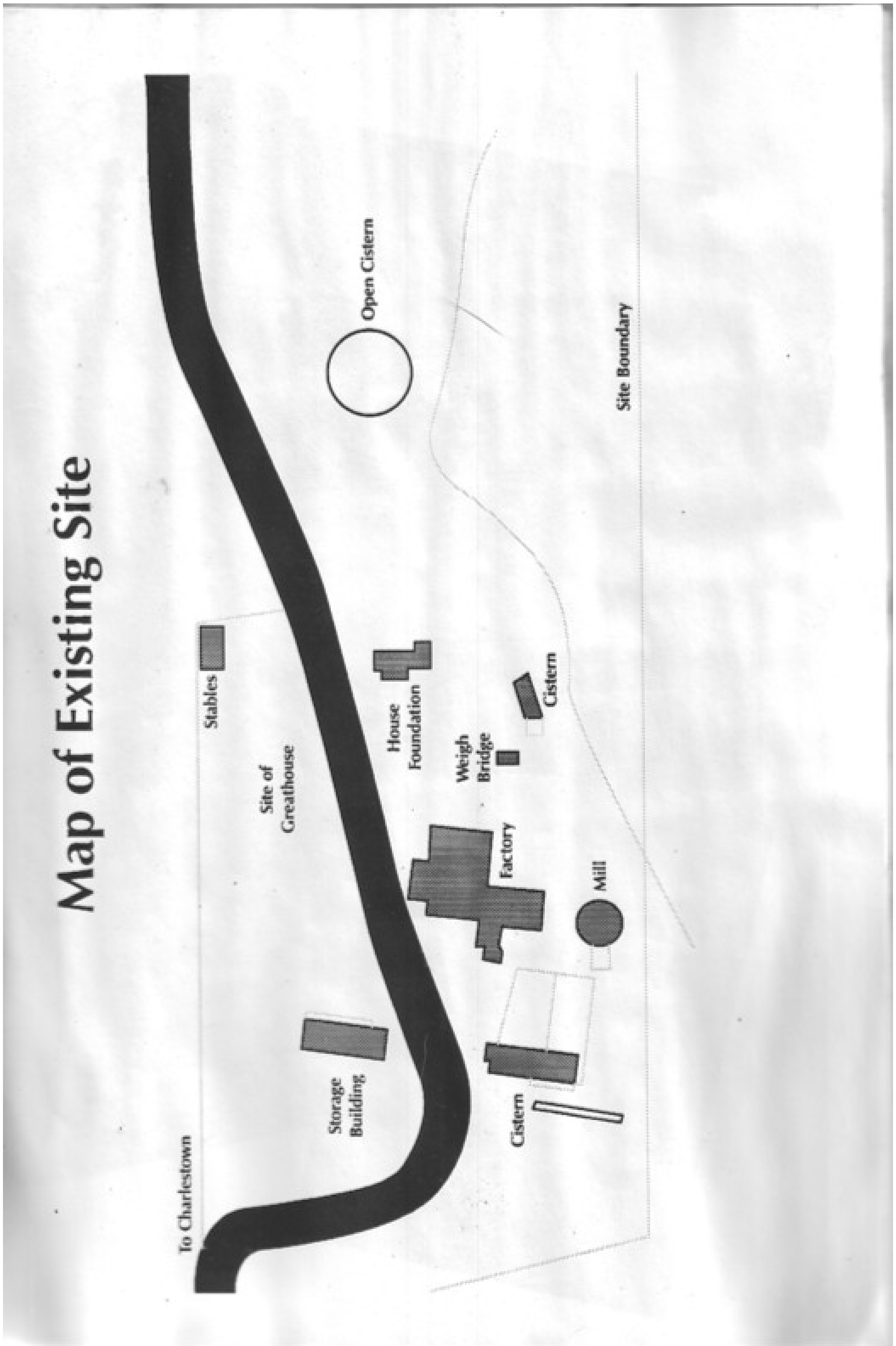
“Hamilton's mill is one of the few in the Caribbean which still retains much of its' machinery and functional architecture, combining seventeenth century layout and practice with some elements of nineteenth century steampower.” (N.Wright & A.Wright 1991)

### 3.1.4 20th Century

After government acquisition of the estate in 1933, land was subdivided for small farming, with some plots being sold and others rented. The lands adjacent to the factory remained in government hands, with some production of root crops and fruit trees continuing on them until the 1980s.

As small farming declined, tourism became more important to the economy of Nevis with historical sites valued as potential attractions, this resulted in the setting up of the Hamilton Heritage Trust in 1993 to oversee the development of the area for tourism as outlined by a study undertaken in 1992. The plan included a hotel and restaurant development, a botanical garden, and restoration of the sugar mill and factory buildings as a tourist attraction. This integrated plan for development was not implemented, however part of the land was used for condominium construction in the late 1990s and early 2000s. The factory structure sustained some damage in hurricanes but most of the sugar processing machinery remains in situ. Currently the New River estate factory and grounds are being refurbished as an historical site and it is possible that this will encourage restoration at Hamilton in the future.

**Fig 3.1: Plan of Estate Yard and Sugar Works** (Source: Hamilton Heritage Centre Executive Summary)



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