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KATMAI OPERATIONS PLAN

SANDIA NATIONAL LABORATORIES

ALBUQUERQUE, NEW MEXICO

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1.0 INTRODUCTION

Volcanism is one of the processes by which the Earth continues to evolve. It is the process by which low-melting portions of the planet's interior are transported upward and added to the upper crust, surface, and, in the case of volatile components, the atmosphere. By taking samples and making measurements inside a simple, young volcano soon after its eruption, scientists can greatly improve understanding of magma behavior as it approaches the Earth's surface and its effects in the surrounding rocks of the Earth's crust. Such an undertaking fulfills the purpose of the Continental Scientific Drilling Exploration Act (Public Law 100-441), which was passed by Congress in 1988 to "enhance fundamental understanding of the composition, structure, dynamics, and evolution of the continental crust. . ." This Operations Plan in conjunction with the Katmai Science Plan (Eichelberger et al., 1989, Simon et al., 1988) outline and describe the core drilling and scientific research necessary to investigate active volcanic processes at Katmai, Alaska, the site of the historic volcanic eruption of 1912. Primary objectives of the project are the following:

1. to test models for explosive eruptions through three-dimensional investigation of a well-preserved volcanic vent and the ash-flow sheet it produced;

2. to determine how metals contained in the magma were transported and concentrated by gases following the eruption by obtaining geochemical profiles through the deposits not yet degraded by weathering or alteration; and

3. to find out how fast and by what processes the igneous rock is cooling through measurement and interpretation of temperature profiles within a simple system of known young age.

The volcanic processes in Katmai National Park are uniquely suited to achieve these objectives because the 1912 activity was a single, well-described volcanic event in a simple, uniform geologic setting. Moreover, structures of the volcano have not been modified by the large-scale collapse that normally accompanies eruptions of this size. The proposed observations will provide the first view of early post-eruption conditions inside a major igneous system. The conclusion that Katmai is uniquely suited for such an investigation has been endorsed by the Panel on Volcanic Studies at Katmai of the National Academy of Sciences (1989).

This core drilling project will extract core continuously and will make down-hole scientific measurements from inside three core holes, located in and near the Novarupta vent at the head of the Valley of Ten Thousand Smokes. Two relatively deep core holes close to the lava dome in the center of the vent and a shallow core hole approximately 3 mi (~5 km) from the dome are planned (Figure 1-1). One hole near the dome at the vent will be drilled vertically to approximately 4,000 ft (~1,200 m) deep to study intrusive equivalents of pyroclastic units, deep structure, and the stratigraphy and temperature regimes of the vent. The other core hole at the vent, sidetracked off the vertical hole, will be approximately 3,300 ft (1,000 m) deep and will be drilled at a 60-degree angle from the surface

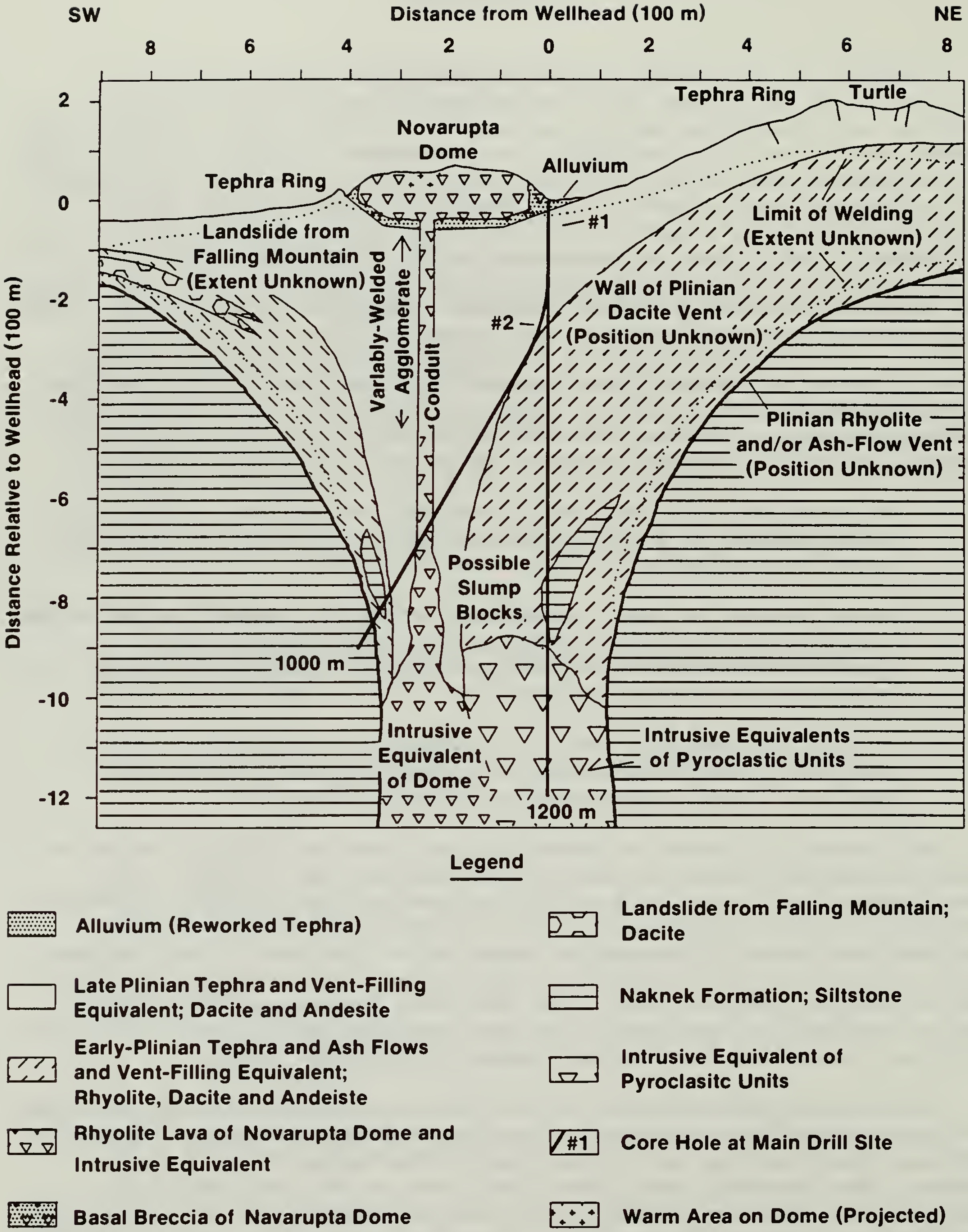


Figure 1-1. Schematic Cross Section of the Vent and Ash-Flow Sheet Along a Curved Line Containing the Two Drilling Sites and the Turtle, Illustrating Geologic Objectives of the Proposed Core Holes

under Novarupta Dome. The sidetracking core hole will be used to study the center-to-wall vent stratigraphy of the conduit, vent conditions, and the deep vent wall and to obtain a measurement of the vent diameter. A core hole remote from the dome site will be approximately 650 ft (200 m) deep and will be drilled at a 60-degree angle from the surface to study a complete ash-flow sheet section and fissure fumarolic deposits.

This project is proposed by a consortium of university researchers, national laboratories, and the U.S. Geological Survey (USGS) who are presently conducting an integrated geologic, geophysics, and drilling program in the Valley of Ten Thousand Smokes, Katmai National Park, Alaska (Figures 1-1, 1-2 and 1-3). A description of the scientific investigations that will use the holes and the core obtained from them is presented in the Katmai Science Plan, titled, "Direct Observation of a Young Igneous System: A Science Plan for Research Drilling in Katmai National Park, Alaska" (Eichelberger et al., 1989, Simon et al., 1988 (a nontechnical version for more general distributing)). The Science Plan has been presented to and accepted by the U.S. Department of Energy (DOE), the National Science Foundation (NSF), and the USGS. Many of the surfaced-based geologic and geophysical portions of this program are underway. However, a more comprehensive application is necessary for drilling, and this Operations Plan is a part of the required documentation. A summary of the proposed core hole objectives is displayed in Table 1-1.

The motivation of this project is a basic scientific interest in the geological and geophysical behavior of the planet. Results from the scientific research at the Katmai site may find application elsewhere, such as evaluating the hazards of explosive volcanoes and finding and utilizing ore deposits and geothermal energy.

Ultimate responsibility for planning and funding the project lies with The Interagency Coordinating Group (ICG), (Section 2.0) and its constituent agencies: the U.S. Department of Energy/Office of Basic Energy Sciences (DOE/OBES), the USGS and the NSF. The USGS will provide liaison between the National Parks Service (NPS) and the organizations that will be conducting operations at Katmai. The USGS will have full authority to execute NPS orders. The DOE will be the legal operator of drilling operations, and Sandia National Laboratories will act as their agent. Sandia National Laboratories will be responsible for managing the drilling, coring, and field operations according to regulations and will accept directions from the NPS through the USGS liaison officer.

The ICG has chartered the Principal Investigators and the Geoscience Research Drilling Office (GRDO) at Sandia National Laboratories to begin detailed planning of the project and to assure that the Science Plan is developed into a well-planned and well-executed engineering operation. The GRDO was established to implement the portions of the U.S. Continental Scientific Drilling Program that are funded by the DOE/OBES.

The Katmai drilling project is a significant logistical effort operating within stringent safety and environmental constraints. Due to the remoteness of the site, the operation must be supported by both helicopter flights and a camp. The equipment for this project could be mobilized and barged from the Seattle and Anchorage areas.

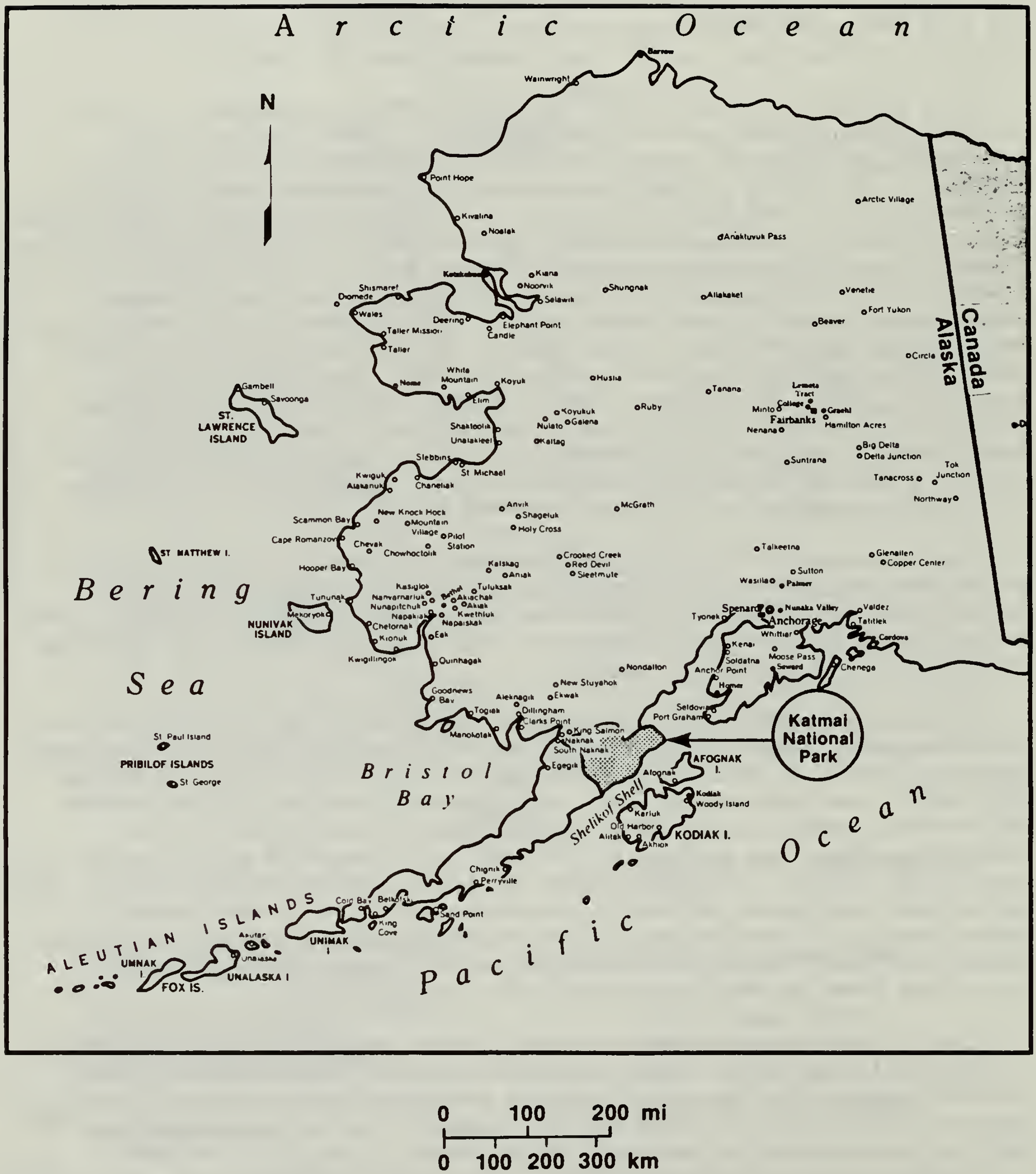


Figure 1-2. Katmai National Park, the Bristol Bay area, Naknek, King Salmon, and the Anchorage Area

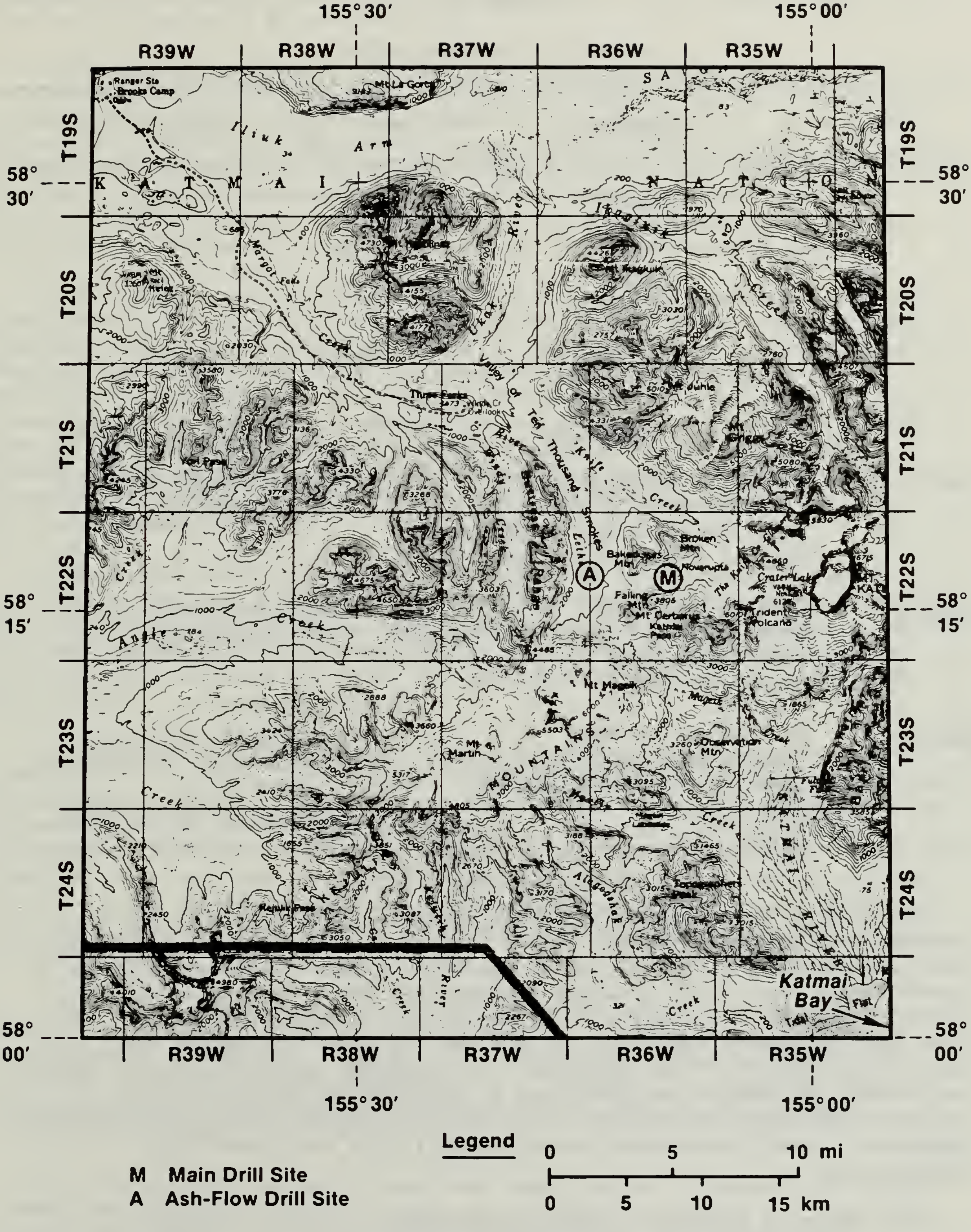


Figure 1-3. The Location of Novarupta Dome Within Katmai National Park, Brooks Camp, the Valley of Ten Thousand Smokes, Katmai Pass, and Katmai Bat Tidal Flats on the Pacific Ocean

Table 1-1

Summary of Proposed Holes

Hole	Location	Depth	Orientation
1	Center of Vent	1200 m	90°
2	Center of Vent	1000 m	60°
3	5 km from Vent	200 m	60°

	Objectives	Basis for Siting
Hole 1	Intrusive Equivalents of Pyroclastic Units Deep Structure and Stratigraphy Highest Temperature Regime	Surface Geophysics of Novarupta Dome
Hole 2	Novarupta Conduit Center to Wall Vent Stratigraphy Vent Conditions Deep Vent Wall	Positioned structure of Novarupta Dome
Hole 3	Section of Ash-Flow Sheet Section at Middistance Sampling Fissure Fumarolic Deposits	Distance from Vent Distribution of Fumarolic Deposits "Sand-Line" Development

The site is environmentally sensitive since it is within both a national park and a wilderness area. However, other drilling operations have been successfully completed in sensitive areas. Because volcanism is recent in the area, high drilling temperatures may be encountered, and current drilling technology will be exercised to the fullest extent. At least two government agencies, the NPS and the State of Alaska, will monitor all phases of the operation. Governmental monitoring begins with the permitting process and continues in the form of frequent visits, including the physical presence of authorities during the actual drilling operation. Other governmental entities will also have permitting jurisdiction.

This document provides a detailed description of the proposed operations essential to the successful commencement and completion of the project and conveys drilling information to permitting agencies. It is anticipated that as a result of discussions with these agencies, appropriate revisions will be made to this plan so that minimal impact on the environment will be assured.

This Operations Plan, in conjunction with possible amendments, the statement issued by the National Academy of Science (National Academy of Science, 1989) discussing the uniqueness of the Katmai site, and a letter of intent from the ICG, will initiate the National Environmental Policy Act (NEPA) process by which the NPS will begin a formal review and evaluation of the drilling project and generate an Environmental Impact Statement (EIS). This document is a description of the drilling operation and may be used as a reference and source material in the preparation of the EIS.

Much of the contents of this document is structured around specific requirements from the NPS, which emanate from 36 CFR 9(B). However, this document also discusses issues raised by other permitting agencies, such as various agencies of the State of Alaska and the U.S. Environmental Protection Agency (EPA). For example, the geothermal regulations of the State of Alaska provide a comprehensive set of detailed drilling rules for use in planning and conducting a prudent, safe operation with minimal impact on the environment. Both the NPS and the State of Alaska share concern and permitting authority over all environmental aspects of the proposed operation.

The scientific goals and drilling objectives of the project are included as well as a discussion of the proposed management of the project. The permitting and compliance requirements are discussed in detail along with approaches to solutions concerning legal issues. Also included are a general description of the area, its geology with appropriate maps, drill site layouts, and camp layouts.

Preliminary core hole designs and the drilling operations are also described in detail. (The drilling company that is selected to perform the operation may suggest revisions, but the overall scope of the operation and proposed core holes will remain the same.) This Plan also discusses proposed drilling fluids, lost circulation, and fluid management. The basis for the core hole design and planned drilling operations is, in part, from a recent internal Katmai Project scoping, performed jointly by the GRDO and Tonto Drilling Services. A broad overview of major safety issues is provided.

This Plan discusses the actual and potential hazards of the drilling project as well as planned, hazard mitigation, accident containment, and environmental protection. Means of preventing and mitigating potential problems if they occur are included; e.g., both a spill prevention and a containment plan concerning petroleum products, drilling fluids, and drilling fluid additives are provided.

Helicopter and camp operations have been planned to support the project within environmental health, safety, and economic constraints. Transportation information has been gathered from detailed discussions with helicopter and camp companies operating in Alaska and the Department of Interior Office of Airline Services in Anchorage. Finalization of details for helicopter and camp operations may depend on future contracts with appropriate companies. Site support functions will take place in King Salmon. A site restoration policy and plan is provided.

The ICG agencies will conduct the project in accordance with professional and governmental environmental and safety standards. Benefits to the park as a result of the project are suggested. References are made to cultural resource, social, economic, and environmental consequences. The scientific goals of the Katmai project must be attained in a manner that has negligible long-term effect on the environment.

2.0 MANAGEMENT

The principal participants in the project are the ICG, the Principal Investigators, the GRDO at Sandia National Laboratories, the Curation Office at Los Alamos National Laboratories, and individual investigators from a variety of institutions. The ICG is a committee of the three government agencies that are major sponsors of the Continental Scientific Drilling Program: the DOE, USGS, and NSF. An interagency accord was reached between these sponsoring agencies constituting the ICG, which was formed to coordinate scientific drilling efforts within these agencies. The ICG's constituency consists of academia, the USGS, national laboratories, and occasional foreign scientists. The Principal Investigators of this drilling project are John C. Eichelberger at Sandia National Laboratories, Wes Hildreth at USGS, and James P. Papike at South Dakota School of Mines. Thomas P. Miller of the USGS in Anchorage serves as a liaison between the project and the NPS.

The drilling and coring of the Katmai core holes will be funded principally through the DOE/OBES. The USGS and the NSF will provide supplemental support for the scientific activities. The ultimate responsibility for the project lies with the ICG and its constituent agencies, although to implement the project, certain responsibilities will be delegated to the GRDO and the USGS. The GRDO and the USGS will be the principal field agencies and therefore the agents of the ICG.

The USGS will provide a liaison between the NPS and the operator. The DOE will be the legal operator with Sandia National Laboratories GRDO as the agent. The GRDO, with the USGS, will secure all permits from appropriate state, federal, and local agencies, and they are singly accountable to these permitting agencies for the operation. The GRDO, with the USGS, will also be empowered by the ICG to respond to requests and directives from the permitting agencies and to interface with the public. GRDO, as agent for the operator, will be responsible in case of an accident and will lead in effecting remedial action.

Figure 2-1 shows a block diagram of communication between the project and major permitting entities. Figure 2-2 shows a block diagram of the principal fielding agencies and principal contractors.

The GRDO and USGS Site Managers will have authority to jointly make decisions in an emergency. A roster of all critical offsite technical and management personnel will be kept updated and available to all parties. Due to the remoteness of the site relative to the locations of sponsors and home laboratories of participants, it is essential that the Site Managers have authority to act on urgent decisions. If there is adequate time, the Site Managers will contact and involve additional authorized people in the decision-making process. Procedures for this will be detailed in the site-specific Standard Operating Procedure (SOP).

Communications between Permitting and Project Agencies

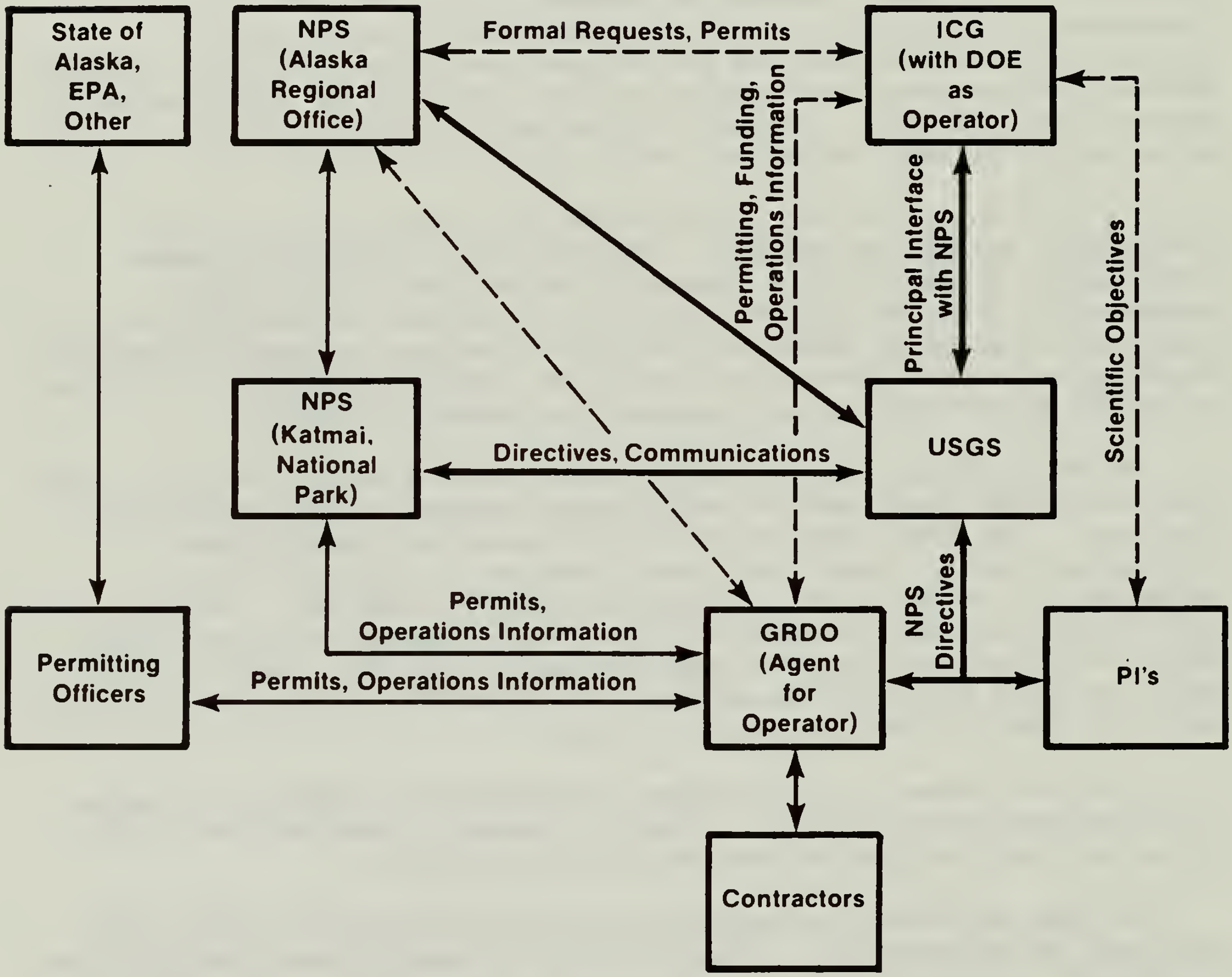


Figure 2-1. Diagram of Communication Between the Project and Permitting Agencies such as the NPS and the State of Alaska

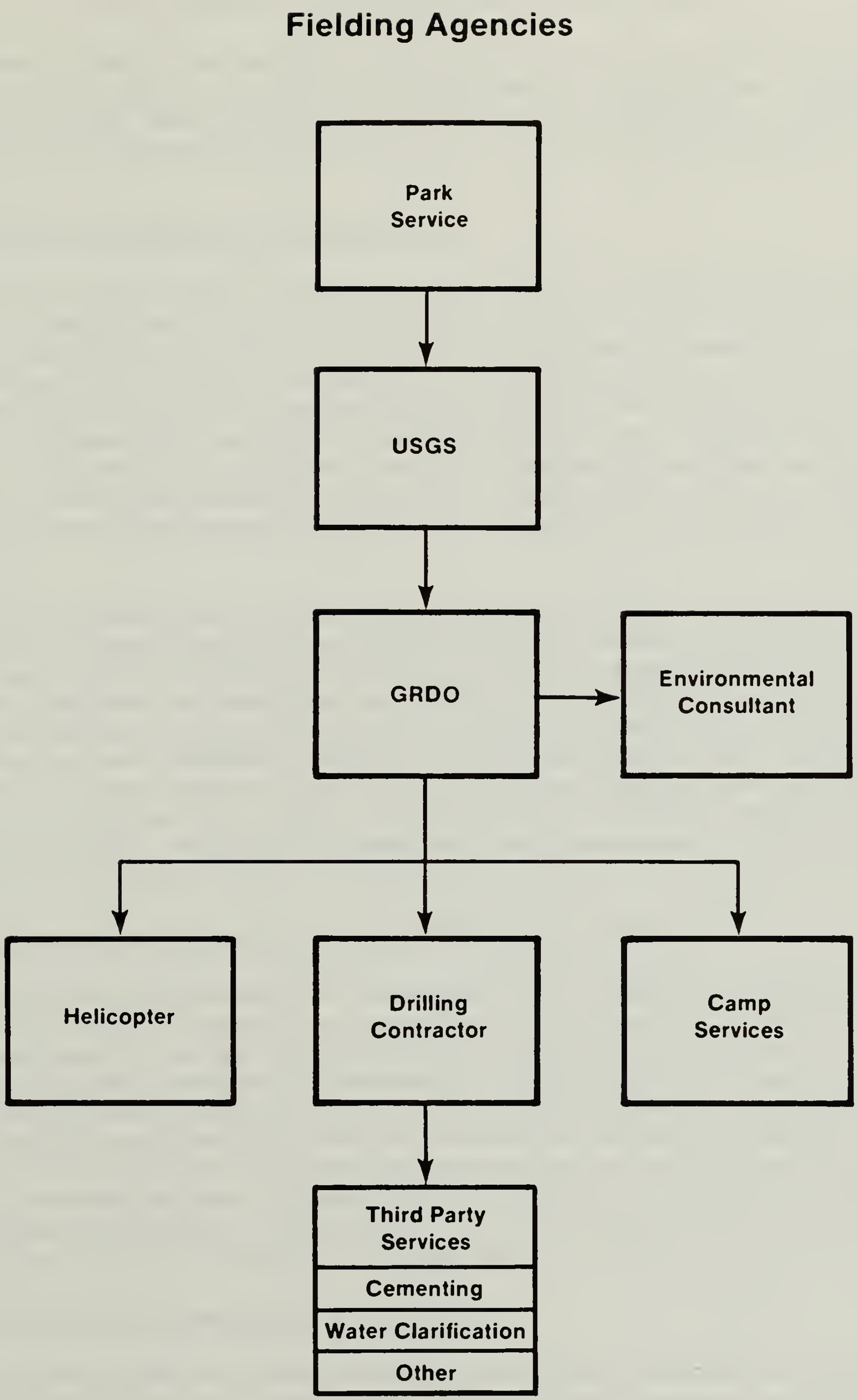


Figure 2-2. Diagram of Principal Fielding Agencies with the Principal Contractors

3.0 PERMITTING COMPLIANCE AND LEGAL ISSUES

Permits to drill and conduct the operation must be obtained from the NPS and various agencies in the state of Alaska. Regulations from the EPA and the U.S. Army Core of Engineers (COE) are also applicable. Permitting agencies and the corresponding activities of concern are listed in Table 3-1.

3.1 Drilling Regulations and Permitting

The NPS requires that information applicable to 36 CFR 9(B) be provided through an Operations Plan and that the subsequent EIS and additional drilling requirements be met. 36 CFR 9(B) contains information requirements for oil, gas, and other drilling activities, and to a large degree this Plan centers on issues addressed in these regulations, such as ownership information, map data, area geology, operation description with timetable, reclamation policies, operating standards, natural and cultural resources, social and economic environment, and environmental consequences. Information involving some of the latter categories would also be included in the EIS.

The Alaska Department of Natural Resources Division of Oil and Gas requires full permitting for the drilling of the Katmai core holes. These regulations govern geothermal drilling and are covered by directives in the Geothermal Regulations and Statutes, PDF 88-7, of the Alaska Department of Natural Resources. These geothermal drilling regulations deal with administrative and technical aspects of geothermal drilling. Both the NPS and State of Alaska regulations confront critical issues such as core hole design, lost circulation, casing and cementing, core hole control and blowout prevention, logging requirements, and abandonment. These are discussed in subsequent sections of this document.

3.2 Permitting for Federal Agencies Other Than the NPS

An oil spill prevention plan is required by the EPA as well as the NPS under 39 CFR 9(B). Inventory information is required under 40 CFR 144.26. Other requirements may be anticipated from the EPA with respect to potential hazardous wastes and returned drilling fluids. A Wetlands Determination must be requested by letter from the operator to the COE containing data such as the location, elevation, geology, hydrology, and flora of the drill site. Scientific nonhydrocarbon coring activities may require a nationwide permit from the COE. The Bureau of Land Management has no formal permitting requirements, but has requested that the project provide them with all technical information.

3.3 Permitting for the State of Alaska

The Alaska Office of Governmental Coordination oversees all specific State of Alaska permits. The following issues will require surveillance by the State of Alaska. (The NPS and the State of Alaska will share authority over most of these items since the NPS is specifically concerned with these items as well as the entire operation.)

Table 3-1

List of Permitting Agencies*

National Park Service	Regional Office, Anchorage Park Office, King Salmon-Permit to Conduct Operation on National Park/Wilderness land
U.S. Environmental Protection Agency	Spill Precention Plan, inventory of certain materials, and other requirements
U.S. Army Core of Engineers	Wetlands Determination, National Coring Program
Bureau of Land Management	Information only
Alaska Division of Governmental Coordination	Coastal Zone determination, interagency coordination
Alaska Department of Natural Resources	
Division of Oil and Gas	Drilling Permit
Division of Land and Water Management	Permit to use water
Alaska Department of Environmental Conservation	
Division of Environmental Health	Permits for camp, water supply, and other requirements
Division of Environment Quality	Solid and liquid waste, spill mitigation plan, possible air quality and noise considerations, inventory of certain materials
Alaska Department of Fish and Game, Habitat Division	Information only at this time

*Other agencies may be involved or called in by those listed above.

- Coastal Zone The State of Alaska requires that the project must first file a Coastal Zone Questionnaire with the Alaska Office of Governmental Coordination to determine whether the project affects the Coastal Zone of Alaska. The distance from the coast and the location of the proposed drill site may preclude both Coastal Zone and wetlands requirements, but formal determinations must be made.

- Water Use Water use will require a permit from the Alaska Department of Natural Resources, Water Management Section. The water use permit will be coordinated with the NPS Water Resources Section, Fort Collins, Colorado, prior to the formal filing.

- Air Quality The relatively small scale of this operation in terms of air emissions may not require a formal permit from the Alaska Division of Environmental Conservation (ADEC) Division of Environmental Quality. The coring rig and camp will be powered by generators that produce emissions. Generators at the site and the camp will produce less than 500 kW. There will be similar concerns for waste incineration.

- Noise Noise will be generated by the coring rig, diesel generators, and gasoline or diesel mud pumps. Formal permitting with the ADEC Division of Environmental Quality may not be necessary for the maximum 500 kW power generated at the site, but noise abatement procedures may be requested by the NPS if the operation overlaps the main park visitor season. The noise generated by helicopter support will be of concern.

- Oil Pollution Diesel fuel, jet fuel for the helicopters, and other petroleum fuels must be stored onsite. Because of questionable flying conditions year-round for resupply, enough fuel and essential supplies must be kept onsite for 10 days to maintain the operation. For example, the drilling rig and the camp will consume less than 500 gal of diesel fuel per day. There will be up to 5,000 gal of diesel fuel stored onsite. Also approximately 300 gal of gasoline will be stored onsite for pumps supporting the drill rig. Finally, approximately 300 gal of jet fuel will be stored onsite to refuel helicopters in an emergency. A contingency plan to mitigate spills is required by the ADEC Division of Environmental Quality as well as the NPS. (The required EPA spill prevention plan outlined in 40 CFR 112 and the required contingency plan for spills outlined in 18 AAC 75 are in Chapter 10 and Appendix B.)

- Hazardous Materials A permit will be required for hazardous materials from the ADEC Division of Environmental Quality and the Environmental Protection Agency (EPA). Drilling fluid additives in concentrated form may require permitting. However, no hazardous materials will be employed or stored onsite. The drilling fluids, as mixed and used, are nonhazardous.

- Drilling Fluids A fluid management plan is required by the ADEC Division of Environmental Quality. This is for the storage of drilling fluids and drilling fluid additives and the handling of used drilling fluids. The Division of Environmental Quality will issue permits based on permit applications. Fluid management is discussed in Chapter 8.

- Solid Waste Solid waste permits and evidence of arrangements with an approved landfill is required from the ADEC Division of Environmental Quality. Use of a trash compactor (where practicable) is planned at the site to facilitate transportation of nondrilling solids out of the park.

- Possible Affected Animal Life The U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game, Habitat Division have no formal permitting requirements for the operation, although they could be called in by the NPS, the COE, or other permitting agencies. The Alaska Department of Fish and Game has requested to be informed of project proceedings and is willing to work with the NPS in matters of joint concern. The project is within the general, but not specific, use area of caribou and brown bears. Denning and calving of these mammals in the spring could be affected by helicopters. Waterfoul will be minimally affected by the operation. Snow buntings may nest around Novarupta Dome in the summer.

- Camp Various permits are required to operate a camp; e.g., a food service permit is required from ADEC Division of Environmental Health. This also includes a permit for a Class B or C water supply. The camp must be constructed to standards set by the Alaska Department of Labor. Water testing will be performed to EPA specifications. Disposal of detergents may require permitting by the ADEC Division of Environmental Health.

- Cultural Artifacts The Department of Natural Resources, Division of Parks and Archaeology will defer to the NPS and the NEPA permitting process for the preservation of cultural resources. The entire operation within the park will be on land surfaces formed in 1912, and no human habitation other than short-term visitor and scientific camps has occurred since 1912.

Permits are not presently required for the excavation of cellar, pits, and sumps, but will be under surveillance by both the State of Alaska and the NPS. The project will contract with an independent environmental contractor to assure compliance with all appropriate regulations and directives. This contractor will make onsite inspections throughout the duration of the project to ensure compliance.

3.4 Legal Issues

It is possible that the GRDO will ask the NPS and the State of Alaska for bonding and surety agreement waivers through the appropriate legal channels. The project will complete all requisite forms for each permitting agency. Through contractual or accepted operating agreements between the project fielding agencies and their sponsors, the financial responsibility for the project rests with the DOE and the USGS.

The operator or designated agent will be held responsible for the Katmai project's compliance with existing statutes and regulations concerning the actual drilling, coring, logging, monitoring, and associated logistical support operations. The operator will also be responsible in case of an accident. The DOE and the Department of the Interior (DOI) are responsible for all principals in the field. Ultimately, the U.S. government indemnifies and holds each of its operating agencies harmless against any delay, failure, loss, expense, or damage of any kind in accordance with existing operating agreements. However, the NPS and the State of Alaska may ask the operator or sponsoring ICG agencies for assurance that funds to mitigate, contain, and clean up a major accident would be forthcoming should such a mishap occur. The project proposes to reserve $100,000 for mitigating an accident. It is understood that a true cost cannot be ascribed to an accident, and that, ultimately, the good faith of the ICG agencies must assure that all accidents are properly remedied regardless of cost.

4.0 GENERAL DESCRIPTION

4.1 Overview of Geological and Surface Features

The drill site at Novarupta Dome is located in Alaska: Range 36 West, Township 22, Section 15, in the southwest quarter. The ash-flow or remote site is in Range 36 West, Township 22, Section 8, in the northwest quarter.

The surface of the vent consists entirely of products of the three-staged 1912 eruption. During approximately 60 hours in June 1912, approximately 8.3 mi^3 (34 km^3) of pumice and ash representing approximately 3.4 mi^3 (14 km^3) of unvesiculated magma erupted. This was the largest eruption of the century and the largest rhyolitic eruption in 1,800 years. The first stage produced rhyolitic air-fall tephra and the rhyolite-rich ash-flow sheet that covers the Valley of Ten Thousand Smokes. The second stage produced dacitic air-fall tephra with subordinate andesitic air-fall tephra. This produced the crater-rim feature known as the tephra ring. The final stage was the extrusion of the predominantly rhyolitic Novarupta Dome itself. The proposed core holes at the dome site are expected to encounter vent-filling facies of pyroclastic units, the intrusive feeder of Novarupta Dome, and the vent wall. They may also encounter intact (nonfragmental) intrusive equivalents of the pyroclastic units.

The surface of the vent has moderate relief of approximately 1,000 ft. There are gently rounded landforms, and erosion has formed numerous deep gullies in the tephra deposits. The ground is loose coarse pumice, which has been reworked by wind and water. Exceptions to the coarse pumice ground are the hard, blocky surface of Novarupta Dome, the soft clayey surface of scattered thermal areas, and numerous areas of moss or a moss and lichen combination. As discussed in subsequent chapters, drilling activities will be confined within the coarse pumice as much as possible. All operations activities will be confined to bare pumice where possible.

The target of the core hole at the ash-flow site is the ash-flow sheet itself. The vicinity has low relief; normally dry channels connect with the Lethe River. The surface material is reworked pumice. There is no vegetation.

4.2 Additional Topographic Maps

A topographic map showing the location of both drill sites and potential sources of water are shown in Figure 4-1. Proposed drill site and camp locations are shown in Figure 4-2 and Figure 4-3.

4.3 Drilling Site Layouts

The proposed drill pad at the Novarupta Dome site is in a suitable level area, east of the dome, within the tephra ring (Figure 4-2). Views of the proposed pad from the top and the middle of the tephra ring are shown in Figure 4-4. The expanse of reworked pumice is sufficient for drill pad construction. Figure 4-5 shows typical coarse pumice at the proposed drill pad site.

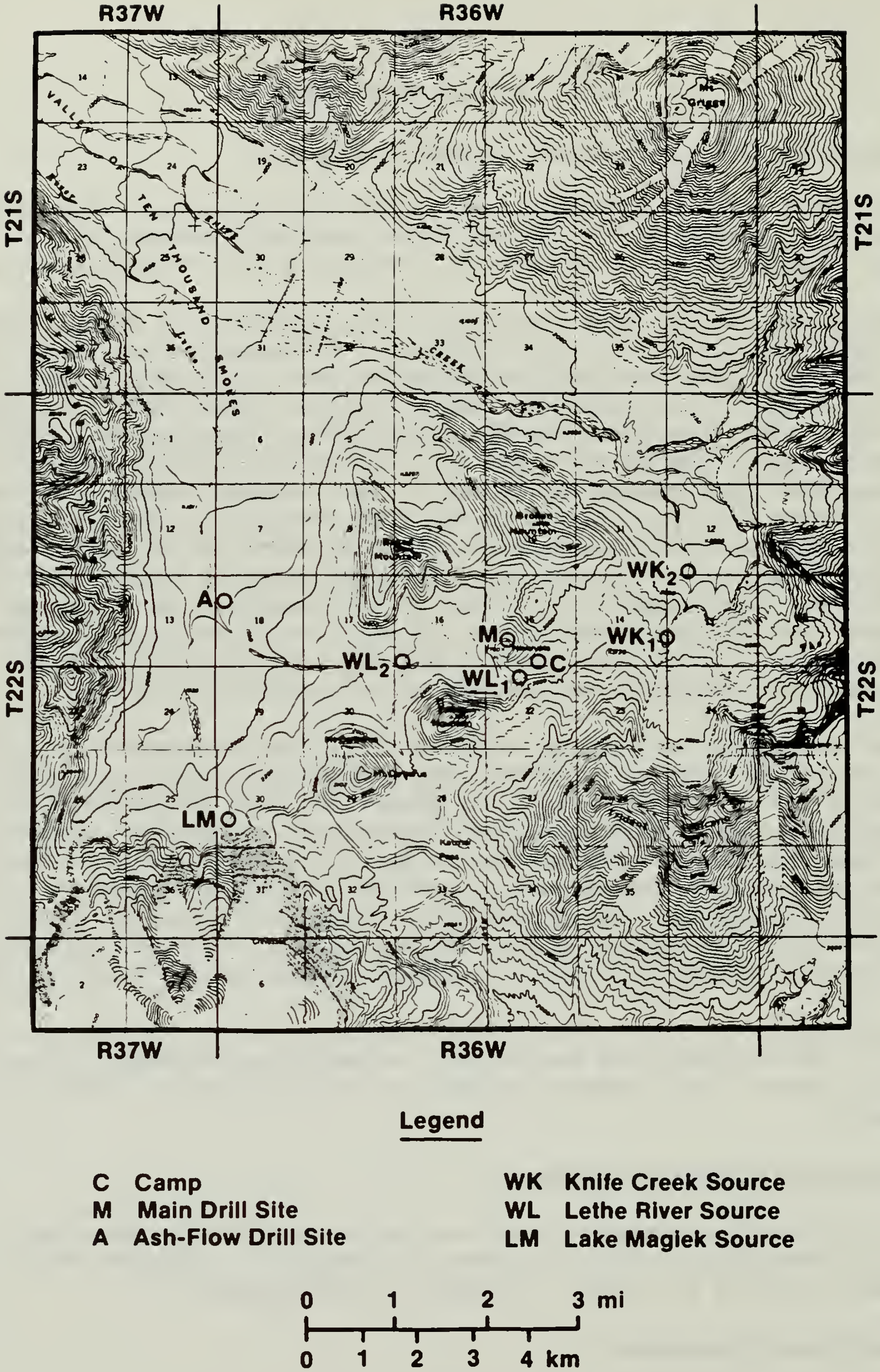


Figure 4-1. Topographic Map Showing the Main Drill Site and the Ash-Fall Drill Site, Potential Water Sources, i.e., Knife Creek Headwaters, the Lethe River, and the Locations of the Springs Draining the Valley of Ten Thousand Smokes Including the Novarupta Dome Area

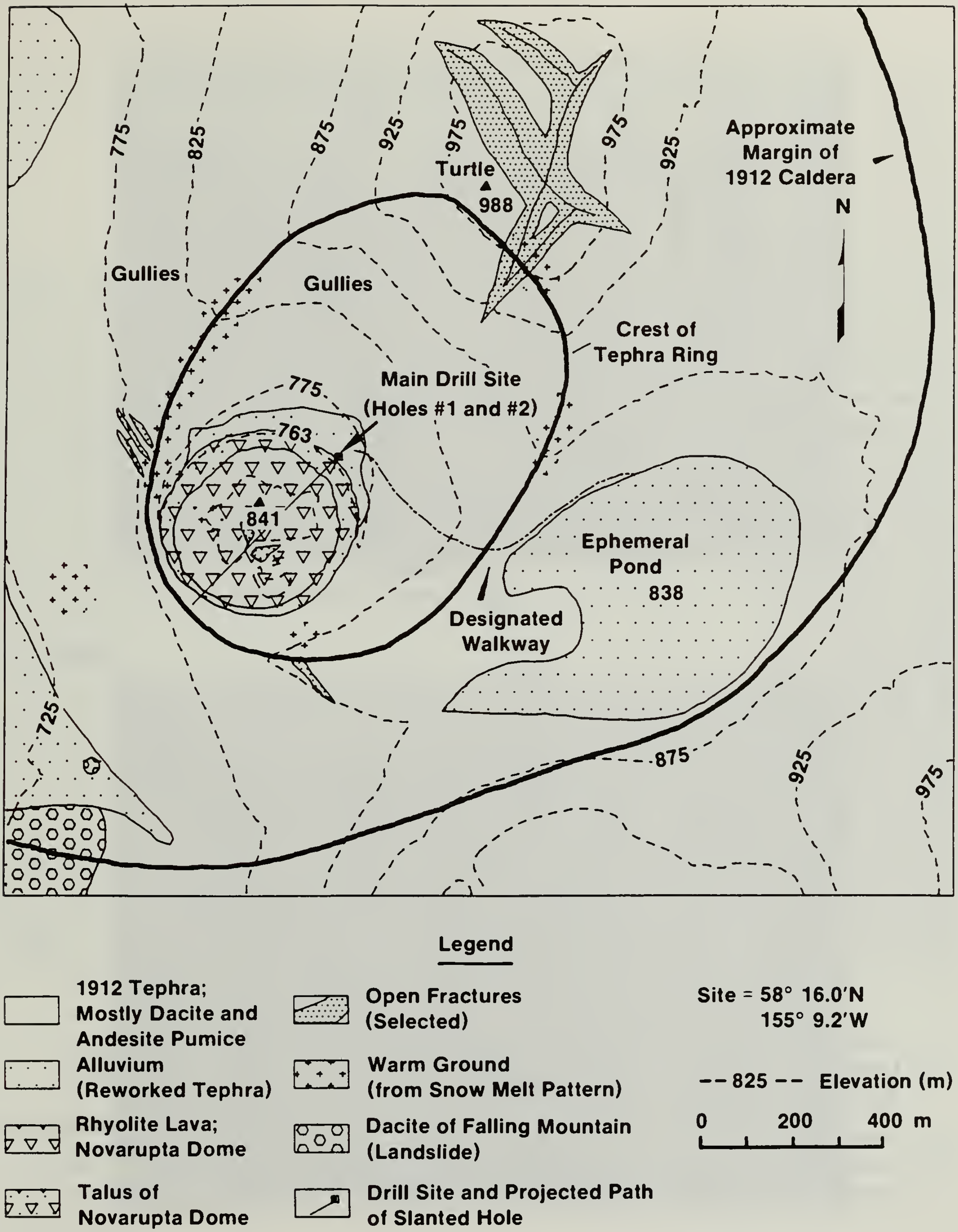


Figure 4-2. Locations of the Drill Site and Possible Campsite Near the Dome

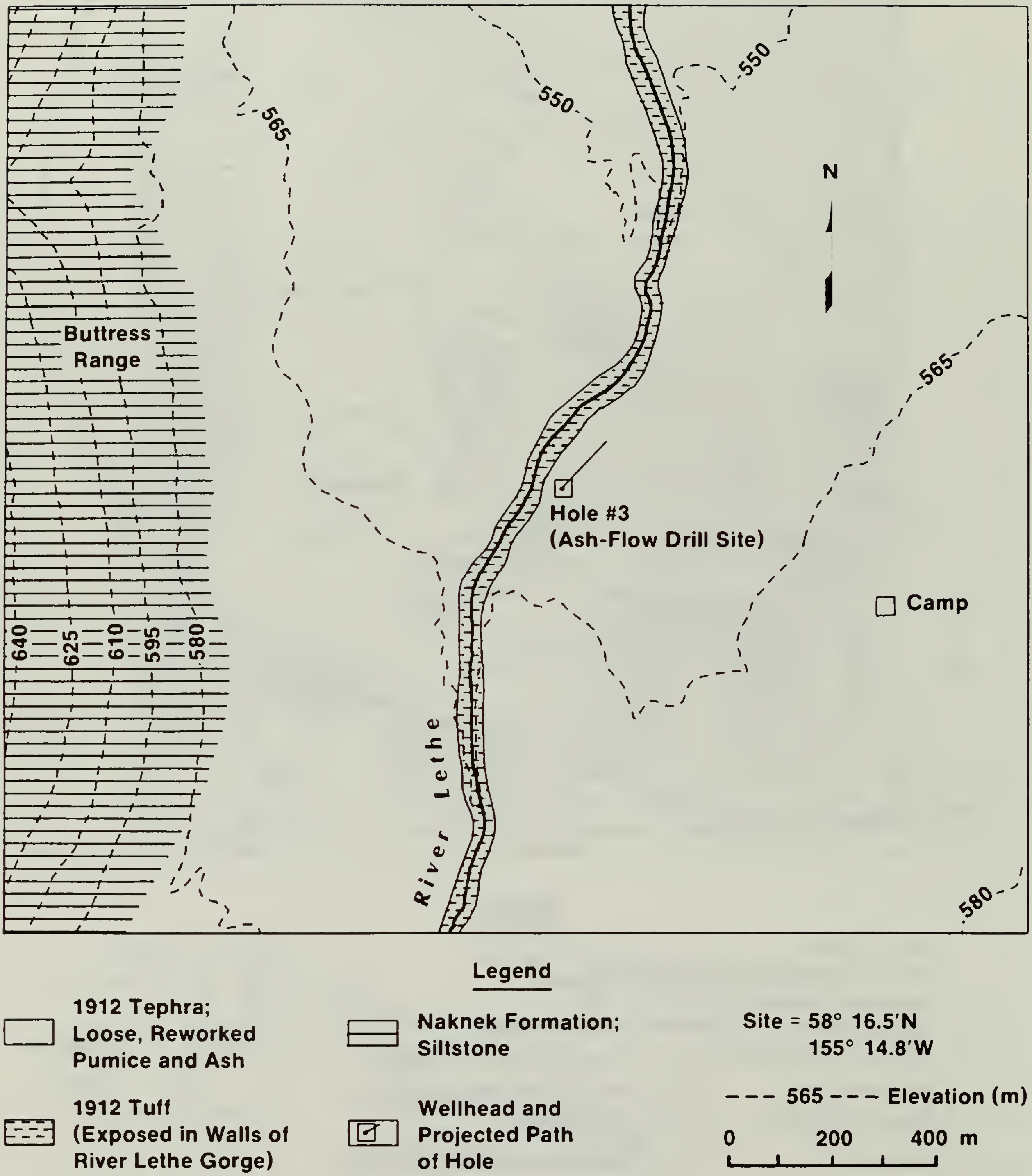


Figure 4-3. Location of the Ash-Flow Site

Figure 4-4. Views of the Proposed Pad From the Top of the Tephra Ring and Halfway Down the Tephra Ring

Figure 4-5. Reworked Pumice at the Proposed Drill Pad Site

Preliminary site layouts required to support the operation are given in Figures 4-6 and 4-7 and are detailed in Chapter 8. While it is too early for final site designs, the elements of a drill site necessary to accomplish the drilling and coring of the core holes are provided. Drilling and coring is discussed in Chapter 8.

4.4 Field Camp Layout

A proposed field camp layout required to support the operation is given in Figure 4-8 and is discussed further in Chapter 12. Details of the campsite may change, but essential elements of the camp and their approximate dimensions are given.

There must be controlled access by foot between the main drill pad and the field camp outside the tephra ring. Designing the access over the tephra ring must be done carefully because of the presence of moss over portions of the ring (Figure 4-9 and Figure 4-4 (top)).

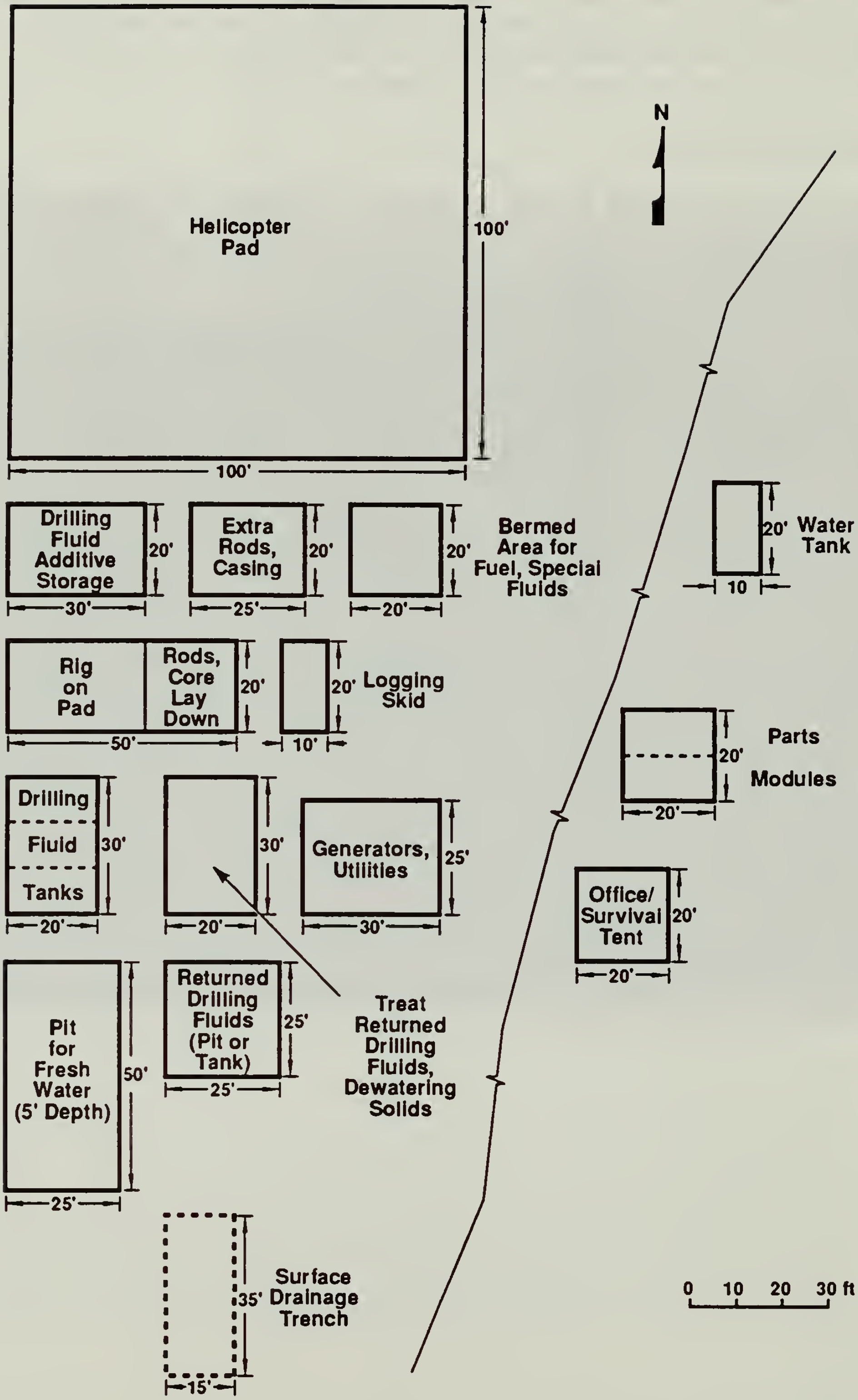


Figure 4-6. Diagram of the Main Drill Site at the Dome

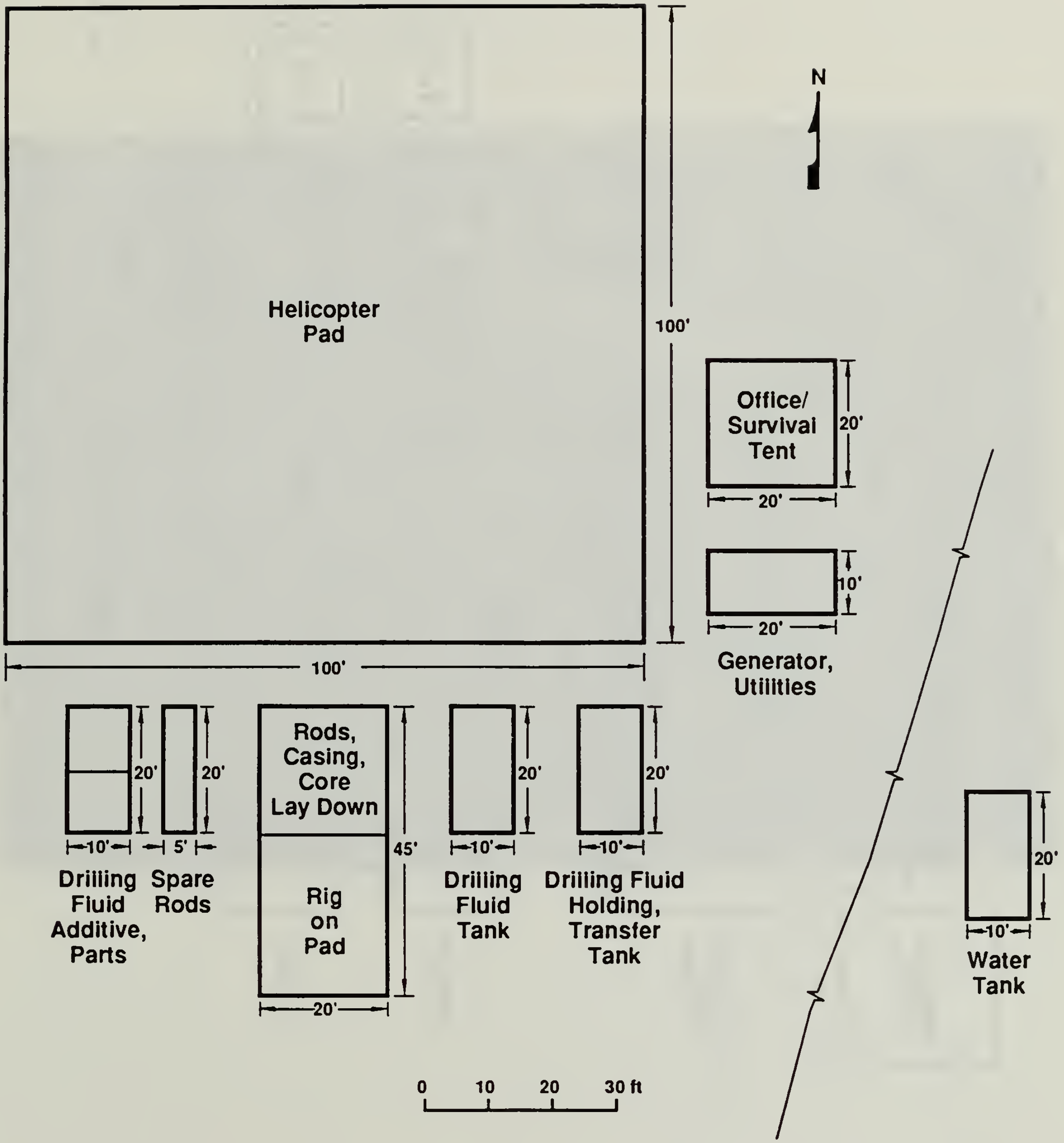


Figure 4-7. Diagram of the Remote Ash-Flow Drill Site

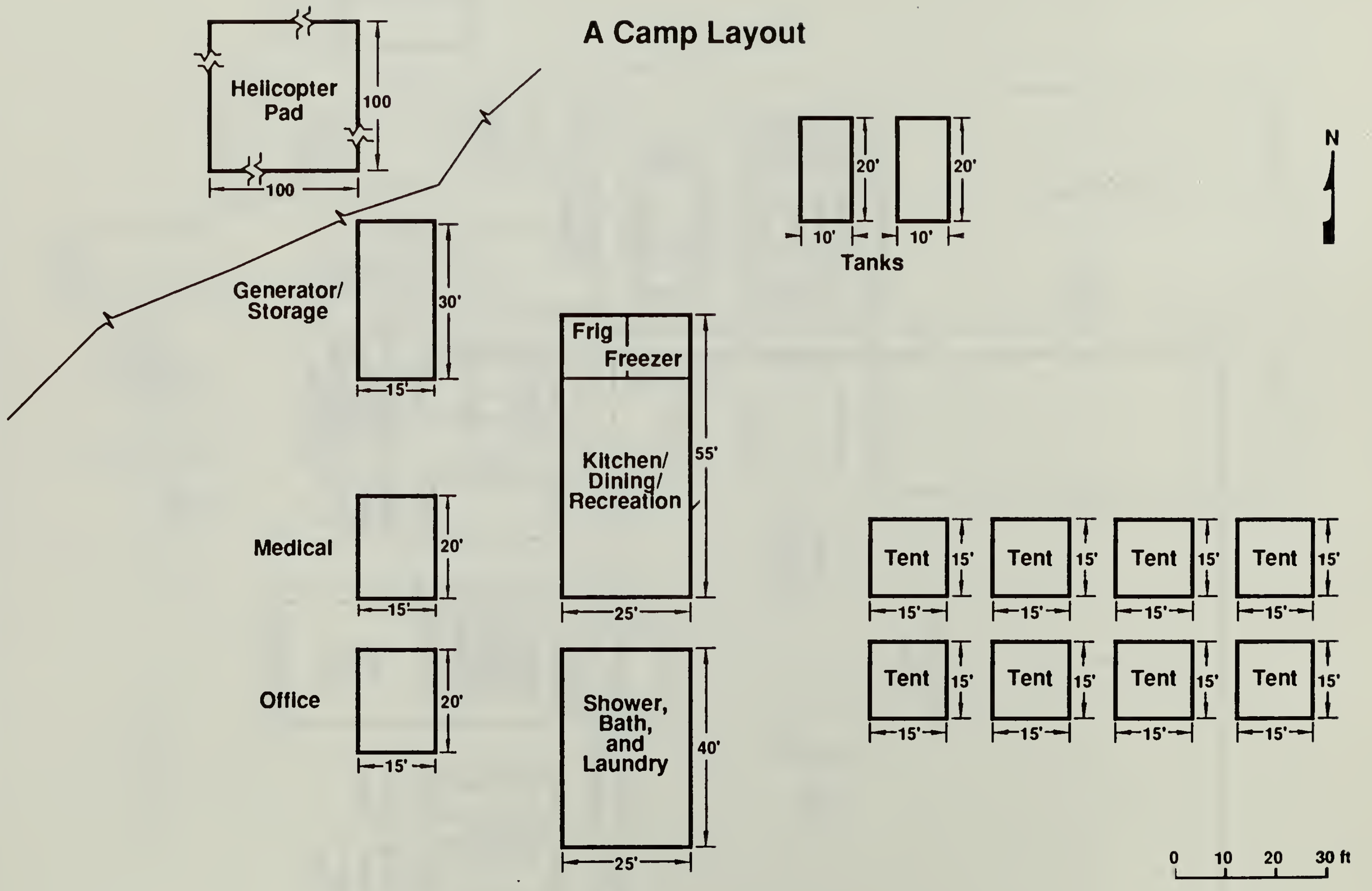


Figure 4-8. Diagram of the Field Camp

Figure 4-9. View of Mossy and Reworked Pumice Areas on the Tephra Ring

5.0 DESCRIPTION OF AREA GEOLOGY

5.1 Vent Drill Site

Two core holes are planned to penetrate and sample the interior of the vent to study the 1912 eruption (Figures 1-1 and 4-2).

5.1.1 Vent Structure

Surface structures representing the three eruptive stages are concentrically arrayed. The volumes decrease with time in order-of-magnitude, so the vents are presumed to be nested as depicted in Figure 1-1. Structural expression for the stage 1 vent is interpreted to be a concentric system of open fractures of approximately 0.6-mi (1-km) radius. The stage 2 vent is clearly expressed by a tephra ring. The stage 3 vent is the extrusion point of the lava dome, indicated by surface topography to be beneath the dome's center.

Based upon geologic and gas-dynamic considerations and a presumed analog (Hildreth, 1983, 1987; Eichelberger and Hildreth, 1986), the vents for the explosive stages are thought to be funnel-like. Lithology of ejected wall rock fragments limits the excavated volume to within the 3,300-ft (1,000-m) Naknek siltstone formation, the base of which is within approximately 5,000 ft (1,500 m) of the surface (Hildreth, 1987). Volumetric considerations of wall rock deposits in near-vent and vent fill deposits suggest the vent may flare near the surface (Figure 1-1) or the fractures may mark a zone of subsidence, with the underlying vent funnel wholly contained within it. Preliminary interpretation of recent geophysical surveys suggest a strongly flared funnel (Section 5.4). The importance of these considerations to the drilling plan is that they indicate that an approximately 3,300-ft-long (1,000-m) hole slanted radially outward from the center of the vent system will reach the vent wall.

A further constraint on the subsurface geometry of proposed vent structures is the lithology of wall rock fragments in stage 2 ejecta, which are dominantly vent fill from stage 1, rather than Naknek Formation. The volume excavated in stage 2 must lie within the stage 1 vent, as depicted in Figure 1-1. Finally, the subsurface feeder for Novarupta Dome is expected to be a rhyolite intrusion a few tens of meters thick, located directly beneath extensional features on the dome's surface. This expectation is based on eroded volcanoes of this type and on drilling experience at Obsidian Dome in California (Eichelberger et al., 1985). Thus, surface geology and analogies to other eroded or drilled systems suggest general constraints in the subsurface configuration at the 1912 vent. However, the cross section shown in the figure remains speculative.

5.1.2 Expected Formations at the Vent

Three types of geologic materials are expected to be encountered in the vent. The most abundant will be the vent-filling facies of the pyroclastic units. This will be tuff-like, consisting of variably welded mixtures of pumice, ash, and wall rock fragments. Because of the flow regime in which it forms, the vent fill will be coarser and will contain more dense components than the equivalent eruptives. Much of the vent fill is probably densely welded, but unwelded zones of unknown thickness, possibly a few tens of meters, will occur near the surface and may occur adjacent to the vent wall at depth. Depending on the degree of welding, the vent fill will range from soft, friable, permeable material to void-free glass or its finely crystalline equivalent. Unless completely unwelded or highly altered material is encountered, the vent fill should drill readily and form a stable hole. Examples of weakly to densely welded vent fill occur as fragments in the late ejecta. The last-ejected of these are thought to represent samples of the system no more than 60 hours after its inception. It is possible, therefore, that all of the vent fill subsequently welded.

Drilling beneath Novarupta Dome will encounter the rhyolite intrusion representing its conduit. This will likely be dense and largely or entirely crystalline. It may contain intensely fractured zones, but will otherwise drill readily and form a stable hole. Other late intrusives that did not vent to the surface may be encountered. In addition, the intact, intrusive equivalent of the pyroclastic units are present at some depth. Theoretical consideration of conditions for magma fragmentation suggests that such intrusives should be encountered by hole 1.

Finally, drilling may encounter blocks slumped from the walls of the vent. The Falling Mountain landslide is an example, but blocks of Naknek or even Trident lavas may occur as well. For the slant hole that is to reach the vent wall, it will be desirable to continue ≥300 ft (≥100 m) into the wall to ensure that the basement rock encountered, presumably Naknek Formation, is in-place wall and not slumped material. The Naknek, whether slumped or in place, should be competent and easy to drill. Difficulties with unstable hole conditions may be encountered if there are substantial nonwelded zones in vent fill adjacent to the cold Naknek blocks or wall. Unstable conditions may require redrilling or cementing of the affected interval, or the setting of casing.

5.1.3 Expected Sections

The target formations for the vent region holes are the formations comprising the vent, extending sufficiently far into the vent wall to observe the chemical and thermal effects of the eruption on the wall rock. These formations provide a record of the eruption processes. Temperature and fluids within these formations record ongoing cooling and alteration processes. For hole 1 specific targets are the intrusive equivalents of the pyroclastic units, and for hole 2, the conduit of Novarupta, the southwest wall of the vent, and a complete radial section through the vent fill.

Both core holes will begin in alluvium, which consists of coarse, reworked pumice. Beneath the alluvium and basal breccia, the holes will encounter coarse deposits of the late dacitic air-fall tephra. At first this will be nonwelded, but will probably become welded within tens of meters. Hole 1 will encounter stage 1 vent fill and deeper intrusions. Hole 2 will encounter the conduit of Novarupta Dome within stage 2 vent fill, the stage 1 vent fill, and will bottom-out into the Naknek Formation immediately outside of the vent wall (Figure 1-1).

5.1.4 Conditions at Depth

Conditions at depth are unknown. There has been no previous drilling in the area, nor in any directly comparable area. Temperatures up to 2,200°F (1,000°C) were present at shallow depth immediately after the eruption. The maximum known surface temperature at present is approximately 190°F (~90°C). Temperatures at approximately 3.3 ft (~1 m) depth at the drill site are approximately 32°F (~0°C). Since this is clearly a recharge area with downward percolating water, the core holes will be cold to some unknown depth. Temperatures well above boiling, pressures above hydrostatic, and toxic gases such as hydrogen sulfide may exist at depth. Precautions to mitigate these hazards are discussed in Sections 10.2 and 10.4.

No permanent bodies of water exist within the vent region. A pond is sometimes present east of Novarupta.

5.2 <u>Valley Drill Site</u>

The geology of the proposed drill site (Figure 4-3) on the ash-flow sheet is expected to be simple. The site is on the surface of the 1912 ash-flow sheet, which fills a glacial valley to form the Valley of Ten Thousand Smokes.

5.2.1 Expected Section

The target formation is the ash-flow sheet. It is covered by a veneer of variably eroded, late dacitic air-fall tephra, and it conceals a thin layer of early rhyolitic air-fall tephra (Figure 5-1). These 1912 eruptive products, in turn, overlie fluvial deposits of the ancestral (pre-1912) River Lethe, glacial till, and Naknek Formation basement. A number of attempts have been made to estimate the thickness of the ash-flow sheet, (Curtis, 1968; Ward and Matumoto, 1967; Kienle, 1969, 1970).

The best estimate (topographic) of the thickness of the ash-flow sheet is approximately 600 ft (~180 m) at the proposed drill site (Curtis, 1968). If the sag in the surface of the sheet in its vicinity is attributed solely to welding following emplacement, then the average compaction of the section is 30 percent at the drill site. Stream cuts show, however, that even the nonwelded portions of the sheet are sufficiently sintered to support vertical faces. The core hole is therefore expected to be stable within the tuff. The top few meters of the hole, in the air-fall tephra veneer, will be unstable. Drilling may be difficult, and the hole, unstable, in the glacial and fluvial debris of unknown thickness underlying the sheet. An effort will be made to reach ≥100 ft (~≥30 m) below the ash-flow sheet to assess thermal and chemical effects of the eruption upon the substrate.

5.2.2 Geologic Structure

The only structures evident in the vicinity of the site are linear fumarole-mound ridges arrayed a few tens of meters apart, roughly perpendicular to the valley axis. Based on exposures cut by the Lethe River, these are interpreted as the tops of deep vertical fractures that

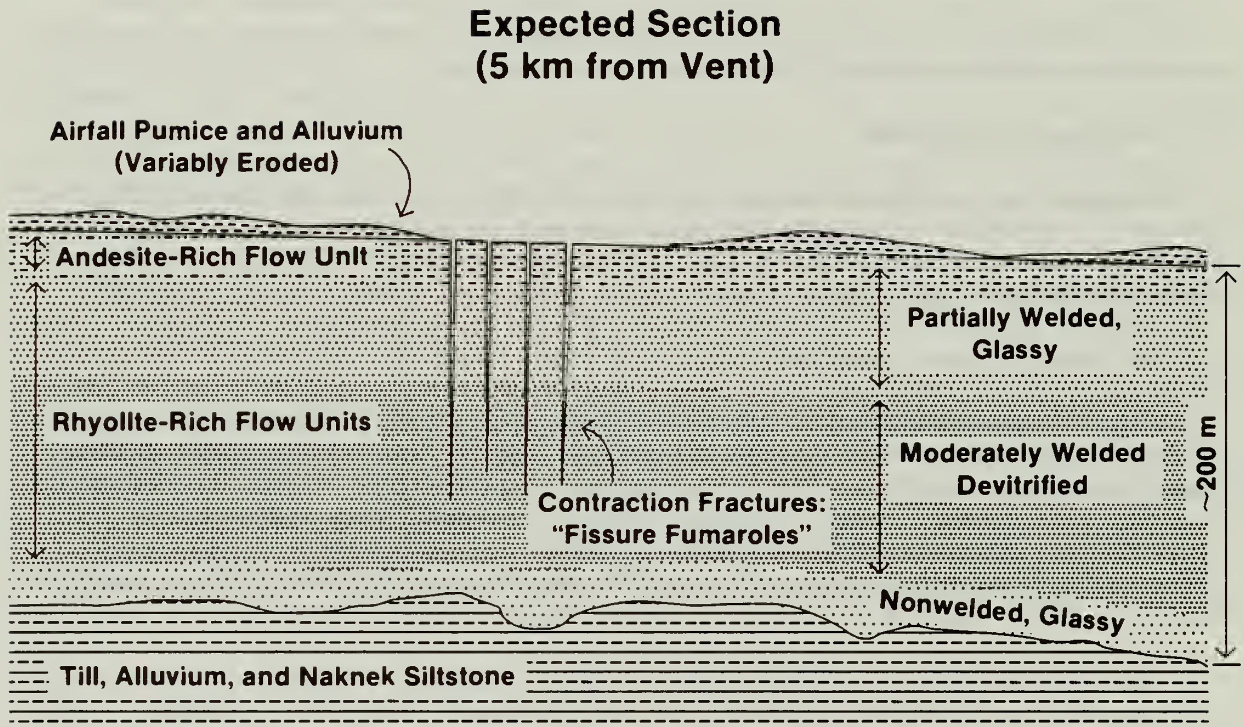


Figure 5-1. Section at Ash-Flow Sheet

served as pathways for hot metal-laden gases during the first several years following emplacement of the tuff (Keith, 1984). The hole will be slanted perpendicular to the trend of these fractures to intersect them at multiple depths and study metal release, transport, and disposition through the vertical extent of the vapor-transport system. Water is present at the Lethe River a few tens of meters from the drill site during the summer and fall.

It is unlikely that toxic gases are still being released from the deposit because this site is well removed from the source vent. No previous drilling has been done on this ash-flow sheet. It is the only welded tuff to have formed during recorded history.

5.3 Geochemistry, Hydrology, and Hydrologic Barriers

Because of its porous and somewhat fractured character, the lower part of the ash-flow sheet in the Valley of Ten Thousand Smokes serves as an aquifer. The aquifer exists just above the interface of the ash-flow sheet with the relatively impermeable Naknek siltstone (Figure 4-3), which is approximately 3,300 ft (1,000 m) thick in the Valley of Ten Thousand Smokes. Vigorous springs pour from its base near the terminus of the sheet (Figure 4-1). Some of these contain a weak thermal component, so it is likely that the interior of the sheet is still warm, though not above boiling.

Extensive water sampling was accomplished from 1979 through 1989 in rivers, streams, and springs in the vicinity of Novarupta Dome, with the heaviest concentration in the ash-flow sheet itself (Figure 5-2, Table 5-1). Conclusions from the sampling are listed below.

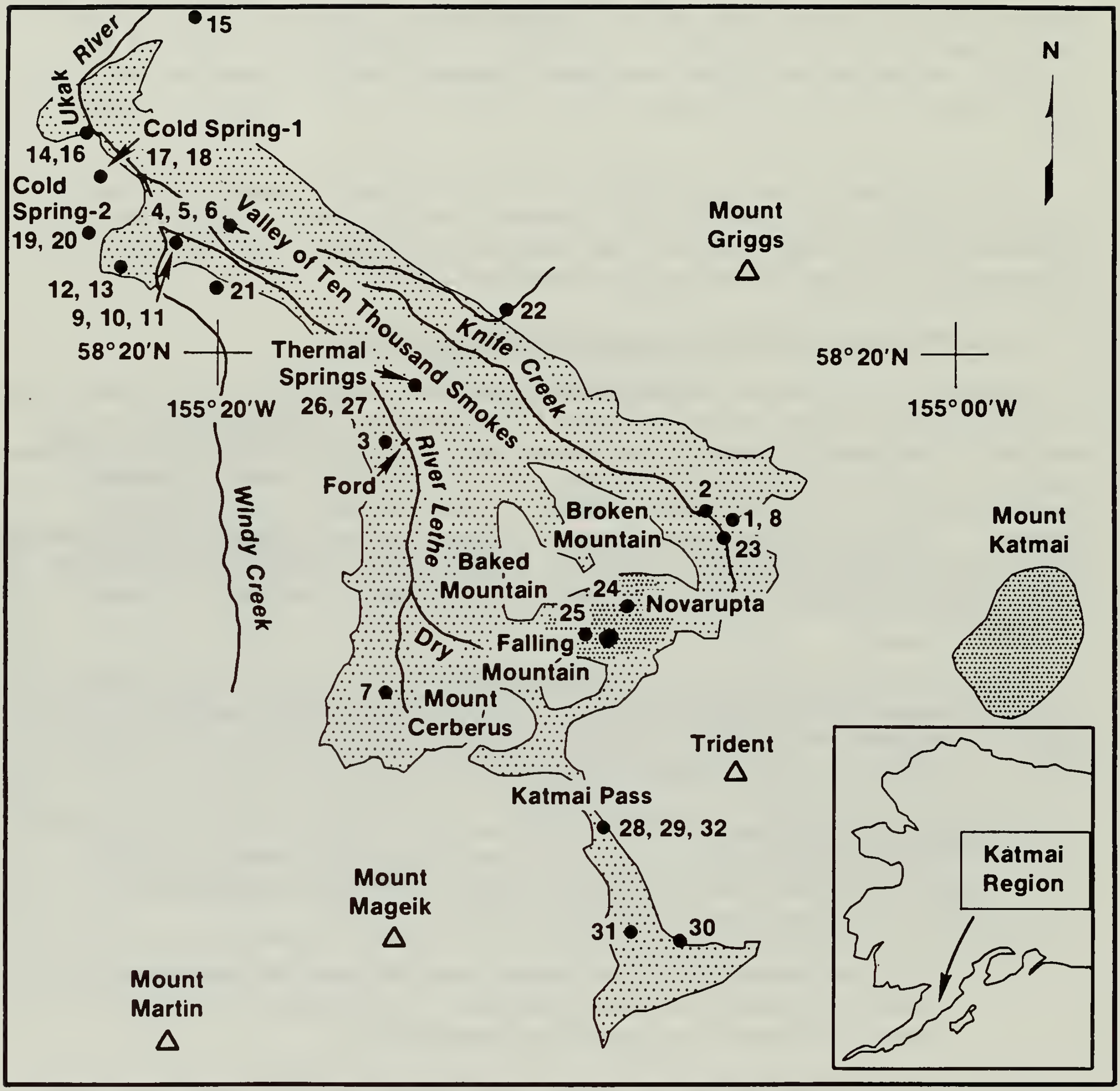
- Streams and Rivers Fairly high concentrations of Cl, F, SO_4, and $HCOP_3$ were observed at some stations apparently emanating from leaching of the ash-flow sheet rather than directly from the volcanic hydrothermal system.

    1. The concentration of the above ions appears to depend on the amount of ash-flow tuff drained. The concentration of the ions does not appear to depend on temperature.

    2. The concentration of these ions appear low for stations where the drainage emanates from outside of the sheet or where there is a small volume of ash-flow tuff drained within the sheet.

    3. The concentration of these ions is fairly high at stations where a fairly large volume of ash-flow tuff within the sheet has been drained.

- Springs Water samples from springs show a rough correlation between temperature and ion concentration. Cold fresh water springs and warmer springs with higher ionic concentrations are present. Observations over the years suggest that the cold spring flow is a function of precipitation. Each headwater of Knife Creek and the Lethe River near the drill site (Figures 1-3 and 4-1) has warm



Legend

- Klater Samples, Including River and Springs (1979, 1982, 1984, 1986, and 1987 collected by T.E.C. Keith and J. M. Thompson)
- Ash-Flow Sheet of 1912
- Calderas of 1912

0 5 km

Figure 5-2. Water Sampling Locations

TABLE 5-1

Chemical Analyses of Waters from the Valley of Ten Thousands Smokes (ppm)

Location	date	temp	pH	SiO_2	Fe	Mn	Ca	Mg	Sr	Na	K	Li	Rb	Cs	HCO_3	SO_4	Cl	F	B
Knife Creek Water Samples																			
Upper Knife Cr	07/01/79	--	3.20	81	--	--	41.4	6.53	--	6.2	7.9	0.05	0.05	0.05	0	159	7	0.49	0.1
	(field PH)		-5.25																
Upper Knife Cr	07/26/82	5	4.18	10.6	--	0.12	16.6	1.87	--	2.85	0.5	.01	.03	.03	5	32	1.5	0.46	0.25
Upper Knife Cr	08/01/86	3	3.92	13.3	--	--	22.7	2.9	--	3.8	0.34	0.01	--	--	0	62	3.4	.22	.05
	(field PH)		5.2																
Lower Knife Cr	06/26/79	--	6.53	149	--	--	51.2	10.2	--	34	16	0.5	.05	.05	37	176	49	1.7	0.1
Lower Knife Cr	12/08/82	11	7.09	28.4	--	0.13	56.4	11.59	.14	42.5	2.37	.08	.05	.34	55	140	57	1.6	.3
Lower Knife Cr	06/08/86	6	6.78	24.0	--	--	44.1	9.65	--	3.1	1.10	.07	--	--	37	104	40.8	1.35	.19
River Lethe Water Samples																			
blw Mageik Lake	08/07/82	7	6.49	52.4	--	.09	10.1	1.83	.05	4.0	1.27	.01	.04	.08	26	13	4.0	.75	.1
at trail Ford	08/05/86	2	6.49	9.8	--	--	4.4	0.94	--	1.5	0.15	.01	--	--	14	14	1.2	.1	.24
abv 3 Forks	06/27/79	--	7.53	113	--	--	47.7	13.4	--	51	30	1.62	.05	.02	81	146	42	2.6	.7
abv 3 Forks	08/13/82	13	7.46	27.6	--	.03	25.1	8.54	.07	35.2	2.5	0.125	.05	.05	82	60	40	1.65	.4
abv 3 Forks	07/20/86	10	7.30	26.5	--	--	28.6	9.2	--	5.3	1.8	0.11	--	--	67.5	71	26.7	1.2	.4
Windy Creek Water Samples																			
at trail ford	06/27/79	--	7.10	36	--	--	15.3	2.11	--	2.4	1.1	.05	.05	.02	81	24	2	.41	.1
at trail ford	07/20/86	14	6.99	10.1	--	--	14.1	2.2	--	3.1	.22	.01	--	--	25	21	1.5	.06	.1
Ukak River Water Samples																			
at footbridge	08/12/82	13	7.35	26.7	--	.07	37.9	9.03	.10	35.9	2.11	.102	.05	.05	27	90	46	1.55	.6
blw toe of flow	08/06/84	15	6.94	53.1	--	--	35.6	9.48	--	31.1	2.46	.08	--	--	58	62	47	1.4	.25
near footbridge	07/19/86	14	7.05	23.6	--	--	39.9	9.1	--	6.2	1.3	.08	--	--	18	83	31.8	.75	.47
Miscellaneous Spring and Creek Water Samples																			
Cold Spring 1	07/19/82	5	7.40	19.4	--	--	16.04	2.98	.03	5.26	.50	.01	.02	--	66	20	2.0	.14	.15
Cold Spring 1	07/19/86	9	7.06	19.1	--	--	18.3	3.4	--	4.9	.17	.10	--	--	46	18	2.4	.05	.1
Cold Spring 2	08/14/82	5	7.37	20.3	--	.01	16.33	3.12	.02	4.11	.74	.01	.03	.08	63	11	2.4	.02	.15
Cold Spring 2	07/20/86	9	7.06	19.1	--	--	18.3	3.4	--	4.9	.17	.01	--	--	46	18	2.4	.05	.1
Iron deposit Cr	08/16/82	12.5	7.22	20.2	1.63	.07	11.2	2.10	.02	4.11	.66	.01	.03	.08	71	5	1.4	.75	.3
btw Juhle - Gri	08/06/84	14	7.01	19.8	--	--	26.0	2.85	--	3.8	.85	.01	--	--	58	25	2	.19	.1
Upper Knife Cr	08/06/84	10	6.27	25.7	--	--	24.1	2.15	--	8.1	0.50	.01	--	--	25	58	5	1.8	0.15
Snow melt	07/25/82	15	5.66	.3	--	--	.15	.01	--	1.4	.01	.01	--	--	11	.2	.3	.28	.1
Snow melt pond	07/28/86	14	5.44	2.0	--	--	.36	.05	--	0.17	.1	.01	--	--	11	2	.4	.25	.1
Spg in old K Cr	07/24/87	15	5.7	55.5	--	--	89.5	17.9	--	73.3	2.96	0.16	--	--	105	330	69.6	3	0.66
Spg in old K Cr	07/24/87	17	5.7	58.6	--	--	9.4	19.9	--	8.3	4.21	0.2	--	--	127	390	73.6	2.9	0.8
Katmai Hot Spring Water Samples																			
a lower spring	08/03/82	40	7.90	105	1.18	.02	136	59	.50	231	29	.58	.49	.52	337	410	262	2.89	2.7
an upper spring	08/03/82	42	7.59	111	1.20	.03	116	65	.57	252	29	.64	.46	.90	377	330	279	2.77	4.2
further updrn.	08/09/84	40	7.53	105	.1	.1	157	70	.50	218	25	.50	.29	.18	569	480	251	2.50	5.5
spg in cr trib	08/03/82	15	8.05	67.5	20.1	1.16	33.5	31.1	.40	98.9	7.9	.04	.09	.05	190	93	145	.10	1.6
btw Trident fl	08/09/84	15	6.84	42.9	.04	.33	44	30	.29	121	8.9	.03	.01	.04	452	54	113	.10	3.4

season flow rates estimated in excess of 200 gal/sec. The thermal springs in the lower part of the valley have estimated flow rates of approximately 5 gal/sec. The flow rates of the rivers at the bottom of the valley are larger, approximately 1,000 gal/sec at the Ukak River at the lower end of the valley. The leaching of pumice and the thermal springs account for large amounts of salt that are carried out of the valley by the water systems above.

These data suggest the presence of two separate hydrological systems: a fresh water system thought to flow at the base of the ash-flow sheet above a fairly impermeable Naknek siltstone and a hydrothermal system existing below this siltstone.

In the region of the vent, Novarupta Dome, it is the vent structure itself with the interface of the impermeable Naknek siltstone that may form a partial hydrologic barrier, local to the Novarupta Dome region. The eruption of 1912 breached the Naknek Formation. Thus, Naknek siltstone may form an approximately 3,300-ft (~1,000 m) cylindrical barrier around the vent at 500 ft (~150 m) or deeper.

5.4 Summary of Recent 1989 Surface Geology Studies

Gravity, magnetic, and electrical techniques have all identified anomalies centered near Novarupta Dome. These results generally support earlier arguments about the subsurface structure that were based primarily on geology. Fracture distribution, widespread thermal activity, the broad gravity anomaly, and, possibly, electrical conductivity indicate the probability of a vent of approximately 0.6-mi (~1 km) radius. The relatively small volume of lithic ejecta, subtle structural, topographic expression of the vent, and narrow magnetic anomaly indicate a smaller structure. Pending results of ongoing modeling, two models seem consistent with these observations. The vent may have a deep welded throat within which Novarupta is centered and may flare broadly at shallow depth. In this case the Turtle is a late asymmetrical accumulation of air-fall tephra. Alternatively, this magnetically defined throat may be the entire vent, with the surrounding fractured basin a zone of modest subsidence. In this case the Turtle is a bedrock high that began to slip into the open hole. In either case, the geophysics confirm what was suspected from geology: that Novarupta Dome marks the center of activity in 1912. Thus, the area adjacent to the dome should be the center of the drilling activity.

6.0 DRILLING OBJECTIVES AND TECHNICAL APPROACH

The results from the Katmai project will provide an in-depth understanding of one of the most interesting features in Katmai National Park. Indeed, it will highlight one of the unique volcanic sites in the world. The size, youth, elevated temperature, and simplicity of the Novarupta vent make understanding its internal structure and conditions an important scientific objective.

Size

The Katmai eruption was the world's largest rhyolitic event in the last 1,800 years, and the only historic eruption to produce a welded tuff sheet. Although 1/10 to 1/100 of the size of the largest eruptions that occur on the earth, the Katmai event is of a class of eruptions that is both large enough to be catastrophic in impact while frequent enough to represent a serious threat to human activities. Its great size contributed to retention of significant heat at shallow depth and, undoubtedly, to much post-eruptive migration of metals.

Youth

Because the event is so recent, eyewitness accounts provide information on the timing of the eruption. The damage to deposits by erosion and weathering is minimal. Most importantly, the age and size of the system are such that the surface is cool, while elevated and possibly high temperatures persist within the upper 0.6 mi (1 km). Thus, at this location the cooling of an igneous intrusion can be directly observed for the first time. The short time since emplacement also minimizes chemical alteration of rare, less resistant minerals and glasses.

Simplicity

The 1912 event was a single eruption of magma passing through uniform sedimentary bedrock at a site where little previous volcanic activity (none rhyolitic) had occurred. Temperature, chemical, and structural observations at depth can be directly related to the 1912 event. In addition, the remarkable 6-mi (10-km) separation between the eruption site and the site where collapse, due to the subsurface withdrawal of magma, took place uniquely permitted preservation of the structure of a major vent.

The following are the primary scientific objectives for the Katmai project. Attaining these objectives will contribute to a greater understanding of silicic igneous activity.

6.1 Objective 1

6.1.1 Describe the Physical and Chemical Behavior of Magma and Its Host Rock During Intrusion and Eruption

The rapid flow of a large volume of thick, viscous magma upward through the rocks comprising the Earth's crust is a complex mechanical problem.

Aspects of the problem include fracturing of bedrock by magma, flow of magma, growth of bubbles, expansion and breakup of the magma to ash, pumice, gas, and excavation of the vent. The problem can be divided naturally into the behavior of magma and the behavior of the conduit system. The project will test existing theories about intrusion and eruption processes and geologic concepts of vent geometry and development.

6.1.2 Approach to Objective 1

Models for molten rock behavior during intrusion and eruption depend first on the size and geometry of the system. Results from the continuous core sections of the drill core holes will provide a subsurface view of vent structure. Drilling results will be combined with surface geological and geophysical observations to develop a fully consistent geometrical model of the vent. A complete section of core through the ash-flow sheet, together with surface geologic observations, will show the sequence in which the eruption deposits formed. Matching these deposits with equivalent layers encountered by drilling inside the vent will show how the vent grew with time. The timing of the vent's periods of constriction, collapse, and intrusion can also be determined. The basement fragment distribution in the vent-fill and the ash-flow sheet will show how the vent was excavated. Identification of down-dropped blocks of basement relative to vent volume will show to what extent the vent formed by collapse of wall rock into magma, rather than by excavation of wall rock by erupting magma.

Glassy rocks in the vent, representing magma that cooled too quickly to grow crystals, will be analyzed for chemically bound gases. This will show how the gases in the magma changed as the magma approached the surface and pressure decreased. The amount and composition of gases contained in the glass will indicate the source or sources of the gases (either from the interior of the Earth or the atmosphere). The core will also be studied to map glass-rich (quickly cooled) and crystal-rich (slowly cooled) zones. This will show how the magma solidified as it lost heat and gas. Zones of alteration will also be studied because these reflect prolonged exposure to circulating hot water. The relative timing of crystallization and alteration events, both before and after 1912, will be determined by radiometric dating.

Results of these investigations should indicate what happens during an explosive eruption and what controls whether an eruption will be explosive and ash-forming, or nonexplosive and lava-forming.

6.2 <u>Objective 2</u>

6.2.1 Determine the Source, Mechanism, and Conditions of Metals Transport

This problem includes identification of the source(s) of metals, the cause and timing of release, the origin of the transporting vapors, and the identification of conditions such as temperature, pressure, and gas composition-controlling transport rates. Possible metal sources are unerupted magma, country (host) rock, or ash. Transporting vapors may have originated from erupted material, or from snow and streams buried by the eruption. Comparison of metals transport in the environments of the ash-flow sheet and the vent may be especially important. Conditions differed substantially between the ash-flow sheet, which is flat and composed of individual ash particles and pumice fragments, and the vent, which is chimney-like and may contain a significant proportion of intact igneous rock (Figure 6-1).

Subsurface mapping of metals enrichment and depletion zones, the spatial relationship of these zones, and their isotopic character will determine the conditions and mechanisms of metals migration. As shown in Figure 6-1, metals mobilization occurs during crystallization, though other possibilities exist. Steam of magmatic or atmospheric origin transports the metals. Note that magmatic vapor may dominate in the chimney-like vent, while an influx of atmospheric water may be more important in the slab-like ash-flow sheet.

6.2.2 Approach to Objective 2

The approach will be to describe as well as possible the distribution of metals in the igneous host rock system and to interpret how portions of the system reached their present chemical state.

For the igneous portion of the system, initial metal concentrations in the magma prior to eruption will be estimated by analysis of glass inclusions from each of the three magma types. The inclusions represent samples of liquid rock encapsulated in crystals and therefore protected from the reduction in pressure that caused the magma to lose gas and metals. Metals concentrations in the magma immediately following eruption will be obtained by analyzing a complete collection of quenched pumices. These baseline values will then be compared with observations from the multiple continuous core sections of the intrusive and eruptive portions of the system. Enrichment and depletion zones of metals will be mapped, and the relationship of the metals-depleted and metals-enriched volumes to crystallization zones, specific magma types, fluid entry, and gas flow will be determined. These observations will be interpreted in terms of the effects of decompression, or pressure reduction, in eruption and crystallization during cooling in metals release.

Similarly, metals concentrations along profiles into the vent wall and into the valley floor beneath the ash-flow sheet will be obtained. These observations will be interpreted to show how the host rock interacted with magmatic gas and magmatically heated water. Conditions and mechanisms of metals transport will be deduced from considerations of the mineralogy of fumarolic deposits and analysis of fluid inclusions in crystals deposited by fumaroles. Results will indicate the chemical and physical conditions controlling metals transport and will lead to conclusions concerning why metals are transported during some eruptions but not during others.

These investigations should find general applicability in the interpretation of the processes responsible for the formation and preservation of volcanic-rock-hosted ore deposits.

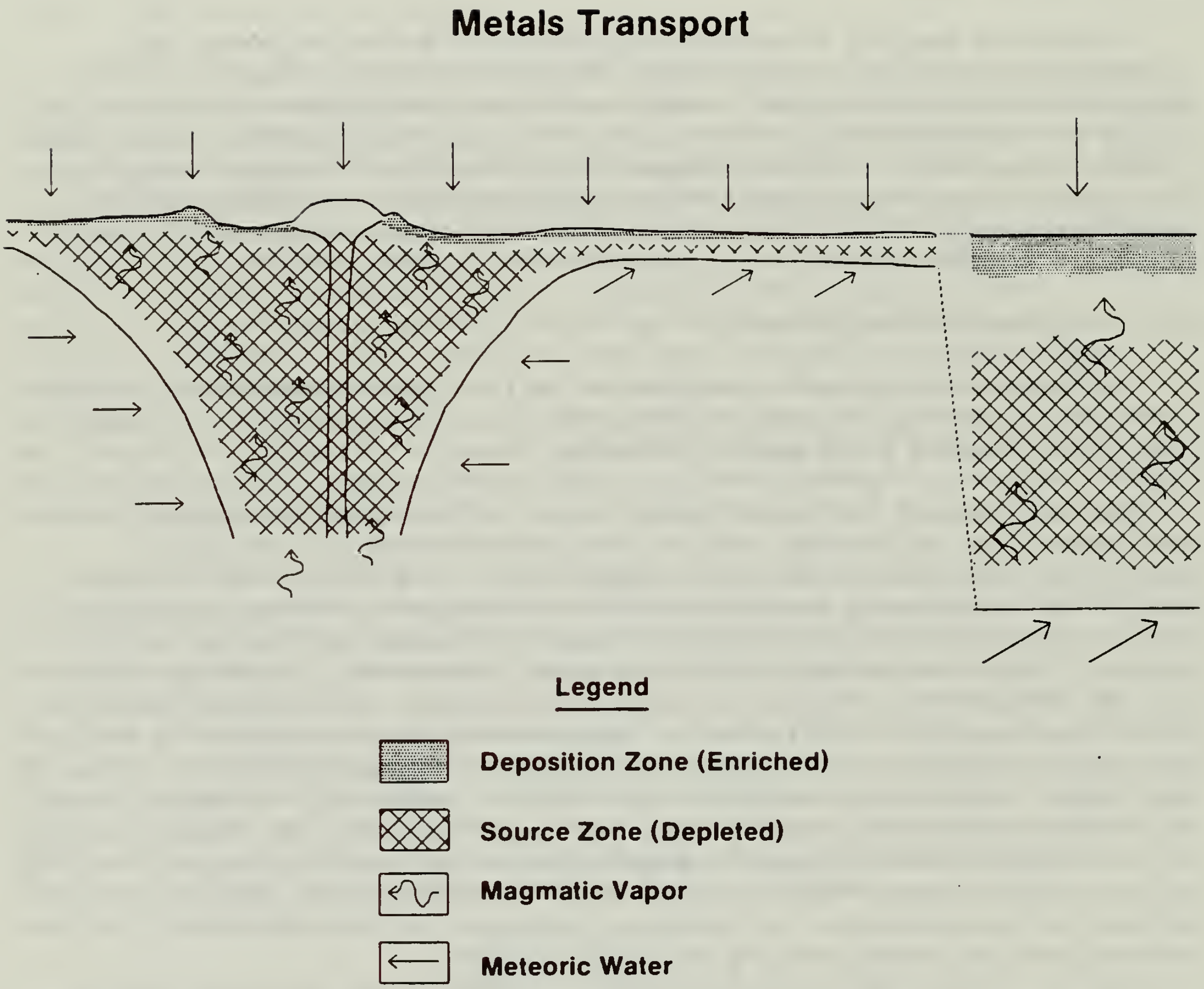


Figure 6-1. Schematic of Metals Transport

6.3 Objective 3

6.3.1 Measure the Current Temperature Distribution and Test Models for Cooling of Igneous Systems

Models predicting the rates and ways by which igneous intrusions cool and undergo changes in mineralogy as a result of cooling have not been tested by observation of actual cooling systems. The vent for the 1912 eruption and its contained intrusions are unquestionably still cooling. In theory, the system has passed from molten conditions, through a very hot vapor stage when there was newly crystallized rock and steam in the vent, to a moderate-to-low temperature hydrothermal stage, when hot water began circulating and altering the rocks to clay. Portions of the vent and conduit could have remained in the vapor stage and could still contain magma which would cause difficult drilling conditions. Drilling into a simple, still-cooling system at a known point in time after its formation will provide fundamentally new information concerning how fast heat travels in the Earth's crust and how fast rocks change their composition. This is a rare opportunity to determine the rates of major geologic processes.

6.3.2 Approach to Objective 3

The Katmai project will observe and sample an active hydrothermal system only 80 years after its formation. This is very young geologically. Magmatic temperatures of 1912 ejecta have been deduced from mineral data (Hildreth, 1983), and these values can be used to estimate temperatures in and near the vent when it first formed. The present temperature conditions will be described by determining the surface heat flow and by measuring the temperatures in boreholes (Chapter 8). Zones of conduction, where heat flows through rock, and convection, where heat is carried by flowing water, will be identified. The relative timing of crystallization and alteration events will provide further information about the post-eruption history.

This first measurement of the rate at which an igneous intrusion has cooled will show the accuracy of present mathematical models for heat flow in the Earth's crust. Results will be applicable to the predicted behavior of repositories for isolation of radioactive waste as well as for understanding volcanism. In general, volcanoes are repeatedly intruded by pulses of magma. Results at Katmai should permit an assessment of the extent to which heat from one eruption may influence the course of successive eruptions.

7.0 CORE HOLE DESIGN

A preliminary core hole design is provided in this document on the basis of information available. Schematics for the 4,000-ft (~1,200-m) vertical hole, with the beginning of the 3,000 ft slant hole shown, and the 650-ft (~200-m) slant hole are shown in Figures 7-1 and 7-2, respectively. Core hole designs are consistent with 36 CFR 9(B) and the State of Alaska Geothermal Drilling Regulations. The project will request two specific variances to the state geothermal regulations, and these are discussed in Sections 8.4 and 8.7.

Because the drilling conditions are expected to be difficult, the diamond core rig chosen for this project will be one of the more powerful rigs that is transportable by helicopter. The rig assembly will also include a drill frame and a derrick. Tools and spare parts will be included (Section 8.1).

The 4,000-ft vertical hole and the 3,300-ft slant hole will be cored through the same drill pad and casing string (Figure 7-1). The verticle hole will be completed first. If drilling conditions are good, the HQ rods of the vertical hole will be pulled, and a permanent whipstock will be placed in the casing between 800 to 1,300 ft (~250 and 400 m) below the surface. The hole will be sidetracked off the whipstock, and a window will be milled out of the casing. A special drilling assembly with a down-hole motor will be employed to continue to build the angle gradually until the described 60-degree slant angle is reached. Then coring will commence underneath the dome.

The tubulars for the vertical hole at the main drill pad will consist of the following:

- 10 3/4 in., 40 lb, K55 casing riser pipe through loose pumice into more consolidated rock to approximately 100 ft (~33 m);

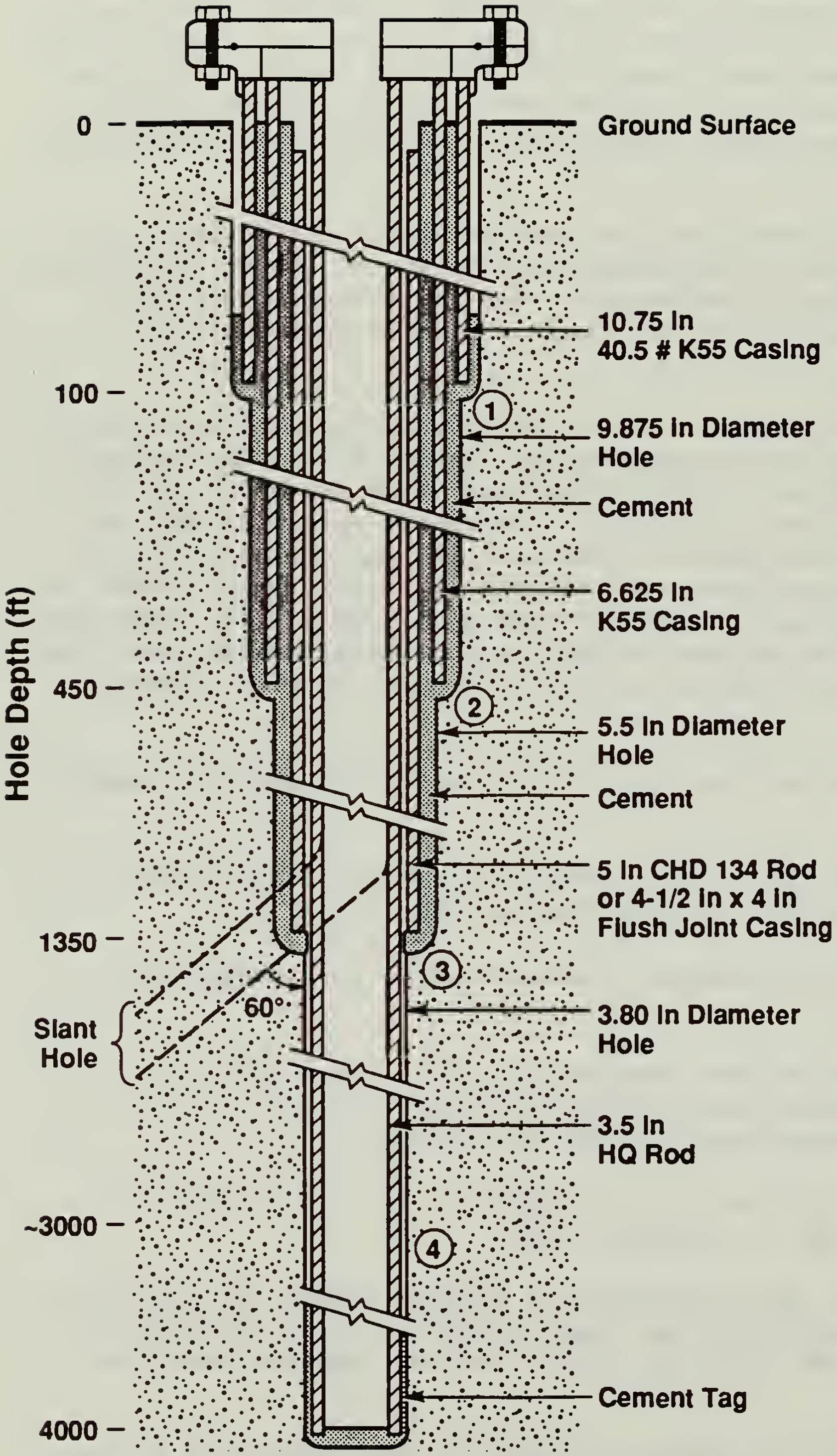
- 6 5/8 in., 24 lb, K55 casing (conductor pipe) to approximately 450 ft (~140 m);

- CHD 134 coring rod as main casing (5 in. o.d., 4 1/2 in. i.d., 14.3 lb/ft) or flush joint casing (4 1/2 in. o.d., 4 in. i.d., 11.3 lb/ft) to approximately 1,350 ft (~400 m);

- HQ coring rod (3 1/2 in. o.d., 3 1/16 in. i.d., 10.6 lb/ft) to approximately 4,000 ft (~1200 m); and

- if problems arise that necessitate a smaller coring rod, continue with NQ coring rod (2 3/4 in. o.d., 2 3/8 in. i.d., 7.7 lb/ft) to approximately 4,000 ft (to be used if HQ rods are set above the target depth).

The coring rod in the slant hole at the main drill site will be HQ to the target depth of 3,300 ft (~1000 m). If problems arise in the slant hole, NQ coring rods will be employed.



Vertical Hole

1. Drive 10.75 in casing (mud riser pipe) until consolidated pumice reached (~100 ft). Cement bottom of Pipe. Set and center 6.62 in casing pipe for bushing.
2. Core CHD 134 (5.3 in hole, 3.3 in core) to ~450 ft. Pull bushing. Ream 9.88 hole to ~450 ft. Set 6.62 in casing (conductor pipe). Cement. Rig up test BOP.
3. Core CHD 134 to 1350 ft. If possible, set HW flush joint casing; if not, leave CHD 134 rods as casing in hole. Cement. Rig test BOB on flush joint casing or CHD 134.
4. Core HQ (3.80 in hole, 2.4 in core) to target depth (~4000 ft). If hole conditions dictate, tack in existing string of HQ rods with cement and reduce to NQ coring rods (3 in hole, 1.8 in core); then proceed to target depth.

Slant Hole (Whipstock Off Vertical Hole)

1. Determine side track depth (1500 ft >depth >800 ft).
2. Pull HQ rods from vertical hole.
3. Set whipstock. Build angle with downhole motor till ~30° is reached.
4. Core HQ to target depth. If hole conditions dictate, tack in existing string of HQ rods with cement and reduce to NQ rods; then proceed to target depth (~3300 ft).

Figure 7-1. Deep Vertical Core Hole Design With Nested Tubulars

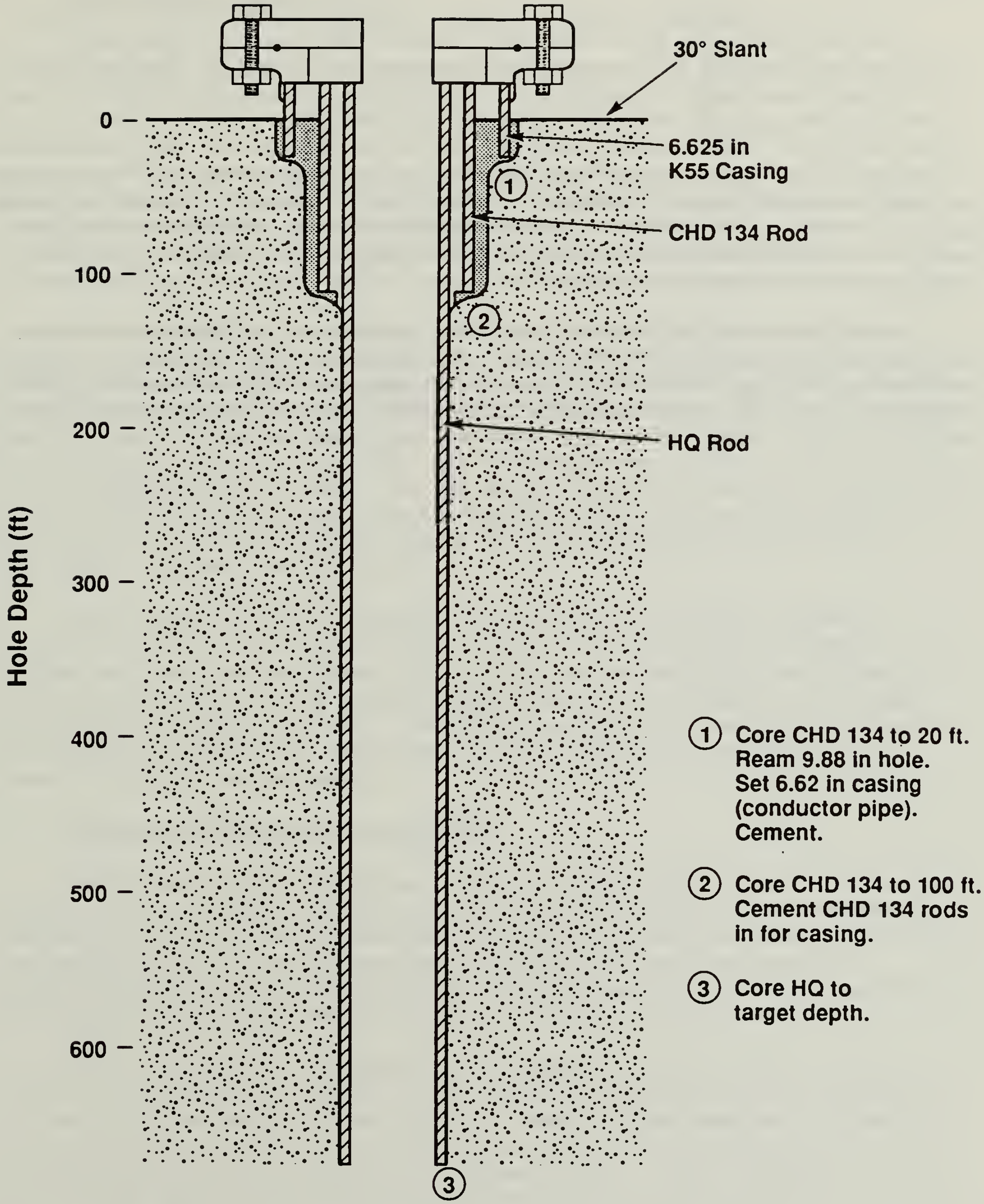


Figure 7-2. Core Hole Design for Ash-Flow Hole

The slant hole at the ash-flow site will have the following tubulars (Figure 7.2):

- 6 7/8 in. (casing, conductor pipe) to approximately 40 ft (~12 m);

- CHD 134 coring rods (casing) to approximately 100 ft (~30 m); and

- HQ coring rods, approximately 650 ft (~200 m).

Blowout prevention equipment will be in accordance with NPS regulations and the State of Alaska Geothermal Regulations. This will include a double gate with both blind and pipe rams and a Hydrill bag. All core holes will have a rotating head assembly. (A Hydrill bag may be sufficient for the slant hole at the ash-flow site.)

The wellhead design will be consistent with State of Alaska Geothermal Drilling Regulations and 36 CFR 9(B). The wellhead will be bolted to the main casing string, will be rated to 2,000 psi, and will have a 4-in. full opening valve. The choke and kill lines below the wellhead can be valved off.

8.0 DRILLING OPERATIONS

8.1 Drill Sites and Equipment

There will be two drill sites. The main drill site will be near Novarupta Dome (Section 4.3) and will be the site of the 4,000-ft vertical hole and the 3,300-ft slant hole that will allow drilling underneath the dome. There will be a secondary, remote ash-flow site, about 5 mi from Novarupta Dome, in the Valley of Ten Thousand Smokes, near the Lethe River (Section 4.3). This will be the site of the less extensive 650-ft slant hole. Both drill sites will be located in actively alluviating basins; therefore, no primary eruption features will be disturbed, and the vegetation in these areas is generally sparse. Equipment will be placed, where possible, on bare pumice, avoiding vegetated or mossy areas.

The main drill site (Figure 4-6) will consist of one coring rig mounted on a drill pad, core lay-down areas, mixing tanks for drilling fluid, storage tanks and a pit for returned drilling fluid, rod and casing racks, spare parts, storage modules for drilling fluid additives, logging module, fuel and water tanks and bladders, generator, pump, utilities area, water storage and overflow pits, and helicopter pad. The drill site will occupy approximately 1 acre. An emergency survival tent will be located at the main drill site because weather may preclude free access between the main drill site and the field camp. A restroom facility will also be located at the main drill site.

The remote drill site (Figure 4-7) will have the same support components as the main drill site, but due to the relatively shallow depth of the core hole at the remote drill site, all supporting facilities at this core hole will be on a much smaller scale. The remote site should occupy approximately 1/2 acre. An emergency survival tent and a restroom facility will also be at the remote site. Neither an overflow nor a reserve pit will be necessary.

8.2 Schedule and Season of Operation

The Katmai project proposes that operations span a nine- to 13-month period, which includes shutdown time during the months of severe winter weather. This will be a single-stage operation (only one main mobilization and demobilization rather than the three-stage operation proposed previously) to reduce intrusion into the park and to reduce the number of helicopter flights necessary to support the operation.

The operation will commence in the summer or early fall of 1992 (Figure 8-1) after the main tourist season is finished and will continue for two to three months. The site will then be shut down and mothballed until spring. Inspections will be conducted at approximately six- to eight-week intervals during this shutdown period. The conductor pipe and main casing operations must be concluded before winter shutdown. The hole will not be left in an open condition. Casing and, possibly, a string of HQ rods will be in place; choke and kill lines, valved off; and the wellhead affixed for the winter.

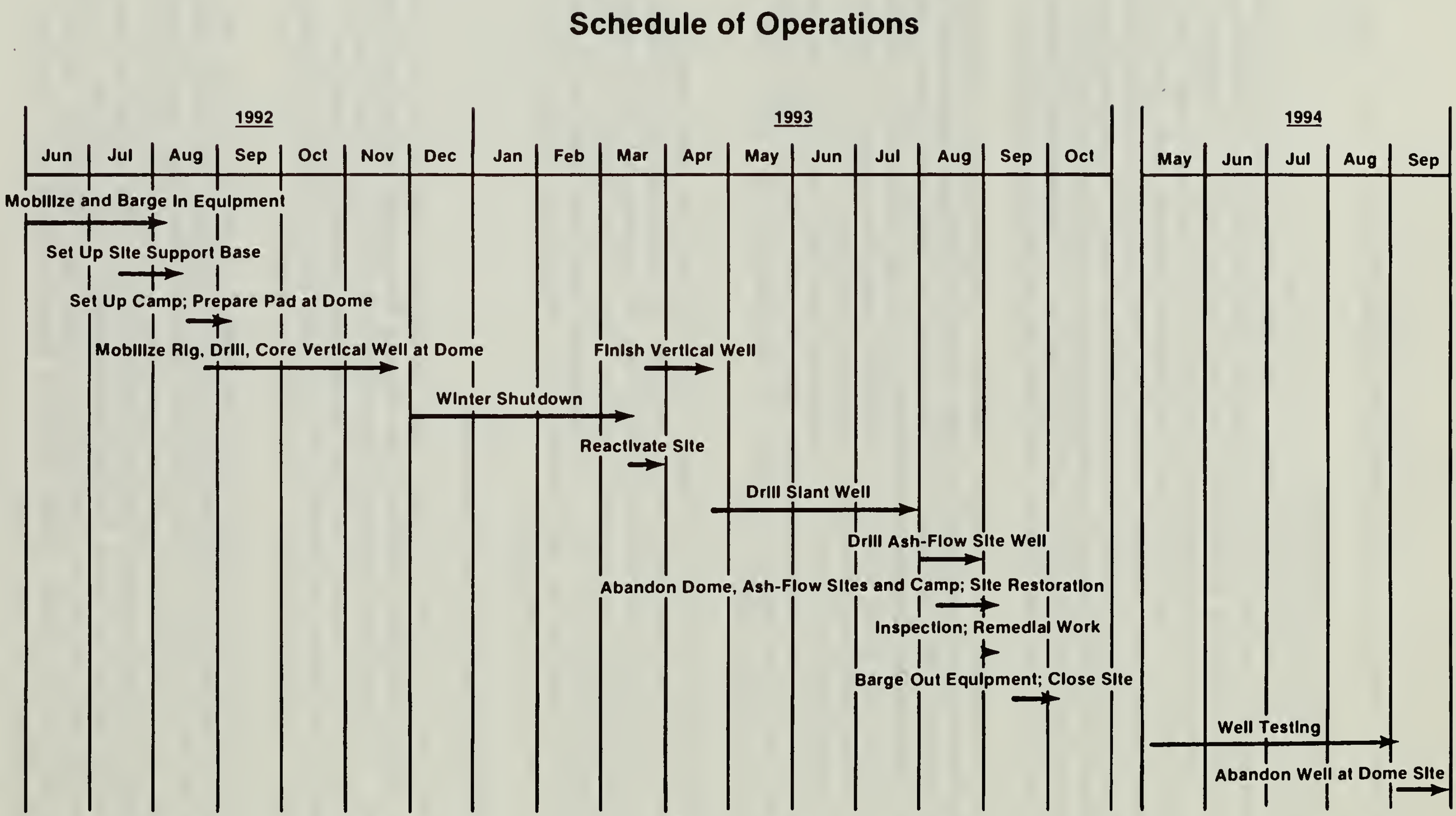


Figure 8-1. Schedule of Operations

Operations will resume in spring as soon as the weather permits, and streams begin flowing and will continue until the three core holes are complete or cold weather in the fall forces the termination of the operation. Additional testing (geophysical logging) and fluid sampling will be requested in the summer of 1994.

8.3 Operational Sequence

The following sequence of operations is planned.

- Barge most of the equipment to the King Salmon Naknek area in the summer of 1992.

- Mobilize the main camp site, run waterlines (Section 8.10), begin excavation of the pits in late July, and pour cement for the drill pad to accommodate both the vertical and slanted deep core holes. An all-terrain balloon-tired vehicle will be used for site construction and to support the operation. It will be used mainly in the flat, unvegetated crater floor at Novarupta Dome, to within a 200-yd radius of the ash-flow hole and for laying and maintaining a 2-in. waterline.

- Mobilize the coring rig at the main site in late July or early August at Novarupta Dome. Commence with drilling and coring of the 4,000-ft vertical core hole on a round-the-clock basis.

- Drive the mud riser through unconsolidated pumice and cement the bottom in place in the consolidated rock.

- Core to the depths of the conductor pipe, ream the hole, and set and cement the conductor pipe. Install and test the temporary blowout prevention equipment.

- Core through the cement in the conductor pipe, core to the casing depth, ream the hole, and set and cement the main casing. Install and test the blowout prevention equipment. At a safe point, after setting the main casing string and, possibly, a sizable length of HQ casing rods, operations will terminate for the winter. This will occur presumably in October or early November.

- Mothball and abandon until spring the equipment and supporting camp after an interim inspection by the NPS and the State of Alaska. The GRDO and, possibly, personnel from the drilling and camp contractors will conduct inspections every 45 to 60 days throughout the winter.

- Begin site reactivation in early April. Commence and conclude the coring of the vertical portion of the deep vertical hole.

- For sidetracking, pull or cut HQ rods to appropriate depth, and set the whipstock between 800 and 1,300 ft. Mill through the casing, build the angle, and establish the slant core hole underneath the dome by continuous coring in the same manner as the vertical hole.

- Complete the slant portion of the deep hole at the main site.

- Cut and pull the uncemented nested portion of the tubulars, fill the hole with fresh water, and affix wellheads for later testing, logging, and fluid sampling.

- Demobilize the rig, move the rig to the remote site, and begin the removal of unneeded equipment from the main site to King Salmon.

- Drill and core the 650-ft slant hole.

- Cut and pull the uncemented portion of the tubulations, plug, and abandon the 650-ft slant hole (Section 8-9).

- Begin the demobilization of the rigs and continue removing the equipment from both of the drill sites.

- Restore both of the drill sites, demobilize the camp, and restore the campsite.

- Perform the final NPS and State of Alaska inspection and the final site restoration, remove the remaining equipment, and abandon the site.

- Return in the summer of 1994, conduct logging and sampling measurements, perform additional NPS and state inspections, and plug and abandon the hole (Section 8.9). Restore site. (A survival tent for no more than five people and a supply tent near the dome would suffice to support this part of the operation, rather than a camp as depicted in Chapter 8.)

8.3.1 Modified Single-Phase Operational Sequence (Fall Operation, Winter Shutdown, Spring Resumption of Operation

Operating in this modified single-phase mode will greatly reduce the number of helicopter flights from that of a three-phase operation (with three mobilizations and demobilizations) proposed in previous documents. Moreover, it will reduce the number of operational days in the park. In the first part of the split operations season during the late summer and early fall, at least the first section of the 4,000-ft vertical hole can be constructed, i.e., the setting of the conductor pipe and main casing string.

Experience gained during the first few months in drilling and operating conditions, and knowledge gained in coordinating the separate aspects of the operation (e.g., drilling, water supply, helicopter, and camp support from King Salmon) will help ensure drilling success at Novarupta Dome. The plan allows time over the winter shutdown to regroup and to address any unusual, difficult, or time-consuming drilling problems prior to beginning the main portion of the operation. This could include questions concerning maintaining a long waterline, lost circulation, or solids and liquids disposal.

Another advantage of this mode of operation is avoiding drilling and coring during the coldest weather months of the year, November through March, when accidents of all types are more likely, and when waterline maintenance is difficult.

Beginning the equipment mobilization by barge in the summer is a convenient time in the King Salmon/Naknek barge season. It is hoped that the operation will conclude prior to the end of the barge season the following year, so that material and equipment can be barged soon after removal from the drill sites. If not, the equipment will be demobilized upon cessation of the project, removed from the park, and stored at King Salmon until sea transport once again becomes available.

8.3.2 Number of Rigs in the Park

Establishing the two deep core holes at the dome in series, rather than in parallel, will provide advance knowledge of the drilling conditions for the second deep core hole at Novarupta Dome. To run two rigs in parallel at the dome could result in the possibility of both rigs encountering identical serious problems simultaneously. Thus, a single rig operation is proposed. This may be more efficient in terms of both fewer total rig days in the park and reduced helicopter support. The hole design, as configured (Figure 7-1), implies a single pad and one (not two) casing strings and also necessitates fewer rig days in the park and reduced helicopter support.

By committing resources for helicoptering one wire line core rig instead of two such rigs, the project can configure a single diamond core rig adequate for the difficult drilling conditions that could be encountered at Novarupta Dome. Having an adequate rig to perform the drilling and coring tasks will ensure a greater degree of success, again, with less time spent in the park. The winter shutdown also allows time to retrofit the rig, if necessary. With only one rig operating at Novarupta Dome, the number of permanent people at the camp will be one-third smaller than if two rigs were operating in parallel.

8.3.3 Mode of Main Mobilization

Carrying out the main mobilization and demobilization by barge from King Salmon is the simplest, safest, most conservative approach, since this part of the operation is difficult logistically due to site remoteness. Support facilities are near, and materials can be stored at King Salmon when sea transportation is not accessible.

8.3.4 Daily Helicopter Support

Supporting the ongoing operation from King Salmon by means of a camp helicopter is the simplest approach to transporting supplies and personnel to the remote field camp. Daily helicopter support will allow convenient air freight shipment from Anchorage and more distant areas, and convenient mobilization for crew changes and itinerant personnel traveling to and from the drill site. Also, operating out of King Salmon is convenient to ancillary operations of the project expeditor and the logging of core from the drill sites.

8.4 Drilling Fluids, Lost Circulation, and Fluid Management

8.4.1 Discussion of Drilling Fluid System and Lost Circulation

Drilling muds are fluids that are used to cool the bit, to lubricate the drill string, and to flush drilling chips from the face of the bit to the surface, thereby keeping the hole "clean." In some operations potable water has been used as a drilling mud. Unfortunately, pure water is a poor lubricant; it has low viscosity, so it does not lift chips readily, and it can cause difficulties if the formation is sloughy or if it contains expanding clays. Thus, drilling fluids are treated with additives that increase its lubricity and viscosity. Often this is accomplished through the use of natural materials such as bentonite clay. However, clays alone can flocculate if the water chemistry is not correct. Thus, materials such as sodium carbonate are added to increase the pH to a range of 9 to 10. In addition, polymers may also be added if the rods begin to chatter in the hole, and greases and corrosion inhibitors are sometimes coated on the drill rods. The design of the mud system often changes as a hole progresses and temperatures increase.

Under normal drilling conditions, muds are pumped down the inside of the drill string. They return to the surface in the annular region between the string and the hole wall. Sometimes this circulation is lost when the hole encounters a permeable or fractured formation. Such lost circulation events are common in volcanic formations. They can cause numerous drilling difficulties. Without circulation it is difficult to cement a casing to the formation because the cement may follow the drilling fluids into the lost circulation zone. Lost circulation can also cause a mixing of fluids in subsurface aquifers. This makes fluid sampling for scientific purposes difficult, since the samples are no longer representative of in situ conditions. Finally, lost circulation can lead to blowout conditions when the hydrostatic head of the fluid in the hole is decreased, allowing high temperature formation fluids to boil. For this reason efforts are always made to maintain circulation when high down-hole temperatures are prevalent. Fluids are then pumped both down the annulus and the coring rods. Plugging materials are also employed.

Remedial action in lost ciculation conditions often consists of pumping plugging materials (Table 8-1) into the permeable portions of a formation. A constraint on such materials is that they pass through the orifices in the bit and in the annular region between the drill string and the hole wall. Diamond core drilling poses a special problem in that this annular gap is small, approximately 1/4 in.

Another solution to a lost circulation problem involves the use of special cements that set quickly so as not to be too disruptive to the drilling schedule. These cements are thin and may be pumped down the drill string. Usually cement treatments are attempted soon after a lost circulation zone is encountered, which means if the lossy zone is thick, several cementing operations may follow in quick succession, each aimed at new loss zones encountered as the hole is advanced. Cementing operations require the presence of special mixing and pumping equipment and trained crews, which is planned (Section 8.7). Cementing operating can generate some solid wastes (Section 8.6.3).

Table 8-1

List of Drilling Fluid Additives and Lost Circulation Materials

Operation	Drilling Fluid Additives
Drill through conductor pipe, low drilling temperatures, <80°C	western sodium bentonite* calcium carbonate sodium, calcium hydroxide
Drill through main casing string, intermediate drilling temperatures 80°C ≤ T ≤ 150°C	liquid anionic polymer for viscosifier and stabilizer* of finer grained sediments
Drill beyond main casing string, high drilling temperatures >150°C	wetting agents-detergent for clear water and low solids drilling fluids* artificial clays** sodium carboxylmethyl-cellulose-filtration control agent* polyanionic celluloses-filtration control agent and viscosifier* polymeric high temperature filtration control agent, acrylamide copolymer* liquid polymeric high temperature thinner* lignosulfate thinners, chromium free* high temperature lubricants, nonhydrocarbon

Lost Circulation Materials

Various fibers, flakes, and granules, shredded paper**
Mica (fine, medium, coarse)
Walnut shells (fine, medium grind)
Sawdust
Rubber tires (medium coarse grind)
Cotton seed hulls

* Tested under shrimp bioassay using EPA protocol Federal Register, Vol. 50, August 26, 1985, pp 3431-3433.
**EPA protocol tests pending.

Sandia National Laboratories has a research effort directed toward solving lost circulation problems in geothermal environments (Loepke, 1990). Encouraging field trials with specially selected lost circulation materials were accomplished on a recent DOE/OBES sponsored well, engineered by GRDO.

8.4.2 Fluid Management and Treatment of Lost Circulation

Drilling fluid additives will primarily consist of degradable polymers or clay type minerals (Table 8-1). Small amounts of rod grease and various lost circulation materials will be utilized. Only nontoxic drilling fluid additives will be used. Lost circulation materials may consist of mica or other small gravel, and other environmentally safe materials (Table 8-1). Material safety data sheets for all drilling fluid additives will be presented as part of the permitting process. If existing information is available in bioassays, such as for shrimp, it will be provided (Table 8.1).

Drilling fluids will be mixed in a 300-gal mixing tank. The fresh drilling fluids may be stored in pits lined with appropriate synthetic materials (or in a portable 1200-gal tank). The lining of a pit will consist of necessary layering to prevent pumice from piercing the lining. If necessary, the pit will be covered in a manner to prevent rainwater from adding to the quantity of the fluid, causing an overflow.

The State of Alaska requirements to maintain circulation and maintain annulus fluid levels close to the surface or 100 ft (30 m), will be followed until casing is set at approximately 1,350 ft (540 m) (Figure 7.1). In the event of extreme lost circulation problems during this phase, the presence of the cementing crew onsite may be necessary. However, once the main (surface) casing string is successfully cemented, a waiver will be requested on the requirement to maintain the 100-ft level of drilling fluid in the annulus, for those conditions where temperature and fluid loss (actual annular fluid level) indicate it is safe to proceed. The request is made for the following reasons:

- No substantial fluid production is planned. (Some small volumes of fluids may be produced, but only for scientific sampling.) This core hole is being permitted as a geothermal well. In reality, however, it is a slim, temperature gradient, scientific core hole. Cementing requirements for tubulars beyond the main casing string are not as critical (Section 8.7).

- Well control during coring is facilitated by the narrow annular dimension of approximately 1/4 in. (~0.6 cm).

- Drilling fluid can be pumped down the annulus as well as the interior of the rods.

- The blowout preventer with the choke and kill lines on the main casing string provides well control and prevents blowouts.

8.5 Returned Drilling Fluids

8.5.1 Fluid Management Plan

A schematic diagram of drilling fluids handling from mixing to disposal is given in Figure 8-2. The following sequence will be employed.

- Fresh water will be sent from a tank or a pit to a 300-gal mixing tank.

- Drilling fluid additives and lost circulation materials, if necessary, will be mixed in the water.

- Drilling fluid will be pumped down coring rods from a lined pit or 1,200 gal mud tank and will lubricate the coring (or reaming) bit and carry cutting to the surface.

- Fluids reaching the surface will pass through a tank/shaleshaker/manifold/centrifuge system where solids will be dewatered by on-line coagulation, deflocculation, and centrifuge (Section 8.6.1) or fluids will be returned directly to the mud tank. Prior to this treatment, returned fluids will be sampled appropriately for heavy metals and other contents of the connate waters of the volcanic hydrothermal system according to CFR 261.24, which lists threshold concentrations of toxic materials.

The water, thus treated, will be returned to a tank or a lined pit for recycling back to the mixing pits.

Water usage will be approximately 5,000 gal/day during reaming out of the hole to set the conductor pipe and to set the main casing string. During coring stages the volume of water used would be approximately 1,000 gal/day. Without manifestations of lost circulation fresh water use could be reduced approximately twofold or more. In addition, recycling and dewatering the solids could decrease fresh water use further, but the hole might still absorb 200 to 300 gallons/day. During periods of complete lost circulation water use could increase to approximately 15,000 gallons/day.

Drilling fluids returning to the surface will be recycled many times. If the drilling fluid can no longer be recycled, it will be sent through additional treatment and filtration stages. This water, unpotable but free of drilling solids and polymer, will be put in a settling pond and allowed to drain into the pumice. If the water has high concentrations of toxic material brought up from the formation that cannot be removed, it will be helicoptered to the Bristol Bay Area for transshipment to an approved disposal site.

On the average approximately 2,000 gal/day of water are used to make drilling fluids; approximately half would be lost to the formation and half must have solids removed and be recycled. As a result of recycling drilling fluids, the volume of drilling fluids sent to a settling pond

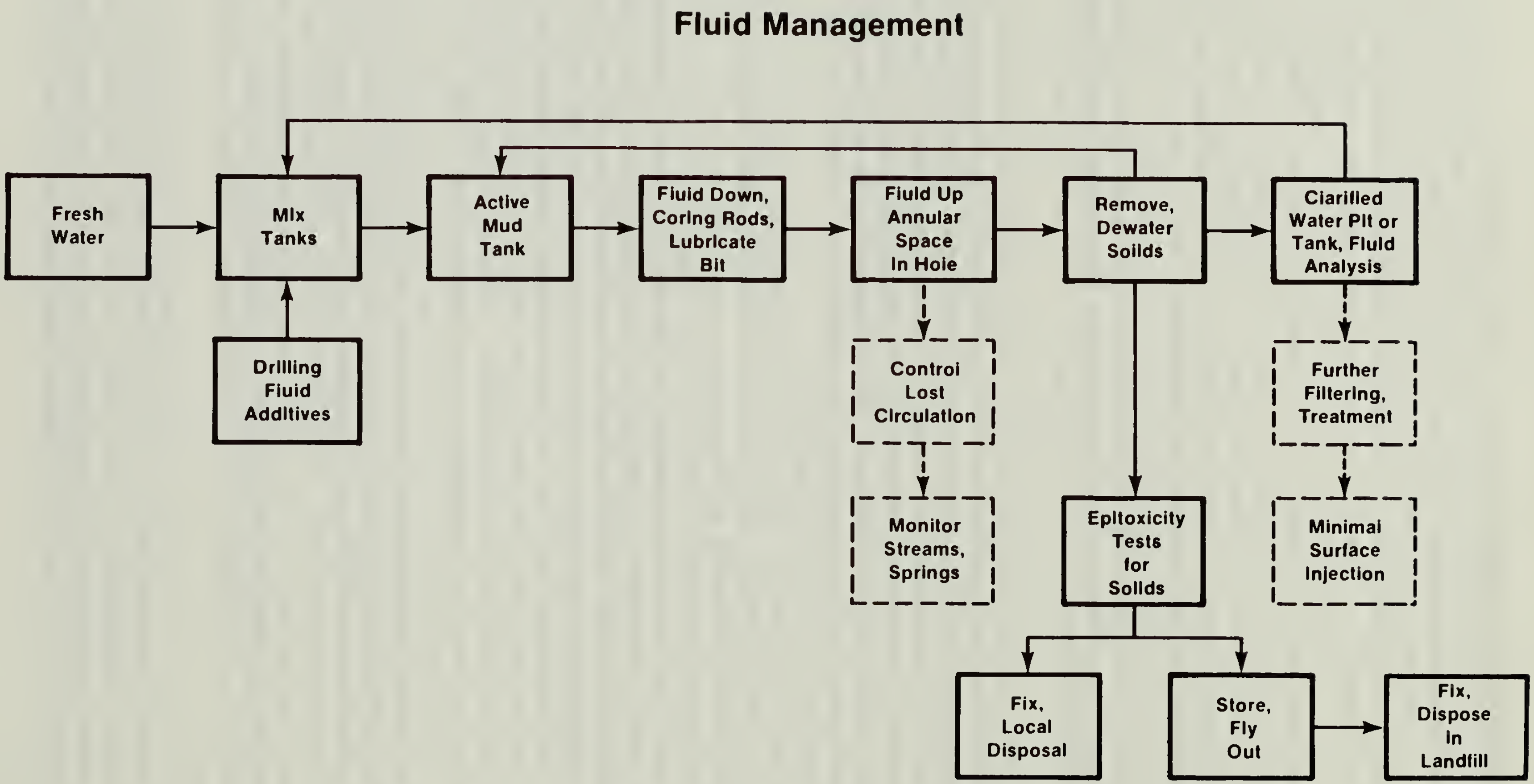


Figure 8-2. Fluid Management Flow Sheet

would be approximately 300 gal/day. The NPS and the other appropropriate agencies will undoubtedly give special review to this issue along with the issue of fluids lost to the formation.

8.5.2 Comments on Monitoring Streams and Springs in the Valley

The proposed settling pond will be close to the drill site and far from nearby streams (Figures 4-1 and 5-2). These ponds will be in a reworked pumice, away from all vegetation. As a precaution, the headwaters of both the Lethe River and Knife Creek will be monitored for any sign of drilling fluids from surface injection or lost circulation. Also, some springs further down in the Valley of Ten Thousand Smokes (Figure 4-1) that are thought to drain the valley will be monitored in a similar fashion (Table 8-2). Monitoring will continue for one to two years after the operation. Because of normally high precipitation in this area and possible subterranean fractures, underground transit of water may be rapid. This is suggested by greater flow of fresh water springs in the Valley of Ten Thousand Smokes during years of greater precipitation.

Table 8-2

Geochemical Monitoring Identified To Date

Fresh drilling fluid
Returned drilling fluid
Cuttings, drilling sludge
Headwaters of the Knife Creek and the Lethe River
Various springs in the Valley of Ten Thousand Smokes

8.6 Drilling and Other Solids From the Operation

8.6.1 Drilling Solids

The volume of drilling solids before dewatering is estimated to be approximately 30 to 70 yd^3. Dewatering the solids will further reduce this volume by approximately threefold. All drilling solids will be removed from the park and fixed in an approved landfill area. Prior to disposition, drilling solids will be tested by means of epitoxicity tests, described in 40 CFR 261.24. If the material contains toxic materials of sufficient concentration, it will be transported offsite for proper disposal.

8.6.2 Nondrilling Solid Waste

Combustible nondrilling solids will be incinerated, if possible. Otherwise, they will be compacted with the noncombustible nondrilling solids and flown out of the park for suitable disposal. Volumes of nondrilling solid waste to be flown out should be <10 yd^3 when compacted.

8.6.3 Solids from the Cementing Operation

Excess cement will be removed from the park.

8.7 Cementing

The bottom of the riser pipe will be cemented into competent formation. The conductor pipe and the main casing string will be cemented throughout their length. If cement is not lifted to the surface, the top of the cement will be measured with temperature logs, and cement will be poured from the top or pumped down a trim line. Casing will be stretched and welded to the casing hanger. High temperature silica flour and spherilite (to lighten cement) will be used in cementing.

It is not planned nor is it technically advisable to cement the interior rods completely to the surface because the interior rods will be cut and removed (Section 8.3). A waiver from the State of Alaska regulations is requested regarding cementing, which requires the cementing of all strings of tubulars. It is proposed that each string of interior rods will be cemented at the bottom over 1/4 to 1/3 of their length. Annular dimensions are small in these slim core holes, and it will be difficult to cement such narrow anulii over their entire length.

Cementing operations will be conducted by a service company with experience in geothermal cementing. Cementing equipment for this operation must be leased or designed jointly with a cementing company to conserve weight, since it will be flown to the drill sites with other equipment during the main mobilization and demobilization. Cementing crews will be flown in and out as needed. It is expected that the needs for the cement crew will diminish when the main casing string is set.

8.8 Hole Measurements Plan

Measurements in core holes will include temperature logging and monitoring, core hole deviation surveys, borehole televiewer measurements with a slim high temperature tool, and, possibly, special logs provided by the Principal Investigators. The vertical hole will be logged before the slant hole is kicked off, since simultaneous access to both vertical and slant holes for measurements would be difficult. Temperature logs and fluid sampling, if appropriate, will be run frequently. The measurements would be run during and after winter shutdown, inspection periods, and prior to site abandonment. Before abandonment of the hole at the dome site, the whipstock will be removed so that a final equilibrium temperature log will be run in the verticle hole.

Principal Investigators and associated scientists will provide a continuous lithology log of the holes from the core. Later, many specialized measurements will be conducted on portions of the core. All data will be made available to permitting and scientific groups.

8.9 Plugging and Abandonment

After the tubulars have been cut and all testing has been completed, fresh water aquifers, if identifiable, will be sealed off, the core hole will be filled with cuttings, and a cement plug will be set ≥25 ft in length. Any protruding pipe will then be cut off and capped below ground level.

8.10 Critical Operational Problems

Critical operational problems associated with drilling include the following:

- Water Supply and Waterlines Waterlines will be required for water supply. The project will obtain water by running 2-in. parallel waterlines from one of two locations along Knife Creek (Section 4.2) to the main drill site, a distance of 2 to 3 mi (~3 to 5 km). Knife Creek is fed by an extensive glacier system and is the most reliable source of water in a 2- to 3-mi range. The water is accessible without climbing down into the deep gullies that are prevalent in the area (Figure 8-3). A short spur line will be used from the main waterline to a recurrent pond near the campsite, outside the tephra ring southeast of the dome (Figure 4-2). Permission will be requested to line this pond, which then could become a reliable secondary, or possibly primary, source of water. (Such a lining is easily removeable.) Bladders or lined ponds will be kept full of water and will be used when the waterline is down for repairs or maintenance. Other possible sources of water include the headwaters of the Lethe River and Mageik Lakes (Figure 4-1). It is not known when Knife Creek starts flowing in the spring.

  The construction of any waterline over the tephra ring will be a difficult, delicate task because much of the soil is soft, and there are areas covered with moss. The route of the entire waterline, especially over the tephra ring, will be chosen carefully to minimize erosion damage and intrusion and may be approved by the NPS. The all-terrain vehicle will be used to lay, maintain, and remove the waterline. As in the completion of the drilling process, the soils under and adjacent to the waterline will be restored carefully.

- The Effect of Loose Pumice The point where the pumice becomes consolidated is not certain, but is estimated at 100 ft (~33 m). Laboratory tests will be performed to determine the weight-bearing

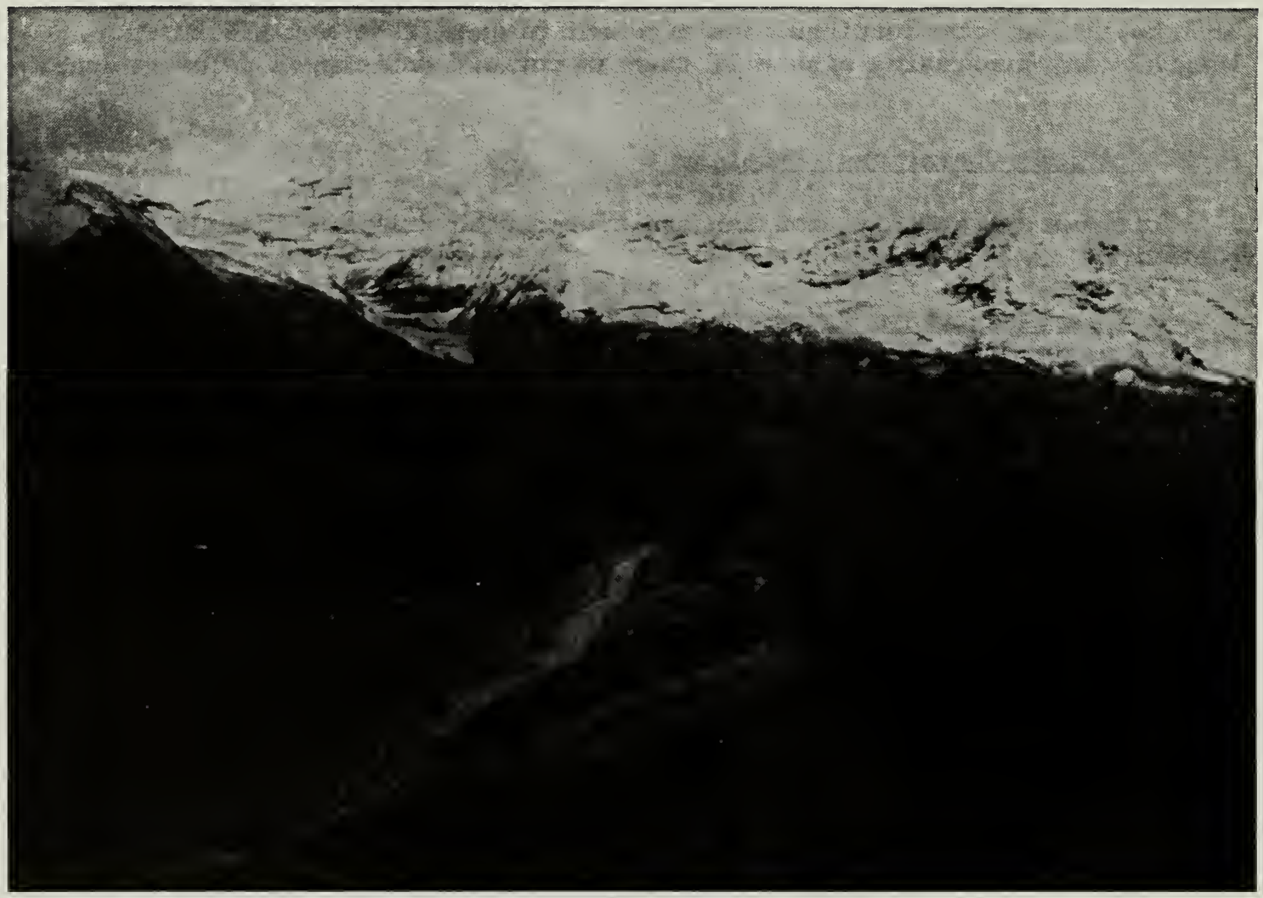


Figure 8-3. Aerial View of Knife Creek Headwaters

capacity of the pumice for sizing the pad. A riser pipe of a diameter larger than the conductor pipe (Chapter 7, Figure 7-1) will be driven by the drill rig until a consolidated formation is reached. The riser and conductor pipe length will be increased according to the amount of unconsolidated pumice. The riser pipe will be cemented as well as possible to the consolidated rock. Care must be taken not to erode the cement drill pad with drilling fluid circulation while working in unconsolidated pumice. The degree of consolidation could impact efforts to maintain circulation while the conductor pipe hole is reamed. Supplementary cementing of the conductor pipe from the top may be necessary.

In a dry period the loose pumice may become a hazard for helicopter operation. Wire meshes or other suitable commercial product will be available to fix the pumice at the landing pad.

- <u>High Core Hole Temperatures and Pressures</u> (Section 10.2.)

- <u>Weather for Helicopter Flying</u> Supplies for the operation are critical, and, therefore, sufficient fuel and materials for 10 days will be stored. Weather conditions in this part of Alaska could interrupt helicopter support to the main site for a significant amount of time.

- <u>Twist Off</u> During drilling and reaming, there is a possibility of twist off. It may be necessary to skid the rig over 2 or 3 ft to start a new core hole.

- <u>Smaller Rig for Shallow Slant Core Hole</u> It may be advisable to bring in a second smaller rig to drill the shallow slant core hole at the remote site. This work could be done either in series or in parallel with the work at the main Novarupta dome site. The work on this well is planned after the two deep core holes at the main dome site are completed.

- <u>Disposal of Liquids and Solids from Drilling</u> The dewatering of solids and the attendant recycling of drilling fluids will greatly mitigate the disposal problem of returned drilling fluids by reducing the volume of excess water. Most of the drilling fluid polymer should be removed by this process. On-line dewatering of solids is not new, but it is not routinely attempted in remote areas. This processing will also reduce the amount of drilling solid volume and render the material in a better form for fixation.

  The drilling fluid consists of clay and polymer. The polymer will be used (and largely degraded) at higher temperatures. All the material is nontoxic. Furthermore, the total daily production of salts by drilling activities is small compared to the salts generated by the leaching process and the volcanic thermal springs in the Valley of Ten Thousand Smokes, which, in turn, are carried by Knife Creek and the Lethe River systems (Table 4-1).

- <u>Hydrologic Effects</u> The hydrologic system of the Valley of Ten Thousand Smokes and the hydrothermal system associated with the volcanoes has been under continuous study for a decade, and additional data will be taken during the 1990 field season. Monitoring of nearby streams and designated springs during and after operations will help ensure that effects of drilling are not manifested in waters nearby the site.

- Lost Circulation Because of narrow annular volumes between the wall of the hole and coring rods, there are limitations on the materials that can be employed to retard fluid loss. Success in retarding fluid loss with special lost circulation materials was attained in recent diamond coring operations, but cementing equipment will be maintained onsite to be used when necessary.

9.0 SAFETY

9.1 General Policy

The GRDO will be responsible for the overall safety of the operation. Levels of responsibility will be established between the GRDO and all parties in the field.

A site-specific SOP will be written for the Katmai project covering potential hazards, responsibilities, and personnel assignments among the groups in the field; personnel safety equipment; emergency preparedness; and professional conduct. Generic safety plans for geotechnical field sites have been provided by the GRDO that include hydrogen sulfide safety and situations where numerous agencies are working together in the field. These safety plans and the safety philosophy for remote geotechnical sites (Wemple, R. P., 1989) are included in Appendix A.

9.2 Medical Services and First Aid

Arrangements will be made to transport injured or ill personnel by the camp helicopter to the clinic in Naknek, Alaska, which is the nearest appropriate medical facility. If necessary, the patient can be flown to Anchorage for further medical treatment after being treated and stabilized at the clinic. Due to the remote location of the project, an emergency medical technican, possibly a part of the crew, will be present onsite. Table 9-1 provides a list of associated planning activities for medical emergencies that must be addressed in the project's SOP. First-aid training will be given to all field personnel.

9.3 Survival Tent

All crew members will be made familiar with the survival tent facilities for possible situations when weather prevents access between drill sites and the main camp.

9.4 Communications

Because of the remote location of the site, elaborate communications will be established:

- commercial or portable satellite radio-telephone communications linking both drill sites to the Anchorage area and beyond;

- commercial or portable satellite telephone service from the site support area in King Salmon through the Bristol Bay Telephone Cooperative;

- a radio net between the main drill site, the remote drill site (during the few weeks that it is active), the camp, and the site support facility at King Salmon;

- a radio net between the main drill site and the USGS in Anchorage;

- access to the NPS radio net will be requested for the conduct of business and emergencies;
- an emergency communication procedure will be set up between the drill sites and the clinic at Naknek; and
- ground radios will be available at each drill site and the campsite to talk to support helicopters while they are in flight.

Table 9-1

Planning Activities Necessary for Medical Emergencies/Illness

---

Qualifications/Credentials Appropriate for Medical Provider at Katmai Drill Site

Advanced Cardiac Life Support (ACLS) and Advanced Trauma Life Support (ATLS) may be appropriate

Alaska Licensure

Midlevel medical provider or paramedic rating with protocols in place to render appropriate remote site care for injury or illness

Certified with Self-Contained Breathing Apparatus Experience in wilderness emergency medicine

Planning Activities to Prepare for Medical Emergencies

Decisions on equipment
- Communications
- Stabilization
- Cardiac monitoring
- Bandaging supplies/irrigations supplies/other supplies

Specific Triage/stabilization/treatment area

Relationship established with EMTs in Bristol Bay area and with Anchorage Emergency Physicians and/or Family Practice Physician

Helicopter transport investigated under various patient conditions

Decisions on medications to keep onsite.

Appropriate licenses/certification

10.0 HAZARDS, HAZARD MITIGATION, ACCIDENT CONTAINMENT, ACCIDENT PREVENTION, AND STORAGE PLANS FOR CRITICAL ISSUES

10.1 Policy for Emergency Preparedness

It will be the policy of the fielding agencies to develop and maintain a state of emergency preparedness for the following:

- the health and safety of personnel;
- the protection of the environment;
- the protection of equipment and property;
- the necessary but scaled-down operations under emergency conditions; and
- the resumption of normal operations as rapidly and economically as possible.

10.2 Anticipated Core Hole Conditions, Temperatures, and Pressure

The drilling conditions at Novarupta Dome are poorly known because drilling into a similar large vent has never been attempted, and the system is so young that only the uppermost portion is exposed. Temperatures greater than 650°F (300°C) may be encountered. (Drilling fluid circulating must be maintained at high temperatures.) These temperatures are near the limit of drilling technology. There are hot spots on the surface of the Turtle (Figure 4-2), but none in the immediate vicinity of the dome. A loading chamber, similar to a lubricator, will be used for the wire line coring when temperatures exceed 175°F (80°C). Down-hole temperatures will be measured with temperature tabs or thermometers during every coring run.

Pressures in the vent are not known. Due to the fractured nature of volcanic vents, hydrostatic pressures can be anticipated. These pressures can be controlled. Pressure control will be accomplished with the blowout prevention system (Chapter 7); the mud pump, which could add approximately 1,000 psi to a column of fluid; choke lines; kill lines to pump fluid down the coring rods and annulus simultaneously; or weighting of the drilling fluid. There will be automatic monitoring of volume and temperature of inlet and outlet drilling fluid flow, the inlet pressure, and the differential between inlet and outlet fluid flow (Table 10-1).

In the unlikely occurrence that down-hole pressure needs to be relieved, the flow would be sent through a blooey line to a mud pit or a larger overflow pit, constructed to relieve down-hole pressure. (The overflow pit could be used to store fresh water for drilling under normal circumstances.)

The quality and experience of the drilling crew are the most important factors in avoiding or mitigating drilling-induced accidents. The GRDO demands that any firm selected shall provide qualified personnel that are experienced in geothermal coring operations. The selection of a drilling contractor is a deliberate and painstaking process for the GRDO. Quality

Table 10-1

Electronic Monitoring Requirements Identified to Date

Drilling Parameters

Inlet fluid: volume, temperature, pressure
Outlet fluid: volume and temperature
Net fluid: volume (inlet-outlet volumes)

Fuels and Sensitive Liquids

Tank levels
Fluid in mixing tanks and pits

Hydrogen Sulfide

Cellar
Rig floor
Mud pits
Offices
Camp
Monitoring module

---

and experience of the crew and equipment to be committed are key factors in this selection process. The government-controlled contracting regulations followed by the GRDO have sufficient flexibility to assure selection of a qualified company with experienced personnel.

10.3 Plan for Prevention and Containment of Fluid Spills

Liquid drilling fluid additives will be stored in lined metal barrels in a covered area surrounded by a berm. The fresh drilling fluid will be mixed and kept in a portable mixing tank or other suitable tank. Used drilling fluids may be stored in a lined pit after processing. Fuels will be stored in bladders or barrels and will also be kept in an area that is lined and surrounded by berm. The berm will be sufficient height to contain the entire volume of liquid. The inside of the berm may be recessed 1 to 2 ft below the surface of the pumice. The fluid level in all mud pits and mixing tanks will be monitored. Solid drilling fluid additive will be kept in storage modules out of the elements. Dewatered drilling solids will be stored in a covered area and surrounded by berm, if necessary. Bermed areas for fuels and other sensitive liquid will be inspected on each shift. Site personnel will be trained in the spill prevention of fuels or sensitive liquids. Detailed plans for spill prevention, mitigation, and cleanup are in Appendix B. These plans will also be included in the site-specific SOP.

The spill prevention, mitigation, and cleanup plans require familiarizing project personnel with regulations covering spills of fuel or hazardous materials, and training in both spill prevention and cleanup operations. Absorbent pads will be available for daily use on the drill site. Appropriate types of pads, sorbent booms, and a skimmer will be available for emergencies involving spills of diesel fuel or other fuels, drilling fluids or their liquid additives, or other sensitive liquids. A contingency contract will be executed with an Alaska firm dealing in spill control. Methods of handling the used drilling fluids are discussed in Section 8.4 and Section 8.5.

10.4 Hydrogen Sulfide Monitoring

A monitoring system will be constructed to monitor hydrogen sulfide concentrations (Table 10-1). Detectors will be set up in strategic locations in accordance with the hydrogen sulfide safety plan to be included in the SOP. The detectors will monitor locations such as the rig floor, mud pits, cellar, office areas, and camp. The field crew will be trained in the use of emergency portable and fixed breathing apparatus, which will be available in strategic places. The portable breathing apparatus will be used for rescue and evacuation. The fixed breathing apparatus on the rig floor would allow the drilling crew to work for a limited amount of time to either secure the well or carry out procedures designed to abate hydrogen sulfide production.

11.0 HELICOPTER OPERATIONS

Due to the remote location of the project, transport of personnel and materials must be accomplished by helicopter. Under ideal conditions two types of helicopters will be employed in support of this project: larger freight helicopters would be used primarily for mobilization and demobilization operations, and a smaller helicopter would be employed to support the day-to-day operations at the drill site. Larger freight helicopters will be sought to minimize the number of mobilization/demobilization flights.

11.1 Helicopter Safety

The Katmai project will conform with DOE/Albuquerque Operations Office Order 5480 1.3, "Aviation Operations and Safety." The appropriate regulations in the Department of Interior Aviation Manual will be followed. Alaska helicopter firms will be sought because of the unique flying conditions in the Alaska bush.

Project helicopter safety and emergency procedures will be prepared by project personnel, the helicopter firm under contract, and DOI/DOE flight safety officers. All project personnel who work at the drill sites will learn these procedures prior to commencing the operation.

11.2 Routes

Helicopter routes will be chosen in discussion with the pilots, NPS, State of Alaska Fish and Game personnel, and other appropriate permitting agencies.

11.3 Number of Flights

The number of mobilization and demobilization flights will depend on the helicopter equipment available in Alaska at the time of the project. The larger freight helicopters can carry loads in the range of 6,000 to 8,000 lb, whereas smaller helicopters commonly used for support of drilling operations have freight-carrying capacity of approximately 1,000 lb or more. The smaller the helicopter used in the mobilization/demobilization, the more drilling and cementing equipment must be disassembled to be transported. For the proposed single mobilization, the weight of the material that must be lifted is approximately 800,000 lb. An estimate of mobilization and demobilization flights is given in Table 11-1 for either the availability of a helicopter with a 7,000 or a 3,000 lb freight-carrying capability. With only one large mobilization and demobilization rather than a multiphased operation, it may be economical to mobilize a large freight helicopter from Seattle or Portland if none are available in Alaska.

Table 11-1 also gives the estimated number of camp helicopter flights. The camp helicopter will average four to six hours of flight time per day, resulting in at least two trips between the campsite and King Salmon during the course of the project.

Table 11-1

Estimated Number of Helicopter Flights

Helicopter Freight Capacity	Approximate Number of Flights
Number of Round Trips for Mobilization/Demobilization*	
7,000 lb	110
3,000 lb	260
Number of Round Trips by Camp Helicopter**	
3,000 lb	560

* This was derived by estimating 8×10^5 lb of freight and 14 months actual loss in sling efficiency.

**Estimating about nine months of actual operations.

12.0 FIELD CAMP OPERATIONS

12.1 Contents and Location of the Camp

The field camp supporting the main drill site at Novarupta Dome will consist of a tent area with arctic walkways, kitchen, dining and lounge area, shower, bath, laundry areas, storage and utilities area, limited office and medical area, fuel and water tanks or bladders, and helicopter pad. Its size will be approximately 1.5 acres (Section 4.4). The number of permanent camp personnel will be minimized; only essential personnel will be onsite. However, the number of personnel present must always be adequate for safe response to drilling or environmental problems. The camp would have sufficent space for visitors in case of severe weather.

Because of safety and environmental considerations, the camp will be in a bare pumice area, southeast of Novarupta Dome, and outside of the tephra ring. This will greatly reduce the density of activity at the dome site. The campsite can be placed to the north (right) or south (left) of the pond in Figure 12-1. The surface of the proposed camp area is covered with only reworked pumice, not moss or other vegetation. This surface will easily be restored at the end of the operation. The area has some degree of shelter and is sufficiently far from the drill site with respect to hydrogen sulfide safety.

12.2 Access Between Drill Sites and Main Camp

A fixed path between the campsite and Novarupta Dome will be designated. It may be necessary to take special precautions on the steep portions of the path across the tephra ring to prevent erosion and to ensure personnel safety. These precautions may include laying boards and erecting a railing arrangement. Personnel will travel back and forth from the camp to the drill site at all hours, often in severe weather. This path will parallel and be adjacent to the waterline running over the tephra ring so that maintenance of the line may be accomplished from this path. After the operation any material laid to protect against wear and erosion or for safety will be removed and the pathway restored.

A minimum survival tent will be placed close to the main drill site. Weather periods can be severe enough to preclude ready access between the campsite and the drill site, and it may be necessary for personnel visiting the drill site to remain there during bad weather periods.

The operations at the remote ash-fall drill site in the valley will be supported by the camp near the main site. Crew changes and supplies for this site will be accomplished by helicopter. A minimum survival tent will also be placed at the remote ash-fall drill site. Weather periods can be severe enough to preclude ready access between the main campsite and the remote site; thus, the crew at the remote site may need to use the survival tent to obtain food and shelter.

12.3 Permanent and Itinerant Occupants of the Camp

The permanent camp personnel at the main site (Table 12-1) will consist of a drilling foreman, six drilling crew members, one welder/mechanic, two

Figure 12-1. Vicinity of Campsite

Table 12-1

Listing of Personnel and Types of Itinerant Occupants at the Field Camp

---

Field Personnel

Principal Investigator
GRDO Site Manager
USGS Site Manager (may also be the Principal Investigator)
Drilling foreman
6 drilling crew (2 three-person crews)
Drill rig mechanic/welder
2 watermen/helpers
3 camp personnel
Park Ranger
Helicopter pilot
Helicopter mechanic
Emergency medical technician (EMT) (may be part of crew)
Chemist

Itinerant Operating Personnel

2 to 3 cement crew
Contract inspectors
Special crafts
Inspectors from permitting agencies and environmental firms under contract

Other Itinerant

Science visitors (National, International)
Students
Visiting park tourists
Management from funding agencies

---

watermen, three camp personnel, one GRDO and one USGS Site Manager, and one Principal Investigator (who may also be the USGS Site Manager). It is anticipated that a Park Ranger will be in residence. The helicopter pilot and mechanic would remain at the field camp as operations and safety requirements dictate. At the camp there will also be an emergency medical technician that could be a member of the crew. Safety requirements may necessitate the presence of a more highly trained medical technician. A resident chemist will be necessary to treat returned drilling fluids.

Provisions will be made for intinerant personnel (Table 12-1) such as the cementing crew, special technicians on short-term bases, inspectors from the NPS and other permitting agencies, and contract inspectors from independent environmental companies. Also, visiting scientists, students, and occasional official visitors from the funding agencies may be present. There could be additional people in camp during crew change time, but this would normally last only for a couple of hours. It is anticipated that visits by scientists, funding agencies, etc. would consist of day tours only.

12.4 Camp Waste

A drain field will be constructed for the grey water in the loose, reworked pumice area near the camp. Fecal material, paper, and wood will be incinerated. Other solid materials will be compacted and flown out to an approved storage area.

12.5 Park Access for Camp Personnel

Access to parts of the park other than for project operations will be controlled by the NPS. Off-duty personnel will be subject to normal NPS permitting procedures for recreational trips within the park. The resident Park Ranger will manage encounters with animals.

13.0 SITE SUPPORT FROM THE KING SALMON/NAKNEK AREA

13.1 Mobilization by Barge and Dock Facilities

Much of the material for the operation's main mobilization could come from the Seattle area, Canada, and the Anchorage area. Materials will be shipped in a barge or other suitable vessel to the King Salmon/Naknek area. Arrangements can be made for docking facilities in the King Salmon/Naknek area either from the Bristol Bay Borough or from one of the local fishing camps. Scheduled barge service to the King Salmon/Naknek area is usually between the middle of May through the middle of October. A chartered barge or other vessel may operate in this area outside of these dates, depending on the weather.

13.2 Support Base at King Salmon

Support facilities will be set up in King Salmon to provide logistical support for the operation; some facilities will be located near the airport to facilitate use of the helicopters. For support, a storage area, forklifts, and other vehicles will be available as well as personnel to help sling equipment for the helicopter. Long-term storage will be arranged.

A technical expeditor will support the drilling and camp operations from this facility in King Salmon. It is possible that a relief drilling crew will be in residence at the facility.

The actual detailed geologic logging of the core will be done from the support facilities in the King Salmon area, but the wiping, marking, and initial inspection of the core must be done in the field by the Co-Principal Investigator in the field. The core will be stored as necessary and shipped from the King Salmon facility after core logging and prior to the close of the operation.

14.0 POLICIES FOR OPERATING STANDARDS, ENVIRONMENTAL PROTECTION, AND SITE RECLAMATION; BENEFITS TO THE PARK

14.1 Statement of Operating Standards

The project will conform to all regulations required for the issuance of permits to conduct this operation. These include 36 CFR 9 and any orders issued by the Director of the Alaska Regional Office, the Superintendent of Katmai National Park, or their agents. The project will conform to the appropriate Geothermal Regulations from Chapter 87 of the Alaska Register, as well as all other federal, state, and local laws and regulations. Any exceptions will be implemented only after specific requests for variances have been made and permission from the appropriate permitting agency has been received. Standards of the American Petroleum Institute will be adhered to where they are applicable to this mode of continuous coring. If conflicting directives arise from different permitting agencies, they will be resolved as quickly as possible. The operation will be conducted in a professional and safe manner. Professional standards will be upheld.

14.2 Policy for Environmental Protection

The project will attempt to prevent or mitigate any damage to the environment that can be found by the project group, the NPS, the State of Alaska, other permitting agencies, or the public during the operation. The project cannot guarantee that there will be no undiscovered damage to the environment anywhere in the park from the operation. However, should any such damage be found and reasonably be attributed to this drilling project after plugging and abandonment, the good faith of the sponsoring ICG agencies dictates that a corrective effort shall be mounted.

The drill site and the campsite will be kept clean, and each aspect of the daily operation will be designed to minimize environmental impact. The campsite and drill site will be policed by designated individuals for loose debris, integrity of tanks and other storage areas, or for other factors which might influence the environment. Specific steps taken to protect the environment are listed in Chapter 10 and Section 14.4.

14.3 Policy for Site Restoration

All surface structures, equipment, remaining supplies, other manmade articles, and debris will be removed. (The possible exception is an appropriate segment of the camp that, at the discretion and request of the NPS, could readily be converted to a shelter.) The core holes will be plugged and capped below the surface and abandoned according to NPS and State of Alaska requirements. No hardware will remain at/or above the surface.

The cement drilling pad will be removed. Dikes and berms will be removed, and these areas will be restored and regraded to their previous contours. The paths used by the vehicle will be regraded. Pit liners will be removed; the pits will be regraded. The waterline will be removed, the surface on the path between the camp and the main drill site and the surface adjacent to and along where the waterline lies will be restored as well as possible. Original surface contours will be restored, and the banked surface material will be reapplied to the surface if possible. Photographs of the drill sites taken prior to construction will be used as a guide for the reclamation work. Reclamation costs will be included in the overall core hole and site abandonment costs.

14.4 Steps for Environmental Preservation

Every aspect of the daily operation will be designed to minimize impact on the environment. The following reaffirms and summarizes measures to be taken to mitigate any impact on the environment.

- Helicopter flight routes will be planned with the NPS and the State of Alaska Fish and Game Department and the helicopter company under contract.

- Photographs will be taken before site excavation to assist in onsite restoration. A final set of pictures will also be taken after site restoration.

- Excavation will be limited mainly to drill pads and pits with minor excavation in the area of the camp.

- Top soil material will be banked for later use, if practical.

- Access to the camp from the drill site will be restricted to a single pathway. Attempts will be made to avoid sensitive areas, such as areas where vegetation is trying to reestablish itself and areas covered with moss.

- A policy for project personnel access to the park for recreational purposes will be planned with the NPS prior to the start of the operation.

- A multilayered array of plastic-like materials is planned for the lining of all pits, with one or more layers of heavy, tough material between the excavated pumice and the main liner. Pit levels will be monitored.

- Storage areas for sensitive fluids will be in lined, bermed, and covered. This area will be inspected for leakage on each shift.

- Solid drilling fluid additives and dewatered solids will be stored in a covered area.

- A balloon-tired vehicle will be used to move equipment and materials and will be confined to the drill sites and the placement and maintaining of the waterline. The vehicle will be configured and used as a combination forklift, crane, and bulldozer. This vehicle is needed because the project will utilize heavier components than those ordinarily used in diamond coring operations. Use of such a vehicle would expedite the operation, requiring less time in the park, and would provide a means to effectively restore the area at the end of the operation.

- Arrangements will be made with a local municipality to place solid and liquid wastes, if any, in an approved waste site.

- A drain field will be constructed for grey water from the camp. Fecal material will be incinerated.

- All materials or wastes will be suitably packaged in proper containers for helicopter transport and waste site disposal. A compactor will be onsite to compact solid trash, as applicable.

- Absorbant pads will be put around machinery, valves, and other areas where fuel may seep.

- Project personnel will be trained in spill prevention and control.

- Materials to combat a spill will be stored at the drill site and at the site support area in King Salmon.

- Independent contractors will inspect the operation for environmental compliance and for fuel, liquid, and solids handling. The independent contractor will also make site checks at a six-month and one-year interval after site abandonment.

- A contingency contract with an Alaska firm, established to mitigate, control, and clean up spills, will be in place in the event that there is a spill of sensitive liquids that requires outside assistance to remedy.

- Solid drilling fluid additives will be stored out of the elements.

- Overflow pits will be constructed in the unlikely event of a blowout.

- Returned drilling fluids and solids will be sampled for analyses.

- Nearby streams, springs, and rivers will be monitored for contamination.

- Funds will be reserved to combat spills and mitigate any damage after the final inspection and the site abandonment.

- Solids will be removed from drilling fluids, and the fluids will be recycled. This will minimize the amount of returned drilling fluids and the volume of drilling wastes.

- Any project related debris detected during the operational or post-operational inspection phases will be removed from the park. Existing debris, unrelated to the project, will be removed whenever possible, and attendant damge remediated.

14.5 Benefits to the Park

The enabling legislation that placed the Katmai region under the protection of the NPS stated that the Valley of Ten Thousand Smokes was to be the object of the scientific study of volcanic processes. The present proposal is reponsive to that goal and employs the best, coordinated, interdisciplinary approach that current knowledge and technology permit. Because the 1912 eruption was the central event that led to establishment of Katmai National Park, the greatly improved understanding of the eruption that this project will provide will enrich the experience of visitors to the Valley. In particular, the third dimension of knowledge that is now lacking, but which drilling will provide, will convey a broadened view that the phenomena observed at the surface, however spectacular, are only an expression of the powerful forces at work beneath the Earth's surface. Annually updated geological displays and nontechnical literature will be made available at the Visitor Center, Overlook Cabin, and in the valley, revealing findings of this project. The project will develop this educational effort under the direction of Katmai National Park's interpretive program.

Scientific results from the project will also contribute to the management of the park by the NPS. The region is volcanically active and is subject to eruptions of the most dangerous type. Future eruptions are certain, and future eruptions of the Novarupta vent at the head of the valley are probable. Thorough knowledge of past eruptions, of which the 1912 event is by far the outstanding occurrence, is the best guide to future decisions concerning closure of areas when new activity threatens.

As mentioned above, the project will support NPS needs, when possible, by removal of existing debris, particularly from the Baked Mountain Hut area, and, if desired, by leaving a portion of the drilling support facilities as a permanent shelter for park visitors and for patrol functions. The intent will be to leave the park in better condition than when the project began, through remediation of previous damage and scrupulous avoidance of new damage.

15.0 DESCRIPTION OF CULTURAL RESOURCES, SOCIAL AND ECONOMIC ENVIRONMENT, AND ENVIRONMENTAL CONSEQUENCES

All work will occur on deposits from the 1912 eruption. There is no soil or forest in the area, although sparse grasses, mosses, and small plants and trees are returning since the eruption. These plants live mainly, but not exclusively, in thermal areas around Novarupta Dome, and in other sheltered areas. Snow buntings reside in the area around the dome in the summer. Small burrowing animals live in some of these thermal areas and on Novarupta Dome. Efforts will be made to avoid the vegetated areas and obvious plant and animal life. Foot traffic or other project-related activity will be minimized around and over these areas.

Numerous soft surfaces containing lichens and moss are present in the vent region and on the outer slopes of the tephra ring (Chapter 4). Efforts will be made to avoid them when possible. Where activity will occur on these areas, temporary wooden planks or outdoor carpet will be set up. If the moss must be removed, attempts will be made to bank it for reapplication later, if feasible.

The sites proposed for the drill sites and camp have mainly bare pumice ground that may be reworked by wind and water (Section 4.1). These sites have minimal to no vegetation. Efforts were made to avoid vegetated areas in site selection.

Bears and possibly caribou may pass through this area, but their incursions are rare. Waterfowl do not inhabit this area.

The primary source of noise in the area is wind. During fair weather in summer, there are some sightseeing flights by light aircraft. Several of the neighboring Aleutian Range vents are sources of air pollution. When the wind is from the southeast, a strong sulfur smell is evident in the Novarupta vent region from the recently active vent of Trident Volcano.

The climate is cool and wet, with limited diurnal variation. It is subject to fog and very strong winds.

Much of the water flow is subsurface, through the porous tephra deposits of the 1912 eruption. Water sampling and analyses suggest surface water draining large areas of pumice is acidic. When the Lethe River flows in summer and fall, it is heavily laden with silt, ash, and pumice.

Any evidence of cultural activities prior to the 1912 eruption is buried under a substantial amount of tephra, estimated to be hundreds of feet thick in the vicinity of the operation.

A description of cultural resources, and social, economic, and environmental consequences will be detailed in the EIS.

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APPENDIX A

GENERIC OPERATING PROCEDURES AND SAFETY PHILOSOPHY AT GEOTECHNICAL SITES

GENERAL SOP FOR ORGANIZATION 6250 GEO ENERGY TECHNICAL FIELD WORK

BACKGROUND

The Geo Energy Technology Department (6250) at Sandia National Laboratories is involved in remote-site drilling and/or experimental operations. In 1987, the Geothermal Research Division of the Department recognized the need for a general set of Safe Operating Procedures (SOPs) that could be applied to a variety of projects. A general set was developed that could then be supplemented with site/project-specific SOPs as addenda. Other documents such as emergency action summaries, maps for evacuation, and National Park and State regulations can also become addenda.

Operations at geotechnical sites may involve the following:

- powerful machinery that rotate and lift heavy hardware overhead,
- considerable electrical power,
- steam/hot fluids vented from the geologic formation,
- hot surfaces on pipe, down-hole tools, and other hardware periodically brought to the surface,
- lethal concentrations of formation gases,
- simultaneous onsite operations by personnel from several companies/national labs/universities,
- shared equipment and various well logging techniques that may require high voltages and explosives, and
- 24-hour per day operation (usually two 12-hour shifts) for several months.

The potential for accidents and serious injury is present. General SOPs have been prepared by the Geothermal Research Division for the following: General Field Work, H_2S Monitoring and Emergencies, Shared Operations, and Access Control.

Preparation of an SOP package forces the project personnel to consider the potential hazards, the consequences of unsafe practices, emergency procedures and to develop a "safety consciousness" that can reduce the risk of injury.

BASIC PHILOSOPHY OF SAFETY

Several basic tenets drive the safety philosophy:

- Safety is a basic ingredient of the project, not just a corporate requirement.

- Remote locations are "special cases" that require a high level of safety and emergency preparedness awareness and planning.

- Safety professionals should be involved in the initial planning and become contributing members of the project team.

- Project personnel will embrace the safety plans if the plans are reasonable and flexible and if safety is promoted as a logical concern for the common welfare.

- Perceptions of safety issues by project personnel may vary due to personalities, technical disciplines, and experience bases. Perceptions are real and must be dealt with if they are counter to good safety practice.

- A composite project group (SNLA, other labs, contractors, universities, etc.) at a remote site requires close coordination on safety issues. One institution must be designated as the lead on safety, and a clear line of authority established.

- Adequate training of site personnel is absolutely essential and helps to develop proper safety attitudes.

- Real-time field decisions on safety issues usually have to be made by the field safety coordinator, and the authority to make those decisions must be delegated by management.

- Management and oversight agencies must be willing to have an operation staffed adequately so that long shifts and fatigue do not become causative factors in accidents and <u>there are sufficient site personnel to deal with any drilling contingency</u>.

This basic philosophy is incorporated into the project from the planning stage through the project conclusion. Typical project phases included in safety considerations are the following:

- contractor negotiations,

- personnel selection and assignment,

- start-up (a particularly critical time as various groups of people begin working together under operational conditions),

- continuing operation (familiarity and routine may lead to lapses), and

- demobilization (critical time, since people are anxious to tear down and leave the site to return home).

SAFETY PLANNING, IMPLEMENTATION, AND MONITORING

PLANNING

Planning for safe operation of a geotechnical field operation should include the costs of personnel time (project personnel, in-house service organizations such as safety, environmental health and medical groups and other support staff) needed to deal with safety issues as well as the obvious budgetary considerations for safety equipment and contractor support for specialized services. Project personnel should be chosen according to good management practices (interest, experience, availability, etc.), but also with consideration of their safety attitude.

Management must be willing to delegate a level of authority to the field safety coordinator that is in direct proportion to the responsibility placed on the coordinator. Recognizing that remote operations are unique, management cannot expect to always be consulted in every decision; therefore, seasoned personnel should be chosen for critical field positions and be given latitude to address unforeseen safety issues within the framework of the project safety philosophy.

Working interfaces regarding safety must be established. Other national laboratories operating under DOE rules and regulations could be expected to operate in a similar fashion to SNL. However, university and contractor personnel and personnel from other governmental agencies may not be indoctrinated in safety practices. It is essential that representatives from all concerned organizations be involved in early project meetings and that safety is one of the primary concerns discussed. Clarification of responsibility and authority for site safety implementation is an important subject at this point.

IMPLEMENTATION

Administrative controls (procedures, signs, visitor logs, etc.) are emplaced at the site as soon as there is appreciable activity. The need for special protective equipment should be anticipated ahead of the actual need and be on-site and in working order. Personal protective equipment (safety glasses, safety shoes, hard hats, etc.) shall be worn as required.

Attitudes regarding safety can be shaped by project leaders and safety coordinators, modeling the behavior expected from other site personnel. Appeals to common sense, basic good judgement, and teamwork in training sessions adds to the shaping of attitudes. Using competent, experienced instructors in first aid, cardiopulmonary resuscitation (CPR), and self-contained breathing apparatus (SCBA) training sessions reinforces the impression that safety will be treated seriously on the project. Anyone with operational responsibilities at the site is required to read the SOPs and verify by signature that they understand and will abide by the safety requirements.

Physical barriers may be needed to remind site personnel of certain hazards as well as to prevent visitors from entering high risk areas. Causal visitors will always be escorted by site personnel if access to an active working area is required. For example, <u>the drill rig foreman always has veto power for requests for access to the rig floor</u>. Concentric zones defining controlled areas with higher risk near the center may be established with either soft or hard barriers, as appropriate.

The site safety coordinator must have the recognized authority to discipline anyone on the site for safety lapses. Willful disregard of the safety rules or continued inadvertent lapses are sufficient cause to ban someone from the site. The safety coordinator should make a reasonable effort to resolve the problem before taking drastic action against the offender. This attempt at resolution may involve the foreman of the drilling crew, a senior scientist, the project leader, or any other authority figure onsite.

MONITORING

Periodic monitoring to see if safety rules are being followed is essential. This is done by the safety coordinator on a daily basis in the course of the project as well as on a periodic basis by other project personnel. Occasional random checks by safety, environmental health, fire prevention, and other professionals are valuable because an outsider's view is not colored by familiarity. As the project progresses, additional safety issues may need attention, and new procedures can be considered addenda to the original SOPs.

EMERGENCY PREPAREDNESS

Safety planning, training, implementation, and monitoring can reduce the probability of an accident or injury occurring; however, the probability can never be reduced to zero. Therefore, an emergency preparedness plan must be developed and emplaced at the site. Site personnel must be informed and trained in execution of the plan and offsite responders must be aware of the planning for emergencies.

OFFSITE EMERGENCY RESOURCES

Geotechnical operations may be located in remote areas where emergency services are available, but the response time to the site can be lengthy due to several factors. Most emergency medical service (EMS) systems in small towns are staffed by dedicated volunteers that are alerted by the EMS system and then respond to the fire station to get the necessary equipment before they start to the scene. Some areas do have volunteers equipped to respond from their homes/job locations and at least provide first-responder evaluation and stabilization of victims. Access to a remote site can be over rough roads or may require helicopter transport, and this can impact response time.

Assessing the local resources and response times in the event of an emergency is one of the first considerations in developing an emergency preparedness plan. This can be done by visiting the local fire station, police department, or medical clinic/hospital. Meeting and talking with these people and establishing a working relationship and trust (remember, the project and its personnel are "outsiders") is very important to efficient activation of these people, if the need arises. It is extremely important to brief them on the location of the site, potential injuries, site-specific hazards, etc.

ONSITE EMERGENCY RESOURCES

The key to the proper onsite response to emergencies is well-trained site personnel. The proper equipment must also be available for use. A well-equipped trauma kit, a backboard, and supplemental oxygen are basics. SCBAs for rescue and shutting down the drill rig in the event of a toxic gas release are also on hand. Initial training in first aid, CPR, and the use of all emergency equipment is given to all site personnel with operational responsibilities prior to start-up. Periodic refresher classes and training of new people coming onsite to work is also scheduled.

> **(Comment: Several comments have been made by site personnel indicating that the training was appreciated, and that the quality of the training and the competence of the instructors was excellent. Some workers would take the initiative to practice and refresh their memory on certain emergency procedures at slack times in the operations.)**

A communication center is established at the site and succinct procedures are posted at the center for emergency use. Telephone lines are not always available or if available, not reliable, so radios on several nets are provided. These nets may be the NPS, private landowners, a local emergency organization, or a special net established by the site personnel with communication to accomodations where the off-shift crew is headquartered.

Evacuation plans are required for sites having the potential for toxic gas release. Evacuation plans vary depending on the wind direction, day or night situations, etc. A regrouping area is designated for each scenario so that a head count may be taken.

Periodic tests of emergency equipment and gas sensing systems are necessary. Every effort is made to resolve and eliminate false alarm problems so that the entire site crew has confidence in the systems. Also, emergency drills are held at slack times to check the response of the site crew.

POST-EMERGENCY CRITIQUE

This critique of any emergency action taken serves to improve on the emergency plan as well as to give site personnel an opportunity to have additional input into the plan. Hindsight tends to be 100 percent correct where foresight is seldom 100 percent. The important point here is that the emergency plan can be improved by a review and frank discussion following the emergency.

GENERAL SOP FOR ORGANIZATION 6240 GEOTECHNICAL FIELD WORK

APPLICATION

The general philosophy and requirements of this SOP are intended to apply to a broad range of applications. Department 6250 is involved in various field activities related to geotechnical research. Typical activities include, but are not limited to, geophysical surveys prior to a drilling operation, onsite instrumentation and control of surface and down-hole devices, developing drilling strategies, overall drill site coordination, interfacing with scientists from government/university groups, and follow-up well logging with unique, state-of-the-art instruments.

PHILOSOPHY

This SOP is structured to be general in nature and to point out a number of situations where potential hazards could arise in field work involving geotechnical experiments. Site-specific and/or operation-specific situations requiring greater detail on potential hazards will be developed as separate addendums and appended to this general SOP. The signatures of all users and the appropriate management approvals should appear on the general SOP and on all appended documents to signify awareness of agreement with, and commitment to comply with, the content. The SOP should cause the users to think about the potential hazards and then to operate in such a way as to minimize the risk without causing unnecessary frustration in conforming to the SOP. An SOP cannot prevent injury to the users. Only the users themselves can minimize the risk of injury by conscientious attention to the situation and awareness of the hazards.

Management Expectation and Delegated Authority - Management expects the users to demonstrate a certain level of personal responsibility in conforming to the SOP; however, a certain measure of delegated authority must accompany the expectation for responsibility. The discretion necessary in using this delegated authority must be agreed to both by management and the personnel involved. Examples of the use of this authority could be the following: shutting down an operation and excluding all personnel until unanticipated results are understood; observation of unsafe practices by a coworker and immediate notification of management, if unable to diplomatically resolve the problem; and asserting oneself in the face of pressure to complete a test on schedule by taking certain unsafe shortcuts.

POTENTIAL HAZARDS

Field work contains a variety of potentially hazardous situations. Examples are the following: large powerful machinery that rotate and lift heavy hardware; considerable electrical power to run the machinery; toxic gases, steam, and hot fluids vented from the geologic formation by the drilling operation; hot surfaces; simultaneous onsite operations by personnel from several companies; shared equipment; well logging operations involving high voltages; and the use of explosives.

All onsite personnel must be made aware of the potential hazards and the proper responses to any emergencies that might occur in spite of the physical and administrative controls imposed by the SOP.

Non-GRDO personnel from other laboratories and universities frequently spend considerable time onsite. These individuals should be required to read and signify by signature that they understand and will abide by the requirements of the SOPs.

Management must be sufficiently aware of the field workload to adequately staff an operation so that long shifts and fatigue do not become causative factors in accidents. Proper responses to emergency situations can be impacted by fatigue.

RESPONSIBILITIES AND PERSONNEL ASSIGNMENTS

Clear-cut lines of responsibility must be established prior to starting a field operation. If teams are established with multidisciplinary backgrounds and different levels of field experience, it is particularly important to assure that each team member understands his responsibility and the limits of that responsibility. Selection of a particular team should be based on the good management practice of utilizing talent, experience, interest, and attitude. Briefings should be conducted, as appropriate, by the team leader to advise all personnel of significant changes in procedure, particular problems that have arisen, anticipated problems for their shift, and any other information that impacts safe operation. All personnel should be encouraged to ask questions about things that they perceive to be safety problems. Perceptions are real, although the problems may not be.

Operations involving personnel from several companies need particular attention to assure that appropriate safety issues have been addressed. Ideally, joint agreements regarding safety planning should be in writing, although practically, real-time field agreements may be difficult to negotiate in writing. Agreements may be simple lists of concerns or more complicated definitions of responsibilities. A document of this sort should be appended to this general SOP.

EXCLUSION AREAS

Exclusive areas shall be established, as appropriate, to exclude non-essential personnel. Breaching of the barriers will be considered a violation of the safety guidelines. Proper respect for the barriers reinforces the seriousness with which GRDO treats safety and sets an example for the non-GRDO workers at the site. The division of turf and responsibility at the remote site occupied by various personnel is recognized as a delicate subject, but that division must be as clear as possible and continue to be clarified as problems arise.

PERSONAL PROTECTIVE EQUIPMENT

Appropriate personal protective equipment will be used by the operating personnel. Hard hats, safety shoes, and eye protection are the most basic protective equipment. Spare equipment shall be available at the site for visitors requiring entry to areas requiring protection. Additional special protective equipment may be required by the site-specific safety plan.

EMERGENCY PREPAREDNESS

Providing a site-specific emergency preparedness plan is an essential part of this SOP. The emergency planning document should contain a discussion of the logic pertaining to an emergency response as well as details of specific issues. The emergency resources available in a region must be ascertained. An appropriate means of communication within the test site and external to the site should be available and tested periodically. If external radio or telephone communications are not available due to geographic features or remoteness of the test site, a reliable vehicle (or helicopter) must be readily available for use in emergencies. A "critical actions" list must be posted in the control area and clearly identified as such. The emergency preparedness plan should be appended to this SOP.

Appropriate emergency equipment should be available at the test site with an industrial first-aid kit as a minimum. Also, personnel should be trained in the proper use of whatever equipment is deemed necessary.

Basic training in first-aid and CPR techniques shall be provided for all personnel regularly participating in field tests. Other companies and institutions participating in a field operation are responsible for assuring that their personnel are properly trained and equipped.

PROFESSIONAL CONDUCT

Professional conduct in keeping with the Sandia National Laboratories Code of Conduct by Sandia National Laboratories personnel at all times while onsite and operating under the safety guidelines is absolutely essential. Therefore, practical jokes or other activities that even remotely affect safety will not be tolerated. The professional integrity of Sandia National Laboratories, Albuquerque as an organization can be undermined by inappropriate behavior.

CONTINUING AWARENESS OF HAZARDS

It may not be possible to identify all significant hazards before beginning a geotechnical field operation. Therefore, it is important that all operating personnel be continually alert to safety concerns that may develop. This general SOP may be appended at any time with additional information.

AUTHORIZED PERSONNEL

Signatures on the Site Signature List signify that the personnel authorized to work on the site have read and agree with the content of this SOP and all appropriate addendums and will abide by the requirements.

GENERAL GUIDELINE SOP FOR OPERATIONS SHARED BY SNLA/OTHER COMPANIES AT GEOTECHNICAL TEST SITES

GENERAL

Shared operations have the potential for miscommunication, unclear lines of responsibility/authority, and the end result, an adversarial relationship between participating personnel; i.e., scientists, visitors, contract workers. The intent of this general SOP is to clarify some of the issues and to impose procedures to avoid some of the problems.

Each participating institution has its own method of operation based on the task to be performed. Also, the operating staff of each institution has certain talents, skills, and personal preferences in completing their task. It is the meshing of these policies and personal preferences that will develop and implement joint safety guidelines. A single overall site officer representing the Legal Operator of the site shall have the authority to make real-time decisions.

OBVIOUS HAZARDS

Obvious, significant hazards will be recognized by all personnel. It is likely that responses to potential emergencies caused by those hazards will be similar, but will differ somewhat based on different experience bases.

SUBTLE HAZARDS

These may be discovered by site personnel and pointed out to others. If everyone has respect for each other, a sense of appreciation will be developed for the personnel watching out for each other's welfare.

INTERMEDIATE HAZARDS

These are hazards/situations identified by one person or group but not fully accepted as such by others. Judgment on these issues may be colored by experience, emotion, financial penalties, personality conflicts, fatigue, and so on. These issues have the potential for severe conflicts between personnel. A method of resolving these potential conflicts must be agreed to prior to beginning operations. Exclusion area boundaries can help to define physical areas of responsibility. However, when actions within a boundary can affect personnel in other areas, some means of resolution must be available. As previously stated, but repeated for emphasis, a single overall site officer representing the Legal Operator of the site shall have the authority to make real-time decisions.

LEGALITY

This document is only to be used as a guideline for development of working documents and agreements that may be needed between the GRDO and others sharing a geotechnical field site.

AUTHORIZED PERSONNEL

Signatures on the Site Signature List signify that the personnel authorized to work onsite have read and agree with the content of this SOP and all appropriate addendums and will abide by the requirements.

GENERAL SOP FOR GEOTECHNICAL FIELD SITES WITH POTENTIAL HYDROGEN SULFIDE EMISSIONS

GENERAL

Geotechnical sites often have hydrogen sulfide (H_2S) gas present in the geologic formation. Sometimes this gas can be detected at the surface (a rotten-egg smell) even before exploration or drilling begins. This gas can be fatal when inhaled in relatively low concentrations. Immediate medical treatment is necessary if a person is overcome. Emergency breathing apparatus should be available onsite for use in escaping a large, unexpected release or for entry into an area where emergency work must be performed.

SENSING AND ALARM SYSTEM

An appropriate sensing and alarm system must be available prior to any significant amount of field work. The Sandia National Laboratories Albuquerque Industrial Hygiene/Toxicology Division 3311 will establish the need, provide proper equipment/training procedures, and monitor compliance with this SOP. Initial and periodic testing/calibration of the sensing system is required. The system may consist of both fixed-position and portable sensors, or, in simple operations, could encompass only portable equipment. Details of the sensing system and persons to contact in case of malfunction shall be included in the site-specific SOP and posted in the control area.

The sensing system shall have two alarm levels (low and high). The ppm concentrations for these alarm levels shall be dictated by Division 3311. Each level shall have a unique audible, visual alarm that can be heard and seen from prominent locations at the site. A wind sock shall be installed in the most favorable location at the site to indicate surface wind direction.

RESPONSE TO ALARMS

Each time that the alarm system triggers, the onsite personnel must assume that the alarm is valid and must react properly. The proper response may vary depending on the situation (e.g., alarm level, wind direction, and location of personnel). It is assumed that the control area location is sufficiently remote from the probable gas release area that control area personnel can immediately determine which sensor is triggering. Operating personnel evacuation from the area indicating a release is always appropriate, and clearing other areas may also be necessary. Total test site evacuation is an extreme measure but might be necessary.

Operating personnel may need to re-enter an area that an unsafe concentration of H_2S to secure equipment that, if left unattended, could cause additional hazards. If reentry is necessary, appropriate self-contained breathing apparatus will be required.

This apparatus should only be used by those trained in its use. Therefore, all people who will work at the drill sites will be trained in its use. A buddy system shall be used by anyone using the apparatus. Strict adherence to the low supply warning devices on the apparatus is required and is reinforced by the "buddy system."

If there are victims that have been overcome, appropriate first aid can be applied, and simultaneously, activation of the local emergency services network must be initiated to acquire more advanced medical support.

EQUIPMENT MALFUNCTIONS

False alarms from malfunctioning equipment are detrimental to safe operation. The alarm system must be trusted by the users. Any malfunction must be immediately corrected so that overall system confidence is restored.

Self-contained breathing apparatus should be checked at least weekly to verify readiness for use. Spare apparatus and replacement air tanks should be stored near the control area and protected from the elements.

BRIEFING OF NEW PERSONNEL

All personnel entering the test site and having reason to work in an area that could develop hazardous levels of H_2S should be briefed by the site supervisor on the current situation, be required to read the SOPs, and signify by signature their intent to comply. Site personnel should also be fully aware of the requirements of this SOP and know how to activate the local emergency services network.

AUTHORIZED PERSONNEL

Signatures on the Site Signature List signify that the personnel authorized to work onsite have read and agree with the content of this SOP and all appropriate addendums and will abide by the requirements.

APPENDIX B

SPILL PREVENTION AND MITIGATION

SPILL PREVENTION AND MITIGATION

SPILL PREVENTION

Prior to the commencement of drilling and coring, the operation will be reviewed by the project and an outside environmental contractor for safe handling of all sensitive materials and for spill prevention. This review will evaluate all operations handling from the barge to the site support area in King Salmon to the drill sites; the use and disposal of all environmentally sensitive fluids; and the operation and maintenance of equipment, record keeping, and emergency spill response for all stages of fluid use.

A monitoring system will be erected to warn operating personnel of any unanticipated drop in the level of a fuel tank. These monitoring functions will be on the main monitoring system displaying the drilling and hydrogen sulfide data. Tanks, lining of pits, and berm construction will, at a minimum, meet federal and state specifications.

Other sensitive materials such as the liquid drilling fluid additives will be stored in a bermed area similar to that for fuels. These storage areas will also be inspected on each shift. Storage areas for solid drilling fluid additives and dewatered drilling solids will also be inspected each shift. All areas containing critical materials will be well-illuminated.

Visual inspections will be recorded and will include examination of bladders, tanks, and other liquid containers and secondary (bermed) containers used for containment and integrity.

The drilling crews and all personnel working at the site will receive training in spill prevention, spill mitigation, and spill containment. The onsite training will include the following:

- transfer operations involving oil, drilling fluids, or grey water;
- operation and maintenance of equipment to prevent oil discharges and discharges of drilling fluids;
- familiarity with and training in the use and application of spill control equipment on hand such as skimmers and boom pads; and
- knowledge of appropriate spill control regulations.

Periodic drill and support site inspections will be made by trained spill control personnel to assure that the handling and storage of all sensitive fluids is proper, seepage of oil from machinery is minimal, records are in good order, and that the general operation is conducted in a manner that minimizes the chance of an accident.

SPILL RESPONSE AND MITIGATION

If a spill occurs, the drilling project will react in a predetermined way according to the severity of the spill. The GRDO Site Manager will coordinate remedial activities. List of phone numbers of key personnel including permitting agencies (the NPS, the EPA, and the State of Alaska ADEC) and spill control personnel will be posted and contained in the site-specific SOP. Depending on the location of the spill, remedial operations will be coordinated either from the main drill site, the remote drill site, or the site support area in King Salmon. All three of these areas will have sufficient communication facilities to coordinate necessary activities.

A contingency contract will be in place with an Alaska firm established in effecting remedial action to mitigate, contain, and clean up spills. Thus, in the unlikely event of a severe spill, additional trained personnel and appropriate equipment could be dispatched to the problem area immediately. The contractor is both a source of trained manpower to combat spills and a source of spill control equipment. If needed, this equipment would supplement spill control equipment that is either at the drill sites or in a site-support facility in King Salmon (Section 13.2).

Onsite equipment at the disposal of project personnel for containing spills would consist of the following:

- Emergency tanks will be used to hold fuel if a transfer is necessary. There will be spare tanks for 50 percent of the fluids stored onsite.

- Commercially available, oil absorbant pads will be used on all fuel lines, connections, and the like, where spills could occur from breaks in the line or leaks. Pads will be placed under machinery, pumps, and the like. A large number of all types of absorbant pads and materials sufficient to meet contingencies will be kept in reserve at the site and at the site-support facility in King Salmon. Approximately 40 empty DOT-approved barrels will be kept at King Salmon and be available to transport waste from a spill.

- Industrial or suitable rug will be used to absorb both fuel and drilling fluid in critical areas around mixing tanks and where small spills of drilling fluid could occur.

- Appropriate absorbant booms will be kept in the site support area in King Salmon. Materials in storage would include adequate supplies of river booms for strong, moderate, or light current and sheltered water booms, sufficient for a first response to any fuel spills.

- A skimmer will be used, suitable for a first response to a spill on water; e.g., if a helicopter goes down on water or if a portion of a helicopter load is lost. (Helicopters can transport between 300 and 1,000 gal of fuel, and their fuel tank capacities range from 300 to 1,000 gal.

The project group will respond to all spills immediately. In general the sequence of events following a spill is the following:

- proceed to the spill site and assess nature of incident,
- determine the nature of appropriate action, and
- implement appropriate response.

The appropriate authorities should be notified as soon as practicable during the above sequence. In general, a response to a spill of sensitive fluids will include the following:

- caring for any injured personnel that may have occurred as a result of the accident precipitating the spill;
- spill containment, including spreading of sorbents and formation of temporary dikes or an appropriate array of sorbent boom pads on water;
- appropriate source removal with proper removal of source contents;
- cleanup and adequate decontamination;
- picking up wastes, resanding residues, installing them in proper containers; and
- proper waste disposal.

The following classification of spills by severity has been made so that responses can be tailored to the severity or volume of the spill.

MINOR ONSITE SPILLS/LEAKS OF FUEL OR CONTAMINANTS <10 GAL

These will be controlled by site personnel. The conduct of normal operations will not be disrupted if a rapid, effective response can be mounted.

SPILLS OR LEAKS OF FUELS AND CONTAMINANTS WHERE >10 GAL ARE INVOLVED

<u>Onsite Spill</u> If possible, containment and cleanup will be conducted by site personnel; if not, contract spill technicians will be brought in to manage the spill. Operations will be curtailed to a minimum level until it is environmentally safe to resume normal operations. (It may be necessary to maintain circulation in the well if a high temperature regime is encountered.)

<u>Offsite Spill</u> Any spill away from the site no matter how small will be regarded as a spill of at least intermediate severity. The spill will be assessed by the project personnel and the resident Park Ranger and, if possible, project personnel from the drill site or from the project support area in King Salmon will make the first response, using helicopter

transport. Minor spills will be cleaned up immediately. If practical, the entire cleanup will be made by project personnel. The firm specializing in spill cleanup under contract will be notified immediately of any offsite spill, and at least one technician will arrive as soon as possible to assist with and inspect the clean-up operation. If either environmental or operational considerations dictate, then a larger clean-up crew appropriate to the magnitude of the accident will be dispatched.

HANDLING AND REMOVAL OF SPILLED MATERIAL

If liquid spills into the lined berm, it will be pumped back into another storage tank or barrel and held for transport, and then removed out of the park by helicopter for proper disposal at an approved site.

Soaked pads and absorbant booms will be helicoptered out of the park for proper disposal. Fluids skimmed off water will be stored in portable tanks for transport out of the park for proper disposal.